



Development of a model for energy management in office buildings by neural networks (case study: Bandar Abbas)

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Abstract

Building optimization measures are implemented to reduce energy consumption and environmental pollution. If energy reduction and optimization in the buildings are not measured, the national economy will be severely damaged. The energy consumption in buildings can be reduced by up to 50% by performing optimization measures in the building sector and applying Article 19 of National Building Regulations. In this study, the effective parameters on energy optimization were identified using questionnaires and expert opinions and then, the energy consumption and carbon dioxide were calculated by entering the parameters into DesignBuilder software. The parameters included types of wall and ceiling, area of windows, type of windows, and insulation of wall and ceiling, each of which contain different modes. In order to limit the problem space, a range of parameters changes in a specified interval was selected. Since it is impossible to model all probable modes, first a finite number of models was tested using the software and then, the interaction of inputs with two important outputs (energy and carbon dioxide) was obtained by training two separate neural networks. The network training facilitates the calculation of the amount of energy and carbon dioxide needed for any desired input needless of DesignBuilder software.

Keywords Building · Optimization · Energy · Carbon dioxide · DesignBuilder software · Neural network

Introduction

Modifying the method and amount of energy consumption in buildings and the tendency toward optimum consumption is related to a variety of issues such as design factors including design of buildings and facilities related to energy production and consumption (Susorova et al. 2013). Technical and economic inefficiency of energy consumption and loss are responsible for approximately one-third of the whole energy consumed in the processes of consumption and environmental problems (Tabares Velasco and Srebric 2012; Mazo et al. 2012). This highlights the need for energy management and increase in energy efficiency more than before (Ebrahimpour and Karimi Vahed 2016).

Nasari and Mehrgani (2017) by examining the effect of a building's physical properties on energy consumption considered several factors affecting energy consumption including plan dimensions (length to width), window area, transparency of walls to the dark surface, and building orientation to geographical directions. The results showed that the rectangle proportionality with 1:1 ratio (length to width) had the minimum energy loss and the optimum percentage of transparency of walls in the rectangle sample was 34.5 with optimum direction of 8 degrees to the east. Also, after selecting the building dimensions, they could reduce energy loss by calculating the optimum window area and determining the proper direction. In a study, Khoda Karami and Parisa (2016) presented simple and practical solutions to reduce energy consumption and create comfortable conditions for employees in a high 15-story office building in Tehran. The results of simulation showed that by proper planning for energy consumption and management in smart office buildings, energy consumption can be reduced by over 35% to 40% annually, with the most savings in the cooling and lighting sectors and increased natural ventilation and building shading arrangements (Khoda Karami and Parisa 2016). In a study at a university building in Tabriz, Ebrahimpour and

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Karimi Vahed (2016) showed that the factors such as application of brighter colors in the building, reduced number of windows in the building, proper time management of the classes, use of inverse low-emitting glass for the outer layer and simple low-emission glass for the inner layer, and using horizontal shading in all windows of the entire building with a depth of 50 cm reduce energy consumption. Rafeian et al. (2011) studied 35 hectares of a residential block in Hashtgerd new city and showed that only by changing the layout, height, dimensions and size of segments, and the orientation of buildings in urban planning and design process with no initial costs, energy consumption was reduced by 30% to 45% with a saving of up to 70,000 USD.

Elsheikh and Abd Elaziz (2019) reviewed PSO plans to improve the performance of solar energy systems and identify research gaps for future work and showed that PSO is a very promising method to strengthen the performance of solar energy systems. Batra and Singhal (2017), in their study, showed that a well-designed building coating reduces the need for air-conditioning and lighting loads. They attempted to find an optimum level of insulation that makes the building's coating economical and effective. Carreras et al. (2016), by taking into account the environmental and economic criteria, presented a multi-objective optimization model to determine the insulation thickness of the outer surface of a building.

Delgarm et al. (2016) presented a multi-objective optimization model for improving the building energy yield using particle-based optimization. To test the effectiveness of the proposed model, they implemented it for a 1-room building and studied the different parameters of the building architecture. Choudhary (2015) conducted energy audits using DesignBuilder software which reduced annual energy consumption from 72/736 to 52/710 MWh. Marino (2015) reviewed energy consumption based on the building color and accordingly found that the saving would be about 21% annually. Antipova et al. (2014) developed a multi-objective linear planning model for selecting insulation, types of windows, and using solar panels. The criteria considered in their study included both environmental and economic criteria. Asadi et al. (2014) examined enhancing energy efficiency in the building through a multi-objective optimization approach, the purpose of which was to reduce energy consumption and costs using solar insulation in the building. They found that there is no single optimal answer but an optimal set of answers to their intended question. Kumar et al. (2014) used a neural network to determine the optimum barrier height in a highway. They considered classified traffic volume, associated traffic speed, and barrier attenuation data as input parameters and dam height as output parameter in order to design a neural network.

Article 19 of National Building Regulations deals with the design; thermal insulation of the outer layer of a

building; mechanical installations and lighting of buildings; building materials and products; heat conductivity and thermal resistance coefficients required for design; providing guidance to facilitate and unify the insulation design calculation method, technical information, and numerical values needed to calculate the types of thermal panels; innovative products such as double-walled glass with special coatings, heat crush UVC, and aluminum windows to improve the thermal performance of the outer layer of the building (Hashemi and Heidari 2012). Given that most buildings in the country lack the well-known technical criteria to prevent the loss of cold or heat energy, optimization of energy consumption in the building will undoubtedly save the energy costs in the country. For this purpose, it is necessary to use appropriate equipment of heating and cooling systems, lighting, insulation, and architecture of buildings that have an effective role in reducing energy consumption (Nasr Malek et al. 2016). Therefore, following Article 19 of National Building Regulations, type of ceiling and window and type of insulation of wall and ceiling, which have been less addressed, are discussed in this study (Iran National Building Regulations 2010).

The energy consumption in buildings can be reduced by up to 50% by optimization measures in the building sector and implementing Article 19 of National Building Regulations. Most people think that implementing Article 19 of National Building Regulations will increase costs of buildings (Iran National Building Regulations 2010). However, the results obtained in study show that if this Article is properly implemented in the building, it will save the costs of operating in addition to reducing the initial costs of building (Khorramabadi and Shahi 2014). Thus, the main objectives of this study can be summarized as follows:

1. Identifying appropriate criteria for reducing heating and cooling loads in Bandar Abbas office buildings.
2. Reducing energy consumption and costs of energy consumption in office buildings and estimating them based on research variables/
3. Reducing greenhouse gas emissions by minimizing cooling and heating loads in the buildings.

Materials and methods

Study area: Bandar Abbas

The study area is Bandar Abbas in Hormozgan Province. Hormozgan Province, with an area of 68,475.8 km², is located in southern Iran and lies between 25° 23' and 28° 57' N and 52° 41' and 59° 15' E. This province is confined to Kerman at the north and northeast, to Sistan and Baluchestan at the south and to Fars and Bushehr at

the west. Strait of Hormuz is one of the most sensitive and vital waterways in the present political territory of the province. Its crescent-shaped width is 187 km long, and its depth varies from north to south due to its steep slope. The depth is about 36 m near Lark Island and 180 m south of Musandam Peninsula. There are also 14 small and large islands of Abu Musa, Bani Faror, Tonbah Bozorg and Kochak, Siri, Shatour, Faror, Kish, Lavan, Qeshm, Lark, Hormuz, Hondurabi, and Hengam in the coastal water of the province.

Hormozgan Province, according to the latest national divisions, has 8 towns, 21 districts, 69 villages and 2046 populated areas. The cities in the province are Bandar Abbas, Bandar Lengeh, Minab, Rudan, Qeshm, Jask, Haji Abad and Abu Musa. Much of the province's area is covered by mountainous areas, which are the continuation of Zagros Mountains gradually extending from northeast to southeast. Continuation of the mountains is accompanied by height reduction in limestone, gypsum and sandy hills and joins the coastal lowlands of the Persian Gulf and the Oman Sea. The coastal lowlands extend around the Strait of Hormuz and create desired conditions for agriculture. Regarding the climatic profile and establishment of Hormozgan Province in the subtropical region, warming is the most important climatic phenomenon in it. Hormozgan Province is one of the hot and dry regions of Iran, and its climate is affected by semi-desert and desert climate. The coastline is warm and moist in summer and sometimes exceeds 52 °C. The average annual temperature in this region is about 27 °C. The climate of Hormozgan Province includes a long warm season and a short cool season. The hot and moist season lasts for 9 months. The summer season starts in early March, and the weather gradually gets hotter until the peak in July and August. The cool season lasts about 3 months with relative dry weather. This season starts in early December and is affected by the cool western air mass. The lowest temperature in the province rarely reaches zero during the coldest nights of the year and usually does not drop below 10 °C in winter days. Basically, the climate of the province is like desert regions and the precipitation is extremely low in it. In this area, there is no significant precipitation for about 9 months of the year and much of it falls once or twice. In all cases, low precipitation is often similar to flooding spring rains, causing severe damage. The relative moisture in the Persian Gulf coasts is mostly high and varies between 20% and 100% (Meteorological Yearbook of Hormozgan Province 2015). The most important winds in the province are:

- “Soheil or Soheili” which is a summer wind blowing from the southeast to the northwest and plays a key role in ripening of date fruits.
- “Nashi” wind that blows from northeast to southwest direction and is cold and stormy.

- “Aqrabi” wind which is a spring wind that blows from south to north from mid-April to the early summer.
- “Qos” wind which is a winter wind that blows from east to west and causes the most precipitation in this area.
- “Shomal” wind that blows along the north shore of the Persian Gulf for 9 months a year. This wind is accompanied by local dust for 40 days in the summer. The wind direction is from southwest to northeast, and in the winter, it is from west to east.
- “Ayoubi” wind like “Qos” wind has a special feature with low precipitation.
- “Sharqi” wind in the summer is among the adverse winds on the northern shores of the Persian Gulf because this wind, when passing the sea surface, gets moist in the summer and raises the relative air moisture and sometimes it causes cloud, fog and raining in some areas.
- “Bahri” or “Northwest” wind often begins to blow in the winter, bringing a breeze from the sea, sometimes with little precipitation (Meteorological Yearbook of Hormozgan Province 2015).

Bandar Abbas has a very high energy consumption in various sectors, especially construction and industry, where household consumption has a major contribution. The power consumption per capita in this province is four times the national mean due to the high temperature in the summer. The electricity consumption by subscribers was about 7,000,000 MW last year, with a peak of 1900 MW. Regarding the current trend of electricity consumption, this value will increase to 18,000,000 by 1404. The subscribers account for 64% of electricity consumption (Saba 2017).

The reason for the prolonged period of heat in the province as well as the increase in summer temperatures is the high power consumption in Hormozgan. Regarding the particular weather conditions in this province and the need to benefit from all the advantages of electricity, it is necessary for subscribers to follow the pattern of consumption (Meteorological Yearbook of Hormozgan Province 2015).

Identifying the parameters

Using library and field studies, first the variables affecting the energy consumption reduction were selected, and the prepared questionnaires were distributed among the experts in this field to extract the most important variables. Moreover, the effective parameters involved in energy optimization in the building were identified using the questionnaires and experts' opinions. Finally, the variables related to north side length, south side length, east side length, west side length, natural ventilation, north window-to-north side length ratio, south window-to-south side length ratio, east window-to-east side length ratio, west window-to-west side length ratio, temperature, split type of cooling system, solar-type cooling



system, window-type cooling system, wall insulation, ceiling insulation, ordinary block wall type, LECA block wall, clay wall, brick wall, concrete wall, joist-type ceiling, concrete slab ceiling, and double- or triple-layered window were determined (Mechanic and Shafiee 2013). Subsequently, the experts' opinion questionnaire (Delphi questionnaire) and criterion significance chart were used to finalize the variables affecting energy optimization, and 20 experts' opinions on energy optimization were collected. Each respondent selected one of the five degrees of significance (insignificant, low significance, significant, high significance, and very high significance) with varying degrees of weight (1, 3, 5, 7, and 9). The number of choices made for each degree of significance was assigned as the score of that degree of significance, and then, the significant variables in energy optimization were determined according to the results of Delphi questionnaire. These variables are optimum percentage of window to wall, low-emitting double-layered glass, simple triple-layered glass, 5-cm wall insulation, and 5-cm ceiling insulation. At the next stage, the values for these parameters are defined in intervals as described in Table 1.

Creating databases and target function identification

Energy consumption can be estimated by simulation software. None of the types of simulation software is capable of automatic optimization. Therefore, the user should model several modes and then obtain the optimal one by evaluating the results. In this study, DesignBuilder software was presented to optimize energy consumption. This software is connected to Energy Plus software for optimization. Energy Plus software makes hourly calculations and then provides the optimized modes (Taqavi 2014). The software automatically examines the double- and triple-layered sizes and the type of windows (with different glass), and the operating time of the ventilation system (depending on the time of the

presence of individuals) provides the optimum percentage for all modes and presents the best results for each part. In this way, the user can easily compare different conditions in the building and get the optimum mode. In fact, this software automatically examines the appropriate parameters to reduce energy consumption and provides the result (Sarabi and Ebrahimpour 2013).

Results and discussion

Since the necessary information about the details of buildings and the weather conditions in Bandar Abbas could be easily obtained from the Engineering System Organization, the studies were conducted on the buildings in the Engineering System Organization of Hormozgan province, as an example, and the results were extended to other office buildings. A four-floor office building—stretched from east to west—with no parking and with brick facade, brick wall, joist ceiling, and windows facing east and west was selected as a case study. The windows with no shading were made of plain glass, floors were connected via stairs and elevators, and the cooling system was split type powered by electricity. The lamps used in the building were of low-consumption type and were on for about 8 h during the day and night on average. As can be seen in Fig. 1, the building facade shows that the volume of the building and its outer body have a lot to do with outdoors and much of the building's energy is lost through its outer body.

In order to study the ways to reduce energy consumption for moving toward low-energy consumption buildings, it is necessary to examine and compare the current energy consumption in the studied building. In this regard, the electricity bills of the buildings in 2017 were prepared and normalized monthly to compare them with the software results. Study electricity bills showed that most of the power consumed was in the hot months of June and July, the highest

Table 1 A set of selected variables

Variables	Alternatives
Ceiling	Joist and/or concrete slab
Wall	Concrete and/or brick
Wall insulation	3–5 cm
Ceiling insulation	3–5 cm
North window area	10–70% of north window area
South window area	10–70% of south window area
Eastern window area	10–70% of eastern window area
Western window area	10–70% of western window area
North window	Low-emitting double-layered glass or simple triple-layered glass
South window	Low-emitting double-layered glass or simple triple-layered glass
Eastern window	Low-emitting double-layered glass or simple triple-layered glass
Western window	Low-emitting double-layered glass or simple triple-layered glass



Fig. 1 Schematic picture of the building of Engineering System Organization

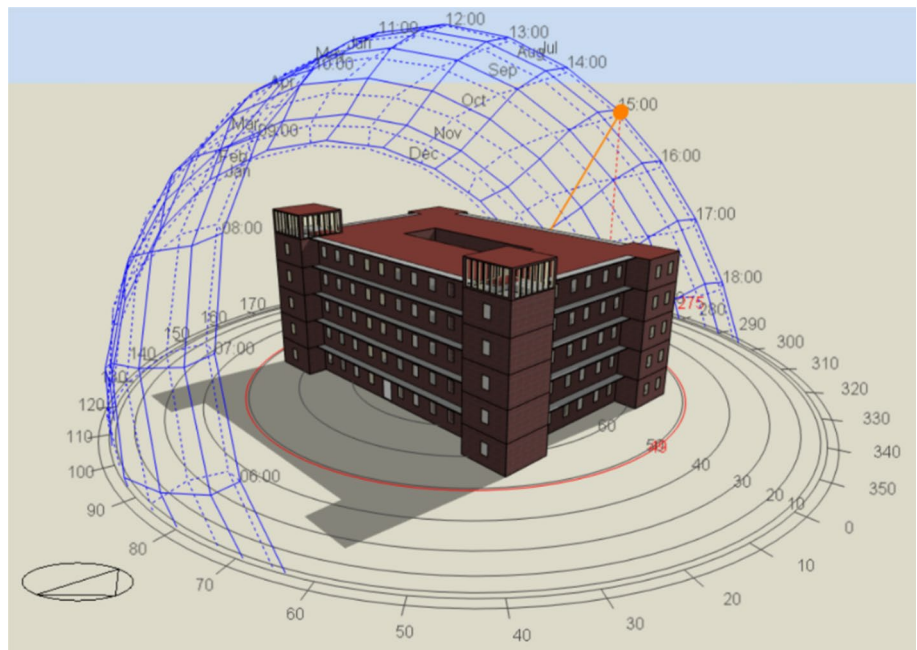


Table 2 Details of the materials used on the existing ceiling and inner and outer walls

Building components	Materials	Thermal transfer coefficient W/m ² K	Thickness (cm)
Joist ceiling	Mosaic	1.49	2
	Plaster		3
	Isogam		1
	Plaster		3
	Pumice		10
	Light concrete		10
	Block		25
	Plaster		3
Brick wall	Outer brick	2.070	20
	Plaster		3

consumption rate in the intermittent periods was 173,911 kWh per the year, peak power load was 37,885.5 kWh, and the lowest power load demand was 49,868 kWh.

Simulation of the existing mode

Brick wall type, joist ceiling, split-type cooling system, and double-layered or wooden window were included in DesignBuilder. The thermal transfer coefficient was calculated for each building component, and the information contained in the software was used to simulate the details. Table 2 shows the details of the ceiling and wall of the building in DesignBuilder software prior to optimizing. The basic materials used in joist ceiling are mosaic,

plaster, isogam (insulation), plaster, pumice, light concrete, block, and gypsum, respectively, from up to down with the thickness shown in Table 2. The thermal transfer coefficient was 1.149 W/m² K which is equal to the maximum permissible thermal transfer from the outer shell of the building. (The values of the outer shell component of the building include the total area of the walls, roof, air adjacent floor, door, window, and adjacent surfaces of uncontrolled spaces, and the floor environment in contact with soil, and they are calculated according to the inner dimensions.) The amount of heat passes through an object according to its thickness, during a time unit and in a specific temperature is expressed in W/m K. The lower the thermal transfer coefficient of an object, the less the thermal transfer it has and the more it is suitable for insulation. The materials used in the brick wall from the building outer shell to inner body are brick and plaster, respectively. The thermal transfer coefficient of the wall was 2.070 W/m² K.

According to the building equipment, power consumption in different months of the year is given in Fig. 2. Most of the energy consumption is related to the cooling of the building, lighting, and electricity room in June, July, and August, respectively. The least energy consumed is recorded in December, January, and February for cooling, electricity room, and lighting, respectively.

As explained in Fig. 2, most of power consumption in the building is related to cooling, lighting, and electricity room, respectively. Figure 3 shows the percentages of the listed uses accounting for 71% of cooling, 18% of lighting, and 11% of the power consumption in room.

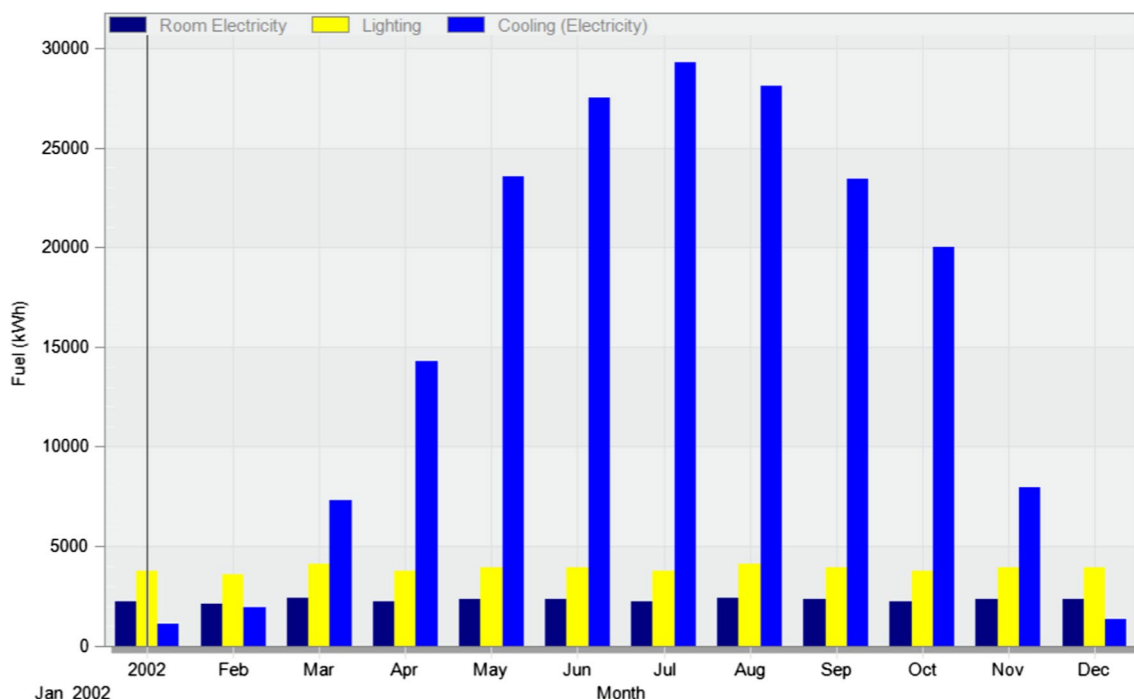


Fig. 2 Energy consumption of the building in different months

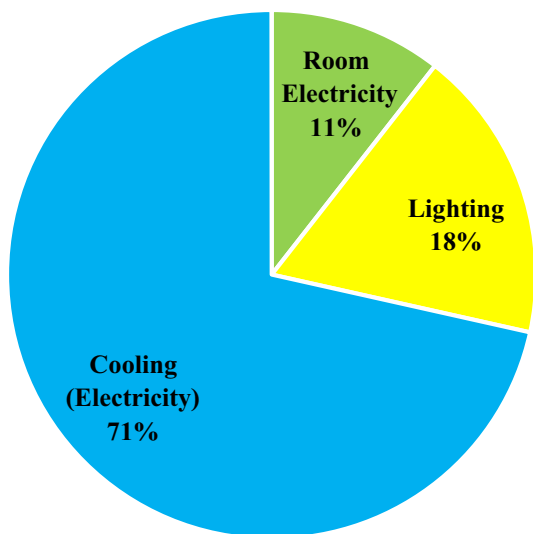


Fig. 3 Power use of the building

Optimization solutions

In order to reduce the energy consumption of the building and optimize energy, several strategies have been proposed as optimizing the percentage of window to wall, wall and ceiling insulation, and using a triple-layered window and different details in the ceiling and wall in the building. In each optimization strategy, the amount of cooling saving

was calculated and finally the optimal mode was simulated using a combination of these strategies. Building components include concrete slab ceiling, concrete wall, ceiling insulation, wall insulation, double-layered glass, and triple-layered glass. Table 3 shows the details of the ceiling and wall in the building in DesignBuilder software for an optimized mode. In the optimized mode, the materials used in the concrete slab ceiling are isogam (insulation), plaster, lightweight concrete, concrete, and plaster with the thicknesses listed in Table 3. The thermal transfer coefficient was 1.683 W/m² K. The materials used in the concrete wall from the building outer to inner body are lightweight concrete and plaster, respectively. The wall thermal transfer coefficient was 2.647 W/m² K.

The results show that the use of brick wall rather than concrete wall, joist ceiling rather than concrete slab ceiling, triple-layered glass rather than double-layered glass, 5-cm polystyrene insulation rather than 3-cm insulation in brick wall and joist ceiling reduces the cooling energy and the thermal loss of the building.

Optimization using DesignBuilder software

As already mentioned, an optimization tool called Design-Builder software was used in this study. All details of the building, which were effective in energy optimization, are included in this software based on the lowest energy consumption in kWh and the lowest carbon dioxide in kg to

Table 3 The details of materials used in inner and outer ceilings and walls in the optimized mode

Building components	Materials	Thermal transfer coefficient W/m ² K	Thickness (cm)
Concrete slab ceiling	Isogam	1/683	3
	Plaster		2
	Light concrete		5
	Concrete		20
	Plaster		3
Concrete wall	Light concrete	2/647	15
	Plaster		3
Ceiling insulation	Polystyrene	0/617	3
	Polystyrene	0/472	5
Wall insulation	Polystyrene	0/811	3
	Polystyrene	0/614	5
Double-layered glass	Double-layered glass	1/338	0/6
	Argon gas		0/2
Triple-layered glass	Double-layered transparent glass	0/689	0/4
	Low-emitting glass		0/1
	Krypton gas		0/12

perform the optimization. Using this tool, the window–wall percentage was obtained as 10% to 70% at 10 units simultaneously on different fronts of the building, brick wall, and joist ceiling. Wall and ceiling insulation thicknesses of 3 and 5 cm, respectively, were considered as the software inputs, and the amounts of energy and carbon dioxide were included as the software output.

Since the brick wall is superior to the concrete wall, the joist ceiling is superior to the concrete slab, and the double- and triple-layered glass is superior to the ordinary glass. Knowing that the 5-cm-thick wall and ceiling insulation play a key role in the building energy optimization and result in less energy loss, they were considered as effective alternatives in the optimization part of DesignBuilder software. The window–wall percentages on the north, south, east, and west sides are 10%, 30%, 50%, and 70%, respectively, in the optimization part of DesignBuilder software. The output of this part includes the total energy of the building in kWh and the amount of carbon dioxide calculated in kg.

Neural network training

The neural network computational method is modeled on the natural mechanism of brain neurons. The neural network neurons connect the input to the output using weight, bias and transfer function, and in fact find a connection between input and output. In training a neural network, the objective is to find the appropriate weights to establish a relationship between input and output parameters. The inputs include independent variables and the outputs include objective functions (Kalami Heris 2013). In neural networks with more than one layer, the output of each layer is equal to the

input of the previous layer. In general, each network has an input layer, one or more hidden layers, and finally an output layer. It should be noted that the neural network programming is done in MATLAB software. In the toolbox of this software, any layer rather than the output layer is called the hidden layer. Training a network is an optimization process involving weight adjustment that may be done in different ways. At the beginning of training, weights are usually selected randomly, and the subsequent optimization process aims to reduce the difference between the output of the network and the given output (Kalami Heris 2013).

In order to train the neural network, the input variables were first turned to specific codes. As shown in Table 4, codes 1, 2, 3, and 4 were assigned to neural network inputs. The applied network was a MLFF type with two hidden layers with 10 and 5 neurons selected, respectively. The training data are $n = 160$, the experimental data are $n = 100$, and

Table 4 Codes for data input to the neural network

No.	Description	Code
1	Brick wall	1
2	Brick wall with 3-cm polystyrene insulation	2
3	Brick wall with 5-cm polystyrene insulation	3
4	Concrete wall	4
5	Joist ceiling	1
6	Joist ceiling with 3-cm polystyrene insulation	2
7	Joist ceiling with 5-cm polystyrene insulation	3
8	Concrete slab ceiling	4
9	Double-layered glass	2
10	Triple-layered glass	1



the transfer function of all neurons is the sigmoid function. Levenberg–Marquardt method was also used to train the network faster.

In this study, the neural network inputs included the type of wall, ceiling and glass, and the optimal percentage of window–wall in four directions, north, south, east, and west. Moreover, the weights and bias values were sought to be optimized, and the objective functions were energy and carbon dioxide. In other words, two neural networks were trained, one for energy and the other one for carbon dioxide. Since the neural network training process uses both training and experimental data, the network output for these two sets of data was examined accordingly.

The horizontal axis in Fig. 4 represents the training data entered the network and the vertical axis shows the amount of energy in kWh. For each data set, the amount of energy calculated by the network is very close to its actual value, indicating the accuracy of the network training.

A proper method to control the experimental data is to use the diagram shown in Fig. 5. As can be seen, the horizontal axis shows the actual amount of energy and the vertical axis shows the amount of energy produced by the network. Ideally, all points should be on the first and third quarter bisectors. The real data are compared to the data obtained from the network with the best line passing through these points (Fig. 5). The points close to the bisector indicate the high accuracy of the network.

The horizontal axis in Fig. 6 represents the training data entered the network and the vertical axis shows the amount

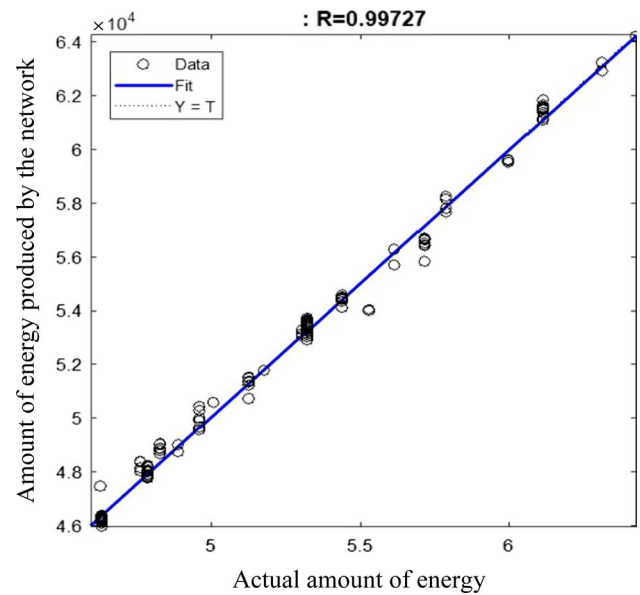
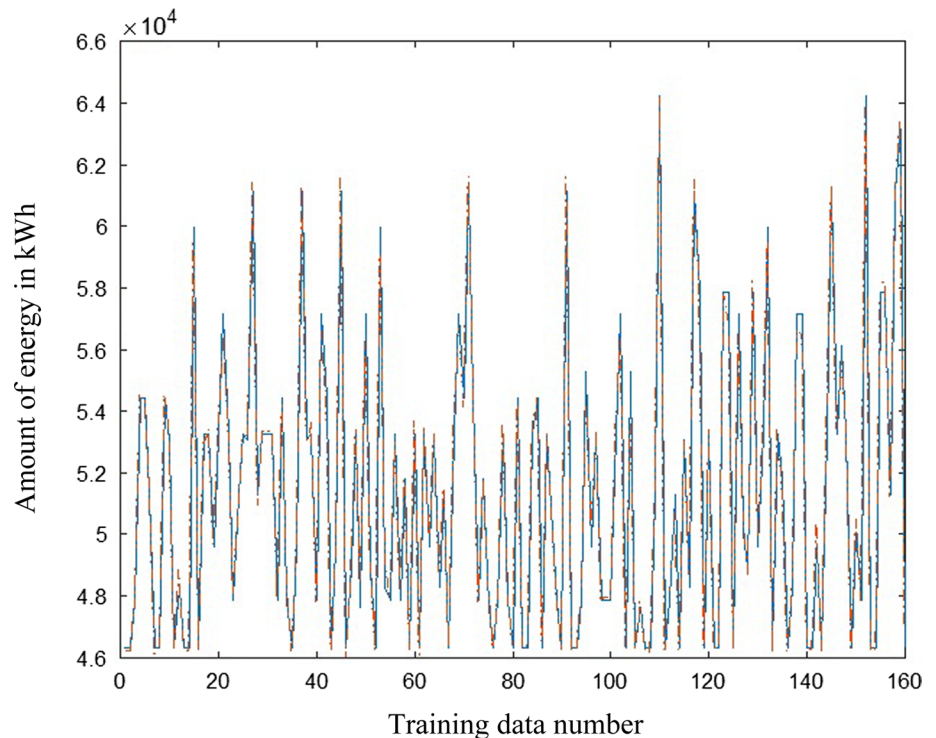


Fig. 5 Comparison of the estimated value calculated by the neural network and energy for experimental data

of carbon dioxide in kg. Moreover, for each data set, the amount of energy calculated by the network is very close to its actual value, indicating the accuracy of the network.

The horizontal axis in Fig. 7 shows the actual carbon dioxide and the vertical axis shows the carbon dioxide produced by the network. Moreover, the best line passing

Fig. 4 Comparison of the estimated value calculated by the neural network and energy for the data training



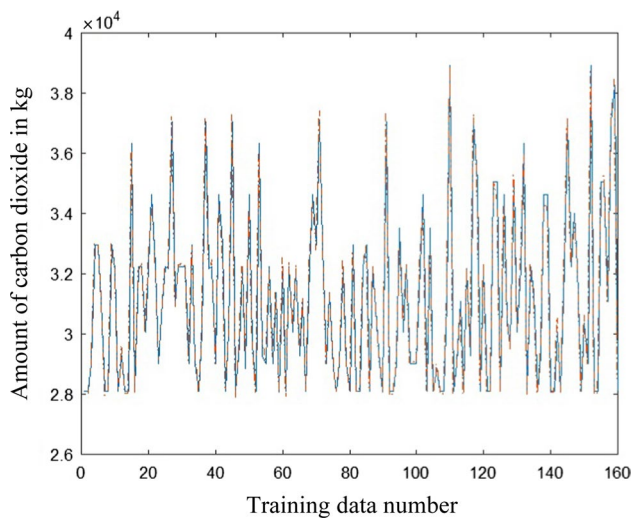


Fig. 6 Comparison of the estimated value calculated by the neural network and carbon dioxide for the data training

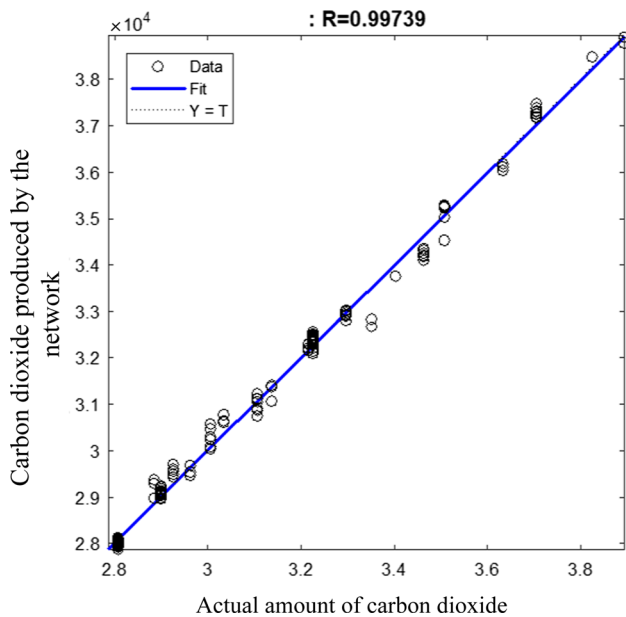


Fig. 7 Comparison of estimated value calculated by neural network and carbon dioxide for experimental data

through these points is very close to the first and third quarter bisectors.

In general, Figs. 4 and 5 show the approximation of real and estimated values, indicating that the neural network is correct and the results of the network are identical. Also, Figs. 6 and 7 show that the correlation coefficient of the data is close to 1 and this confirms the appropriateness of network modeling. In this way, it would be possible to obtain the given outputs accurately after training the network for each input data set without DesignBuilder software.

Conclusion

In this study, the current state of building in Engineering System Organization in Bandar Abbas was investigated and modeled using DesignBuilder software. The obtained results were analyzed, and the different options were evaluated of and compared. The results of the neural network developed for different inputs showed that 5-cm-thick brick wall insulation, joist ceiling with 5-cm-thick insulation, and triple-layered glass were the best among the scenarios proposed for reduction in energy consumption and carbon dioxide produced in the cooling and lighting sectors.

It was concluded that the physical properties of buildings can affect energy consumption and greenhouse gas emissions. The results indicated that the variables affecting the reduction in energy consumption in buildings are common in all studies. The present study partially addressed the parameters that reduce energy consumption and consequently carbon dioxide. The optimal percentages of windows to walls in different directions were also studied. Finally, it was confirmed that the implementation of Article 19 of National Building Regulations in buildings can lead to reduction in energy consumption and carbon dioxide production.

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Compliance with ethical standards

Conflict of interest The author declares that they have no conflict of interest.

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