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SCIENCE ENGINEERING ENTREPRENEURSHIP DESIGN

Synthetic Biology: Developing Spider Silk

Adaptive Alcohol Cooking Stove

Design and Static Testing of a Low Cost Inflatable Wing

Determining the Best Load Scheduling Algorithm For a Home with Electricity Supply from Grid and Solar

Contents

Editor’s Note

In 2017 I co-led a workshop in Synthetic Biology for junior high school students in Berekuso, Ghana. The workshop’s objective was to introduce these young minds to the intriguing applications of Synthetic Biology in making the world a better place. The workshop included a discussion on DNA and a brief DNA extraction demonstration — we took them through a practical process of extracting DNA from a banana.

It was amazing to experience these students’ euphoria who may not have entirely understood the information they were exposed to but were yet grateful for the novel exposure.

Synthetic Biology is a budding field of study in the African context. You can imagine how difficult it was to communicate such concepts in a relatable scenario to children in a remote area with no exposure to information about genetics. In hindsight, I believe the workshop was a step in the right direction to start conversations about biological engineering at Ashesi, especially with the introduction of an allied course.

In this issue, we have two exciting research papers on Synthetic Biology from students who participated in the Synthetic Biology course at Ashesi University last year.

As we battle these trying pandemic times, we hope this issue will incite research interests in engineering and science-related topics like vaccine production, renewable energy development, and many others.

“We may encounter many defeats, but we must not be defeated.” - Maya Angelou

Miquilina S. Anagbah

Editor-in-Chief

Contributors' Notes

"Every once in a while, life throws you an opportunity to redefine yourself. You could either rise up to the challenge or live with the regret."
~ Ruth Cardello

Last year came with its fair share of challenges and many researchers and authors have answered the call. Every research and author in this special second issue of the SEED journal has braved through the storm of 2020 and has come out with impeccable, exploratory research and editorial pieces.
This second issue includes both creative and research pieces. Some centered around the current pandemic of COVID-19 and some centered around research in budding fields. This issue promises to provide the reader with insight and understanding of diverse fields. This will hopefully inspire us to rise above the challenges we face and use them as an opportunity to redefine ourselves.

Thank You!
Jean Ewurama Roberts

Elena Rosca (PhD)
Faculty Reviewer

Dear Students, Faculty, Staff, and Ashesi. Community,

I hope this note finds you well and healthy. We made it through a year of continuous adjustments, some anxiety and uncertainty, remote teaching, and learning, and zoom hopping. But we are strong and continue our exciting learning journey!
We have been delayed with our journal publication but not for lack of excellent work submitted to us, so apologies for this delay, but at last, here we are with our second issue!
In this issue, you will enjoy lots of great and exciting research from our members, such as Developing Spider Silk with Synthetic Biology, and Design and Static Testing of a Low-Cost Inflatable Wing.
My deepest gratitude goes to our team, who has worked very hard to put this issue together, especially to our Chief Editor Miquilina, a true inspiration. The most heartfelt thanks to Dr. Jonas Ecke, who has assisted us with the reviews and writing center, who has worked with the students to polish their writing.
We hope you will enjoy this issue, find it interesting, exciting, and valuable. We are wishing a strong finish to this academic year and looking forward to seeing you on campus soon.

"Research is seeing what everybody else has and thinking what nobody else has thought."

Best,

By
Freeman Dotse Kumi, Rosemond Nyatefe Tawiah, And Elena Rosca (PhD)

Reducing Coconut Husk Pollution Using Cellulose- Degrading Bacteria to Make Self-Illuminating Ceiling Tiles.

The study of Engineering is always exciting! Did you ever know that even Biology can be engineered? Well, it can, and is done presently. The fusion of engineering and biology is a breakthrough as seen by many scientists and is termed Synthetic Biology. Synthetic Biology, according to the National Human Genome Research Institute, is a field of science that involves redesigning organisms for useful purposes by engineering them to have new abilities [1] Amazing, right? Organisms can do the extraordinary based on the instructions (DNA or gene) you place inside it. Because of these mind-blowing possibilities, companies worldwide are harnessing the power of nature through engineering to solve problems in medicine, manufacturing, agriculture, and many other aspects of life. Conservation is also another critical area in which synthetic biology has been much appreciated, termed as Bioremediation where microorganisms break down and consume pollutants. Consider this scenario; applying synthetic biology principles in biodegrading coconut husks to reduce its arising pollution and further incorporating this achievement into building self-illuminating ceilings. Other applications include self-illuminating recreational facilities, such as pathways in communities using biological parts from specified self-illuminating bacteria. It is also imperative to note that, Synthetic Biological Engineers care about you and the environment; thus, safety is of utmost importance to them and they ensure that their designs cause no harm to neither you nor our world.

Unfortunately, pollution has become a major global issue. Governments, individuals, and organizations have taken initiatives to help reduce pollution since various types of pollution (water pollution, land pollution, air pollution etc.) have revealed numerous life-threatening manifestations. Some of these indicators include climate change and the spread of air and water-borne diseases such as , cholera and typhoid fever leading to the loss of lives. Pollution has led to environmental degradation and has been observed to have begun since the industrial revolution [2].

Land pollution is among the first three types of pollution negatively affecting the environment [3]. The husks of coconut in Ghana is a major contributing factor to land pollution in the country [4]. Coconut is a drupe fruit that primarily grows in tropical regions (e.g., in Ghana) and is locally consumed while some are exported. Currently, annual production in Ghana is 224 million coconut fruits, and smallholder farmers produce 179 million of the total production as of 2019, according to the Coconut Producers and Exporters Association [5]. Due to very high temperatures in the country and the medicinal benefits of the nutrients for consuming coconut, there has been active patronization of coconut; thus, lots of waste is being produced daily. The husks of these coconuts have been seen to be disposed in gutters, deserted lands, in water bodies, and dumping sites and have raised significant concerns from locals and sanitation organizations since these pollutants have become catalysts for natural disasters like floods. Even though many individuals and some inclined conservative organizations have tried to recycle these husks and the fibres into other useful products like coconut fibre mats, coconut fibreboard, coconut fibre seedling pots, coconut fibre dish scrub pad, etc. there is still massive pollution of coconut husks. [6]

Fig 1. Image of coconut juice, mesocarp, epicarp, and endocarp

Reducing Coconut Husk Pollution Using Cellulose- Degrading Bacteria to Make Self-Illuminating Ceiling Tiles.

Fig. 2 Coconut husks disposed on land sites waste indiscriminately

So, how do we give these bacteria a specific role to play? Escherichia coli (E. coli) is a commonly used bacteria for bioengineering experimental purposes. Most strains of E. coli are harmless and able to metabolize glucose in both aerobic and anaerobic circumstances. The engineered bacteria (chassis) with antibiotic resistance, in this case E.coli, can be modified by inserting a sequence of DNA into it, facilitating the production of an enzyme to perform a task, for instance, breaking down cellulose found in a coconut husk. Bioremediation has become very useful in our society because organic wastes are biologically degraded under controlled conditions to an innocuous state or below the concentration limits established by regulatory authority [7]. The process also reduces the quantity of pollution and emissions produced compared to the traditional methods of getting rid of biological pollutants such as coconut husk. Traditional methods such as burning the coconut husk release soot, an impure carbon particle that pollutes the environment and harmful gases that harm life directly or contribute to the greenhouse effect. Hence, fostering global warming. Even though Bioremediation involves using microorganisms to break down and consume pollutants, modifications through the power of synthetic biology can be made to these organisms to possess other features that can be useful to the environment.

Coconut contains cellulose nanofibrils as a part of its chemical composition. Hence, the genetic makeup of a cellulose digesting bacteria, for example, the Fibrobacter succinogenes S85 found in the rumen of herbivores [8], can be modified to digest the cellulose nanofibrils in coconut. Interestingly, more than one modification can be made to an engineered bacterium. For instance, the genetic makeup of the coconut husk degrading bacteria can also be further modified such that it can produce luminescence during the night for aesthetics purposes or to enhance visibility. 'Does this call for electricity? 'you may ask; surprisingly, not at all. It is simple. For example, lux operon (BBa_K1725352) obtained from the Vibrio fischeri, a rod-shaped bacterium found globally in marine environments has bioluminescence properties and could be used for such purpose and has proved itself to be accurate in its functionalities as seen from the image below. [9].

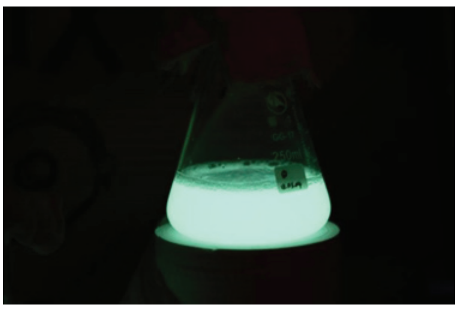

Fig. 3 The lux light generator expressed in a medium

Therefore, putting genetic parts such as promoters, Ribosome Binding Sites (RBS), Coding Sequences (CDS), Terminators, and even repressors lead to the proper functioning of an engineered bacteria. All these genetic parts come in different forms and have specific roles they play when they come together. Hence, these parts are explicitly chosen according to their desired function required in the chassis (host bacteria). There are also different ways of putting the desired gene into a chassis. One of these ways is called the BioBrick Assembly using the Restriction Enzyme Cloning or Digest method, where the gene is being placed in a plasmid by the use of restriction enzymes (e.g., PstI, EcoRI, etc.). Then, this new plasmid (recombinant plasmid) is placed in the bacteria. Here is an analogy of the cloning process; consider making a BBQ beef brisket sandwich which would be your engineered bacteria. The sandwich bread is the bacteria to be engineered and the sandwich filling consisting of beef, vegetables, spices and cheese, which collectively determine the taste of sandwich are the cloned plasmids which determine the functionality of the engineered bacteria.

Reducing Coconut Husk Pollution Using Cellulose- Degrading Bacteria to Make Self-Illuminating Ceiling Tiles.

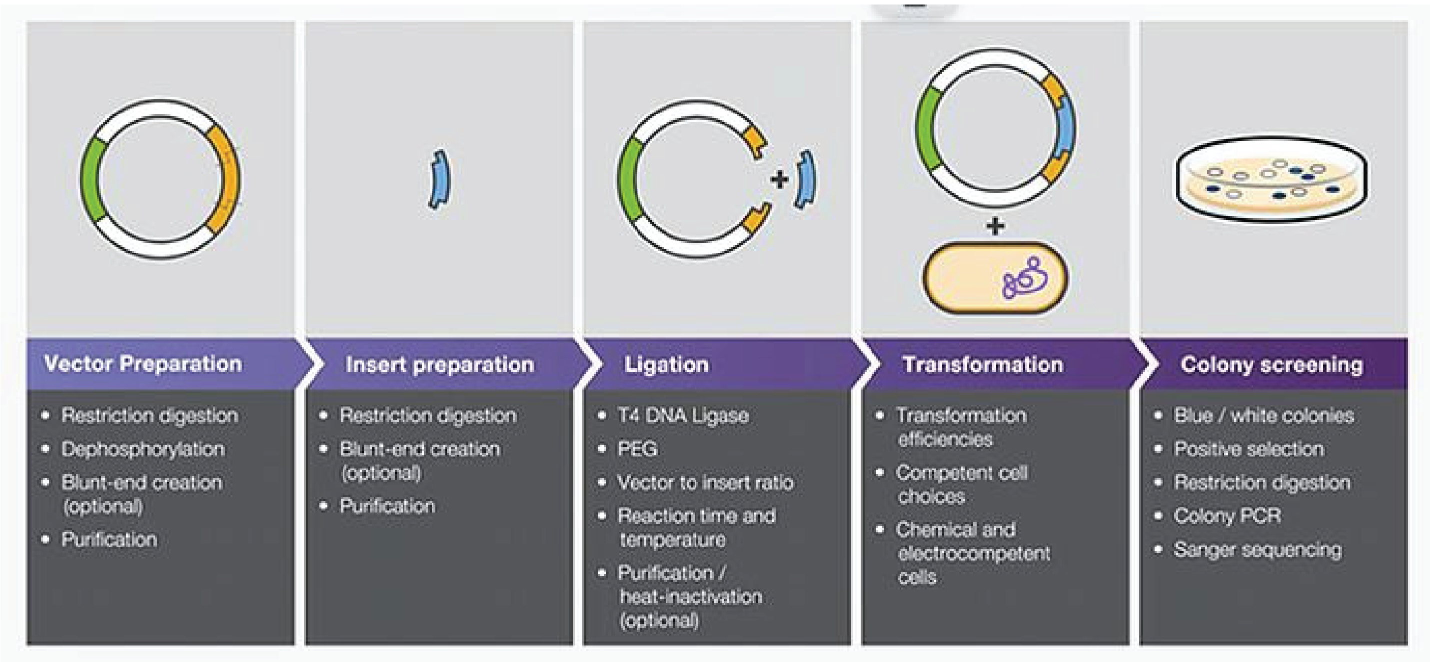

Fig.4 Summary of the Restriction Cloning Process

Referring to the above example of an engineered bacteria digesting cellulose and being self-illuminating as well, this is how our bacteria was engineered. Using the Restriction Enzyme Cloning method, we came up with two recombinant plasmids (one for cellulose digestion and one for the self-illumination. From our obtained results, both DNAs were successfully transferred into the plasmid, which will further be placed in E.coli bacteria cells to perform both functionalities at the same time. These results were developed and simulated using some Synthetic Biology Software – used in designing our required plasmids – SnapGene and TinkerCell. This approach is an advantage of Synthetic Biology because designing plasmids and engineering bacteria is not only done in a Biology Lab but can be first simulated virtually and later experimented physically in the lab.

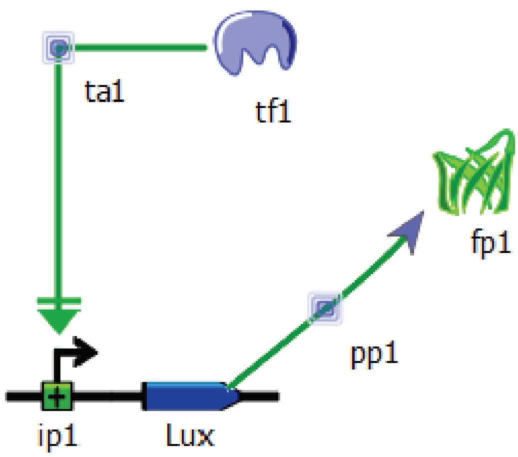

Fig. 5 Image shows a successful cloning of the puc19 plasmid with the endoglucanase (cellulose) gene to form a recombinant plasmid

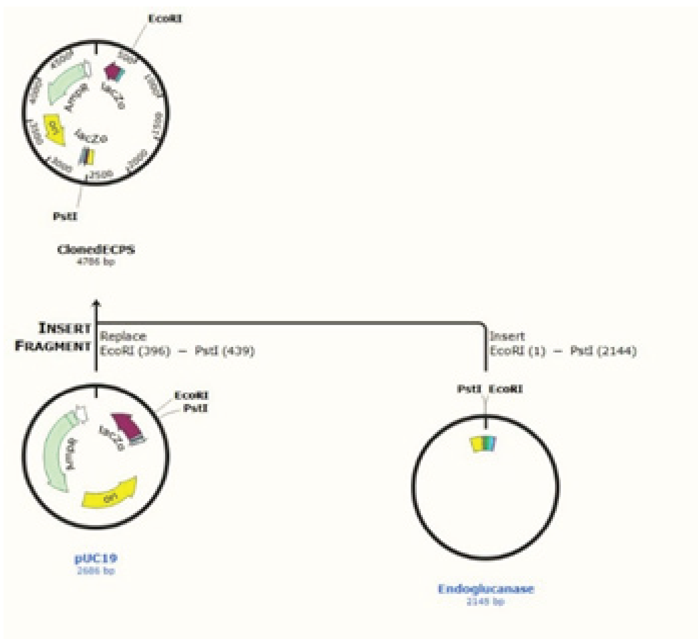

Fig. 6 Genetic circuitry of the LUX in Tinkercell showing the expression of the fluorescent protein (fp1)

Indeed, synthetic biology is a field that has brought about vast improvements and groundbreaking results. Even though this field of science has not been explored to its full potential, it is inspiring what the future holds.

It is always a great day for science!

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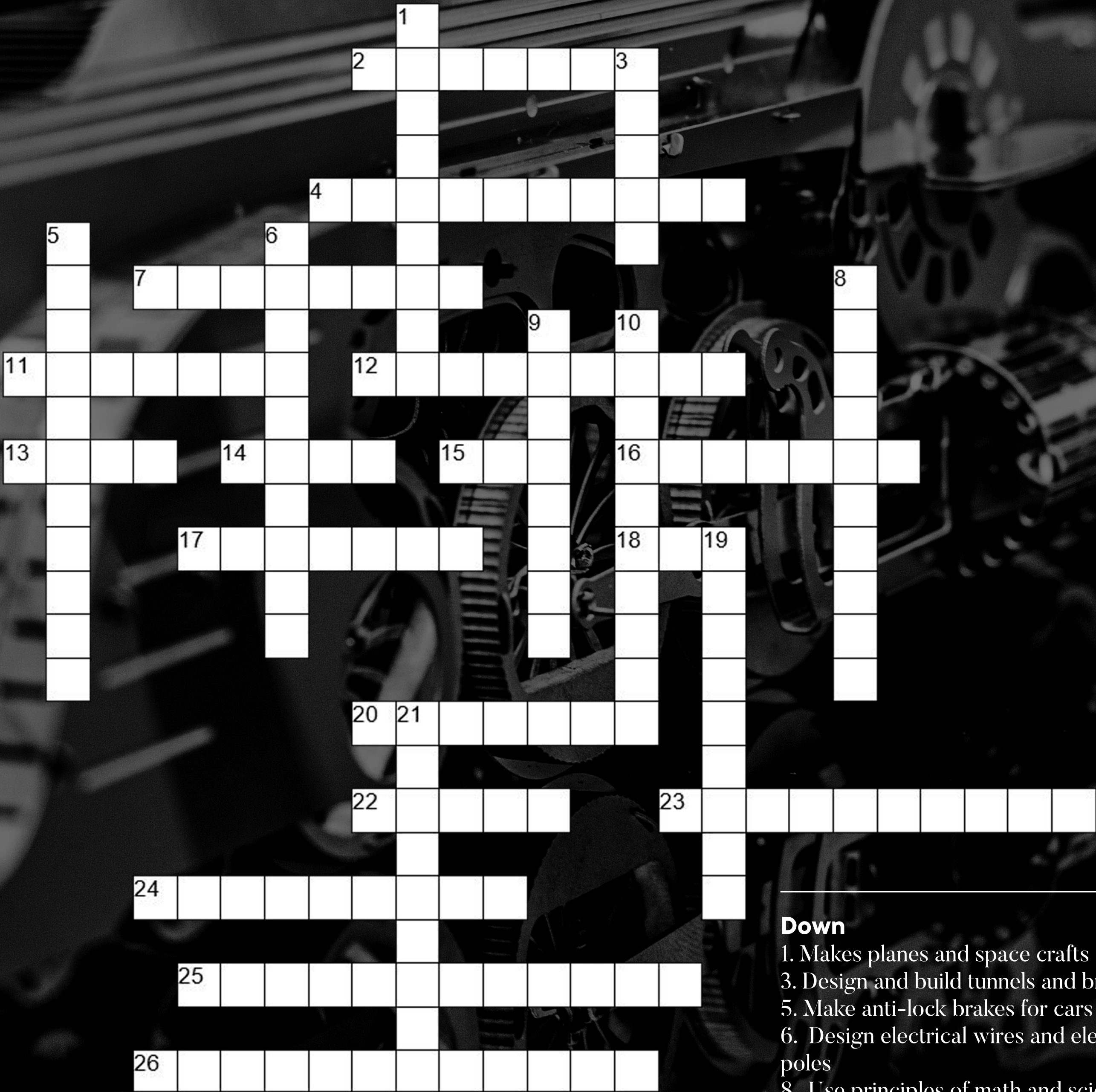
Crossword Puzzle: Engineering



Across

2. Deal with movements humans make
4. Insulate houses and buildings
7. Design components of railroads
11. Manipulates and studies DNA
12. Work on exploration
13. Make food processing machines
14. Design X-Ray machines to view bodies
15. Make Jet engines
16. Design highways and flow of traffic
17. Design Nuclear power plants
18. Process oil reserves
20. Make sure an item is of good quality
22. Test the stress point of materials
23. Makes advances in technology for health
24. Design animals habitats
25. Makes medicine suitable for animals
26. Oversees water quality and sewage treatment

Down

1. Makes planes and space crafts
3. Design and build tunnels and bridges
5. Make anti-lock brakes for cars
6. Design electrical wires and electrical poles
8. Use principles of math and science to design mechanical products
9. Maintain design of software systems
10. Design phones and how they transmit data to one another
19. Supervise lightning manufacturing
21. Responsible for making sure your utilities are available

Image by: Mykola Makhlai (unsplash)

By
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Determining the Best Load Scheduling Algorithm For a Home With Electricity Supply From Grid and Solar.

Abstract

Improving energy efficiency is becoming increasingly critical to reduce energy consumption and to solve the environmental crisis. The following paper describes a mixed-integer linear programming optimization algorithm to minimize the peak demand at the micro-grid level and to reduce the cost function in a smart home environment. The optimization methods take into account the time-varying electricity price and the varying energy demand peaks to determine the most suitable time to use home appliances. The algorithms are further used to compare the energy cost reduction results with and without the use of renewable resources and more precisely photovoltaic modules. Also, the sizing of a photovoltaic system is implemented to achieve further efficient energy optimization and appliance scheduling. Finally, a cost-benefit analysis is performed on all the scheduling algorithms to determine which is the most cost-effective.

1. INTRODUCTION

The ever-increasing world population produce exceedingly high energy demand. With issues of global warming and pollution from fossil-based energy supplies at the forefront of public debates and concerns, [1] solar energy –amongst other renewable energy sources – have been well embraced and integrated into society. Residential photovoltaic (PV) installations have helped reduce the number of grid-energy dependents over the past years. However, unutilized excess solar energy produced at peak hours raise a cause for alarm for energy wastage [2].

Successful residential solar-grid energy sharing relies significantly on the effective use of energy in homes and management of constraints associated with pushing power unto the grid through master planning and short-term look-ahead scheduling. The primary focus of this research interest is to investigate how homes can most effectively maximize solar consumption from their residential PV installations; reducing the amount of excess solar energy fed unto the grid and reducing the dependency on much battery storage. The second part of the project would analyze the electricity tariffs trends for the day, to determine the time of the day with the cheapest electricity. Finally, the MILP and ANN algorithms would be used to schedule loads for home consumption and the best in terms of highest reduction in electricity tariffs would be determined.

Background

For a third-world country like Ghana where the utilities provided by the government are not enough for the populace, it is essential that residential PV installations are embraced to reduce the number of grid energy dependents and hence reduce the cost of electricity for homeowners. However, for homeowners, allowing energy produced from PV installations to be pushed unto the grid without generating any revenue from it [3] represents a loss. Therefore, the maximum energy consumption of solar energy in a home would enable homeowners to maximize the benefits of their solar installations while reducing the cost of electricity.

Objectives

The long-term goal of the research is to develop a formalized energy selling structure from PV installation in homes to the grid at high tariff-hours so that households can maximize profit. The objective of the current study is to investigate and analyze the best scheduling algorithm for home appliances between Mixed Integer Linear Programming and Artificial Neural Networks. Significantly, the study has the following sub-objectives:

1. The first part of the research would investigate load consumption patterns of household appliances and classify them into schedulable and "unschedulable" loads.
2. The second part would schedule the loads using MILP and ANN and a comprehensive cost-benefit analysis, which is done to determine the best scheduling algorithm between the two.

Research Methodology

The primary research method for this study is a literature review and modelling with MATLAB. MATLAB is a programming language that has mathematical modelling APIs for creating the ANN and MILP models. In sequence, this study will follow these technical steps:

a. Following the literature review, it will first model a typical household with energy-consuming loads in MATLAB. Also, based on solar irradiation graphs and peak hours of sunlight, a structured load-scheduling system would be implemented.

b. In the second stage of the study, existing tariff rates at different times of the day would be modelled against energy production in the form of the PV home installation.

c. Then, the load in the house would be scheduled to operate at different times of the day. Graphs of scheduled loads with ANN and MILP would be produced.

d. Finally, a cost-benefit analysis of all scheduling algorithms would be done to determine the best scheduling algorithm.

2. LITERATURE STUDY

This section introduces the concepts of literature on the subject of optimizing solar consumption in PV residential solar installations, using load scheduling. It describes the idea of solar energy optimization, load scheduling, household loads and related studies of electricity tariff variations across different times of the day. It will show the concept of energy maximization and attempt to explain the integration of load scheduling, both against the unscheduled load in a standalone residential PV installation.

Solar Energy Optimization

Self-consumption is one of the most effective ways to target the maximum benefit of a residential photovoltaic (PV) installation. When a residential entity consumes his/her generated PV electricity instantaneously, grid-related energy bills decline. By acting as both the producer and the consumer, the “prosumer” can move toward greater future independence from the grid and electricity rate variations.

Of course, achieving the largest drop in demand for electricity from the grid requires coordinating household energy use with the periods of most outstanding availability of PV-generated electricity. Yet, because residential energy use is typically highest in the mornings and evenings, whiles energy availability peaks at midday, load-management is required.

The difference in solar irradiation, across different times of the day, would be reflected in differences in the output of the residential PV module. As a result, wattage-heavy loads can be scheduled to perform at peak hours of sunshine [10]. This scheduling can be achieved by considering the load profiles and load priorities. In the Ghanaian context, an air-conditioner is of high priority at peak sunlight hours, while the lamp may not be needed because of natural light in the home.

Load Scheduling

Load scheduling is a way of managing household loads that enables homeowners to conserve electricity while reducing the cost of electricity bills [11]. One can achieve an efficient load schedule operation when a load profile of all household appliances is created. This profile helps to identify the high wattage loads and allows for appropriate scheduling to reduce the cost of electricity. It enables loads to be classified as schedulable and “unschedulable” based on consumer-behaviour.

Purpose of Load Scheduling

The objective of household load scheduling is to improve its energy and cost-efficiency in line with consumers comfort and constraints. Towards this end, experts consider renewable source availability prediction and day-ahead electricity market price forecasting. Furthermore, they propose dynamic priority allocation and scheduling for appliances aligned with consumers comfort and constraints[12]. Also, to effectively schedule appliances according to real-time weather and electricity market price changes, an algorithm for real-time household load scheduling is required.

Classification and ‘Schedulability’ of Household Loads

According to the article, ‘Real-time Household Load Priority Scheduling Algorithm based on Prediction of Renewable Source Availability’, written
by Xin Liu, the loads in a home can be classified as [11]:

A. Real-time energy consumption loads
B. Periodic nonreal-time energy consumption loads
C. Nonperiodic nonreal-time energy consumption loads

These three categories work as follows:

A. Real-time energy consumption loads
The real-time energy consumption loads are directly related to human behaviour. Thus, when a user switches such an appliance on, energy will be consumed instantaneously and continuously until the user turns it off. This behaviour implies that the electricity cost of a real-time energy consuming load is directly related to the duration of its usage [11].

B. Periodic nonreal-time energy consumption loads
The periodic non-real-time energy consumption load is intermittent and fluctuant when it is in use. A typical example of such a load is the air-conditioner. The air-conditioner periodically consumes energy to maintain a desired temperature. The upper and lower bounds practically define the desired temperature, and the air-conditioner begins energy consumption when its temperature is higher than the upper bound. Note that this type of appliance is also related to consumer behaviour because the air-conditioner consumes more energy when the user opens the door in contrast to when it is kept shut [11].

C. Nonperiodic nonreal-time energy consumption loads
Nonperiodic non-real-time energy consumption loads consume energy consistently and may have an operational limit. However, the load may have a deadline to finish running. The pool pump, washing machine and dishwasher belong to the category of devices that are deemed as nonperiodic nonreal-time energy consumptions loads [11].

3. DESIGN AND SYSTEM REQUIREMENTS

The model should offer a real-time priority scheduling algorithm based on predictions of renewable source availability without compromising the home user's comfort. Home appliances are classified into three categories, according to the Demand Response categorization for load-management. The model should dynamically allocate scheduling slots based on their different energy consumption modes, and the cost of electricity at particular times in the day. Finally, an algorithm for real-time household load scheduling would be proposed.

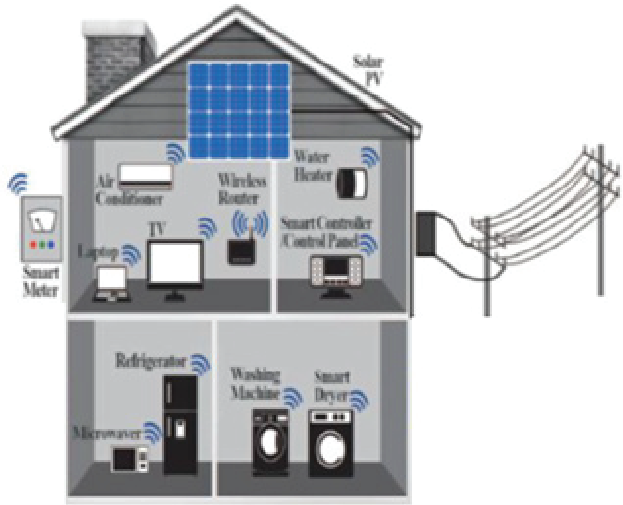


Fig. 1 Model home with appliances

A model green home is a house with solar panels, which ideally provides energy for all the home appliances during the day. In the evening, the household relies on the national grid for power. On days with little sunshine, the grid acts as a backup for the home. The load scheduling aims to ensure that

$$\text{consumption} - \text{production} = 0$$

However, on any rare occasion where there is excess energy produced that cannot be consumed by the home appliances, the excess energy is fed into the grid.

Load Profile for Major Household Appliances

In this paper, for load profiles of appliances, a mid-size home is considered with the following significant electricity consuming appliances: a dishwasher, washing machine with dryer, refrigerators, and air-conditioners. These appliances are considered in this model to study their demand response and optimize their operation over a period of time to minimize the total energy cost and level the load curve.

The Dishwasher

The dishwasher washes rinses and dries in individual cycle sequences, and it takes approximately an hour and 25 minutes to complete all the cycles on average. The dishwasher is classified in the category of a schedulable load because its usage does not directly depend on user's comfort.

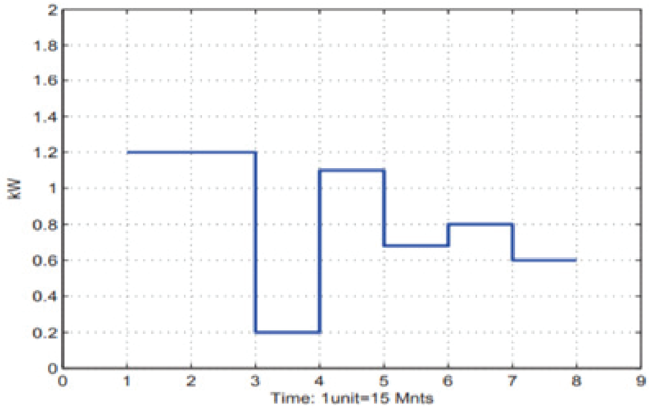


Fig. 2 Load profile for dishwasher

Laundry

The laundry machine represents the case of two appliances – washing machine and drying machine – working consequentially. The washing machine, similarly to the dishwasher, has three cycles of operation: wash, rinse, spin, and dry. It takes about two hours to complete all the cycles. Laundry is classified in the category of a schedulable load.

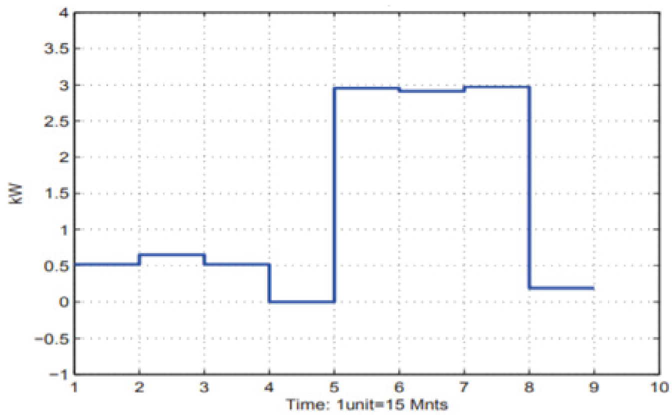


Fig. 3 Load profile for laundry

Air-conditioner (AC)

The load consumption pattern of the air-conditioner is shown below, represented by a series of square wave trains. When the AC compressor is working, it consumes 0.25 kW. The peaks in Figure 4. show that the AC compressor is working, usually at 0.25kW, and the troughs depict the momentary compressor off-time. AC is classified as a continuous non-shiftable load with a sub-classification as weather-based load.

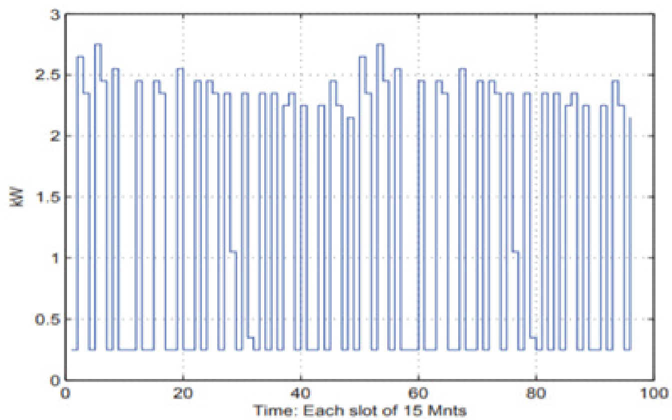


Fig 4. Load profile for air conditioner

Oven

The load profile of the oven is shown in Figure 5. The oven is used both in the morning and evening. For this scenario, the two different times of use show the same energy consumption pattern. The spike represents the energy needed to heat the oven, and the fall is the energy required to maintain the already heated oven in operation. Its electricity consumption is approximately 0.53 kWh. The oven is considered an "unschedulable" load.

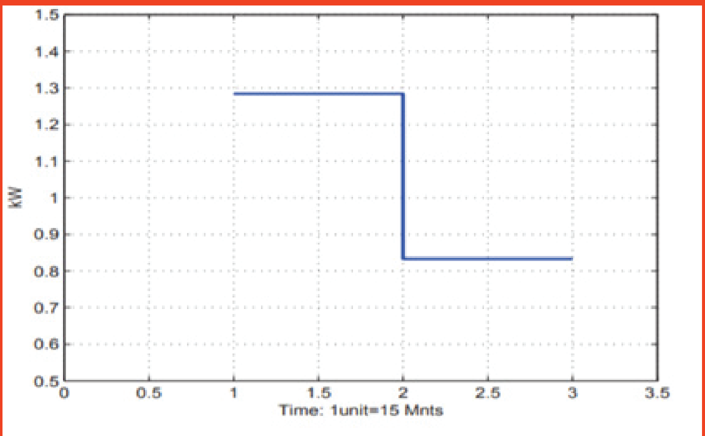


Fig. 5 Load profile for oven

Solar Power Supply as Micro-Grid

In the model home understudy, there is a solar installation which is conceptualized as a micro-grid of 3kW. The photovoltaic (PV) system is connected to the grid in which the direct current produced by PV panels is converted to alternating current (as per national AC standards) by smart inverters.

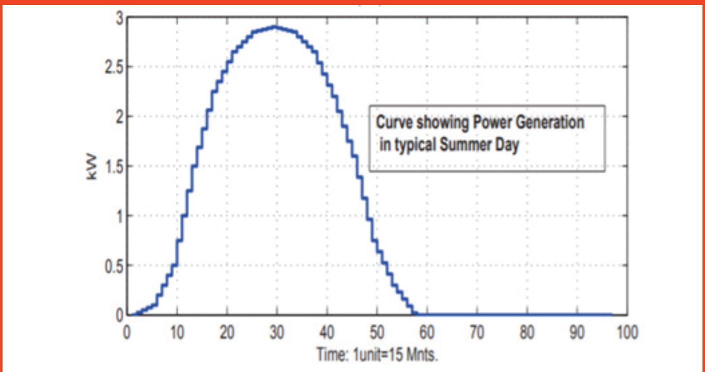
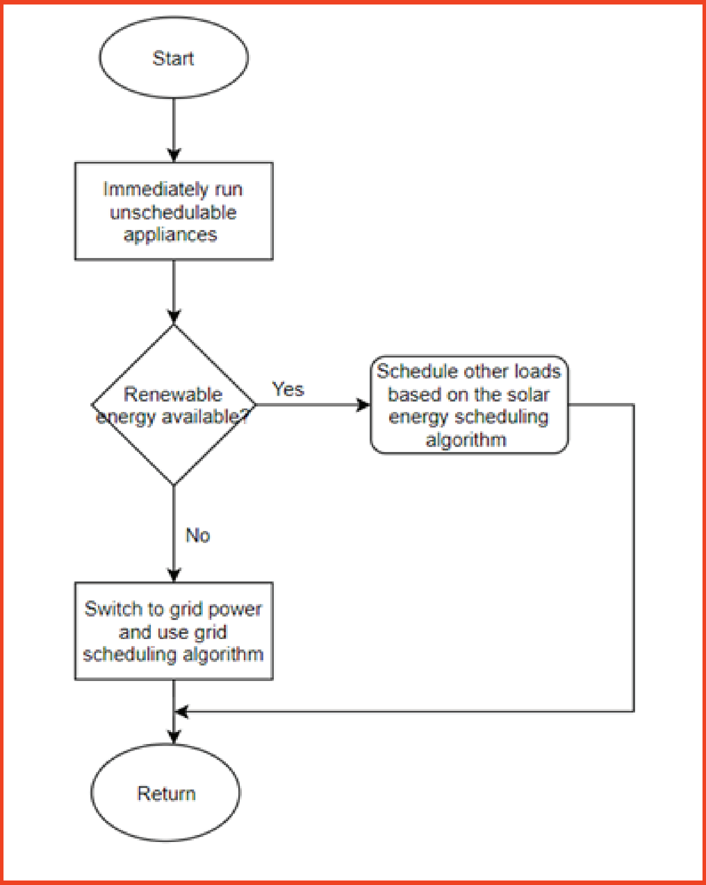


Figure 6 Photovoltaic (PV) Generation Profile

Flowchart of Scheduling Algorithm



Duration of Operation

The 24 hours in a day is divided into 24-time slots. Thus, each time slot represents 1 hour. The appliances can be set to start at any time within this time frame and end its cycle of operation before or during the 24th time.

Execution Window of each Operation

The home appliances would commence operation at a user-specified time frame. More precisely, for each device, there is a time before the appliance cannot start and an ending time, by which it should have finished running. The following rules apply to each slot; surely not later than the assigned 24 hours. For illustration, results on graphs will show the time slots for each hour of the day given the following constraints:

1. Should an appliance run more than once, then other appliances with non-colliding execution windows could run at the same time with it.
2. If an appliance would not be used at all in a day, then its duration of use should be set to zero.

4. OPTIMAL LOAD SCHEDULING WITHOUT SOLAR ENERGY

To be able to make a better conclusion on the load scheduling with solar energy, a control load scheduling with grid energy only would be modelled in this section. The electricity price fluctuation for every hour is also considered. The optimization scheduling required the use of the MILP in the MATLAB simulation and the addition of scheduling constraints.

Method 1: Mixed Integer Linear Programming

Linear optimization techniques are widely used to solve engineering problems by minimizing or maximizing an objective function. Indeed, many concrete problems can be expressed as a linear program and be efficiently solved by an algorithm. For instance, optimizing the time it takes to go from Ashesi to Accra can be accomplished using linear programming methods. In linear programming, all functions and constraints are related to a variable x with the form:

$$a^t x + b$$

There are three main types of linear optimization techniques; namely continuous, integer and mixed-integer. The continuous optimization method deals with real number variables. Algorithms are used to solve this type of optimization to generate iterated values of the variables until a solution is found [12]. The second integer programming optimization is similar to the previous. This is the last mixed-integer linear programming technique that would be used in this paper. The mixed-integer technique uses both discrete and continuous variables while minimizing or maximizing an objective function under a set of constraints [13]. The MILP mathematical equation is given by:

$$\max, \min\ c^T x$$

Let an appliance set G be defined as G = {1,2,3, … . , n}, where n represents the total number of time-shiftable appliances, and let a vector $p_{i,j}$ – which represents the power consumption of the *ith* appliance in a time slot j ∈ H = {1, … ,24} – be defined by the equation below:

$$p_{i,j} = (p_{i,j}, 1, p_i, 2 \ldots, p_i, 24) \in R24, \text{ for } i \in G \ \&\ J \in H$$

The power consumption formula $p_{i,j}$ has to be included within a specific range defined by the standby power α and the maximum working power β. The standby power, also called vampire power, refers to the small amount of electric power consumed by the appliances while they are switched off. The maximum working power defines the maximum energy that an appliance can consume over a period of time. The consumption constraint is formulated in the equation below:

$$\alpha_{i,j} \le p_{i,j} \le \beta_{i,j}\ \forall j \ \&\ i \in G$$

The electricity price (tariff) changes over a time of 24 hours according to the Electricity Company of Ghana's index on tariffs for residential usage. The defined electricity cost is given by a 1 * 24 matrix such as: [0.9,0.8,0.8,0.9,1,1,0.8,1,0.1,0.1,0.1,0.1,0.1,0.1,0.1,0.9,0.1,0.2,0.1,0.2,0.1,0.2,0.1,0.2,0.1].

Let the summation denoted as $\sum_{i\in G} p_{i,j}$ represent the non-negative required power of all five appliances for a time slot j, where $n = 5$ and $G = \{1,2,3,4,5\}$, since only five appliances are considered. The objective function, which represents the residential electricity bill for a day in our case, is given by multiplying the electricity cost that varies according to the fluctuation method used by the appliances' power consumption as seen in equation below:

$$\sum_{j\in H} cost_{j,s} \sum_{i\in G} p_{i,j} = \sum_{i\in G} cost_{j,s}{}^T p_i$$

Where the value of s = {1,2,3} represents which method of electric price fluctuation is used. The optimization objective based on the MILP method can be formulated as follow: $\sum_{i\in G} cost_{j,s}{}^T p_i$. The optimization function is given by a 5*24 matrix as seen in the equation below:

$$\sum_{iEG} cost_{j.3^T} * pi = \begin{matrix} cost_{1.3} \\ cost_{2.3} \\ . \\ . \\ . \\ cost_{24.3} \end{matrix} * \begin{bmatrix} p_{1,1} & p_{1,2} & p_{1,3} & . & . & p_{1,24} \\ p_{2,1} & p_{2,2} & p_{2,3} & . & . & p_{2,24} \\ p_{3,1} & p_{2,3} & p_{3,3} & . & . & p_{3,24} \\ p_{4,1} & p_{2,4} & p_{4,3} & . & . & p_{4,24} \\ p_{5,1} & p_{2,5} & p_{5,3} & . & . & p_{5,24} \end{bmatrix}$$

$$= \begin{bmatrix} cost_{1,3} * p_{1,1} & cost_{2,3} * p_{1,2} & cost_{3,3} * p_{1,3} & . & . & cost_{24,3} * p_{1,24} \\ cost_{1,3} * p_{2,1} & cost_{2,3} * p_{2,2} & cost_{3,3} * p_{2,3} & . & . & cost_{24,3} * p_{2,24} \\ cost_{1,3} * p_{3,1} & cost_{2,3} * p_{3,2} & cost_{3,3} * p_{3,3} & . & . & cost_{24,3} * p_{3,24} \\ cost_{1,3} * p_{4,1} & cost_{2,3} * p_{4,2} & cost_{3,3} * p_{4,3} & . & . & cost_{24,3} * p_{4,24} \\ cost_{1,3} * p_{5,1} & cost_{2,3} * p_{5,2} & cost_{3,3} * p_{5,3} & . & . & cost_{24,3} * p_{5,24} \end{bmatrix}$$

To implement the MILP model in MATLAB, the solver "intlinprog" is used and is based on the following arguments: f, intcon,A, b, Aeq, beq, lb, ub) [14]. The vector f represents the coefficient vector, intcon refers to the vector of integer constraints, A is the linear inequality matrix, Aeq is the linear equality constraint matrix, beq is the linear eqvvuality constraint vector and lb and ub refers to the lower and upper bounds.
Below is the general form of the MILP method in Matlab:

$$min f^T x \text{ subject to } \begin{cases} x(intcon) are\ integers \\ A.x \leq b \\ Aeq.x = beq \\ lb \leq x \leq ub \end{cases}$$

Table 1 Home Appliances and their Corresponding Scheduling Time

Appliances	Type	Daily Power	Energy Consumption Patterns
Oven	Time and power shift-able	1100W	Preferred hours: 7am-9am: 300Wh,10am: 200Wh
Washing Machine	Time and power shift-able	500W	Preferred hours: 12pm: 500Wh
Iron	Time and power shift-able	400W	Preferred hours: 9am: 500Wh, 1pm: 300Wh
Dishwasher	Time and power shift-able	400W	Preferred hour: 12pm-2pm: 400W
Heater	Time and power shift-able	800W	Preferred hour: 9am: 500Wh, 2pm: 300Wh

Based on the power consumption pattern given in the table, the following scheduling graph in Figure 8 was obtained using MATLAB:

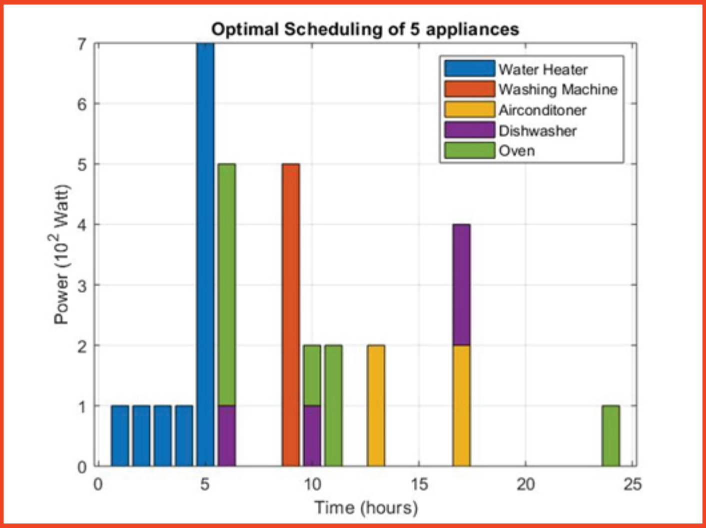


Figure 8 MILP Scheduled Loads Without Solar

Method 2: Artificial Neural Networks

From Figure 9, the inputs are the availability of grid supply, the rating of the device, and the user's want. The user's want is an arbitrary value between 0 and 5, with five being the highest. If the user's want is 3 and above, the load would be scheduled for grid consumption. If the user's want of the device at a time is less than 3, then the load is not scheduled at all.
Contrarily, the ANN outputs are the signals determining consumption from the grid, or consumption from the solar system or no consumption at all. The ANN parameters are shown in the table below:

Table 2 ANN Parameters

Parameters	Value
Number of inputs	5
Number of outputs	5
Number of hidden layers	2
Number of neurons in hidden layer N1	18
Number of neurons in hidden layer N2	20
Number of iterations	1000
Learning rate	0.6175
Regression Coefficient	0.99518

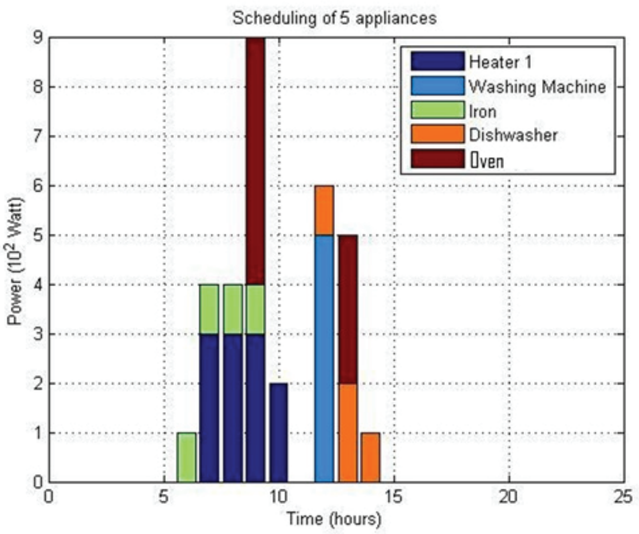


Figure 9 ANN Scheduled Loads Without Solar

5. OPTIMAL LOAD SCHEDULING WITH SOLAR ENERGY

This section focuses on the ultimate scheduling of household loads, which involves the consumption of solar energy and the grid. The same approach from section 4 was used; however, here the solar energy produced was considered. Data of solar irradiance for Ghana was downloaded from NASA's website for an average day in May. The factors of my MILP model depend on:

1. User Want,
2. Power Rating of the device,
3. Sunshine availability

The user want is an arbitrary number between 0 and 5, with 5 being the highest. If sunshine is available, with a user want of 3 and above, and the Power Rating of the device is less than the solar energy produced, the load would be scheduled for the solar energy to be consumed. If all conditions remain constant, however, the power rating of the device is higher than the solar energy produced. Under these conditions, the load is scheduled for grid. If the user want of the device is less than 3, then the load is not scheduled at all.

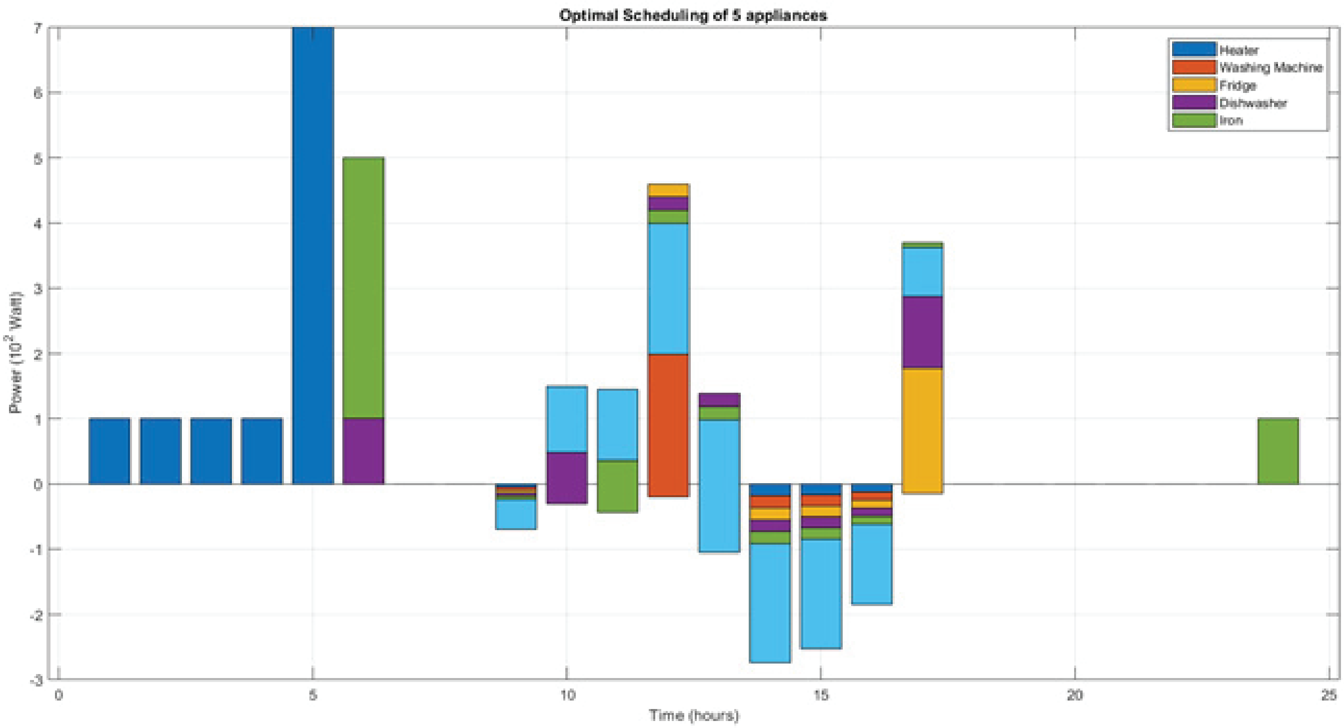


Figure 10 MILP Scheduled Loads With Solar

Method 2: Artificial Neural Networks

This section focuses on the ultimate load scheduling of household loads, which involves the consumption of solar energy and the grid, using Artificial Neural Networks. The same approach from section 4; here, however, the solar energy produced was considered. Data of solar irradiance data for Ghana was downloaded from NASA's website for an average day in May. This makes the factors for my ANN network change from four to five, with the availability of solar energy included. Household loads were scheduled according to Table 1 in Section 4.

The parameters are Sunshine Intensity, User Want, and Power Rating of the device:

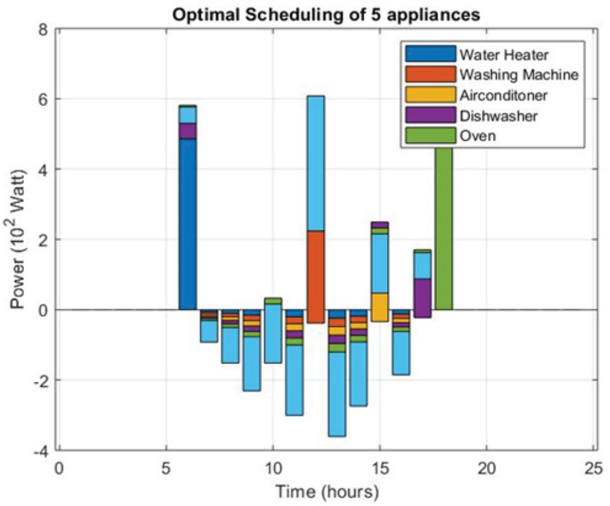


Figure 11 ANN Scheduled Loads Without Solar

6. LOAD CONSUMPTION WITHOUT OPTIMIZATION

A control of the load consumption in a home without any form of scheduling is illustrated below with the normal energy consumption patterns in a home.

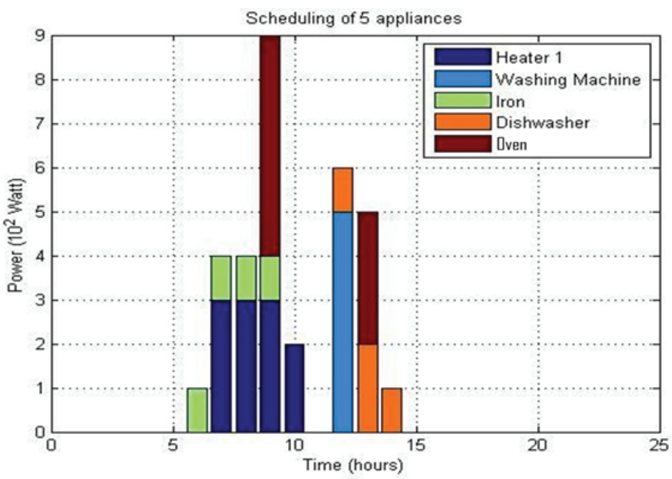


Figure 12 Load Consumption Without Scheduling

1. Cost Benefit Analysis for the Best Optimization Algorithm

After having compared the different pricing methods and their relative cost, it is important to compare the costs associated with the different optimization methods. Three different approaches are compared, namely: optimal scheduling, PV optimal scheduling and optimization, which are based on the assumption that the surplus of solar energy can be sold back to the grid. The percentage reduction of the daily cost is formulated for each method with respect to the scheduling plan without optimization. We assume that the selling price of the solar energy back to the grid is equal to the electricity cost value for a constant pricing method. A summary of the different costs with respect to each pricing and optimization method is given in the tables below.

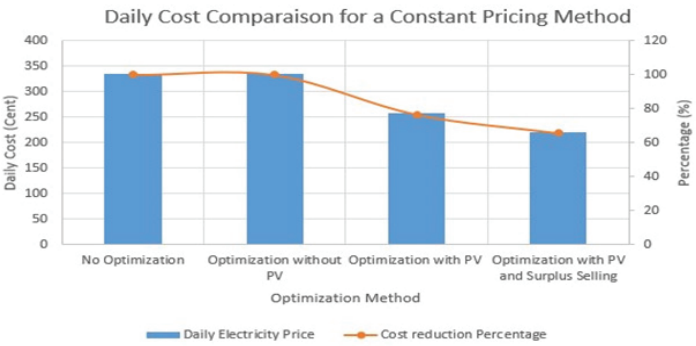
The percentage change of the cost from one optimization approach to another and with respect to each billing method can be calculated using equation (15).

$$percentage\ change = \frac{cost_{i+1} - cost_i}{cost_i}$$

The percentage change can then be derived and gives an idea about the most cost-effective pricing method.

Scheduling With Solar Energy		
Appliances	Cost Without Optimization ($)	Cost with PV Optimization ($)
Heater	0.099	0.069
Washing Machine	0.055	0.049
Iron	0.032	0.03
Dishwasher	0.048	0.048
Oven	0.064	0.045
Total	0.298	0.24

Daily Electricity Cost of the Appliances ($)				
Pricing/ Optimization Method	No Optimization	Optimization without PV	Optimization with PV	Optimization with PV and Energy Selling
Daily Electricity Cost	0.336	0.336	0.257	0.221



The cost analysis shows that the optimal scheduling of electric appliances reduces the cost and proves to be effective. It can be concluded that the most cost-effective method is the bi-daily pricing method because the savings can reach 47.1%, even if its initial cost without optimization is higher.

7. CONCLUSION AND FUTURE WORKS

Reducing the environmental impact of energy generation and responding effectively to the energy demand is crucial toward achieving sustainability. The purpose of this capstone project was to identify the best algorithm for household load scheduling to reduce the cost of electricity bills in the home. Two optimization method – the Mixed Integer Linear Programming and Artificial Neural Networks – were considered. The scheduling optimizations were implemented respectively according to the availability of solar energy. Moreover, the optimization part was divided into two main sections, namely optimizing without solar energy resources and optimizing in conjunction with solar energy. The simulation results showed that optimizing the scheduling of the electric appliances could reduce the bill by up to 38%, when no renewable energy is considered and by up to 47% when it is considered with renewable energy.
Finally, the results obtained demonstrated the efficiency of the ANN to achieve the appliances optimal scheduling, as against the efficiency of the MILP. In this project, the utility function, which represent the satisfaction level of the consumer, was not considered. The algorithm and optimization method could be enhanced by taking into account the user's time of preference to use a particular appliance.

Acknowledgments

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Mother Earth

It's 13 o'clock GMT, year 2 on planet Mars. Tony is in his office when he gets an alert on his transparent glass phone, "your meeting with the board begins in 5 minutes - will be happening in French. Download French Language?"
He chooses: "Absolutely."
A long queue stretched from the front gate of the community hospital to the main road a mile away. A few women had their umbrellas up to protect their complexion from the sun's harshness. People rubbed shoulders with other individuals, trying to maneuver their way to the front of the queue. The atmosphere was charged with frustration and sweat; the slow movement of the queue only made things worse. Despite the visible tension, the queue got longer, with each person eager to get the vaccines being administered at the hospital. Vaccination against all speculative infections, including HIV/AIDS and COVID-19, was one of the main criteria for acquiring a ticket to Mars. There were a limited number of vaccines, since rhodium, the resource used for these vaccines, was scarcer than hens' teeth.
Tony was one of the people to embark on the journey to Mars. The earth was dilapidating, skin and lung cancer rates were skyrocketing. And on Mars, a comfortable life was promised: a furnished apartment, and a monthly allowance. He had nothing to lose from embarking on this journey; well... apart from his mother.
"We're only taking people younger than 30. Your mother is 60. Sorry man, definitely out of the picture. Say your goodbye wishes; according to the contract you cannot return to the earth until 10 years." This was the reply he received when he turned in an application for his mom to be allowed on board; the woman who raised him single-handedly, working many shifts to get him through school. How could he leave her behind?
"My baby boy, come here," Tony's mother said to him when he broke the news to her.
"You want to know the truth? I'm afraid. Yes, your brave mother is afraid; afraid of being alone. You've been my whole life, and now fate is clutching you from my hands There is no doubt that, more than anything, I need you more now than ever; but ..."
Tony stared hard at his mother and asked, "But what?"
She smiled softly, "But, your life is now beginning, mine is ending. Please, go to Mars. Start a new life. We can call every day."
Tony went away with 10,000 other people in Spacecraft Titan. Composed mainly of titanium and aluminum, Titan was fully equipped to carry its occupants for three months successfully to their destination. Frozen dried food was kept in Titan's stores for its occupants, and fuel cells were used to create electricity and water. Sleeping couch bags were strapped down unto the floor in each passenger's chamber to prevent the bags from bumping into objects because there was no gravity, and blindfolds were provided since there was no sunset.
Tony could tell the difference in the quality of air on the Red Planet. The sun was setting along the coast and Mars' two moons could be seen amongst the orange clouds in the sky. The land was tilled, bringing forth different species of flowers, some nameless. Tall magnificent glass buildings with graphical user interfaces had been constructed. Sky-road ways had been built, and there were a few sleek flying cars in the sky, stopping when the air-traffic lights turned red, and speeding off when they turned green.
"Welcome to your new home," the tourist interrupted Tony's intense gaze.
"You'll be having your orientation for a week, and then settle into normal lives with jobs."

Tony smiled.

Tony swipes the downloaded French language from his phone to his left hand, and the nanobots in his body transport it through his hands, up through the nerves in his arms and neck, sending the downloaded data to the insular cortex in the left hemisphere of his brain.
He chooses a room setting on his phone: a light-coffee color theme with an elegant glass table and mahogany glass seats to match. He sets the temperature to 20C and puts his glass phone on the center table. The room transforms accordingly, and the glass table with matching seats appear. The meeting attendees appear as well.
" Où est Tom ?"
Tom appears on his seat, "Vraiment désolé."
"D'accord, Allons-y."
Tony's digital clone appears and walks towards him, "Your wife needs some funds urgently."
"Alright, take along the required IDs and get the necessary transactions done. Thanks."
"Anytime Sir."
Tony's meeting is over and he's in the boardroom's washroom. His phone begins to vibrate continuously. He looks at the screen. Someone's calling: "Mom". It's a video call. He sighs, then swipes the phone interface onto the washroom mirror. He can see his mother clearly in the large-sized mirror. The wrinkles on her forehead have increased from seven to ten. Her skin looks pale as the grey ashes on his cigar saucer. Crow's feet are rapidly eating into her eyes.

"Son."

"Mother."

"How's Mars?"

"It's erm... pretty fine. How's Earth?"

"Oh, you know, the usual: people dying, lands being swallowed up by the ocean, air's so thick it's difficult to breathe. Some say hell is finally here," she smirks.

"Mhhmm."

"We don't communicate as often."

"Work's been swallowing me up, mom."

"I know."

There's a period of silence.

Tony's mother breaks it, "The doctors say I don't have long. Maybe a couple of months, or fewer."

"Really? When did you know this?"

"Not long. My organs are beginning to fail me."

"I know you can't return to earth to see me, Tony. That's okay," she adds.

Tony turns and looks away from the mirror for a few minutes. He looks back up with tears in his eyes.

"I'm coming mom, I'm coming back to Earth."

The End.

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Maximizing Energy Harnessing In Solar Ovens To Use Environmentally Friendly Energy: Material And Angle Of Inclination.

Department of Engineering
Ashesi University
Solar Oven | inclination |
reflective panel | aluminium | prototype

Abstract
Non-renewable energy, such as fossil fuel, has been the traditional way of providing power. What has alarmed the global public is that these non-renewable resources are fast depleting and are harming the climate because they cannot be converted to clean power. The conversion of non-renewable energy into other forms of energy results in the emission of harmful gases such as greenhouse gases (i.e. carbon dioxide and methane). Other toxic gases released include benzene, which is cancer-causing and nitrogen oxides which contribute to photochemical smog. To reduce these effects, innovations on clean and renewable energy have recently emerged as an alternative way of providing sustainable environmental energy. One of them is solar energy, which is defined by the Comprehensive Guide of Solar Systems as the use of the sun's energy either directly as thermal energy using photovoltaic cells in solar panels or transparent photovoltaic glass to generate electricity [8]. According to research, it is one of the most efficient and readily available sources of energy for the inhabitants of the earth [9]. This paper reports on how a solar oven can be home-made, using cheap and readily available materials in the quench of using clean and renewable energy as an alternative to harmful fossil fuels for baking. We compared the heating effect of three readily available aluminium composites. We also analyzed the compromise angle of inclination of the reflectors for maximum possible energy harnessing to increase the efficiency of the solar oven. The analysis is statistically based and was examined using a 0.05 significance level.

INTRODUCTION

With the growing population of the world, the pressure on global energy resources has increased. Fossil fuels have overtaken the market for a long time. Among other places, they are also used in rural areas and developing countries, though the overall emissions of rural areas in developing countries are comparatively low. Fossil fuels emit harmful pollutants into the atmosphere when they are burnt, which leads to air pollution and global warming [1]. Such effects have brought into existence international bodies such as the United Nations Environmental Programme. They now focus on limiting warming to specific levels of global mean temperature, such as 2°C or 1.5°C [2]. To ensure nothing less than human survival, scientist and engineers need to formulate alternative renewable energy resources with immediate action.

Everyday activities, such as cooking could be instrumental in generating technologies that reduce emissions. Cooking, after all, is one activity that humanity cannot live without because its survival depends on food. According to Betts et al. [5], about two million metric tons of firewood and charcoal are consumed daily in developing countries. Mostly the cooking is done on open fires, which leads to low fuel efficiency and high pollution emission. Inhabitants of rural areas mostly burn fuels and charcoal in poorly ventilated rooms, which exposes them to harmful gases. Women and children are most affected

The gases emitted contain carbon dioxide, which is detrimental to the health of the users as well as the environment in which they live. Diseases and conditions such as acute respiratory infection, low birth weight in pregnant women, among other ailments, have become very rampant in developing and rural areas where charcoal and firewood are used as a source of heat for cooking [5]. Solar cooking provides a better option for using charcoal and firewood as cooking fuel. It is environmentally sustainable as it uses clean and renewable energy. Solar cookers might not entirely solve the issues of global warming and deforestation, but solar cooking is a better way of reducing the amount of carbon emission into the atmosphere. It never runs out, and it is a natural source.

Moreover, it creates jobs for rural immigrants since the maintenance of some of the solar appliances requires a vast workforce [6]. Solar cooking has become one of the world's best and most exciting solutions to problems associated with the rural way of cooking, which involves the burning of fuelwood sources and other environmental issues related to wood. In the findings of a study, Droege highlights fuelwood as a crucial source of energy in households. The study found that homes of more than six inhabitants require more fuelwood. Since a majority of the respondents were unemployed or low-income earners, they need an alternative efficient but cheap source of energy to cook [7].

A solar oven is a device that helps harness and utilizes direct sunlight energy to warm foods and drinks. It can be used in places where there is much sunshine, such as Africa, which is in the tropical zone. It requires minimum technical know-how to build and is most suitable for developing countries and rural areas where electricity is scarce. It is useful because it has moderate temperatures which would retain the nutrients in the food. Finally, health hazards such as irritation to lungs and eyes are avoided as cooking is smoke-free. Solar ovens come in various forms and have three major parts. The feature common to each oven design is the shiny reflective surface that directs the sun's rays onto a dark cooking vessel.

For this project, we aimed at designing and constructing solar cookers to compare the reflective index of aluminium composites on the heating effect of the solar oven. Also, we analyzed the angle of inclination of the reflective surface/plate relative to the horizontal ground to get the best design of the solar oven that can harness the maximum amount of heat energy per day. The degree of inclination determines the amount of sunlight that will effectively heat the oven.

METHODS

Three identical solar oven prototypes were made using aluminium, aluminium foil and alucobond to create the reflective material as shown in figure 1(a). All the aluminium composite sheets had the same dimensions and were all shined on the surfaces.

Varying Reflective Material

The angle of inclination of the reflective plate was kept constant at 45 degrees for the three prototypes (see figure 1(c)). Three identical containers were then filled with 50 millilitres of water, and the initial temperature of the water was measured using the temperature probe. The containers were placed inside the prototypes, and the top was covered by a transparent glass to minimize heat loss to the environment. The three ovens were then taken outside and placed on the same position, where the light intensity was approximately equal to allow exposure to the same intensity of sunlight (figure 1(e)). After 25 minutes, the final temperature of the water in the containers was measured using the temperature probe (figure1(c)). The procedure was repeated six times to get six temperature values for each sample.

Varying the Angle of Inclination

The angle of inclination is defined as how much the reflective surface is raised relative to the horizontal base. It was measured from the horizontal plane of the oven to the flat surface of the reflective plane (figure 1(d)). Two angles were used (45 degrees and 80 degrees). The first angle was set to 45 degrees on all the ovens, and six sets of temperature values were taken over in 25 minutes. The angle was then changed to 80 degrees, and six temperature values were taken for each prototype. The average temperatures were then calculated.

Data Collected

Two sets of temperature data were collected based on the varying the angle of inclination. Six data points were collected for each prototype, and the averages were used for statistical analysis.

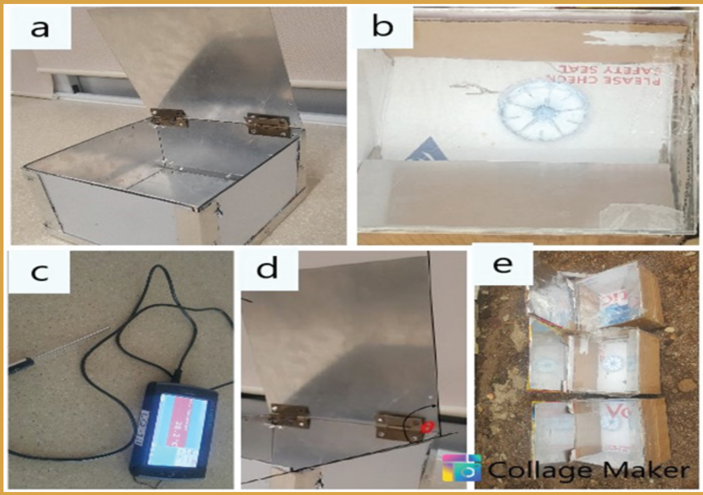

Fig. 1. (a) the completed prototype (b) the container with the water inside the oven. (c) the temperature nob used with a lad Quest (d) depicts how the angle was measured relative to the reflective panel (e) the three prototypes were placed on an open space.

Results and Discussion

All the statistical analysis was done using R studio at the 95% confidence interval. We first conducted a normality test to determine whether to use parametric tests or not.

Test for Normality

The test was done on the six data points for each material on the prototype with Shapiro package. Shapiro is a statistical package in R studio, that is used to test if the data follows a normal distribution. The test was carried out for both the data on different materials and data on different angles of inclination. All the p values for the test were greater than 5%, indicating that there was no statistical difference, thus the data followed a normal distribution (at 95% ci).

Table 1 The results of the Shapiro Test

Material	P-value	Normal Distribution
Aluminium High Carbon	0.2362	Yes
Alucobond	0.1002	Yes
Aluminium foil	0.1331	Yes

One-Way ANOVA Test

We carried out an Analysis of Variances (ANOVA) test to test the difference between the mean heating effect of different materials. In this test, we had only one factor, the material and one level of the angle of inclination of the panels. The response was the maximum temperature recorded in the oven for each material. The table below shows the summary of the one-way ANOVA.

Table 2. The Hypothesis

H_0	H_a	*Result*
µaluco = µfoil = µhighC	µaluco ≠ µaluco ≠ µaluco	acceptH0

At the 95% confidence interval, the p-value of 0.709 > p-critical of 0.05, showed that there was no statistical difference between the mean heating effect of the different aluminium composite materials. This result meant that the three materials produced the same heating effect statistically. Thus, we used a non-statistical judgment to choose the best material on which to vary the angle of inclination. Aluminium foil was selected because of its affordability and portability. It is also practical in the construction of the oven. We went on to perform a two-tailed student t-test on the two angles for aluminium foil.

Two-tailed T-test

The heating effect produced by the two angles was statistically compared at the 95% confidence level. This confidence level is ideal for a device that would be used for non-medical purposes. T-test was used because our sample size was less than 30, and the population variance was unknown.

Table 3. The Hypothesis

H_0	H_a	*Result*
µ45deg = µ80deg	*µ45deg ≠ µ80deg*	*rejected*H_0

After the test at 95% confidence interval, the p-value(0.009323) < p-critical(0.005)), meant that there was a statistical difference between the heating effect produced by a 45-degree angle and the one produced by an 80-degree angle. Eighty degrees had a higher heating value than a 45-degree angle.

CONCLUSION

There was no statistical difference between the average heating temperatures of the aluminium composite materials used. Based on our experiment, we concluded that the three materials had the same heating effect. Since they all have the same heating effect, we recommend the use of aluminium foil in rural areas, since it has the least cost and an average life span. However, those willing to pay the high price may use high aluminium carbon, which requires more experienced personnel to cut and has the longest life span. There was a statistical difference between the heating effect of the two angles with the 80-degree angle having the more excellent heating value than 45 degrees. Based on our design, we recommend that in the construction of solar ovens, the angle of inclination of the reflective surface should be between 70 degrees and 80 degrees. Users of solar ovens should position their oven in an open space to harness maximum solar energy at any given time.

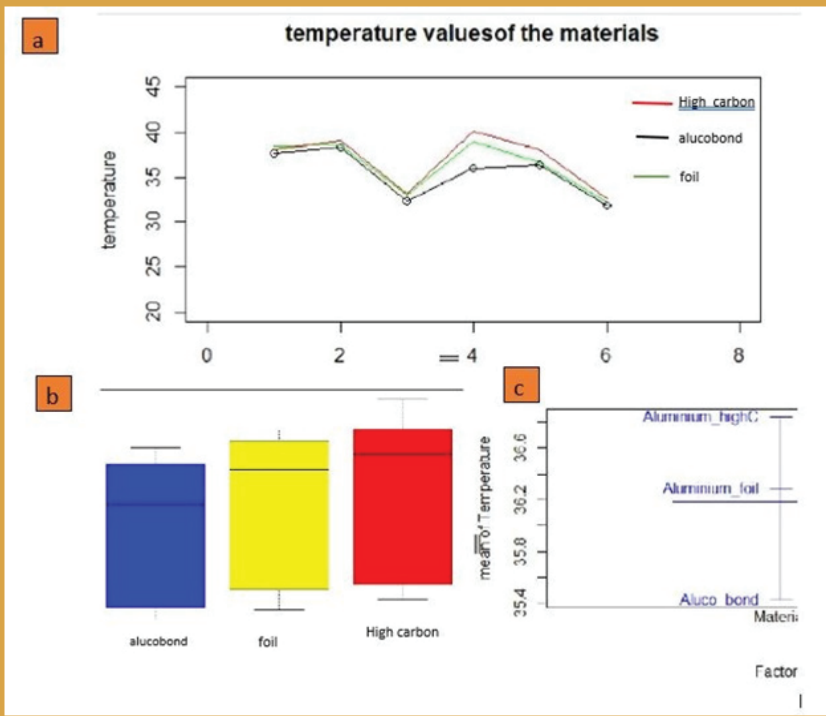

Fig. 3. (a) the line graph showing the distribution of temperature values for each material (b) the box and whisker plots for the data (c) graph showing the distribution of the mean heating values for the materials.

ACKNOWLEDGEMENTS

Much appreciation and thanks go to our lectures Dr Elena Rosca and John Rani, for making this project a success.

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Interview

Jennipher Alista Panashe
Co-Founder and Managing Director
SisuTerra Technologies

Bio.

A Mechanical Engineering graduate from Ashesi University, Jennipher is an aspiring entrepreneurial engineer with a burning desire to acquire new skills and experience in the engineering field. Her experience has been in the field of petroleum engineering and automobiles. She has worked as an assistant project engineer at reputable companies like Fueltec Zimbabwe, Scania Automobiles West Africa and Universal Engineering and Consultancy Services, Ghana. Jennipher is also a passionate activist of environmental and sustainable development in Africa. Her desire is to touch lives, change a lifestyle and bring hope to the people around her. Outside work, Jennipher loves reading, travelling, hiking, doing research and voluntary work.

SEED: What was the first considerable hurdle for your start-up as you began to emerge?

Jennipher Alista Panashe: Finding the right product-market fit. We have gone through several pivots to be where we are today. You may think that you are developing a cool product yet with no users to patronize the product. There is a need to continuously re-evaluate your market to ensure you are solving the right problem for your customers.

S: What advice would you give to students looking to also be players in the tech-start-up space?

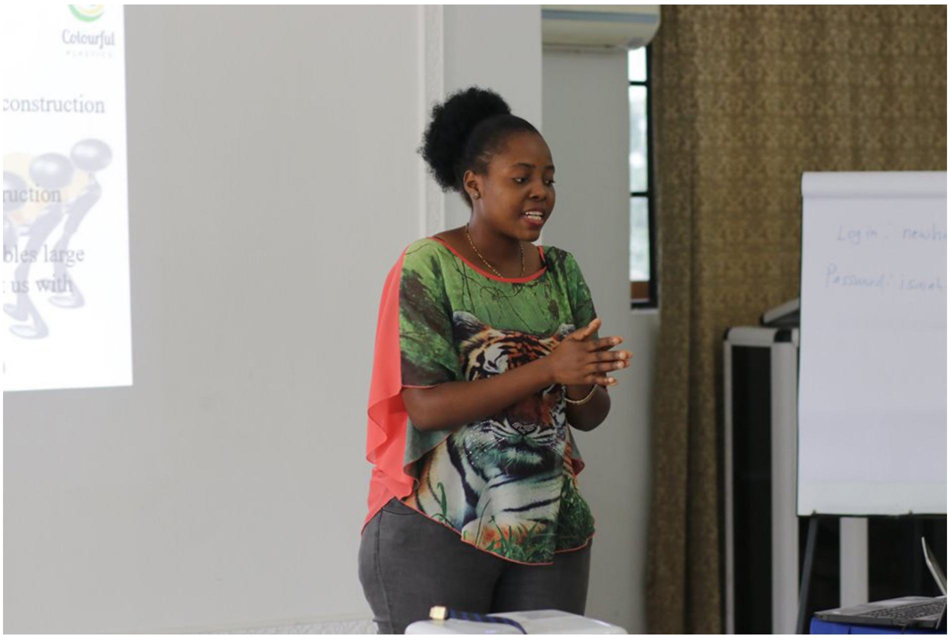
JAN: Start early. I believe we could have done more if we had taken the idea world cup from the start. In addition, look at what other players in the industry are doing. We all need inspiration.

S: How indispensable was your major, in helping you to fully identify your problem space?

JAN: Without the class community engagement project in Ashesi, the idea would not have been conceived. Our entrepreneurial journey started as a service-learning project for the Leadership 4 for Engineers Course. As part of the leadership 4 class for, my teammates and I were required to find a problem in our community and provide an engineering solution to it. We chose pollution as a problem that we wanted to focus on and eventually came up with the concept of plastic roads.

S: What drove you to fervently begin this start-up?

JAN: The main reason I chose this path of entrepreneurship is the passionate desire I have for a clean and sustainable environment. I am, basically, turning my passion into a business that is meeting the needs of the people around me.



“Fun-challenging-but-growth-enabling-experiences!”

S: How long has your business been running for?

JAN: Though we started working on the idea in November 2018, I would say we started in June 2019. We started working on the idea fully last year. However, at the moment we are finishing up our R&D phase. We hope to start operations by the end of this year.

S: Would you give any credit to Ashesi for helping you enter this tech-business?

JAN: Yes, definitely. FDE, Leadership classes and all the hands-on experience helped us to become-who we are today. I am really grateful for the Ashesi experience and mindset.

S: What are three key things you wish you knew then, but you know now?

JAN:
1. How to start seeking funds early.
2. A lean start-up is the best approach to starting a business.
3. Branding and PR are very important strategies to employ early in a start-up. Let the world know about what you are doing.

S: If you had to summarize your experience in this new sector, into one word, what would it be?

JAN: That’s pretty hard. I will make my own word. ***Fun-challenging-but-growth-enabling-experiences!*** It’s still one word, right??

S: Do you fear you might not be able to compete with bigger competitors?

JAN: Not really. The market is huge! There has been a demand for building green and also an upsurgeof parties that have been pushing for the adoption of green building materials and technology. Both the public and private sectors are demanding healthier, cost-effective, and resilient buildings. Due to this impetus for sustainable construction, SisuTerra’s model is carved to serve such an emerging niche.

S: What does a fully established SisuTerra Technologies company look like to you?

JAN: A fully established SisuTerra Technologies has a track record of building durable infrastructure with less. We envision smart cities, “Colourful Cities” , built with recycled and/or sustainable products that are durable. A typical “colourful” city has recycled plastic pavements and houses made up of plastic blocks and tiles. We want to build GREEN Cities!

S: Are you open to the idea of collaborating with another company, and are you a non-profit?

JAN: We like to call ourselves a hybrid business . SisuTerra operates on a hybrid business model strategy that helps us to be both commercially and socially viable. Our hybrid model is centred on our value proposition; we are solving environmental pollution and poor infrastructure, while also delivering value engineered products that significantly save time and money. And yes, we are very much open to collaborations. We cannot tackle this plastic pandemic challenge alone. In addition, our desire is to enable people’s access to sustainable and affordable building materials.

Design and Static Testing of a Low-cost Inflatable Wing

Nomenclature:
A = area of the wing
d = vertical deflection of the wing
E = Young modulus
F = force exerted by the weights on the wing
I = second moment of area
c = chord of the wing
L = length of the wing

By:
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Abstract

Remote controlled (RC) planes, popularly known as drones or Unmanned Aerial Vehicles (UAV), have gained much attention due to their ability to perform sophisticated tasks, such as environmental monitoring, medical delivery and surveillance. This research was inspired by the demand to explore and develop alternative ways of making UAVs more feasible, less costly and more efficient by utilising the idea of inflatable wings. Previously developed inflatable wings were made from expensive fabricated materials. The use of costly materials is, however, not feasible developing countries, specifically in African countries, which struggle to adopt new technologies due to limited resources. The objective of this study is to create and design a lightweight inflatable wing using low cost and readily available materials that will allow the massive deployment of small aircraft. It also explores different fabrication methods that will enable the low-cost manufacturing of the physical model.

Introduction

Remote controlled (RC) planes, popularly known as Unmanned Aerial Vehicles (UAVs), have gained attention due to the sophisticated tasks they are performing in our day-to-day lives. As a result, efforts have been made to find different ways of making UAVs more feasible, less costly and more efficient [1]. A deployable UAV is an aircraft that can change its aerofoil/wing size specifically by reducing its size for easy storage. Inventors made early designs out of foldable and flexible wings. From 1486 to 1490, an engineer called Da Vinci tried to develop flapping wings by devising many different flapping mechanisms. Other design mechanisms, such as wing folding, were explored. Research carried out by Moon et al. investigated the 4D printing technology for deployable UAV development [2]. Their design mechanism comprised of hinges, which allows the plane to fold its wings to reduce size for storage. However, these hinges in the design increase the weight of the aeroplane and hence reduce flight endurance and efficiency. The limitations of the above systems led to the re-focus of inflatable wings.

Literature Review

Numerous laboratory and flight tests have been performed to demonstrate the damage tolerance of inflatable wings. The survivability rate has remained at 100% beyond one hundred flight test impacts and has been verified by similar laboratory testing [3]. This paper studies and evaluates the previous literature that mainly focuses on different designs and materials that have been used to build wings for RC planes. Among relevant research, one study proposed an inflatable wing design that aimed to address the limitations encountered in the existing models by employing an indirect 3D printing [4]. Their design intended to reduce aircraft weight and complexity while improving the aerodynamic characteristics of the aircraft. The inflatable wing was fabricated integrally with a lattice structure as a reinforcement, using a flexible impermeable material silicon rubber. This structure regulated the shape of the inflatable wing and increased the stiffness of the wing by absorbing parta of the load exerted on the wing. The lattice structure was fabricated using a silicon rubber, which was injected into the 3D printed meld with a syringe for casting.

Figure 1: Inflatable wing in a wind tunnel with fiducial markers at the University of Kentucky.

The proposed indirect 3D fabrication may have undesirable characteristics required for the lightweight inflatable wing. The hexagonal lattice structure in the wing interior provides wing stiffness. However, it may result in increased wing weight that reduces flight endurance. Also, the fabrication methods are quite sophisticated and costly, especially for African companies to adopt. Looking more into previous designs, other researchers

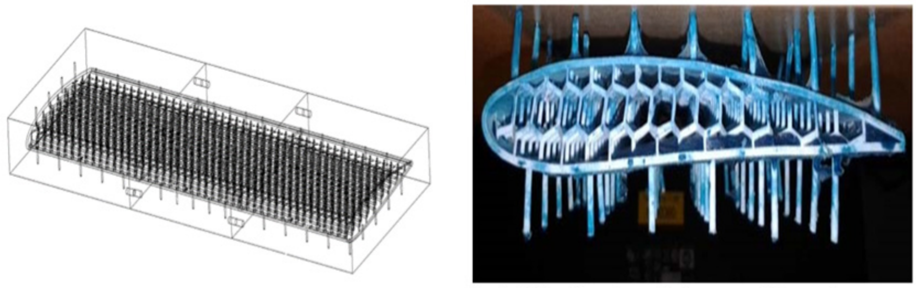


Figure 2. (a) The lattice structure wing. (b) Hexagonal diamond structure of the inflatable wing

presented work on testing of inflatable wings for UAVs [5]. The discussion focused on the aerodynamic forces generated by the shape and also the correlation between internal pressure and wing stiffness. Two design variants were developed and tested: 3(a) inflatable wings that require constant pressurisation and 3(b) inflatable/rigidizable wings that harden into a persistent shape once inflated. The rigidizable wings are constructed using a composite material that becomes rigid on exposure to UV light. The aerofoil was created by sewing woven material. The rigidizable wing was made using layers of the resin-impregnated woven fabric selected for handling characteristics, and an internal containment layer.

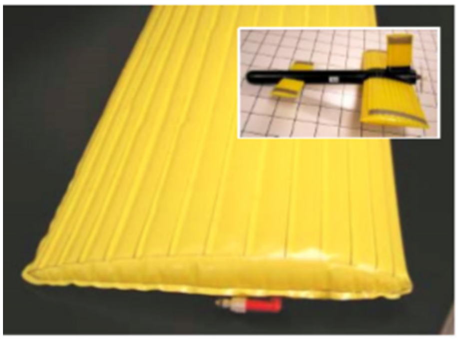
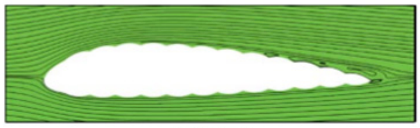


Figure 3. (a) Non-rigidizable inflatable wing

Figure 3. (b) rigidizable inflatable wing

Following their designs and analysis, the rigidizable wing was preferred for adoption. This choice was because it does not need constant pressurisation to maintain its shape, as required by the non-rigidizable wing. However, the rigidizable wing uses a multi-spar design that does not use foam spacer material and so packs compactly. This arrangement might increase the weight, which is undesirable for RC planes and also increases the cost of production of this composite; hence it is expensive to acquire.
More designs have been explored to improve the aerodynamic characteristics of aerofoils. In the paper, **Flight Testing and Simulation of a Mars Aircraft Design Using Inflatable Wings,** Reasor et al. present two aspects of the current development efforts of inflatable wings for Mars exploration, i.e. low-altitude flight testing of an inflatable wing aircraft and computational fluid dynamics (CFD) simulations of different wing geometries [6]. They performed flight tests that demonstrated flight performance, such as endurance and stall velocity. They also built smooth and bumpy aerofoil samples, which were tested across a range of conditions including weather and payload. CFD and experimental observation suggested less flow separation over the bumpy profile as compared to the smooth counterpart. The results also indicated that the presence of bumps on the leading edge reduces the dynamic pressures on a wing resulting in a loss of lift.'

(a) Smooth



(b) Bumpy

Figure 4. Flow profiles of bumpy and smooth aerofoils

The numerical simulations have suggested that bumpy aerofoils must be adopted as it helps make control surfaces more effective. However, there is a need for more simulations to determine the optimum configuration for a given specification/application.

Design Protoype and Analysis

The insights gained from the literature review helped identify the gap in the need to explore the possibility of using low cost and readily available materials for the design of the inflatable wing. Large wingspan increases flight endurance; however, it is not suitable for deployment. Two main models were explored, which were:
• Foldable wings: result in increased weight which is an undesirable flight characteristic.
• Inflatable wings: have a minimal packed-volume-to-weight ratio, thus they are desirable for substantial endurance.
Ultimately the inflatable wing was chosen as it has optimum flight characteristics than foldable wings.

Material Selection

One of the research questions was to design an inflatable wing using low cost and readily available materials. A material selection process was performed on some of the materials that were suggested from the literature review. The Pugh Matrix was used to evaluate and determine the material that fits the criteria. From the table below, it is observed that Hypalon emerged as the best-fit material. However, PVC was used for building prototypes as that was the only available material at the time.

Table 1. Pugh Matrix used for Material Selection

Evaluation Criteria	Weight	Baseline	Kevlar	Hypalon	PVC	Neoprene	Urethane
Manufacturability	4	0	-4	+4	+4	+4	+4
Cost	3	0	0	+3	+3	-3	-3
Strength	2	0	+2	+2	0	-2	0
Availability	1	0	-1	+1	+1	-1	-1
Total			-3	+10	+8	-2	0

Designing Prototype

Two designs of the inflatable wing were sketched. The first design was made up of a traditional singled volume aerofoil structure; a control design which was compared with the proposed design solution for the research. Factors from the literature, as well as biological inspiration, influenced the design solution. The proposed design consists of sperate cylindrical chambers that run parallel to the wingspan. The cylindrical sections are of varying sizes to accommodate the shape of the wing. Unlike the traditional design, which has a single volume chamber, the proposed model has air pumped into the individual chambers that make up the aerofoil.

The following factors were considered when coming up with the design prototype.

• Insights from the literature showed that readily available materials such as PVC are abandoned because they possess poor static characteristics for a wing, which includes stiffness. In the design solution, the proposal of separate cylindrical volumes helps to aid the stiffness, as well as flexural strength of the wing.

• The literature also showed that the main disadvantage of the inflatable wing is its inability to maintain the internal air pressure to keep in-flight configuration. In case of a fault, inflatable winged aircraft usually lose lifts. The use of separate individual cylinders helps to solve this challenge. If one cylinder is faulty, the other cylinders will be able to maintain the shape of the wing at least, hence avoiding accidents and loss of the drone.

• Lastly, the inspiration for the design was gained from the natural biological setup of the honeycomb.

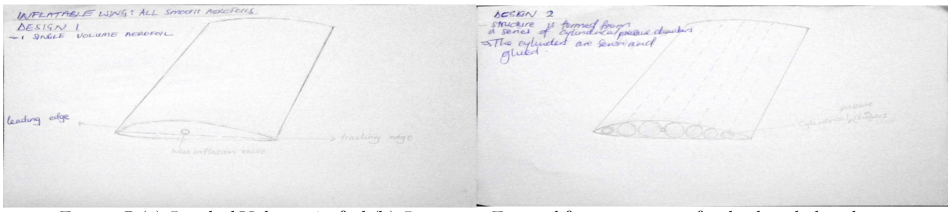


Figure 5 (a) Singled Volume Airfoil (b) Structure Formed from a series of cylindrical chambers

The above two figures show pencil sketches of the inflatable wing design. Figure 5(a) shows the traditional single-volume design, and Figure 5(b) is the sketch of the proposed design solution.

Building the Prototypes

Two prototypes of inflatable wings were made using PVC, epoxy glue and pressure valves. Protractors and pencils were used in the fabrication process. The wing can be rolled when storing energy and then deployed when beginning flight.

Figure 6. Finished inflatable wing prototype

Experimental Design and Test

Static Tests

Two tests were carried out to determine the static characteristics of the wing. These are the bending test and wing stiffness test. Favourable static aspects of the wing emerge when it does not deform permanently after a load has been applied to it.

a) Bending test

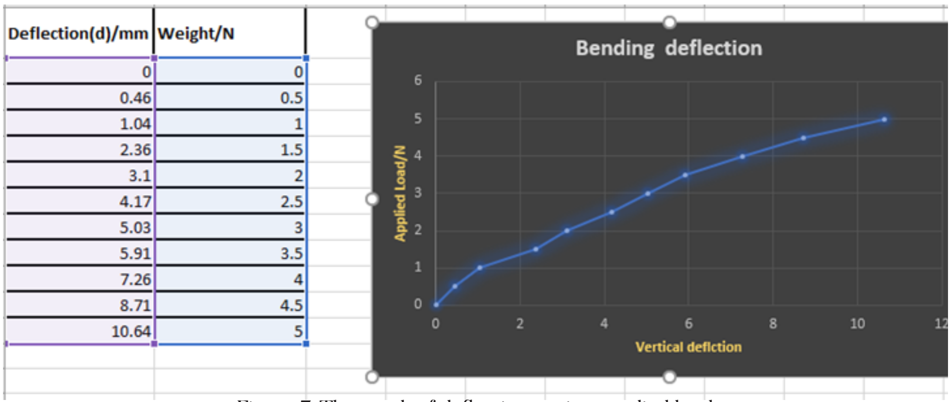
The test involved the following steps:

• The wing was mounted on a rigid test stand like a cantilever beam

• A load of 0.5N (50g) was added at the wingtips, and vertical deflection was measured

• The preceeding step was repeated with the gradual addition of 0.5N weights until 5N

The graph of load against deflection was plotted using excel:

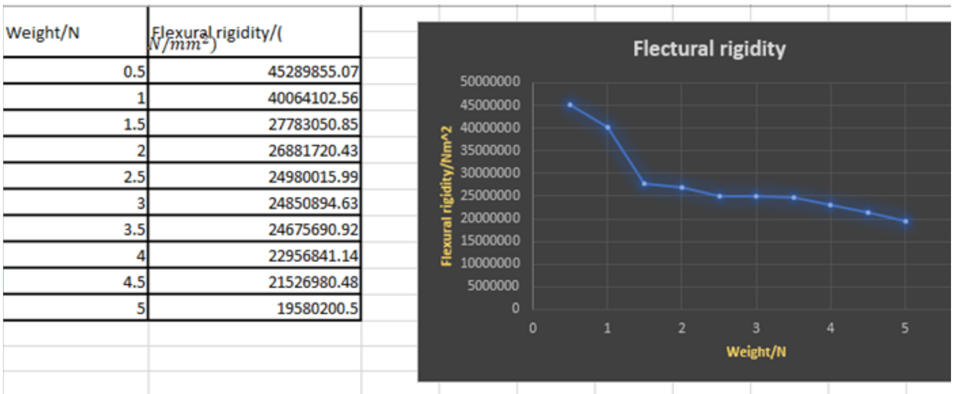


Deflection(d)/mm	Weight/N
0	0
0.46	0.5
1.04	1
2.36	1.5
3.1	2
4.17	2.5
5.03	3
5.91	3.5
7.26	4
8.71	4.5
10.64	5

Figure 7. The graph of deflection against applied load

b) Wing Stiffness Test

With the data above, the flexural rigidity of the wing was calculated from the formula EI=(FL^3)/3d. The graph of weight against rigidity was plotted.



Weight/N	Flexural rigidity/(N/mm^2)
0.5	45289855.07
1	40064102.56
1.5	27783050.85
2	26881720.43
2.5	24980015.99
3	24850894.63
3.5	24675690.92
4	22956841.14
4.5	21526980.48
5	19580200.5

Figure 8. Graph of weight against flexural rigidity

The graph shows that the flexural rigidity decreased as the load are increased, hence the aircraft must have a maximum weight limit.

Future Work and Conclusion

This research paper was able to answer the research questions by conducting experiments using cheap and readily available materials. Also, it illustrated how the designing of an inflatable structure to attain the same or improved static characteristics by applying the multiple cylinder design. The primary limitations were related to making the inflatable wing airtight. The single-volume prototype (control design) was not tested to compare the results with the proposed design prototypes. There were shortages of resources such as the lack of a wind tunnel to examine dynamic characteristics of the wing; hence only static tests were carried out. More future work needs to be done to complete the research project. These include:

- Wind tunnel testing to determine drag and lift characteristics of the wing,
- Development of an autonomous inflation system to allow easy deployment,
- Building the UAV prototype to assess the features of the wing.

Acknowledgements

I want to express my sincere gratitude to my supervisor, Dr Heather Beem, for her continuous unwavering support in this research project. Also, I would like to thank the Research facilitators, Dr Sena Agyepong, Christopher Zanu, William Annoh and the Provost, Angela Owusu-Ansah, for their advice and guidance on how to conduct world-class research. Lastly, I would like to acknowledge Mr Isaac Fukuo for funding this research project.

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Adaptive Alcohol Cooking Stove

ABSTRACT

The concept of the alcohol stove was birthed from the idea of burning pure organic compounds. The growing popularity of the can-alcohol stove has made the idea attractive. Most people today use it when camping, to heat food, and to cook as well. The alcoholic fuel must have a substantial alcohol percentage of about 70% and above before it can be used as fuel. This property makes rubbing alcohol (methylated spirit) suitable for the stove. It is lightweight and releases relatively low-level pollutants when combusted. Alcohol can also be extracted through simple fermentation, allowing our target consumers (low-income farmers) to make it themselves. Our aim was to design an environmentally friendly stove that is low in emissions and can be used for cooking meals in rural areas. We accomplished this through careful design and simulation, using Autodesk Fusion 360 and the Circuit.io App. Autodesk Fusion 360 is an engineering-based software that aids in constructing 3-D objects of proposed prototypes. The Circuito.io app is an Arduino supported software, that helps to assemble different electronic components and provides averaged pricing of all the parts used. The mechanical strength of the stove handle was validated through factors such as the Von Mises stress applied. The heat produced from five ounces of methylated spirit was enough to boil water and oil for close to 30 minutes. The results obtained testify that the alcohol stove is a good model that fits adequately in the rural setting.

INTRODUCTION

The project is focused on design, analysis, and testing of an adaptive cookstove for people living in rural areas. The project was reviewed at various checkpoints to ensure a successful final product. The objective was to make a stove that: is environmentally friendly (i.e. uses green technology), reduces emissions, enables fuel regulation, and must be able to cook full meals. The application of alcohol as a fuel has been adopted worldwide. However, it is essential to note that the fuel used must have a substantial alcohol percentage of about 70% and above. This requirement makes rubbing alcohol (methylated spirit) the right choice [1]. The fuels used are lightweight and generate relatively low-level pollutants when combusted [2]. Brazil, a country booming with natural resources, has been interested in using alcohol as a fuel source for vehicles [3]. After reviewing the paper on 'Numerical Fatigue Analysis of Induction, Hardened and Mechanically Post Treated Steel Component' [4], we realized our initial choice of an induction stove would not be the best, as it works only on magnetic cook pots. In pursuit of designing a stove with reduced emissions, we explored the use of alcohol (i.e. ethanol). Its presence in a mixture reduces carbon dioxide (CO2), carbon monoxide (CO) and organic compound concentration (VOCs). A gallon of fossil fuels releases roughly 19.64 pounds of carbon dioxide into the atmosphere. By comparison, an 80/10 blend of fossil fuel and ethanol will emit 17.68 pounds of carbon dioxide [5]. A mix of 10% ethanol and gasoline can reduce the carbon monoxide load of gasoline emissions by 30% [5]. A blend of 10% ethanol and gasoline can reduce the amount of volatile organic compounds in the exhaust by 7% [5].

METHODOLOGY

The first stage of design was to assemble a 3-D model of the stove, using Autodesk Fusion 360. This model contained the different materials that was to be used in building the stove.

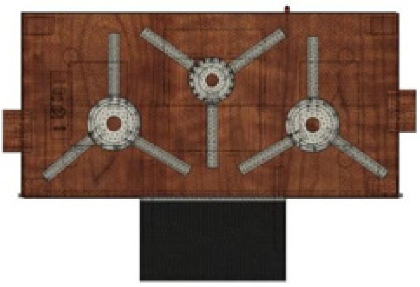


Fig. 1 (top view)

Fig.2 (side view-electronics underneath)

Materials Selection and Material Science

In designing this alcohol stove, we used a well-selected repertoire of materials that increased our product's performance. Our choice was informed by what we learned in our material science course. The selected materials were also incorporated in the 3-D model (Autodesk Fusion 360 software), to see the capability of these materials chosen during the simulation.

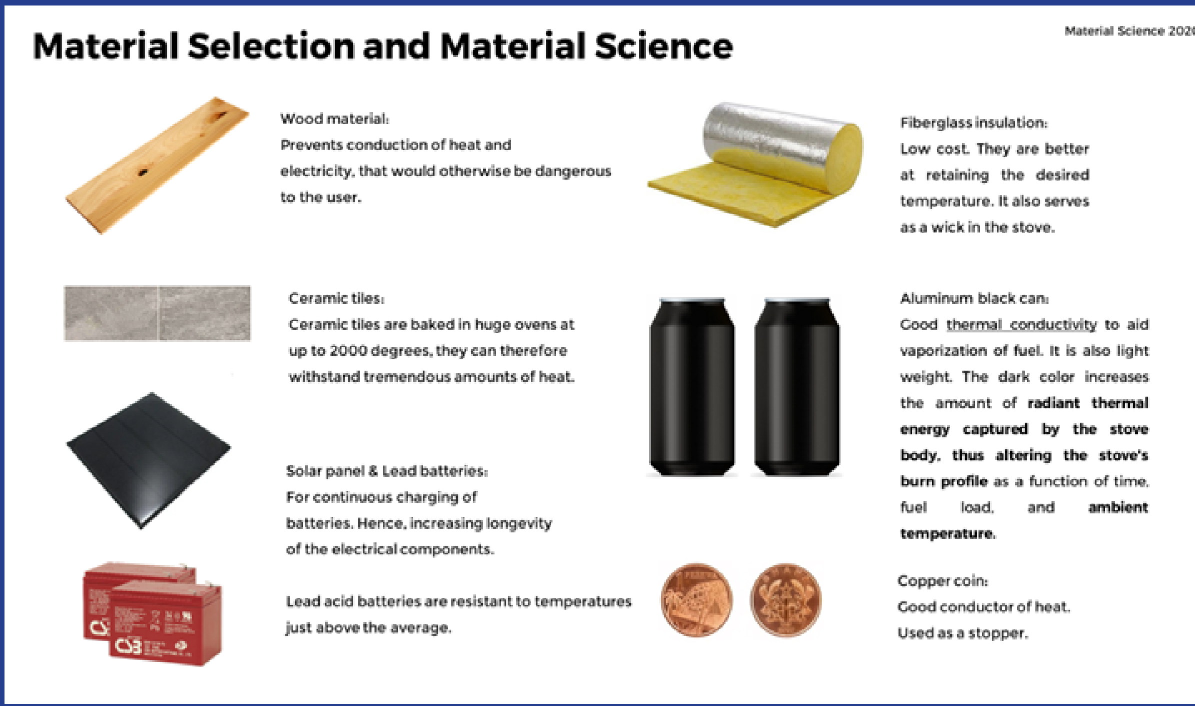


Fig.3 – Summary of materials and their respective uses

RESULTS AND DISCUSSION

Simulations

The team conducted two sets of simulations, one on the electrical components and the other on the mechanical parts. For the mechanical aspect, our two results explored how the handle of the stove would perform when weight is acted upon the stove. This includes its normal weight and the weight of pots and/or food. There was also a simulation conducted on the alcohol container. This helped in discovering how the container would radiate heat when the alcohol burns within it.

Electrical Simulations

Using the Circuit.io App, we were able to build our electronic circuit. We included a humidity and alcohol sensor to detect the temperature and alcohol gas around the stove, to make sure the user is operating at safe levels. That is, if some of the alcohol spills on the stove structure and/or the temperature of the surface is above 40 degrees, the LED will glow red. This signal warns the user about a possible/impending fire hazard. If it safe to cook, the LED will remain as bright green. The user must ensure that the cook top is well cleaned before attempting to switch on the stove.

The fan at the bottom of the stove helps to cool the electricals to prevent them from getting hot and possibly endangering users (by explosion of the lead batteries). The 6V solar panels continually charge the spare lead acid battery. We also estimated the cost of all the electrical components, which did not exceed $80. The written Arduino code for the sensors run successfully without any errors.

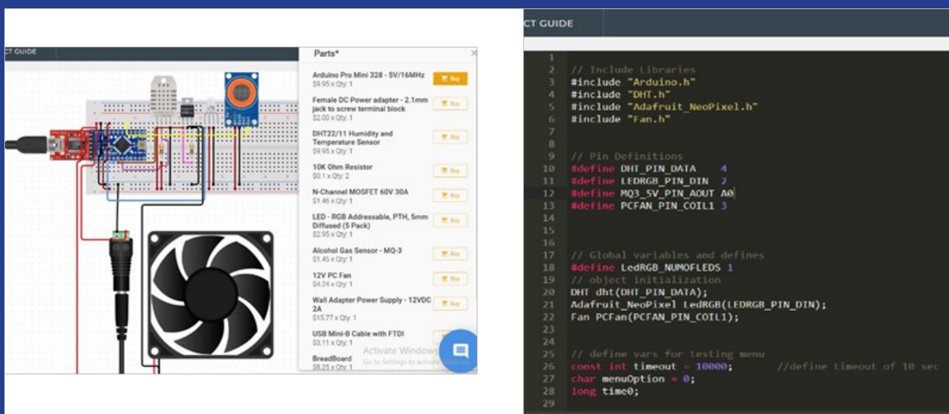


Fig. 4 & 5 – A figure of the electronics and the Arduino code

Mechanical Simulations

Simulation 1: On Stove handle: The stove will be carried up with its set of grips. We simulated this design to validate whether the handles were bolted tightly enough not to break. We used an aluminum handle. Aluminum has a yield strength of 34.47MPa and an ultimate tensile strength of 89.63MPa. Our results checked for displacement in the x, y, and z directions, shear stress and finally the safety factor per body. The aluminum handles are going to be bolted to the frame of the stove. We then constrained the hole that will be bolted and applied an upwards force of 30N on each handle.

Each handle had a 30N force that equally balances out the overall 60N force of the stove and the pots. At first, we estimated the total weight of the stove, food, and pots to be about 25N. We multiplied this factor by 2.4 and used the estimated

60N to ensure that our structure was stable enough. Our minimum safety factor was found to be 1.134, and the maximum was 15. The real safety factor was about 8, which is just in the middle. This meant that the handle would be strong enough. The structure will therefore be capable of carrying eight times the design load. The displacement resistance was quite impressive, as the maximum displacement of the handle was merely 0.05802 mm, rendering it insignificant.

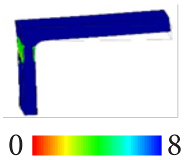


Fig.6 - Safety Factor (Per Body)

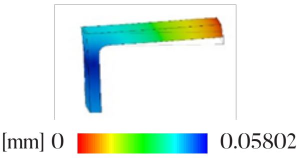


Fig. 7. Displacement

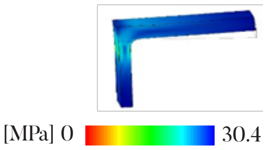
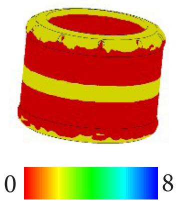


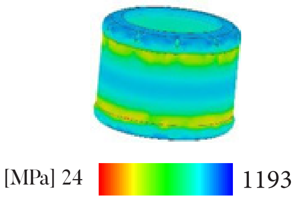
Fig. 8 Von Misses

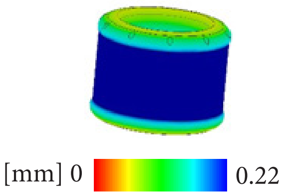
Fig 9. Sketch of balancing forces on a lifted pot

The handle promises to be rigid and robust. The Von-Mises stress measures the yielding profile of a material. It was observed that the maximum allowed Von Mises was 30.4MPa. But the recurring Von Mises in our handle was about 15 to 50% of the maximum. It added to its unique strength and high yield strength.

Simulation 2: On the alcohol container: This helped us know how radiation from the alcohol fuel, and the weight inflicted on it, would affect the container. It must not break, else the alcohol could spill. The aluminum container radiated heat when the ethanol fuel was ignited. For stoves, the temperatures produced range from 80 to 200C.







Using a thermal load analysis on the canister, we found out that the can performs well. The expansions of the aluminum-can in all directions, i.e. in the x, y, and z directions, are very low; the displacement is 0.09872mm, 0.09951mm, and 0.1534mm, respectively.

This is true because when we were conducting cook tests, the aluminum-can contained the burning fuel for a very long time, and there was no significant deformation of the can. We set the temperature of the can to be 200C (the highest, for more allowance). The safety this time was not so good as it was around 1 and 2. Whiles the maximum allowed was 11.35. We stipulate that its weakness might be due to the radiating heat, which causes the material to be more ductile. Since ductile materials have less strength, it makes sense that the number of loads allowed on the container is low. However, as engineers, we will place on our product that the safety factor is 1, and no more than 22.5 N (pots + food) can be placed on each burner. The ceramic tile we lagged at the bottom of the container will help contain some of the heat. Please note that the only stress our ceramic tiles will experience is compressive strength (as they are placed at the bottom).

In our assessment, the stove was a success (in prototypes and simulations). We fried eggs (90 °C, 300 cm^3 volume of the pan), boiled eggs (100 °C, 712 cm^3 volume of the pot), and cooked noodles (100 °C, 500 cm^3 volume of the pot). The fuel was regulated using the number of holes on the alcohol-can as well as the size of the can. All project requirements were satisfied.

Fig. 13 - Cooking experiment tset-up

Fig. 14 & 15 - Lit alcohol stove and protoype

CONCLUSION

We studied in material science that ceramics have an average compressive strength close to ten times higher than their average tensile strength (Yiporo, Abade – Abugre, 2020). Therefore, it did not require a load analysis. This research fact saved us a lot of time and computation. However, we aim to make our stove less costly in our future works. As a team, we were able to design a stove that is environmentally friendly, reduces emissions and has fuel that can be made by local people in rural areas. We believe this breakthrough will make the lives of the low-income rural inabitants much easier, as they can cook meals from clean and efficient alcohol.

ACKNOWLEDGEMENTS

Many thanks goes to Dr. Danyuo Yiporo and Mrs. Miriam Abade-Abugre, for gifting us with the knowledge and encouragement to pursue this project.

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Interview

Kwadwo Agyapon-Ntra
Chief Technology Officer
Niqao Technologies Limited

Bio.

Kwadwo Agyapon-Ntra is a co-founder and the Chief Technology Officer of Niqao Technologies Limited, a Fintech startup based in Accra. He's an alumnus of the Meltwater Entrepreneurial School of Technology (MEST) and KNUST's Department of Computer Engineering. He loves technology, especially the promise of AI, but outside of that he spends his time writing (mostly on his blog) and plays a few musical instruments.

SEED: What was the first considerable hurdle for your start-up as you began to emerge?

Kwadwo Agyapon-Ntra: Registration was our first hurdle. Niqao was founded by a multinational team, and the laws of Ghana can make starting a business with foreigners quite a headache. Some of the financial requirements were just intimidating. Fortunately, there are two Ghanaians on the team, so with the appropriate legal advice (you should get legal advice early) and the help of some mentors, we were able to satisfy our legal requirements as a limited liability company while keeping the best interests of our foreign co-founders.

S: What advice would you give to students looking to also be players in the tech start-up space?

K. A-N: Spend less time talking, and more time building. The most useful talks happen when you're asking for feedback on a tangible MVP. When you iterate quickly with your development, you can fail fast and adapt quickly... because you will certainly have a few failures in your learning. Also, although execution should be everything to you, presentation is everything to the customer. Design with the customer in mind.

S: How indispensible was your major, in helping you to fully identify your problem space?

K. A-N: Our problem space is finance, and my major in university was Computer Engineering. There is almost no correlation. However, business training from MEST was certainly helpful in identifying the problem space. Computer Engineering was more helpful in crafting a solution.

"Presentation is everything to the customer. Design with the customer in mind."

S: What drove you to fervently begin this start-up?

K. A-N: I believe in creating stuff I want to use. (Even as a hobbyist writer, I write things I want to read.) A service to help people purchase necessities, even when they don't have cash readily available, is something I wanted to use myself. I was one of our first customers. LOL.

S: How long has your business been running for?

K. A-N: We're less than a year old. We pitched Niqao in early August 2019, but we have been oocially registered and running since October 2019. So roughly ten months.

S: What are three key things you wish you knew then, but you know now?

K. A-N: Three things I wish I knew:a. Every member of the team is a salesperson in the beginning.
b. No amount of planning can be substituted for actually doing the work.c. The startup field is a place to learn. Your ideas are not new, and there's a reason why what you're trying to accomplish has not been done yet, so be ready to learn and unlearn.

S: Do you fear you might not be able to compete with bigger competitors?

K. A-N: That fear is realistic, especially in the Fintech space with all its regulations. We have found that a wise approach to mitigating this risk is to look for ways in which our services can benefit some of these would-be competitors and ooer collaboration.

S: What does a fully established Niqao company look like to you?

K. A-N: A fully established Niqao will be completely integrated with Africa's financial and commercial services as a means of payment. We are hoping for, and working towards, the day when the term "Niqao it" will be to the idea of buying, as "Google it" is to the idea of searching. It's still farther than it is near, but it's very possible.

S: Are you open to the idea of collaborating with another company?

K. A-N: We are very open to collaboration; especially with financial institutions, merchants, and possibly, logistics companies.

S: If you had to summarize your experience in this new sector, into one word, what would it be?

K. A-N:

Enlightening!

SEED™ JOURNAL

Synthetic Biology: Developing Spider Silk

By:
Zoe Tagboto, Goodie Dawson, Fynnba Biney

Synthetic biology is an interdisciplinary science that involves applying engineering principles by redesigning organisms. This redesign is to give the organism new abilities like producing a substance, such as a medicine or fuel, or even gaining a new ability, such as sensing something in the environment(NIH, 2020). This science allows researchers and companies to be more innovative by giving them the ability to harness the power of nature to solve global problems in diverse areas such as medicine, manufacturing, cosmetics and engineering. An example of a material scientists are using synthetic biology to engineer is spider silk, a protein made by spiders that if mass-produced could have positive impacts in the medical industry, beauty industry, security and more. To better understand the potential impact of synthetic biology, it is important to investigate the benefits of producing materials like spider silk, how synthetic biology makes mass production easier, and future innovations that the mass production of spider silk using synthetic biology can inspire.

Spider silk is produced by spiders to create their webs, to restrain their prey and to protect their eggs. It is a unique protein due to various features such as its antimicrobial properties, the fact it is very resilient, its extreme flexibility and its biodegradability and biocompatibility (Matchar, 2017). These qualities make spider silk an extremely desirable material that if mass-produced can be used for a wide range of applications. Its strength and resilience make it a desirable alternative to Kevlar (a material used in bulletproof vests) while its antibiotic properties make it a desirable material for use in developing bandages or sutures(Kraig Biocraft Laboratories). However, despite these properties, spider silk is not widely used due to the difficulty in mass-producing the material. Unlike silkworms which can be farmed to produce silk, spiders are carnivorous, territorial and destroy each other's webs, making it almost impossible to farm the silk naturally(Andersson, Johansson, & Rising, 2016).

Synthetic biology provides an innovative way to tackle the inability to farm spider silk naturally. Instead of having cannibalistic spiders produce the silk, researchers can engineer bacteria to do this by inserting genetic material into the bacteria which would enable them to produce recombinant spidroins which can then be spun to produce spider silk (GreatBay_SZ, 2019). Engineering this silk in the lab also gives researchers the ability to produce spider silk specific to the purpose of that the silk is being produced for (GreatBay_SZ, 2019). Mixing different combinations of the recombinant spidroin could produce silk of different properties, stronger silk for Kevlar, and more flexible silk to produce textiles for example. This research is currently being done and companies like Kraig BioCraft Laboratories and Bolt Threads are successfully using Ecoli to produce spider silk for a wide range of applications.

The mass production of spider silk by researchers and companies provide areas for individuals to combat problems they may see in society. One such problem is prevalent in the hair care industry, specifically with the production of synthetic hair. Synthetic hair is "made from ultra-fine strands of plastic, and the petrochemical-derived materials such as polyester, acrylic, and PVC which are not biodegradable" (Cartwright, 2020). This means that they ultimately end up in landfills and contribute further to our global waste problem (Wilson, Thomson, Moore-Millar, & Ijomah, 2019). Natural hair is an alternative, however, is far more expensive and is not always ethically sourced. There is currently only one sustainable option, braiding hair made from banana fibre, however, producing this hair is labour-intensive and is also significantly more expensive (Raw Society, 2020). Spider silk could be a much cheaper alternative, as production costs would be lower, and it would also be biodegradable, thus good for the environment and attractive to braiding hair producers.

Image by Paul Levesley (unsplash)

In conclusion, synthetic biology is an exciting field that has remarkable potential in driving the next phase of global innovation. It allows researchers the ability to study natural organisms and figure out ways to produce materials that previously would have been too difficult to produce naturally. In addition, this production could tackle the problem of pollution, because unlike the production of synthetic materials like plastic, bacteria produce more efficiently, reducing waste and their production is also much more sustainable. Spider silk is one such material whose natural properties can change the way in which we manufacture products across various industries.

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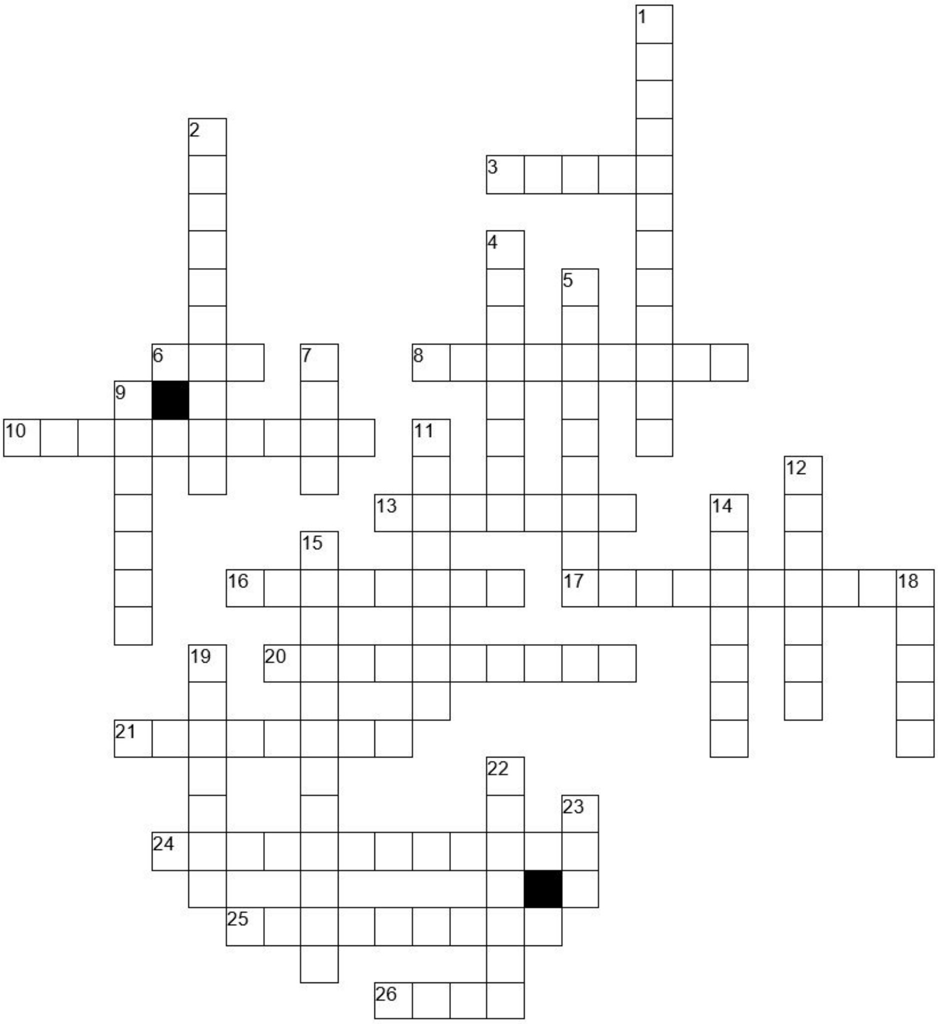
Crossword Puzzle: Engineers A-Z



Across

3. Design and build tunnels and bridges
6. Work in processing of oil reserves
8. Work on exploration
10. Insulate houses and buildings
13. Deal with movements humans make
16. Design electrical wires and poles
17. Design phones and how they transmit data to one another
20. They use the principles of math and science to design mechanical products
21. Supervise lighting manufacturing
24. Oversees water quality and sewage treatment
25. Makes planes and space crafts
26. Design X-ray machines to view bodies

Down

1. Make anti-lock brakes for cars
2. Advances in technology and health
4. Maintain Design of software systems
5. Design animal habitats
7. Make food processing machines
9. Design Nuclear power plants
11. design components of Railroads
12. Responsible for making sure your utilities are available
14. Manipulates and studies dna
15. Makes medicine suitable for animals
18. Test the stress point of materials
19. Designs highways and flow of traffic
22. Makes sure an item is of good quality
23. Make Jet Engines

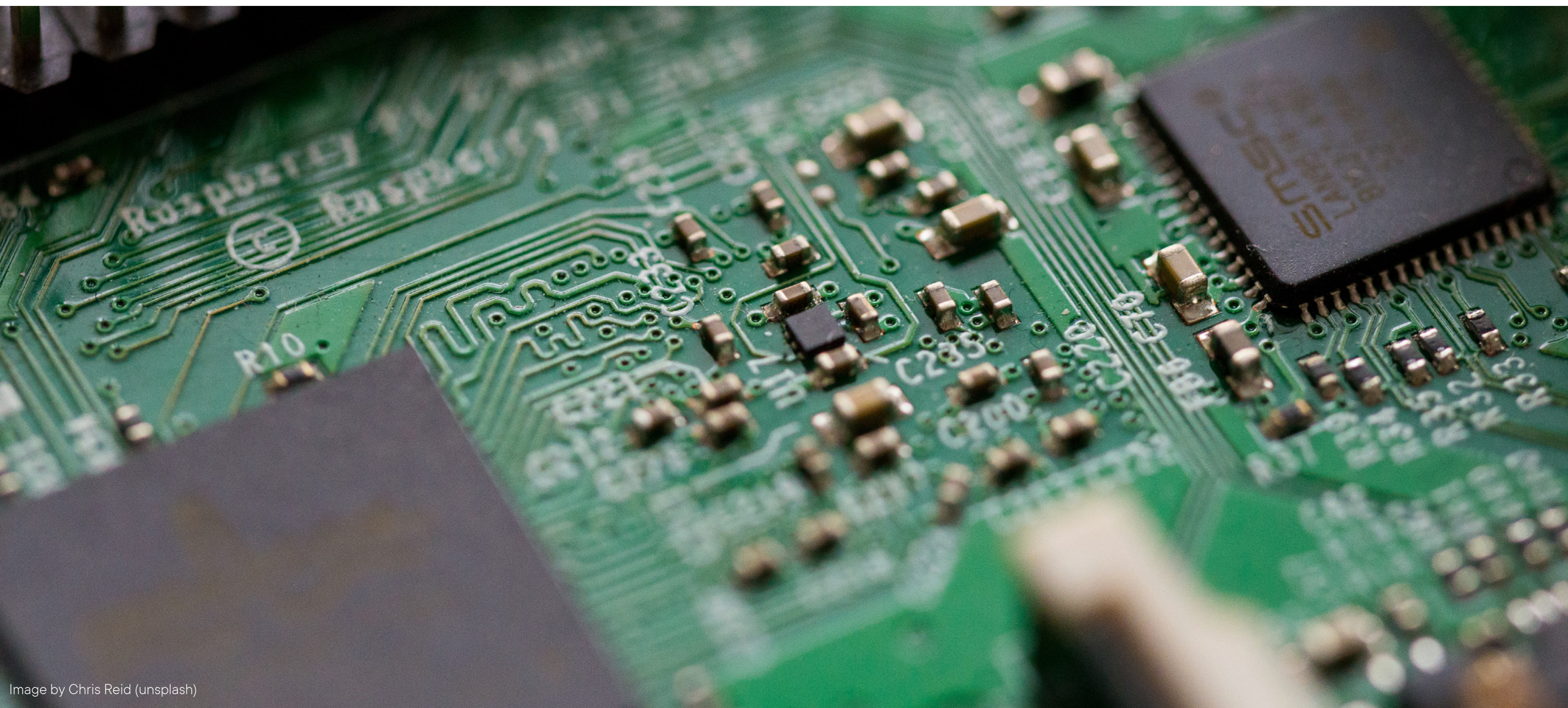


Image by Chris Reid (unsplash)

System Dynamics Applied to the Effect of Carbon Dioxide Emissions on Global Warming Modelling

By:
Nana Oye Djan
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ABSTRACT

Future predictions of carbon dioxide emissions and its effects on global temperatures do not look too promising. Since the advent of the industrial evolution that has seen an increase in burning of fossil fuels and other sources for energy, carbon dioxide emissions from these have skyrocketed. Comparing the increase in global temperature anomalies and the increase in carbon dioxide emissions, it seems there is a correlation between the global temperature anomalies and the increase in carbon dioxide emissions. This paper uses systems dynamics to model the increase in carbon dioxide emissions using several parameters and variables that are changed to see how much each affects carbon dioxide levels and in effect global temperature anomalies. In doing so, this paper provides a simplified model of global warming.

1. BACKGROUND INFORMATION

In the 21st century, the term greenhouse effect has a negative connotation. Common terms often associated with it are: global warming, climate change, burning of fossil fuels, etc. and none of them are mentioned in a positive light. However, global warming and the greenhouse effect are not inherently detrimental to life on earth and have not always been destructive and disadvantageous. In their paper, The Science of Climate Change, Oppenheimer and Anttila-Hughes state that, "the greenhouse effect is a prerequisite for life as we know it because without it, Earth would be colder (by about 32°C or 57.6°F and drier: a frozen desert." [2]. In the 18th century, most scientists saw warming as beneficial rather than problematic, due to the temperature anomalies at that time (seen in Figure 1).

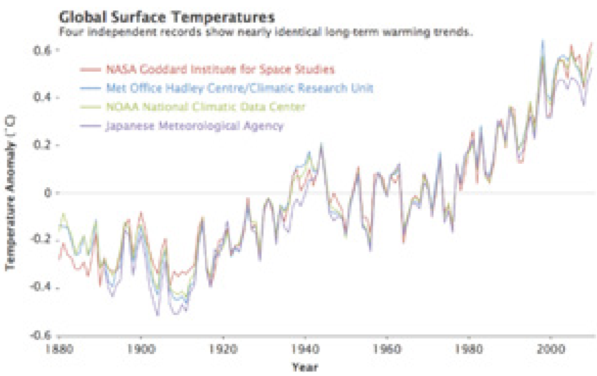


Figure 1: Temperature anomalies from 1800 to 2016

By the end of the 20th century, after the advent of the industrial revolution, the temperature anomalies had risen too high to be ignored as seen in Figure 1.

2. PROBLEM STATEMENT

"The greenhouse effect is a natural process that warms the Earth's surface" [3]. When the sun's rays reach the earth, some bounce back into space, the rest is absorbed by greenhouse gases. These greenhouse gases re-radiate the heat trapped which keeps the Earth warm enough to sustain life [3]. Among these greenhouse gases are carbon dioxide, water vapor, carbon monoxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons (CFCs). The main interest of this paper is the effect of carbon dioxide on global warming and what it means to the Earth decades, and even billions of years from now.

3. JUSTIFICATION OF THE PROBLEM STATEMENT FOR INVESTIGATION

Carbon dioxide as well as other greenhouse gases have a lifetime of about few days to a few thousand years [4]. Due to their relatively long lifetimes, they stay long enough to be uniformly distributed in the atmosphere [2][4]. This means for as long as there is more than the recommended concentration of carbon dioxide in the atmosphere, climate change will continue to be a problem [5]. Furthermore, the effects of carbon dioxide emissions linger for several decades, meaning that future generations will have to battle a problem they had no hand in creating [2]

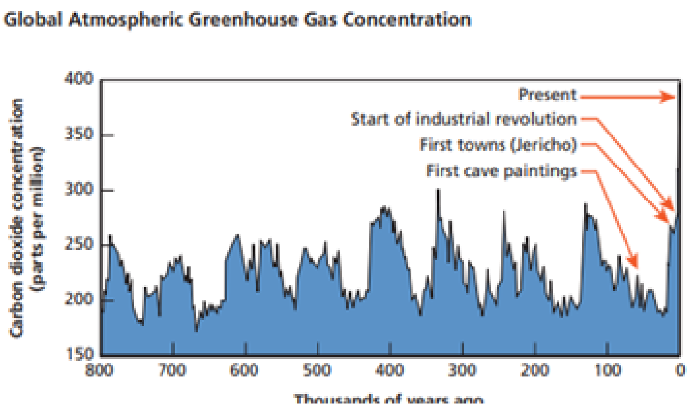
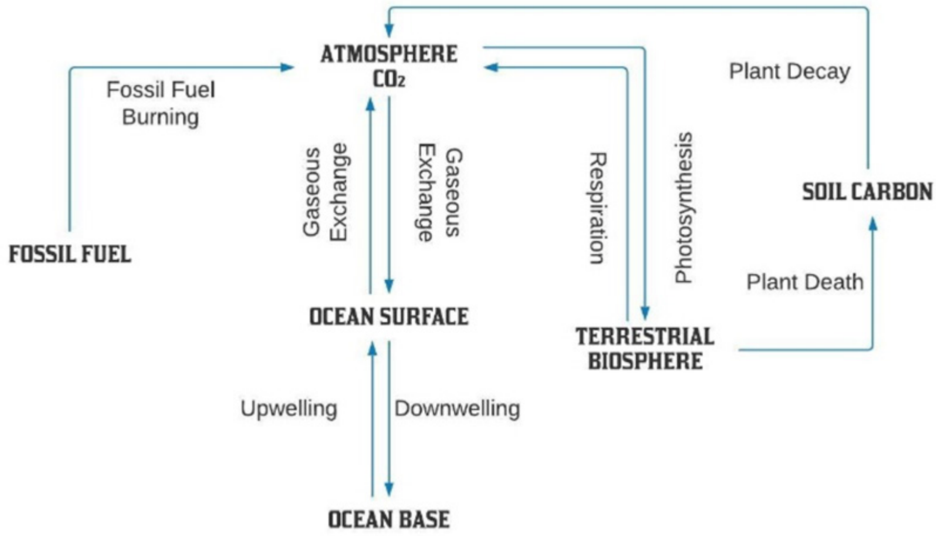


Figure 2: Increase in greenhouse gases, specifically carbon dioxide concentration over the course of human history, from the first cave paintings to present time (21st century [5])

This is made worse by the increasing carbon dioxide concentrations over time (seen in Figure 2).
All these make it clear that climate change because of carbon dioxide emissions is a problem that humanity must think about.

The aims and objectives of this research paper are to:

a. To model the concentration of carbon dioxide in the atmosphere
b. To identify parameters and variables that affect the concentration of carbon dioxide emissions and their effect when ignored or varied.
c. To investigate the effect of carbon dioxide on global temperature anomalies
d. To predict the concentration of carbon dioxide emissions over a period of 200 years
e. To make recommendations on how to tackle the issue of climate change.



4. MATERIALS AND METHODOLOGY

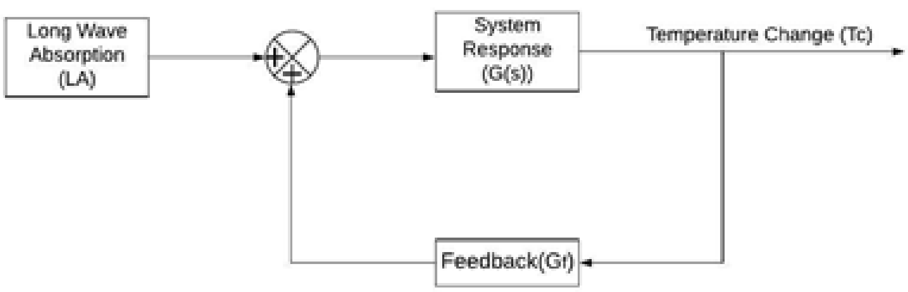
4.1. Model formulation

Many sources contribute to carbon dioxide emissions each year. Among these sources, those of interest for this paper are fossil fuel burning, plant death and decay and, respiration from living organisms. Carbon dioxide is also taken from the surroundings through a variety of means and the main one of interest is photosynthesis. A very simplified carbon dioxide cycle was used to estimate the concentration of carbon dioxide produced on an annual basis (as seen in Figure 3).
To achieve each of the aims and objectives of this paper, there were some assumptions that were made to further simplify the carbon dioxide cycle and obtain a block diagram.

4.2. Assumptions Made

a. Global warming only affects the atmosphere
b. The only contributing factor to global warming is carbon dioxide
c. G_s and G_F were assumed to have constant values. The initial value for carbon dioxide present in the atmosphere (at t=0) is assumed to be 36138285*10^3 tonnes, which is the concentration of carbon dioxide emissions in the atmosphere as of 2014 [6].d.

For this paper, the system's boundary is the atmosphere; no other part of the earth is being considered.



G_s is the system's response to the input, which is the long wave absorption of carbon dioxide, while G_F represents the effect temperature change will have on carbon dioxide concentration levels in the atmosphere. Given G_s and G_F, the temperature change in the atmosphere can be determined using the following equation:

$$T_C = \frac{G_s}{(1 - G_s G_F)} L_A$$

Where $L_A = 5.35 \ln\left(\frac{C_i}{C_o}\right)$

$$G_s = -1.59$$

$$G_F = 0.187 \text{ [7]}$$

5. RESULTS AND ANALYSIS

5.1. Analysis of Results (Without Changes made to the Parameters)

Using the model formulated for this paper, the graphs seen in Figure 5 were generated using the MATLAB code in Appendix A. It is observed that an increase in carbon dioxide emissions results in an increase in global temperatures [5].

N.B. These graphs were generated using the assumptions stated in Section 4.2. No changes have been made to any variables.

5.2 Changes because of changing parameters

To reduce the complexity of the model, the only parameters changed were:
a. The initial carbon dioxide concentration and,
b. The sign of G_F. G_F is assumed to be a damping factor due to a variety of reasons, meaning that it was a negative feedback. G_F is made a positive feedback to observe its effect on global temperatures.

N.B. The effect of each is considered individually, not as a lumped effect

The various values assigned to the parameters being varied (as described in Section 5.2 can be seen in Table 1.

Table 1: Values assigned to parameters being varied

Case	C_o
Very low C_o	0.0036138Gt
Very high C_o	3613.8Gt
Initial value of C_o with G_F as a positive feedback	36.138Gt

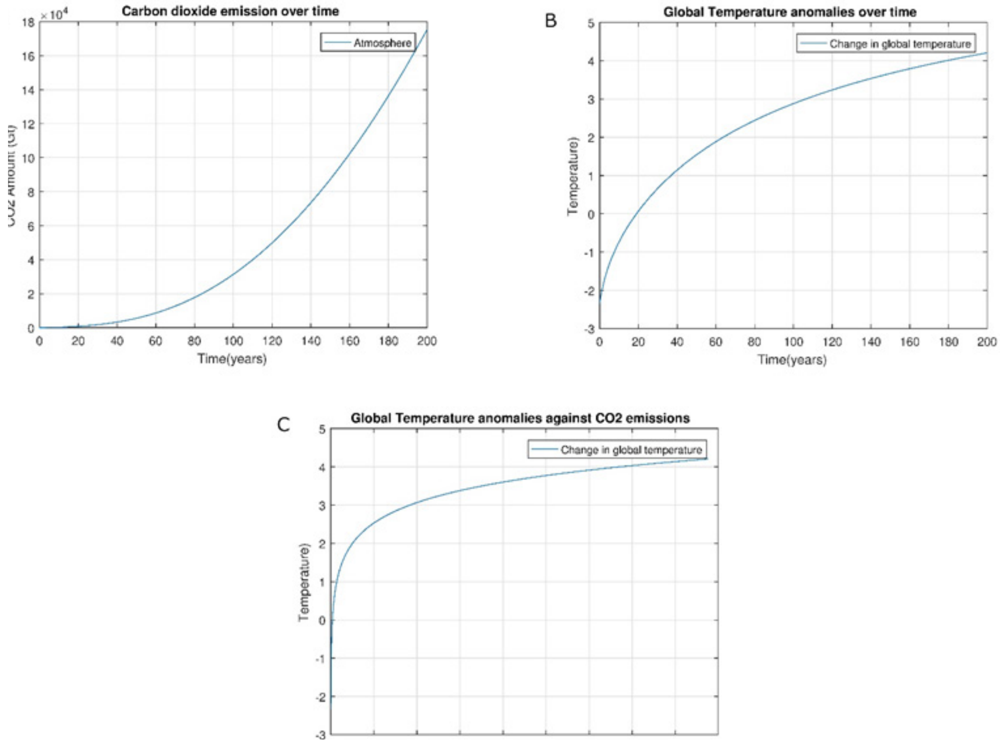


Figure 5: Graphs generated from system model. A shows the graph of carbon dioxide emissions over time. B shows the global temperature anomalies over time. C shows the global temperature anomalies against CO2 emission. It is observed that CO2 emissions are in some way related to the increase in global temperatures.

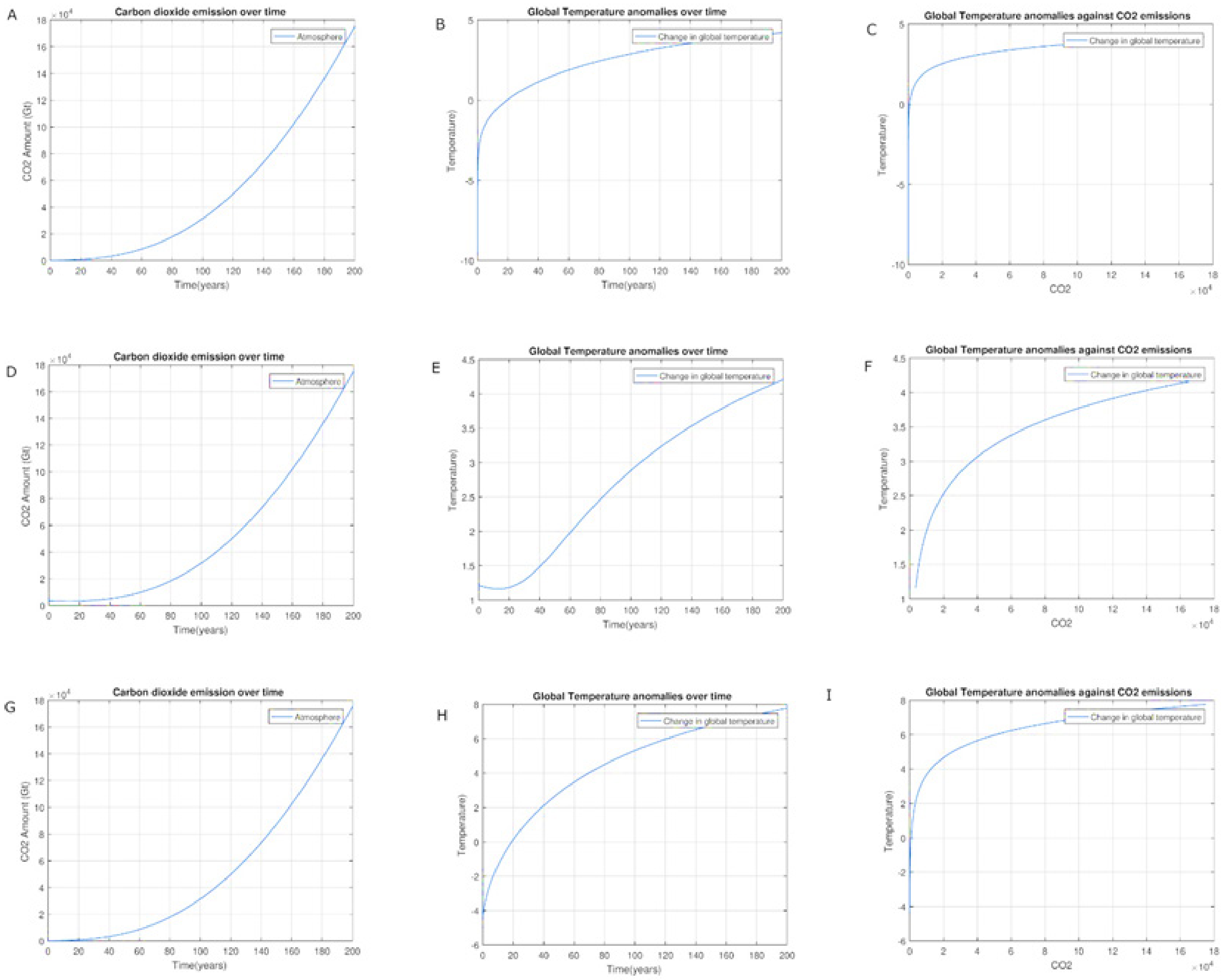


Figure 6: Simulation Results. (A - C) show Case I, the result of making the initial CO2 concentration very low. (D - F) show Case II, the resulf of making the initial CO2 concentration very high. (G - I) show Case III, the result of making Gf, a positive feedback value.

From each of the above cases, it is seen that, as the concentration of carbon dioxide increases, global temperatures increase. However, for the first two cases, it is observed that not much change occurs when the initial concentration of carbon dioxide is increased or decreased.
In Case III, it is obvious that changing G_F to a positive feedback did not affect the levels of carbon dioxide concentrations, but rather, had a pronounced effect on global temperatures, increasing it by as much as 2°C as compared to B and C.

The model formulated can be used to model the effect of other greenhouse gases on global warming. It can also include them to estimate the lumped effect on global temperatures.

6. DISCUSSION OF RESULTS AND ANALYSIS

From the system's model, it is expected that an increase in the concentration of carbon dioxide emissions in the atmosphere results in an increase of global temperature.
In all cases (Figures 6), it is observed that expectations were met.
Although all expectations were met, the model might be inaccurate because it does not consider other parameters and variables that influence global warming. In addition, there are other gases apart from carbon dioxide that contribute to global warming.
Furthermore, the model assumes the current state of the world will exist even 200 years from now, which is impossible; there will be inevitable changes, which this model cannot consider.
However, this model is a good start to predicting global temperatures for the future.

Several limitations to the project made the model inaccurate:
a. Since there was the lack of actual data, most of the research was secondary.
b. There was difficulty in isolating articles focused on the effect of carbon dioxide on global warming
c. There was the lack of current data for other initial conditions (fossil fuel burning, soil carbon, ocean surface, terrestrial biosphere, and deep ocean), which also influence the amount of carbon dioxide in the atmosphere.
d. The lifetime of carbon dioxide makes its effect extremely long lasting. With the other limitations, recommendation on the next steps will be hard to suggest with this model.

The following adjustments can be made to the model to make it a more accurate representation of the global warming system:
a. Expanding the system's boundaries, and modelling other contributing factors to carbon dioxide emissions, such as cement production.
b. Including other greenhouse gases in the model.

Global warming is a cause of panic to millions around the world because of its negative connotation. It is a problem – if not checked – that could lead to the apocalypse of the world. However, by predicting carbon dioxide levels over the next few years, a good step has been taken, one that will lead to many more in the right direction.

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