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# Design and Construction of Solar Powered Automated Chicken Coop

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## 1. Introduction

The senior design project is a capstone project course taken in the final year of the Electronics and Computer Engineering Technology (ECET) program at Sam Houston State University (SHSU). Introduction of renewable energy applications to engineering technology curriculum at SHSU has impacted students, faculty, and university community very positively and promoted feasibility and adoption of eco-friendly energy technologies. As number of recent graduates employed on various positions in the solar energy related companies increase steadily, student interest to renewable energy courses, sustainability related student associations, and energy-related hands-on project applications has increased as well.

The objective of this capstone project is to design and implement an automated solar powered chicken coop that aims to provide a sustainable and efficient solution for chicken housing. With a focus on renewable energy, this project utilizes photovoltaic (PV) panels to convert the solar energy into electricity, which will then be used to power various control systems and components within the coop. The automation aspect of the design simplifies the caretaking process and provide a more comfortable living environment for the chickens. The combination of solar power and automation creates a self-sufficient and eco-friendly solution, reducing the dependence on traditional energy sources and promoting sustainability. The project is not only providing a functional chicken coop but also demonstrating the potential for the use of renewable energy in other areas of agriculture and beyond.

The design and implementation of a solar powered automated chicken coop requires a combination of technical and practical real-life skills. Some of these skills include circuits, analog and digital electronics, automation and control systems, microprocessors, power, and basic knowledge of chicken keeping. Knowledge of electrical circuits, electrical energy systems and components, such as PV panels, batteries, and controllers are essential for this project. Knowledge of automation and control systems, including microcontrollers, sensors, and actuators, is paramount in the design and implementation of an automated chicken coop. Also, understanding chicken behavior, nutrition, and health is also an important aspect in designing an effective automation system for a chicken coop. This allows the ability to provide a comfortable and safe environment for the chickens. This paper reports overall project design and implementation with functional block diagrams, design sketches, and circuit diagrams, challenges and troubleshooting, and bill of materials.

## 2. Problem Definition

This project aims to address several challenges presented with traditional chicken coop management particularly in remote locations. This includes the use of non-renewable energy sources and manual labor, which can be costly, and inefficient. The address these challenges the proposed automated chicken coop must utilize renewable energy sources and include automation technologies that simplify the caretaking process and reduce the amount of time needed for human intervention. The coop must also meet the specific needs of the chickens, which include proper and healthy ventilation, lighting, feed, and clean water. The task of designing and implementing a solar-powered automated chicken coop is a complex and multi-disciplinary challenge that requires a thorough understanding of solar PV systems, electrical power, automation technologies, chicken caretaking management and practices.

## 3. Literature Review

In terms of solar-powered automated chicken coops, some of the current advancements include the integration of PV panels, battery storage systems, and control systems to provide power for the coop's various functions and systems. Automation features such as feed and water dispensers, active ventilation, and lighting systems are also being integrated into the design to simplify the caretaking process and improve overall efficiency. Considering the battery charge algorithms utilized by a solar charge controller is significant. Opting for a Maximum Power Point Tracking (MPPT) solar charge controller allows for the charging process to be more efficient [1]. Our approach involves utilizing an MPPT solar charge controller to enable the efficient draw of power and charging of LiFePO4 batteries from the PV panels. Human control with microcontrollers is an important consideration. When a microcontroller is combined with a web server, it provides an opportunity to develop a user-friendly interface that can be accessed through a local network. Such an interface facilitates convenient management, access, and monitoring of the system environment for users [2]. A microcontroller presents an efficient approach for managing solar energy systems. With controlling and monitoring features integrated into a microcontroller, users can bypass the need for expensive and proprietary energy monitoring systems [3]. Employing a microcontroller to monitor the environment of a chicken coop is crucial for ensuring the chickens' welfare in this project. Through the use of a microcontroller to track ammonia, temperature, and humidity levels, users can act proactively to maintain the chickens' health [4]. The combination of motor drivers with a microcontroller offers an efficient and accurate means of controlling linear actuators [5]. In this project, linear actuators will regulate the windows and door of the chicken coop. By interfacing the microcontroller with the linear actuators, specific tasks can be automated, thereby reducing the amount of user interaction required. Heat stress is a significant environmental stressor for chickens, and it can adversely impact their feed efficiency, body weight, egg production, and egg quality. However, implementing specific strategies can help reduce the amount of heat stress that the chickens experience [6]. A microcontroller that is equipped with light sensors enables users to control linear actuators based on the time of day, specifically at sunrise and sunset. This will allow automation of the chicken coop doors and windows [7]. To provide consistent egg production throughout the whole year it becomes necessary to provide supplemental light to the chickens specifically during winter when the shortest day occurs. By utilizing a microcontroller and smart LED lightning supplemental light can be provided to chickens to keep egg production consistent throughout the year [8].

## 4. Engineering Design Approach

The engineering approach for designing and implementing a solar powered automated chicken coop involves a combination of electrical, mechanical, software engineering principles.
The design process can be divided into the following phases:

a. Chicken Coop Structure: The mechanical aspect of the coop should be carefully evaluated to guarantee its stability, robustness, and the creation of a secure and comfortable habitat for the chickens. The chicken coop has already been constructed by the student author and the next step is to integrate the solar system and automation into the existing structure.
b. PV Panel System: The automated chicken coop requires a source of energy, and this will be achieved using a 210 W solar panel in conjunction with a solar charge controller. A PV panel will be installed south facing and will charge a 12V, 105Ah LiFePO4 battery that will supply power to the various systems of the automated chicken coop.

c. Automated Door System: The automated door system in the chicken coop will control entry and provide security for the chickens. A 12V linear actuator will be utilized to move the door, opening, and closing it vertically. To operate the linear actuator, a combination of a motor driver and a microcontroller will be employed. The motor driver will provide positive or negative 12V to control the direction of the actuator's movement, while the microcontroller will send signals to the motor driver to control the actuator. In this way, the door can be opened or closed with precision and accuracy, ensuring the safety and security of the chickens.
d. Ventilation System: The chicken coop will feature a ventilation system to control the temperature and air quality within. The system will consist of temperature and humidity sensors, automated windows controlled by motor drivers and 12V linear actuators, and 12V fans that can run on the coop's solar-powered 12V battery. The design will prioritize both efficient airflow and energy conservation.
e. Lighting System: Chickens need a certain amount of light to maintain a healthy and productive lifestyle, including stimulation for egg-laying. The chicken coop lighting system will be powered by the solar panel system, which will provide a sustainable and eco-friendly source of energy. The lights will utilize light sensors in conjunction with timers to light the coop based on available natural light.
f. Control System: To efficiently coordinate the functions of all components within the chicken coop, a control system is required. This will be accomplished through the use a Single Board Computer (SBC), and microcontroller, which can be programmed to regulate the various systems in response to inputs from sensors and timers. The microcontroller will act as a central hub, directing the operation of all components to ensure that everything runs smoothly and efficiently. The SBC will take in the data from the microcontroller in order to store and present it to the user.
g. Software: This project utilizes the open-source software Home Assistant and ESPHome. Home Assistant is home automation software that integrates a large number of devices. Such as ESP microcontrollers via ESPHome software. The ESP32 microcontroller will be configured to take in sensor data and output control signals in response to sensor data in order provide automation to the chicken coop.

   The functional block diagram in Figure 1 depicts the solar powered automated chicken coop system. A 210 W PV panel is connected to a charge controller that charges a 12V LiFePO4 BMS battery package. The 12V LiFePO4 Battery Management System (BMS) protects and manages charge/discharge of the LiFePO4 Cells. The LiFePO4 battery then provides 12V power to a fuse and relay module to distribute power to the various system components such as 300W inverter, ventilation fans, and linear actuators. There is a 12V to 5V DC step down converter that steps the 12V voltage down to 5V to supply power to the Raspberry Pi 4, and sensors. The autonomous section is controlled by the Raspberry Pi 4 and an ESP32 microcontrollers. There are a display, multiple indicator lights for user management and troubleshooting, and a web interface to manage the system remotely.

For this project, there are several procedural steps that were completed. Given this fact the procedure section will be split into three sections; Solar PV System, Automation System Hardware, and Automation System Software.

a. Solar PV System: One of the primary goals of this project was to generate all required electrical power using a solar PV array. To achieve this objective, we installed a 210W PV panel on a solar panel stand, which was fixed at a static angle of 30 degrees from the horizontal position. The PV panel was positioned facing south as seen Figure 2. Next, we wired the PV panel into an MPPT solar charge controller, which was located inside the electronics enclosure. To protect the PV panel circuit, we incorporated a 15A circuit breaker in-line, as shown in Figure 2. Additionally, we constructed a LiFePO4 battery using four prismatic LiFePO4 cells wired in series, providing a 12V battery.

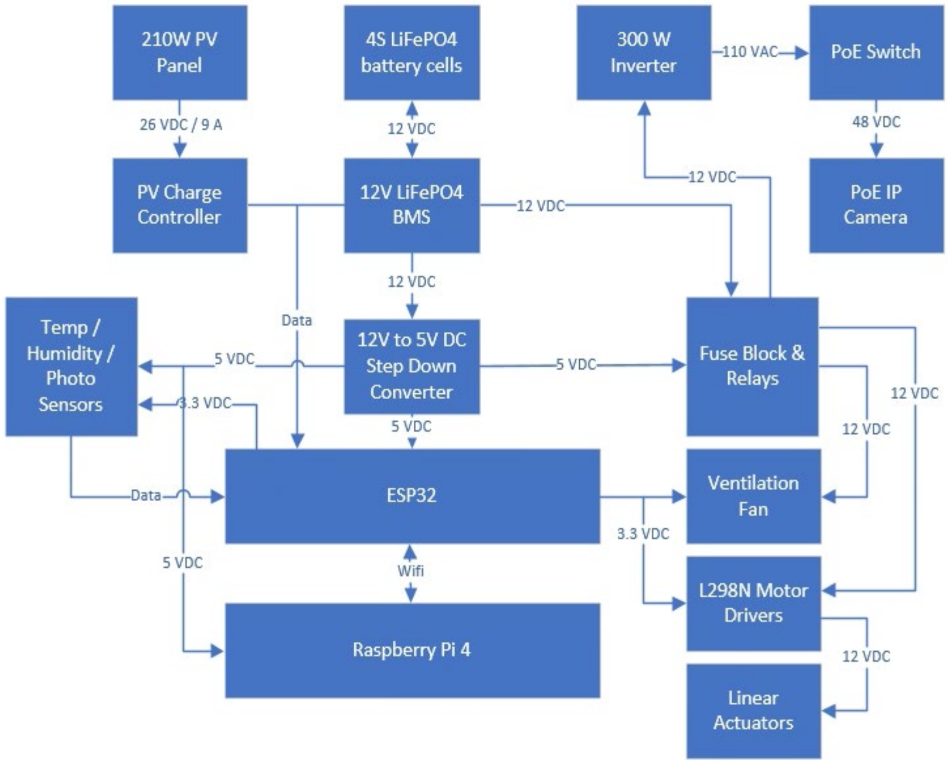


Figure 1. Solar Powered Automated Chicken Coop Functional Block Diagram

To safeguard the battery cells and obtain battery statistics via UART to the home automation software, we integrated a LiFePO4 BMS in-line with the LiFePO4 cells. Once the PV panel was connected to the solar charge controller,  the LiFePO4 battery was also connected to the same circuit as illustrated in Figure 2. To accomplish the objective of securing full power from solar PV panels, we needed to set up a 210W PV panel on a solar panel stand that is set statically at 30 degrees from horizontal with the PV panel facing south, as shown in Figure 2.

Figure 2. PV Panel Install and Charge Controller

b. Automation System Hardware: To enable the automation system of the chicken coop to function as intended, specific hardware components are necessary. A custom control board was developed using a protoboard, as seen in Figure 3. The control board houses several crucial components required for the system to function, including an ESP32 microcontroller, a 12V to 5V buck converter, an L298N motor driver, a relay board, and a logic level shifter. These components are color-coded and presented in Figure 3. Additionally, within the electronics enclosure, several other components are present, such as a Raspberry Pi 4, a 12V fuse block, a custom-made control board, a PoE switch, and a 300W inverter, as seen in Figure 4. The other automation system components, which include an IP camera, fan, DHT sensor, and LED light, are illustrated in Figure 5 as being installed. Additionally, Figure 6 shows the hatch door, which has a linear actuator mounted on it. The linear actuator has a 12-inch travel and is controlled by the L298N motor driver.

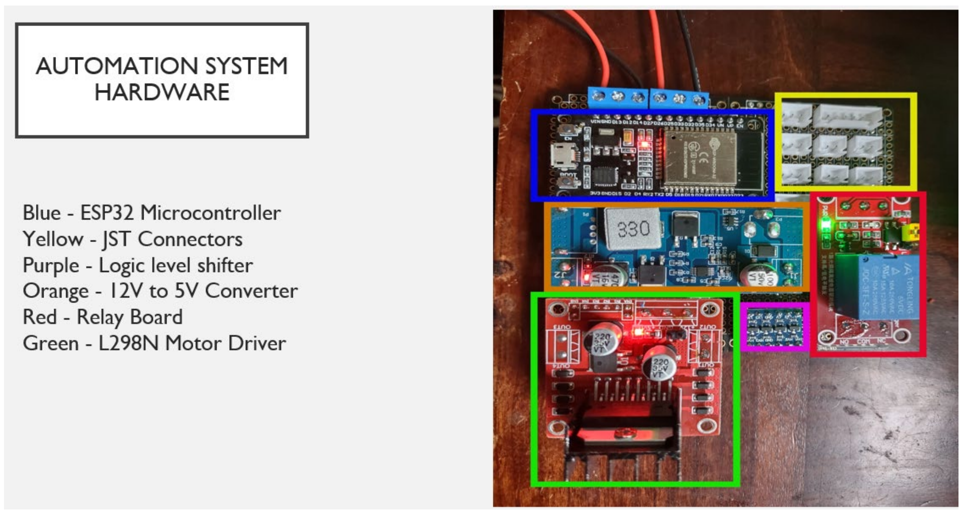


Figure 3. Control Board Diagram

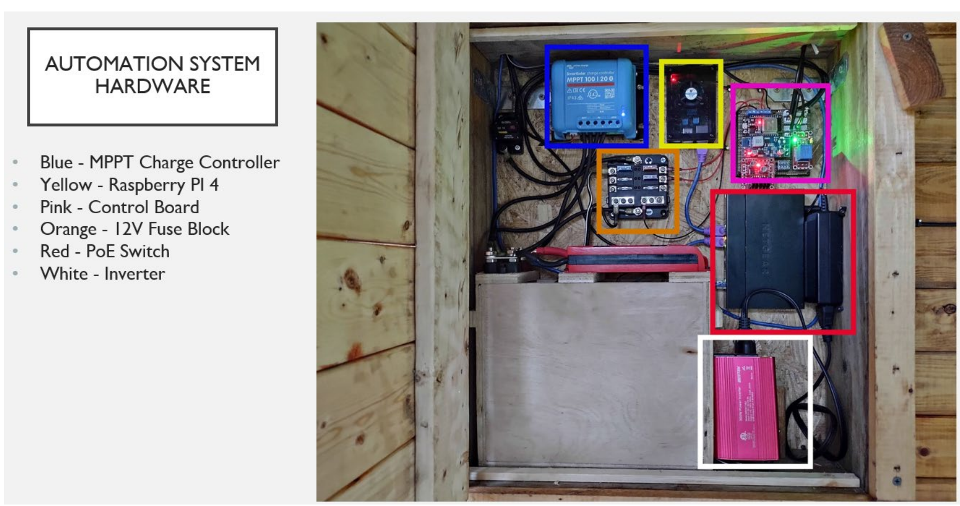


Figure 4. Enclosure Diagram

c. Automation System Software: The heart of the automation system's software is the *Home Assistant*, an open-source software for home automation. It serves as a central control hub for multiple integrations, including ESPHome, a system that enables control of ESP microcontrollers through configuration files.

Figure 5. Coop Camera, Fan, light, and DHT sensor

Figure 6. Automated Coop Door Closed and Open

To control and update ESP microcontrollers through *Home Assistant*, ESPHome must be integrated. As shown in Figure 7, *Home Assistant* has been installed on the Raspberry Pi 4. ESPHome can be installed through add-ons once Home Assistant is installed. Once installed, ESP microcontrollers can be updated. To integrate various sensors and devices, a configuration file must be uploaded to the ESP microcontroller, as shown in Figure 8. This configuration file contains instructions on which pins to use for specific input and output functions. The physical wiring of the microcontroller determines which pins are utilized. Once the configuration file is uploaded, a customized dashboard can be created, as shown in Figures 9 and 10. Entity data within the *Home Assistant* software is logged, providing users with valuable statistical data, as demonstrated in Figure 11. Automated tasks can be set up within *Home Assistant* by creating automations to be programmed to send notifications to the user when specific conditions are met, as shown in Figure 12.

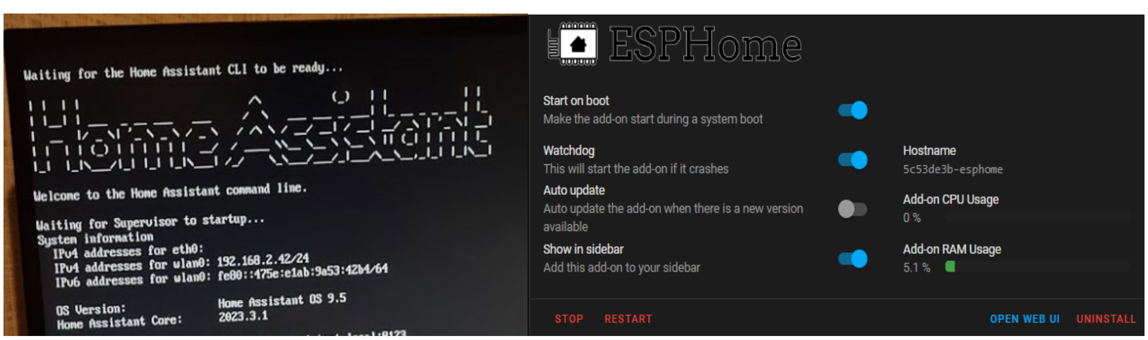


Figure 7. Home Assistant CLI installed and ESPHome Installed

```yaml
uart:
  - id: uart_victron
    rx_pin: GPIO16
    baud_rate: 19200
    rx_buffer_size: 256

  - id: uart_daly
    rx_pin: GPIO19
    tx_pin: GPIO18
    baud_rate: 9600

victron:
  uart_id: uart_victron
  id: victron_ss
  throttle: 10s

daly_bms:
  uart_id: uart_daly
  update_interval: 20s
```

```yaml
sensor:
#DHT22
  - platform: dht
    id: ext_dht
    pin: 13
    temperature:
      name: "External Coop Temperature"
    humidity:
      name: "External Coop Humidity"
    update_interval: 30s
    model: DHT22

  - platform: dht
    id: int_dht
    pin: 27
    temperature:
      name: "Internal Coop Temperature"
    humidity:
      name: "Internal Coop Humidity"
    update_interval: 30s
    model: DHT22
```

Figure 8. ESP configuration file for DHT sensors, UART communication with Solar Charge Controller, and UART communication with Daily BMS

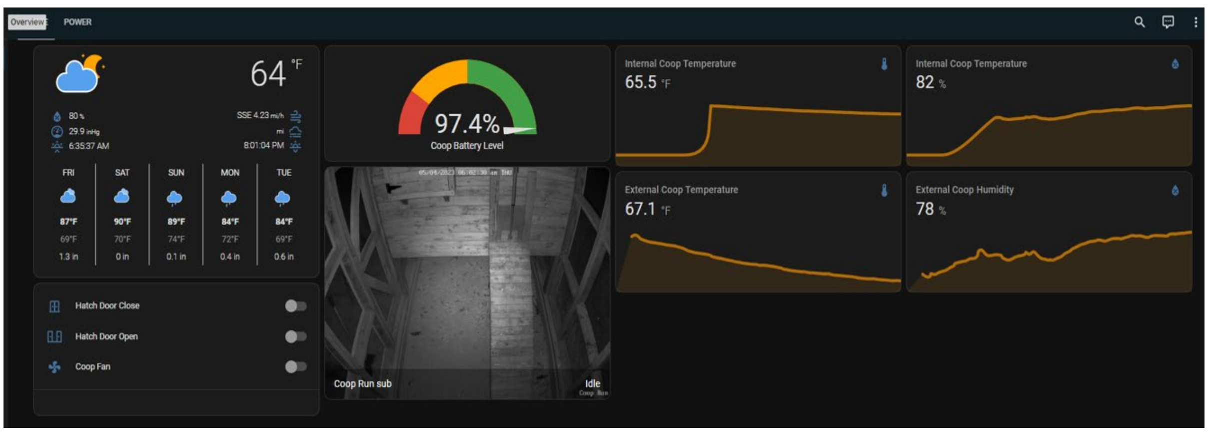


Figure 9. Home Dashboard in Home Assistant

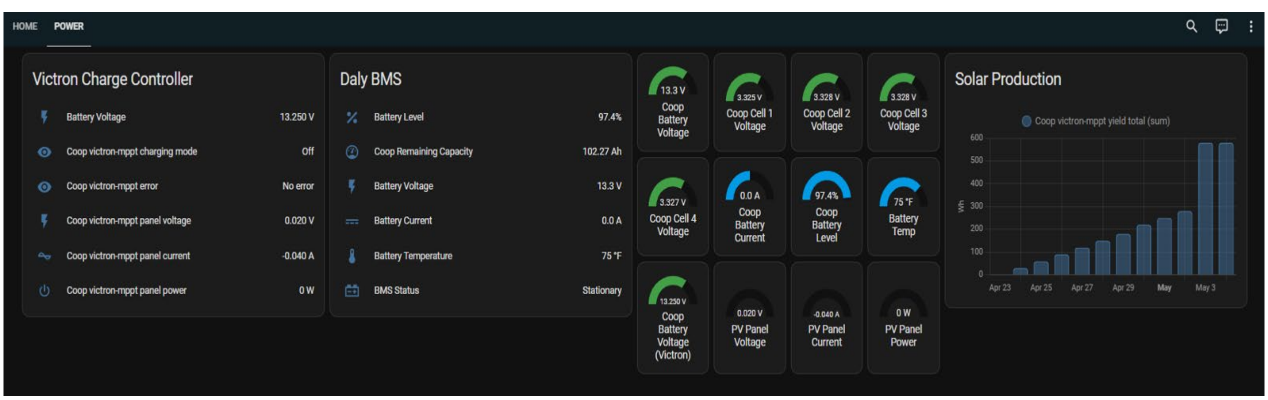


Figure 10. Power Dashboard in Home Assistant

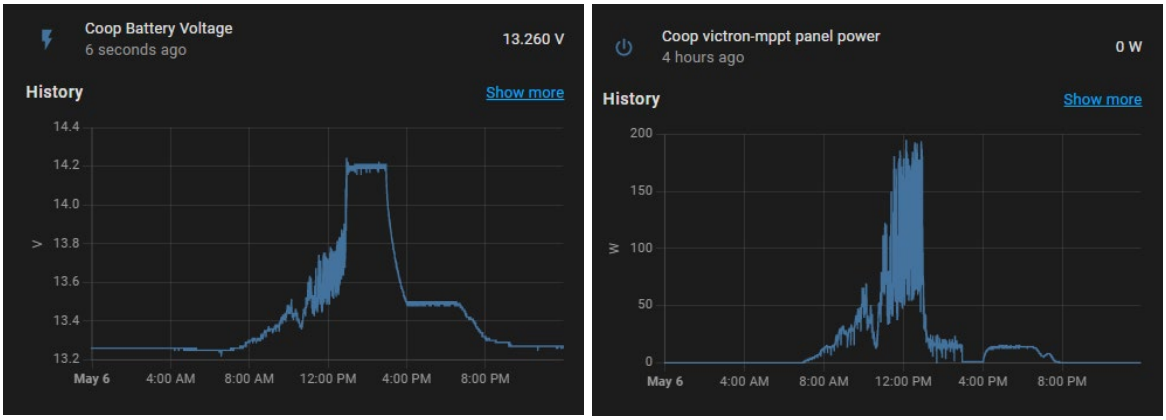

Figure 11. Logged data for battery voltage (left) and PV Panel power (right)

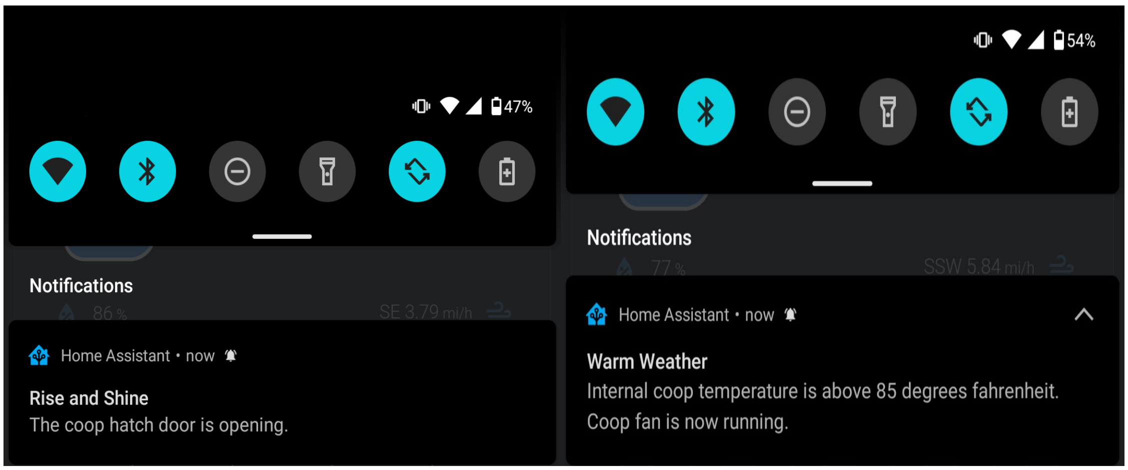

Figure 12. Push Notifications from Home Assistant automated tasks

## 5. Conclusion

The objectives of this project were to power all chicken coop electrical components with solar power, simplify caretaking processes through a low-cost automation, and add remote monitoring to a web interface. The senior design project has met and exceeded these objectives. Firstly, all electrical components of the chicken coop are now powered exclusively through solar power. Additionally, some caretaking processes have been automated, freeing up caretaker time and improving efficiency. The addition of remote monitoring allows the caretaker to monitor the chickens remotely, further increasing efficiency and responsiveness to chicken coop events. Overall, the project has successfully achieved its stated objectives.

ETEC 4199 Senior Design I and ETEC 4399 Senior Design II courses at the Sam Houston State University contain all the student learning outcomes (SLOs) developed in the Electronics and Computer Engineering Technology program. The SLO4 requires students to function effectively as a member as well as a leader on technical teams.  The corresponding Performance Indicators (PIs) for SLO 4 are (a) organize and complete work as a team, and (b) practice a collaborative and inclusive team environment. Out of 12 senior design projects in both courses, only this project included a special case; one senior student who are working full-time and having family and children that made him as only one person working in the project that was established at his own farmhouse. However, three in-class presentations before a final senior design seminar provided valuable feedback from students and faculty to the project design and implementation.

Student also met with faculty advisor weekly face to face or by Zoom meetings outside of regular class hours for progress and resolving design challenges.

A solar powered automated chicken coop is a sustainable and efficient solution for chicken owners. The integration of a solar power system, temperature and humidity sensors, automated windows, and fans make it possible to maintain a comfortable environment for the chickens while reducing energy consumption. The use of renewable energy sources and automation makes it a practical and eco-friendly option for chicken coop management. The proper design and installation of these systems ensure optimal performance and durability, making the chicken coop a smart and responsible choice for animal husbandry.

Table 1: Bill of Materials

| Bill of Materials (BOM) (May 2023) | | | | | |
|---|---|---|---|---|---|
| **Hardware** | **Vendor** | **Item#** | **Qty** | **Unit Cost** | **Cost** |
| 3.2V LiFePO4 105Ah Battery Cell | 18650BatteryStore | LF105 | 4 | $75.00 | $300.00 |
| 210 W Kyocera Solar Panel | Private Seller | KD210GX-LPU | 1 | $70.00 | $70.00 |
| Victron SmartSolar 100/20 Charge Cont. | Private Seller | SCC110020060R | 1 | $45.00 | $45.00 |
| 100 Ft Solar PV Wire 600V, 12 AWG | Wire-PV6 | Wire-PV6-12-00-100 | 1 | $41.74 | $41.74 |
| Raspberry Pi 4 | pishop.us | Pi4 | 1 | $35.00 | $35.00 |
| DALY BMS 4S 12V 89A LiFePO4 | Amazon | B08PFM1WJM | 1 | $63.00 | $63.00 |
| DaierTek Bus Bar Terminal Block | Amazon | B09YNK5CHY | 1 | $27.99 | $27.99 |
| ECO-WORTHY 12V, 12" Linear Actuator | Amazon | B00NM8H5SW | 1 | $42.99 | $42.99 |
| 1/8" x 5/8" x 12" Copper Bus Bar | Amazon | B0B7DZ9ZL8 | 1 | $17.99 | $17.99 |
| BESTEK 300W 12V to 110V DC Inverter | Amazon | B004MDXS0U | 1 | $29.99 | $29.99 |
| Icrimp Solar PV Cable Crimping Tool | Amazon | B00OMNT17E | 1 | $15.98 | $15.98 |
| Renogy Solar Panel Mounting Z Brackets | Amazon | B00BR3KFKE | 1 | $9.54 | $9.54 |
| BougeRV PCS Solar Connectors | Amazon | B073TX1N5Q | 1 | $11.99 | $11.99 |
| 6 AWG Silicone Wire 3ft Red & 3ft Black | Amazon | B09Z2MHXD3 | 1 | $18.99 | $18.99 |
| 6 AWG M8 Copper Wire Lugs | Amazon | B092ZM1NVM | 1 | $8.49 | $8.49 |
| M8 Junction Block Bus Bar | Amazon | B081DGKJ2M | 1 | $10.79 | $10.79 |
| 4pcs L298N Motor Driver Cont. Board | Amazon | B07BK1QL5T | 1 | $11.49 | $11.49 |
| KNFRXO 6Way 12V Fuse Block | Amazon | B0B73M7G35 | 1 | $15.49 | $15.49 |
| Philips Hue White A19 Smart Bulb | Amazon | B095KTKDSY | 1 | $10.53 | $10.53 |
| Lexar 64 GB Micro SD Card 2 Pack | Amazon | B09JNKHJ2Q | 1 | $15.99 | $15.99 |
| BINZET 12V to 5V 25W Step Down Reg. | Amazon | B00J3MHT1E | 1 | $9.98 | $9.98 |
| 2X4-8FT #2 Pressure Treated & Stud | Home Depot | 206970948 | 4 | $3.98 | $15.92 |
| 2X4, 92-5/8 HT Whitewood Stud | Home Depot | 202091224 | 8 | $3.24 | $25.92 |
| 1/2in 4ftx2ft Sande Plywood | Home Depot | 202093791 | 1 | $18.95 | $18.95 |
| GLOSO T3 15A & Tocas 70A DC CBs | Amazon | B0BG6D2L7C & B07D7S2VBY | 1 | $42.94 | $42.94 |
| | | | | **Total Cost:** | **$916.69** |

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