Utilization of double skin facades to reduce carbon emissions and energy efficiency in Egypt

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Abstract:

The COVID-19 virus has required improving air quality and reducing carbon dioxide levels in buildings to help reduce its spread. Recently, double-skin façades have the ability to reduce cooling loads and carbon emissions. Consequently, they have become very popular.

This study, which is simulation-based, aims to provide a comparative analysis between using double-skin facades and their effect on CO2 emissions and energy efficiency abatement in educational buildings in Egypt.

The results indicate that, when using double skin facades with a depth of 120 cm for corridor façades and shaft box facades, carbon emissions are reduced by 23.80%, 17.98%, carbon equivalent is reduced by 24.73%, 18.26, and energy consumption is reduced by 29.77% .

While the use of the Box Window Façades with a depth of 90 cm is the most efficient, which reduces carbon emissions by 18.32%, carbon equivalent by 19.83%, and energy consumption by 27.84%.

Multi-story facades with a depth of 150 cm reduce carbon emissions by 21.23%, carbon equivalent by 21.58%, and energy consumption by 29.49%.

The study concluded that the double facades of the corridor type with a depth of 120 cm are the best for improving air quality and reducing carbon emissions in educational buildings in Egypt, followed by double facades of the multi-story type with a depth of 150 cm, then double facades of the box window type with a depth of 90 cm, and then double facades of the shaft box type with a depth of 120 cm.

Keywords:

COVID-19; carbon reduction; energy efficiency; double skin facades

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الملخص

لقد تطلب الوقاية من الاصابة بفيروس كوفيد -١٩ (COVID-19) تحسين جودة الهواء وتقليل مستويات ثاني أكسيد الكربون في المباني للمساعدة في تقليل انتشاره. في الآونة الأخيرة ، تتمتع الواجهات المزدوجة الجلد بالقدرة على تقليل أحمال التبريد وانبعاثات الكربون. وبالتالي ، فقد أصبحوا يتمتعون بشعبية كبيرة. وخاصة مع تنوع اشكالها واستخدامها ليس فقط بيئيا ولكن ايضا في تشكيل الواجهات الخارجية للمبني.

تهدف هذه الدراسة ، التي تعتمد على المحاكاة ، إلى تقديم تحليل مقارن بين استخدام الواجهات المزدوجة الجلد وتأثيرها على انبعاثات ثاني أكسيد الكربون وخفض كفاءة الطاقة في المباني التعليمية في مصر.

تشير النتائج إلى أنه عند استخدام واجهات مزدوجة الجلد بعمق ١٢٠ سم لواجهات الممرات وواجهات صندوق الأعمدة ، تنخفض انبعاثات الكربون بنسبة ٢٣,٨٠٪ ، ١٧,٩٨٪ ، كما ينخفض مكافئ الكربون بنسبة ٢٤,٧٣٪ ، ١٨,٢٦ ، بالاضافة الي تقليل استهلاك الطاقة بنسبة ٢٩,٧٧٪ ، ٢٩,٧٧٪ على التوالي.
بينما يعتبر استخدام واجهات النوافذ الصندوقية بعمق ٩٠ سم هو الأكثر كفاءة حيث يقلل انبعاثات الكربون بنسبة ١٨,٣٢٪ ومكافئ الكربون بنسبة ١٩,٨٣٪ واستهلاك الطاقة بنسبة ٢٧,٨٤٪.
تعمل الواجهات متعددة الطوابق بعمق ١٥٠ سم على تقليل انبعاثات الكربون بنسبة ٢١,٢٣٪ ومكافئ الكربون بنسبة ٢١,٥٨٪ واستهلاك الطاقة بنسبة ٢٩,٤٩٪..
وخلصت الدراسة الي ان الواجهات المزدوجه من نوع الممرات بعمق ١٢٠ سم هي الافضل لتحسين جوده الهواء وتقليل انبعاثات الكربون بالمباني التعليمية بمصر ثم تليها واجهات مزدوجة من النوع متعددة الطوابق بعمق ١٥٠ سم ثم واجهات مزدوجة من النوع الصندوقي بعمق ٩٠ سم ثم واجهات مزدوجة من النوع العمودية بعمق ١٢٠ سم.

الكلمات المفتاحية:
كوفيد-١٩ ؛ تخفيض الكربون ؛ كفاءة الطاقة؛ واجهات مزدوجة الجلد.

Introduction

COVID-19 indicates a global short-term problem, as well as climate change, which is also a near-term issue. Therefore, it is necessary to reduce CO2 emissions. (Peng, 2021) (Wibowo, 2021) (Schade, 2021) (Chapman2020) (Adwibowo, 2020) To achieve the sustainable development goals. Based on the current International Energy Agency's World Energy Outlook 2019, buildings are responsible for 25% (IEA, 2019) of total CO2 emissions and use 50% (Flor J. F.-A., 2021) of all the electricity consumed globally (Newell, 2019) (Kober, 2020).
The construction industry In Egypt, is uninterested in the energy efficiency and CO2 of different building projects, till now. So it is necessary to find a method to reduce buildings' environmental impacts.
In a hot arid environment, facade configurations can account for up to 45 percent of a building's cooling loads (Sotelo-Salas, 2021).
The studies interested in the effect of the double facades on the building studied the thermal properties and energy consumption, but did not study their effect on the carbon emissions of the building. As for the studies concerned with carbon emissions, they dealt with the effects of modern materials such as pcm and did not deal with the different types of double facades. Therefore, in this paper, the study will study the effect of double facades and their type on energy consumption and carbon emissions.

Carbon emissions

Carbon dioxide emissions are created during the use of solid, liquid, and gas fuels, as well as fossil fuel combustion, and it is the most common total impact on global warming, and it is also the most common GHG released by human activities (Khan, 2020) (Mardani, 2020) (Kirikkaleli, 2021) (Andrew, 2020).
CO2-eq (carbon dioxide equivalent) (kgCO2) is a metric used to assess emissions from other greenhouse gases based on their global-warming potential (GWP) by converting rates of other

gases to the comparable amount of carbon dioxide with the same GWP. By multiplying them by their Global Warming Potential, which includes CH4 and N2O, into equivalent CO2 emissions (GWP) (Lintunen, 2021) (Smith, 2021) (Bright, 2021).
According to what WELL recommends, indoor carbon dioxide (CO2) should be managed at 800 parts per million (ppm) or less (Standard, 2018) (Roskams, 2021) “Fig.1”. However, some research suggests that CO2 levels in the indoor environment over 1000 ppm are an indication of ventilation rates that are unacceptably significant in terms of body odor (Daisey, 2003) (Poirier, 2021) (LOWITZ, 2017).
Literature reveals that the PCM with Tm = 26 °C has the lowest payback period (1.8 years). Over the life of the wall, using the most efficient PCM wall decreases carbon emissions by 52.7 kg/m2 (Li, 2021).

Double skin facades

Buildings consume over 40% of primary energy and contribute significantly to global greenhouse gas emissions that cause climate change. According to the International Energy
Double skin façades (DSF) are architectural devices that are affixed to the exterior of a building to reduce the thermal transfer and air conditioning loads (Alobeidi, 2019). It is composed of an additional completely glazed exterior skin that is built over the existing building façade, creating a normally ventilated air cavity between the layers (von Grabe, 2002) (Barbosa, 2016). They can allow light and ventilation (Hou, 2021) to pass through, fully block solar radiation and airflow (Ayegbusi, 2021), seek interconnection between levels, increase privacy, or allow visibility of space, depending on their objective, design, and construction (Flor J. F.-A., 2021). In addition, it can improve energy efficiency while also improving occupant comfort (Gelesz, 2020).
According to the literature, energy savings and using double skin facades, thermographic images revealed that the double skin facades would save 0.27–0.42 kw.h.th/m2/day by reducing the air conditioning inlet temperature to 4–6 °C during summer days. In the best environment, integrating the proposed DSF system into buildings could lead to a reduction in total electricity usage of up to 4283039.4 KW.H. (Radmard, 2020). Which prove that using double skin facades (DSF) will save energy in hot and humid climates compared with the single skin façade (SSF) model (Wang, 2021). According to a study on the DSF, energy savings range from 17.2 percent to 28.7 percent when using a suitable combination of the DSF design (M., 2020).
A study indicates that, the double-skin façade system can reduce annual cooling energy consumption by 22 percent to 32 percent when combined with a natural ventilation air cavity (Aldawoud, 2020).

Types of double skin facades

According to its air flow organization, the double- skin facades (DSF) can be classified as a Box-window type, a Shaft-box type, a Corridor type, or a Multi-story type. (Alemdağ, 2017) (Aksamija, 2018) “Fig.2”.

- Box window façades:

Box window façades have horizontal and vertical partitions at floor level and also vertical partitions between windows. Normally, each air space has natural ventilation.

• Corridor façades

Corridor façades have continuous horizontal air voids for each floor level. They are actually separated at the floor levels. Each of the three ventilation modes is available.

• Shaft box facades

Shaft box facades are similar to corridor facades, but they have vertical shafts.

• Multi-story facades

Multi-story facades with continuous air cavities that span the building's entire height and width; no horizontal or vertical partitions in the cavity.

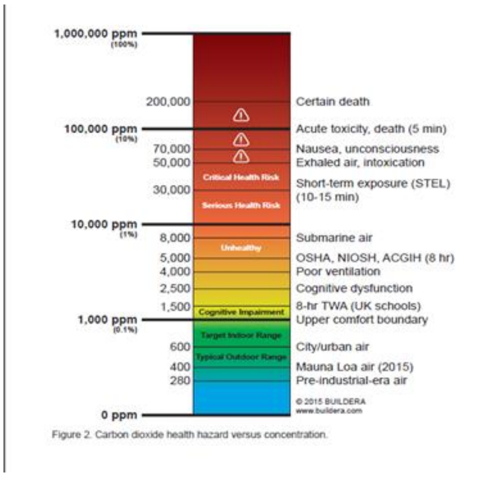

Fig. 1

carbon dioxide hazard scale (LOWITZ, 2017)

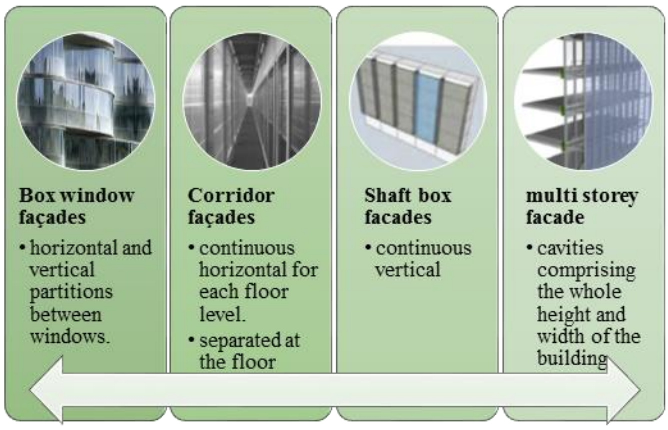

Fig. 2

Types of double skin facades

Methodology

The research utilizes a practical technique to assess the assumption's applicability by using a simulation program (designbuilder). Working on an actual, already-existing building with real data and situations gives a pragmatic sense to the research. As a result, the study reflects a controlled experiment rather than a theoretical theory.

The methodological approach used in this work comprises constructing a set of variables for the test building's double skin facades, on which the simulations are run. To compute and evaluate carbon emissions, carbon equivalents, and energy savings. Which is divided into four cases:

Case 1: Using Box Window Façades with Varying Depths of 30, 60, 90,120,150 c.m.

Case 2: Employing Corridor façades with Varying Depths of 30, 60, 90,120,150 c.m.

Case 3: Utilizing Shaft box facades with of 30, 60, 90,120,150 c.m. depths.

Case 4: Using Multi-story facades with Varying Depths of 30, 60, 90,120,150 c.m.

Case study

The case study chosen is the Faculty of Media, Beni Suef University- It is located in the city of Beni Suef, which is in the northern region of Upper Egypt.

Description of case study:-

The building contains classrooms, laboratories, a radio and television studio, administrative offices, and services. "Fig.3".

Fig. 3 plan , elevation , interior of case study

Inputs for the simulated model

The table below (table1) contains the building inputs of a case study to make a simulation in a designbuilder program after drawing the building in it.

Table 1. Inputs of the case study in Designbuilder program

|Parameters	Sub- parameters	Inputs
Layout	Location	Beni Suef
Activity	Activity template	Classroom- teaching area – offices-studio
	Working time	Sunday to Thursday day, from 8:00 am until 5:00 pm
	holiday	Holidays 2 days/week
	Equipment	Smart board, computer, sound system, and studio equipment.
	Occupancy schedule	From 8:00a.m. to 17:00 p.m.
Construction	Finishing material for external walls	Savito in external walls curtain wall metal partitions
	Glass type	Double green glass
simulation	Double facades material	curtain wall with metal partitions with the required width
	Time of simulation	8:00:17:00, 21 Mar/Sep
	Tested façade	east
	Width of double faced or module	30-60-90-120-150cm

Results of the case study

In the basic case, the value of carbon emissions in the building is 1168kg, which is higher than the required rate.

CASE1: the use of box window facades with a depth of 30 cm, it decreases by 14.5 percentage, while it decreases with the use of a DSF with a depth of 60 cm at a rate of 16.5 percentage.

Compared to the base case and 18.32 percentage with the use of a DSF with a depth of 90 cm, then the amount of emissions is fixed with an increase in depth to 120 cm and 150 cm.
In the basic case, the value of carbon equivalent in the building is 1205kg, which is higher than the required rate, and still higher by the use of box window facades with a depth of 30 cm. Then it decreases by 16.8 percent, to a depth of 60 cm. Compared to the base case and 19.83 percentage with the use of a DSF with a depth of 90 cm, then the amount of carbon equivalent is fixed with an increase in depth to 120 cm and 150 cm. “Fig.4”. (table2)
The value of energy consumption In the basic case, it is 463.kW, and it decreases at a rate of 18.96%, 24.08%, 27.84%, 29.39%, and 30.29% respectively, with changing the depth of use of DSF by 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm.

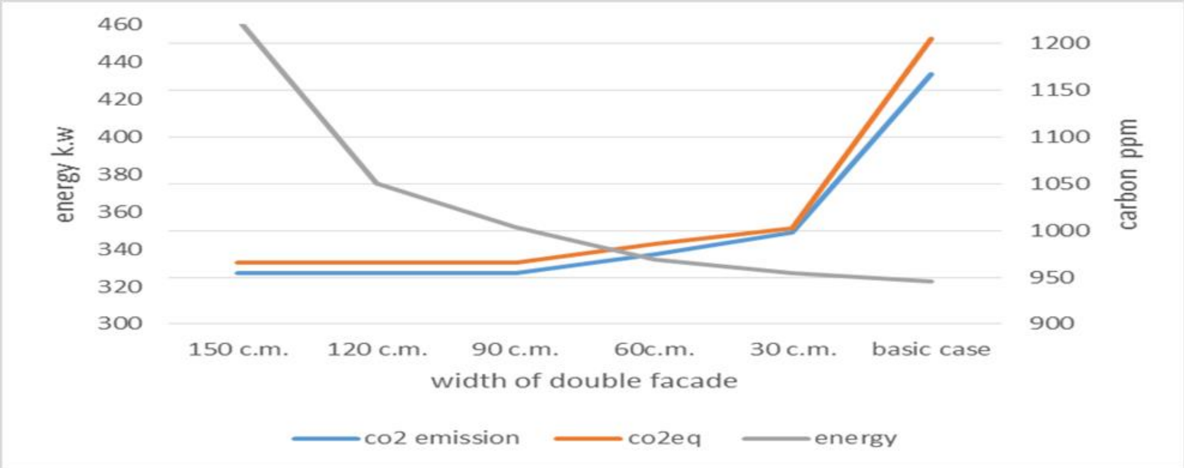

Fig. 4 Results of simulation CASE1: the use of box window facades

Table2, results of simulation CASE1: the use of box window facades

cases	co2 emission ppm	savings%	co2 equivalent ppm	savings%	Energy consumption 100 kw	savings%
basic case	1168	basic case	1205	basic case	463.26	basic case
30 c.m.	998	14.55	1002	16.85	375.44	18.96
60c.m.	975	16.52	986	18.17	351.73	24.08
90 c.m.	954	18.32	966	19.83	334.30	27.84
120 c.m.	954	18.32	966	19.83	327.12	29.39
150 c.m.	954	18.32	966	19.83	322.95	30.29

CASE 2: With the utilization of corridor façades, the amount of carbon emissions is reduced by 15.33%, 17.21%, and 19.5%, when the depth is 30 cm, 60 cm, 90 cm, and 120 cm, respectively. Then constant at 23.80% when the depth is 120cm and 150 cm. “Fig.5”. (table3)
CO2 equivalent is reduced by 17.1%, 18.76% and 20.5% when using a double facade of the corridor type with a depth of 30 cm, 60 cm and 90 cm, after that it is fixed at 24.0% at a depth of 120 cm and 150 cm.

The use of corridor facades positively affects energy consumption, as it decreases by 23.22%, 25.24 %, 28.8%, and 29.77%, 30.71% when the corridor depth is by 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm, respectively.

Table3. results of simulation CASE 2: the utilization of corridor façades

cases	co2 emission ppm	savings%	co2 equivalent ppm	savings%	Energy consumption 100 kw	savings%
basic case	1168	basic case	1205	basic case	463.26	basic case
30 c.m.	989	15.33	999	17.10	355.68	23.22
60c.m.	967	17.21	979	18.76	346.35	25.24
90 c.m.	940	19.52	958	20.50	329.85	28.80
120 c.m.	890	23.80	907	24.73	325.33	29.77
150 c.m.	890	23.80	907	24.73	321.01	30.71

Case 3: The employment of Shaft box facades with 30 cm depth, the quantity of carbon emissions reduces by 9.67%, but it is higher than the required rate.
Then with increase the depth to 60 cm and 90 cm carbon emissions reduce by 15.92% and 16.35% then constant in reduction with 17.98 % when increasing depth to 120 cm and 150 cm. “Fig.6”. (table4)
As a result of simulation carbon equivalent, the Shaft box facades at 30 cm and 60 cm are outside of accepted ranges. After that, it entered the acceptable range at a depth of 90 cm, 120cm, and 150cm, reducing emissions by 18.09% and 18.26%.
When the Shaft box facade depth is 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm, energy consumption is reduced by 23.22 percent, 25.24 percent, 28.8 percent, and 29.77 percent, 30.71 percent, respectively.

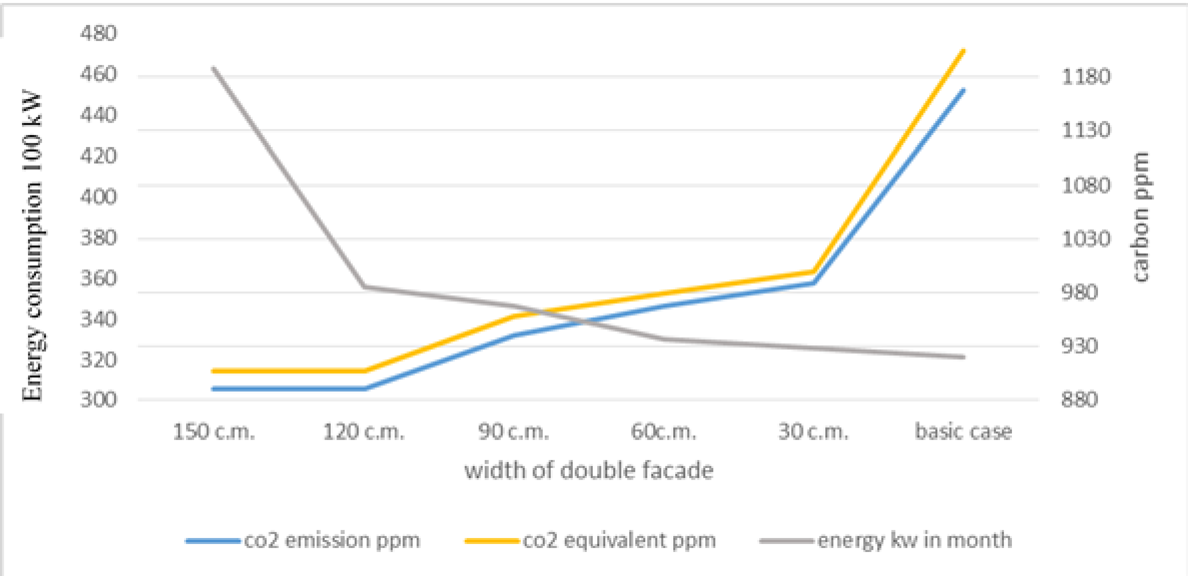

Fig. 5 Results of simulation CASE 2: the utilization of corridor façades

Table 4. results of simulation Case 3: The employment of Shaft box facades

cases	co2 emission ppm	savings%	co2 equivalent ppm	savings%	Energy consumption 100 kw	savings%
basic case	1168	basic case	1205	basic case	463.26	basic case
30 c.m.	1055	9.67	1110	7.88	386.82	16.50
60c.m.	982	15.92	1002	16.85	355.35	23.29
90 c.m.	977	16.35	987	18.09	337.38	27.17
120 c.m.	958	17.98	985	18.26	331.62	28.42
150 c.m.	958	17.98	985	18.26	328.95	28.99

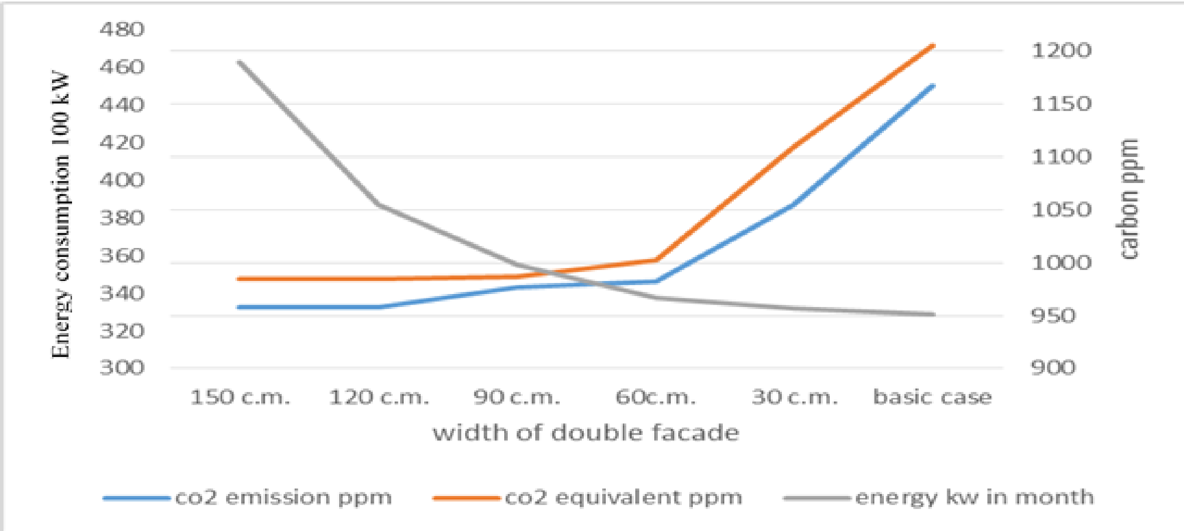

Fig. 6 Results of simulation Case 3: The employment of Shaft box facades

Case 4: Using Multi-story facades, it reduces carbon emissions by 14.64%, 15.67%, 17.38%, 19.09%, and 21.23% when the depths are 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm, respectively.

As a consequence of modelling carbon equivalent, it decreased by 16.85%, 17.84%, 19.42%, 19.83%, and 21.58% when the depths were 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm, respectively.

When the Multi-story facade depth is 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm, energy consumption is reduced by 22.29%, 24.23%, 28.42%, 29.49%, and 30.35% respectively.

Table5, results of simulation Case 4: Using Multi-story facades

cases	co2 emission ppm	savings%	co2 equivalent ppm	savings%	Energy consumption 100 kw	savings%
basic case	1168	basic case	1205	basic case	463.26	basic case
30 c.m.	997	14.64	1002	16.85	360.00	22.29
60c.m.	985	15.67	990	17.84	350.99	24.23
90 c.m.	965	17.38	971	19.42	331.62	28.42
120 c.m.	945	19.09	966	19.83	326.66	29.49
150 c.m.	920	21.23	945	21.58	322.66	30.35

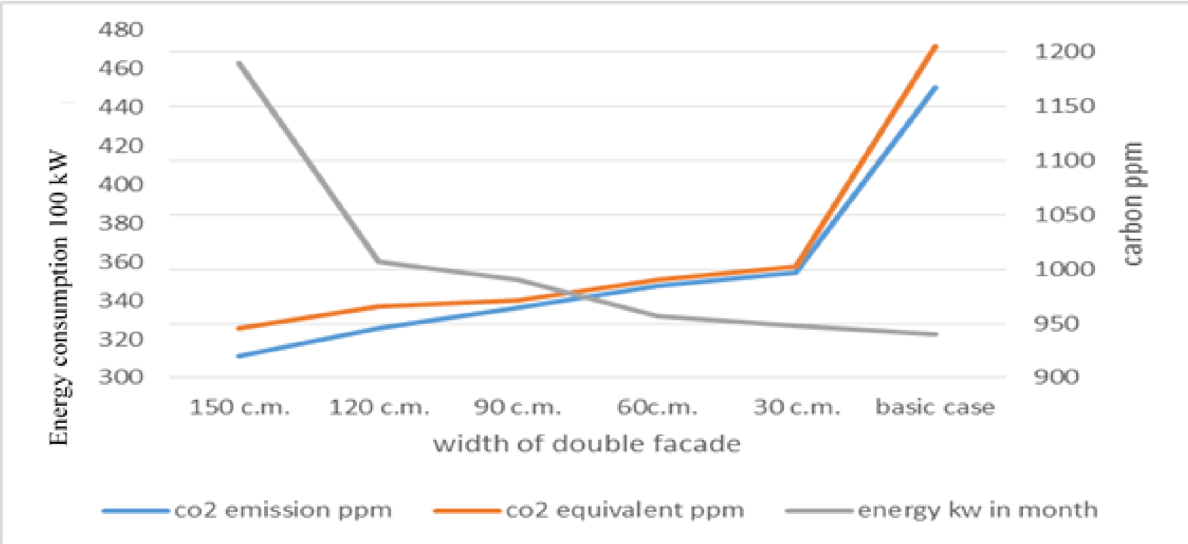

Fig. 7 Results of simulation Case 4: Using Multi-story facades

Results, analysis and discussion

A comparison study was performed on the types of double-façades to examine carbon emissions and energy efficiency. In the Faculty of Media, Beni Suef University. The studies indicated that:

As a result of simulating the use of the Box Window Façades, it is clear that the use of DFs with a depth of 90 cm is the most efficient in terms of carbon emissions in the building, which reduces by 18.32%, and with increasing depth, the percentage of emissions remains constant. In addition to a 19.83% reduction in carbon equivalent. Reduces energy use by 27.8%.

Utilizing double skin facades with Corridor façades type with a depth of 120 cm is the most efficient in carbon emissions, which reduces by 23.80%, and with increasing depth, the percentage of emissions fixed. This results in a reduction of 24.73% in carbon equivalent. This reduces energy consumption by 29.77%.

For this model, the use of Shaft box facades with a depth of 120 cm reduces carbon emissions by 17.98%, and as the depth increases, the amount of emissions remains constant. In addition, they reduce their carbon equivalent by 18.26%. This cuts the amount of energy used by 29.77%.

The consequences of modelling involving multi-story facades are that the depth of 150 cm is the most efficient in terms of carbon emissions, which reduces by 21.23%, and with increasing depth, the percentage of emissions is fixed. This reduces the carbon equivalent by 21.58%. This reduces energy consumption by 29.49%. **Table** 6

Finally, because of the importance of double skin facades and their effect on university buildings, it is important to apply them to improve their carbon emission and energy performance in university buildings to provide the best possible air quality and comfort for students.

Table 6**, Optimal width for different types of double skin facades and their effectiveness.**

	Optimal width	reduces of carbon emissions	reduces of carbon equivalent	reduces of energy consumption
Box Window Façades	90 cm	18.32%	19.83%	27.84%
corridor façades	120 cm	23.80%	24.73%	29.77%
Shaft box facades	120 cm	17.98%	18.26%	29.77%
Multi-story facades	150 cm	21.23%	21.58%	29.49%

Conclusion

The use of double skin facades reduces carbon emissions in the building by 17.98 to 23.80 percent when compared to the base case, and this percentage varies depending on the type of double skin facades and the depth of the cavity.

In addition to the rationalisation of energy use, which decreased from 27.8% to 29.49%, the percentage also depends on the size and type of cavity.

As a result of the simulation, it became clear that the horizontal corridors system is the best system that achieves the best efficiency in energy use as well as carbon emissions and other gases affecting global warming. This affects the air quality in this system, which is what we need now to reduce infection with the COVID-19 virus, which is a short-term benefit, and the long-term benefit is the effect on climate change and global warming.

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