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TOWARDS NANOTECHNOLOGY APPLICATION FOR SUSTAINABLE ARCHITECTURE

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ABSTRACT

The research problem lies in reaching sustainability of buildings through nanotechnology and its applications in architecture. Sustainable urban and architectural environment should adopt alternative technologies rather than traditional ones in an attempt to find smart, renewable and recyclable building materials. These would then be adapted to serve human beings and the environment. The research is based on the inductive inference approach and includes the identification of nanotechnology and its impact on the environment, sustainable architecture. The analytical approach, which is the study of Nano applications in construction through the analysis of some examples of existing projects and then reaching the results and recommendations. In light of the world's suffering from the spread of epidemics and current natural conditions, it is recommended to use nanotechnology to improve the performance of building materials and coatings to raise the efficiency of buildings using these environmentally friendly materials in order to reach a sustainable building that serves humanity and the environment.

KEYWORDS: Technology, Nanotechnology, Architecture, Sustainability.

1. INTRODUCTION

The research seeks to illustrate how important it is to use smart nanotechnology by applying it to the concept of sustainability as one of the most important scientific developments that have a significant impact on architecture.

The research aims to study the concept of sustainable design and building technology, to know how to integrate them and to illustrate the long-term potential and cost of using such technology in order to achieve significant results in design techniques, and to create new building materials that will help save energy and

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preserve the environment. It is to be implemented locally for environmental, functional, and financially efficient buildings through:

- The role of nanotechnology in achieving sustainability principles in construction.
- Study the applicability of nanotechnology in architecture to achieve a sustainable environment.

The research problem lies in how to reach sustainability of buildings through nanotechnology and its applications in architecture to reach a sustainable environment based on an alternative technology rather than the conventional ones. Also, to find alternatives such as smart, renewable and recyclable building materials to balance technological intelligence and environmental sustainability to minimize the depletion of energy and natural resources of building materials. The construction sector is one of the largest sectors affecting the environment and consumes energy and raw materials so there is a great need to review the characteristics of the materials used.

The research methodology follows the deductive inductive approach, covering an introduction to nanotechnology, Nano materials and their impact on thought and architectural form as well as on environment and sustainable architecture and their relationship to Nano architecture.

2. THE CONCEPT OF SUSTAINABLE DEVELOPMENT

It is the process of designing buildings in an environmentally friendly manner, taking into account the reduction of energy consumption, resources and materials, while minimizing the effects of construction on the environment while maintaining harmony with nature [1-10]. The principles of sustainable architecture are climate adaptation, reduced use of new resources, respect for the site, and comprehensive design.

3. NANO TECHNOLOGY

The fifth generation of technological development (nanotechnology) has become the interest of many developed countries with the objective of developing and saving energy used in the building sector by 90% [2]. This is because nanotechnology

represents a scientific revolution in various fields of life from the use of computers to applications in architecture to reach a balanced environment.

3.1 Nanotechnology Concept

The word Nano is a term derived from the ancient Greek language. The short-form means dwarf and is defined as a very accurate metric unit of measurement, equivalent to 10^{-9} meters, which is ten times the unit of atomic measurement known as angstrom, which is used to express the units of diameters, measures of atoms, and molecules of matter [3].

3.2 Principles of Nanotechnology

The most fundamental principles of nanotechnology is the ability to control atoms in the manufacture of materials and machines and purify them from impurities. Nano materials are used in building materials, with their new and better properties, and are less intensive in the use of energy [3].

3.3 Sustainable Architecture under Nanotechnology

The world began to link nanotechnology architecture to sustainability in all designs and projects owing to the importance of achieving the principles of sustainability for humanity [5]. Nanotechnology is opening up a new world of advanced materials that are more efficient and self-developed, giving new possibilities in sustainable construction, increasing the efficiency of the building's performance and improving the internal and external environment of the building while saving energy as shown in Fig. 1.

3.4 Nanotechnology Applications in Architecture and Construction

Nano science is concerned with the study and production of materials ranging in size ranging from 1:100 nm. These materials are combined with traditional building materials to improve their physical and chemical properties to obtain materials with new properties that exceed the characteristics of conventional materials with respect to strength, durability, and rigidity and thus increase their lifespan. At present, there is a

breakthrough in the field of nanotechnology arising from its integration with sustainability in order to achieve sustainable architecture. Table 1 summarizes some Nano materials and the extent to which they achieved sustainability in architecture [2].

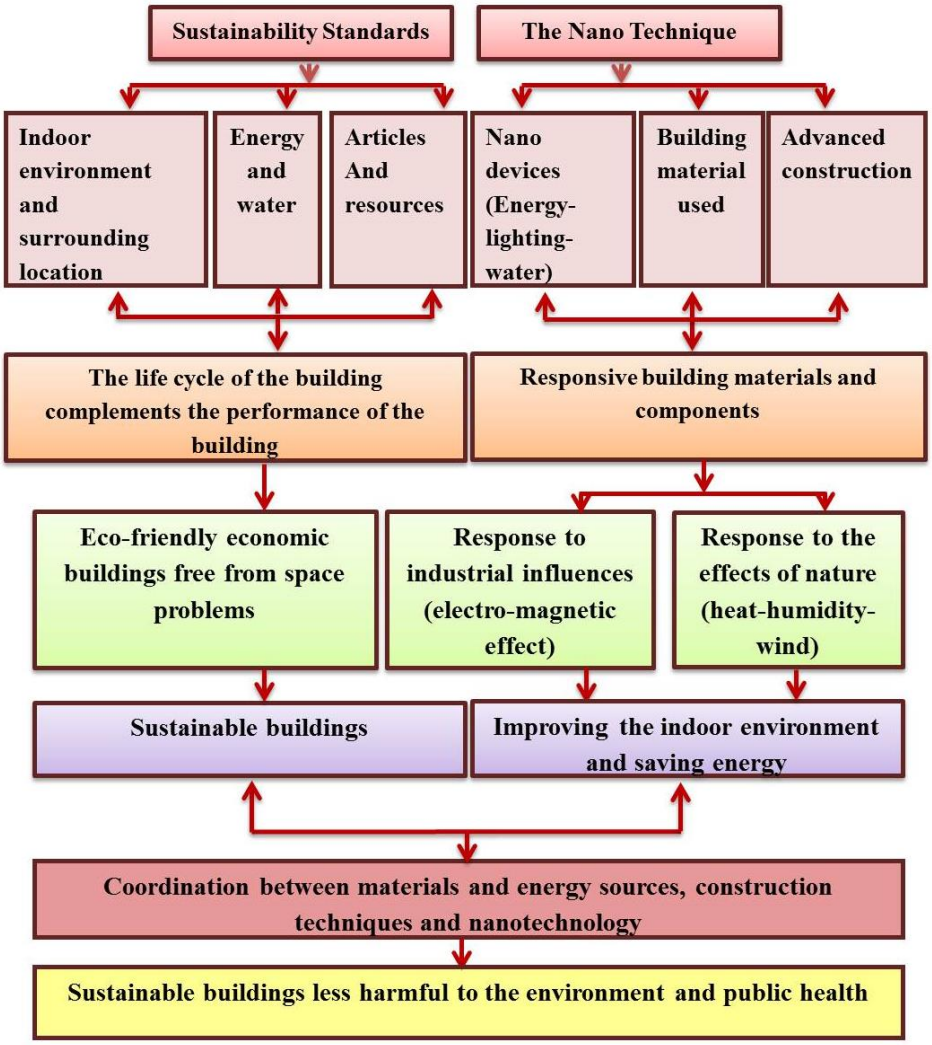

Fig. 1. Relationship between nanotechnology and sustainable architecture [4].

4 METHODOLOGY FOR ACHIEVING SUSTAINABILITY STANDARDS THROUGH NANOTECHNOLOGY APPLICATIONS

The research aims to examine the impact of using nanotechnology applications in construction to determine their role in achieving sustainability standards through an analytical study of selected examples of future projects being implemented using nanotechnology applications.

Table 1. Nanomaterials used in buildings.

Building materials	Nanotechnology applications	Results of building Nano structures
Carbon nanotubes	- Concrete and iron to increase the mechanical strength of buildings - High resistance adhesives - Increased anti-corrosion protection with structures - Improvement of conductors and conductors - 100 times stronger than iron and 6 times lighter in weight - 10 times lighter than steel and 250 times stronger than steel - Electromagnetic radiation dispersion of up to 70% - Flame resistance by adding carbon nanotubes to liquid glass	- Increased durability and rigidity - Building longevity - Energy Efficiency - It speeds up the processes of water saturation of the silica gear mixture - Increased frost resistance from 150 to 400 degrees Fahrenheit by 50%
Nanowires	- Zinc oxide in combination with graphene to produce new solar cells and nanoscale sensors - Silica oxides for storing energy with high-efficiency batteries	Energy Efficiency
(Silica Nano) in concrete	- An alternative to cement with concrete - Adding 3% increases the compression and bending strength of the normal cement mortar by 10% to 25%, respectively	- Reduces carbon dioxide emissions - By adding 3% calcium cilium silicate, the tensile strength in the cement paste increases by 45%.
	- Adding it by 6% to 11% increases the strength of the concrete pressure by 30% to 40% add it by 2%	- Air Purification - Increases concrete strength by 17% - Self-cleaning
	By adding silicon dioxide SiO_2	The glass has a fire-resistant property
Thin-film insulation	- Blocking sunlight - Low room temperature by 3-4°C	- Reducing electricity costs for air conditioning - The ability to absorb infrared radiation
Solar Absorbing Windows	- The heat gain coefficient is 0.56 - Visible light transmittance of 75%	- Reducing external noise - Formability on flat and curved building facades
Self - Cleaning – Louts effect		- Non-sticking of impurities on the paint surface - Reduced maintenance cost
Self-cleaning – photo catalytic-		- Easy cleaning of surfaces - Combating air pollution - UV blocking - Reducing maintenance costs
Reflection	- Improve the light transmittance of glass to 98% and plastic to 99% - 20% improvement in building lighting efficiency	- Low light reflected to 1%. - Improving the performance of solar cells with an average reflection coefficient of 2.9%.

4.1 Manuel Gia Gonzalez Hospital Project

Manuel Gia Gonzalez Hospital, located in the Tlalpan neighborhood of South Mexico City, was completed in 2013. It was designed by Allison Dring and Daniel Schwaag. Units were used to cover the entire facade, which is a three-dimensional collectible decorative architectural unit that removes air pollutants through applications of nanotechnology in a self-cleaning coating- optical stimulation- using titanium dioxide, TiO_2. The units are characterized by ease of installation and assembly. The ductility of the formation is shown in Fig. 2.

Fig. 2. Manuel Gia Gonzalez hospital project units [21].

Table 2 summarizes the impacts of using TiO_2 on the Manuel Gia Gonzalez Hospital. Other impacts of using the TiO_2 units are elimination of car pollutants, reducing wind speed, and building shading to keep building temperature low, and reducing building heat loads [9].

4.2 The Italian Pavilion Building at the 2010 Expo, Architect Giampaolo Ambregi

The building is located next to Hanbo River in Shanghai, China, which relied on construction with Nano materials, namely light-emitting concrete, which saves energy and is self-cleaning, and stainless steel low-emission concrete.

Table 2. The impact of nanotechnology applications at Gia Gonzalez hospital.

Nano-materials used				
Coating	Glass			
Criteria of sustainability				
Internal environmental efficiency	Materials and resources	Energy efficiency	Water efficiency	Site sustainability
- Self-cleaning walls - Air purification - Natural lighting - Natural ventilation	- Non-polluting materials - The best use - Self-cleaning materials - The average lifetime of the materials is longer than that of conventional materials	- Air purifier from the cover of the building - Natural lighting for the entire building - Natural air cooling Save maintenance and cleaning energies	- Self-executing facades and walls	- Air technology for the outdoor environment - Air pollution control - No negative impact on the site - Reducing the carbon release
Employing Nano -applications to achieve sustainability standards				
The Internal Environment	Building Envelope			Structural Structure
The internal voids are based on nanomaterials: The facades are self-cleaning and resistant to bacteria and fungi. The internal facades act as a filter and internal air filter	The cover of the building deals with two levels: The first level: The cover of the traditional building, which serves internal spaces and nurtures them with light and air The second level: The suspended facades and work on the level of the external and internal environment so that they work to purify the external air with the processes of purifying the air feeding the building and shading operations and it consists of modular units (prosolve370e) equipped with Nano coating to stimulate light			The dependence on nanomaterials was not mentioned in the structural structure
Result				
- The building is a merger (nanotechnology + green architecture) "green Nano architecture" - The building's strategies are based on solar energy and interact with it to combat air pollution and work on filtering and purifying the air. - The building introduces a new concept of using building facades - The building relies on (prosolve370e) to achieve air technology strategies - The building presents a new concept of architecture and its role in improving and removing environmental pollution and helping to improve the internal and external environment in the field of air pollution [5].				

4.2.1 Building design

The building is designed in the form of a square block divided into 12 parts connected to each other by the Venetian barriers, making the galleries visible. The building relied on transparent concrete as a main material ranging from 30% to 85%, thus covering a total area of the building equivalent to 45%. The stainless curtain wall

of glass panels are also self-cleaning. The cover of the building represents technological advances in the study and production of innovative materials in the dynamic and high vitality in terms of the use of transparent concrete panels and alternating with non-surface slabs. Transparent concrete gave harmony in the functional expression of the interior spaces of the building as shown in Fig. 3 [6].

Fig. 3. The Italian Pavilion building [22].

4.2.2 Impact on the performance of the environmental building

- The interior climate of the building was controlled as the building was designed as a dynamic climate machine. The pavilion adopts solar energy technology and airflow in the summer to reduce temperature through the automatic regulation system.
- Using the latest innovative materials such as transparent concrete. This enables the control of the internal and external temperature and humidity of the building.
- Clear glass is characterized by being a low emission material and saves energy [7].
- Active concrete in the walls and ceramic tiles in some internal voids reduces smoke and purifies the air from different pollutants as shown in Fig. 4.
- Providing light energy thanks to the low emission technology that allows the entry of sunlight and avoids ultraviolet and infrared radiation as shown in Fig. 5.
- Reducing environmental pollution by adopting the technology of optical cleaning. This permanently cleans the facades, which reduces environmental pollution, because there is no need to use industrial detergents that harm the environment This is also known as self-cleaning technology

- Energy saving as energy-saving glass is used to collect heat as in some areas it contains photovoltaic modules that absorb solar energy and convert solar radiation into electrical energy so as to provide complete electrical energy and improve the temperature in enclosed spaces [8].

Fig. 4. Lighting concrete wall [22].

Fig. 5. Concrete and curtain wall facade [22].

4.3 Capital Business Park, 26th of July Corridor, Al Sheikh Zaid

The study of facades is one of the main challenges faced by designers to reach thermal comfort within the spaces. Most public buildings are built from curtain walls for speed and ease of installation, and use with large flat swabs for wider and clearer vision. The world accordingly began to search for and interact with smart materials in buildings [11, 12].

- This building was chosen because it is an existing administrative building occupying a large area. It is multipurpose building employing a large number of workers in the different sectors as shown in Figs. 6, 7 [23]. This increases energy consumption in the building during the day. The design of the facade is based on a fixed design network, a traditional facade of curtain walls treated for thermal emission. The lack of control on solar radiation and its inability to self-clean affect the energy efficiency of the building.

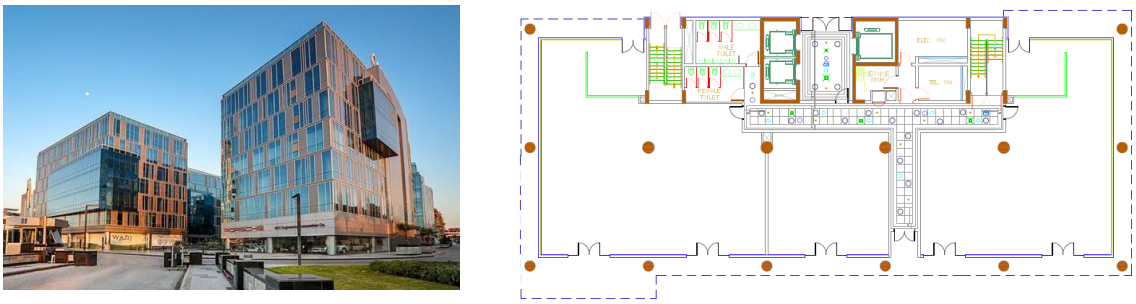

Fig. 6. Capital Business Park facade and plan [23].

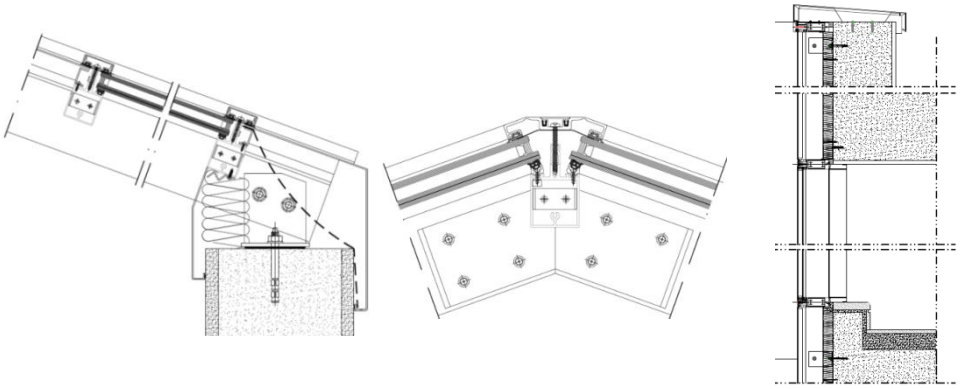

Fig. 7. Section of curtain wall and skylight [23].

A study will be carried out on the building's external cover materials and the extent to which the building benefits from the cover. The glass used has a thickness of 6-8 mm and is thermally treated to increase the building's energy consumption. It is non-soundproof, easy to break, cracked, non-fire resistant and unable to self-clean.

Since smart materials systems have been developed over the past years and this technology could be introduced in a variety of ways to help develop the exterior of the building. This would enable control of the thermal environment within the vacuum. Smart interface systems have many benefits in the building, and there are many smart interface system functions such as:

- Introducing appropriate processors into the facades to take advantage of natural light and acoustic insulation of noise surrounding the building to provide internal energy for the building.
- Electrical glass is one of the modern systems of solar radiation control where the permeability of light and transparency can be controlled and changes the dimming degree by electrical control. When sunlight shines on the glass, the glass changes from transparent to degrees of blackouts required by the electrical current as shown in Fig. 8 [14, 15].

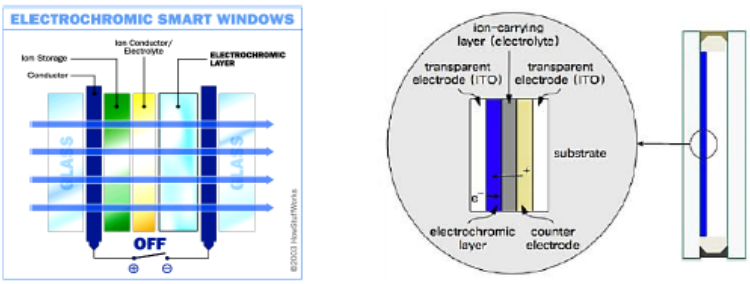

Fig. 8. Electro-chromic smart windows [14, 15].

- Self-Cleaning glass is a treated glass against the adhesion of dirt and contains a thin layer of 15 micron Nano titanium dioxide. Dirt is removed by photosynthesis or by water, saving effort, time and money in the cleaning process.
- UV protection glass is a transparent glass that does not obstruct vision or exhaust natural light, and thus reduces the energy consumption of light and reduces the inlet of ultraviolet (invisible rays). This is a large percentage of solar radiation, increases the vacuum temperature and increases air conditioning loads without light benefit, reducing solar thermal energy gains by about half [16, 17].

A multi-functional glass based on surface nanosecond tissue that produces a wide range of conical features such as self-cleaning glass that resists fog and is anti-reflective and can be used in part of the building or as a cover block of the building with maximum sustainability of design.

Nano architecture has contributed to the improvement and elimination of environmental pollution and has helped to improve the internal and external environment. The ability to process and clean the windows and enhance the concept of interaction with different levels of intelligence, turning the static structure cover into a reactive cover and dynamic system that adapts to the construction and user needs [18].

4.4 Off the Grid: Sustainable Habitat 2020 Tower, Architect Philips's Design Probes, China [9].

The project Off the Grid Sustainable Habitat 2020 Tower is located in China, designed by Philips's. It based on the development of sustainable housing through nanotechnology applications so that it works with the principle of no residues and self-sufficiency of water and energy through the casing of the bio building. It consists of multifunctional Nano cells of a cylindrical shape that allows for a conical shape as a flower during the work of the cell and consists of an inner body of solar cells and its center is Nano devices to purify the air and around openings connected to water paths that open during the presence of rain.

The construction structure of the building is a network of interlaced pipes at an angle of 45 hollow savoir-so-wide through which nanowires pass through the

electricity generated from solar cells. Also, there are pipes to transport rainwater water to the water tanks and the air transportation after the process of purification to the internal spaces as shown in Fig. 9.

The atmosphere of the building acts as a bio transmitter between the external and internal environment where it feeds the inner spaces with natural lighting and generate swaying electricity for night lighting through solar cells and providing fresh air and fresh water. Table 3 summarizes the impact of applying nanotechnology to the Off the Grid Tower.

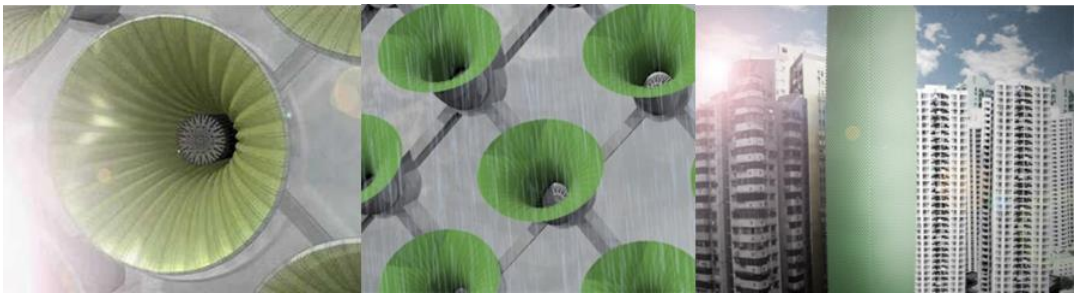

Fig. 9. Active skin channels light and generates energy.

Table 3. Impact of nanotechnology application at the off the grid: sustainable habitat 2020 tower

Nano-materials used: Glass				
Criteria of sustainability				
Internal environmental efficiency	Materials and resources	Energy efficiency	Water efficiency	Site sustainability
- Natural ventilation - Air Filter - Natural lighting - Pure water - Health heating - The blanks are smart. - Natural cooling	- Optimal exploitation of all materials. - Recycling of solid and organic building waste - Use of smart and non-polluting materials for the environment - Multi-use materials	- Electricity generation from PV cells - Air purification by Nano cells - Recycling waste for biogas generation - Turning grey water - Self-sufficiency of natural energy	- Collecting rainwater and storing it in channels - Attracting moisture from the air - Purification and filtration of rainwater - Use the water in a closed loop for reuse. - Purification of drainage water.	- Air pollution control - No negative impact on the site - Air purification for the external environment - Self-sufficient energy. - Self-sufficient water and drainage systems. - Reducing carbon release - A breather for the big cities.

Table 3. Impact of nanotechnology application at the off the grid: sustainable habitat 2020 tower, (Cont.)

Employing Nano -applications to achieve sustainability standards		
The Internal Environment	Building Envelope	Structural Structure
- The internal environment is smart and does not do the activities of lighting or water except when the user's need is sensed and determine the quality of the activity that you are doing do not waste any unused energies	- The casing of the building is a vital transporter of energy through sensors and power tanks in response to the internal spaces required - The casing of the building is a collection of Nano devices (multifunctional Nano cells) - Water purifiers, air purifiers, energy tanks and photovoltaic cells are integrated into Nano	He did not mention the building's accreditation. On Nano materials in Structural structure, but he benefited from it in a job Wire paths And the pipes.
Results		
- The building is a merger (nanotechnology + green architecture) "green Nano architecture" - The building is the integration of nanotechnology with smart architecture where the building relied on Nano devices to achieve the sustainability of the building from the urge to rely on the external environment and the renewable natural energies to self-sufficiency of electricity, water, air and biogas energy		

5. COMPARISON OF THE STUDIES

Table 4 summarizes the different sustainability aspects of the study as applied to the studied cases.

Table 4. Summary and comparison of the studied cases.

Project	Hospital General Dr. Manuel Gia Gonzalez	The Italian Pavilion Building At The 2010 Expo	Capital Business Park,	Off the Grid Tower, Sustainable Habitat 2020 Tower
Location	Tlalpan neighborhood of South Mexico City	China , Shanghai , Next to Hangpu River	26th of July Corridor, Al Sheikh Zaid,Giza,Egypt	China
Type of Building	Hospital	Expo	Business Park	Tower
Nano-materials	Material (prosolve370e) , Coating And Glass processor	Transparent Concrete And Glass processor	Glass processor	Glass processor
Project	Hospital General Dr. Manuel Gia Gonzalez	The Italian Pavilion Building At The 2010 Expo	Capital Business Park,	Off the Grid Tower, Sustainable Habitat 2020 Tower

Table 4. Summary and comparison of the studied cases, (Cont.)

Employing Nano -applications to achieve sustainability standards	- The facades are self-cleaning and resistant to bacteria and fungi - The suspended facades and work on the level of the external and internal environment so that they work to purify the external air with the processes of purifying the air feeding the building and shading operations and it consists of modular units (prosolve370e) equipped with Nano coating to stimulate light	No negative impact on the site - Reduce environmental pollution thanks to photo cleaning technology, which helps not to use industrial cleaners that harm the environment thanks to self-cleaning technology - Glass contains photovoltaic units which help save energy and improve the temperature in place by converting solar radiation into electrical energy - Flexibility in vacuum design	No negative impact on the site - Control the internal climate of the building through automatic regulation and reliance on solar energy to heat the place - Helps not to use industrial cleaners that harm the environment thanks to self-cleaning technology - Glass contains UV protection glass units which help save energy and improve the temperature in place	-The casing of the building is a vital transporter of energy through sensors and power tanks in response to the internal spaces required - The casing of the building is a collection of Nano devices (multifunctional Nano cells) Water purifiers, air purifiers, energy tanks and photovoltaic cells are integrated into Nano
Summary of Results	-The building's strategies are based on solar energy and interact with it to combat air pollution and work on filtering and purifying the air. -The building relies on (prosolve370e) to achieve air technology strategies -The building presents a new concept of architecture and its role in improving and removing environmental pollution and helping to improve the internal and external environment in the field of air pollution	The building depends on all its elements (construction structure - the cover of the building - interior spaces) to achieve sustainability strategies - The building relied on nanotechnology (Nano materials + Nano devices) to achieve the sustainability of the building from a range of strategies for the exploitation of materials	The building depends on all its elements (the cover of the building - interior spaces) to achieve sustainability strategies - The building relied on nanotechnology (Nano materials + Nano devices) to achieve the sustainability of the building from a range of strategies for the exploitation of materials	- The building is the integration of nanotechnology with smart architecture where the building relied on Nano devices to achieve the sustainability of the building from the urge to rely on the external environment and the renewable natural energies to self-sufficiency of electricity, water, air and biogas energy

6. CONCLUSIONS

- Nano applications in architecture have introduced a new world of advanced building materials that are more efficient.
- The use of nanotechnology in the design process led to a fundamental change in architectural thought and added a new dimension to the architect to enable full embodiment of ideas.
- It provided wide possibilities in the design of flexible or complex shaped blocks.
- Nanotechnology has contributed to the improvement of the performance of many building and cladding materials and raised its environmental and plastic efficiency.
- Nanotechnology takes internal building materials to new levels in terms of performance in the fields of energy and light. Nano materials have covered several points, aesthetic, functional, economic and environmental.
- Characteristics of Nano materials: They are multiple and divide Nano materials as well as define their uses. They help Nano materials to preserve the environment, including self-cleaning materials and air purifiers, among others.
- When using nanotechnology, intelligence and sustainability can be combined to describe the building, as some aspects of smart technology provide ideas and technologies that achieve sustainability results.
- There are no restrictions in design thinking by use nanotechnology. They are used in either traditional or modern buildings, or public or private buildings.
- Different uses of Nano materials and their effect on the external appearance of the facades and structural materials applied to the nanotechnology (concrete, iron and wood) and the effect of each of the materials on the structures of the buildings have been reached. Finishing materials (glass, aluminum, coatings and insulation materials) have been identified together with the extent of their impact on the building.

The following recommendations are the result of the study carried out in this work.

- Directing scientific and applied research to nanotechnology sciences to find an integrated system of nanotechnology applications in engineering sciences with their various architectural, civil, and environmental specializations.
- The need to increase the awareness of specialists in the field of architecture to the potential of nanotechnology applications in architecture through conferences, seminars and lectures.
- Call for the intensification of academic subjects on Nano architecture in university curricula.
- Utilize smart and sustainable nanotechnology materials and systems as innovative alternatives in value engineering studies for engineering designs and projects.
- The necessity of working on studying the negative aspects and warnings of nanotechnology and raising awareness of its dangers and how to avoid them or reduce their effects.
- The ability to absorb and adapt nanotechnology according to the requirements of development programs in the Arab countries, to prepare legislations and governmental departments and laws for nanotechnology in the Arab world.
- Educating architects on the most important ideas and outlines related to nanotechnology, so that the architect is aware of the importance of awareness of nanotechnology as a tool affecting architectural thought.
- Presenting the idea of using nanotechnology at the level of large national projects with huge budgets and under the auspices of state institutions.
- Raising the efficiency of existing buildings by applying nanotechnology to buildings.
- Forming an integrated research team that covers all disciplines related to nanotechnology in architecture to carry out a series of specialized research and studies, and to conduct integrated studies on the environmental and economic aspects, maintenance, and operation.

- Research bodies should pay attention to research in the field of nanotechnology to infer new materials that contribute to solving building problems in terms of cost and energy consumption.

DECLARATION OF CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

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نحو تطبيقات تقنية النانو لتحقيق العمارة المستدامة

برزت تكنولوجيا حديثة تسمى بثورة النانو تكنولوجي والتي تعد قفزة تكنولوجية هائلة اثرت في جميع المجالات وخاصة بالعمارة والعمارة المستدامة. ويلخص البحث الى ان النانو تكنولوجي تعتبر ثورة العصر والمستقبل وتطبيقها في مجال العمارة ويساهم في تطويرها فكرا وشكلا وموائمة البيئة حيث جاءت عمارة النانو لتشكل حلقة الوصل ولتساعد في الوصول الى تحقيق التوازن بين تكنولوجيا النانو والعمارة المستدامة وتسد الفجوة التكنولوجية بينهما من خلال استحداث مواد للاكساء والانشاء تمتاز بخصائص ذكية ومستدامة صديقة للبيئة حيث عززت تكنولوجيا النانو مفهوم التفاعل مع المستويات المختلفة مع الذكاء فتحول غلاف المبنى الثابت الى غلاف متفاعل ونظام ديناميكي يتكيف مع العوامل البيئية الخارجية.