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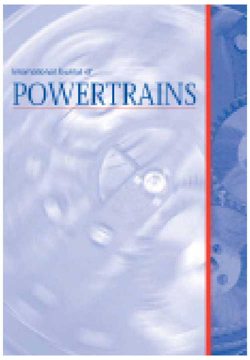


**International Journal of Powertrains**

ISSN online: 1742-4275 - ISSN print: 1742-4267
https://www.inderscience.com/ijpt

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# Performance analysis of precise energy consumption algorithm for smart home using hybrid renewable energy

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**DOI:** 10.1504/IJPT.2023.10054772

**Article History:**

| | |
|---|---|
| Received: | 09 November 2020 |
| Last revised: | 20 December 2020 |
| Accepted: | 01 February 2021 |
| Published online: | 20 March 2023 |

# Performance analysis of precise energy consumption algorithm for smart home using hybrid renewable energy

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**Abstract:** Energy demand is increased day by day, so there is a need for energy management, and it plays a vital part in the 21st century. At present, non-renewable energy is utilised most of the time. The people are not aware of the wastage of energy when their home appliances turned on the whole day. So, hybrid renewable energy is an alternate source for supplying continuous power for their smart home in the future. The collected renewable energy is utilised for the smart home usages. To minimise power consumption and to predict energy consumption precisely is a stimulating task in the future. This work proposes an innovative precise energy consumption algorithm (PECA) that is used to calculate the smart home power consumption accurately. PECA utilises smart plug, smart gateway, and mobile app administration platform to build and deploy a deep learning model. The smart plug and smart gateway combined into the complete distributed sensor network is to analyse, improve, and expand the energy consumption efficiently. Artificial intelligence is used to predict the energy usage data, optimise resource consumption, reduce the cost and maximise renewable energy usage.

**Keywords:** renewable energy; precise energy consumption algorithm; PECA; smart home; smart plug; smart gateway; deep learning; artificial intelligence.

**Reference** to this paper should be made as follows: Anguraj, D.K., Sathya, C., Vinothini, C., Jayanthi, M. and Rani, J.V. (2023) 'Performance analysis of precise energy consumption algorithm for smart home using hybrid renewable energy', *Int. J. Powertrains*, Vol. 12, No. 1, pp.1–14.

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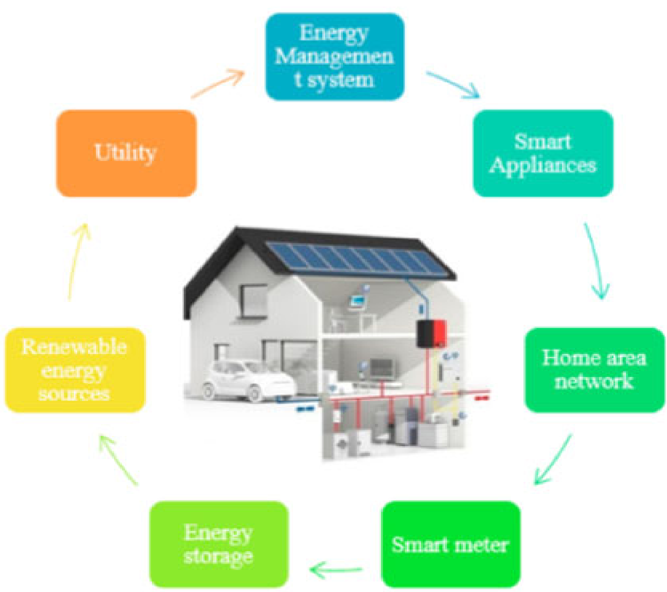
## 1 Introduction

Nowadays, the renewable energy is utilised for smart city applications. The smart home is a home that efficiently utilises renewable energy with the help of artificial intelligence techniques. The main aim of this work is used to reduce power consumption for smart homes and maximise renewable energy production.

The AI-based smart meters are utilised in the smart home which reduces human activity like the usage of electricity measurement with manual operation. It gives an accurate measurement of electricity usage and to monitor the indoor temperature to utilise electricity optimally.

In the future, the governments have decided to utilise the smart meter for the smart home to precise the energy consumption in a smart way. The AI-based algorithm collects the data from the smart meter to take a better decision to minimise power consumption and to produce accurate results.

**Figure 1** Smart home power management system (see online version for colours)




The smart home electrical appliances are controlled virtually with the help of smartphones. The latest technologies like hot water temperature control for water tank, automatic ceiling fan and LED light to minimise the power consumption effectively. The automatic ceiling fan is controlled by an Arduino UNO microcontroller and its speed is increased or decreased automatically with the help of a room temperature sensor. The LED light is increased/decreased its brightness based upon the room intensity value. Based upon all the parameters the smart home electricity is minimised.

The AI-based systems are intelligent to make an intelligent house which consists of automatic window openings, automatic ceiling fan, automatic LED light, automatic cooling and heating, hot water systems, smart meter, a smart plug, smart gateways, electric vehicle charging point, etc. All these features are integrated to make a future smart home as acts as a small power plant for all of the individuals. The smart home power management system is a cyclic process which is shown in Figure 1.

## 2 Literature review

Deep neural networks, random forest, and Rpart regression models are utilised for power consumption analysis. When compared to other models, the random forest gives the most accurate result for power consumption analysis (Zekić-Sušaca et al., 2019). Different approaches are utilised to review energy consumption using machine learning applications. The latest machine learning software tools are utilised to predict the accurate energy estimate values (Garcia-Martin, 2019). The MANFIS-based intelligent home power managing scheme is used to hand grip power generation, depletion and arranging the utilisation. The outcome displays that 57.62% of the energy rate is decreased and the topmost energy depletion is decreased by 44.4% (Jabash and Jasper, 2020). The energy consumption real-world dataset is validated using lengthy short-range memorial as an encoder and gated recurring entity as a decoder in combination with the ACP model (Almalaq and Zhang, 2019). ML and big data both play a vital role in smart buildings appliances and devices comprise valued data that needs to enable appropriate activities and improved choice creation (Qolomany et al., 2019).

The smart home generally increases the energy efficiency, decreases the energy usage cost and carbon footprint which contains renewable properties, and converting the part of the resident. Different technologies are utilised for customer performance with deference to power utilisation (Zipperer et al., 2013). In earlier days, conventional prediction models are utilised for energy consumption prediction. The evolutionary deep learning model combined with GA with LSTM is used to enhance the energy consumption calculation (Almalaq et al., 2018). Deep learning models to process the massive amount of data rapidly and powerfully for numerous IoT solicitations on smart plans (Ma et al., 2019). The smart plug, smart gateway, and mobile application management platform is to analyse and improve the power consumption effectively (Lee and Yang, 2017). AI utilises methods like expert systems, artificial neural networks (ANNs), and fuzzy logic is to contribute dominant tools for a plan, model, mechanism, estimate, error diagnostics, error-tolerant mechanism and renewable energy system (Bose, 2017). The intelligence or smart home aims to minimise the power consumption of the home. To achieve this, the smart home utilises big data analytics, machine learning, and statistical methods are applied to reduce the cost and minimise energy consumption (Paredes-Valverde et al., 2019).

The prediction method comprises of four dissimilar layers, specifically data acquirement, preprocessing, estimate, and performance assessment to minimise energy consumption and fair investigation in housing constructions. The data are collected with the help of the acquisition layer. To clean and remove abnormal data, the preprocessing layers are utilised. The prediction layer utilises DELM, ANFIS, and ANN to forecast the power depletion of the building. The performance evaluation layer compares three prediction algorithms namely MAE, RMSE, and MAPE to evaluate the energy prediction results (Fayaz and Kim, 2018). The hybrid machine learning models are utilised to predict renewable energy production like wind energy, solar energy and biofuels. The power demand is predicted with the help of hybrid ML highly contributed to energy efficiency and sustainability (Mosavi et al., 2019). Home automation system integrated with IoT, big data, and ML models contributes to having a better energy efficiency. The home comports, energy-saving, safety purpose big data, HEMS-IoT, and machine learning techniques are utilised. The energy consumption is measured with the help of the J48 machine learning algorithm and the Weka API tool (Machorro-Cano et al., 2020). A novel machine learning model is utilised for the forecast of power consumption. The accuracy and act of the prediction techniques are utilised for innovative hybrid and ensemble estimate models (Mosavi et al., 2019).

Reinforcement learning is utilised for optimum power consumption for smart household appliances. The Q-learning technique is utilised to measure the energy power consumption for individual home appliances. The Q-learning household power managing system combined with ANN to reduce the consumer electricity bill (Lee et al., 2019). The IoT platform application utilises intelligent model facilities for a smart house. The IAT, IES, and IST are the three smart models to collect data and to provide help service automatically (Jo and Yoon, 2018). The embedded intelligent devices are involved with power meters and household usages to investigate the level of power consumption. The consumer electricity usage is categorised into different levels with the help of a cluster-based analysis power consumption algorithm (Ullah et al., 2020). IoT-based smart devices are integrated into smart buildings to efficiently manage energy utilisation. The WBFA, WDO, and BFO hybrid algorithms are utilised to measure energy consumption precisely (Hafeez et al., 2019). The new building design is considered to reduce $CO_2$ emission and energy consumption. This work considers machine learning-based approach includes ANN, SVM, and Gaussian-based regression and clustering generally applied for improving building energy performance (Seyedzadeh et al., 2018). Statistical modelling analysis utilises machine learning-based approaches like SVM and NN to bring out precise estimating of power utilisation. The result shows that SVM-based machine learning approaches provide better results (Yu et al., 2015). The hybrid smart household renewable power administration scheme associates solar power and power storing facilities for an intelligent home to reduce the power consumption throughout high request stages (Ma et al., 2020). Energy management is a major problem in the present city condition. The smart city utilises hybrid renewable energy like solar and wind power for a smart bus shelter to utilise the renewable for its whole infrastructure (Ashwin et al., 2020). The monkey king algorithm is used to minimise the energy consumption in a wireless sensor networks (Kalaipriyan et al., 2017). The artificial immune system is used to solve the minimum energy broadcast problem (Raghav et al., 2017). The synergic deep knowledge model is used to absorb and forecast the various metric of the arthroplasty (Muthusamy et al., 2020). Vehicle-to-grid technologies produce massive distributed renewable energy for smart homes (Zhou et al., 2016).

# 3 Methodology

## 3.1 Solar energy production for smart home

Solar energy is an alternate source of energy to be utilised for smart home electrical appliances. The solar panel absorbs the solar energy to convert it into electrical energy. The solar panels are installed on the roof of the smart homes to produce sufficient electricity for their whole infrastructure. The essential elements of solar systems are solar panels, battery, inverter and interconnecting cables. Assume that the average power consumption of the smart home is 15 units per day. One unit matches 1 kWh which is essentially the procedure of 1,000 watts in 1 hour. For example, 100 watt glows 10 hours it consumes 1,000 watts or 1 kWh.

Assume the smart home needs 15 units per day which are equal to 15 kWh. The 3 kWh rated five solar panels can produce 15 kWh energy per day. Assume that the solar panel size is 17.6 square feet. The five solar panels are installed with 88 square feet space of the smart home.

### 3.1.1 Renewable energy prediction

The National Weather Service (NWS) utilises the simulation model to predict climate prediction into sun power band calculation. The foremost basis of renewable energy is solar energy which is utilised for the smart home. The solar energy harvesting power is estimated based upon the climate conditions, the cloud coverage between 0% and 100%. The NWS publishes the climate reports of sky conditions every 24h. The power collection of solar panel $PC_s(t)$ is collected at all times $t$ has remained intended to build upon the atmosphere circumstances ($C(t)$) as follows:

$$PC_s(t) = P_{\max}.(1 - SC(t)) \tag{1}$$

where $P_{\max}$ is the complete creation energy of the solar panel. The solar power creation is projected for the next 24 hours as built upon the above equation (1).

$$EP_s(k+1) = \int_{nT}^{(n+1)T} PC_s(t)dt \tag{2}$$

where $T$ is the same for 24 h duration, $EP_s$ is the energy production of solar energy and $t = nT$.

## 3.2 Power consumption prediction

To forecast power consumption of the area exponentially biased stirring average (EBSA) was used. The EBSA gets the benefit of daytime traits of everyday consumption and familiarises them to periodic variations. The overall power consumption of a smart home is calculated as follows:

$$P_c(k+1) = \propto .P_c(k) + (1 - \propto).P_c(k) \tag{3}$$

where $P_c(k)$ specifies the number of power consumption for the $n^{\text{th}}$ day and $P_c(k+1)$ specify the probable $(k+1)^{\text{th}}$ day energy consumed. $\propto$ indicate the days before prediction error.

A different amount of power is consumed from one day to another day. So the prediction interval between lower and higher energy consumption is calculated in equations (4) and (5).

$$P_{CL}(k+1) = \propto .P_{CL}(k) + (1-\propto).P_{CL}(k) \quad (4)$$

$$P_{CH}(k+1) = \propto .P_{CH}(k) + (1-\propto).P_{CH}(k) \quad (5)$$

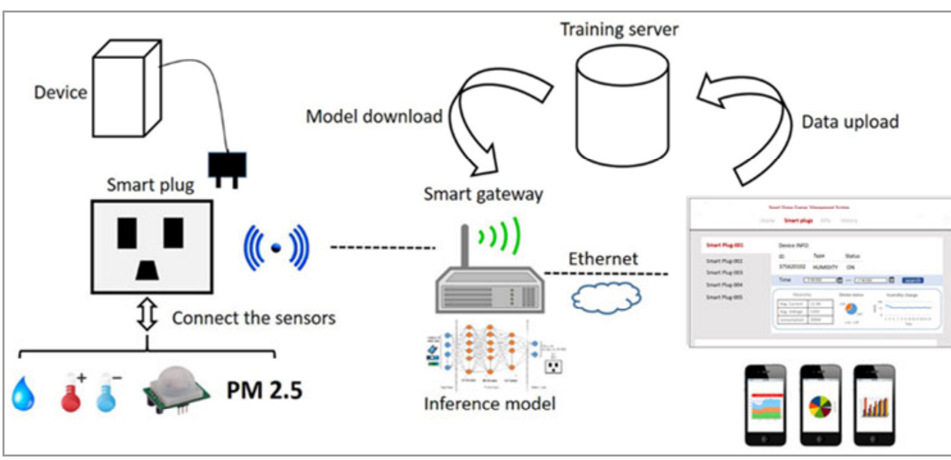
where $P_{CL}(k)$ and $P_{CH}(k)$ are the lesser and the upper power depletion on the $k^{th}$ day correspondingly.

### 3.3 Smart home power controlling system

The smart power controlling system comprises three parts: an intelligent plug, an intelligent gateway, and mobile app management platform. The smart plug is the part of the system which is used to control and monitor the electrical appliances. According to environmental changes, the power supply is switched on/off automatically. The smart plug's major components are Arduino UNO, Xbee ship, light sensor, temperature sensor, current sensor, breadboard and relay box. The smart plug is dissimilar from general ones because of its light sensor, thermal device, PM2.5 device and humidity device. The power-saving choice is measured by the intelligent gateway and the intelligent plug which equipment the power-saving choice mechanism spontaneously without human intervention.

The intelligent gateway is the responsibility for communication and data gathering. The smart gateway utilises the deep learning technique to preprocess and pre-train the data. To analyse and discover the power consumption of the smart home, the smart gateway is utilised. Finally, the intelligent gateway can take power-saving as a better decision on the intelligent plug.

**Figure 2** The overall architecture of smart home energy controlling system (see online version for colours)




The administration stage acquiring the information from the intelligent gateway and outlines the information for the customer. The administration stage accepts all information, examines the information, and improves the choice principles, which are served back to the customer. A mobile solicitation is delivered for the customer to regulate and screen information. The complete architecture of smart home power management is shown in Figure 2.

The energy administration learning scheme is divided into two categories: training and inference. The novel information reaches continuous learning and permits the factors to be retrained and restructured affording to the contested information. The gateway accepts a new perfect factor joined with a limited model for modification so that the assessment appliance is further precise. The DNN comprises one input layer, three hidden layers, and one output layer. The hidden layer H1 consists of 20 nodes, H2 consists of 20 nodes, and H3 consists of five nodes correspondingly as shown in Figure 3. The grouping model takes five input feature vectors like the current, voltage, timestamp, duration and sensor data.

**Figure 3** Smart plug deep network decision rule (see online version for colours)

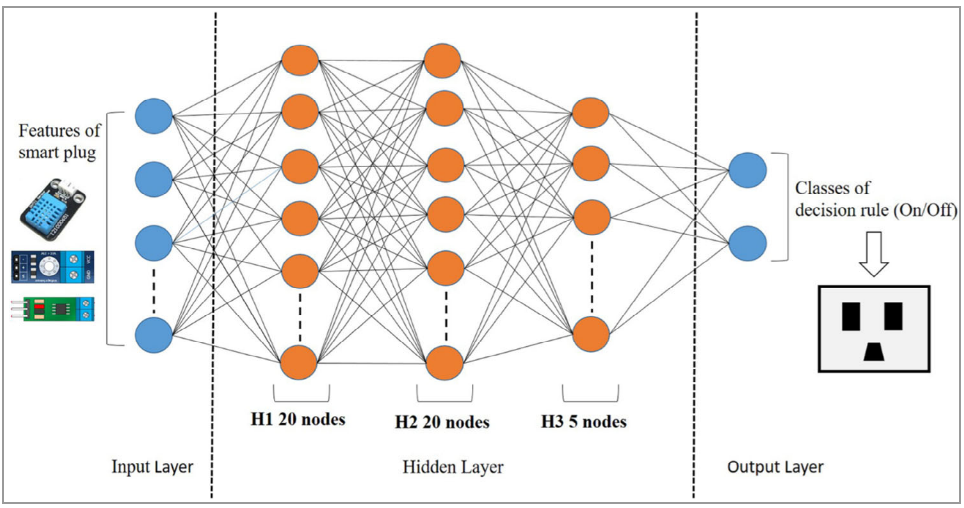
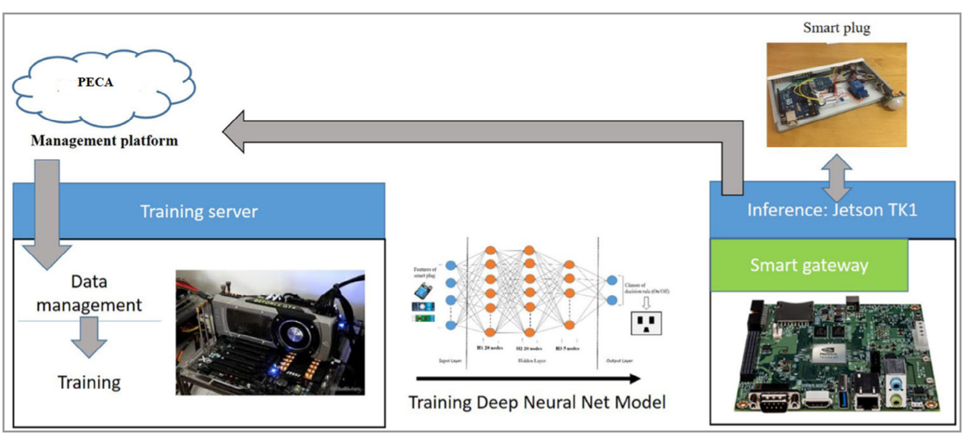



**Figure 4** The continuous learning smart home power management system (see online version for colours)



An intelligent home administration system implements the training data based on the present data and directs the expert model factor values to the gateway. The gateway takes a better decision based upon the training DNN and produces the output affording to the grouping rules. The power consumption is achieved with the help of gateway enhanced power-saving decision rules. The information received by the gateway is directed to the mobile administration platform to instrument constant learning outcomes for an additional strong pertained model. The continuous learning intelligent home power controlling system is shown in Figure 4. The smart home people can easily monitor the smart home information with the help of a mobile device.

### *3.4 Precise energy consumption algorithm*

The simple precise energy consumption algorithm (PECA) analysis is used to harvesting energy estimation and power consumption analysis of the smart home. This algorithm will support you to recognise how much energy can be kept in the battery-operated existing power, the climate projection, and probable electricity consumption for the next 24 hours. The PECA process code is showed and defined in Procedure 1. The probable power inside the battery that could be utilised on the $(k + 1)^{th}$ day is $E_s(k + 1)$. To evaluate the resulting $E_s(k + 1)$:

$$E_s(k+1) = \eta . E_s(k) \tag{6}$$

where $\eta$ is the inverter and $E_s(k)$ volume, the surplus energy kept within the battery-operated is at the jump of the lesser $k^{th}$ day time.

**Procedure 1** Precise energy consumption algorithm

| | |
|---|---|
| 1 | If $E_s(k + 1) + EP_s(k + 1) \geq P_{CH}(k + 1) + P_{CL}(k + 1)$ then |
| 2 | Usage the battery straight to building energy; |
| 3 | Else if $E_s(k + 1) + EP_s(k + 1) \geq P_{CH}(k + 1)$ then, |
| 4 | While $E_s(k + 1) + EP_s(k + 1) - P_{CH}(k + 1) > 0$ do |
| 5 | Usage the battery straight to building energy; |
| 6 | Else if $E_s(k + 1) + EP_s(k + 1) < P_{CH}(k + 1)$ then |
| 7 | While $E_s(k + 1) < P_{CH}(k + 1) - EP_s(k + 1)$ do |
| 8 | Charging the battery |

The PECA is used to minimise the energy consumption of the smart home as well as maximise renewable energy production. The produced energy is optimally utilised for all electrical appliances within the smart home.

## 4 Results and discussion

The choice of an independent solar kit mostly depends on the prediction of the consumption of home appliances. The logic of calculation is to combine the energy ratings (W) of your electrical devices and multiply by the number of hours (h) use per day (kWh/day). Then, refer to the solar output tables to determine the necessary number of solar panels. Table 1 calculates the projected total average consumption for the smart home in kWh/day.

**Figure 5** Smart home monthly energy usage (see online version for colours)

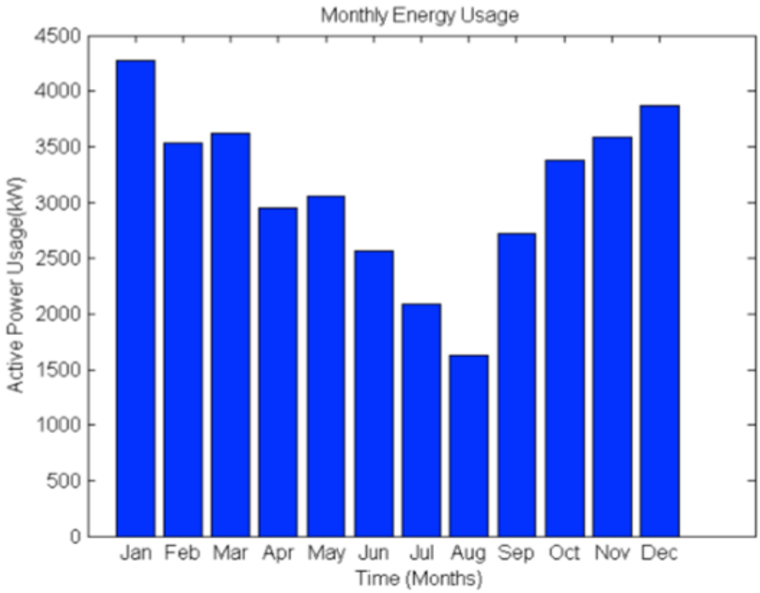



**Figure 6** Smart home average energy usage for a day of the week (see online version for colours)

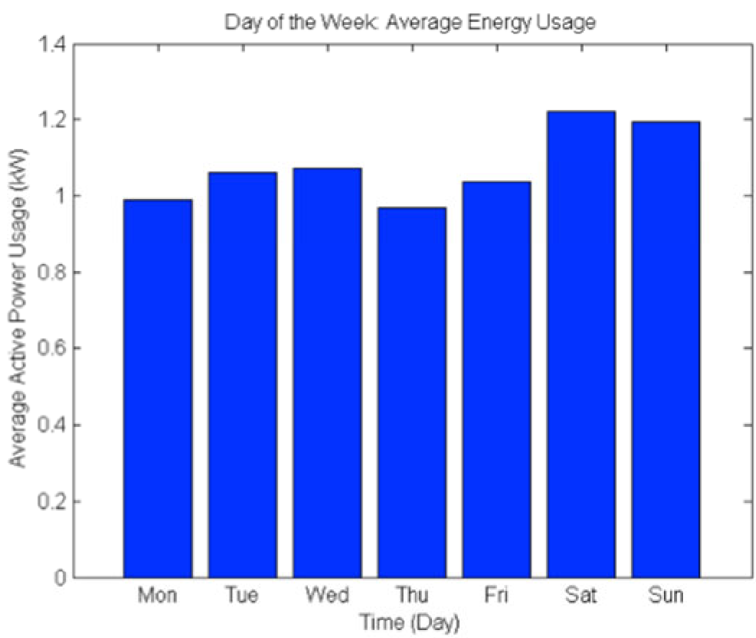


**Table 1** Total power consumption of smart home with specific appliances

| *Appliances* | *No. of items* | *Power (W)* | *Period of utilisation* | *Average frequency* | *Average annual consumption (kWh)* | *Average annual consumption (kWh)* | *Estimated average consumption (wh/day)* |
|---|---|---|---|---|---|---|---|
| Air conditioner | 1 | Up to 200 | 60 days | 5 h/day | 960 | 960 | 16,000 |
| Fridge | 1 | Up to 200 | 365 days | Continuous | 201 | 201 | 550 |
| LCD TV | 1 | Up to 250 | 335 days | 4 h/day | 241 | 241 | 720 |
| Washing machine | 1 | Up to 2,200 | 48 weeks | 4 cycles/week | 173 | 173 | 900 |
| Computer | 1 | Up to 80 | 240 days | 4 h/day | 72 | 72 | 300 |
| Iron | 1 | Up to 1,100 | 48 weeks | 5 h/week | 260 | 260 | 1,100 |
| Hair dryer | 1 | Up to 600 | 48 weeks | 30 min/jour | 11 | 11 | 300 |
| Vacuum cleaner | 1 | Up to 800 | 48 weeks | 2 h/week | 70 | 70 | 800 |
| Cooker | 1 | Up to 10,000 | 335 days | 2 h/day | 3,200 | 3,200 | 9,500 |
| Lamp (energy saving lamp) | 8 | Up to 25 | 335 days | 5 h/day | 34 | 272 | 800 |
| Electric oven | 1 | Up to 2,500 | 48 weeks | 1.5 h/semaine | 162 | 162 | 2,500 |
| Microwave | 1 | Up to 1,500 | 48 weeks | 1.5 h/semaine | 90 | 90 | 750 |
| | | | | | Total in wh/day | | 34,220 |

**Figure 7** Change of energy usage per hour (see online version for colours)

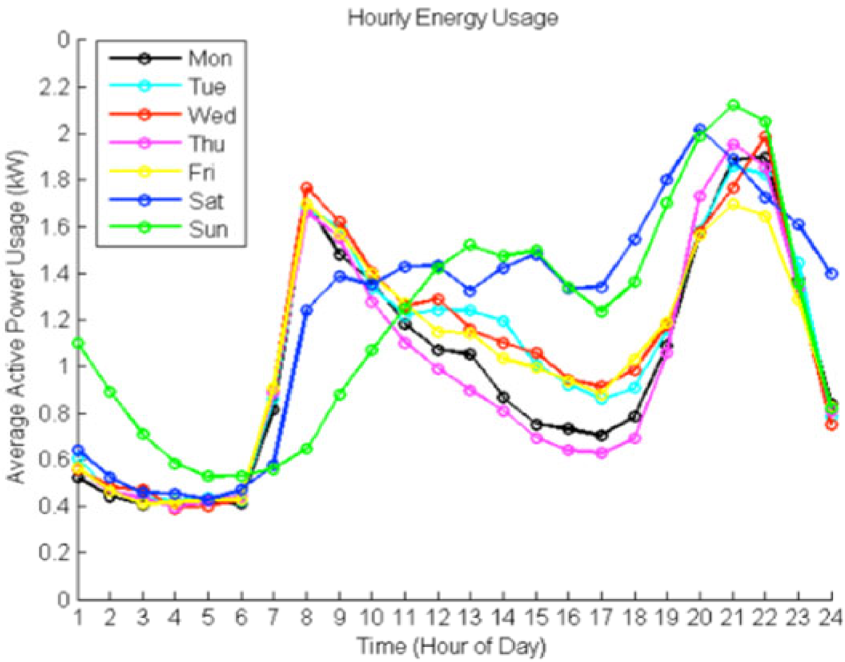
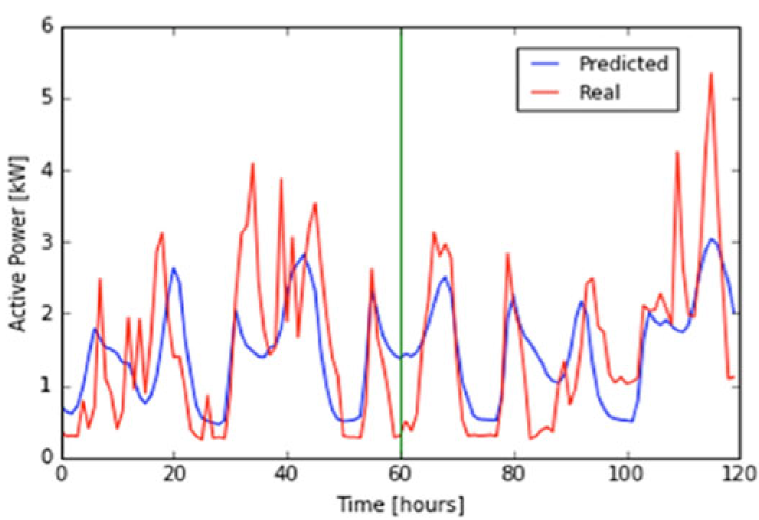



**Figure 8** Precision energy consumption prediction vs. real (manual) consumption (see online version for colours)




As per the experiment analysis, solar energy production per day is 15,000 W. So, the annual renewable energy production for smart home is 15,000 × 365 = 5,475,000 W (i.e., 5,475 kW). As per the utilisation of home appliances total energy consumption is

34,220 W. So, renewable provides sufficient energy for all the appliances of the smart home. The excess energy is moved to smart grid.

The monthly energy usage for smart home precision energy consumption is shown in Figure 5. Generally, the first and last three-month usage is more compared to all other months. The smart power utilisation for a day of the week is shown in Figure 6.

Figure 7 shows the day-wise change of energy usage per hour prediction. Figure 8 shows the precision energy consumption prediction versus real (manual) energy consumption is compared. The result shows the precision energy consumption gives accurate results compared to real consumption.

## 5 Conclusions

The precision of the energy consumption for smart homes using renewable power managing system was proposed. This mechanism is to minimise cost and maximise renewable energy usage. The proposed model reduces the power consumption by 50% and makes the most of the renewable power consumed at the level of 60% of the complete power generated. The proposed PECA algorithm decreases the complication and controls the smart home power consumption. This is not only minimising the electricity bill but also moving the extra energy to the power grid. In all aspects, the proposed model has high performance compared to the existing model. In the future, this work will be implemented everywhere else.

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