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EMBODIED ENERGY ASSESSMENT OF CONSTRUCTION MATERIAL IN INDIA USING ARTIFICIAL NEURAL NETWORK

Abhilash Mukherjee[a], Himmi Gupta[b], Mr. Jit Kumar Gupta[c]

[a] *ME Scholar, Civil Engineering, National Institute of Technical Teachers Training & Research*
[b] *Assistant Professor, Civil Engineering, NITTTR,Chandigarh*
[c] *Chairman,IGBC,Chapter-Chandigarh*

Abstract: ***The increase in demand for urban areas resulted in an unprecedented increase in production as well as consumption of construction materials in the building sector. The production of materials requires considerable energy and contributes to pollution and greenhouse gas emissions. Efforts to minimize energy consumption and pollution-related to the construction materials is done by measuring the embodied energy produced by those materials. Embodied energy is evaluated by measuring the total energy required by the raw material up to the transportation process. This article deals with the embodied energy of common building materials used in India's construction industry. The construction material with their embodied energy is provided as an input data to the neural network. On the basis of which, ANN trained the system to suggest an appropriate material that release less embodied energy to the environment. The performance in terms of accuracy, mean square error and embodied energy are determined. From the experiment, it is observed that the average accuracy of the designed embodied energy tool is 98.52 %.***

Keywords: Embodied energy, ANN, Green materials

I. Introduction

Building industry is one of the most energy-consuming industries and the implementation of green building is a useful way to promote sustainable human development. The development of constructing green building is started early in foreign, and the process of green building evaluation goes through mainly three steps; (i) evaluation , presentation and demonstration of the constructing project (ii) the impact of constructing project on environment is evaluated (ii) the overall performance of the construction project is measured and validated [1]. The architecture of the green building, which has environmental, health, social and economic aspects, is traditionally different. For an example, to overcome the challenges facing during the development of construction project and the environment, there is a need to eliminate the concept of simple development and sustainable use of natural resources for efficient economy[2]. An engineer must discuss sustainable use of natural resources as a long-term asset, and look at other factors to analyze the economic value of the environment as well as the benefits of the projects. While constructing a green building, an engineer needs to concentrate on different factors. Therefore, evaluation of the green building is a difficult and complicated task. This research will build a clear and sophisticated multi-dimensional green building assessment index system, focusing on the combination of life cycle assessment methods (LCA) and ANN, to provide a number of references to the sustainable development of India's construction industry[3].

1.1 Life Cycle Assessment

"LCA is an essential method for evaluating the overall environmental effect of goods, processes /services. It is the main tool used to determine the impacts of products or the services offers by the product on the environment or normal lifecycle.

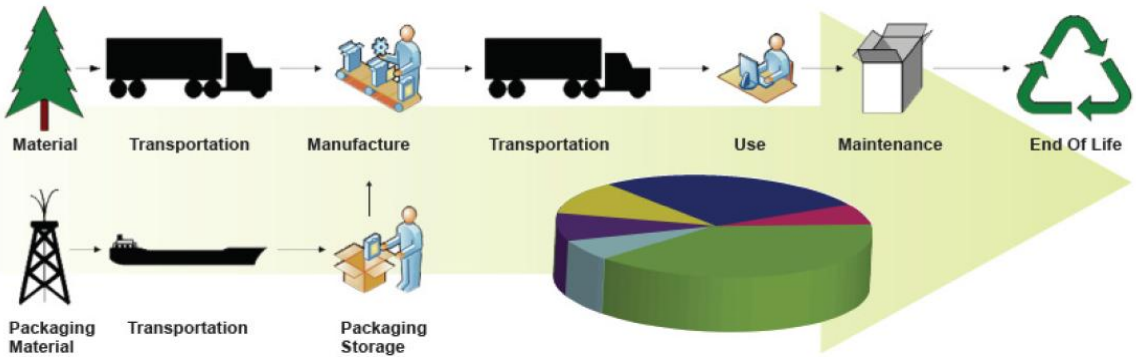

Figure 1: Life cycle assessment [3]

The carbon footprint of product should consider the following:

- Delivery and extraction of raw materials
- The usage, delivery with the maintenance of product for lifespan
- Wastage, developed energy, emissions
- Content being re-cycled
- Product's final disposal route

Emissions of energy and pollutants like CO2 (carbon dioxide) can be seen as embodied inside the material during the entire LCA [4]. Therefore, the built-in power can be seen as deal with the amount of energy needed and provide it to the construction site. The embodied energy may be defined as the amount of energy needed to process and supply to the construction project. To know the quantity of the embodied energy, a methods is required, which integrates the energy input to the main part of the material supply chain. Presently, it is considered to combine to extract raw material, process and transport that material to the constriction project. The effect of releasing pollutant energy (CO2) that is the main cause of the global warming might be seen in the entire life cycle [5]. The concept of embodied energy is explained below.

1.2 Embodied energy

The concept of 'embodied energy' was primarily used for various purposes in 1970s, and to analyze total consumed energy, the energy inputted to the system through different paths is analyzed. But, there is a trade-off between process and embodied energy is observed during the entire LCA process, which can be shown in graphically in figure 2.

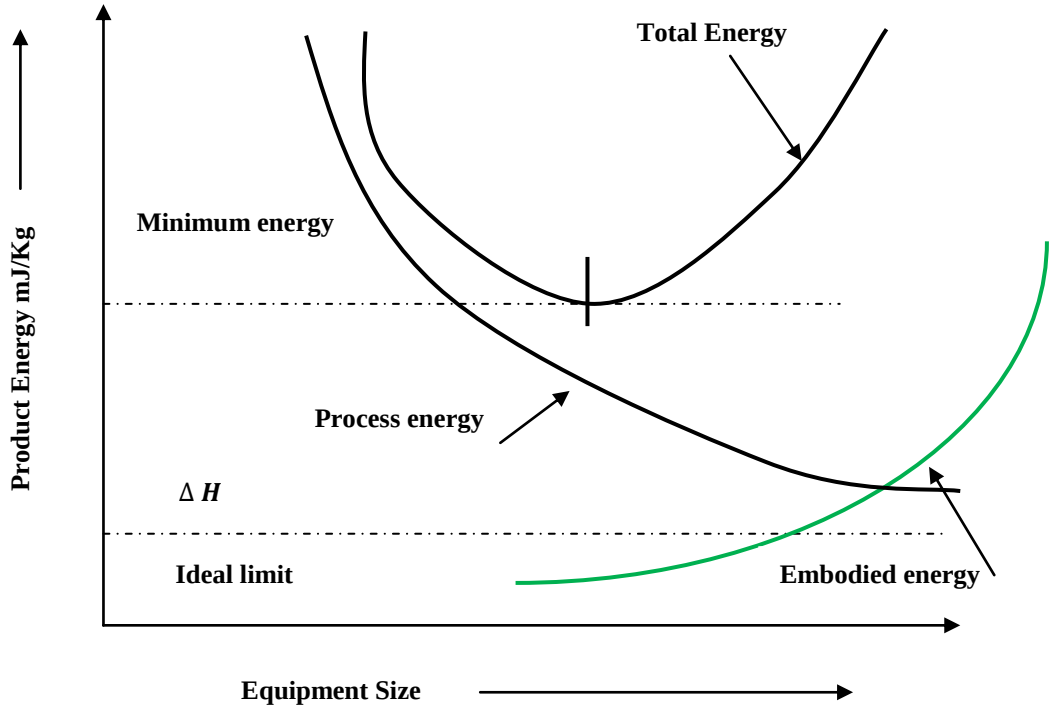

Figure 2: Product (process and embodied) energy requirements related with process equipment [6]

From the above figure it is clear that the minimum energy required during the construction project is somewhat higher compared to the thermodynamic minimum. Or the embodied energy is seen as an combination of the overall energy required for the construction and the energy need by the equipment. Therefore embodied energy has same importance as that of construction material. Embodied energy is defined by different researchers, who provide different nuance to this term. The author Koskela and L.[7] has defined embodied energy as it is the total energy consumed by the material used during the construction.

Gonzalez and Navarro [8] declare that construction materials with high embodied energy emit high Co_2 compared to the martial with less embodied energy.

Treloar et al. [9] stated that embodied energy is the energy needed to give a product either directly or indirectly during all processes such as from the raw material to the finished product.

II. Low carbon material

The civil engineers must pay attention on the building materials, energy used during the construction project and the available natural resources. Also, the impact of used materials on the environment has been taken into consideration.

2.1 Raw materials CO2

Co_2 Emission from any process industry is divided into two groups: first one is the carbon compound obtained from the raw material comprises of carbon dioxide. Other one is the carbon produced during the combustion of fissile fuel. The prediction of evaluating Co_2 of the latter one is more complicated as compared to the former one. The carbon emission in construction project comprises of direct as well as indirect carbon emission. To measure the carbon emitted by the raw material and the constructing material are the two main factors to measure carbon emission [10].

2.2 Cement and concrete

The effect of building made up by concrete on the environment is basically due to clinker, the main material utilized to produce cement. It emits less than 1 ton of Co_2 per unit tons of clinker created. Reduction of clinker content replaced by complementary cementing materials (CCM) decrease Co_2 emissions [11].

2.3 Wood

Buchanan and Levine [51] demonstrated that wooden structures require less processing energy and less carbon emissions than bricks, aluminum, steel and concrete. It can be possible by constructing building using the wood because the lower fossil fuel demand compared with other materials and also have longer life. It has been observed that the building manufactured in Newzeland using wood as a construction material decrease 20 % of the carbon emission compared to brick and aluminum material.

2.4 Bricks

Brick is the highest energy releasing material. Bricks are made of clay and come in a variety of shapes to provide the building with high strength. This is the most commonly used construction material to build homes and organization in India [12]. The list of embodied energy released by construction material is shown in table below:

Table 1: Embodied energy for common building materials

Material	PER Embodied energy mj/Kg
General Aluminium Cast Products	155 159
Extruded	154
Mortar (1:3 cement:sand mix)	1.33
Mortar (1:4)	1.11
Mortar (1:5)	0.97
General Plaster	1.8
Plasterboard	6.75
General Concrete	0.75
20/25 Mpa	0.74
25/30 Mpa	0.78
28/35 Mpa	0.82
32/40 Mpa	0.88
40/50 Mpa	1
Primary Glass	15
Secondary Glass	11.5
Fiberglass	28
Toughened Glass	23.5
PVC	67.5
General Steel	20.1
Bar & rod	17.4
Coil (Sheet)	18.8
Coil (Sheet) - Galvanised	22.6
General Steel	20.1
Bar & rod	17.4
Coil (Sheet)	18.8
Coil (Sheet) - Galvanised	22.6
General Steel	20.1
Bar & rod	17.4

Coil (Sheet)	18.8
Coil (Sheet) - Galvanised	22.6
General	10
Glue Laminated timber	12
Hardboard (High Density Fiberboard)	16
Laminated Veneer Lumber	9.5
Medium Density Fiberboard (MDF)	11
Orienter Strand Board (OSB)	15
Particle Board	14.5
Plywood	15
General Clay Bricks	3
EXAMPLE: Single Brick	6.9 MJ per brick
Limestone Bricks	0.85

III. Related work

In the year 2002, **Alcorn er al.,[13]** has used three techniques such as statistical analysis, input/ output and process analysis to reduce the embodied energy in New Zealand construction industry. **Thormark and C.[14]** has worked in the apartment constructed in Sweden to determine the embodied energy. It has been observed that using recycling process 35 % of embodied energy has been reduced. **Gustavsson et al. [15]** Studied and compare the emission of CO2 from the building that uses concrete material and wood material. It has been observed that the building made up from wood material release small energy and also emit small carbon dioxide to the environment as compared to the concrete made building. In the same field**, Buratti et al. [16,]** in 2014 determine the embodied energy of a residential building using neural network as a classification technique by considering regression and mean square error. **Kumar et al. [17]** Presented ANN (Artificial neural network) to explore the total heat and carbon emission of 6 -storey building. The energy performance of a building is affected by a lot of factors, like the surrounding weather conditions, the structure and characteristics of the building, the operation of the lighting, HVAC system and other secondary components, occupancy along with their behavior.

IV. Technique used

In this research, ANN is used to classify the material that can release minimum embodied energy. For an example, timber frame can be used instead of heavyweight construction as it release less embodied energy. The general architecture of ANN is shown below.

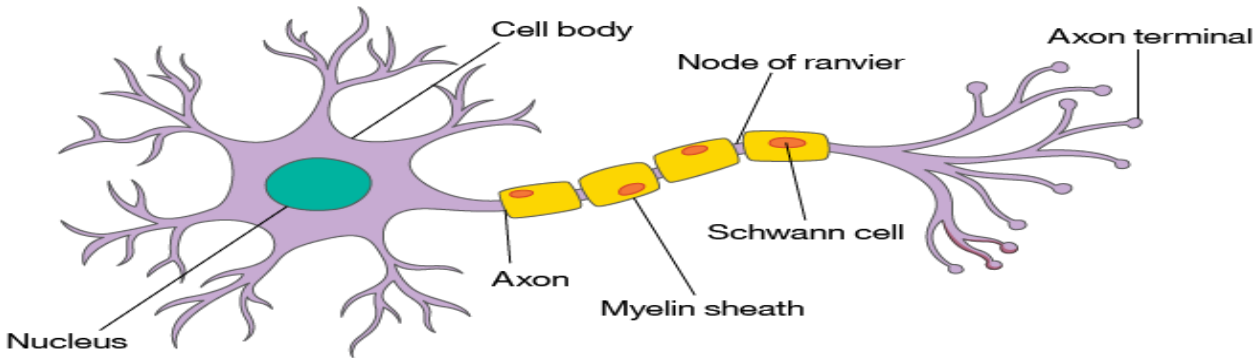

Figure 3: Biological structure [18]

Neural network is a mathematical model that allows the simulation of biological neurons network behavior. The important characteristics of ANN are that it is not programmed but works on the basis of training data.
Generally, ANN comprises of four components named as:

- Neurons
- Topology
- Weights
- Learning algorithm

In ANN, the initial stage and weights are allocated randomly, whereas, in human brain, the connection among neurons do not started randomly. The center of the cell is known as nucleolus that carries the information through the Axon.

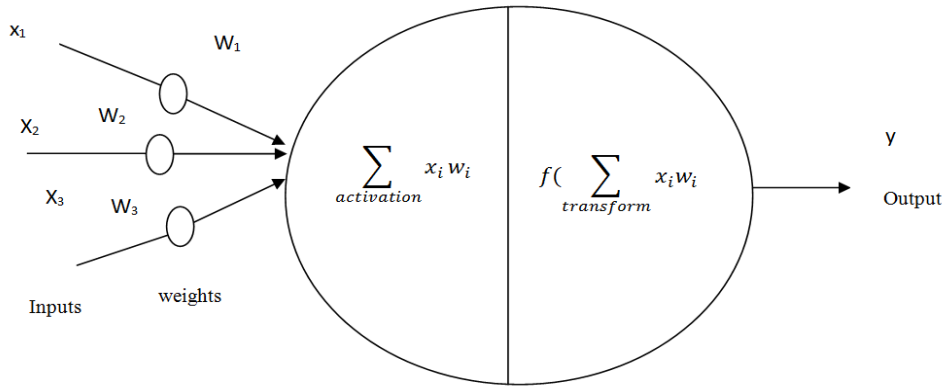

Figure 4 represents the mathematical model of ANN structure. The models comprises of three inputs, each input independently multiplied with weight and added. The output obtained is passed through the transformation function. Here, the value is compared with the threshold value. If there is any difference obtained then that value is known as error value which is passed to the neurons present in the hidden layer. The error value adjusts the value of neurons in such a manner so that the difference at the output layer is minimized. In this way, ANN trained the system as per the desired goal [18].

V. Methodology

The methodology can be explained with the following flow diagram
Step 1: Initially data is gathered from construction sites.
Step 2: Artificial neural network is used to train the system according to the size/ material/ number of building components.
Step 3: ANN is used to classify the total embedded carbon and predict lesser embedded carbon material for the same use.
Step 4: Determine the performance metrics in order to show the efficiency of the proposed work.

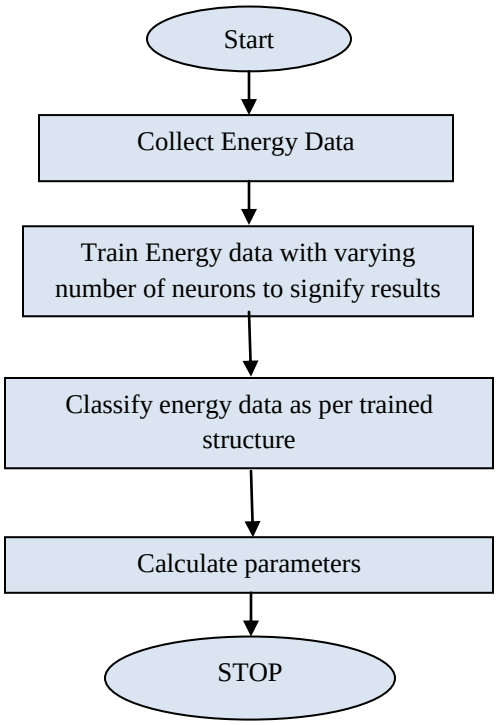

Figure 5: Flowchart of proposed work

VI. Experiment Results

The experiments are performed on MATLAB tool with ANN as a classification algorithm. The screenshots with the detail description are provided below:

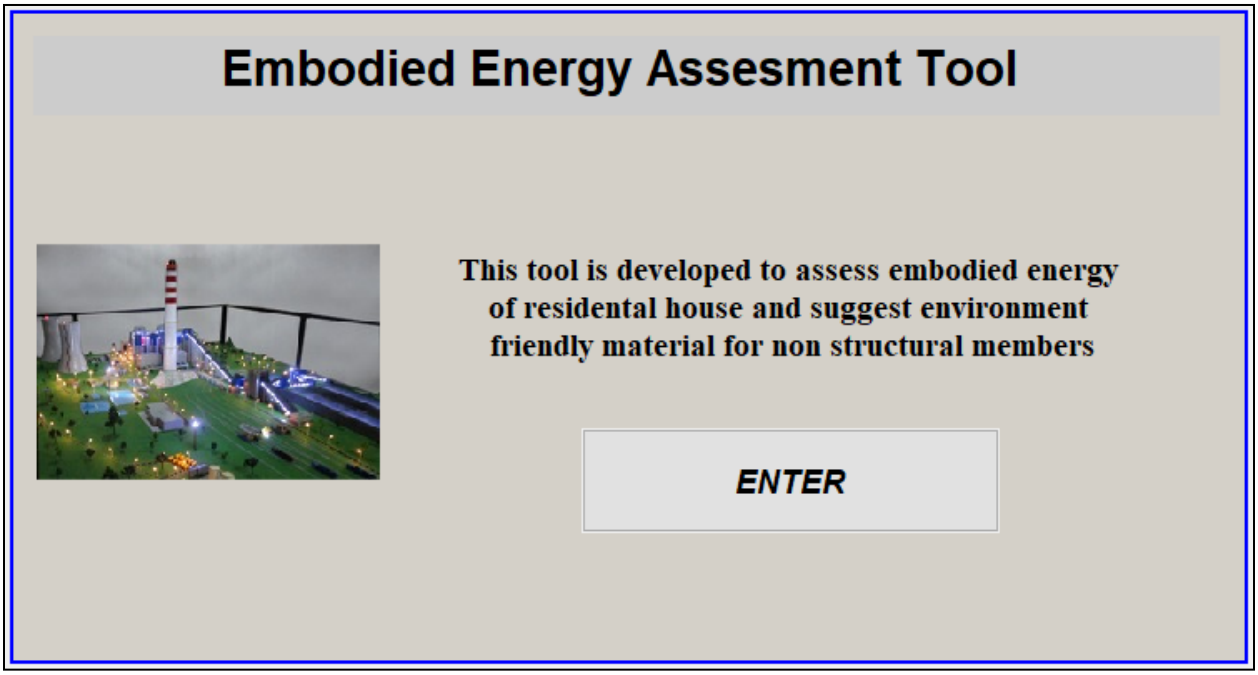

Figure 6: Embodied energy assessment tool

The research is done to construct a building and suggest environment friendly material to civil engineer by utilizing artificial intelligence technique. After clicking on enter button, following window appears on the screen.

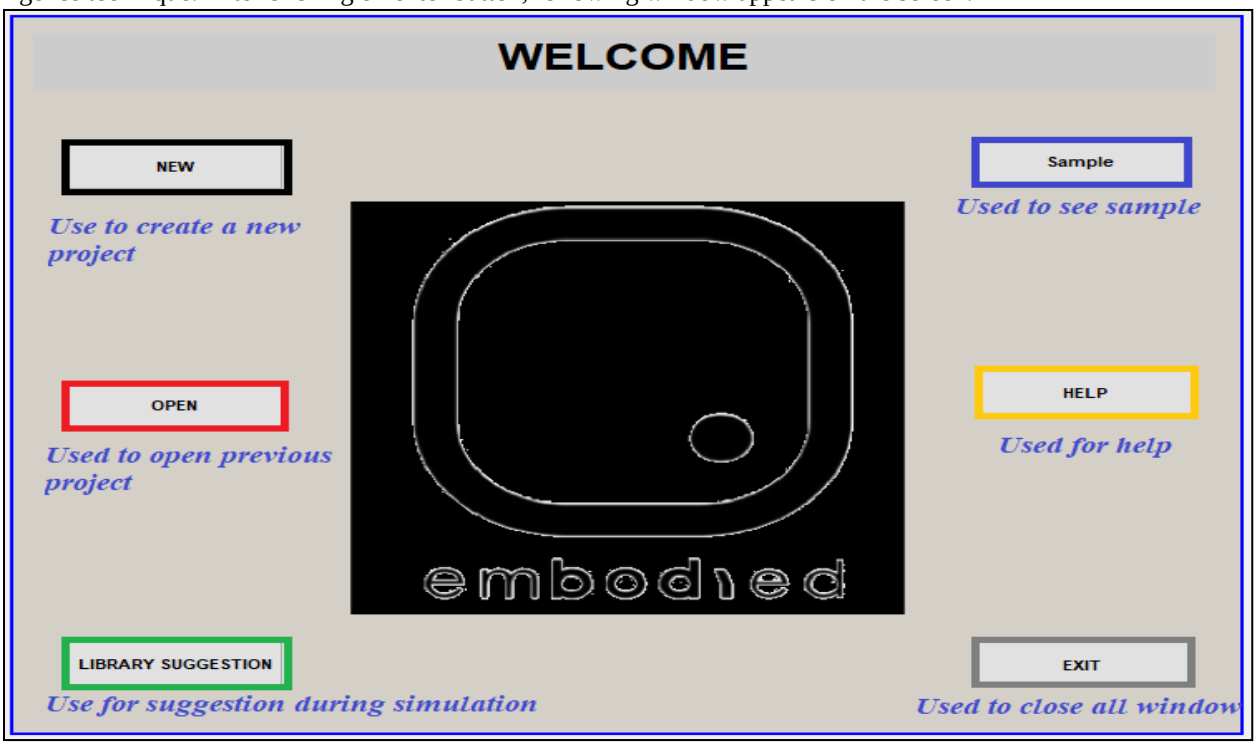

Figure 7: Welcome window

Figure 7, represents the welcome window of the proposed Embodied energy research. The window comprises of various buttons namely (1) new (ii) open (iii) Library suggestion (iv) sample (v) help and (vi) exit. New button is designed to create new project. Open button is used to open previous project. Library suggestion icon is utilized suggest during simulation. Sample sub panel is designed to see sample. Help and exit buttons are used to take assistance related to the project and to close the welcome window respectively. The description of each button with example is provided below.

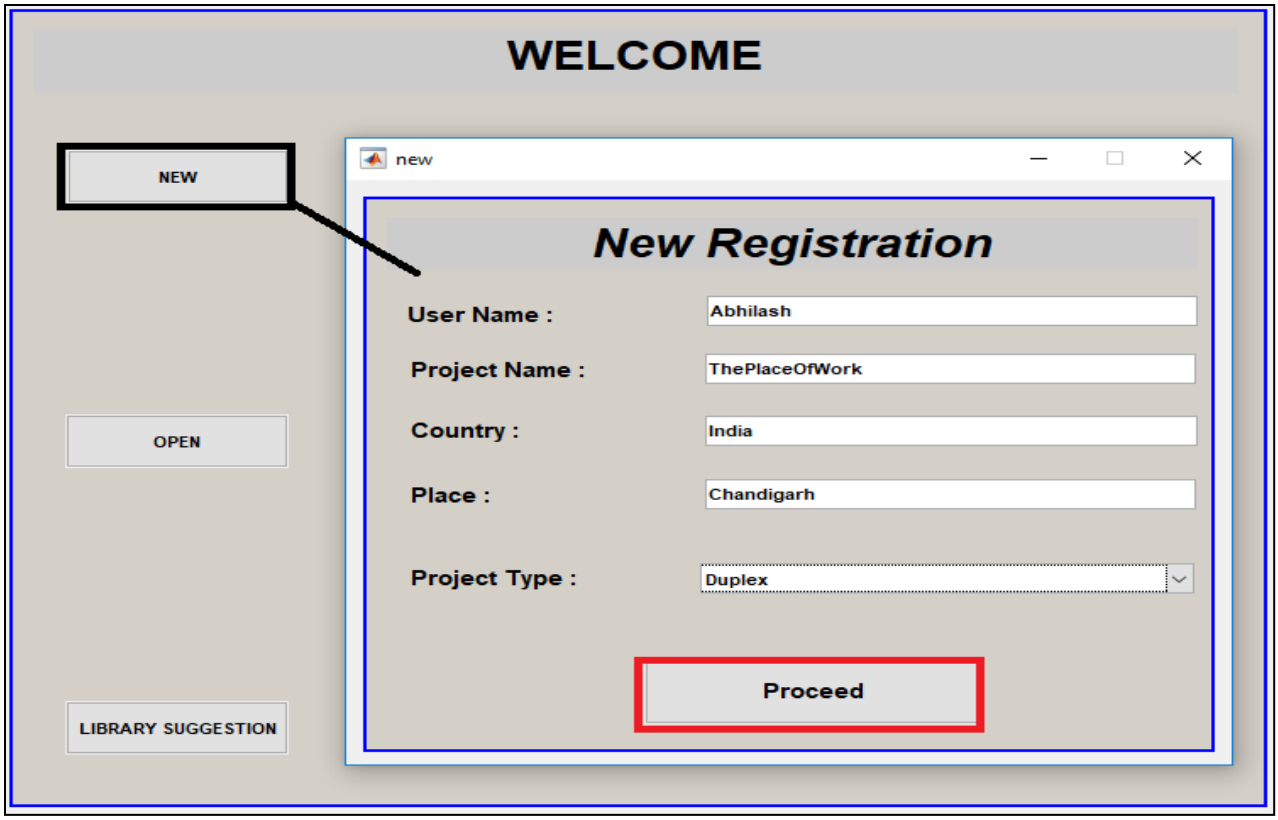

Figure 8: New registration

Figure 8, shows the window appear after clicking on the new button. After obtaining new window, user fills the details related to the project like user name, project name, country, and place and project type as shown in figure 8. After clicking on proceed button following window appear on the screen.

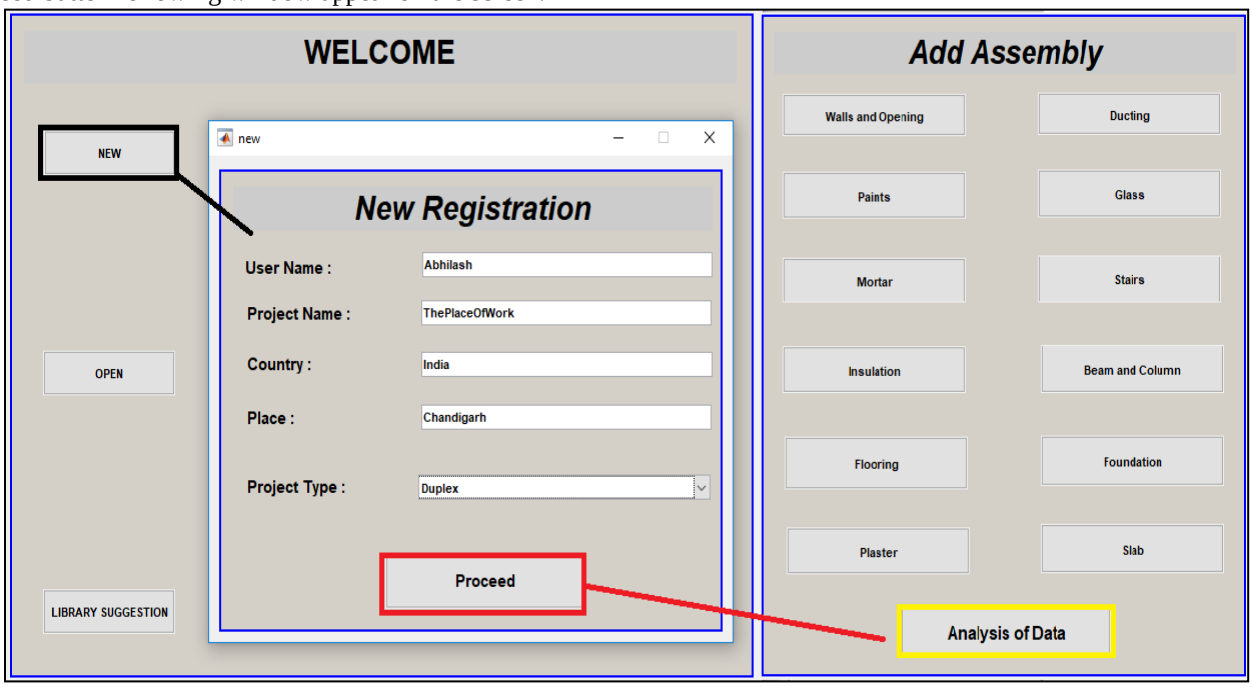

Figure 9: Add Assembly

After registration of the project, we have to enter the assembly details that are necessary for the completion of a project. The things that we are considered in our project are: (i) walls and opening; (ii) Ducting; (iii) Paints (iv) glass (v) Mortar (vi) Stairs (v) insulation (vi) beam and column (vii) Flooring (viii) foundation (ix) plaster and (x) slab. When we, click on walls and opening button, following window appears on the screen.

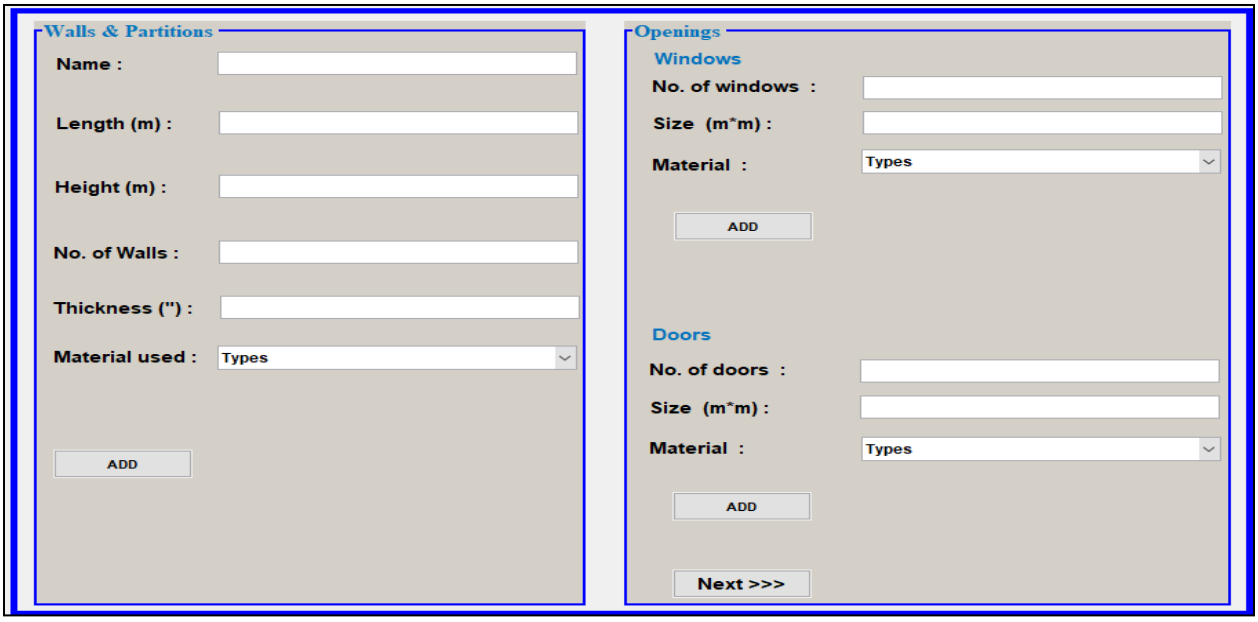

Figure 10: Walls and opening

Walls and opening widow comprises of two panels namely: walls & partitions and opening respectively. In walls & partitioning panel, the detail about name of the wall, length, height, number of walls, thickness and material used are added by an engineer. Opening panel again subdivided into two sub panels namely windows and doors. The detail of windows like number of windows used in the project, size and material are added under the window panel. In the similar way, the detail of doors such as number of doors used along with size and material are add by clicking on the add button. Similar process has been performed for paints, mortar, insulation, flooring, plaster, ducting, glass, stairs, beam and column, foundation and slab. The system is trained by using neural network, the structure of ANN is displayed as follows.

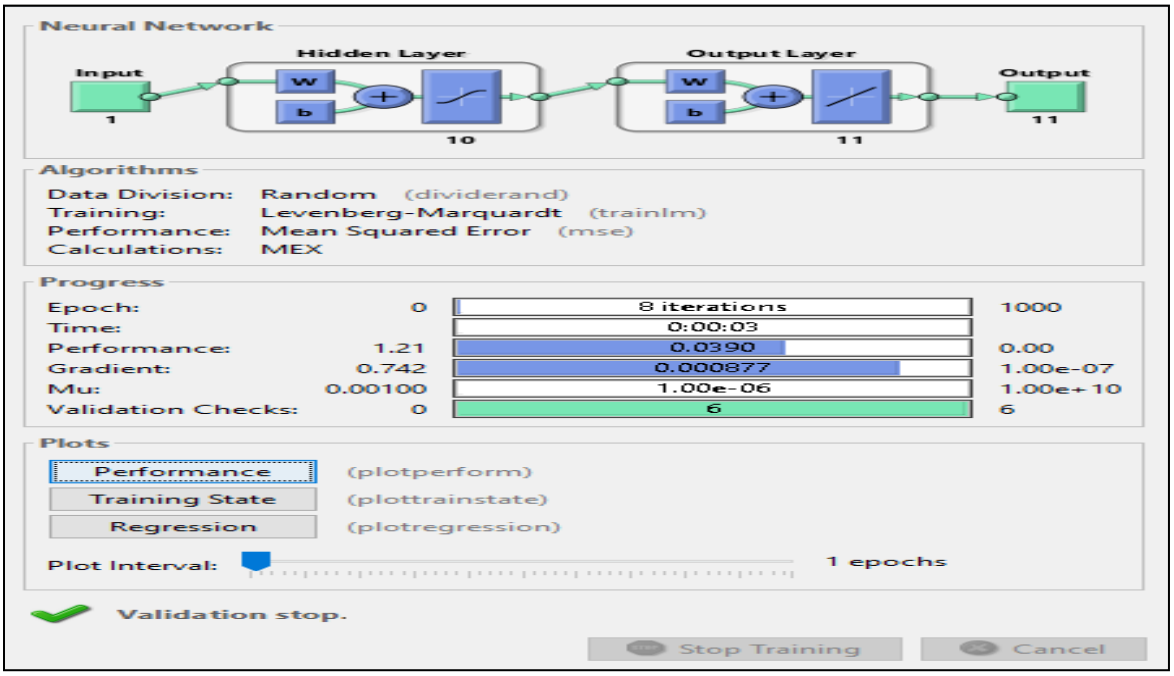

Figure 11: ANN model

ANN encompasses three layers, input, hidden and output layer. Embodied energy of the material used in the proposed work is provided as an input to the input layer. In the hidden layer, the materials are compared with each others for an example if we are using wood as a building material to make window, then the material of woods such as timber, plywood etc are compared to select the best one that is the material that release less embodied energy to the environment.

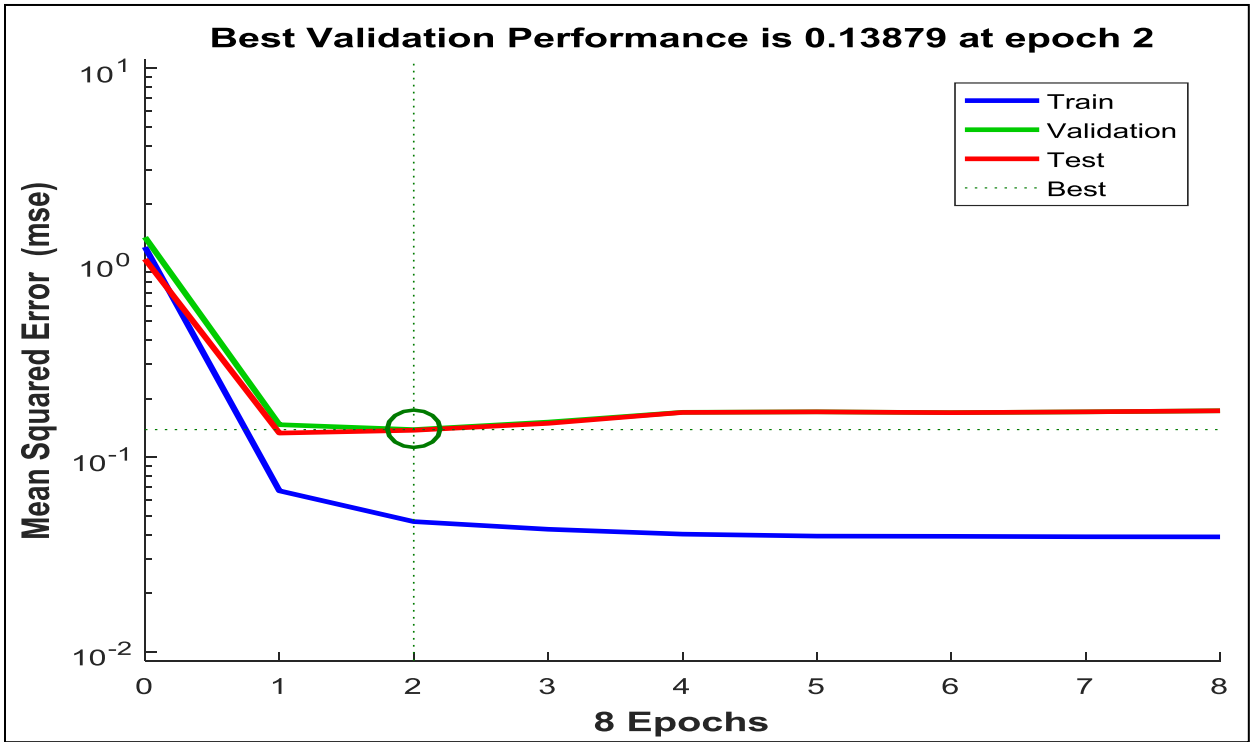

Figure 12: Mean square error (MSE)

Figure 12 depicts the graph obtained after the training process. The MSE graph with respect to number of iteration is shown in figure 12. From the graph, It is observed that there are four lines represented by the blue, the green, the red and the dotted line that represents the train data, validation, test and best data respectively. From the figure it is clear that the MSE is less than 0 and is obtained at second iteration.

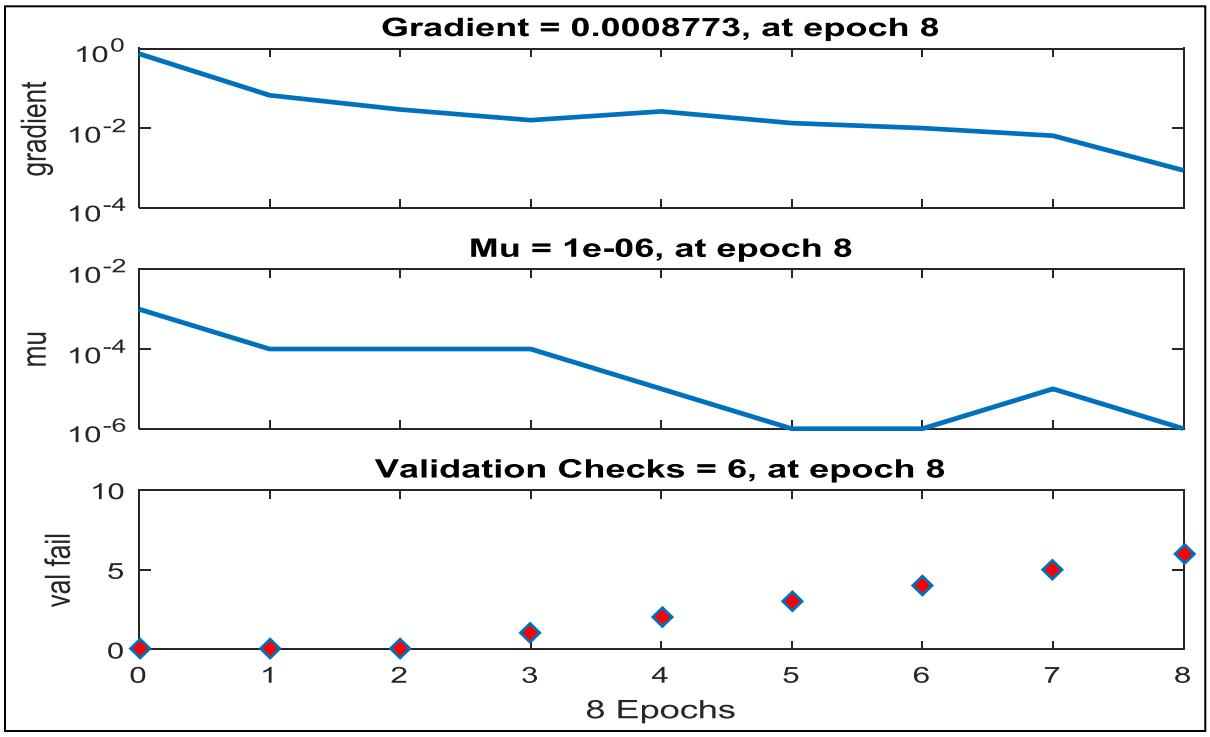

Figure 13: validation fail, mutation and gradient (ANN)

Figure 13 comprises of three graphs namely validation failure value, mutation and gradient that have been analyzed with respect to the number of epochs. From the above graph, it is clear that to train the system the validation has been performed maximum of 6 validations. Mutation is the process, to adjust the value in such a manner so that the target can be achieved. Here the mutation value up to $1e^{-06}$ has been added to achieve the target. Gradient is the total of all the materials used in the project.

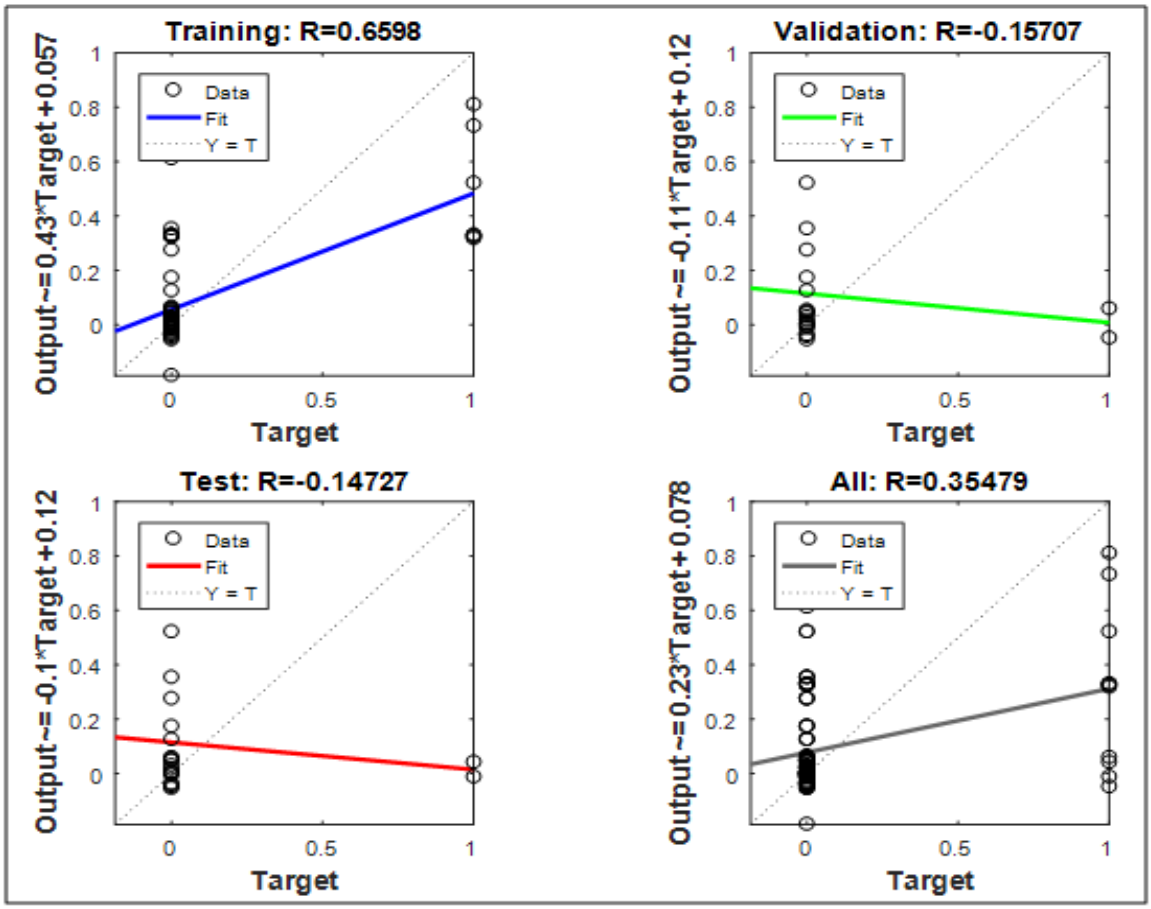

Figure 14: Reression

When we click on regression button in neural network training, figure 14 is displayed on the screen. The above figure provides the information related to the dataset used for training the neural network. There are total four graph first for trainig data, second for validation, third for test data that are automatically taken from the training dataset and last for ouput of training. In the graph two lines are present first is solid line and second is doted line which represents the accuacy of training. The three plots stand for the training, validation, and testing data. The dashed line in every plot represent the perfect result – outputs = targets. The solid line shows the finest fit linear decay line between outputs and targets. The R value is a sign of the bond between the outputs and targets. The computation parameters are measured to determine the efficiency of the proposed work. These parameters are measured for three construction projects as defined in table 2.

Table 2: Computation parameters

Number of projects	Estimation Accuracy	Embodied energy	Estimation error
Project 1	99.14	15485695878TJ	0.858
Project 2	98.56	24256869548TJ	0.857
Project 3	97.86	38256589548TJ	0.849

In this research, we have considered three number of construction projects. Project 1 consists of single storey building with three rooms and five windows, Project 2, duplex is designed that comprises of six room and 9 numbers of windows. Project 3 is designed for multi-storey building that comprises of three floors each incorporated with three numbers of rooms and having total 12 numbers of windows and 15 numbers of doors. While designed these three projects the accuracy of the designed automatic system for project 1, project 2 and project 3 are 99.14, 98.56 and 97.86 respectively. The accuracy of the designed system demonstrated that the artificial neural network suggest material while designing single storey, double storey and multi-storey building with less embodied energy.

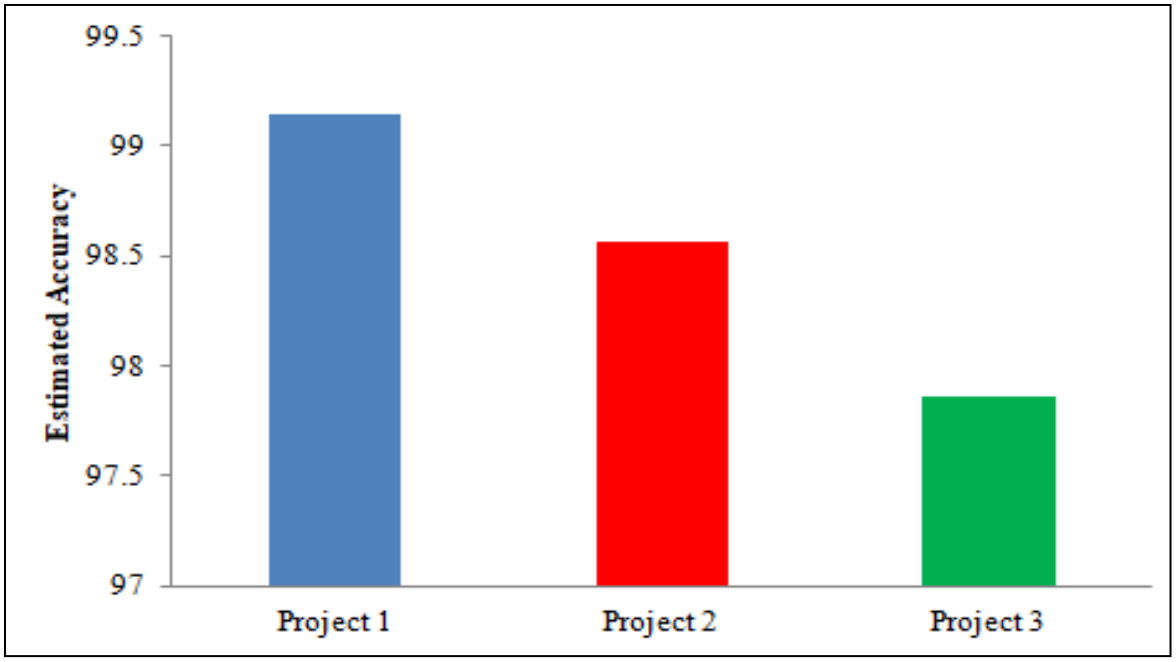

Figure 15: Estimated accuracy

The estimated accuracy determined for the designed project is shown in figure 15. X-axis and y-axis represents the measured estimated accuracy and number of projects respectively. Project 1, project 2 and project 3 are represented by the blue, the red and the green bar respectively. The average accuracy determined for the project is 98.52 % respectively.

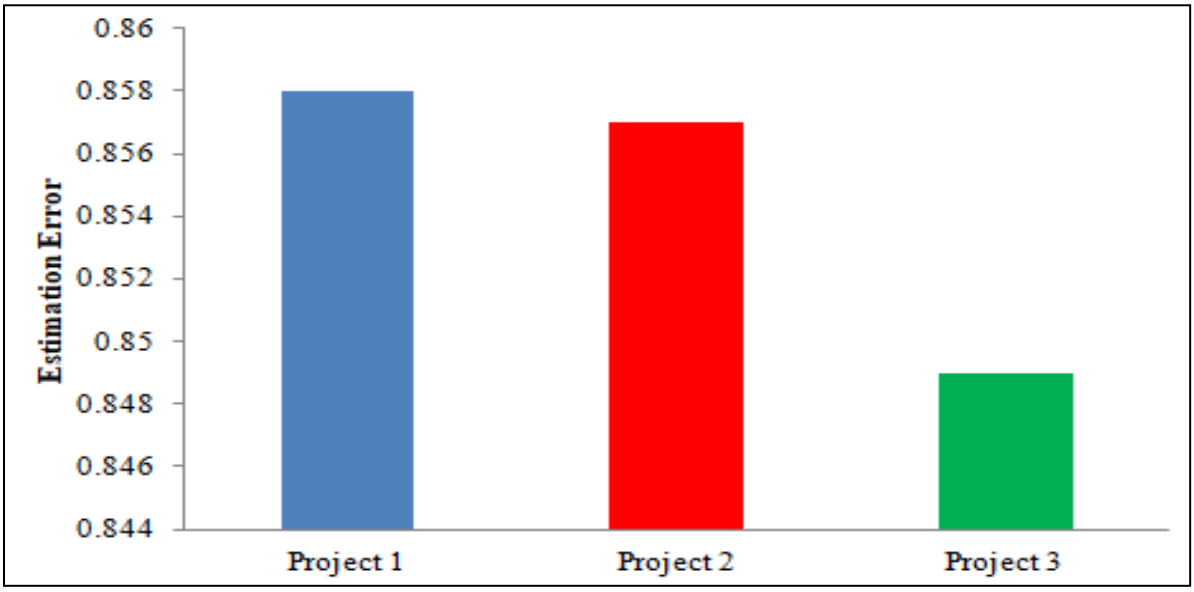

Figure 16: Estimation Error

The estimation error is measured the difference between the desired target and the achieved target after the simulation of the proposed work. From the above figure, it is observed that the error value is very small, which means that the designed embodied energy construction tool performs well and suggest the material with high accuracy.

VII. Conclusion

An embodied energy tool has been designed by using the concept of artificial intelligence technique. This document speaks about the construction material life cycle perspective with the embodied energy and identifies best material with the help of neural network that release less embodied energy to the environment. The energy has been calculated on the basis of embodied carbon and the construction material weights. Neural network compared the embodied energy of all the materials fall under the main category like wood, cement, plastic etc. and the material that release less energy will be suggested by the

neural network. From the experiment performed by considering different construction material to designed single, double and multi storey building it has been determined that the suggested best material by using neural network up to 98.52 % with an estimation error up to 0.854 has been achieved.

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