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Smart Green House Gas Footprint Display with Integrated Smart Power Monitoring and IoT Actuation

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***Abstract** : This research paper is about a one-for-all device that has a central synchronization with a Wireless Sensor Network connected to other part of the house. This network can do an all-round power saving and environment awareness tasks. The device takes power consumption readings from the mains, and displays the Greenhouse gas (GHG) emissions and footprint of the users in a particular time frame along with the current electricity bill. The WSN mainly focuses on Kitchen, Bathrooms and AC rooms. A certain toxic amount of Carbon Monoxide gas is produced from burning of stoves in Kitchen. During cooking, a gas sensor (MQ7) is placed in the kitchen measures the amount of different gases, especially CO. Chimney is turned on only when CO reading crosses a certain threshold. In this way, power consumed by chimney can be reduced markedly. Similarly in the water tanks above the house, a water temperature sensor is placed. This sensor allows the intensity of the water heater to be automatically regulated depending on the temperature of water in the tank. If water is already at the user-required temperature, the water heater is adaptively changed to a lower temperature or switched off, so as to consume less power. The third sensor is placed in an AC room. Even the high star-rated ACs are a major concern in power consumption, electricity bill and GHG emissions. Hence the temperature sensor is placed which measures the room temperature and outdoor temperature. If it is cold enough, the AC switches-off, thereby saving unnecessary power consumption.*

***Keywords:** Green House Gases, Carbon Footprint, Power Consumption, Power and Energy Saving, PIR Module, motion sensing, IoT, Arduino*

I. INTRODUCTION

With an increasing demand of luxury, and inefficient sustainable development and renewable energy usage, the amount of greenhouse gas emissions is increasing every day, and it starts from the very root level of electricity consumption in buildings. The maximum amount of GHG emission happens from power stations, with a whopping 2.4 million pounds per second. Figure 1, below shows how different sectors contribute to the Greenhouse Gas Emissions annually, projected by the Emission Database for Global Atmospheric Research (EDGAR) [1].

The need of the hour is to make people aware of what they have been contributing to the many disasters and helping them recompense for their mistakes, and this work efficiently does both of them.

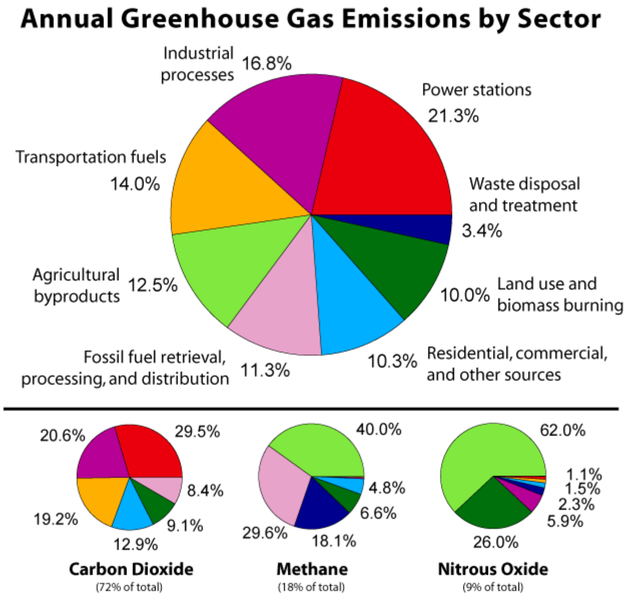

Figure 1. Amount of GHG Emission per sector and per gas contribution by the Emission Database for Global Atmospheric Research (EDGAR) – Wikipedia (2010)

II. LITERATURE REVIEW

Consumption of Energy and its effects are of a major concern all around the globe. In places like Mexico, fossil fuels are the main source of electricity generation. Even though the resources are limited, the research works in this regard show that the emissions are not as mentioned in [2]. The researches have been broad as well as appliance specific such as televisions, air conditioners, refrigerators, etc. Up till the year 2021, replacement of these appliances assures a conservation of 15,087 Tg CO2. According to the United States, already made advancement in forming standards for above 30 appliances and more than 40 energy efficiency labels, in regards to all the existing ones, such as Carbon Credits, and consider a 35% reduction in GHG emissions, but these standards are not deep rooted and thus not well implemented [3]. Further lifestyle approaches have been made, which analyze carbon footprints other than industrial usage and finds that consumer activities end up with 28% of energy consumption and 41% of GHG emissions in US alone, from [4].

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In major Asian cities, sustainable development and energy management is a current phenomenon and recent attempts are being attempts by the policy makers to bring GHG emissions in the considerable parameters of urbanization as from [5].

III. PROPSED METHODOLOGY

This smart and easy-to-use device amalgamates Internet of Things (IoT) Information and Communication technology (ICT) with the household energy consumption at consumer levels, and aware the user of their equivalent GHG footprints by standard calculations [6]. It also gives control of the home electrical in the hands of users, right at their places, and alerts them about redundant power usage at places they might be unaware about. Since the work supports Power and Energy saving at all the possible levels, it works in majorly three modules, and hereby, we present the methodology in three modules, i.e.,

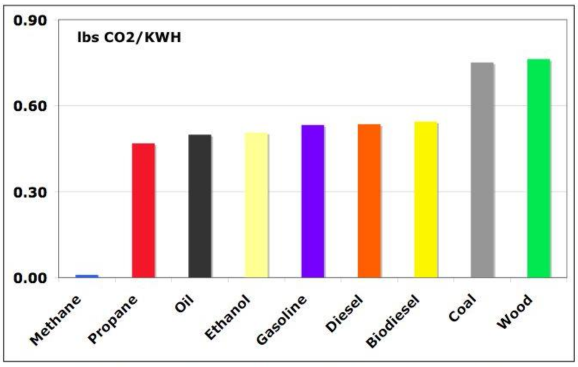
A. The Power Consumption Monitor;

B. The IoT Sensors and Actuators; and

C. The Web-Application

A. The Power Consumption Monitor:

This device in this module is a simple kilowatt-hour meter that is attached to the power meters of a building and takes the power consumption as input. This reading is now sent to the web-application to be processed further via a Bluetooth module. These readings are displayed both on a small LCD in the device as well as the web app. In Figure 2 the bar plot describes relation between energy consumption and CO2 emissions from various sources.



Source: DOE, Stanford University, College of the Desert, & Green Econometrics research

Figure 2. CO2 Emissions/ KW- hour - Green Econometrics (2008)

B. The IoT Sensors and Actuators:

The mentioned sensors are suggestively ideal for practical use, although different but similar sensors were used for the prototype. Temperature Sensor (DS18B20) and Carbon Monoxide Gas Sensor MQ-7 is deployed on the main water tank and on the chimney in the kitchen respectively.

DS18B20

This packaged digital temperature transducer accurately measures temperatures in wet ambience, with an easy 1-Wire interface to the main controller. The sensor attached on the water tank will sense the temperature of the water. The User is facilitated with a potentiometer with whose value the temperature sensed from the water will be compared and further decisions will be taken. Therefore, if the water temperature is warm enough and greater than the threshold temperature set, the water heater is switched off in order to save power. The temperature sensor data is sent to a controller (Arduino Uno) via a Wireless Sensor Network (WSN) using ZigBee module. Arduino Uno controls the switching of the geysers. A copy of sensor data is also sent to a server (Raspberry Pi). The server sends the data to the cloud and this data can be retrieved, analyzed and can be edited on a webpage designed. User can edit and set a Threshold value of temperature and control the switch through the webpage as well.

MQ-7

This gas sensor analyses the volumetric ratio of Carbon Monoxide in the air and returns analogue voltage value to the controller mapping it from a range of CO concentrations of 10 to 10,000 ppm. The temperature rating is -10 to 50°C and operates at no more than 150 mA at 5 V potential differences. The sensor is attached on the chimney in the kitchen. Since CO amount after a certain value is dangerous, hence sensor measures the CO gas emitted in the kitchen while cooking. Again a certain threshold value can be set to compare with measured CO level by the sensor. Generally, the chimneys in the kitchen are switched on for more than enough time while cooking, contributing a good amount in power consumption. To conserve more power, the chimney can be switched on only when a certain amount of CO level is detected. Therefore, the sensor measures the amount of CO present continuously and the data is sent to the processor. The processor compares the sensor data and the threshold value; when the sensor data value exceeds the threshold value, the Chimney is switched on, thereby conserving power consumed by the chimney. Similar to Temperature sensor used for water heater, a WSN of (DS18B20) and (MQ7) is created and a copy of sensor data from chimney and water tank is sent to Main Server through Zigbee module. The Zigbee standard does its operations under IEEE 802.15.4 and utilizes unlicensed bands such as 2.4 GHz, 900 MHz and 868 MHz. Arduino Uno controls the Switch, communicates with sensor, gets the data and send the data through ZigBee module to Main server. The user can see, interact and analyze the data that is transferred from main server to cloud and to a webpage [7].

IV. PROPOSED ALGORITHM

Set red LED;
Instantiate mq2 sensor;
Initialize threshold mq2 sensor = 400;
Initialize val to 0;   // for sensor analogue values
set tempPin   // the output pin of LM35
Set Blue led
Set tempMin = 20;
Set tempMax = 40;   // setup() Block begins
Set Red LED, gasA0, Blue LED as OUTPUT
Temperature pin as INPUT; //loop() Block for infinite iterations
{

```
 val = analogRead(potPin);
 val = map(val, 0, 1023, 0, 80);
 int analogSensor = analogRead(gasA0);    //reads the data from the sensor

// checks if it has reached the threshold value
if (analogSensor > threshold)
 {
   digitalWrite (red, HIGH);
 }
 else    //if analog < threshold, normal condition
 {
   digitalWrite(red, LOW);
 }
 delay(100);                //delay of 100 microseconds
  temp = readTemp();     // get the temperature from sensor and store it in temp variable
//Compare the value of temperature value to the Minimum

preset threshold;
 if(temp  < tempMin) {
     fanSpeed = 0; // Fan doesn't start or stops instantly
     digitalWrite(fan, LOW); // Set the fan pin as low;
  }
```

C. The Web Application:

This web based application works as both the interface between all the modules and the place where user is alerted about their current GHG emissions as well as their till then electric bill. CO2 emissions are calculated using the given

Equation: 1,640.7 lbs CO2/MWh × (4.536 × 10-4 metric tons/lb) × 0.001 MWh/kWh = 7.44 × 10-4 metric tons CO2/kWh

(U.S. weighted average of national Carbon Dioxide marginal emission rate, AVERT, year 2016 data)

The readings received from the Power Consumption Monitor are multiplied by the appropriate factors so that they can be converted into the amount of each GHG emission. The user is regularly alerted by the app of their increasing GHG footprints. Also, the IoT part of the app works efficiently by easily accessing the electricals of any place in the house. The alerts about the redundant appliances are also given via this app itself. Another tab displays the current electricity bill and expenses in the past, for an efficient budget management.

V. RESULTS AND ANALYSIS

All the modules have been verified at prototype level and all of them worked as expected, under experimental errors. The objective of this paper is to present a cut-above solution to reduce and monitor the power consumption in household, notably the power consumption by chimney in the kitchen, Geysers in Bathrooms. As mentioned in the Methodology section, following results were obtained after the implementation of the proposed system.

A. Hardware:

The prototype implemented is shown in Figure 3 consisting of Raspberry Pi B3 as server computer to receive and send sensor data to cloud. Figure 3. Raspberry Pi B3 as computer to send sensor data to cloud Arduino Uno to display sensor data and bill on LCD [8].

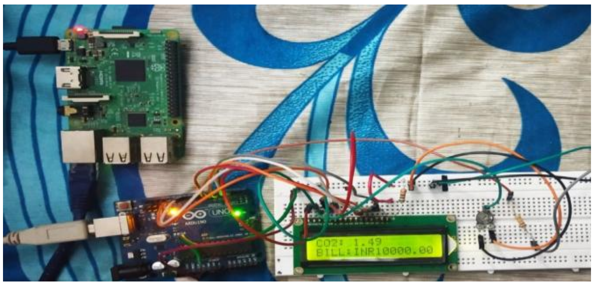


Figure 3. Raspberry Pi B3 as computer to send sensor data to cloud Arduino Uno to display sensor data and bill on LCD.

•Users were able to control the relays from a range of ~10 meters uninterruptedly.

•The power usage was correctly displayed on the LCD.

•Each of the sensor nodes are setup on different locations in the house with a temperature sensor to sense the water temperature in the tank of the house. For the prototype, LM35 sensor is used. Corresponding this sensor and LED (Blue color) is installed, that is lit-off when water temperature is above a certain threshold indicating the geyser should be off to save power as the water in the tank is already warm enough.

The fan in the potentiometer was analogous to any continuous device, such that speed of the fan proportionally changed with temperature. For a minimum value of 20ºC, the fan remained off, and was mapped accordingly to a threshold temperature, for maximum speed of fan via PWM.

•To test practically, a potentiometer is connected to LED (blue color) along with LM35 sensor. Potentiometer value is mapped from (0->1024 to 0->80) with Min Value of Temperature to be sensed is set to 20 C and maximum to 40C .When potentiometer value is less than LM35 sensor value, LED turns ON, indicating the Geyser is ON.

•An MQ7 gas sensor node installed on chimney to monitor the CO level in the kitchen. A Red LED corresponding to this sensor is arranged for the prototype. Above a certain threshold value (400 is usually a dangerous CO level) Red LED is switched on indicating Chimney to be ON, thereby saving power, i.e. only to use chimney when CO level is higher than a certain threshold.

•To test the conditions, sensor is setup near the smoke, threshold value set to 400. Thus LED red is turned on indicating the chimney is ON.

Table1: Results: Sensor Data

Sensor Type	Sensor data value	Threshold Value	Corresponding LED Status
MQ2 (gas sensor) (With threshold Value))	1.) 242 2.) 255 3.) 301 4.) 503 5.) 556	400	1.) OFF 2.) OFF 3.) OFF 4.) ON 5.) ON
LM35 temperature Sensor Potentiometer value set to (27)	1.) 25 2.) 26 3.) 27 4.) 29	Potentiometer value - 27	1.) OFF 2.) OFF 3.) ON 4.) ON

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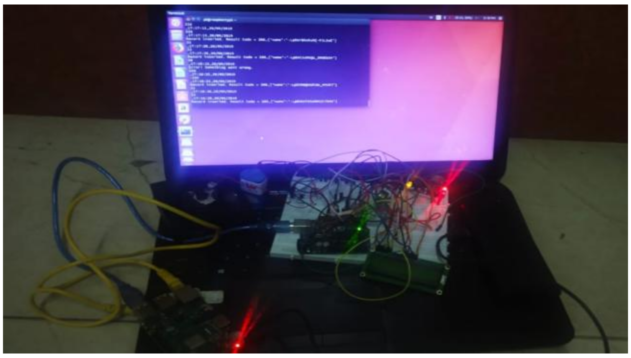

Figure 4. Prototype of sensor data logging in Firebase cloud

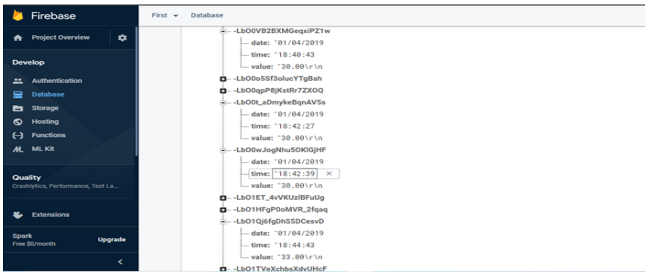

Figure 5: Data dynamically updated on Firebase console database with device ID, type of data and timestamp

B. The Software:

The power consumption values from the meter were correctly displayed and dynamically updated. The CO2 values and the electricity bills were perfectly calculated and given to the user. All the notifications regarding increasing GHG footprint and the redundantly running appliances were timely displayed via the app. Figure 4 shows the web app menu for notifications and controlling over the web. Web app has user login feature and display of GHG emission and his current electricity bill as shown in Figure 5 and Figure 6. One can edit his or her profile in 'My Info' page. Sample web app profile is shown in Figure 7.

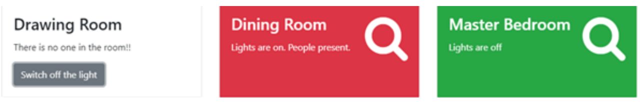

Figure 6. The web alerts and controlling

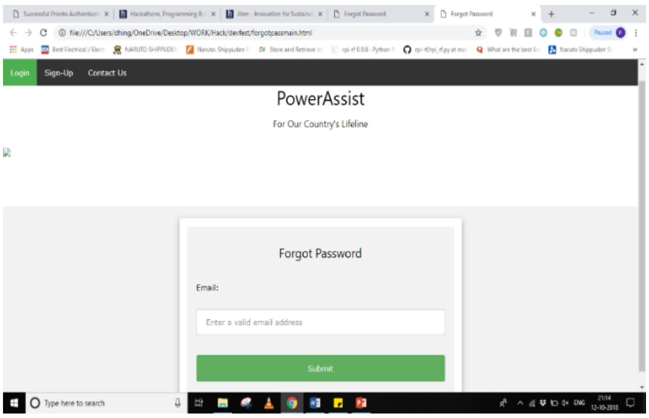

Figure 7. Password Recovery

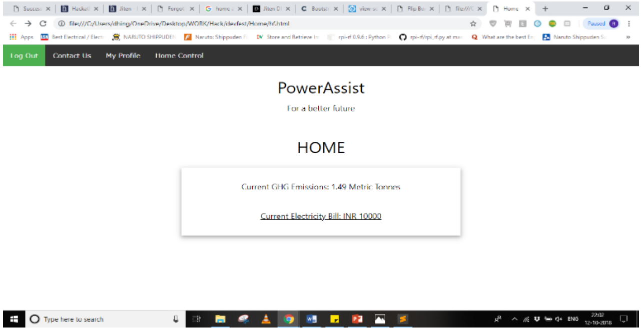

Figure 8. GHG Emissions and Current electricity Bill

Figure 9. The 'My Information' page

VI. CONCLUSIONS

In this product based research work, we have attempted to make everyone aware about their part in the deterioration of environment, adding convenience to their lives and simultaneously reducing the power consumption efficiently. Thus, we are using technology in engineering better lives and a better world for both, ours and the generations to come. The following inferences can be obtained: More reliable and custom designed sensors and actuators prove to be more efficient. The data received was reliable only to prototypic and experimental limits. The given idea presents only an early structure to all the possible ideas of merging technology in any field, let alone energy consumption and saving. It uses only the available technologies in the most efficient way possible. The multiplication factors need to be updated periodically and thus a collaboration with government and non-government organizations is necessary for a feasible market product.

VII. FUTURE ASPECTS

The future plans for the work include addition of supervised machine learning algorithms to read the patterns of power consumption of each user and advise the user regarding more pocket and environment friendly energy consumption. More smart automation and actuation is needed to let the device make decisions of its own and make it less user dependent. More precise, and individual module control is needed to be given to the user so that user can have information of both, building as a whole, and all the nodes in different rooms as independent entities.

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Jiten Dhingra is a student of electronics and communication field, a B. Tech. graduate from Vellore Institute of Technology, Vellore, India. He has been an active participator and achiever in various national and international events such as Hackathons and Conferences. He has been the youngest author in IEEE Technological Innovations in ICT for Agriculture and Rural Development 2018. He has been a technical member of International Student Chapters such as International Institute of Technology and Institute of Electrical and Electronics Engineering. He has been working on projects at various levels, such as college-funded and industrial-product based research works in the domains of Internet of Things, Industrial Automation and Industry 4.0, Embedded Systems, Web Development and Robotics.

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