From pyramids to smart buildings and cities of the second part of this century

De la piramide la clădiri inteligente și orașe din a doua parte a acestui secol

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Abstract: *The paper presents the history of building construction development, possibilities of new technologies leading the construction sector to many challenges, and new solutions of energy systems in buildings, but of course with the complete and exclusive use of renewable energy sources. In the paper are presented efforts from building the pyramids, huts, till present smart buildings. And comment what is expected in the future during this century. This article presents overview of various information of many official and unofficial thoughts of different authors, building planners, UN statistics and also IT engineers and their plans regarding the development of smart cities and buildings and direction where may the world go in coming future. The buildings in which people live and work were always "smart", for the time when they had been constructed and built. Centuries have passed, knowledge and experience of people have been developed to the present level of science and technologies, and they will continue to develop along with many threats that are associated with the development. Today's smart buildings are the result of achieved high levels of knowledge, experience, and use of the state-or-the-art and science and technology.*

Keywords: *smart buildings, buildings of the future, smart city.*

Rezumat: *Lucrarea prezintă istoria dezvoltării construcțiilor de clădiri, posibilitățile noilor tehnologii care duc sectorul construcțiilor la multe provocări și soluții noi ale sistemelor de energie în clădiri, dar, desigur, cu utilizarea completă și exclusivă a surselor regenerabile de energie. În lucrare sunt prezentate eforturile de la construirea piramidelor, colibelor, până la prezentarea clădirilor inteligente. Articolul comentează ce se așteaptă în viitor în decursul acestui secol. Se prezintă o imagine de ansamblu a diferitelor informații despre opiniile oficiale și neoficiale ale diferiților autori, proiectanți de construcții, statistici UE și, de asemenea, ingineri IT și planurile acestora cu privire la dezvoltarea orașelor și clădirilor inteligente și direcția unde poate merge lumea în viitor. Clădirile în care locuiesc și lucrează oamenii au fost întotdeauna „inteligente" pentru perioada în care au fost gândite și construite. Au trecut secole, cunoașterea și experiența oamenilor au fost dezvoltate până la nivelul actual al științei și tehnologiilor și vor continua să se dezvolte împreună cu multe amenințări asociate dezvoltării. Clădirile inteligente de astăzi sunt rezultatul unor niveluri ridicate de cunoștințe, experiență, utilizare a cunoștințelor sau tehnicilor și a științei și tehnologiei.*

Cuvinte cheie: *clădiri inteligente, clădirea viitorului, oraș inteligent*

1. Introduction

Since his first hut and cottages (Fig.1), the man has strived to make them on the locations that are exposed to sun but protected from too much solar radiation during summer, protected from wind during winter, to build them near water, to have natural lighting, and to have fire for heating and cooking.

Having acquired experience and skills for building huts, then for homes made of soil, and later for building using stone, bricks, and concrete, houses and buildings were "smarter" for that time (Fig.2 first central floor heating) and this tendency has continued up to the present time.

Figure 1. The prehistoric huts in Lepenski vir

Figure 2. The first central "Roman" floor heating

When buildings are "smart" i.e. they have automatic actions that the man integrated in buildings and programmed to be responses of technical systems in buildings according to his knowledge that has not reached its peak yet, and thus that knowledge will continue to advance and rise and buildings may become independently smart. There was in history a long Multi-Millenial way from the huts and cottages to the contemporary buildings, and it is questionable how long will be the current journey to the future buildings, settlements and cities.

However, it is certain and clear that there were, and there will be, many steps to reach all relevant goals of the currently cientifically defined Smart City targets [2].

2. The facades as a man's cloths

While the man can intentionally adapt his “insulation” by appropriate selection of clothes, it is impossible to do the same with buildings. However, there are engineering solutions. Thus, it could be add one more façade and created buildings with “double façade”.

However, that “second” façade is a static part of a building and it has effects during lower outdoor temperatures, but during other seasons, at high temperatures, it has not significant thermal effect, except for the sun protection (depending on local climatic conditions).

In the double façade, various forms of shades, curtains, or similar devices, are put in the inter-space for the protection of the sun. From the constructional point of view, a double-façade outer envelope may be continuously extended by covering the total height of a building, or discontinued with breaks at each floor level.

Disregarding the height, the inter-space is opened both at the bottom and at the top, thus providing the outdoor air circulation in the summer, when the temperature of inter-space should be as low as possible, in principle equal to the outside temperature. Or the openings may be closed, which is the case during the winter, in order to trap the air in the inter-space, which will act as an insulation layer, with the temperature above the outside temperature, producing lower heat losses of a building (Fig. 3).

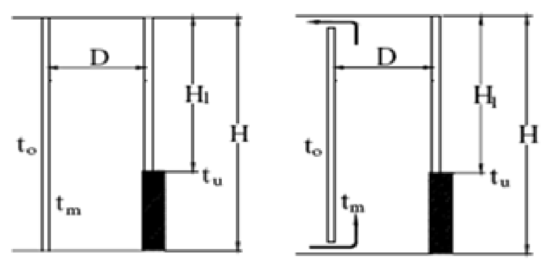

Figure 3. Double-facade constructions (left) and a wall with water flowing down

3. Fasades wetting - thermoregulation

During high summer temperatures the human body’s temperature is lowered by sweat evaporation; sweat is produced by sweat glands and the process “involves” the central nervous system. By copying the example of “sweating” the roof surface was sprinkled with water or pools with water were constructed on high buildings.

There were also attempts to moist the façade walls, but for that purpose wall must be specially processed if it is not totally of glass.

This effect was applied to a large glass façade of the British Pavilion at the World Expo 1992, in Seville. Thus cooled façades require large amounts of water and the effect was primarily visual.

A thin water layer, especially on vertical walls, is possible by using the water cooling system with the application of Ti02 super- hydrophilic coating, developed in Japan and described in the paper written by Jiang He and Akira Hoyano Water is sprinkled (Fig. 4.) at the top of a wall or window flowing down the wall.

The water is collected at the bottom into a water reservoir. This water is also pumped up with collected rainwater and reused for sprinkling cycles. Such technology produces a very thin water layer with the uniform water distribution because of Ti02 hydrophilic coating.

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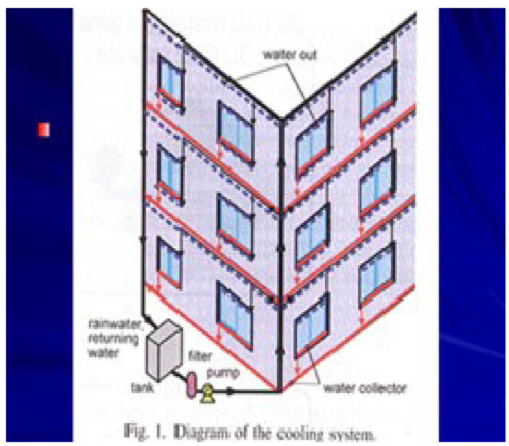

Figure 4. Piping system above the coated façade with Ti02

Thus by implementing coating technology made possible maintenance of the temperature of thin film of water on external surfaces coated with Titanium dioxide TiO_2 enabled control of facades surface temperatures and reduction of the Urban Heat Ireland. It has been also studied analytically.

Physical model of this innovative technology has been developed and according to it also its mathematical model has been defined. Using determined mathematical model, modeling via numerical solutions have been developed, enabling further modeling dynamic analysis of different case studies via numerical simulations (Jiang He and Akira Hozano "A numerical simulation method for analysing the thermal improvement effect of super- hydrophilic photocatalyst coated building surfaces with water film on the urban&built environment").

The idea to copy the humane body setting effect was applied on building glass facade of British Pavilon, in the midle of XX century at the World EXPO in Spain. The visual effect was impressive on nice sunny days, however necessary large amounts of water consumption, as well as the corresponding need for building a huge glass facades construction, was eliminating this idea of general mass applications.

The solution with reduced water quantity with more effective evaporation textile curtain over the glass facade resulted in much smaller water quantity needs with slower water flow through. Also this solution did not qualify for reaching smart buildings of the future [3].

Further approaches and attemps to get building "smarter" were related to implement water flowing down the building facades outside fasades.

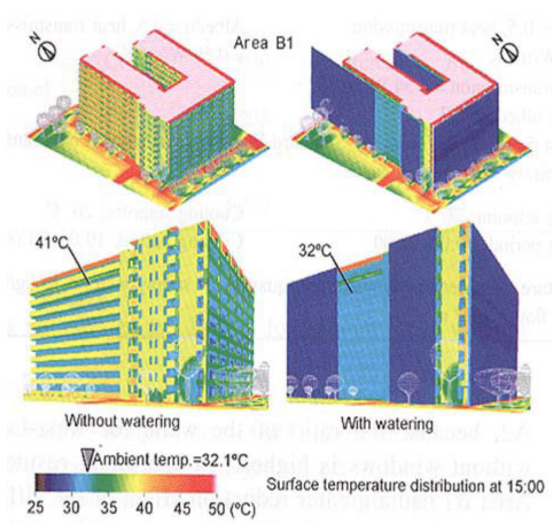

Figure 5. Surface temperatures of coated and noncoated facades

Thus by implementing coating technology made possible maintenance of the temperature of thin film of water on external surfaces coated with Titanium dioxide TiO_2 enabled control of facades surface temperatures and reduction of the Urban Heat Ireland (Fig.5). It has been also studied analytically. Physical model of this innovative technology has been developed and also it mathematical model, as well modeling via numerical simulations.

The Phase change materials for reduction of building cooling load was the next step to try to approach achieving smart buildings. This reduction could by implementation of phase change materials (PCM) for thermal storage. These materials could be organic, (fatty, acids, parafin, non parafin), inorganic (salt hydrate, metallic) or eutectic materials which are minimum melting compositions of two or more compounds in all combinations organic or inorganic materials.

Phase change material could be between two of the glass panes in the window. At the lower temperatures the PCM is translucent solid, but as it heats, the PCM melts and becomes transparent. This lets the window itself to absorb heat from solar energy during a day and then releases the energy later on, as this PCM cools.

Materials to be used must have large latent heat per 1kg, high thermal conductivity and range of the melting-freezing temperature 15-30^{0}C or even higher. Beside these conditions, PCM shall have small volume change during phase change process.

4. Artificial Intelligence breakthroughs

Since the end of the last century and especially since the beginning of this century, information technologies have been developed, new building materials have been discovered and used.

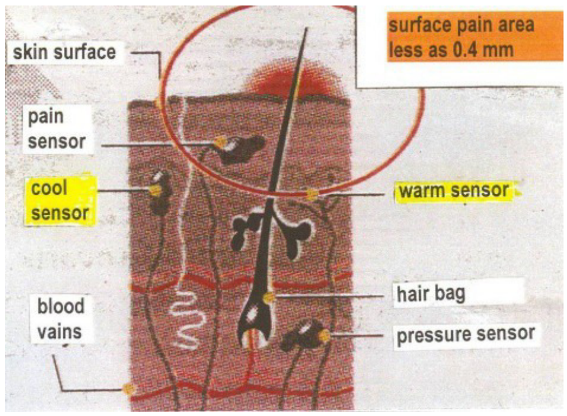

Figure 6. "Sensors" in the human skin

In addition technical system automation and building management systems (BMS) have been introduced, and in the spaces where people live and work are installed electromagnetic sensors as elements of the "nervous" system (Fig.6) of a smart building [1].

This has all been done in order to provide comfort and healthy conditions for occupants, also buildings resilience. But the imperative in all is to reduce energy consumption and to use only renewable energy sources for heating, refrigeration, air-conditioning, lighting, and for smart - rational utilisation of these systems. Such buildings have become so called "smart buildings" [6].

5. Buildings as a humane body

The human body is an extraordinarily "constructed system" by its way of synchronized activities of organs, oxygen supply, carbon dioxide elimination, and its thermoregulation [4]. It is a two-pipe system with distribution and return "pipes" (Fig.7), variable amount of bloodstream and the heart as a central pump, which has been, to some extent, copied in the central heating systems. In many details, the human body function works as the central heating or cooling system with the heart as a pump (Fig.7).

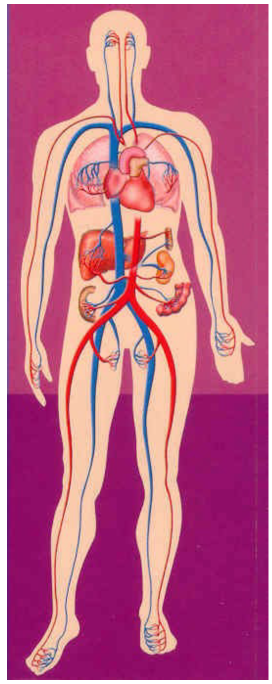

Figure 7. Blood circulation

When the temperature is high, the blood is directed towards the external surface, towards the skin, in order to emit the excess amount of the human body’s heat into the environment. And, if the body temperature falls down, the bloodstream is directed towards the internal organs.

The new central control systems for buildings provide information using so called micro-electro-mechanical systems located on representative points in the building, just like a human body, having the system with sensors in the skin all over the body, signaling to the center in the man’s brain, in the hypothalamus which commends the adequate reaction of a body (Fig.8).

In the article of ASHRAE Journal, “Buildings of the Future“, the author writes that micro-electro-mechanical systems invented in the second half of the past century found wide application in different branches of industry as well as in buildings.

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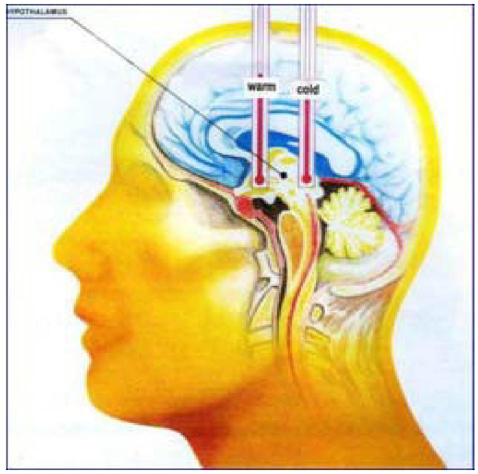

Figure 8. Central control system

Skin sensors can detect heat or coldness, but also the pain. In a building the new smart energy systems can use mini - size robots located inside ducts or pipes moving locally and finding location, which is actually the detection of the building's "illness".

6. Windows chromic effects

In the article of ASHRAE Journal, "Buildings of the Future", the author writes that micro-electro-mechanical systems invented in the second half of the past century found wide application in different branches of industry as well as in buildings [5].

The author also points out the possibility of the protection from solar rays through windows and, thus, reduction of cooling loads in buildings using electro - chromic (Fig.9) and using temperature chromic windows (Fig. 10).

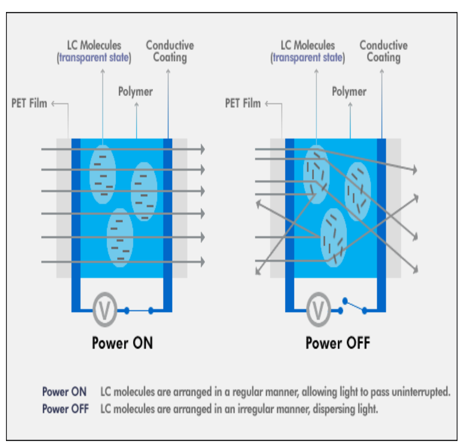

Figure 9. Electro chromic glasses

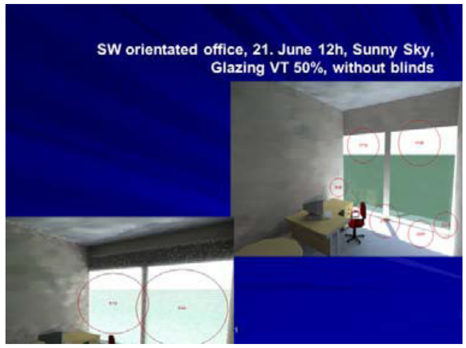

Figure 10. Temperature chromic window galzing [11]

The new central control systems for buildings provide information using so called micro-electro-mechanical systems located on representative points in the building, just like a human body has the nerv system with sensors all over the body, especially in the skin, sending information to the center of the nervous system in the man's brain, in the hypothalamus.

The new technologies found applications in windows with electro-chromic (Fig. 9) and thermo-chromic glasses. Chromic materials have the possibility of changing their color reversibly when they are placed in a different environment. Thus, glazing automatically changes its shading coefficient protecting indoor of a building from solar cooling loads.

Thermo-chromic windows can adapt to changing sunlight intensity and reduce heat load in buildings. They use the sun energy to tint the window glass and stop the sun's energy that otherwise would be a heating load for the building.

Electro-chromic technology has been researched from the 80- ties of the XX century and the examples of electro-chromic window prototypes have been demonstrated in a number of buildings in Japan, Europe, and USA. Full-scale field tests have been conducted in Berkeley California and at the DOE Headquarters Building in Washington.

When a voltage is applied between the transparent electrical conductors, a distributed electrical field is set up. This field moves various coloration ions (most commonly lithium or hydrogen) reversibly between the ion storage film through the ion conductor (electrolyte) and into the electro-chromic film. The effect is that the glazing switches between a clear and transparent blue-gray tinted state with no degradation in view, similar in appearance to photo- chromic sunglasses.

The main advantages of electro-chromic windows are that they typically only require low voltage power (0–10 volts DC), remain transparent across the switching range, and can be modulated to intermediate states between clear and fully colored. In the tinted state solar radiation is absorbed. Low-emittance coatings and an insulating glass unit configuration can be used to reduce heat transfer from this absorptive glazing layer to the interior.

Typical electro-chromic windows have an upper visible transmittance range of 0.50–0.70 and a lower range of 0.02–0.25. The Solar Heat Gain Coefficient ranges from 0.10–0.50. A low transmission is desirable for privacy during the day and for control of direct sun and glare, potentially eliminating the need for interior shading.

A high transmission is desirable for admitting daylight during the time of the day that the sun is not shining directly into the space, during overcast periods and for passive solar heating in winter. Therefore, the greater the range in transmission, the more able the window is to satisfy a wide range of environmental requirements.

7. Buildings of the future

The life of new generations will be changed and indeed, it is today already changed. The people will be mostly living in cities and staying indoors and be in new towns. There is expectation that all existing buildings will be renovated in next 100 years.

The buildings in which people live and work were always smart for the time when had been built and for the technology of that time. Still is not fully clear how the pyramids were bult [9], what was the construction related knowledge of that time, and it was over 7000 years ago. There is still not enough precise explanations how the stones of several thousand kilograms were cut, how were taken up even to 40 m and more.

Results of the CFD (Computational Fluid Dynamic) and thermodynamic investigation of air streams in ventilated and non- ventilated archeological tombs in Valley of the Kings, Luxor did show that there was certain not negligible physics understanding and knowledge behind the internal spaces shapes and dimensions ([7], [10]).

Figure 11. Egyption pyramids [10]

The future buildings are going in the height and will have optimized systems for personalized environment, for improved health and wellbeing, personalize comfort provision. Occupants have to learn behavior and expectations, quantify and improve health and wellbeing, building systems will be modular, durable construction Interoperable adaptive building components will consist of modular systems, embrace intelligent envelopes, composed of programable - interoperable components.

Environment: samples interaction of human and natural systems in the built environment. Fully harvest onsite resources, tied from health influencers, and monitor environmental influences. In next three decades there will be smart beds which will adjust to how much sleep would a person need, how long need to rest. Also are predicting automatic color changes of furniture, walls, floors, curtains in rooms.

Utilities, transactive networks and distributive solutions for high efficiency and resilience, integrated centralized and decentralized networks, connected to transact services and resources ([6],[8]).

Community will have multifunctional and diverse services to support community cohesion, adopt to changing needs, connected by multi modal transportation network, measure and disclose holistic performance.

8. Smart city

The smart city makes use of automated technology to gather data, and then uses that data to regulate and control any number of municipal systems. These systems range from transportation to education, but also include complex networks of buildings, roads, bridges and electric grids. Making cities smarter means making them aware of the inputs that contribute to how these various systems operate, then using technology automatically make things more efficient.

The goal of a smart city is to cultivate more sustainable environment and be sustainable city. One with less waste and inefficiency. This isn't limited to just non fossil fuel forms of energy production, either.

Smart cities are making use of waste management facilities that can convert garbage, and even sewage into usable electrical energy. And the waste that cannot yet be converted into fuel is being better sorted into recyclables or in waste. For example, Barcelona is consistently known as leader city for various metrics used to analyze city intelligence. Despite being one of the oldest and most storied cities in the world, they have managed to implement city wide upgrades to their electrical grids, smart traffic and parking systems, even street lights that are properly timed and use low energy bulbs and solar power for operation. Such changes can be slow to adaptation due to the grand scale with which such transitions must happen on. "Smart" doesn't necessarily point to the automated, artificial intelligence of these different systems, but can simply refer to the way in which planners, architects, and city officials approach any number of ubiquitous issues. Being smart about urban design and architecture means understanding economic growth, density and zoning, and how the existing network of roads and grids can be better.

It has almost everything to do with the people who live in and are moving to these cities, and what sort of cultural underpinning they represent. Those societal values are vital to determining the direction a city is heading, and how smart it ultimately becomes.

In addition a smart city is a self-aware city, filled with self- aware people who are willing to take on the conscience that comes with being sustainable. Those people understand the impending environmental and social issues facing our future, and understand that if we do not start putting a plan in place to change how we live, things could get bad and they could get bad fast.

The number of Earth population is now about 7 milliards and each day this number is increasing. The UN experts have done projection how the world could look in 2100. The prediction is, that world population could increase to 10 milliard and 80% will live in cities. The experts believe due to it that the result will be in so called Mega Cities with population, over 20.000.000 as now are Delhi, Mexico City and Beijing, some USA cities.

9. Other changes

Today there are about 7000 languages and a lot of them will no more be in use, and dominant language will be English. In the 2010 average life length of world population was 65 years what was about 22% less than in 2100 when the predicted average life would be 81 years. But it was not taken as possibility improvements of medicine and also negative influence of hunger, new illnesses, consequences of nuclear wars, and also the impact of global warming. Energy sources as petrol, oil gas and coal will not exist if we are going to reduce their use significantly. It is expected increased use /of Hydro energy and wind, solar and another renewable energy sources.

Hunger and water. Even today there are about one million of hungry people and grow of population would this problem make even more serious. About one million people are hungry. May be the global warming producing drought increases this risk. Also, wars, weapons, bombiing using and spreading “depleted” uranium which has dangerous consequences to health.

10. How to define a smart building

The definition of the notion of a smart building is not easy, since this is the sector that is evolving very quickly. In both, literature and practice there are different definitions, but one can notice that they depend on specialty of the institution that takes part in the constructing and equipping such buildings: whether its focus is on design, construction works, installation, science and development, or politics.

So, what are today’s “smart buildings“ and what do they do? The simple answer is that there is automation involved somehow that makes managing and operating buildings more efficient. But different organizations and institutions define „smart buildings“ on a different way depending of their specialty.

On IBM is „Smarter buildings are well managed, integrated physical and digital infrastructures that provide optimal occupancy services in a reliable, cost effective and sustainable manner. They help their owners, operators, and facility managers improve asset reliability and performance, who, in turn, reduce energy use, optimize how the space is used, and minimize the environmental impact of their buildings“.

American engineering and design company LLC has the following definition: “A smart building is the integration of building, technology, and energy systems. These systems are also including building automation, life safety, telecommunication, user and facility management systems. “Smart buildings provide smart actionable information about a building or space within a building to allow the building owner or occupants to manage the building, etc.

The European Commission has the following definition: smart building means a building empowered by information and communication technologies in the context of the merging Ubiquitous Computing and the Internet. The US Government Services Administration, which was working on cutting the energy levels of all government buildings, realizes as follows:

"Technology alone will not do it. The smartest part of smart buildings is people. Siemens defines "only solutions which create the greatest synergy between energy efficiency, comfort, safety and security will be sustainable over the longer term solution that turn buildings into living organisms: networked, intelligent, sensitive and adaptable".

11. Conclusions

Providing feedback and information through dashboard is good; with smart technology we can learn anything about a building and optimize its performances. What a dashboard can really do is enable better decisions, inspire participation, spread knowledge and best practices, communicate at a human scale and propagate new norms in how we use our buildings.

The level human knowledge and state of technology has developed but not yet has reached its peak in the field of technical innovations. The farther development may be caused by commercial competition, political ambitions, differences in the standard of living and levels of people's education, and uneven distribution of natural resources. Although, buildings should be designed [11] via ISBD (Integrated Sustainable Building Design) process, buildings today are still being planned, constructed and managed in the same way as they have been for decades, sometimes, somewhere for centuries.

Net zero fossil energy buildings, modeling predictive automated control systems and multi-functional design are examples of critical importance when developing buildings for the next 100 years. Importance of building performance simulation (BPS) – analysis of the inextricable linkage of building's all year energy demand for HVAC and other building's technical systems sustainable energy supply and renewable energy sources availability to reach zero energy building status.

Further R&D needs for the continued BPS advances, solar, geothermal and other renewable energy sources integrated implementation, as well as hybridization and mixed distributed energy co- and tri-generation for building's greening and sustainable neighborhoods, settlements, as well as rural and urban "high performance" Zero Energy Planning.

Thus buildings and construction must change, according to well known industry experts like American researcher Nora Wang [12]. The changes could be dramatic. They could revolutionize the landscape and the way we live, work and play in cities around the world.

There is a possibility that the highly advanced developed knowledge and technology might return the world to its beginning, but also to some new conditions, even harder than those experienced by the humankind during the past: unhealthy environment, high CO_2 concentration, global warming and weather extremes, longer too high temperatures periods. However, science, technology, and events to come may make some positive surprises and refute these doubts.

It is important to invest in development of future -nano technologies and artificial inteligence but also in developing human canclousness with great technology. Othervise people could easy destroy themselves and entire life conditions at our planet. But inteligence which brought us at thye present technology level neglect such thoughts.

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