**MEASURE ENERGY CONSUMPTION**

**AI PROJECT PHASE-1**

**TEAM LEADER:NAVEEN.S**

**BHARATHIDASAN ENGINEERING COLLEGE**

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ABSTRACT**:**

Energy consumption measurement plays a pivotal role in today's world, where sustainability and efficiency are paramount. Accurate measurement of energy usage is essential for individuals, businesses, and governments to make informed decisions about resource allocation, cost management, and environmental impact reduction. This paper presents a comprehensive approach to measure energy consumption, encompassing various techniques, technologies, and methodologies. The proposed system is versatile, adaptable, and scalable, making it suitable for a wide range of applications, from residential households to industrial complexes. The modules discussed in this paper offer practical solutions for gathering, analyzing, and interpreting energy consumption data, ultimately leading to more sustainable energy practices.

Module1 : Data Acquisition :**This module focuses on the collection of energy consumption data from various sources. It involves the deployment of sensors, meters, and data loggers to capture real-time and historical energy usage information.**

Key components include

**Sensor Installation**: **Proper placement and calibration of energy sensors, such as smart meters, current clamps, or temperature sensors, to ensure accurate data capture.**

**Data Logging**: **Development of data logging systems that record energy consumption data at predefined intervals and store it in a centralized database or cloud platform.**

**Data Sources: Integration with various sources, such as electricity grids, renewable energy sources, HVAC systems, and other appliances, to create a holistic view of energy consumption.**

**Module 2: Data Analysis This module focuses on the processing and analysis of the acquired energy consumption data. It employs algorithms and techniques to extract meaningful insights, identify patterns, and detect anomalies. Key components include:**

**Data Preprocessing:**

**Cleaning, filtering, and transforming raw data to eliminate noise and ensure data quality**

**Analytics Algorithms: Implementation of statistical, machine learning, and artificial intelligence algorithms for predictive modeling, load forecasting, and anomaly detection.**

**Visualization: Development of interactive dashboards and visualization tools to present energy consumption trends and insights to users in an understandable format.**

**Module 3: Energy Management This module emphasizes the management of energy consumption based on the insights gained from data analysis. It facilitates decision-making and optimization of energy usage to reduce costs and environmental impact.**

**Key components include: Demand Response: Implementing demand response strategies to reduce peak loads and optimize energy consumption during high-demand periods.**

**Energy Efficiency Recommendations: Providing recommendations to users on how to reduce energy consumption through equipment upgrades, behavioral changes, or automation.**

**Cost Analysis: Calculating the cost associated with energy consumption and offering cost-saving strategies based on real-time data.**

**Module 4: Reporting and Monitoring This module ensures that energy consumption data is readily accessible and actionable for users. It involves creating reports, alerts, and monitoring systems to track and manage energy usage efficiently.**

**Key components include: Report Generation: Automatic generation of energy consumption reports for various stakeholders, including homeowners, facility managers, and government agencies.**

**Real-time Monitoring: Continuous monitoring of energy consumption and providing alerts for abnormal usage patterns or equipment malfunctions.**

**User Interfaces: User-friendly interfaces for accessing energy consumption data through web applications or mobile apps.**

**In conclusion, this comprehensive approach to measuring energy consumption addresses the growing need for data-driven decision-making in the energy sector. By combining data acquisition, analysis, management, and reporting, this system offers a powerful toolkit for individuals and organizations to optimize energy usage, reduce costs, and contribute to a more sustainable.**

**Future extraction**:

**Studies on direction of causality between energy consumption and economic growth have become more popular since the 1970s**[**Magazzino et al., 2021a**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b369)**,**[**Magazzino et al., 2021b**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b368)**. Although most studies attribute the earliest work to**[**Kraft and Kraft (1978)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b336)**, work by**[**Carter (1974)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b150)**, Hudson and Jorgensen (1974), Humphrey and Stanislaw (1975),**[**Odum and Odum (1976)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b420)**, and Pachuria (1977), preceded it**[**Payne, 2010a**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b458)**,**[**Payne, 2010b**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b459)**. But the most important debate, is about the dynamic causal relationship that energy consumption plays in economic growth, is very useful for policy making to both energy and macroeconomists**[**Shahbaz et al., 2013a**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b514)**,**[**Shahbaz et al., 2013b**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b513)**. Studies on survey literature have been done by**[**Payne, 2010a**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b458)**,**[**Payne, 2010b**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b459)**,**[**Omri, 2014a**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b430)**,**[**Omri, 2014b**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b431)**,**[**Sebri (2015)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b503)**,**[**Gozgor et al. (2018)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b261)**,**[**Jakovac (2018)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b292)**, while**[**AlKhars et al. (2019)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b49)**studied a case of GCC countries between 2006 and 2019 as shown in**[**Table 1**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#tbl1)**; while these studies covered a shorter period with hardly 200 studies each, this study will cover a longer period with over 1000 studies; which increases its explanatory power and representatives of the whole. It will be helpful in synthesising the finer details of the previous works and also act as a useful bench mark for future studies**[**Havranek et al. (2020)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b272)**.**

**This study seeks to investigate**[**stationarity**](https://www.sciencedirect.com/topics/engineering/stationarity)**, cointegration and direction of causality on energy consumption and economic growth. The motivation of this study is to summarise previous studies and draw relationships peculiar to energy consumption–economic growth nexus. It categorically gives a sweeping review on the existing empirical literature on energy consumption and economic growth**[**Shahzad (2020)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b520)**.**

**Table 1. Meta-analysis on energy consumption and economic growth.**

| **Study/Hypothesis** | [Payne,2010a](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b458)**,pa**[yne, 2010b](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b459) | [Omri, 2014a](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b430)**,**[Omri, 2014b](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b431) | [Sebri (2015)](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b503) | **Jackovic (2018)** | [Gozgor et al. (2018)](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b261) | [AlKhars et al. (2019)](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b49) |
| --- | --- | --- | --- | --- | --- | --- |
| **Growth** | **23.1%** | **29%** | **27.5%** | **42.7%** | **25%** | **18%** |
| **Feedback** | **28.2%** | **27%** | **32.6%** | **7.2%** | **41%** | **43%** |
| **Conservation** | **19.5%** | **23%** | **12.4%** | **47%** | **21%** | **26%** |
| **Neutral** | **29.2%** | **21%** | **27.5%** | **3.1%** | **13%** | **13%** |
| **Total** | **100%** | **100** | **100** | **100** | **100%** | **100%** |
| **Sample size** | **102** | **136** | **153** | **132** | **136** | **59** |

### Hypotheses on energy consumption and economic growth

**The direction of causality between energy consumption and economic growth has been categorised into four hypotheses that we continue to independently test and verify. The hypotheses for this transmission mechanism is given as: growth, conservation, feedback, and neutrality**[**Alper and Oguz (2016)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b54)**.**

**(i) First, the growth hypothesis argues that energy consumption has a unidirectional causality running to economic growth process. This argument fronts the idea that energy consumption may induce economic growth either directly or indirectly by complementing capital and labour in the classical production function. The growth hypothesis is supported if there is unidirectional causality from energy consumption to economic growth (**[**Destek and Aslan, 2017**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b200)**,**[**Kahia et al., 2017a**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b308)**,**[**Kahia et al., 2017b**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b310)**,**[**Zallé, 2019**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b633)**,**[**Mbarek et al., 2018**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b380)**). The coveted Granger test in this growth hypothesis that energy causes economic growth guides policy that should step up**[**investment in energy**](https://www.sciencedirect.com/topics/engineering/investment-in-energy)**consumption and any conservation measures will harm the health of the economy. Under the growth hypothesis,**[**energy conservation policies**](https://www.sciencedirect.com/topics/engineering/energy-conservation-policy)**that reduce energy consumption may have an adverse impact on economic growth. This hypothesis has a double edged sword; it has growth with positive, (**[**Awodumi and Adewuyi, 2020**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b93)**) and negative results between energy Consumption and economic growth (Imran and Saddique, 2010,**[**Tran et al., 2020**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b574)**,**[**Titalessy, 2021**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b570)**).**

**(ii) Second, the conservation hypothesis postulates that energy conservation policies designed to reduce energy consumption and waste may not have an adverse impact on economic growth (**[**Al-Mulali et al., 2019**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b44)**,**[**Aydin, 2019**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b95)**,**[**Vo and Le, 2019**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b589)**,**[**Nasreen et al., 2020**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b411)**). The conservation hypothesis is confirmed if there is unidirectional causality from economic growth to Energy consumption. If in this hypothesis economic growth Granger causes energy consumption then the growing economy may be obstructed by other factors like governance, infrastructure, trade openness and/or Energy consumption inclusive**[**Almozaini (2019)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b51)**.**

**(iii) Third, the feedback hypothesis emphasises the interdependent relationship between energy consumption and economic growth and their complementarity for instance**[**Salahuddin and Gow (2019)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b489)**,**[**Kahia et al. (2019)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b309)**,**[**Saint Akadiri et al. (2019)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b485)**, others that used panel data studies with same results include**[**Jammazi and Aloui (2015)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b295)**,**[**Osman et al. (2016)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b437)**,**[**Bildirici and Gokmenoglu (2016)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b130)**. The presence of bidirectional causality between energy consumption and economic growth lends support for the feedback hypothesis including**[**Rasoulinezhad and Saboori (2018)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b477)**,**[**Saad and Taleb (2018)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b480)**, Shahbaz et al. (2018),**[**Tugcu and Topcu (2018)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b578)**,**[**Zafar et al. (2019)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b630)**, and**[**Salahuddin and Gow (2019)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b489)**. Granger causality test is bidirectional and this two way causality relationship has important policy implications for instance undertaking energy efficiency must be done cautiously so as not to adversely affect the ‘overall health’ of the economy.**

**(iv) Finally, the neutrality hypothesis considers energy consumption to be a small component of an economy’s overall output and thus may have little or no impact on economic growth as supported by**[**Belal et al. (2021)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b118)**,**[**Orhan et al. (2020)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b436)**, and**[**Sunde (2020)**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b551)**. In this hypothesis the Granger causality test diminishes, as most times there is ‘no Granger’ causation between the variables of interest, energy conservation policies may not have an adverse impact on economic growth under the neutrality hypothesis. The neutrality hypothesis is supported by the absence of a causal relationship between energy consumption and economic growth (**[**Apergis and Payne, 2010a**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b76)**,**[**Apergis and Payne, 2010b**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b77)**,**[**Apergis and Payne, 2010c**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b78)**,**[**Azam et al., 2015**](https://www.sciencedirect.com/science/article/pii/S2352484721011264#b98)**).**

**Model Developent**

**1. Data Collection: Gather historical energy consumption data. This can include electricity, gas, or other forms of energy usage. Ensure the data is accurate and covers a sufficient time period.**

**2. Feature Selection: Identify relevant features that may impact energy consumption, such as temperature, occupancy, time of day, and appliances used. These features will be used as input variables for your model.**

**3. Data Preprocessing: Clean and preprocess the data. Handle missing values, outliers, and normalize or scale the data as needed.**

**4. Model Selection: Choose an appropriate machine learning or statistical model. Common choices include linear regression, decision trees, or more advanced techniques like neural networks for complex patterns.**

**5. Model Training: Split your dataset into training and testing sets. Train the model on the training data, and use the testing data to evaluate its performance .**

### Energy consumption visualizations

**With data visualization, consumers can acquire a better understanding of their appliances’ consumption, showing how they contribute to the whole energy consumption. Thus, with the right incentive, consumers can become more aware and more energy-efficient. For instance, some studies have already shown interest in energy consumption visualization inside buildings (**[**Smith et al., 2019**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b58)**,**[**Chen et al., 2020**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b13)**), where the former is interested in light commercial buildings’ energy consumption visualization, and the latter is focused on domestic consumption visualization and human behavior simulation. In addition,**[**augmented reality**](https://www.sciencedirect.com/topics/engineering/augmented-reality)**(AR) is also utilized to enhance the consumers’ awareness regarding electronic devices/appliances consumption (**[**Bekaroo et al., 2018**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b7)**).**

**From the reviewed studies like**[**Bonino et al. (2012)**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b10)**, such visualization charts can help the users from different aspects including:**

* **1.To identify consumption trends which will enable them to reduce the consumption. For example, the trends might show that the consumption is at its highest in the evening between 4–5 PM, when the user’s family is back from work/school.**
* **2.To determine the energy consumed by individual appliances so that the users can identify which appliances are responsible for high energy consumption.**
* **3.To investigate the impact of the consumption either monetarily or environmentally. For example, the visualization might indicate the cost of operating a**[**washing machine**](https://www.sciencedirect.com/topics/engineering/washing-machines)**or the number of trees that need to be planted to compensate the consumption.**
* **4.To keep track of the energy consumed by individual members of a household, so that members with high consumption can be made aware of their consumption while informing them with more intelligent choices.**
* **5.To be able to set a goal for everyday consumption and receive tips on how this goal can be achieved by making intelligent choices like switching off an appliance.**
* **6.To enable the control of appliances from the visualization directly. For example, if the visualization notifies that an appliance is consuming high energy, then the user should be able to switch off that appliance.**

**Using data visualization charts to show users their energy consumption can have positive effects in reducing it, as visualizations are capable of tackling the most important factor in the electricity supply chain; the**[**human factor**](https://www.sciencedirect.com/topics/engineering/ergonomics)**. With the rapid increase and growth of**[**technologies**](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/science-and-technology)**, mobile phones have become an integral part of people’s lives and are used for a variety of applications.**[**Weiss et al. (2010)**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b68)**confirmed the suitability of using mobile devices to track energy consumption. They have also found that mobile phones are suitable for the task due to the high interactivity and portability they offer. While,**[**Micheel et al. (2015)**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b38)**found that users prefer a mobile device to keep track of their water and energy consumption due to its quick access and instant alerts. Hence, our visualizations are built to be used on a mobile application. According to**[**Blumenstein et al. (2016)**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b9)**, through their increasingly widespread usage, mobile devices have become a highly important target environment for Visualization of Knowledge. However, much too little focus has been given to the assessment of digital simulation strategies on mobile devices.**

**In an effort to understand the commonly used visualizations, we reviewed the papers that visualized energy consumption in a single unit, in multiple units, and over wider geographical areas. Though we are only interested in visualizing the energy consumption in a single unit, we reviewed related work that visualized consumption over multiple units and wider geographical areas as the fundamental visualization remained consistent across all categories. These visualizations often visualized the consumption for a single unit and then built an extra layer of visualization on top of the fundamental visualization to aggregate the consumption across several units.**

**We also decided to review only 2D visualizations as they are better suited for users who are not very skilled with computers (**[**Sebrechts et al., 1999**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b55)**). With the evolution of mobile phones, users often turn to mobile applications for entertainment, technology, home-automation, gaming, etc. Hence, we decided to create a mobile application that monitors energy consumption that would be useful for energy consuming end users.**

**The energy visualizations are reviewed and classified based on categories loosely inspired from the authors of**[**Bonino et al. (2012)**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b10)**and**[**Murugesan et al. (2015)**](https://www.sciencedirect.com/science/article/pii/S0959652622024350#b41)**. These categories will help the readers identify popular features supported by the visualization, the target platform they are used in, the area for which consumption is visualized, and other details that describe the visualization.**

**program**

internet = 54.56  
cleaning\_lady = 72.00  
insurance = 52.40  
material\_usage = 30.00  
maintaince\_boiler = 5.52   
currentYear = int(datetime.today().replace(day=1).strftime('%-Y'))  
currentMonth = int(datetime.today().replace(day=1).strftime('%-m'))  
passedMonth = currentMonth - 1   
\_, num\_days = calendar.monthrange(currentYear, currentMonth)   
class Energy:   
 def \_\_init\_\_(self, gas, elect\_1, elect\_2, water, number\_days ):   
 self.gas = gas   
 self.elect\_1 = elect\_1   
 self.elect\_2 = elect\_2   
 self.water = water   
 self.number\_days = number\_days   
   
 def cost\_total(self):   
 number\_months = passedMonth + (self.number\_days / num\_days)   
   
 other\_costs = (internet + cleaning\_lady + insurance +   
 material\_usage + maintaince\_boiler) \* number\_months   
  
 # All cost until time t-1  
 total\_cost\_old = (((df[df['month'] == '01\_may\_2022'].gas[1]   
 - df[df['month'] == '31\_december\_2021'].gas[0]) \* df.gas\_pr)   
 + (((df[df['month'] == '01\_may\_2022'].electric\_1[1] +   
 df[df['month'] == '01\_may\_2022'].electric\_2[1]) -   
 (df[df['month'] == '31\_december\_2021'].electric\_1[0] +   
 df[df['month'] == '31\_december\_2021'].electric\_2[0])) \*   
 df.elect\_pr) + ((df[df['month'] == '01\_may\_2022'].water[1] -   
 df[df['month'] == '31\_december\_2021'].water[0]) \*   
 df.water\_pr))   
   
 # All cost between t-1 and t-2   
 total\_cost\_new = (((self.gas - df[df['month'] ==   
 '01\_may\_2022'].gas[1]) \* df.gas\_pr\_new) + (((self.elect\_1 +   
 self.elect\_2) - (df[df['month'] ==   
 '01\_may\_2022'].electric\_1[1] +   
 df[df['month'] == '01\_may\_2022'].electric\_2[1])) \*   
 df.elect\_pr\_new) + ((self.water - df[df['month'] ==   
 '01\_may\_2022'].water[1]) \* df.water\_pr))   
  
 # Total cost until now   
 cost = total\_cost\_old[0] + total\_cost\_new[0]   
 cost\_total = round((other\_costs + cost), 2)   
 return cost\_total

**Now, I assemble all pieces and add a picture to the app.**

image=Image.open('app\_photo.jpg')  
image.thumbnail((800,300),Image.ANTIALIAS)  
photo=ImageTk.PhotoImage(image)  
label\_image=tk.Label(image=photo)  
label\_image.grid(column=3,row=0)

**Here is the final version of the desktop app which calculates the living expense on the 20th of July (energy and other necessary expenses):**

