THE AVAILABILITY OF NANOMATERIAL FOR BUILDING PRODUCTION IN THE CONTEXT OF SUSTAINABILITY

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
AHMAD ZYAD ALJENBAZ

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Architecture

NICOSIA, 2017

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Approval of Director of Graduate School of Architecture

Prof. Dr. Nadire ÇAVUŞ

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Architecture

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Ahmad Zyad Aljenbaz

Signature:

Date:

ACKNOWLEDGEMENT

Completion of a Master's degree involves contributions from individuals who deserve recognition. A special word of thanks is due to Dr. Çiğdem Çağnan, for guiding me in this undertaking. As well as her willingness to work long hours toward the completion of my degree.

I would like to thank the one who was more than a father to me my uncle Mr. Mohammad zuher Almsaddi for his support through the duration of my study. Also, I would like to express my deepest thanks to my family, and especially to my Mother for their understanding, endless patience, support and care.

Eventually, there is a long list of friends that I would like to thank. I can’t mention them all but I would like to thank them from all of my heart for their valuable help and support since I was in my early study until now.

To my parents…

ABSTRACT

Nanotechnology is a very new technology which created by manipulating the small particles in the material in order to make new products with different features or new in physical, mechanical and chemical properties. Nanotechnology brings new solutions in economic, ecologic and social ways to participate in achieving sustainability. The advantages in nanotechnology to reduce the harm to the environment had been shown in building construction field by using nanomaterials with traditional products or by creating new products. This thesis is divided into five parts which review this topic in a serial and scientifically method. Firstly, it starts with general information about the thesis problem, scope and aim, the importance of the thesis, methodological approach is explained. In the following chapters, the definition of nanotechnology generally and classification of nanomaterials in building production is made. Nanotechnology, nanomaterial and nanoarchitecture applications in building production are examined together with examples. Nanoarchitecture and its relations with sustainability are analyzed. Finally, the nanomaterials are tested in a test and evaluation matrix according to environmental-social-economical sustainability criteria. Test results are explained with a test evaluation report.

Keywords: Nanotechnology; nanoarchitecture; nanomaterials; sustainability; nanomaterials test matrix

ÖZET

Nanoteknoloji, malzemenin içerisindeki küçük parçacıkları manipüle ederek farklı özelliklere sahip veya fiziksel, mekanik ve kimyasal özellikleri açısından yeni ürünler üretmek amacıyla ortaya çıkan çok yeni bir teknolojidir. Nanoteknoloji, ekonomik, ekolojik ve sosyal yönlerle sürdürülebilirliğin sağlanmasına katkıda bulunmak için yeni çözümler getirmektedir. Nanoteknolojinin yapı üretimi alanında çevreye verilen zararları azaltma yönündeki avantajları, nanomalzemelerin geleneksel ürünlerle birlikte kullanılması veya yeni ürünlerin üretilmesi yoluyla olmaktadır. Bu tez, konuyu seri ve bilimsel bir yöntemle inceleyen beş bölüme ayrılmaktadır. Öncelikle tezin problemi hakkında genel bilgi ile başlayarak, tezin kapsamı ve amacı, önemi, metodolojik olarak bakış açısı açıklanmaktadır. Sonraki bölümlerde sırasıyla, nanoteknolojinin genel tanımı yapılarak yapı üretiminde kullanılan nanomalzemeler sınıflandırılmaktadır. Nanoteknoloji, nanomalzeme ve nanomimari uygulamaları örneklerle birlikte incelenmektedir. Nanomimarinin sürdürülebilirlikle olan ilişkilerinin analizleri yapılmaktadır. Sonuçta nanomalzemeler, çevresel-sosyal-ekonomik sürdürülebilirlik kriterlerine göre bir test ve değerlendirme matrisinde test edilmektedir. Test sonuçları bir test değerlendirme raporuyla açıklanmaktadır.

Anahtar Kelimeler: Nanoteknoloji; nanomimari; nanomalzeme; sürdürülebilirlik; nanomalzeme test matrisi

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LIST OF ABBREVIATIONS

3D:	The third dimension
3G:	3rd Generation
ACS:	American Chemical Society
AFM:	Atomic force microscope
ALD:	Atomic layer deposition
AR:	Anti-reflective.
AU:	Gold
BREEAM:	Building Research Establishment Environmental Assessment Method
BRT:	Bus Rapid Transit
BSU:	Ball State University
℃:	Degree Celsius
C60:	Fullerenes
CG:	Computer graphics
Cm:	Centimeter
CO:	Carbon monoxide molecule.
CO2:	Carbon dioxide
CVD:	Chemical vapor deposition.
DNA:	Deoxyribonucleic acid
DTI:	Department of Trade and Industry
ECOFYS:	A Navigant company, is a leading international energy and climate consultancy focused on sustainable energy for everyone
EPA:	Environmental Protection Agency
EPIL:	Elan Pharma International
ETC:	Easy to Clean
ETFE:	Ethylene tetrafluoroethylene
EU:	European Union
FE:	Iron atom
GHG:	Green House Gas
GNA:	Green Nano Architecture
GNT:	Green Nanotechnology
H2:	Hydrogen
HQ:	Headquarters
HVAC:	Heating, Ventilating, and Air Conditioning
IIT:	Illinois Institute of Technology
INP:	Indium Phosphide
IR:	Infrared Radiation
IT:	Information Technologies
KKC:	Kaldewei Kompetenz-Center
Km/h:	Kilometers per hour
Km:	Kilometers
LEDs:	Light-Emitting Diodes
LEED:	Leadership in Energy and Environmental Design
M:	Meter
M²:	Square Meter

MBE:	Molecular Beam Epitaxy
MEMS:	Micro Electro Mechanical Systems
MIT:	Massachusetts Institute of Technology
Mm:	Millimeter
MSV:	Meidericher Spielverein football team
MTE:	Millions of Tones
NA:	Nanoarchitecture
NASA:	National Aeronautics and Space Administration
NEMS:	Nanoelectromechanical Systems
NH:	National Highway
NM:	Nanometer (nm)
NMI:	Nano Manufacturing Institute
NO:	Nitrogen Oxide
NSTI:	Nano Science and Technology Institute
NT:	Nanotechnology or Nanotech
NVS:	Nano Vent-skin
NYC:	New York City
PCMs:	Phase Change Materials
PNAS-1981:	Positional Assembly to Atomic Specification
PNCs:	Polymer Nanocomposites
PTFE:	Poly Tetra Fluoro Ethylene
PVC:	Polyvinyl Chloride.
S&T:	Science and Technology.
SAM:	Scanning Acoustic Microscope.
SBS:	Sick Building Symptoms.
SEM:	Scanning Electron Microscope.
SI:	System Internationale
SiO2:	Silicon dioxide
STM:	Scanning Tunneling Microscope
SVOC:	Semi-Volatile Organic Compound
SW:	State highway
TiO2:	Titanium dioxide
TV:	Television
U. S:	United States
UC:	University of California, Berkeley
UCLA:	University of California, Los Angeles
UEFA:	Union of European Football Association
UK:	United Kingdom
USA:	United States of America
UV:	Ultraviolet
VIPs:	Vacuum Insulation Panels
VOC:	Volatile Organic Compound
W.C:	Water-Closet
W/MK:	Watt per meter Kelvin

CHAPTER 1

INTRODUCTION

Nanotechnology is called to the science which produces materials on a very small scale. It is a new multidisciplinary science. The relation between this new technology and architecture is with materials science.

Nanotechnology products which identified by the manufacturer, there is right now more than 450 products on the market and more than 600 intermediate components, raw materials and industrial equipment items which used by manufacturers of nano.

Since it is a new technology, there are a lot of questions about these products according to the risk that's coming from nanomaterials on users, workers and the environment. Environmental Protection Agency (EPA) and other organizations work together to find new methods and move forward with a plan of action, in order to have a regulatory system which is effective for nanotechnology to achieve sustainability, in order to make an environmentally sustainable society in the twenty-first century.

In this thesis, it gives a look at the beneficial bonds between nanotechnology, architecture, and material science on the scale of molecules and sustainability. It goals to achieve a reduction in environmental impacts by conserving the resource and make improvements in eliminating the waste in both products and processes.

It concludes, with evaluation and analysis of nanomaterials that can be recommended in order to help the development of nanotechnology to grow green and participate in sustainability.

1.1 Thesis Problem

Because of global warming and the pollutant in the environment, the scientists and building developers, search in many ways to find a solution to achieve sustainability. *Can nanotechnology help to solve this problem?* The effort spent to find an answer for this question brought this study to become a thesis. The professions which work on the buildings have hesitated to use this new technology in building production because the lack of knowledge in new applications and their possibility to improve new building materials. Also, the research literature and the studies about the use of nanomaterials is less. This thesis tries to explain the possibility of using nanomaterials in building production, by analyzing table and material evaluation matrix according to sustainability criteria.

1.2 The Scope and Aim of The Thesis

Nanotechnology is the fastest improving tech of the 21st century. Nanomaterials, which is a product of this new technology is used in the architectural field. Compared with traditional products. The materials which produced with this technology can be more durable, longer lasting, better quality, lighter and smaller.

The main goals of this thesis are:

- Introduce nanotechnology to the architect's which may impact on the life.
- Examine the properties of nanomaterials and their impacts on both architecture and environment.
- Reveal the possibility to use nanotechnology applications in architecture by presenting some effective examples.
- Discuss from the point of view of architect's, whom concern with sustainable components in building production. A way to achieve sustainability through usage nanotechnology in optimizing the use of building materials. Improving the environmental conditions of the building, decreasing the consumption of energy, decreasing air pollution and introducing renewable energy.
- Clarify the advantages and disadvantages of nanomaterials and their affect to achieve sustainability, by analyzing the applications.
- Give information about the potential futuristic nanoarchitecture applications to achieve sustainability, by introducing some examples.

- Analyze and evaluate the applications of nanomaterials within the context of the environment, human health, energy and resource conservation.

This thesis includes nanomaterials which are used or have the potential to be used in the field of architecture to achieve sustainability. The other nanomaterials that are used in other fields are excluded.

1.3 The Importance of the Thesis

Nanotechnology is still considered new in this field, there is a lack of literature. For this reason, this thesis may be a fine addition to the references of this field. Knowledge of nanotechnology applications in architecture and building production can help to solve many of the most important recent global problems. It can reduce dependence on nonrenewable sources, improve the health system and help with the global issue of sustainability. Such as reducing energy and raw materials consumption, the emissions of CO2 and saving the natural resources.

1.4 Methodology

All the data onto this thesis are collected according to the literature survey from primary sources such as books, journals, articles and internet sources. Literature review is done to collect data for analysis table and evaluation matrix.

After literature review, the data bank is formed and analysis is made focusing on nanomaterials used in building production. In the analysis, the criteria for achieving sustainability and nanomaterial applications are taken and tested within a matrix. The test results are explained with an evaluation report. To reach the aim of the thesis these steps are followed;

- Definition of the nanotechnology generally, then through the architectural applications had are made (Table 2.3).
- Different examples in nanoarchitecture are reviewed and classified (Figure 3.4).
- The advantages and disadvantages of using nanomaterials in building production are analyzed (Table 3.16).

- Analysis of nanomaterials in building production within the context of sustainability are made (Table 3.16).
- Different applications of nanomaterials within an evaluation matrix are studied and evaluated (Table 4.7).
- Test evaluation results are reported.

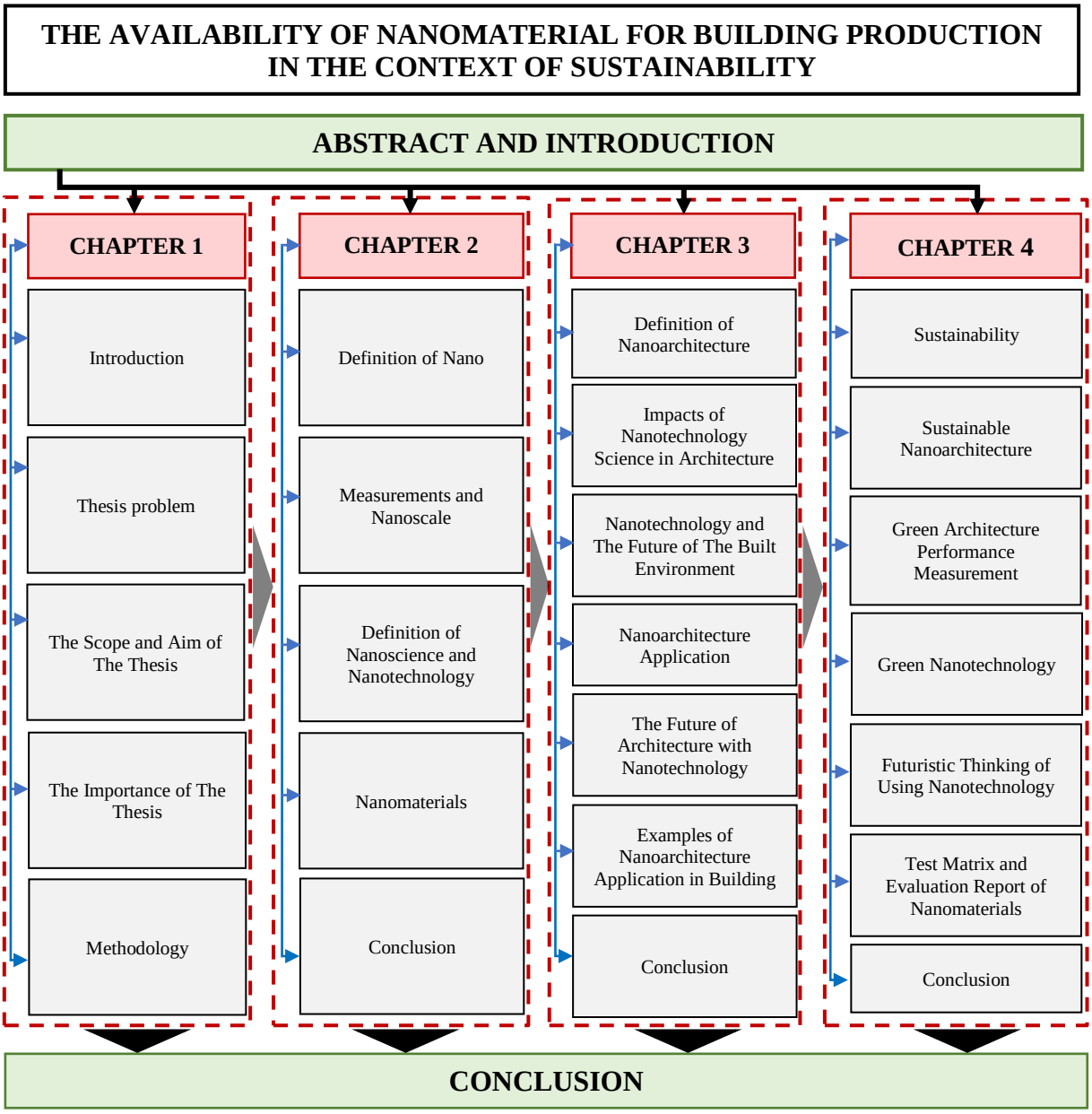


Figure 1.1: Thesis structure chart

CHAPTER 2

DEFINITION OF NANO

Amid the most recent decade, a fresh out of the new term has entered into English dictionary which is Nano. That tuned into the word in lots of movies, it can be recognized on TV and in daily papers and magazines. Scientists say it can clear the strategy for new possibilities. There are different option sentiments concerning of wherever this new innovation can reach. In any case, everyone has a similar feeling that this science and in like manner the fresh out of the new advancements that originated from it have the shot of recognizably affecting to the reality (Loeve, 2010).

Nano, is a shortcut that originates came from the Greek word for dwarf person, it parsimoniously implies one billionth, along these lines, one nanometer (1nm) is equal one billionth of a meter (Figure 2.1). Nano have 3 essential terms to consider when you end up attempting to comprehend the developing news scope and scientific discovery inside the range of nanotechnology and those are Nanoscale, Nanoscience and Nanotechnology (Loeve, 2010).

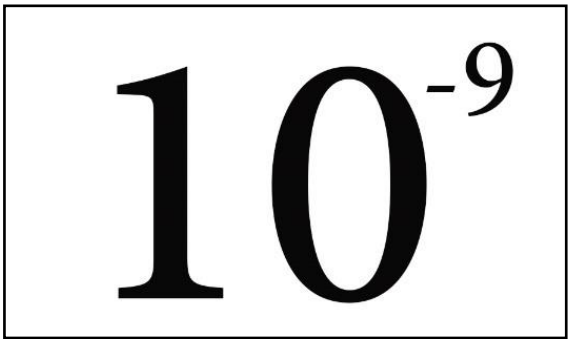


Figure 2.1: This is the way Nano is spoken to scientifically in mathematic way, ten to the negative ninth equivalents one billionth or 1/1,000,000,000 (Loeve, 2010)

2.1 Measurements and the Concept of Nanoscale

Usually when, measure mass, length and quantity, are measurement in the metric system, here in (Table 2.1) list of metric measures to assist those that are not familiar to this process (Loeve, 2010).

Table 2.1: List of metric measures (Loeve, 2010)

Unit	Abbreviation	Description
Meter	m	Roughly three feet or one yard
Centimeter	cm	1/100 of a meter, about portion of an inch
Millimeter	mm	1/1,000 of a meter
Micrometer	μm	1/1,000,000 of a meter, frequently called a micron-most coordinated circuits are at this scale
Nanometer	nm	1/1,000,000,000 of a meter, the extent of a solitary particle

Nanoscale gadgets usually have at least one dimension (height, length, depth) that have been measures within (1-999 nm). As mentioned previously, nanometer is equal to one-billionth of a meter. Everyone struggles to envision this appallingly little scale, nevertheless, that an idea can be getting by the method for assessment coordinating with subjects, should be looked at some standard objects. Get a book and investigate the thickness of each page, the typical page is almost 100,000 nanometers thick. Consideration on the nanoscale the object has one dimension in the vicinity of 1 and 999 nanometers, therefore that is all the more generally without a doubt no longer amongst the nanoscale area. A solitary human hair is including 10,000 nanometers wide, that is the littlest dimension that's humans capable of looking with the eye. Albeit, in fact, nanoscale objects are in the 1-999 nm area. Frequently when some individual indicates one thing as being at the nanoscale, they're talking identified with objects are smaller than a hundred nanometers (Figure 2.2) (Richter et al, 2000).

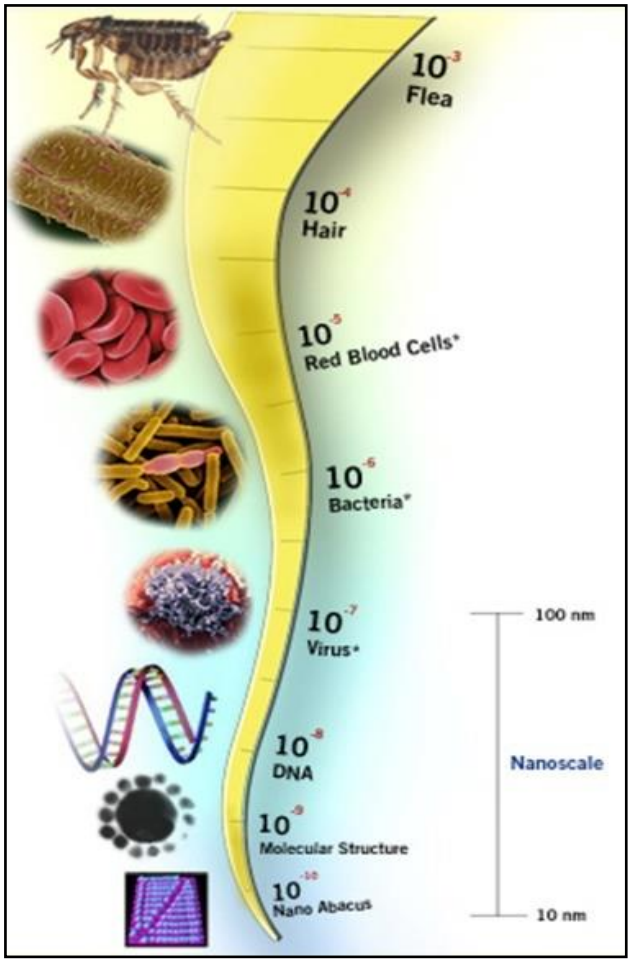


Figure 2.2: Images © Dennis Kunkel Microscopy, Inc. to show the range of Nanoscale (Richter et al., 2000)

2.2 Definition of Nanoscience and Nanotechnology

Nanoscience is the range of science where the size assumes an essential part (in the area of one to a hundred nanometers) at the time when matter size are beneath 100 nanometers that well notes astounding chemical and physical properties. For instance, if had cut a piece of gold into littler and littler things and it may in any case, have indistinguishable color, even in melting point, however at specific scopes of the nanoscale. Gold particles carry on differently. At the (Figure 2.3) beneath its show how gold nanoparticles in totally extraordinary shapes and sizes are distinctive colors. The chemical properties reactivity, combustibility and so on likewise the physical properties melting point, conduction and so forth, can all modification at the nanoscale. Along these lines, the properties are joined to the size of the material, size subordinate properties are the principle reason that nanoscale objects have such magnificent potential (Kolasinski, 2012).

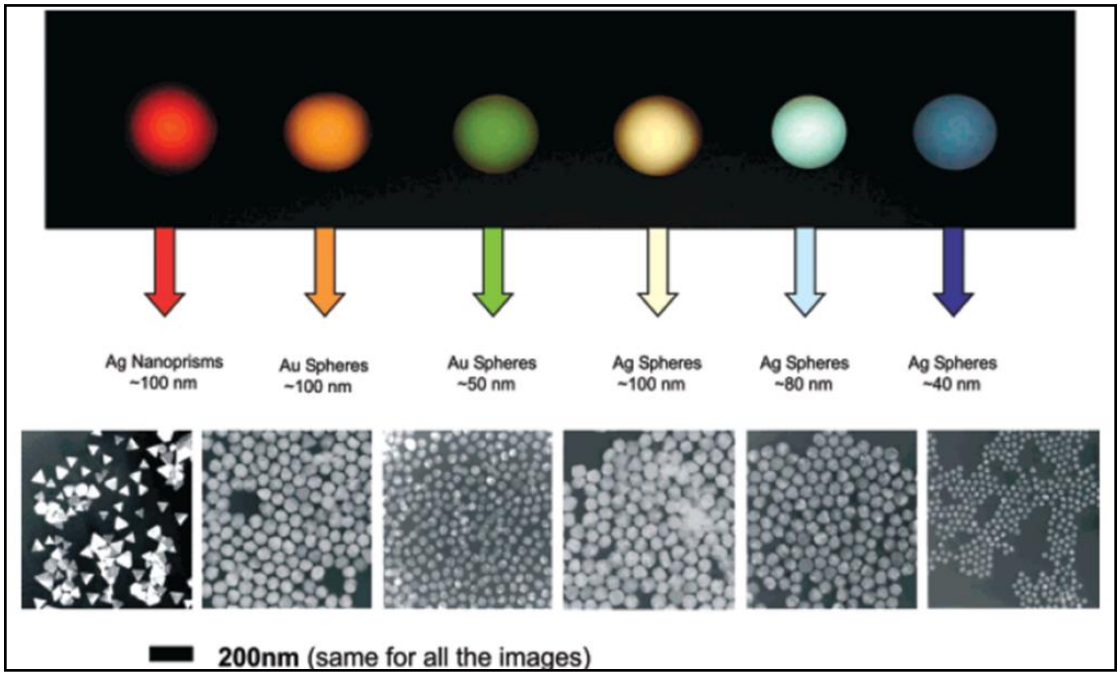


Figure 2.3: Gold particles have different colors according to the size and shape (Kolasinski, 2012)

Nanotech is an abbreviation of Nanotechnology that is the investigation of the management of matter on the range of atomic and molecular scale. For the most part, nanotechnology is working on manages structures of that measurements by one hundred nanometers or littler also includes creating materials or gadgets in this size. Nanotechnology is different and various in many ways, beginning from original extensions of customary gadget physical science, to completely new methodologies are constructed generally depending on molecular self-gathering, to growing a brand-new material in small dimensions reach to the nanoscale range. Even to a hypothesis on if would straightforwardly take control of matter on the area of atomic scale. For instance, in a case if taken aluminum and cut it down half, the piece of aluminum still same. However, when retain slicing aluminum repeatedly till it's reaching out to the dimension of the nanoscale, it ends up unstable and that is frequently because of the change of the molecular structure (Drexler, 1986).

There has been a lot of discussion on the longer term of implications of nanotechnology. Nanotechnology has the potential to form several new materials and devices with wide ranging applications, like in medication, electronics and energy production. On the opposite hand, nanotechnology raises several of constant issues as with any introduction of recent

technology, including considerations regarding the toxicity and environmental impact of nanomaterials and their potential effects on world economics, also as speculation concerning numerous doomsday situations. These concerns have to lead up to a debate among support groups and governments on whether or not special regulation of nanotechnology is guaranteed (Drexler, 1986).

2.2.1 The history of nanotechnology

The first use of the ideas in nanotechnology (but the pre-dating use of that name) was in "There's lots of room at the bottom", a talk given by physicist Richard Feynman at an American Physical Society meeting at Caltech on twenty-nine of December 1959. Feynman represented a method by that the ability to manipulate individual atoms and molecules may well be developed, using one set of precise tools to make and operate another proportionately smaller set, thus on right down to the required scale. Within the course of this, he noted, scaling problems would arise from the changing magnitude of varied physical phenomena gravity would quieten down necessary, surface tension and Van der Waals attraction would become more important, etc. This basic idea seems plausible and exponential assembly enhances it with parallelism to provide a useful amount of end products (Drexler, 1986).

Buckminsterfullerene C60, otherwise called the Bucky ball, it is the simplest phase of the carbon structures known as fullerenes and the main subject of research which is under the nanotechnology range are the members of the fullerene family (Figure 2.4) (Drexler, 1986).

Professor Norio Taniguchi from Tokyo Science university was the first who define the expression "nanotechnology" at 1974 in a paper which says: Nano-technology mainly contains the processing, the separation, the consolidation and in addition the deformation of materials with the aid of one atom or through one molecule. In the Eighties, the elemental thought of this definition was explored in much more depth by Dr. K. Eric Drexler, who promoted the technological significance of nanoscale phenomena and devices through speeches and likewise the books Engines of production: The Coming Era of Nanotechnology (1986) and Nano systems: Molecular equipment, manufacturing and Computation, then the term obtained its current sense. Engines of creation: the upcoming era of nanotechnology is regarded the first book on the subject of nanotechnology. Nanotechnology and nanoscience

got started within the early eighties with two fundamental developments: the birth of cluster science and the invention of the scanning tunneling microscope (STM) (Figure 2.5) (Drexler, 1986).

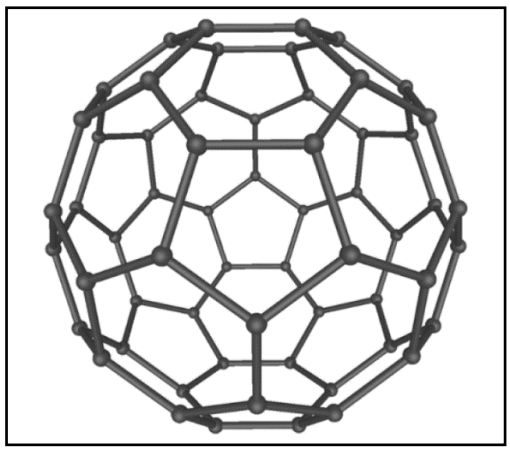


Figure 2.4: Buckminsterfullerene C60 (Drexler, 1986)

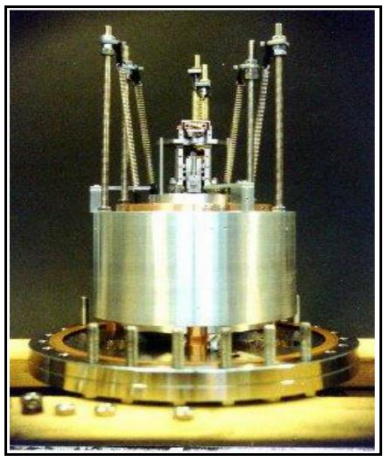


Figure 2.5: The first scanning tunneling microscope (Drexler, 1986)

This progress resulted in the discovery of fullerenes in 1985 and carbon nanotubes a few years later. In another development, the synthesis and properties of semiconductor nanocrystals have been studied. This resulted in a fast-growing number of metal oxide nanoparticles of quantum dots. The atomic force microscope was once fabricated six years after the STM used to be invented. In 2000, united states national nanotechnology Initiative was founded to coordinate Federal nanotechnology study and development (Drexler, 1986).

2.2.2 The fields of use nanotechnology

- Nanotechnology in medicine

The reasons of why using nanotechnology in treatment right now to being create contain utilizing nanoparticles to give medications, heat, light or maybe different supplies to uncommon cells inside the human body. Engineering particles are used in a way to allow the identification or potentially recuperating of infections or wounds inside the targeted cells. Thus leading to reduce the damage to healthy cells in the body, nanomedicine is the name of future of nanotechnology in health treatment, which include fabricated nano-robots that used to do repairs on the cell stage (Hawk's, 2015).

• Nanotechnology in electronics

Using nanotechnology with electronic which called Nanoelectronics give the answers of how can boost the capacities of electronic instruments. Also attempt to decrease the weight and using of energy on it. The most area of nanoelectronics is work in progress and can be investigating in more details by considering the following area:

- developing the tv and monitors which include making it less weighted and thinner and power utilization decreasing.
- growing the capability to store of memory chips, they are working right now on a memory chip with a space of one terabyte of memory in only one square inch or more.
- making transistors which use in integrated circuits, much smaller in size (Hawk's, 2015).

• Nanotechnology and space

Nanotechnology can make space travel more achievable. The Improvements in nanomaterials which can create light-weight solar sails and for the space elevator make a cable to be possible. All that by methods for decreasing the fuel required for ship, with these advances the traveling in space would be cheaper in the cost. Also with help of some new technology like, nanosensors and nanorobots the performance of spaceships, spacesuits and the equipment can be better, which that make nanotechnology have a major role of the ultimate frontier (Hawk's, 2015).

• Nanotechnology and chemical sensors

Because of the small size of nanotechnology detecting elements it can allow sensors to find a very little number of chemical vapors, in different ways. Which is like, carbon nanotubes, zinc oxide nanowires or palladium nanoparticles those can be utilized nanotechnology sensors. The sensor elements need only a small number of gas molecules to make changes on their electrical properties and due to this it detects a very low concentration of chemical vapors (Hawk's, 2015).

• Nanotechnology and fabric

When used nano-sized particles with fabric, that develop the fabric properties and without increasing in weight and thickness, so it would be much better of the previously-used techniques (Hawk's, 2015).

2.2.3 The applications of nanotechnology

It used to enhance the environment some of the nanotechnology technics that's ensure, cleaning the pollution, enhancing manufacturing strategies to reduce the creation of new pollution and making the opportunity to energy resources to be more effective. Nanomaterials can provide a benefit to the society and in below some of the filed that nanotechnology are used in it such as the environment, energy, economy, security and safety (Nanowerk, 2010).

2.2.3.1 Nanotechnology in environment

In natural and man-made environment, nanotechnology can help to clear up issues like soil and groundwater remediation, air purification, pollutants detection and sensing. Its same for human waste reduction inclusive of nuclear waste which additionally requires developing safe geological disposal with strategies proper for society. A better prediction of weather change is immediately related to the know-how of the role of aerosols (nanoparticles) in the atmosphere (Nanowerk, 2010).

• Nanotechnology's potential to reduce greenhouse gases

The major consideration which targeting environmentally beneficial nanotechnologies were the Green House Gas (GHG), they make a detailed investigation on five applications of nanotechnology which is: the added substance to fuel, solar cells, the economy in hydrogen, insulation and batteries (Table 2.2) (Nanowerk, 2007).

Table 2.2: Environmentally beneficial nanotechnologies summary (Nanowerk, 2007)

Application	Impact of nanotech in area	Infrastructural changes	Benefit (Mte CO2 per annum)	Timescale for Implementation (yrs)
The added substance to fuel	Critical	Low	<3	<5
Insulation	Moderate	Low	<3	3-8
Photovoltaics	High	Moderate	c.6	>5
Electricity storage	High	High	10-42	10-40
The economy in hydrogen	Critical	Very high	29-120	20-40

First column: have an impact on of nanotechnology describes the influence nanotechnology is likely to have within the area in comparison with different technologies.

Second column: Infrastructural alterations indicate the hassle bring the nanotechnology to market.

Third column: advantage is the estimate of the maximum potential CO2 saving with the aid of imposing the technology.

Forth column: Timescale for implementation is the projected distance (in years) before the technological know-how can be completely implemented.

• The application of nanotechnology to environmental issues

nanotechnology scientists, researchers and developers are seeking to help the environment, they are trying by the accompanying avenues:

1. Using silver nanoclusters as an impetus to make pollution lesser at some stage of the manufacture phase of materials.
2. Silicon nanowires are used to producing solar cells that produce power which is installed in a polymer which give a lowering in cost, but also higher productivity solar cells.
3. Use windmills which is designed with nanotech to help in produce the power and expand it.

4. Iron nanoparticles can separate the body from the water and dissolve the natural solvent in place, in order to clean the natural chemical polluting groundwater.
5. Searchers are creating nanostructure films which it works is to capture CO2 inside the exhaust stacks of the power plant and don't let it go to the air and poison it.
6. Gold nanoparticles which are comprised of permeable manganese oxide are used to remove volatile organic compounds (VOCs) from the room air. Which is separated VOCs at the temperature of the room.
7. Make use of graphene layers to keeping hydrogen which is used for fuel-cell powered engines. By utilizing it to increase the required power of hydrogen to the graphene surface in a fuel tank. That results to an extended amount of hydrogen storage and the fuel tank can be lighter (Rickerby, 2007).

2.2.3.2 Nanotechnology in energy

The most extreme concerns experiencing the developing nations is the security of energy supply and climate change. The path of using sustainable resources and creating nuclear energy can be taken in order to handle energy consumption and related issues. That's can be conceivable in a long-time term. Nanomaterials can bring an enormous effect potentiality to this area and according to the predictable if it's correct. They get transformational changes in the way of converting and utilizing power and introducing a sustainable, clean, effective, decarbonized, energy system (Nanowerk, 2010).

• Solve some problems related to the environment by using nanomaterial with energy
Saving energy, which happens thru many applications such as, solid sate lights (LEDs) and (OLEDs). By using technology to enhance insulation with nanogel (Figure 2.6). Enhance the performance of the combustion of fuels and make the car weight lighter. Storing energy, by utilizing of lithium-ion batteries for all electronics device and hybrid car (HEV) and using materials which that able to store hydrogen to be utilized in hydrogen-powered vehicles or gas cells. Generating energy, it's typically focused on the reformation of energy to electricity and control it by many applications in, thin film, solar photovoltaic (Figure 2.7) and hydrogen fuel cells (Lambauer, 2012).

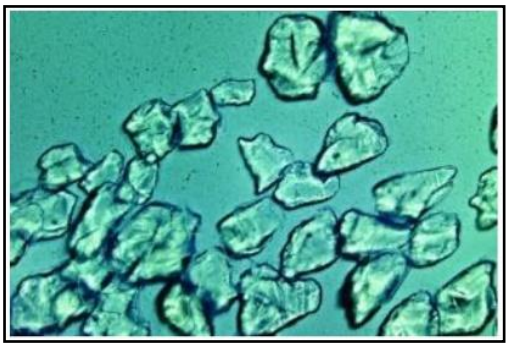


Figure 2.6: Nanogel material (Lambauer, 2012)

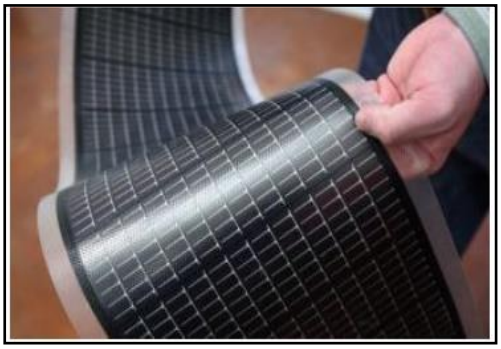


Figure 2.7: Solar Thin film (Lambauer, 2012)

• Application of nanotechnology to produce energy

This is some exciting strategies which is had been developed with nanotechnology to create much more efficient and effective energy according to the cost:

- Using carbon nanotubes to made windmill blades, which is Improving the power generated through windmills.
- Use sheets of nanotubes, in order to produce power from waste heat.
- Produces power from clothes, scientists have progressed in piezoelectric nanofibers, which is flexible and adequate to be formed in clothes.
- Use carbon nanotubes in wires, to reduce the loss of energy in electric transmission wires and to decrease the value of solar cells.
- Reducing the cost of fuel cells and upgrading the production of batteries and improving the general performance.
- Can use of raw materials to produce more efficient fuels (Rickerby, 2007).

2.2.3.3 Nanotechnology in economy

The most leading drivers of economic growth and quality of lifestyles is innovation and science. The research on nanomaterials shows, that it had tremendously effect on health, information, power and a wide range of fields in which there are essentially financial feature to the commercialization on the most recent advances. They depend on the sensible cost of substantial amounts of nanomaterials to emerge intrinsically of the huge capacity for widespread nanomaterials applications, because of the rising state of the field. The widely

available of nanomaterials use, are not all Nanomaterials form situated in the laboratory. Fewer still are taken into consideration of commercialized product. Nanomaterials products also are very costly and as known the costs are always the main factor. It's always referred to as a blocking factor in the improvement of applications including nanomaterials. So many groups which that commercially produce nanomaterials (like different type of nanotubes or nanoparticles) are moving from produce phase to the studies sector to become producers of commodity products. So this move are driven by means of the development of an expanding number of actual applications that request large amounts (Nanowerk, 2010).

Nanotechnology combines ecology and economy. Utilization nanotechnology gives ecological and financial advantages in a way of energy performance and the maintenance of sources. The technologies which help to decrease climate change are very needy more than ever. Later, the ecology and the economic system are having to indivisibly linked, because of that the defensive measures are less expensive than correcting the destruction caused (Leydecker, 2008).

2.2.3.4 Nanotechnology in security and safety

Nanotechnology can give solutions for prevention and safety from natural threats, or industrial risks and terrorist threats, also can provide adequate response to the security and safety of important facilities and the environment (Nanowerk, 2010).

Aside from environmental and human health concerns, much less direct societal concerns could also rise up. Nanosensors for example, raise questions of privateers and control, who manage the transparency of windows in public places or a child's room of the environmental and human health concerns. There are also the social concerns it should be in thought. As an example, nanosensors have a role in privates and control which is be wondering. Who control the transparency of windows in public places for example. How the data which collected about every singular user can be used. The developing on the smart environments have influence the designing, maybe the building can have a powerful network of smart parts interacting with their environment and users (Rickerby, 2007).

2.3 Nanomaterials in Building Production

Nanomaterials are the field which works on materials technology based generally on a strategy of nanotechnology. It's depend on studying about materials on their morphological functions at the nanoscale and specifically, the materials which have extraordinary properties founding from their nanoscale dimensions. Nanoscale can describe in general, is the smaller than one tenth of a micrometer in one dimension at least, despite the fact that in some time it utilized by materials that are littler than one micrometer (Nanowerk, 2010).

The regular way at the main time to classify nanomaterials according to their dimensions, which is as below:

1. Zero dimension: Nanoparticles
2. One dimension: Nanowires, nanorods and nanotubes
3. Two dimensions: Nanocoating's and nanofilms
4. Three dimensions: Nanocrystalline and nanocomposite materials

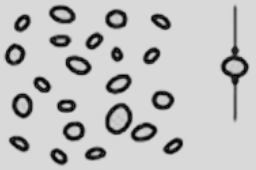
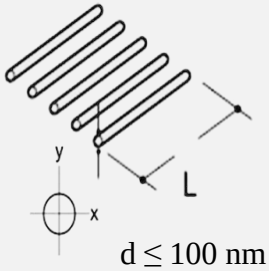
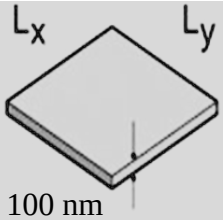
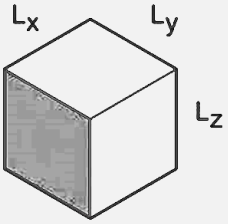
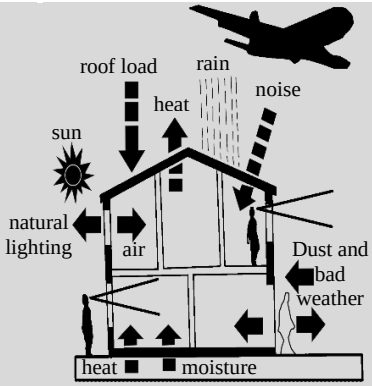
Those classify are basically depending on the different kind of dimensions, which is not related to the nanoscale size (<100 nm), while moving in these classifications from zero dimension to three dimensions, it more and harder to define as well. The classification of nanomaterials according to their dimensions can be seen in (Table 2.3) (Williams, 2007).

2.4 Conclusion of the Chapter

This chapter explores the general definition of nanotechnology, starting from the beginning of the nano, nanoscale and nanoscience. It's shown the history of the nanotechnology and in which field it can be used and how it would be useful for the environment, economy, energy, security and safety. From that, it can be concluded;

It's difficult to not notice the beneficial potentials of nanotechnology and prevent the improvement of research related to it because it's had emerged in many different fields. Nanotechnology has been developed by using it in architecture side by side with sustainability criteria to make sure that technology not cause any harm and that would be seen in the next chapters.

Table 2.3: Classification of nanomaterials in building production (Arcan, 1999) (Williams, 2007)

	Nanomaterials Dimension	Nanomaterials Type	Example
Nanomaterials	**a**: 0-D All dimensions(x,y,z) at nanoscale	•Nanoparticles	 d ≤ 100 nm
	b: 1-D Two dimensions(x,y) at nanoscale, other dimension (L) is not	•Nanowires •Nanorods •Nanotubes	 d ≤ 100 nm
	c: 2-D One dimension (t) at nanoscale, other two dimensions (L_x, L_y) are not	•Nanocoating's •Nanofilms	 t ≤ 100 nm
	d: 3-D No bulk dimension at nanoscale	•Nanocrystalline •Nanocomposite materials	
	e: Building •structural nanomaterials •nonstructural nanomaterials	•Concrete •Steel •Wood Glass Drywall Roofing	

CHAPTER 3

BUILDING PRODUCTION AS NANOARCHITECTURE

Nanotechnology can bring an effect to the architecture. By effecting on the productions and the properties of materials. The material could behave in a numerous way as much as their capability to be controlled in material properties at the nanoscale. As an example, carbon nanotubes, show how the material can be useful after developing. It's much stronger than steel by one hundred stronger and that because of its "molecular perfection". It's demonstrated in the paper, by Peter Yeadon, which is called "Year 2050: Cities in the Age of Nanotechnology". Also, due to the fact, carbon atoms can bond with other matter, such material may be an insulator, semiconductor or conductor of electricity. Carbon nanotubes could have a vast impact on the architecture industry. As such result materials can act as a switchable conduit, a light source, a generator of energy or even a conveyor of matter (Figure 3.1) (Yeadon, 2009).

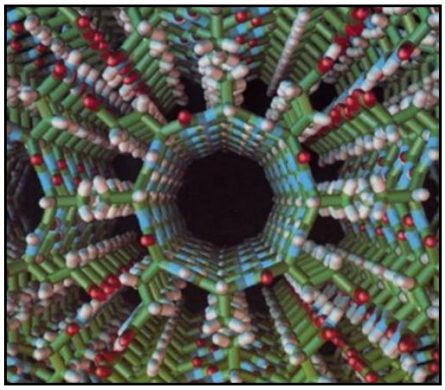


Figure 3.1: Polypeptide organic nanotube nanotechnology
BC Crandall (Yeadon, 2009)

The construction and architectural design, development, such as how materials gain a new feature and that happen by changing the properties which found important in the matter. Nanotechnology reveal a new way to build, for an example it can made use of self-assemble in carbon nanotubes in order to create structures from bottom-up. All areas of architecture can be affected, by nanotechnology and gain great benefit, the architecture can achieve revolutionary ideas in the life along with nanotechnology (Yeadon, 2009).

The revolution of nanotechnology had been explained and because of that the architectural uses of it can arise. Such as walls with an ability to change their transparency, windows with an ability to change their transparency and sensitive covering. Nanotechnology in general, can bring to the architecture, excellent interactive features. That would be according to the needs of users. The imagination of the designers can be unleashed, due to the emerge of new methods of construction, materials and the advent of using nanotechnology in the everyday use (Yeadon, 2009).

3.1 Definition of Nanoarchitecture in Building Production

Nanoarchitecture is the conversion of architecture in the new nano revolution in the 21st century. The use of nanotechnology in architecture varies from materials, equipment's, to forms and design theories (Figure 3.2).

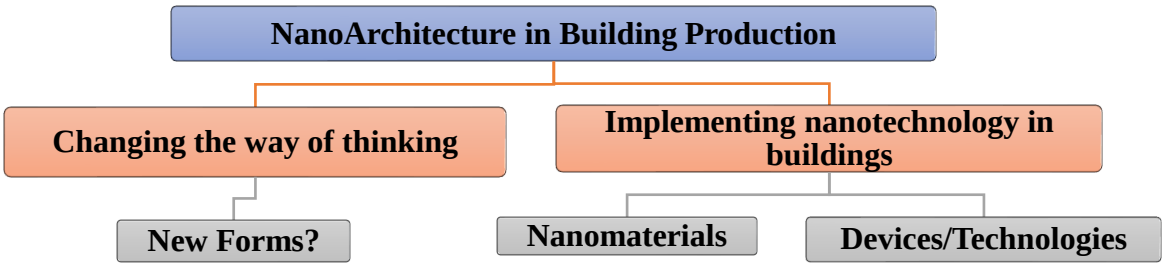


Figure 3.2: The use of nanotechnology in architecture

After spending on nanotechnology industry eight billion dollars in year, finally it begun to change the building and the way of use it. Nanotechnology have the ability to coordinate the way of life and the built environment. Generally, it would be the most transforming technology that have ever seen, which produces a lot of researches and discussion, more than other technologies that use it before. Such as space travel, nuclear weapons, computers or any other, also it come with it many concerns, consequences and a lot of questions, that's spread the expectations. Also, the fears in all field in life, like financial, cultural, social, political and spiritual, so until now the seeking to improve the built environment are still most of it unknowing (Figure 3.3) (Johansen, 2002).

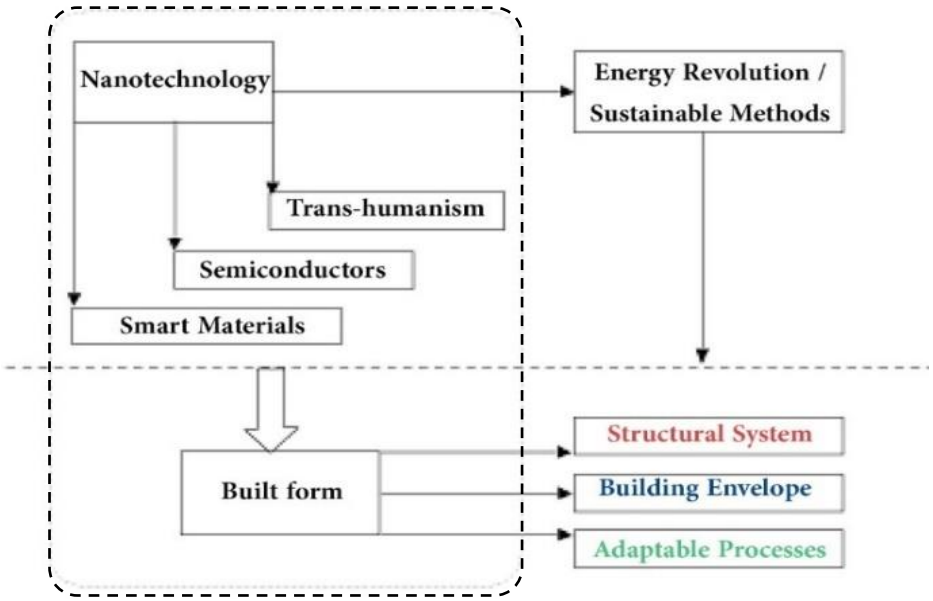


Figure 3.3: Plans of the built environment (Johansen, 2002)

3.2 Impacts of Nanotechnology Science in Architectural Design

Every day is heard about progressing in a new development and that scientific development can change the lifestyle continuously. That would be notable when be seen the progress that they achieved in the area of nanotechnology. This technology can make a change and improve the way of design in many different methods where the progress is being at the molecular level of matter.

In the research "Nano Bio Building: Nanotechnology, Biotechnology and the Future of Building" by way of Dr. George Elvin. He says that most of the designers are ignorant in the materials composition and their consequences that they use. Some of the designers have an idea about using self-cleaning windows and smog-eating concrete. But also, they don't know that the titanium dioxide is the one in charge of those actions. Because of that, it's so important to the designers keep their knowledge about the scientific advancements (Elvin, 2006).

The intelligent environment is the most area which would be affected by nanotech. Using nanosensors can make the features of the architecture responsive. It collects data and make communication between the objects with each other, between object and user, also with the environment. Every new material obtains a transient property. So, architecture features and material effect on the stage of design by making the higher focus on the areas of interaction (Elvin, 2006).

The architecture experts work on a framework on how to design to achieve dynamic environments. That would be by operating on fields of interaction. The architects concentrate on the relationships just like they are concentrating on designing forms in the design phase. All of that due to the smart architecture which is changing the states and communicating massively. It's quite often that each form and their relationships create their own rule systems on which part of the smart architectural area can be functional. The nanotechnology science develops constantly, according to that develop, the design field gain benefit from it and it appears new architectural techniques. As innovating nanomaterials and nanosensors give the designer a renewed area, the creativeness of design attains to a new level (Elvin, 2006).

3.3 Nanotechnology and the Future of the Built Environment

So many of nanomaterials are available already for architects and contractors they are starting to change and develop the buildings, on how it affects the user and how the user effect on it. There is a lot of research on new nanotechnologies, which maybe in the next twenty to fifty years, would have a big impact on building. As an example, carbon nanotubes, in the future, can bring to the buildings a strength and flexibility. Which give a new function, new form and different relation in each of user, building and the environment, between each other. In the long term, the effect of nanotechnology on the life and environment in the future can be better. Invisible walls, theromprotectant skins and self-replicating structures, all of that can be in the range of possibility. The effects on social and environment are great, even so, it's still real. This is the danger and the promises of nanotechnology, that its consequences are high and near, that as billions of dollars each year are spent in new improvement, research and new advances pour out (Brandon and Lombardi, 2010).

The nanobots take control of the earth and even the rampant self-increasing viruses are actually not the real risk here. The real hazard is that the lack of knowledge on Nanotech on the society, so some day will be found that a technological revolution has occurred and still don't have any idea on how to keep up with it. It's the time to think and discuss the opportunities that provide this technology to the world and be ready for it (Brandon and Lombardi, 2010).

The aim of Small Plans is to start thinking about the potential influence on the building that nanotechnology has. This technology has many unpredictable methods, but by locating the possibilities of nanotechnology. Future of the built environment and the architecture, if had try to figure out the impact of nanotechnology in the 50 or 100 years from now the potentialities reach to infinite. So, when be investigated more instant impact of nanotechnology and the impact of the recent technologies on development and research those long-range situations would be lessened. The actual questions that nanotechnology proposes, is that the consequences of personal, social, moral and environmental had to be explored. Nanotechnology may can change the built environment, by using it to create building more healthy and comfortable place to live (Brandon and Lombardi, 2010).

In building design nanomaterials had been used in many fields, as seen in Table 3.1, such as insulation, coatings, solar energy and others in order to enhance the efficiency of the building. Within this scope the architect and engineer had reach to make projects that based on the nanotechnology like Nano house, Nano tower. Also, they create a whole city such as Nano City or Masdar City, which solve the environment problems and increase the depending on renewable resources. The nanomaterials are scaled according to their dimensions and also classified from the point of planning approach (Figure 3.4).

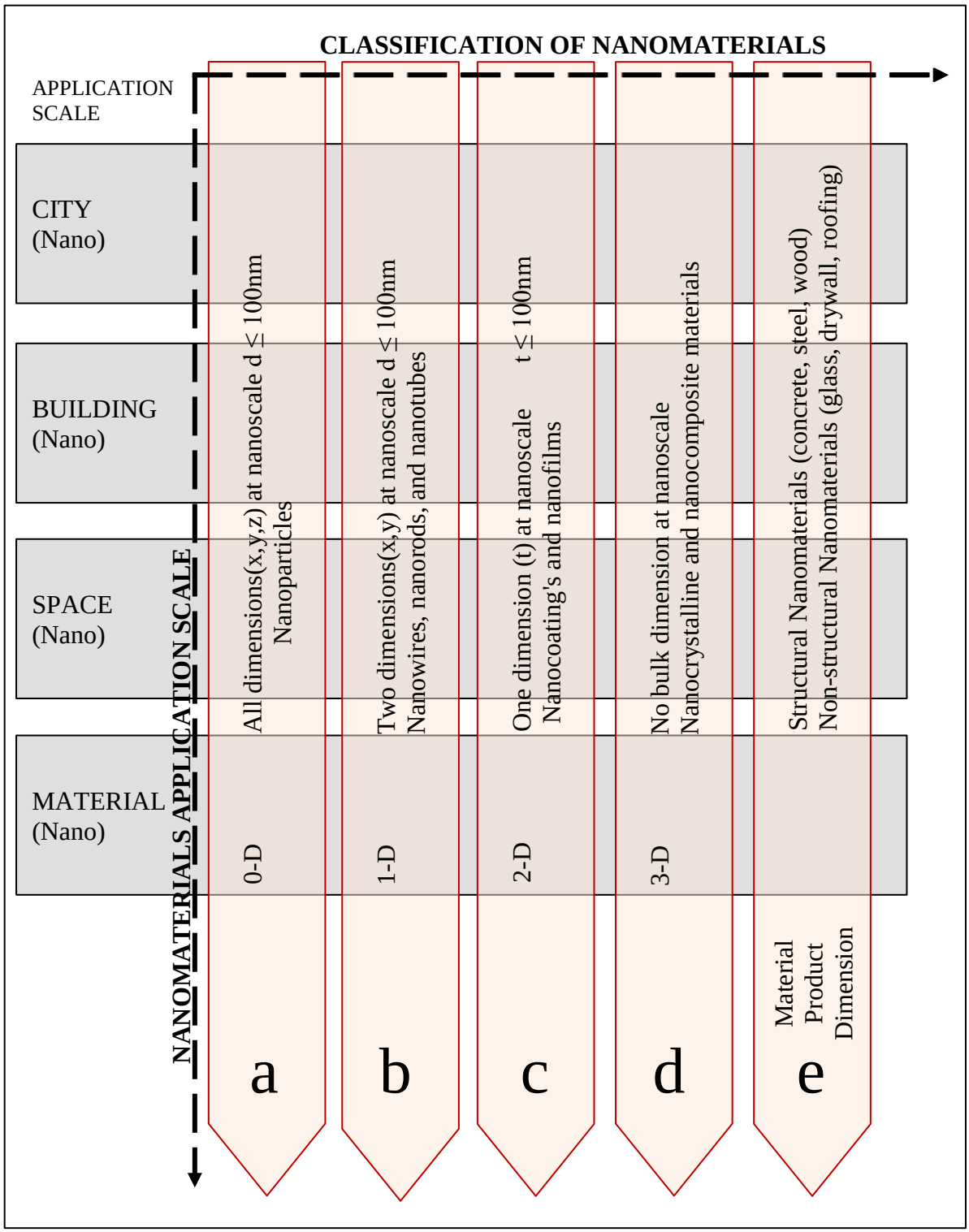


Figure 3.4: The use of nanomaterials in different scales according to dimensions and types

3.4 Nano Architecture Applications

The capacity to manipulate matter on the scale smaller than one billionth of a meter, are given the possibility to change the built environment in many ways. At the main time, this tech is nanotechnology, its already had been used in many methods, like as utilized with manufacturing objects. Such as clothing and the sun protection, also use it with architecture have not to be far away. Soon enough, methods like coatings and insulation, have to reach to a new level of efficiency in the fields of intelligence, lighting, energy and safety. These beginning in nanotechnology world can change the character of buildings and the way of how it related to user and environment in future. The efficiency of the building and building design have to change, due to carbon nanotubes progress (Figure 3.5) and other discovered materials. In below (Table 3.1) shows nanoarchitecture applications in building design (Elvin, 2007).

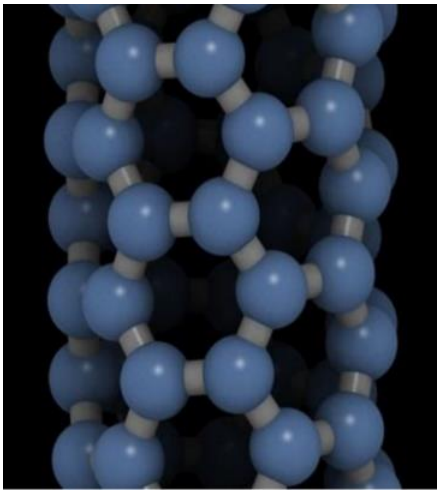


Figure 3.5: Nanotube Ynse Dreams time (Elvin, 2007)

Table 3.1: Nano architecture applications in building design

Insulation	Aerogel
	Thin-film insulation
	Thermal insulation: Vacuum insulation panels (VIPs)
	Temperature regulation: Phase change materials (PCMs)
Coatings	Self-cleaning coatings • Self-cleaning: Lotus-Effect • Self-cleaning: Photo catalysis
	Easy-to-clean (ETC)
	Anti-fogging
	UV and Solar protection
	Anti-graffiti
	Anti-Reflective
	Anti-fingerprint
	Scratch-resistant coatings
	Anti-corrosion coatings
	Antimicrobial coatings
	Moisture resistance
	Fire-Proof
Lighting	LEDs
	OLEDs
Solar Energy	Inorganic silicon solar cells
	Organic thin-film solar nanotechnologies
Air Purification	
Water Purification	
Fire-Proof	
Structural Materials	Concrete
	Steel
	Wood
Non-structural Materials	Glass
	Plastics and polymers
	Drywall
	Roofing

3.4.1 Insulation

• Nanogel aerogel

Nanogel is a brand of aerogel insulation particularly utilized in building products and oil and gas industries. It is every so often known as frozen smoke, it is made with the aid of Cabot Corporation, which has a plant in Frankfurt, Germany. It is an aerogel that consists of 95% air, in nano sized pores that repress heat transfer through the aerogel. It is made of grades of fuzzy to translucent. It may be tailored to different environments (Figure 3.6). All of these features are in nanogel, but some product can be like nanogel but only in one feature of these and because of that nanogel are unique material. The benefits of nanogel aerogel are listed below.

1. It has high light transmission 75% through cm.
2. Thermal conductivity is low R-value of eight inches, U-value of 71 W/m2K.
3. Reduce the gain of solar heat.
4. Reduce the spread noise by use the Sound attenuation.
5. The durability to resist the change of color, performance degradation and mold.
6. Manufacturing process and green product.
7. Capability to reduce the waste of building energy and carbon footprint.
8. Have an excellent light diffusion and reducing of solar transmission, in addition, it has a low weight:60-80 kg/m^3.
9. Also have other features, like, architectural flexibility, aesthetically appealing and UV resistant (Baetens and Gustavsen, 2011).

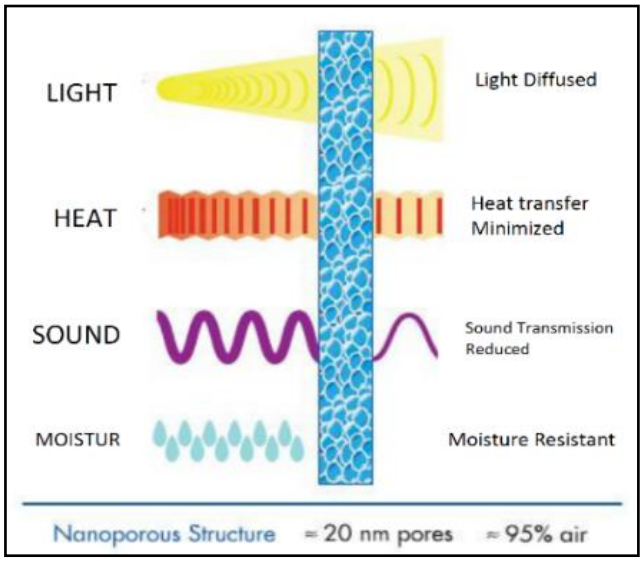


Figure 3.6: Nanogel aerogel system (Baetens and Gustavsen, 2011)

The potential applications are;

- Industrial roof lights (Figure 3.7).
- Offices, shopping malls and hotels.
- Schools and museums.
- Conservatories and private housing.
- Sporting and leisure centers, swimming pools.
- Facade glazing and curtain walls (Figure 3.8).
- Special projects such as train stations, airports, etc.

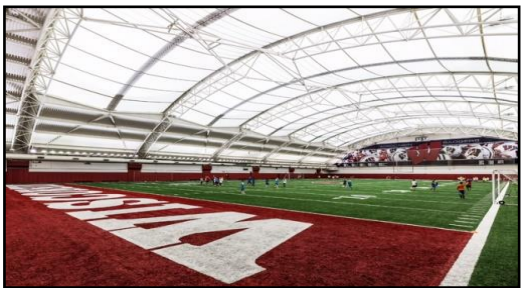


Figure 3.7: Nanogel aerogel for natural light applications (Baetens and Gustavsen, 2011)

Nanogel have great design advantages which are delivered to the architects and construction owners. That happens when it used in roofs or facades (Figure 3.9). Whatever the way was in installing it. Nanogel keeps on its features, such as enabling constant thermal efficiency. But at the same time, it allows the daylight to enter and improve the aesthetics of building without any loss. In fact, it achieved enhancing, at the comfort and productivity to the user (Buratti, 2013).

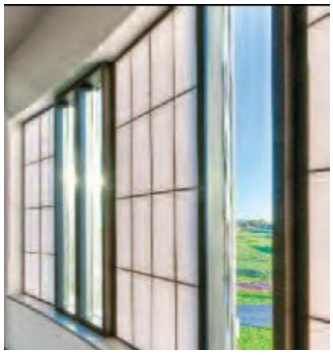


Figure 3.8: Structural composite panels for skylights and facades (Buratti, 2013)

Figure 3.9: U-Channel glass (Buratti, 2013)

• Thin-film insulation

The very thin layers of material which are extended from nanometer fractions single layer to multi micrometers in thickness, that is called the thin films, the most applications which that represent thin films are, optical coatings and digital semiconductor gadgets (Figure 3.10) (Schodek, 2009).

The thin films can be used as nanocoating Insulation which is applied in glass and fabrics, for instance, masa shade curtains, are fiber sheets which are covered with a nanoscale stainless steel film. Due to the potential to imbibe infrared rays from stainless steels, so the curtains capable of blocking the sunlight, lowering in the summer season the temperatures of room 2-3ºC better than traditional products (Figure 3.11) and decrease the costs of electrical use in air conditioning (Elvin, 2007).

Figure 3.10: Thin film sheets (Schodek, 2009)

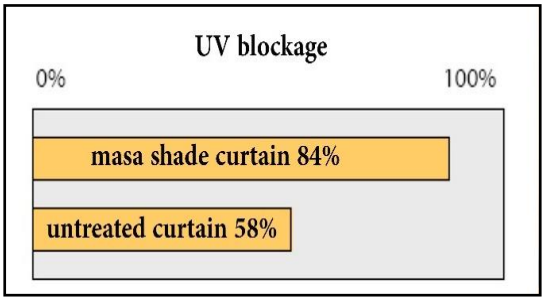


Figure 3.11: Masa shade curtains reduce room temperatures and air conditioning (Elvin, 2007)

• Window Film

Heat absorbing films applied to windows as properly. Windows synthetic with the aid of Vanceva include a nanofilm interlayer which, consistent with the corporation. Offers cost effective control of heat and energy loads in building and solar overall performance superior to that of formerly available laminating systems. By selectively lowering the transmittance of solar energy relative to seen light. They are saying, those solar overall performance interlayers bring about savings within the capital cost of energy control equipment in addition to working fees of weather control equipment. Benefits encompass the capability to block solar heat and as much as 99 % of UV rays whilst allowing seen light to pass through (Figure 3.12). In (Table 3.2) shows the performance results of Window Film (Chopra, 2004).

Figure 3.12: Nanofilm control of heat and energy loads in building (Chopra, 2004)

Table 3.2: Performance results (Chopra, 2004)

Visible light transmitted	61%	Total solar energy rejected	52% on angle 61%
Infrared rejected	97%	Visible light reflected int	8%
Visible light reflected Ext	8%	UV rejected	99,9%
Glare reduction	31%	Luminous efficacy	1.11

3.4.2 Coatings

The area of research on nanotechnology coatings are considered as the most widespread studies. It's applied on concrete, glass and steel, most of the coating are includes Chemical Vapor Deposition (CVD), spray and plasma coating. In order to create bonding with the base of material by producing a layer above it, to provide surface of functional properties or the preferred protective. One of the most important goals is to make self healing possible to achieve by the procedure of "self-assembly". Coatings in fact, are very skinny coverings which are located on the material's surface. In order to develop it's appearance or their characteristics surface. Such as using coatings to improve sturdiness or adding characteristics, which offer protection to the material or resistance of corrosion, its also possibly used to exchange the quality of adhesion, qualities of reflective, coloration, or many other (Figure3.13) (Elvin, 2007) (Schodek and Ashby, 2009).

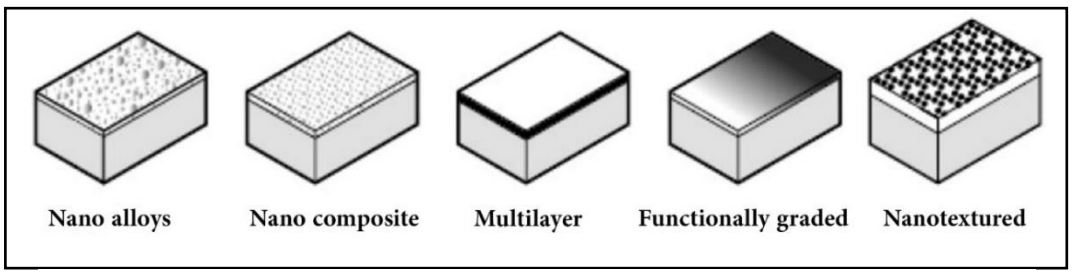


Figure 3.13: Typical nanocoating forms (Schodek and Ashby, 2009)

- **Self-cleaning coatings**
- Self-cleaning (Lotus-Effect)

The first investigation of the Self-cleaning surfaces was in the Seventies which is by botanist Wilhelm Barthlott, at the University of Heidelberg, he had noted that his research on self-cleaning effect not only located in oriental Lotus leaves, also in European Nasturtium and the South African Myrtle Spurge (Figure 3.14) (Elvin, 2007).

He discovered that there is common character between all of them. At the microscopic range they show a water repellent surface, there is little surface of contact for water to settle down. Because of it's has been covered with small knobbles or spikes, with the assist of nanotechnology manufactured lotus surfaces had been created. The lotus effect very useful in the place that exposed to the water like the rains. It's can reduce the need of cleaning in order to that the surface which receive water stay clean and give a decreasing in the repairing demands and of course cleaner appearance (Figure 3.15) (Dfatadeo, 2014).

Figure 3.14: The Lotus plant with its natural self-cleaning forms (Schodek and Ashby, 2009)

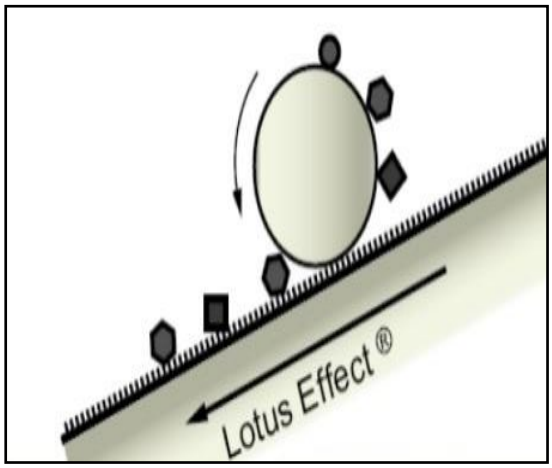


Figure 3.15: Principle of the lotus effect (Schodek and Ashby, 2009)

• Self-cleaning (Photocatalytic)

Photocatalytic coatings had made the surfaces more reality which contains nanoparticles titanium dioxide (TiO2). It's working by a procedure which is breaking the dirt by exposing it to the ultraviolet rays of sun's and cleaned away with rain water. This procedure is called photocatalysis. Volatile organic compound (VOCs) are normally oxidized with carbon dioxide and water. The way of applying it are by a paint it on, thin nanocoating film, or combine it with the material on their surface level. In (Figure 3.16) and (Figure 3.17) shows how photo catalysis act on surface to destroy the dirt and keep it clean (Schodek and Ashby, 2009).

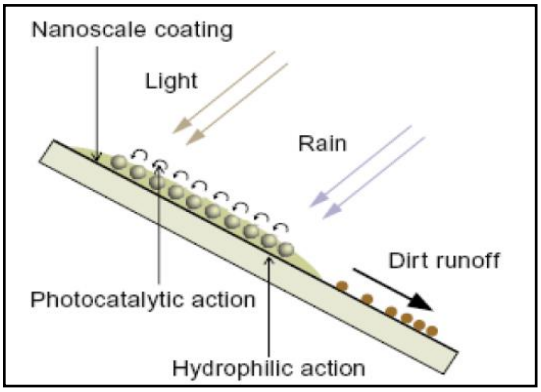


Figure 3.16: How photo catalysis act on surface (Schodek and Ashby, 2009)

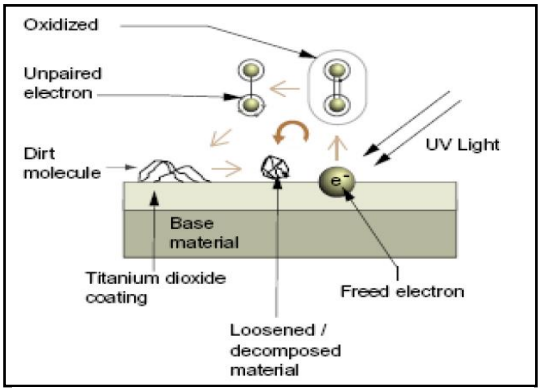


Figure 3.17: How the surface act with photo catalysis (Schodek and Ashby, 2009)

The (Figure 3.18) shows the basic process: Organic dirt & grime is broken down and decomposed. Until now UV light, such as present in sunlight, is necessary to initiate photocatalysis. When water impacts on the surface, it spreads to form a film washing away the loose dirt. which result to clean surfaces.

Figure 3.18: Diagram shows how photo catalysis work (Leydecker, 2008)

• **Easy-to-clean (ETC)**

Known as easy to clean (ETC) surfaces are water repellent and accordingly are on the whole confused with other self-cleaning functions identical to the Lotus effect. However, no longer like the latter. Easy to clean surfaces are smooth rather than rough, these surfaces have a lower force of surface attraction considering the fact that to a decrease of their surface energy, principal to diminished surface adhesion, this factors water to be repelled, forming droplets and running off, easy to clean surfaces are hence hydrophobic and normally more over oleophobic (Rossi, 2015).

Figure 3.19: Comparison of ceramic surfaces (Rossi, 2015)

Figure 3.19: Comparison of ceramic surfaces, on the left side without ETC coating, on the right side with ETC coating, the flexibility of ETC ceramic, it's almost like wallpaper, it can resist the expose of water, because of their water-repellent surfaces (Rossi, 2015).

This operate is used for coating ceramic sanitary installations and bathe cubicle glazing, timber, metallic, masonry, concrete, leather as well as textiles are likewise candidates for hydrophobic coatings. Easy to clean surfaces are much less susceptive to dirt accumulation (dirt-repellent). The hydrophobic degree is different according to the angle of touch on the surface. It can explain the degree of moistening and the properties of the surface of the angle of contacts (Figure 3.20) (Dfatadeo, 2014).

Money and time can be saved by using easy to clean applications. Water droplets despite its benefits, there are bad effects, like the time for drying, are long and this would take in consideration. So, it's necessary to know where and how the easy to clean work and employed in the best place, which is the dry droplets, that leaving the remains of dirt behind (Dfatadeo, 2014).

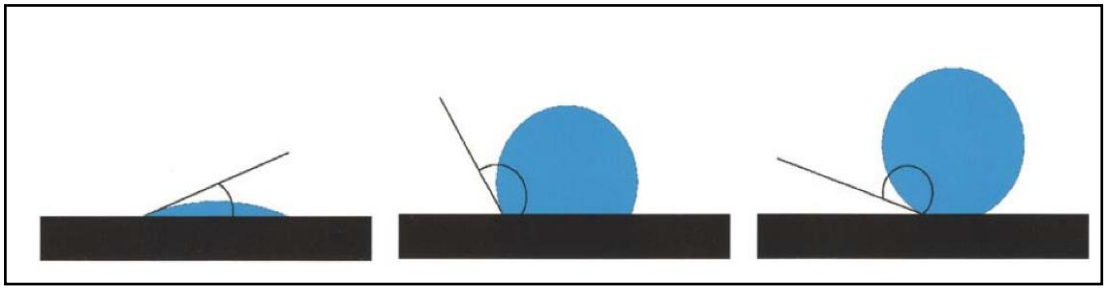


Figure 3.20: The hydrophobic degree is different according to the angle of touch on the surface, it can explain the degree of moistening and the properties of the surface of the angle of contacts (Rossi, 2015)

- **Anti-fogging**

A clear view free of fogging are achievable with a help from nanotechnology and without using any electrical power. It happens by using nanoscalar TiO2 in ultra-thin coating. Which is having high attraction of wetness because of high surface energy that it has. Ultra-thin film layer formed on the wetting surfaces. In fact, it's still on the surface, but invisible, that because of the film is transparent, which is give a clear look (Leydecker, 2008).

One of the examples of where can used this coating, is on bathroom mirrors (Figure 3.21), also on the glass in the room which using air-conditioning. The anti-fogging coatings are not only used on glass it's also can apply it on plastics. This coating is applied on the surface of material by spraying. But the problem, is that's not a permanent solution, because of the effect didn't last long. Until now anti-fogging coating still on developing, nevertheless it's ready to be on the marketing field (Leydecker, 2008).

Figure 3.21: Mirrors with anti-fogging coating do not steam up (Leydecker, 2008)

• **Ultraviolet (UV) and Solar protection**

UV protection has two forms, they are made of industrial and organic additives, the two kinds are utilized in combination. The first one is applied to the upper layer in the form of a protecting lacquer. That's because it works on absorbing UV in order to filter the harm rays from sunlight before them arriving at the surface of materials. The second one, are different than the first one approach, their influence came at a later stage and it's called "free-radical scavengers". The most important condition is transparency, in order to protect the color and structure of the material which applied it to it. To make that done, the single particles of UV-absorbing within the formulation, her size should be smaller than 15 nm, under this dimension it's not scatter the visible light and become visible (Leydecker, 2008).

The discovery of nanotechnology gives a new way to apply the electrochromic glass on the buildings and without needing to continuous electric current. It only needs one switch to change the transmission of light, from darkness to transparency. The best solution to coloring glass is the photochromatic glass. Due to that takes less time than the ultra-thin nanocoating, it's automatically changing to the darker, just when it contacts with the sunlight, with no need to switch it manually (Figure 3.22). Nanotechnology has successfully provided, solar protection by methods of energy-efficient, that can be add it to the other functions of the glass (Rossi, 2015).

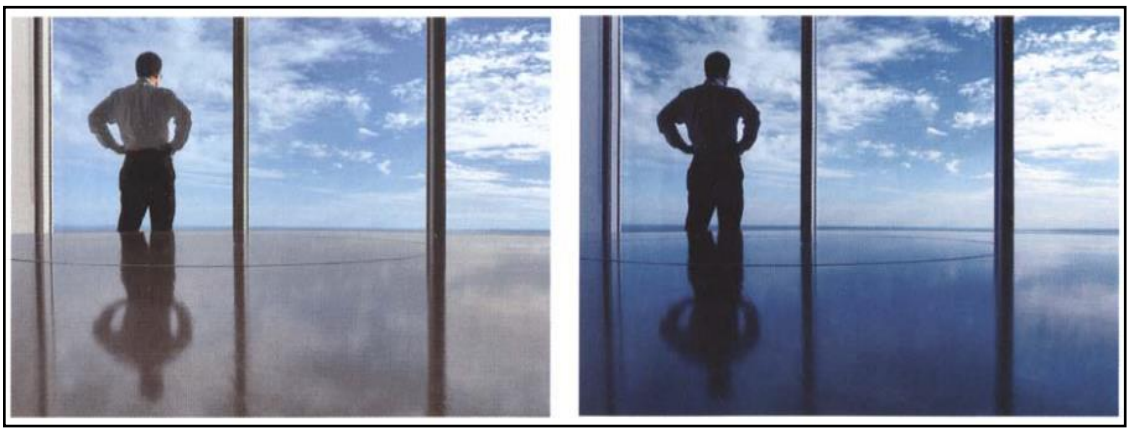


Figure 3.22: Electro chromatic glass until now the maximum length is 120x200cm (Rossi, 2015)

• **Anti-graffiti**

There is a lot of unpleasant graffiti which can found it on the buildings, bridges and maybe on barriers. Because of that solutions to prevent it are needed and of course, nanotechnology achieve a new method to preserve the building fabric, by using anti-graffiti coatings. It's highly effective and it has the ability to make materials, water resistant when used with it, that means the graffiti should be easily removed. It also can be utilized on highly absorbent and porous materials, like concrete, brick, lime sandstone and other. Despite the fact that the coating is effective on impregnation materials. Its allow to the material to maintain their vapor permeability, because it doesn't close the pores in materials and it avoids the damage from moisture. Brandenburg Gate in Berlin are protected with an anti-graffiti coating (Figure 3.23) (Rossi, 2015).

Figure 3.23: Brandenburg Gate in Berlin are protected with an anti-graffiti coating (Rossi, 2015)

• **Anti-reflective**

To solve the problem of reflection it used anti-reflective glass and that's not new, it was used in the glass which utilized in the exhibition. But it's complicated to manufacture and very expensive. The particles of the transparent nanoscalar surface, according to the wavelength of light are much smaller. It's offer solution, to the anti-reflective efficient and cost, it offers a thickness of the coating equal to 150 nm and it consider perfect and the reflected light ratio reduced from 8% to 1% or less (Figure 3.24). Also, there is another cost-effective method is the moth-eye effect which is one of the anti-reflective surfaces methods, which is used to reduce reflections at the night (Leydecker, 2008).

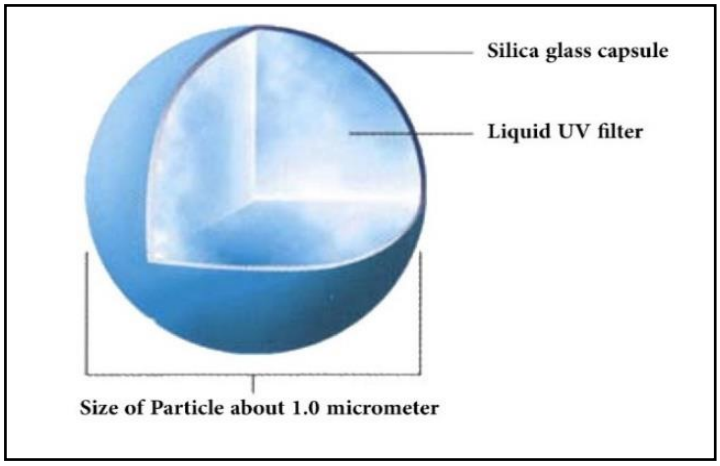


Figure 3.24: Silica glass capsules are used in nanoporous anti-reflective coatings with a thickness of 150nm that are also able to reflect the invisible spectrum of light (Leydecker, 2008)

By using nanotech, it can destroy, all the bad influences of the anti-reflective technology, which is like the complication of the production process and the limited spectral field, in order to take use of the increasing solar transmission which is a result from broadband spectral de-reflection, it can be used a large number of anti-reflective glass in construction (Figure 3.25) (Leydecker, 2008).

Figure 3.25: A photovoltaic module with and without anti-reflective (AR) solar glass coating (Leydecker, 2008)

- **Anti-fingerprints**

Inside the building, usually used glass and steel in it, but there is a problem that is fingerprints appear in clearly and annoying way. Nanotech had solved the problem by covering the surfaces with an anti-fingerprints coating which keeps it with a clean appearance. These coatings can make the fingerprint almost invisible. The coating changes the refraction of light on the surface and the reflections of light gives a smooth appearance to the glass or steel, which make feel the surface are cleaner, this coating is very flexible with the material

which is installed on it. So, if bent or twist the material, it's go with it without breaking or fracturing, this would be very helpful in order to use it in any different shape. Usually, it's used in furniture and elevators, the benefits of this nanocoating's are like the other before to maintain the clean appearance and decreasing in the cost of cleaning and in addition to anti-fingerprint it's also has the ability to resist scratching (Figure 3.26) (Rossi, 2015).

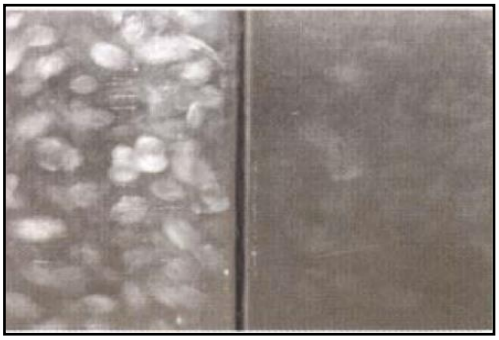


Figure 3.26: The effect of the anti-fingerprint coating on this sheet of stainless steel is clear (Rossi, 2015)

3.4.3 Lighting

One-third of the energy in the building are used by lighting and other application. Lighting not only consuming the power of building, also the light source is creating heat that emits from it. Which affects the temperature of the room, that lead to increasing the cost of cooling the room. As example, Incandescent lighting it lose 95% of their energy on heat, maybe there are some lights using less heat and energy. But still, there is another problem, fluorescent lights, for instance, it contains amounts of mercury, more efficient lights should be looking for with potential to save energy (Figure 3.27) (Elvin, 2007).

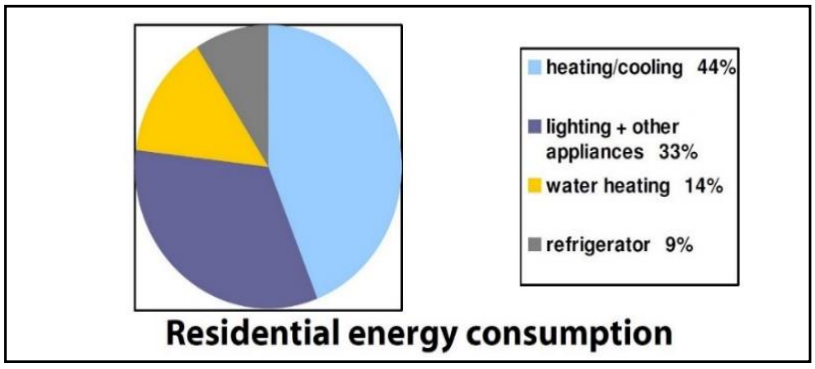


Figure 3.27: Lighting and other appliances (purple) consume one-third of all energy in buildings (Elvin, 2007)

- **Light-emitting diodes (LEDs)**

The diode is that the device which made from two conducting materials and allows for the current to pass in only one direction. When electricity across by diode, the atoms accelerate to the higher level of energy. When the atoms transfer the electrons to the second material it would be releasing in energy, during that the light can be created and depending on from what diode had crafted of the how it is configured, can be the color of the light from the LED (Baretz and Tischler, 2003).

- **Properties of LEDs;**

Efficiency: LEDs are better than incandescent bulbs because its produce more lights in one watt and the performance are not change according to the size or shape.

Color: don't need to the color filters, to color the light, in LEDs can emit the color of light which need.

Size: LEDs are very small its reach to 2 mm^2 and smaller.

On/Off time: LEDs very quick to turn up and down.

Cool light: LEDs are different than other light, it does not generate heat or maybe a little, in IR form which only harm the fabrics or some sensitive materials.

Life time: LEDs have a long time until it goes out of order, the life of LED evaluate between 35,000 to 50,000 hours and maybe more (Baretz and Tischler, 2003).

- **Nano LEDs**

Nanomaterials are used in so many applications that related to light and in future, it can be use in a big range of application areas and it's expected to help of nanomaterials, can achieve a progress in performance for chromogenic materials. When the chromogenic materials, facing change in their surrounding energy, it's have the ability to change their optical properties. Nanophosphors have been already used in different lighting devices and LEDs, nanowires of indium phosphide (INP) can be used with LEDs in a range of color yellow, green and it's perfectly suitable. By making an intersection between differently doped areas in a wire with that way the LED achieved. Nano LEDs used in light-emitting displays, light sources, or integrated optics for communications purposes (Figure 3.28) (Baretz and Tischler, 2003).

Figure 3.28: Lighthouse tower, Rio de Janeiro using LED light (Baretz and Tischler, 2003)

• **Organic light-emitting diodes (OLEDs)**

When the LED, emissive layer of electroluminescent which is composed of a film of organic mixtures, then it's called, OLED, those layers of organic semiconductor material is established between two electrodes, which is one of those electrodes are transparent, to warranty efficient OLED, by increase OLED lifetime and the emission of light, to do that it's relied on the structure of the device and the kind of materials (Figure 3.29) (Kulkarni and Jenekhe, 2004).

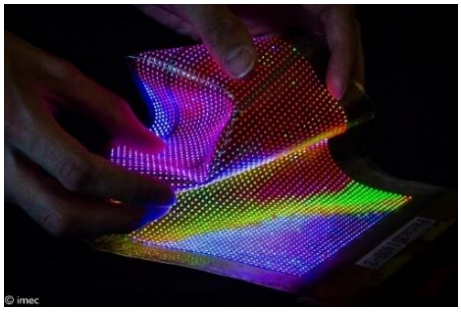


Figure 3.29: Demonstration of a flexible OLED device and color (Kulkarni and Jenekhe, 2004)

The properties of OLEDs are**;**

- OLEDs are highly effective light brings a brand-new Properties, OLEDs are very thin and flexible it can be located on any shape and it can cover big area.
- Because of its high flexibility, so it's very desirable from designers, entrepreneurs and users.
- It's come with a lot of colors and high quality in the emission light (Kulkarni and Jenekhe, 2004).

3.4.4 Solar energy

The renewable energy should be used which comes from the sun ray, that's satisfy all needs for energy, because of that it had to find an economical and effective method to change this energy to electricity (Elvin, 2007).

- Silicon solar cells

Today in silicon solar cells, materials are taken 40% of the cost and study about it says that after five years a decreasing reach to 30%, but when take a look at thin film solar utilizing nanotechnology, founded the products cost near to 1% or 1.5% (Dfatadeo, 2014).

- Thin-film solar nanotechnologies

Nanotechnology is main to advances in silicon-based total photovoltaics and new nanocrystalline materials. Thin-film materials and conducting polymeric films, it's estimated that thin film producer Nano Solar's cells are 6.7% efficient, at that level, just a 3.3% growth in efficiency to 10% might permit every cellular to capture 50% more energy, reducing the price per watt by using 33% (Figure 3 30) (Morton, 2006).

The organic thin film, are generally depending on the polymers and nanoparticles. Which is materials that don't cost much. The flexibility of the organic thin films is one of their features, which makes it easy and perfectly suitable to apply in any application of the building, therefore it's much better than normal glass panels. This feature, gives a great opportunity to work on new architectural ideas and concentrate on the aesthetic side, which was hard to do with the normal flat panels. The Wake Forest University is working on an improvement on other nanotech feature which includes spraying on polymer-based solar collecting paint, which their efficient are 6%, which is comparable to the other cells it has double amount (Figure 3.31) (Elwan et al, 2015).

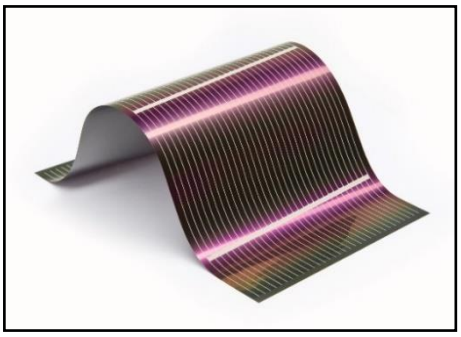


Figure 3.30: Organic Thin-film (Morton, 2006)

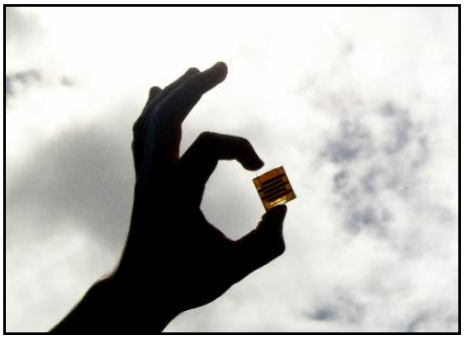


Figure 3.31: Making solar smaller and stronger (Elvin, 2007)

The first solar energy panel which is improved and designed mainly for spread the utility on scale system is Nanosolar Utility Panel™, comparing to traditional thin-film panels, it have different cost advantages as in (Table 3.3) below (Schmidtke,2010).

Table 3.3: Comparison between conventional thin-film and nanosolar (Schmidtke,2010)

	Nanosolar	**Conventional Thin Film**	**Nanosolar Advantage**
Power(W)	160-220	70-80	3x More power per layup step
Current(A)	6	1	Longer panel string
System voltage(V)	1500	1000	Longer panel string
Panel size(m^2)	2.0	0.72	Less mounting time
Panel string length	64 m	12 m	Fewer inverter home runs
Mounting span(m)	1	0.6	Less mounting material
Connectors	Edge	Standard	Significant savings in cabling material

• Case study of nano solar in Germany;

Some trained teams in Germany they made 18m^2 of nanosolar panels (Figure 3.32) and conventional thin film panels (Figure 3.33), they note that nanosolar panels need less than 30% in mounting time and less than 85%in cabling time, which saves time (Schmidtke,2010).

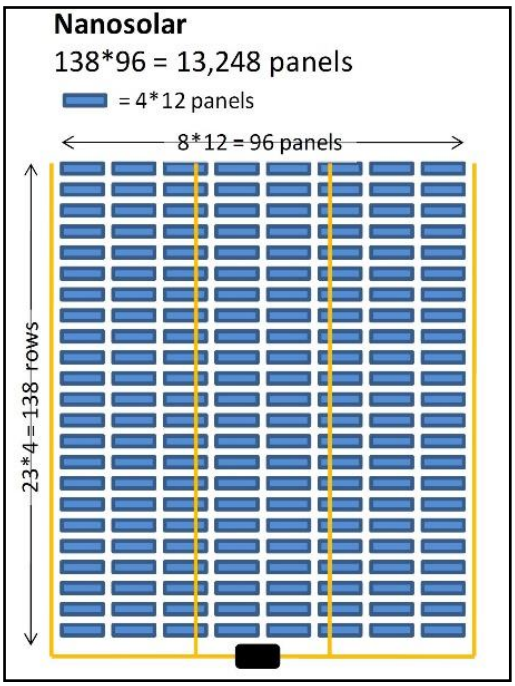


Figure 3.32: Nanosolar (Schmidtke, 2010)

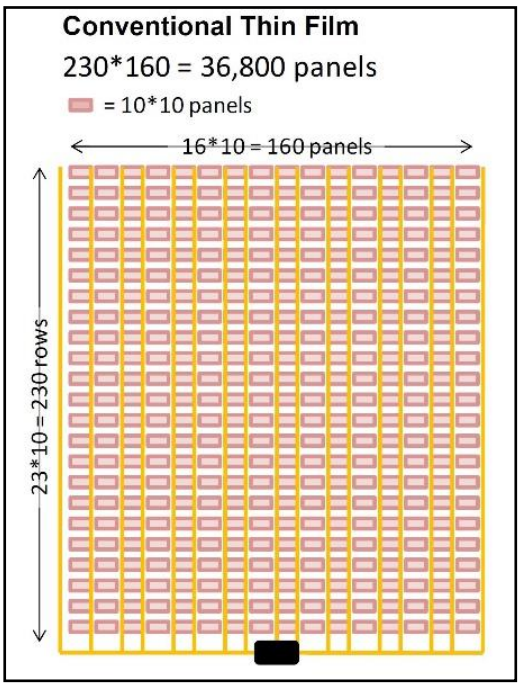


Figure 3.33: Conventional thin film (Schmidtke, 2010)

The result of the comparison between two examples of 2.66MW systems (Table 3.4) are, nanosolar panel installation are less than the conventional thin film installation in DC cabling by 73% lesser.

Table 3.4: Comparison between two examples of 2.66MW systems (Schmidtke, 2010)

Designed with	nanosolar Panel	Conventional thin film panel
Field dimensions	300m x 230m	300m x 230m
DC Cabling Panel string length	64m	12m
The system requires	4 home runs	17 home runs

3.5 The Future of Architecture with Nanotechnology

The nano-products and nanomaterials show noticeable improvements in the environment, in saving energy and reduced depend on non-renewable resources, also reduced waste, toxicity and carbon emissions some can even absorb and break down airborne pollutants. The benefits of nanotechnology for green building come at the first from coatings and insulating materials which are available today and the advances in solar technology, lighting, air and water purification and, finally, structural materials and fire protection.

The building industry is moving to sustainable thinking and discovering nanotechnology and use it in the building can help to accomplish it. At the present time, the most urgent issues in the environment are the green building. In the USA 43% of the carbon dioxide emissions, are because of the require of energy services in commercial, residential and industrial buildings. Buildings spend energy between 30 and 40 percentage of the energy in worldwide. In the USA forty percentage of the waste come from constructing and they spend 60 million dollars per year for healthcare, for the sick building syndrome (SBS), to construct the building and operate it. It's needed to take in consider all the risks in the world, such as ozone depletion, out of fossil fuels, soil erosion, environmental pollutants, elimination of Forests, human health risks and climate change, obviously, the environmental problem is very affected by the buildings (Figure 3.34) (Elwan et al, 2015).

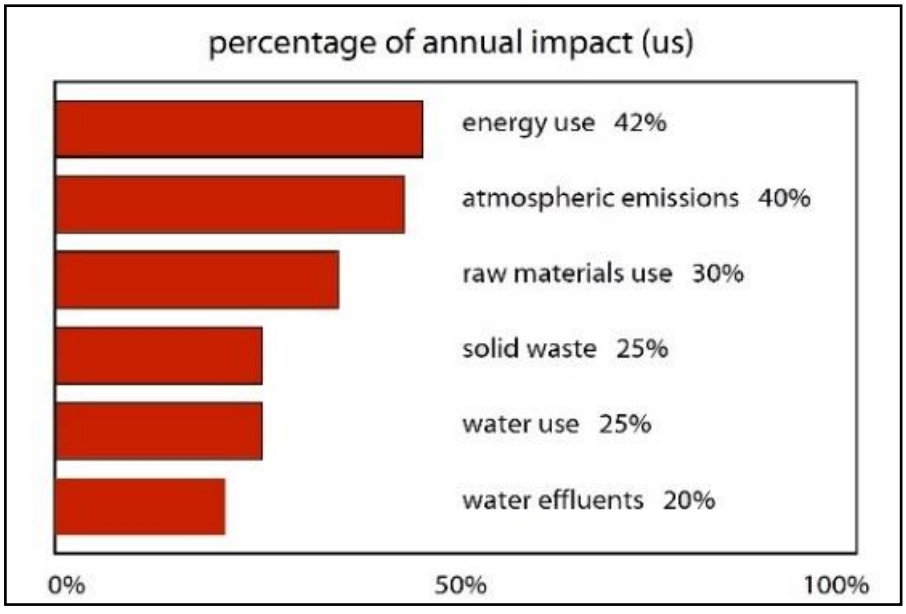


Figure 3.34: Buildings figure in world energy consumption, carbon emissions, and waste (Elvin, 2007)

3.5.1 Nanotechnology effect on environment

Nanotechnology can reduce the emission of carbon in the world, by three ways:

1. Generation of renewable photovoltaic energy.
2. Transportation.
3. Improved insulation in residential and commercial buildings (Elvin, 2007).

It can be noticed that, the last two of those are focusing on the industry of building, which suggests that the revolution of nanotechnology would be driving by the building. More sustainable products can be created, by an assist from nano products which is now in the markets. Also, it achieves other advantages like conserving the energy in the building, reduce waste and toxic outputs and dependence on resources that nonrenewable by providing new materials capable of it. There are other products which are still in development, it provides for the building more enhancing in energy and environmental performance. The advances of nano were guaranteed in power conservation in architecture by creating new materials such as insulating nanocoatings and carbon nanotubes. Also, some new processes like photocatalysis, can decrease the toxicity of the material, make enhancing in structural and nonstructural materials in flexibility, strength, durability and improve the insulation of the building, all of that by nanomaterials (Table 3.5) (Elvin, 2007).

Table 3.5: Ranking of environmentally friendly nanotechnologies (Elvin, 2007)

Rank	Technology
1	Electricity Storage
1	Engine Efficiency
2	Hydrogen Economy
3	Photovoltaics
3	Insulation
4	Thermovoltaics
4	Fuel Cells
4	Lighting
6	Lightweighting
6	Agriculture Pollution Reduction
7	Drinking Water Purification
8	Environmental Sensors
8	Remediation

3.5.2 The effort to speed up nanotechnology use in the future of architecture

Markets are full of uncertainty, especially when new technologies are introduced. The application of nanotechnology to a market as broad as the building industry poses many challenges for businesses, professionals and government agencies. There are three primary forces that could thwart a boom in nanotechnology for green building:

1. The idea of nanotechnology is refused by the public due to the less of knowledge about it.
2. Innovation is fought by construction industry
3. The costs of nanomaterials and nanoproducts still consider high (Elwan et al, 2015).

The construction industry is slow to use new technologies like nanotech, but these forces below are working to speed up the using of nanotechnology for green building:

1. Increasing in requirements of green building.
2. Spending on development and research for nanotechnology in the world, four billion dollars per year.
3. Nanotechnology products and materials are in expand.
4. Nanotechnology products have clearly advantage for the environment.
5. Decreasing the cost of nanomaterials and nanotechnology products (Dfatadeo, 2014).

3.5.3 Future trends and needs of nanotechnology in building production

It's needed from the building enterprises and the nanotech community to spend an effort to achieve the promises of nanotechnologies for the building. Communication is always the key to solve much of things in life. In order to fill the gaps between the methods in construction and the potential of nanotech, a lot of studies should be done, this research can help to defeat the resist of innovation by the construction industry and the public concerns around nanotechnology.

- Life cycle analysis

Independently defined environmental performance data should encompass the entire life cycle of the products tested. A specific insulation product, for example, could appear to save energy in its application but consume great amounts of energy in its raw material processing and manufacture, distribution and disposal or reuse. Life cycle energy and waste analyses should include data on raw material acquisition, raw material processing and manufacture,

product packaging, product distribution, product installation, use and maintenance, disposal, reuse and recycling.

- Life cycle considerations

1. Where did this material come from?
2. Is it renewable?
3. How much energy was used in harvesting?
4. What effect on habitat?
5. How was it processed or fabricated?
6. How much energy was used in manufacture?
7. What were the environmental impacts of manufacture?
8. How did it arrive on-site?
9. How can it minimize construction waste?

- Regulation

Nanotechnology has concerns, which showed up like every new technology, as an instance the body absorbs nanoparticles easier than large particles, also, the way they accumulated in the environment or the body, few of people know how it was done. There are concerns about the workplace regulation of nanotech-based materials and processes. That's because of the huge number people who work in the construction enterprise. As an instance, researchers from a new study found harmful side effects in carbon nanotube manufacturing, that it has compounds causing cancer, toxic hydrocarbons, air pollution and different substances of concern. Right now, they are working with four major U.S nanotube producers, in order to find strategies which, help to develop a product more environmentally friendly. Until now, the National Institute for Occupational Safety and Health (NIOSH) offers for workers who in direct contact with nanomaterials, only guidelines for workplace safety (Dfatade, 2014).

3.6 Examples of nanoarchitecture applications

Nanotechnology has been used in interior and exterior design occasionally and more or less by coincidence. At this chapter, there are some examples of using nanotechnology in architecture inside and outside of the building. It shows the strategy and methods of using the nano in interior and exterior design, the main concept is different, according to the different use, for the needs. The spaces can be enhanced by using "nanosurfaces" for the concerning, of aesthetic, cost-effective and environmental concern, cost-effective and enhancing of comfort, are going together. Also, should consider the cost not only at the

manufacturing stage but also the following costs when it's used, which continuously decrease.

- **Applying the self-cleaning Lotus Effect on the building**

After ten years of construction and political debate, the Ara Pacis Museum is now home to an archaeological highlight in Rome. The Ara Pacis Augustae, a sacrificial altar that was inaugurated by the Emperor Augustus himself, was given a new container that remedies the environmental as well aesthetic deficits of the previous pavilion from 1938 in which the monument was formerly kept. In (Table 3.6) shows the general information of the project (Rossi, 2015).

Table 3.6: Ara Pacis Museum, Rome, Italy (Rossi, 2015)

Architecture	Designed by Partners, NYC, USA & Richard Meier
Product	"Lotusan, self-cleaning paint" (Lotus-Effect)
Manufacturer	"Sto"
Opened	2006

At this building, self-cleaning coating has been invisibly incorporated into the white surfaces to ensure the stability of their color, in the massively polluted city, for that it'd be having much chance to remaining white for a long time (Figure 3.35) (Rossi, 2015).

Figure 3.35: Ara Pacis Museum (Rossi, 2015)

- **Applying the self-cleaning photocatalytic on the building**

At Narita International Airport has been doing a full improvement, in 2006, in big process by using textile for covering. In (Table 3.7) shows the general information about the improvement at the airport (Leydecker, 2008).

Table 3.7: Narita International Airport of Tokyo, Chiba, Japan (Leydecker, 2008)

Architecture	"Nikken Sekkei Ltd", Japan
Product	" TiO2 photocatalytic self-cleaning membrane"
Manufacturer	"Taiyo Kogyo Corporation"
Opened	2006
Area	6.250m2

They provide the protection, by membranes, from the weather, to enhance the level of comfort in passengers, also, they use the photocatalytic self-cleaning coating with the membranes, which lead to keep the value of cleaning at the minimum, in spite of the traditional coating, glass, PTFE or ETFE materials, they have self-cleaning, but they can't prevent the deposits of dirt from accumulating (Figure 3.36) (Leydecker, 2008).

Figure 3.36: Narita International Airport (Leydecker, 2008)

- **Applying photocatalytic cement within concrete**

The design of this church was about making three sails which are a very huge, reach to 36m in high, that give her a remarkable appearance. (Table 3.8) shows the general information about the project (Dfatade, 2014).

Table 3.8: Jubilee Church, La Chiesa del Dio Padre Misericordioso (Dfatade, 2014)

Architecture	"Designed by Richard Meier & Partners, New York, USA"
Product	"TX Active, TX Millenium, photocatalytic cement"
Manufacturer	"Italcementi"
Completion	2003

They had used the prefabricated high-density concrete for creating those walls and they add to the mixture Carrara marble and TiO2 to gain their white color, by adding the photocatalytic self-cleaning, they had achieved to keep the building clean and stay white, in a world full of pollution, by exhaust gases and other, it does not only stay clean, it's also fighting the pollution, on the surface of the sails, by decreasing the number of volatile organic compounds (VOCs) and nitrogen oxide from the air (Figure 3.37) (Dfatade, 2014).

Figure 3.37: Jubilee Church (Dfatade, 2014)

- **Use of nanotechnology in the fireproof protection**

The landmark 160 m high office tower in Bonn, the former capital city of Germany on the River Rhine, accommodates more than 2000 members of staff. The oval tower's facade is cladded in high-tech transparent glazing and transparent materials are also used throughout its interiors: glazed partitions, glazed staircases and glazed connecting bridges are central elements of the interior design concept. (Table 3.9) shows the general information about the project (Dfatade, 2014).

Table 3.9: Deutsche Post headquarter, Bonn, Germany (Dfatade, 2014)

Architecture	"Murphy and Jahn, Chicago, USA"
Product	"SGG Contraflam fire safety glass"
Manufacturer	"Vetrotech SaintGobain"
Area	"90.000m2"
Completion	2005

The ellipsoidal tower's facade is covered in high-tech transparent glazing and transparent materials are additionally used throughout its interiors glazed partition glazed staircases and glazed connecting bridges are basic elements of the interior design idea, a fire protection glass with a certainly slender profile was chosen for the project, Space, form construction and materials are carefully organized, leading to a harmonious whole concept (Figure 3.38) (Dfatade, 2014).

Figure 3.38: Deutsche post HQ. Germany (Dfatade, 2014)

- **Use of nanogel in curtainwall**

At the Sculpture Building and Gallery of Yale University, they use to cover the studios, a high-performance curtainwall, which is combine of Nanogel® aerogel with glass and Kalwall®, in order to keep most of the glazed envelope, without harm the building's high degree of energy performance, the architect had used a triple glazed curtain wall, of super insulated R-20 and insulated glass. (Table 3.10) shows the general information about the project (Baetens and Gustavsen, 2011).

Table 3.10: Yale University Sculpture Building (Baetens and Gustavsen, 2011)

Architecture	Kieran Timberlake Associates LLP, Philadelphia
Location	New Haven, Connecticut, USA
Date	2007
Green Certification	LEED Platinum Certified
Style/ Type	Museum & Academic / contemporary architecture
Nanomaterials used	Nanogel® aerogel
CO2 Emissions	Greenhouse gas reduction by (energy saving - natural light)

Nanogel-insulated translucent panels: This curtainwall provides a reducing in both loss and gain of the heat in a year, the gaps in the curtainwall are keeping the warm air trapped in it, by the insulation of nanogel and then used in winter to warm the internal space or release it outside in summer, this make a useful thermal control barrier which increase the performance of energy to allows at the same time, the facade to take natural light to inside, thus it well be decreased in the cost of artificial lights, the transparent of building, the weight of facade system, shining light via 8ft operable windows, triple glazed low-E vision panels and a transparent double-cavity space spandrel panel using Nanogel.(Figure 3.39) show section diagram of yale university sculpture building (Baetens and Gustavsen, 2011).

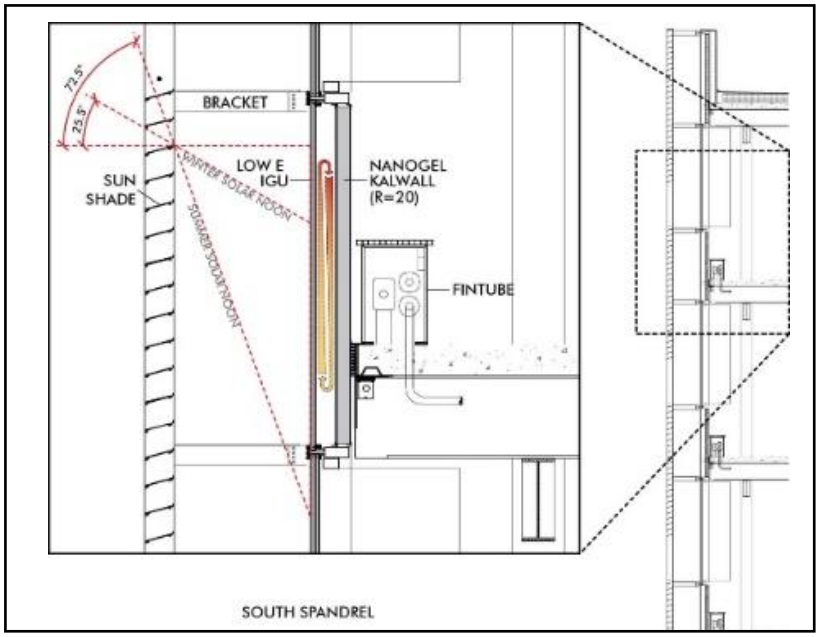


Figure 3.39: Section diagram, Yale University Sculpture Building (Baetens and Gustavsen, 2011)

- **Use of nanoceramic wall covering**

The research center was conceived and built for Degussa, Creavis. With its transparent facade, clear forms, material and color concept, the architecture embodies the company philosophy: the transfer of know-how from science to business. Degussa benefits from being able to use their in-house products. (Table 3.11) shows the general information about the project (Leydecker, 2008).

Table 3.11: Science to Business Center Nanotronics & Bio, Marl (Leydecker, 2008)

Architecture	Henn Architekten, Munich, Germany
Product	ccflex, nanoceramic wall covering
Manufacturer	At the time of construction Degussa, today Evonik
Completion	2005

They embody the philosophy of the company: the transfer of know-how from science to business, by designing it with the clarity of materials, forms, the concept of color, and transparent facade, The feature of nanoceramic wall covering is that very strong, resist the impact, flexible and resist to moisture and it can installed like the way of installing normal wallpaper, because of his water-repellent surface, the best place to use it are in moisten areas such as baths (Figure 3.40) (Figure 3.41) (Leydecker, 2008).

Figure 3.40: Waterclosets of the science to business center nanotronics & bio (Leydecker, 2008)

Figure 3.41: Science to business center nanotronics & bio (Leydecker, 2008)

The Nanoceramic layer is made up of tiny crystals of alumina a material which, although it is a powerful electrical insulator, has a good thermal conductivity. This makes it an ideal dielectric providing it can be applied densely and uniformly. This nano-crystalline structure has a grain size of 20~40nm. These grains are atomically bonded to the surface of the aluminum and are packed very densely across the surface forming an electrically impervious barrier. With such a fine crystal structure, the material retains aluminum's natural flexibility giving an ability to create flexible thermally conductive substrates on thin aluminum foils, but also high resistance to temperature cycling.

• Comparison between nanoceramic tiles and conventional ceramic tiles

This comparison (Table 3.12) show the deference between nanoceramic and conventional ceramic in their applications, how they found on the market and their advantages.

Table 3.12: The big difference between the conventional ceramic materials and the nano produced flexible ceramics (Schwartz, 2005)

	Nano-material Ceramic	Conventional material Ceramic
Applications		
Contract flooring	+	-
Decorative elements	+	+
Sanitary wet rooms	+	+
Veneer	+	-
Wall coverings in exteriors	+	+
Wall coverings in interiors	+	+
Markets		
Construction	+	+
Home, Lifestyle & Personal Care	+	+
Print, Paint & Coating	+	-
Advantages		
Antibiotic	+	-
Breathable	+	-
Durability	+	+
Easy to clean	+	+
Environmental Friendly	+	-
Flame-resistant	+	+
Flexible, easy to process	+	-
Impact-resistant	+	-
Easy of Mobility	+	-
Scratch-resistant	+	-
SVOC free	+	-
UV-resistant	+	+
Waterproof	+	+

- **Exterior wall self-cleaning**

This experiment had been done on old granite wall which is become dirty after years, by adding nano photocatalyst coating to the wall it's become cleaner. In (Table 3.13) the general information about the experiment.

Table 3.13: Granite wall which has become old and dirty after years (Daoud, 2013)

Surface	Granite
Product	Nano photocatalyst coating
Application	by spray
Period	3 months

This photo (Figure 3.42) shows a very old granite wall and because of the time and whether it becomes dirty and in bad shape, they divide the wall by yellow tape for the area which coated with the photocatalyst, on the left part of the marked area they install the photocatalyst. Three months later (Figure 3.43) it's noticed the result of the covering, the left side remain clean, but the right-side change to darker because of air pollution (Daoud, 2013).

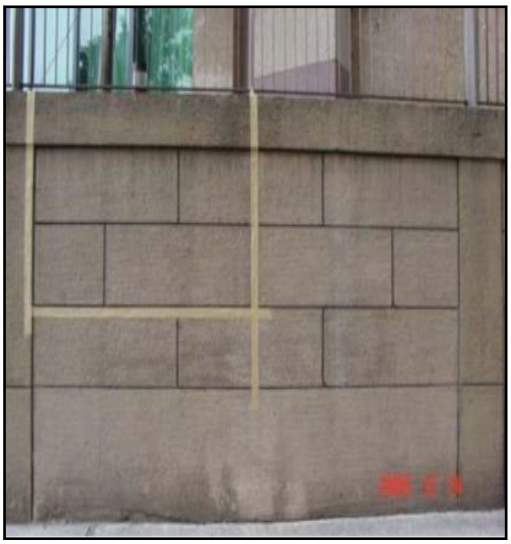


Figure 3.42: A granite wall which has become old and dirty after years, (Photo dated Dec. 14th, 2005) (Daoud, 2013)

Figure 3.43: After 3 months of weathering. (Photo dated Mar. 15th, 2006) (Daoud, 2013)

• **External limestone cladding self-cleaning and anti-moss**

Building exterior self-cleaning, UV discoloration protection. Inhibit biological growth, Road self-cleaning and car exhausts purification. self-cleaning photocatalyst coating is the combination of photocatalyst and nanotechnology. Just simple application of solar stucco top coat on the building exterior surface brings diversified excellent features to the building. In (Table 3.14) information for an experiment on building with self-cleaning coating (Daoud, 2013).

Table 3.14: External limestone cladding self-cleaning & anti-moss (Daoud, 2013).

Surface	Limestone
Product	Nano photocatalyst coating
Application	by spray
Period	224 days

Coating can be sprayed on exterior walls, roofs, on highway barriers and sidewalks to provide the self-cleaning & air purification function. Solar stucco self-cleaning coating can keep the surfaces in a very clean look and reduce the cleaning & maintenance costs. At this building (Figure 3.44) had been taken before photocatalyst coating is applied on the surface and after 224 days of weathering after applying the photocatalyst coating the (Figure 3.45) had been taken. Finally, its show how the nano photocatalyst coating kept the building in a clean look and reduce the cleaning & maintenance costs.

Figure 3.44: Before photocatalyst coating is applied on the surface (Daoud, 2013)

Figure 3.45: After 224 days of weathering (Daoud, 2013)

- **Using nanotechnology in operating theatre**

To keep the operating room and other room in hospital clean and anti-bacterial, the Hydrotect tiles photocatalytic surface had been used in it, which help to keep the room clean of any bacteria. In (Table 3.15) show information about operating theatre in Goslar, Germany which used that application.

Table 3.15: Operating theatre, Goslar, Germany (Dfatade, 2014)

ARCHITECTURE	Schweitzer + Partner, Braunschweig, Germany
CLIENT	Harzkliniken, Goslar
PRODUCT	"Hydrotect" tiles, photocatalytic surface with antibacterial effect
MANUFACTURER	Agrob Buchtal Architectural Ceramics, Deutsche Steinzeug AG
COMPLETION	2005

Hygiene is the most important condition inside the operating room, in order to that they have been covered the wall and floors with photocatalytic tiles and they have used antibacterial tiling to reduce the risk of getting infected, at the Klinikum im Friedrichshain, the architects had made one more step further, they decrease the number of joints in the tile which has considered the weakest point of the tile (Figure 3.46) (Dfatade, 2014).

Figure 3.46: Operation theatre interior shows the green antibacterial tiles (Dfatade, 2014)

• **The holistic application of nano surfaces in interiors**

Nano functions have been employed in interior design only occasionally if at all and more or less by chance. The schematic plans for a hotel room and a patient's room in a clinic or hospital demonstrate concepts for a general strategic approach to using nano functions in interior design (Figure 3.47), (Figure 3.48). The overall concept varies depending on the respective needs of the different users. The spaces are optimized through the strategic use of nano surfaces with regard to aesthetic, economic and ecological concerns. Improved comfort and cost-effectiveness go together. Cost assessments should take in consider not only of the initial expenditure but also the follow-on costs, which are reduced considerably. Despite the fact that these are visionary concepts, they could already be realized today in this or a similar form.

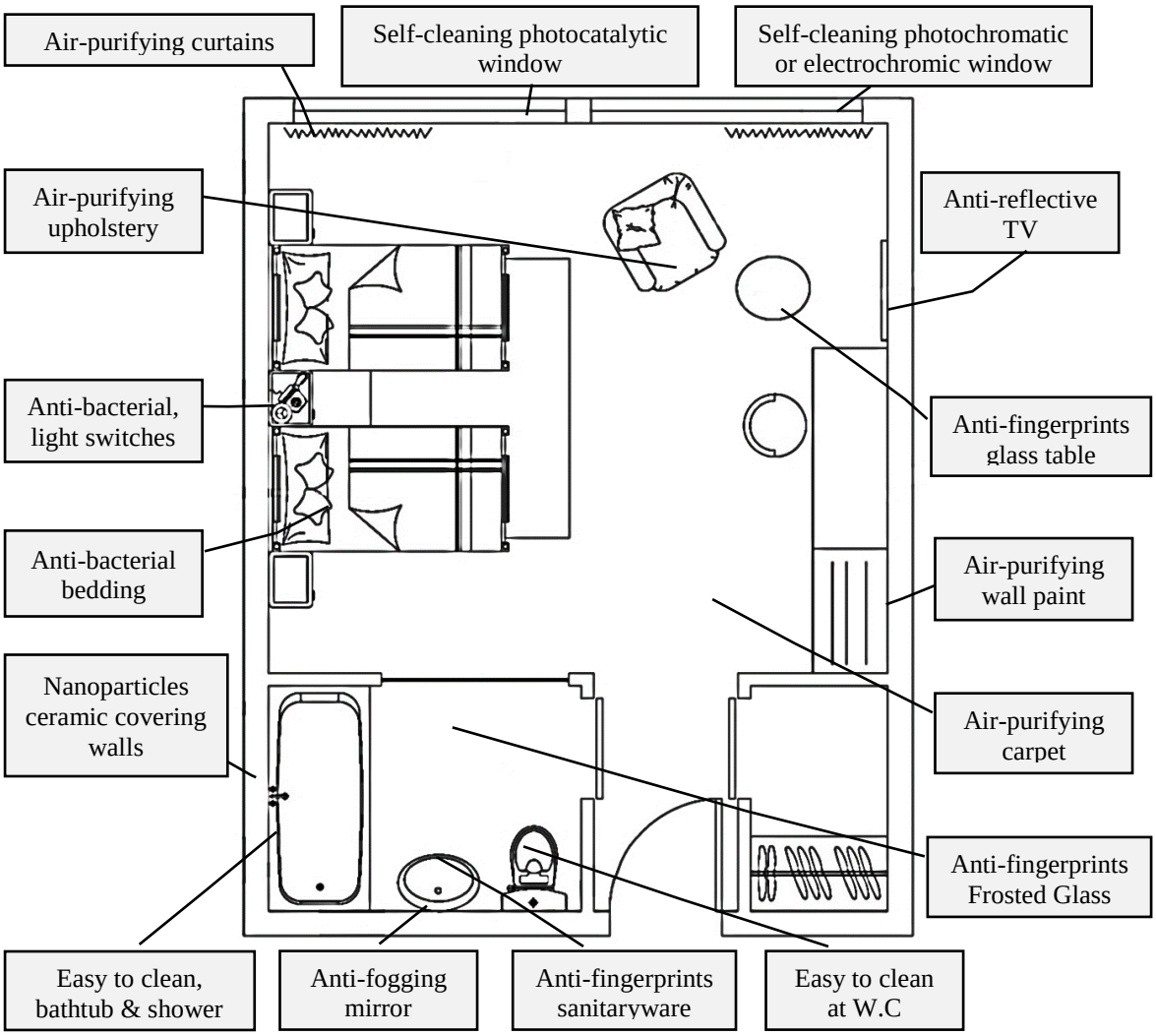


Figure 3.47: The use of nano functions in a hotel room

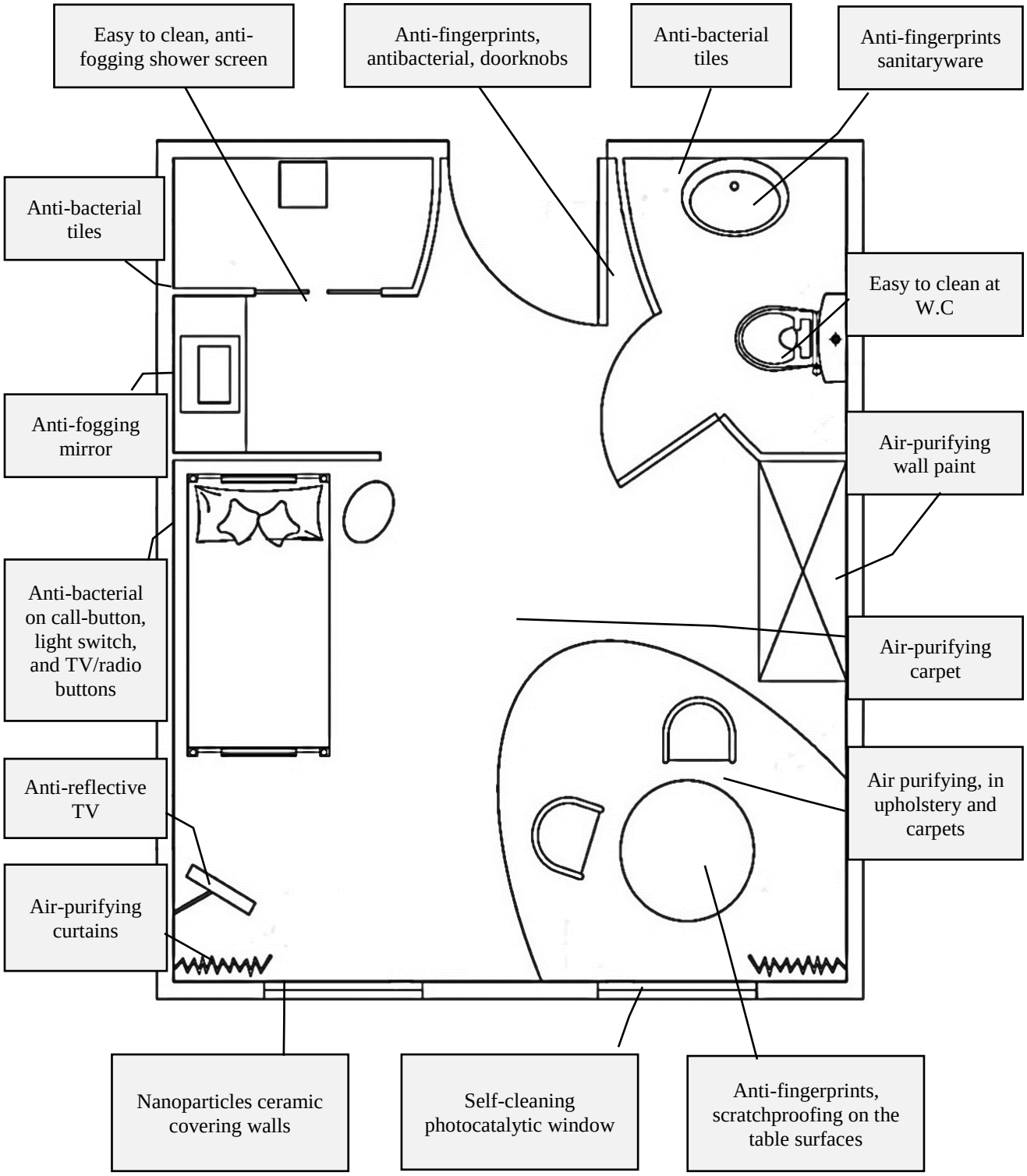


Figure 3.48: A patient room in a hospital with a general strategic approach for the use of nano functions

3.7 Conclusion of The Chapter

This chapter is talking about applying nanotechnology into architecture and how it impacts to the architecture in the way of thinking and design. Also show what it gives to the future of environment of benefits. After that it explains the application of nanoarchitecture on the buildings with mention some examples and comparisons in real life. At the end, it can be concluded;

This small-scaled science is giving huge ideas for the architecture. Nanotechnology, it gives promises to change the architecture in different ways. Nanotech can bring a big evolving in building performance, energy efficiency and in achieving sustainability to the buildings. Nanotechnology can make the insulation more efficient, less dependent on nonrenewable resources and less toxic. The insulating materials which made from nanotechnology are more efficient than normal materials in about 30 % more. The Nanogel can achieve a great saving in energy by providing natural light for indoor spaces, because it makes 75% translucent panel.

OLED lighting also creating with nanotechnology it's more efficient than normal lighting five times more. By depending on OLED lighting the greenhouse gas emissions can be decreased. Using OLED lighting with sensors and ICT to make smart-lighting, it's reduce the consumption of energy. At silicon solar cells, 40% of the cost is materials, but in thin-film solar using nanotechnology, the cost of materials is about 1% or 1.5%.

The new materials and processes that came from using nanotechnology, provide a great potential to fight climate change and to improve the environment. According to the report, “Nanotechnologies for Sustainable Energy “, The Current applications of nanotechnologies resulted in a global annual saving of 8,000 tons of carbon dioxide in 2007, rising to over 1 million tons by 2014.

From that application of nanomaterials previously. The advantages and disadvantages of nanomaterials in building production had been made according to environment–human health and energy-resource conservation (sustainability criteria) in (Table3.16). This table helps to explain the relation between nanotechnology and sustainability and how can nanotechnology participate in achieving sustainability which that showing in the next chapter.

Table 3.16: Analysis of nanomaterials in building production within the context of environment–human health and energy-resource conservation

NANOMATERIALS	ADVANTAGES	DISADVANTAGES
Insulation • Aerogel • Thin film insulation	-High heat insulation value provides effective energy conservation -Reduce consumption of resources -Take up less space than traditional insulators -Reduce transportation costs -Reduce the amount of harmful gas -Indoor thermal balance remains at the ideal level	-New and expensive products. -Special knowledge and experience in terms of usage -Difficulties in production and observation with nanoscale -Insufficient information on their continuity has been obtained -Special production, control and repair methods are needed -Difficult to evaluate the effect of nanoparticles in the environment to follow the traces of the ecosystems -The effects on human health and environment have not been fully determined -Meaning standards and test methods are not fully clarified
Coating • Self-cleaning • Easy to clean • Anti-fogging • UV and Solar protection • Anti-graffiti • Anti-reflective • Anti-fingerprint	-Reduces the time of working on cleaning -Reduce the need for artificial illumination -Reduce material consumption by extending the service life -Increase air quality -Prevent the spread and formation the bacteria -Reduce the use of chemical substances in the cleaning process -Reduce the formation of harmful gases which pollute the environment, by making the harmful components in the air harmless -Does not contain any harmful substances	
Lighting • LEDs • OLED	-Reduce the amount of energy for lighting -Doesn't need maintenance, provides high efficiency and brightness -Has long lifespan and high impact strength -Reduces cooling costs -Don't need to the color filters, to color the light, in LEDs can emit the color of light which need -OLEDs are very thin and flexible it can be located on any shape -Does not contain a harmful substance like mercury to the environment and human health -Prevent energy loss and conserves energy -Indoor thermal balance remains at the ideal level -Provide enough natural lighting	
Solar energy • Inorganic silicon solar cells • Organic thin film solar nanotechnologies	-High efficiency and wide use areas -Restricts the use of exhausted fuels -Increases the use of renewable energy -Saves energy and reduces energy costs -Prevents energy losses -Reduces the release of harmful gases -Reduces consumption of raw material, contributes to environmental balance	

CHAPTER 4

NANOARCHITECTURE AND SUSTAINABILITY

Nano-architecture is the combination of architectural design with nanotechnology. The use of nanotechnology in architecture varies from materials, equipment's, to forms and design theories. Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The director of the American Chemical Society Green Chemistry Institute Paul Anastas, says that nanotechnology necessary to create sustainable technologies not only an option and as be seeing, the community of nanotechnology are ready to face Anatsas challenge. The market for sustainable nano products, increased from 1.2 billion dollars in 2006 to 5.3 billion dollars by 2021. Creating a green building it's coming from the need to heal the environment and also have to be required by law and corporate policy. In order to gain acceptance from environmental performance criteria such as LEED. Can give a clear measure of sustainability, nanotechnology when it used with green building, it's deliver benefits like decreasing the emissions of carbon and effects of weather change. So clearly, these efforts would be focused on building production, nanotechnology for green building, in addition, to using it to gain the needs of corporate and municipal sustainability. Also, it used to increase the pressures both national and international, to decrease the emissions of carbon too.

4.1 Sustainability

Sustainable design should address the triple bottom line of social, economic and environmental issues: social in the sense of community engagement and inclusiveness. Economic in the sense of long-term growth and prosperity. Environmental in the sense of local and global impact. In addition, the sustainability agenda affecting the built environment, in general, embrace the following key topics: energy and carbon dioxide emissions, water conservation, waste recycling, materials sourcing, associated transport and biodiversity. The sustainable building refers to the quality and characteristics of the actual structure created using the principles and methodologies of sustainable construction. It can

be defined as healthy facilities designed and built in resource efficient manner. Using ecologically based principles (Mebratu, 1998).

- Definition of sustainability

  Used more in the sense of human sustainability on planet earth and this has resulted in the most widely quoted definition of sustainability and sustainable development. That of the Brundtland Commission of the United Nations: sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It is usually noted that this requires the reconciliation of environmental, social and economic demands the *three pillars* of sustainability (Figure 4.1). This view has been expressed as an illustration using three overlapping ellipses indicating that the *three pillars* of sustainability are not mutually exclusive and can be mutually reinforcing (Richardson, 1997).

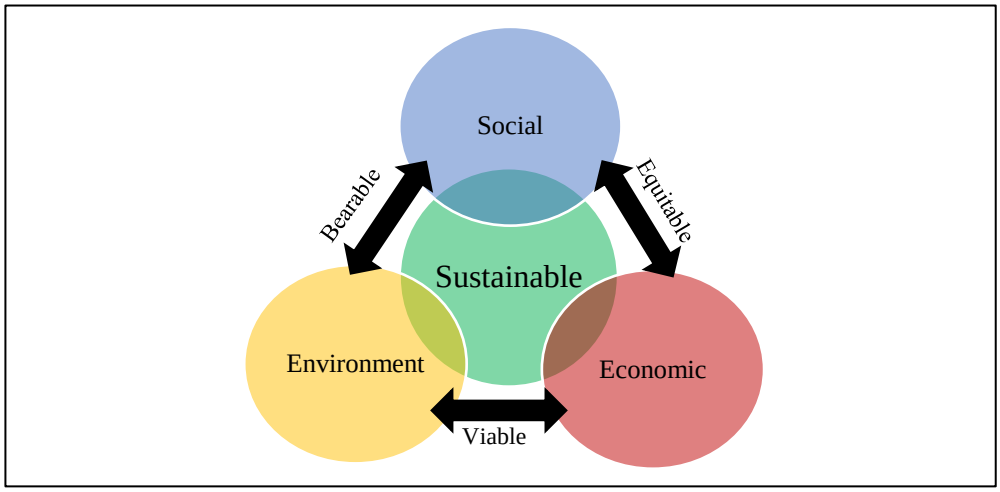


Figure 4.1: The three pillars of sustainability

- Sustainability principles

  Sustainability is studied and managed over many scales of time and space and in many contexts of environmental, social and economic organizations. The focus ranges from the total carrying capacity of planet earth to the sustainability of economic sectors, ecosystems, countries, municipalities, neighborhoods, home gardens, individual lives, individual goods and services, occupations, lifestyles, behavior patterns and so on;

- Maintain and enhance quality of life.
- Enhance economic vitality.
- Ensure social and intergenerational equity.
- Enhance environmental quality.
- Incorporate disaster resilience/mitigation.
- Use a participatory process (Mebratu, 1998).

Sustainability often refers to the *three pillars* of Social, Environmental and Economic Sustainability (Figure 4.1). Sustainable building involves considering the entire life-cycle of buildings, taking environmental quality, functional compatibility and future values into concern. It is worth mentioning that sustainability cannot be seen in isolation, as it has very meaningful linkages with economic as well as social parameters, without which it not accepted by the society at large (Richardson, 1997).

- Sustainable Design

It is the philosophy of designing physical objects, the built environment and services to comply with the principles of economic, social and ecological sustainability. Sustainable design is mostly a general reaction to global environmental crises, the rapid growth of economic activity and human population, depletion of natural resources, damage to ecosystems and loss of biodiversity (Richardson, 1997).

- Principles for Sustainable Design

1. *Low-impact materials*: Choosing non-toxic, sustainably-produced or recycled materials which require little energy to process.
2. *Energy efficiency*: Using manufacturing processes and produce products which require less energy.
3. *Quality and durability*: Longer-lasting and better-functioning products have to be replaced less frequently, reducing the impacts of producing replacements.
4. *Design for reuse and recycling*: Products, processes, and systems should be designed for a commercial performance.
5. *Bio-mimicry*: Redesigning industrial systems on biological lines, enabling the constant reuse of materials in continuous closed cycles.

6. *Service substitution*: Shifting the mode of consumption from personal ownership of products to provision of services which provide similar functions, e.g. from a private automobile to a car-sharing service. Such a system promotes minimal resource use per unit of consumption.
7. *Renewability*: Materials should come from nearby (local or bioregional), sustainably-managed renewable sources that can be composted when their usefulness has been exhausted.
8. *Healthy Buildings*: Sustainable building design aims to create buildings that are not harmful to their occupants nor to the larger environment. An important emphasis is on indoor environmental quality, especially indoor air quality (Mebratu, 1998).

4.2 Sustainable Nanoarchitecture (SNA)

The use of nanotechnology gives ecological and economic benefits for energy efficiency and the preservation of sources. Technologies that assist decrease weather exchange are in need more than ever before, at the future, ecology and the economy have to become inseparably attached. As preventive measures maybe cheaper in the long term than treating the harm caused, ecology pays off and whether protection pays off contributed one is open to technological possibilities and the conditions of use. They involve, environmentally friendly manufacturing strategies, energy efficiency, reduced environmental pollutants and the preservation of assets are possibilities which nanotechnology offers. Preferably, emphasis should take delivery of to the overall eco-balance throughout the whole lifecycle of a merchandise or building rather than one single feature. Sustainability is very necessary, buildings are usually designed with 20-30-year periods, that may make it hard to comprise coatings with 2-3 years durability. There are, however, a few corporations that provide a 10 year assure for their nanotechnology-based products, creation processes. Also, can be made more efficient and more economical with the help of nanotechnology, by way of decreasing the amount of energy and raw materials needed to a minimum either directly or indirectly (Leydecker, 2008).

The revolution of nanotechnology has produced a great advance in the performance of the building, environmental sensing, sustainability and the efficiency of energy, all of that make the building greener. In order to recognize the great benefits, between building and nanotech, which wait for each of them. The community of nanotech should be explored, it had to explain the great possibilities in the economy in operation and demonstrate, construction and

in design green building, to owners of the building, contractors, engineers, architects, and others. At the moment when international building enterprise spends one trillion dollars in the year, the nanotech can fulfill its promise of benefits in health to the environment and user (Leydecker, 2008).

- Employ nanotechnology to existing buildings

It's predicted for nanomaterials in the insulation at the marketplace for all enterprises would reach to 590 million dollars in 2014, the application of insulating nanocoatings would be the biggest participation of nanotechnology in buildings which already exist, to reduce the emissions of carbon at the 21st century (Elvin, 2007).

At current European buildings, according to ECOFYS, when adding thermal insulation to them, it would decrease the cost of energy of the building and also the radiations of carbon by 42% or 350 million metric tons. But even if it has a low price effective strategy for decreasing radiations of carbon, it's hard to apply to the existing buildings with some of the traditional materials. Because of the need to make the partial destruction of the wall in order to reach the place where insulation would be in it. Nanocoating's insulation can beat the values of insulation in traditional materials by using application of a transparent coating to the building envelope which is very simple, at the insulation of present structures. Aerogels can take a very important role. More study is needed on the cost of insulating with the products of nanocoating to be defined. It's urgent to improve the probability of their abilities to save energy. Because at mid-century, half of the buildings ha to be already constructed (Dfatade, 2014).

The emission of carbon can also be reduced by another way which is the organic thin-film solar technology that equipped with the aid of nanotechnology. Thin-film solar cells are cheaper than the conventional glass technology because it can produce as rolls of plastic. Because of their flexibility it very easy to install and to adapt on facades of the building more than normal glass plates. Which make photovoltaic in a combination of more adaptable and affordable. production of nanosolar in a factory at U.S they triple the production of the solar cell, this is mean that it's time to use nano with solar energy (Elwan et al, 2015).

A big saving in energy can be gain by using LED and OLED and also a great performance comparing to normal lighting, at Wal Mart's by using of LED lighting on refrigerators, they are saving in the price of energy about 2.6 million and decrease about 35 million pounds of carbon radiation, that's mean the time to use these technologies has come (Elwan et al,.2015).

- Reduced processing energy

The plans of saving energy primarily concentrate on decreasing the cost of their operation. That's because it generally uses 5 times as much energy in operating the building. In addition, nanotechnology offers a big saving on the products which related to the building during the manufacturing it as well. For example, DuPont, nanoparticle paint has been licensed as ecology coatings, in order to reduce the cost of materials by 75% and the using of energy in coating application by 25%. The paint only needs a temperature of the room to be cured by using ultraviolet (UV) light, instead of the ovens 204ºC which required for normal auto paint and in that's saving comes, this technology can be used on the surfaces of the building industry and factory coated facade panels (Elvin, 2007).

- Nano sensors and smart environments

Nanotechnology has wonderful enhancements in the performance of building materials, but also there is something greater in the result which is nanosensors. When installed nanosensors in building materials it's collect information about users of the building, the environment and performance of the material. Also, it's make communication between other sensors and users in order to change the building to networks of intelligent, interacting elements. When elements of the building convert smarter, by gathering information on humidity, corrosion, pressure, vibration, temperature and many other factors, this data can give the ability to enhance building preservation and monitoring and protection. The big developments of saving energy can anticipate also. As an example, it can recognize patterns of adjusting heating, cooling and building occupation according to the environmental control systems (Dfatade, 2014).

Also, in windows, it would have the ability to be adjusted by their self to let radiation of the sun pass through or to reflect it away. Finally, networks of embedded sensors communicate with each other and with those used in building users. Which lead to smart environments that can change according to preferences and requirements of the single user. It's define a lot of things like the temperature of the room, the color of the wall, by invisible continuous communication between sensors (Dfatade, 2014).

The community are already starting to work on smart environments, as an example, there is a project that funded by 9.5 million euro at the European Union which Leeds Nano Manufacturing Institute (NMI) is a part of it, to make an improvement at the house by using a unique wall that has wireless inside it, sensors with less battery and identity of radio frequency to gather information on temperature, vibrations, humidity, gas levels and stresses. Professor Terry Wilkins, the NMI leader, chief executive said, the smart sensor network detects the problems when it occurred and warn the user immediately. Which gives them a time to act right and be safe. High-power gypsum board and the novel load bearing steel frames are used to create the wall of the self-healing house, that have nano polymer particles with it. So that's help in fill cracks because it's changing into a liquid if it pressed under pressure level and then harden the cracks and make a solid material. Cheap wireless sensors can be used which are based on nanotech, to alert the engineers from crack problem and the damage in the buildings, bridges and other structures, that's according to a study from the International Journal of Materials and Structural Integrity (Dfatade, 2014).

Nanotechnology-based sensors and wireless MEMS, if they designed properly, they had to be the main part, of self-sensing concrete structures which are used to form it. The developers had explained, these devices transmit and collect information about structure health, which by finding an early formation of very small cracks and measuring the rate of key parameters, like moisture, temperature, chloride, acidity and carbon dioxide levels all of that can cause a reduction in safety of the structure, (Elvin, 2007).

4.3 Green Architecture Performance Measurement

Many of these tools which mentioned earlier measure sustainability of the built environment. These tools have been developed to determine if any capacity exists for further development, or whether a development is sustainable, or whether progress is being made towards sustainable development. Indicators are also an important part of the range of the tools available and relate mainly to parameters that can be measured to show trends or sudden changes in a particular condition. It is important to distinguish between those tools used for measurement and those used for assessment, as well as those tools that can be used to affect a move towards sustainable development by changing practice and procedures. In general, the tools are attempting to achieve continuous improvement to optimize building performance and minimize environmental impact. Provide a measure of a building's effect on the environment and set credible standards by which buildings can be judged objectively (Fuerst, 2009).

Many countries have introduced new rating tools over the past few years in order to improve the knowledge about the level of sustainability in each country's building stock. On one hand, it can be argued that the individual characteristics of each country, such as the climate and type of building stock, necessitate an individual sustainability rating tool for that country. Like BREEAM (U.K. and Europe), LEED (U.S. & Canada), Green Star (Australia) (Lee and Burnett, 2008).

- Leadership in Energy and Environmental Design (LEED)

This program is the verification arm of the U.S. Green Building Council (USGBC®) (Figure 4.2). LEED is redefining the way of thinking about the places where living, work and learn. As an internationally recognize mark of excellence. LEED certification provides independent, third-party verification that a building, home or community was designed and built using strategies aimed at achieving high performance in key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality (Fuerst, 2009).

Figure 4.2: Logo of LEED organization (Fuerst, 2009)

LEED-certified buildings are designed to:

- Lower operating costs and increase asset value.
- Reduce waste sent to landfills.
- Conserve energy and water.
- Be healthier and safer for occupants.
- Reduce harmful greenhouse gas emissions.
- Qualify for tax rebates, zoning allowances and other incentives in hundreds of cities.

- Building Research Establishment Environmental Assessment Method (BREEAM)

BREEAM is the world's leading and most widely used environmental assessment method for buildings. Until now, BREEAM has certified over 200,000 buildings since it was first launched in 1990 (Figure 4.3). BREEAM assessment uses recognized measures of performance, which are set against established benchmarks, to evaluate a building's specification, design, construction and use. The measures used represent a broad range of categories and criteria from energy to ecology. They include aspects related to energy and water use, the internal environment (health and well-being), pollution, transport, materials, waste, ecology and management processes (Lee and Burnett, 2008).

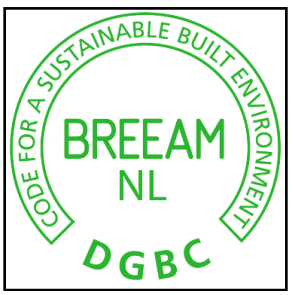


Figure 4.3: Logo of BREEAM organization (Lee and Burnett, 2008)

This program aims to;

1. To mitigate the life cycle impacts of buildings on the environment.
2. To enable buildings to be recognized according to their environmental benefits.
3. To provide a credible, environmental label for buildings.
4. To stimulate demand for sustainable buildings.

• The European Union 7th Environment Action Program

Over the past decades the European Union has put in place a broad range of environmental legislation. As a result, air, water and soil pollution has significantly been reduced. Chemicals legislation has been modernized and the use of many toxic or hazardous substances has been restricted. Today, EU citizens enjoy some of the best water quality in the world and over 18% of EU's territory has been designated as protected areas for nature. However, many challenges persist and these must be tackled together in a structured way. The 7th Environment Action Program (EAP) are guiding european environment policy until 2020. In order to give more long-term direction, it sets out a vision beyond that, of where it wants the Union to be by 2050: In 2050, we live well, within the planet's ecological limits. The prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably and biodiversity is protected, valued and restored in ways that enhance the society's resilience. The low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society (Lenschow, 2005). Figure 4.4 show the 7th EAP priority objectives.

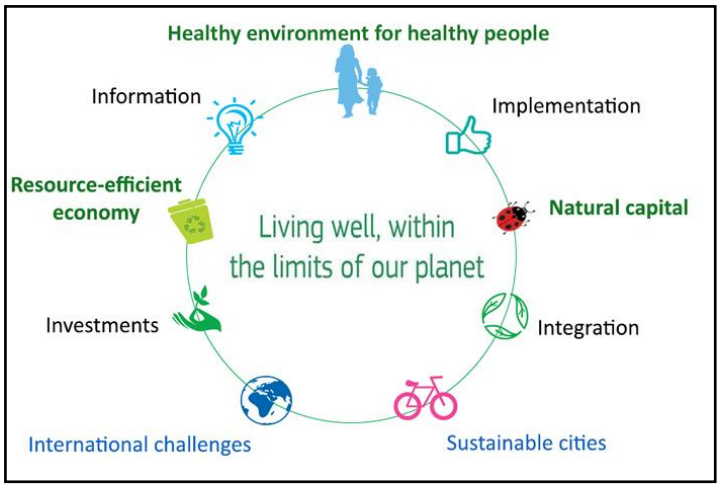


Figure 4.4: 7th EAP priority objectives (Lenschow, 2005)

- 7th EAP priority objectives:
  1. to protect, conserve and enhance the Union’s natural capital.
  2. to turn the Union into a resource-efficient, green and competitive low-carbon economy.
  3. to safeguard the Union's citizens from environment-related pressures and risks to health and wellbeing.
  4. better implementation of legislation.
  5. better information by improving the knowledge base.
  6. more and wiser investment for environment and climate policy.
  7. full integration of environmental requirements and considerations into other policies.
  8. to make the Union's cities more sustainable.
  9. to help the Union address international environmental and climate challenges more effectively (Lenschow, 2005).

The program entered into force in January 2014. It is now up to the EU institutions and the Member States to ensure it is implemented and that priority objectives set out are met by 2020.

All those measurements and strategies which was mentioned in the preceding paragraph has encouraged the scientists and researchers to use nanotechnology with green building. The features of nanotechnology are useful to participate in achieving the sustainability to the buildings production.

4.4 Green Nanotechnology (GNT)

Green nanotechnology is a term which is called, to the improving of clean technology, in order to reduce the risk of health and environment, which is related to the products that used and manufactured with nanotechnology and also invite to replace the traditional products with new products of nano, which is friendlier with the environment in all their life cycle (Schmidt, 2007).

• Goals of Green Nanotechnology

1. Produce the nanomaterials, without making any damage to the health of the user and environment, Green Nanotechnology it's the using of nanotechnology to make the fabrication processes for non-nanomaterials friendlier for the environment. Nanoscale catalysts, for instance, it's make the chemical reactions more efficient and lessen in the waste and using the alternative energy systems which created by nanotechnology.
2. It's offer to environment, solutions for their problems by manufacturing products of nano.
    - Dangerous waste area, air pollution, desalinated water, all of that can be cleaned quickly by nanomaterials.
    - Fuel for transportation would be saved and the materials which use in production reduced also because the lightweight of nanocomposites.
    - The pollutions which came from energy production with using light-emitting diodes (LEDs), it would be reduced.
    - No more need to use cleaning chemicals on the surface or it would be decreased after using self-cleaning coatings.
    - Material and waste use are decreased, by utilizing the enhanced battery life (Schmidt, 2007).

Green nanotechnology is usually called to the using of nanotechnology to make improvement in the environmental and sustainability of the processes which producing bad externalities, it's also called to the nanotechnology products which used for improving sustainability, in general, it's about doing the right thing, in making green nanoproducts and use it to support sustainability (Elvin, 2007).

4.5 Futuristic Thinking of Using Nanotechnology

All that beneficial advances which came from nanotechnology when it's employed in the building, it brings to the designer a new way of thinking in using materials. by using those new technologies and other technology. Which leads the designers to show up so much of futuristic ideas and projects, starting from using new materials to create a whole city that based on that technology, all of that to make life well and clean the environment of pollutants.

• Nano house

It's designed by each of the architects, designers, scientists, engineers and builders together," It is a new type of ultra-energy efficient house which uses all new nanotechnology materials. Carl Masens is the one who designed the Initiative of the nano house in 2002 in the Institute for Nanoscale Technology and James Muir is the architect who had visualized it and implemented it, they have put all the nanotechnology applications, in the house, like self-cleaning windows, wood can resist the damage of UV. (Table 4.1) show the general information of the project (Altun and Örgülü, 2014).

Table 4.1: The team of nano house project (Altun and Örgülü, 2014)

Coordination	Carl Masens
Architecture	James Muir
Design	Douglas Tomkin
Energy	Joe Zhu

The shelter is a basic need. Everyone understands what a house is. In this context, it is easy to see where nanotechnology can be used and how the new technology impacts upon the lives. "The Nano House takes us from imagination to reality. The principles upon which it is based are energy efficiency, sustainability and mass customisation," Mr Masens says. The Nano House has a radiative cooling paint as the outer surface of some of the roofing material. A metal roof coated with this paint become a cooling element in a building rather than a source of unwanted heat gain. Other features are self-cleaning glass, cold lighting systems and the dye solar cell - a photovoltaic cell based on titanium dioxide rather than silicon. The architectural model of the house is the first stage of the concept, with the creators planning a full-size version in the future (Figure 4.5) (Altun and Örgülü, 2014).

Figure 4.5: Nanohouse model (Altun and Örgülü, 2014)

• The nano towers

Allard Architecture has proposed to make The Nano Towers, is the new headquarters for DuBiotech Research Park in Dubai", it provides 160.000 m^2 of laboratories, office space, residential and hotel, all of that in a tower reach his height to 262 meters, the exterior structure has created as repetitive grid which has equal length of non-curved beams, the concept of the tower comes from the shape of carbon tube on the nanoscale. (Table 4.2) show the general information of the project (Altun and Örgülü, 2014).

Table 4.2: The nano towers (Altun and Örgülü, 2014)

Architecture	Allard Architecture
Function	Mixed use
Situation	Proposal
Location	The new headquarters of the DuBiotech Research Park in Dubai
Height of tower	262m
Area	160 000m2

The entire facade of the tower is faceted, inspired by a nano scale carbon tube, the structure creates junctions where the geometry shifts from vertical to horizontal. This creates multiple opportunities for dividing the interior space along mullion lines (Figure 4.6) (Altun and Örgülü, 2014).

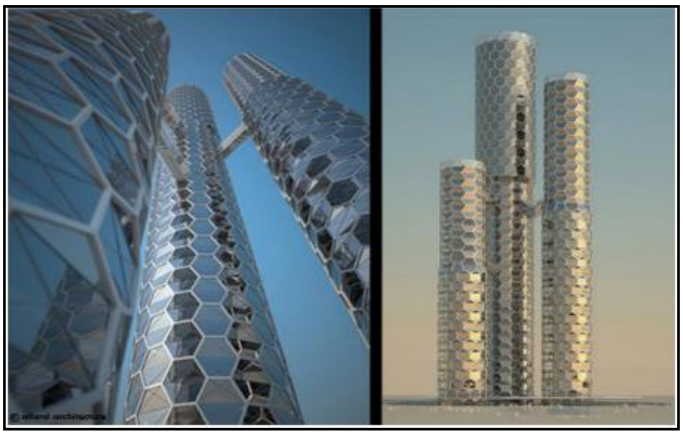


Figure 4.6: The nano towers (Altun and Örgülü, 2014)

• Nano vent skin

It's about using the wind turbines on the nanoscale (Figure 4.7), which is designed by "Agustin Otegu", the concept is about wall contains different kinds of microorganisms which work to change the natural energy to electricity and absorb it, sunlight and wind power converts by those bioengineered organisms, to renewable energy and also they absorb CO2, there is no any genetically change on those microorganisms, they all work as one colony everyone has a specific task in this process, they absorb sunlight from the organic photovoltaic skin on the surface and then move it to nanofibers in the nanowires. Then they send it to the storage units at the end of each panel, every turbine generates energy by chemical reactions and also act as filter to absorb CO2, it can be saying NVS is almost same human skin in the works. Like in human skin, when it hurt, the brain sends signals to that area to be restored, also in NVS in each corner of the panel have a sensor, if one of the turbines had broken, a signal sends to the central system by nanowires and microorganisms are sent by the central tube to restore this area to the self-assembly process, they develop a model to make a test on the wind tribunes. This Building was developed to show how Nano Vent-Skin can be used on new designs and concepts (Figure 4.8) (Altun and Örgülü, 2014).

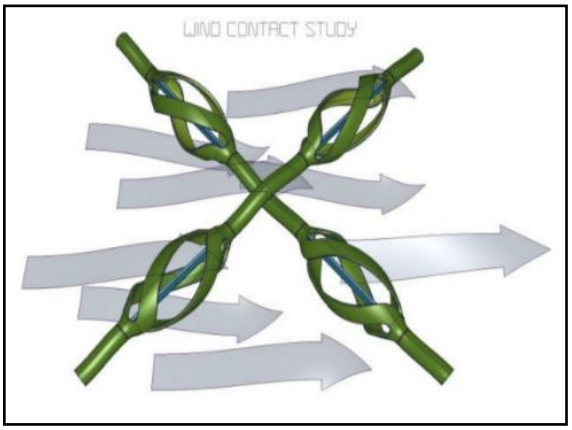


Figure 4.7: Nano vent-skin wind contact study (Altun and Örgülü, 2014)

Figure 4.8: NVS view (Altun and Örgülü, 2014)

• Utopia one; tall emblem structure

The winner in the Competition of ThyssenKrupp Elevator to design a tall emblem structure for Zaabeel Park in Dubai, is the Utopia One (Figure 4.9) which was applied by Cesar Bobonis-zequeira, Ivan Perez-rossello and Teresita del Valle, its high tower which designed with unique shape and also they use material like the one that used in smooth sculptural which created earlier in the park, they uses Nano cell technology on the outside walls, to provide an energy to the elevator systems, electrical systems and HVAC systems and the grey water can be reuse in irrigation and to provide water for the HVAC systems. (Table 4.3) show the general information of the project (Hemeida, 2010).

Table4.3: Utopia one: dubai tall emblem structure (Hemeida, 2010)

Architecture	Cesar bobonis-zequeira, Ivan perez-rossello and Teresita del valle
Location	Zaabeel Park.Dubai
Situation	Proposal

The elevator is constructed of glass all around and encased inside a shaft with a glass exterior to permit views to the outside as one rises. The observation deck (oculus platform) is formed by a ring that supports a glass floor intended to give the sensation of flight. Nano-cell technology are integrated to the exterior skin of the building, providing a portion of the energy to run the elevator systems, HVAC systems and electrical systems. Nano-cell technology is a thin photovoltaic film bonded to metal surfaces. Heat sensitive glass reacts to the sun's position and controls the heat gain in the glassed surfaces. Water management features are reusing grey water for irrigation and providing water for the HVAC systems (Figure 4.10) (Hemeida, 2010).

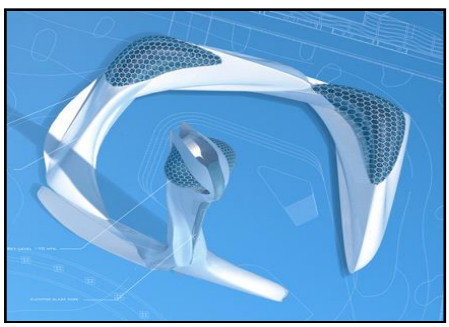


Figure 4.9: Bird's eye view of utopia one (Hemeida, 2010)

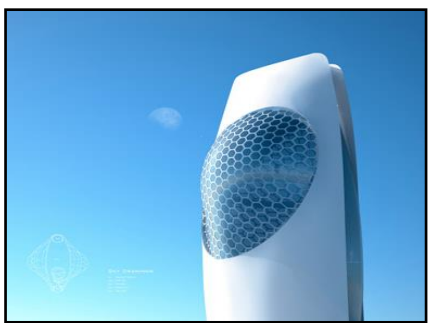


Figure 4.10: Utopia one power, through nano technology (Hemeida, 2010)

• Masdar City (zero carbon city)

Its built in the United Arab Emirates which is remarkable ecological city, its located outside of the capital Abu Dhabi, the workers on this project are about 40,000, Masdar City is about 6 square kilometers and it's designed to accommodate houses for 40,000 people and 1500 businesses, because it's located in medial of the desert so it's depend on the sun to give the power to the city, the largest solar farm in the Middle East, is the Masdar's solar farm, which is already built, inside the city it's not allowed to the cars or skyscrapers the streets are only for pedestrians and the streets very narrow which make buildings close to each other, that provide a nice shades. (Table 4.4) show the general information of the project (Walsh, 2011)

Table 4.4: Masdar City (Walsh, 2011)

Architecture	Norman Foster
Location	Abu Dhabi – U.E.A
Date	2016
Type	Zero Carbon City
Technologies Used	Photovoltaic Farms – Solar Power – Pod Car -Renewable Energy
CO2 Emissions	Strategy is to reach zero emission

Masdar city (Figure 4.11) is divided to five units in below;

1. *Masdar City*: An area for living which contain houses enough for 40,000 residents, 1,500 Cleantech companies and its accommodate 50,000 visitors and it provides a test base for their technologies.
2. *Masdar Institute of Science and Technology*: It's Developed in collaboration with the Massachusetts Institute of Technology (MIT), it's can accommodate about 200 faculty members and 800 students.
3. *Utilities and Asset Management*: The Utility team is working to develop a renewable energy, by focusing on concentrated solar power (CSP), wind, photovoltaic (PV) and waste to energy and the first hydrogen fired power plant in the world, which are in the city and it's produce more than 500MW of power.
4. *Carbon Management:* It aims to drive the economies of low carbon in all the world by taking advantage of carbon reduction projects and it develops a carbon capture and storage network at the Emirate of Abu Dhabi.

5. *Industries*: It's working on developing clean strategic energy projects locally and internationally which include a PV production facility in Germany and Abu Dhabi and solar manufacturing group in 4 Square kilometers in Abu Dhabi (Walsh, 2011).

Figure 4.11: Masdar city (Walsh, 2011)

The design concept of the city is taken from the spirit of Abu Dhabi, so its design according to the traditional Arabic architecture, these traditional design techniques can reduce the Consumption of energy and improve the environment quality and with the shaded walkways and narrow streets the solar ray are reduced and create a wonderful green space.

The diagonal orientation of the streets and public spaces makes best use of the cooling night breezes and lessens the effect of hot daytime winds, whilst further reducing the effects of direct sunlight, traditional passive features such as wind towers, blinds and solar shades help to further improve comfort levels (Walsh, 2011).

The most advanced building in the world can be found in the building of the city. They designed the building in an intelligent way, in order to decrease the use air conditioning and artificial lighting. All the building meets the high standards which put by the Internationally

recognized organizations, also Masdar City consider an important partner in the sustainability program (Figure 4.12) (Figure 4.13) (Walsh, 2011).

Figure 4.12: Interior view of Masdar City #1 (Walsh, 2011)

Figure 4.13: Interior view of Masdar City #2 (Walsh, 2011)

The German firm Conergy had built a solar power plant to supply the power for the construction work and follows another larger solar power plant in the future. It's expected to generate 130 megawatts of solar energy by the solar power plant and photovoltaic modules which are on the roof. The desalination plant which powered by solar power, it's generate fresh water to the city, it's recycle ~80% of the water, in comparing of water usage with other cities. The usage would be a half of the use, they are building wind farms outside the city and they plan to make the largest hydrogen power plant in the world (Walsh, 2011).

By integrating with alternative energy technologies, almost zero footprints. Masdar can achieve a reducing in energy footprint and excellent energy efficiency, they install around the city high fences which is reduce the hot wind's impact from the desert. They had used solar glass in the buildings which decrease the heat. In the building complexes, they have cooling towers their efficiency is high, a trees and fountains had to be made which help also in cooling the weather. The average temperature of the city has to be lesser than the surrounding desert by 20 degrees and the reduced of the waste reach to almost zero, plastics wastes has to be recycled and reused, biological waste are used to create a nutrient rich soil (Walsh, 2011).

Figure 4.14: Masdar city analysis (Walsh, 2011)

Responsive to the culture and spirit of Abu Dhabi, the design of the city is inspired by the traditional Arabic architecture and urban planning of the region and includes many examples of where traditional design techniques help to reduce energy Consumption and to improve the quality of the Environment. Shaded walkways and narrow streets reduce glare and solar gain and create pleasant and attractive outside green spaces. The diagonal orientation of the streets and public spaces makes the best use of the cooling night breezes and lessens the effect of hot daytime winds, whilst further reducing the effects of direct sunlight. Traditional passive features such as wind towers, blinds and solar shades help to further improve comfort levels. The buildings in the city are amongst the most advanced in the world. Intelligent design of residential and commercial spaces reduces the need for artificial lighting and air conditioning. Building units use solar glass whose composition is new materials that further reduce the heat burden. Building complexes have high efficiency cooling towers. Fountains and trees must be grown as an additional cooling device. Huge umbrellas unfold during the day and close up at night as shown in these photos. Architects and engineers are projecting that Masdar's average temperature has to be 20 degrees lower than the surrounding desert.

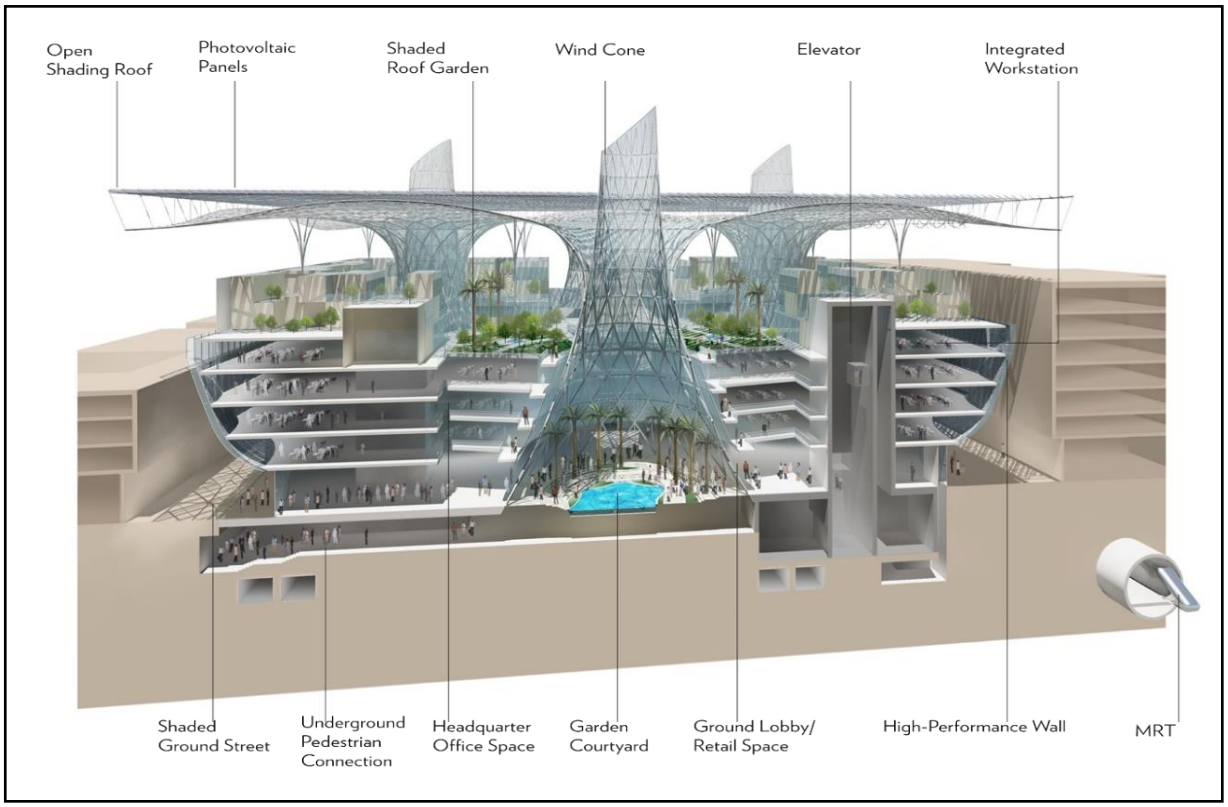


Figure 4.15: Section (AA) of Masdar headquarters (Walsh, 2011)

• Nano-Polis China

The Nano-Polis, a Nanotech Research and Development Park which is located in the city of Suzhou, the concept of design it is taken from both Urban Planning of the traditional Chinese Urban and the modern science. (Table 4.5) show the general information of the project (Zeng, 2016).

Table 4.5: Nano-Polis China (Zeng, 2016)

Architecture	HENN Architekten
Location	Suzhou, China
Date	In Future
Type	Nano-zero-energy city
Technologies Used	Nanotechnology is the primary focus of the development, the arrangement and planning of the building mass was done with consideration to scale and fractal logic.
CO2 Emissions	Innovative technologies such as solar harvesting and rainwater collection work together with simple strategies of pedestrian access and public transportation to decrease energy consumption while creating a comfortable place to live and work with Zero Carbon.

The nanotechnology considers the primary focus of the arrangement, the development and planning of the building mass and also it was done with consideration to scale and fractal logic the site is divided into S, M, L and XL size, which according to specific functions are also subdivided and arranged, this scalar logic are using different scales from urban to nano and provides to the user to interact with the buildings on an intimate human scale and give opportunities to create large iconic landmarks in the site (Zeng, 2016).

Nano-Polis designed in straight lines shape with staggered internal connections and a clearly defined border, like most of the traditional cities in china, also they take from the traditional Chinese cities the idea of the fractal which is constructed in the recursive logic of blocks, areas and districts, respectively from S to XL (Figure 4.16) (Zeng, 2016).

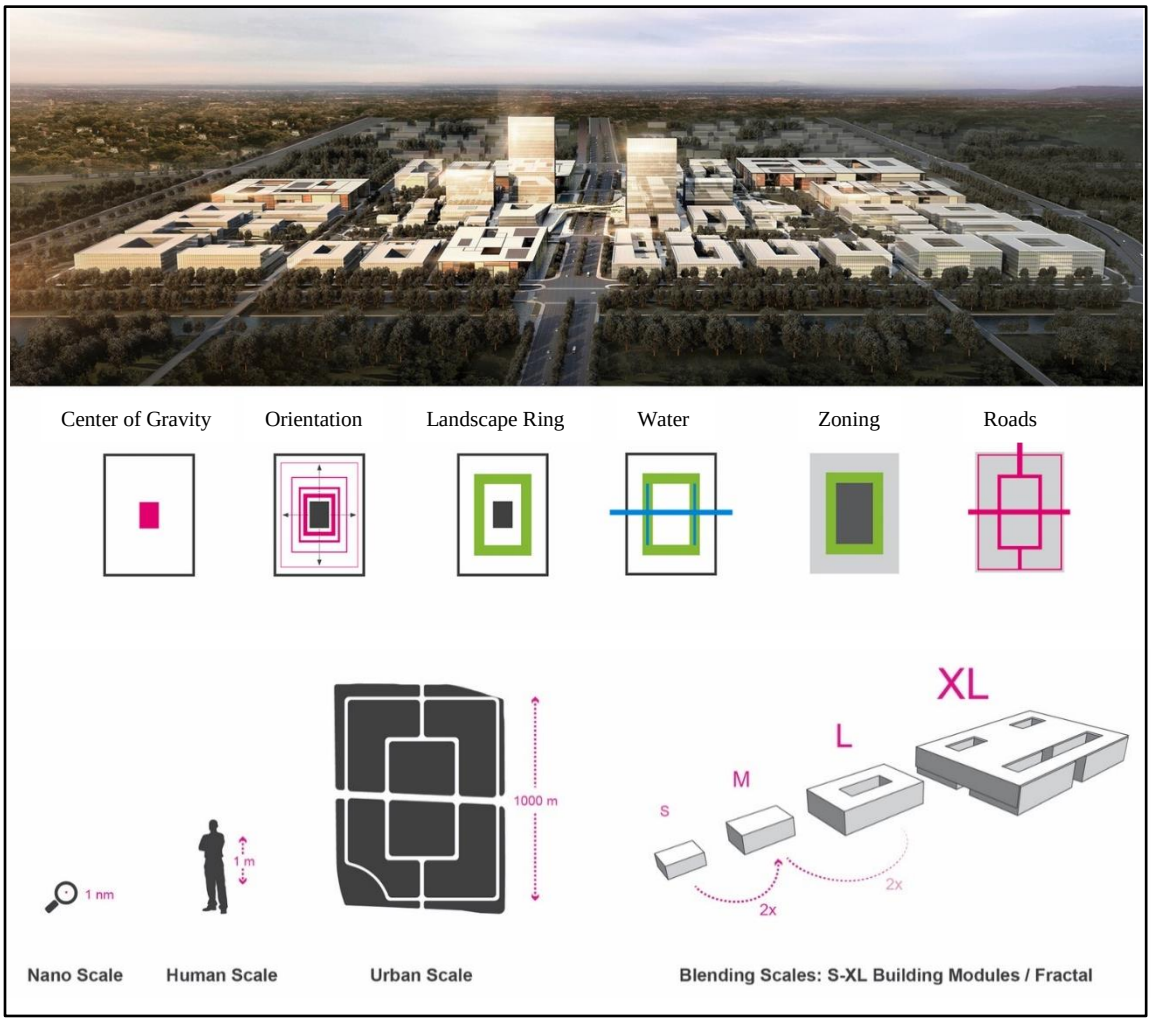


Figure 4.16: The concept of Nano-Polis (Zeng, 2016)

The overall development includes a cluster of high and medium-rise buildings surrounding a central plaza. This area houses most of the administrative, exhibition, conference and public areas as well as temporary housing facilities. This iconic centre is surrounded by a transitional green belt which references the traditional Chinese gardens that Suzhou is known for. A natural river flows east to west through the site which feeds a series of ponds, canals and water features throughout this zone. This green buffer zone connects by a series of shared roofscapes, courtyards and galleries to the outer ring: The entire complex is defined by a dense belt of research and production facilities that create a defined urban edge to the surrounding context (Figure 4.17) (Zeng, 2016).

Figure 4.17: Nano-Polis perspective view and site plan (Zeng, 2016)

The design of Nano-Polis uses a plenty of environmentally responsible systems in planning for the design of Nano-Polis, in order to make a comfortable place to live and work, they used a new technology like rainwater collection and solar collection and integrated with other simple strategies of public transportation and pedestrian, to reduce the consumption of energy, (Figure 4.18) (Figure 4.19) (Zeng, 2016).

Figure 4.18: Internal view of Nano-Polis (Zeng, 2016)

Figure 4.19: Center view of Nano-Polis (Zeng, 2016)

In (Figure 4.20) shows the way of designing the area (A) and kind of the applications that used in it, such as, green roof and the application of nanotechnology products in the field of paint, bricks, tiles, fire-resistant insulation materials, energy-saving glass and so on.

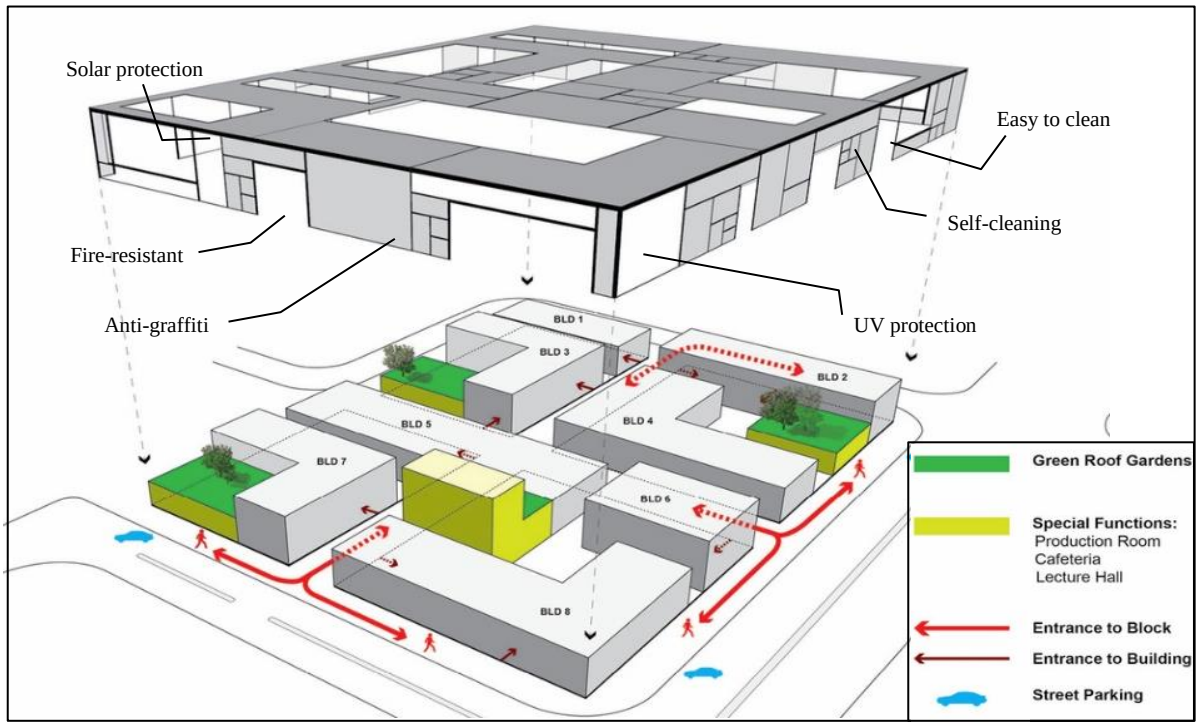


Figure 4.20: Diagram of area A (Zeng, 2016)

- Comparison between Masdar City and Nano-Polis China

Table 4.6: Comparison between Masdar City and Nano-Polis China

	Masdar City	Nano-Polis China
Facts	Designed by "Norman Foster" It's located in Abu Dhabi U.E.A.	Location: China Area: 1.65 km2
Purpose	All the building meets the high standards which put by the Internationally recognized organizations, also Masdar City consider an important partner in the sustainability program.	Nano-Polis it's the "Nanotech Research and Development Park", and It contains R&D, Production, Office, Conference Center, Exhibition Center, Hotel, Restaurants, Shopping, Housing and Sports Facilities.
Objectives	Traditional design techniques help to reduce energy Consumption and to improve the quality of the Environment in traditional Arabic architecture and urban planning of the region.	Nanopolis pushing forward the development of new emerging industries led by nano-technology and strive to forge a core engine for the development of nano-based industries.
Strategies	Strategy is to reach zero emission.	In Nano-Polis design they use a different kind of responsible systems environmentally in the planning for its. and decreasing the consumption of energy by using Innovative technologies, in order to make a comfortable place to live and work.
Design Concept	An extraordinary ecological city of the future is being built in the United Arab Emirates, outside of the capital Abu Dhabi. The work force are reaching to 40,000. Situated in the desert, Masdar is a small city that's almost equal 6 square kilometers (2.3 m2). It is designed to house 40,000 people, 1500 businesses and accommodate up to 50,000 commuters.	The molecular theory has a reflection on the planning concept. the site are divided into sizes S, M, L and XL, which are further subdivided and arranged according to specific functions

4.6 Test Matrix and Evaluation Report of Nanomaterials

According to sustainability definition and their principles that mentioned earlier with using the information from (Table 3.16) a test matrix had been made. The matrix shows the result of nanomaterials in building production under the criteria of sustainability (Table 4.7). This matrix evaluates the nanomaterials application according to sustainability and shows how nanotechnology can be useful in achieving sustainability.

Table 4.7: The test matrix and evaluation of nanomaterials in building production (Dfatade, 2014) (Yilmaz, et al, 2015) (Çağnan, 2015)

SUSTAINABILITY CRITERIAS			NANOMATERIAL TEST CRITERIAS / NANOMATERIALS APPLICATION IN BUILDING PRODUCTION	NANOMATERIALS														
				Insulation			Coatings							Lighting		Solar energy	
				A Aerogel	B Thin film insulation	C Vacuum heat insulation panels	D Self-cleaning	E Easy to clean	F Anti-fogging	G UV and Solar protection	H Anti-graffiti	I Anti-reflective	J Anti-fingerprints	K LEDs	L OLEDs	M Inorganic silicon solar cells	N Organic thin film solar
Environmental-Social-Economical		1	Prevent energy loss and conserves energy	+	+	+	0	0	0	0	0	0	0	+	+	+	+
		2	Reduce natural resource consumption	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		3	Take up less space than traditional materials	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		4	Transportation costs	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		5	Reduce production of harmful gas to environment	+	+	+	+	+	+	+	+	+	+	0	0	+	+
		6	Keep indoor thermal balance at ideal level	+	+	+	0	0	0	0	0	0	0	+	+	0	0
		7	Reduce time of cleaning	0	0	0	+	+	+	+	+	+	+	0	0	0	0
		8	Reduce the need for artificial lights	+	0	0	+	+	+	+	+	+	+	0	0	0	0
		9	Long lifespan / Ease of application	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		10	Increase in air quality	0	0	0	+	+	+	+	+	+	+	0	0	0	0
		11	Prevent the spread of bacteria	0	0	0	+	+	+	+	+	+	+	0	0	0	0
		12	Reduce use of chemical substances in cleaning	0	0	0	+	+	+	+	+	+	+	0	0	0	0
		13	Don't contain harmful substances to environment	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		14	Reduce use of energy for lighting	+	+	+	0	0	0	0	0	0	0	+	+	0	0
		15	No need repair and maintenance	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		16	High efficiency and brightness in lighting	0	0	0	0	0	0	0	0	0	0	+	+	0	0
		17	Reduces cooling costs of space	+	+	+	0	0	0	+	0	0	0	+	+	0	0
		18	No need for color filters to change color	0	0	0	0	0	0	0	0	0	0	+	+	0	0
		19	Thin and flexible can be located on any shape	0	0	0	+	+	+	+	+	+	+	+	+	0	+
		20	Doesn't harm the environment and human health	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		21	Provide enough natural lighting decrees energy	+	+	+	0	0	0	+	0	0	0	+	+	0	0
		22	Increase the use of renewable energy	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		23	Saves energy and reduces energy costs	+	+	+	0	0	0	0	0	0	0	+	+	+	+
		24	Reduces consumption of raw material	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		25	Recyclable	+	+	+	-	-	-	-	-	-	-	+	+	+	+
		26	New and expensive products	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		27	Special knowledge to use in building production	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		28	Reusable	+	+	+	-	-	-	+	-	+	-	+	+	+	+
		29	Durability more than traditional materials	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Test Marking Key:

+	Positive effect
0	No effect
-	Negative effect

The Results:

+	61%
0	29%
-	10%

- Evaluation Report

After making a matrix on the most applications of nanomaterial according to environmental, economic and social sustainability criteria's, the results have shown that the advantages are more than the disadvantages. Where the positive effect ratio was estimated at 61%, while the negative effect was 10% and 29% has no effect. From these results.

The test matrix shows that nanomaterials can prevent losing energy, conserves energy, reduce natural resource consumption, in addition of that nanomaterials take up less space than traditional materials and the cost of transportation are less. Appling nanomaterials reduce the production of harmful gas to the environment, keep the indoor thermal balance at the ideal level of the user, reduce the time of cleaning and reduce the use of chemical substances in cleaning. Also, nanomaterials have a long lifespan, ease of application and don't need for repairing and maintenance.

When applying nanomaterials in interior space, it’s can increase the air quality, prevent the spread of bacteria. The nanomaterials don't contain harmful substances to human health or the environment, durable more than traditional materials, the use of renewable energy is increasing, it reduces the consumption of raw material. Most of the nanomaterials products are recyclable and reusable.

Nanomaterials, when used with lighting products it's, can reduce the use of energy for lighting, high efficiency and brightness, reduces the cooling costs of space, no need for color filters to change the color, thin and flexible can be located on any shape, saves energy and reduces energy costs.

But because of the products of nanomaterials are new technology, still expensive and needs special knowledge to be used in building production. It can be concluded that the application of nanomaterials can be useful to help in achieving sustainability, protect and enhance the environment.

4.7 Conclusion of The Chapter

This chapter has covered how the nanoarchitecture can help to achieve the sustainability to the building and the environment. That's by defining the sustainability and explain the principle of sustainability. Previews the possibility of nanotech to achieve sustainability to the buildings by applying it to existing building or even by using new processes like nanosensor which is added to the materials. Introducing some green architecture measurements such as LEED and BREEAM and how the scientists work on green nanoarchitecture to achieve that measurements which lead to better environment. Shown some of the ideas and suggestions for projects that based on the nanotechnology which would be in future like Nano house, Nano tower and also a whole city such as Nano City or Masdar City, which can solve the environment problems and increase the depending on renewable resources. Finally, an evaluation and analysis had been made in evaluation matrix which exposure the advantages and disadvantages of nanomaterials applications in building production according to sustainability criteria in (Table 3.16). In addition, an evaluation report had been made for the evaluation matrix. This chapter can be concluded;

Nanotechnology gives the opportunity to move to new levels by creating new architecture methods and improve the traditional ones. The green nanotechnology is used to ensure that any risks of this new technology on architecture had to be prevented. It also ensures that used to achieve sustainability and to change the techniques of architectural design in design also in energy and by presenting new materials, which can change the architecture concept in the world.

This research has led to promising results for a better future for architecture. These results appear in designing, for whole cities, such as Nano Polis, have been built on the basis of this technology. It has its effects on the building materials, decoration, and energy. After making the evaluation matrix and completing the evaluation report the positive effect of using nanomaterials was 61% while the negative effect was 10% and 29% was not affected. The results of the evaluation matrix show that nanomaterials can help in achieving sustainability to the building production. This ensures a better future for architecture and environment.

CHAPTER 5

CONCLUSION

Conclusion

Nanotechnology is a very new technology which created by manipulating the small particles in the material in order to make new materials with different features. From the point of sustainability, it's a new and important value in building production field. Using nanomaterials in building production had shown that can help to reduce the harm to the environment. When approached methodologically to the nanomaterials, the following steps below are examined;

Started with the definition of nanotechnology, what it has introduced to the world, its effects on architecture and the present-day architect's thought. Classification of nanomaterials in building production had been done according to their dimensions, starting from nanoparticles, reaching to the size of the building (Table 2.3).

Nanoarchitecture combines nanotechnology with architecture and its versatile effects on building production. It is concerned with the influences of the discovery of nanotechnology on architecture. Nanotechnology has its influence on properties of materials and energy. This, in turn, has led to an influence on the methods of thinking and architectural designs. A review and classification of the use of nanomaterials in different scales and types has been made (Figure 3.4).

An analysis had been made in table 3.16 which exposures the advantages and disadvantages of nanomaterials applications in building production within the context of environment-human health and energy-resource conservation.

The different applications of nanomaterials are studied and evaluated within an evaluation test matrix (Table 4.7). Their efficiencies in applications together with suitability have been determined. Test result are explained with the test evaluation report. The results are; positive effect 61%, no effect 29%, negative effect 10%.

According to the nanomaterials test matrix and the evaluation report. It can be concluded that nanoarchitecture can contribute in achieving sustainability. By decreasing the emissions of carbon, climate change effects it brings advantages to each of economic, social and environmental fields, despite the potential risks. That's because the advantages which that came from nanomaterial are much more than the disadvantages. Which was 61% are the positive effect of using nanomaterials and only 10% negative effect while 29% are not affected.

Using nanotechnology in building production, the environmental problems can be decreased. According to studies, to achieve a reduce in the emission of carbon, saving in energy is needed. 40% of energy using in the world comes from the buildings. Developing the coating of the buildings and making the materials more efficient with nanotechnology the building industry can help to improving sustainability and conserving energy.

Scientists and building developers who work on sustainability, try to make sustainability in the buildings, which achieves the needs without affecting on the future needs. In order to achieve this, aim they are trying to reduce the use of nonrenewable resources. In green building, the most important thing according to that is conserving energy because, it's save the resources and decrease the pollutants and wastes.

The architects and engineers found sustainable materials to use it in the buildings production. Nanomaterials, which are the products of nanotechnology as can be seen in matrix (Table 4.7) are friendly to the environment, have long life span, energy conserving, cheaper, easy to clean and apply onto traditional materials. Thus, they can be considered as helpful and suitable for achieving sustainability.

This thesis clarifies the applications that's offered by nanomaterials in building production and to examine the new materials from the point of view of architects and sustainability criteria. This thesis can be an addition to the literature bank of nanomaterials books.

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