This paper is part of the Proceedings of the 6th International Conference on Harmonisation between Architecture and Nature (ARC 2016)
www.witconferences.com

Smart nanotechnology to deliver zero carbon eco-neighborhoods: case study – neighborhoods of the functional city, "H" building typology in Mediterranean countries

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Abstract

Smart cities are a necessary step towards a new sustainability scenario that accommodates the objectives of sustainability from a cross and synergistic perspective, with the support of new technologies, networks and more efficient large-scale systems (such as a minimum unit neighborhood). This paper addresses the urban renovation of the actual city by improving the envelope of an urban typology, using nanotechnology materials on the façades, roofs, and external renovations. This research presents the role of nanomaterials to enhance a sustainable society, on the existing city, with suitable constructive systems and in an easier way. The opportunity to use nanotechnology for the rehabilitation of residential neighborhoods built after the Second World War, which combines a number of advantages, will be presented.

Keywords: smart city, nanotechnology, and Mediterranean, zero carbon eco-neighborhood.

1 Introduction

The neighborhoods of open block development, built on the periphery of most western cities, are a great opportunity to transform residential areas built after the two World Wars (1950–1970), into new eco-neighborhoods. These areas attracted many people from the countryside to the industrial city under a new urban ideology, born in the Athens Charter (1914). These urban lots have high density, high efficiency of mobility networks and urban services, but also they have large

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/ARC160171

green open spaces that can allow the sun and wind to go into most of the houses. Under this model, large amounts of neighborhoods were built in all European cities, which now are old and have particular problems, which must be solved. Because of the high number of dwellings, it can become a real field of transformation of the actual city, towards a more sustainable, more efficient, and lower energy consuming model, thanks to technological advances in materials and constructive systems where nanotechnology has a special interest in saving energy, can provide long life materials for the exterior façades, and can reduce greenhouse gas emissions.

The main problems of these periphery urban areas can be summarized as:

1- High density and low soil occupancy, which derives to a large number of open spaces, vacant, unused, often full of garbage and turned into wasted and unsafe spaces for most of the population in many parts of the day and night.
2- Obsolete housing, sometimes very small, with inadequate thermal insulation in walls, windows and roofs that make them very inefficient and largely wasteful of energy resources, for both heating and cooling. Aging populations, with new needs of accessibility and free mobility problems and safety, requiring access to public space
3- Large presence of automobiles, because of the lack of underground parking, which makes urban spaces collapse and be underused by residents and visitors
4- Lack of urban identity, motivated by two reasons. First the monotonous replication of the buildings, forming staggered fronts or almost endless horizons; and secondly by the lack of character of these public spaces, with no hierarchy, no rhythm, no variety or attractive spaces, and with no identity for the neighbors.

However, this urban morphology can also be drawn as a great opportunity, and is able to confront a high conversion to a zero carbon emissions neighborhood, because of the following reasons:

A- The presence of a lot of free space, which can help create a good microclimate that first improves the thermal conditions of public space, and then that around the buildings, reducing energy consumption in winter and summer.
B- The typological repetition makes it possible to study each of the types and present specific envelopes renovations to each orientation, and then these solutions can be applied to large-scale residential developments. In this sense, we are going to propose in the study an answer to the block "H" typology, which is the most frequently used in residential neighborhoods in Europe. Some possible actions are closed-loop systems with an LZC energy source (from residential waste); district heating systems with an LZC energy source (biofuel, geothermal, solar or waste); individual solar PV cells and collectors,

or large-scale renewable energy installations (wind, tidal, wave, solar or hydropower).

C- High density is profitable enough to make innovative solutions such as nanotechnology materials, networks of cold or heat on a neighborhood scale, the application of photovoltaic solar energy from the urban scale, etc.

2 The eco-neighborhoods

Eco-neighborhoods have proliferated in several European cities in recent years, but we cannot think that they are the best ways to solve the problems of urban sustainability in cities. In this sense, eco-neighborhoods are like “a drop of water in an ocean”. They are a new way of establishing residential units in a more integrated way; more varied, more diverse, more efficient with better articulated, more complex spaces. Eco-neighborhoods are examples of good practice of architecture and urbanism under the criteria of urban sustainability, but cannot be converted into the model of action everywhere, since the answer lies in the transformation, adaptation and renewal of existing neighborhoods to make them a new reality: new eco-neighborhoods within the consolidated city. In this sense, Salvador Rueda (EMVs [3]) defines the eco-neighborhood as having four cornerstones:

A- *Compactness*: which facilitates contact, exchange and communication, which are, as we know, the essence of the city.

B- *Complexity*: which refers to the heterogeneous tissue constituent, inseparably associated. This feature involves assessing the mixing of sexes of uses and urban functions, access to the city without restrictions, also increasing relationships between carriers of information, which allows for increased synergies of all kinds, and finally, increasing the likelihood of contact between the “different” one of the basic characteristics of complex cities is provided: creativity.

C- *Efficiency*: which aims to achieve maximum efficiency in the use of resources and on the other hand, the minimum disturbance of ecosystems.

D- *Social stability*: refers to the increasing diversity (of people and uses) and generates social cohesion to create the conditions to support equal opportunities.

The Superior Council of Colleges of Architects of Spain (CSCAE, 2012), in the invitation to tender on ways of inhabiting 2006, defines the eco-neighborhood as:

1- With social cohesion, density and compactness, mixed uses (emphasizing the multifunctional nature of public space), predominance of public transport (which also refers to the ease of access to allowances, equipment, etc.) and saving energy and material resources.

2- Proper integration with the environment wanted, “with a smooth transverse relationship with the neighborhoods and surrounding areas with good access to services and facilities and a good connection to global networks” and a respect for the pre-existing. Both milestones considered signs of cultural identity and respect for landscape elements and preservation of natural areas.

3 The case study: neighborhoods of the functional city, “H” building typology on Mediterranean countries (Plan Especial espacios abiertos Moratalaz (Madrid) 2009)

Many authors have studied the relationship between urban form and energy consumption. As summarized in these recently published tables, it has been established that residential peripheral neighborhoods (Williams [11]) are areas of great potential for transformation and becoming a new reality. The typology of the tower as an “H” is this case study. There is a large amount of towers built with the “H” typology for its ease of construction and enabling four apartments per floor, all open to the sun and wind. However, neither the sun nor wind are equal in all directions and in this typology a huge difference in thermal comfort appears between houses with good orientation arc south of the northern arc. In the case of Madrid, the discomfort of the west façade is also added, where large overheating occurs in summer (Fig. 1).

Figure 1: The funtional city. Moratalaz neighborhood. (Source Madrid’s City Council 2007.)

In Figure 3, the “H” building typology is analysed and a differentiated solution of each façade is proposed, with balconies and terraces according to different orientation, to improve the thermal comfort of these apartments, and to reduce their energy consumption and urban pollution. In these solutions, the new nanotechnologies are very appropriate in establishing a differentiated approach depending on each façade.

Table 1: The authors' adaptation with new last file and column from 2012 (Williams [11]).

Energy and urban form relationships				
	Density of development	Layout and orientation	Siting in relation to micro-climate	**Functional city open blocks**
Energy investment in infrastructures	Yes			**It is possible to be addressed**
Energy requirements for space heating	Yes	Yes	Yes	**It is possible to be addressed**
Potential for CHP/DHS	Yes	Yes		**It is possible to be addressed**
Potential for use of renewable energy sources	Yes	Yes	Yes	**It is possible to be addressed**
Energy requirements for transport	Yes			**They already have**
Potential for efficient public transport	Yes			**Must be improved**
Potential for walking and cycling	Yes			**Must be improved**
Functional city. open blocks	**Yes**	**Variable**	**It can be improved**	

Figure 2: Top picture: site plan of this kind of neighborhood. Lower pictures: Moratalaz, Madrid. Views of the low quality urban public spaces in these neighborhoods.

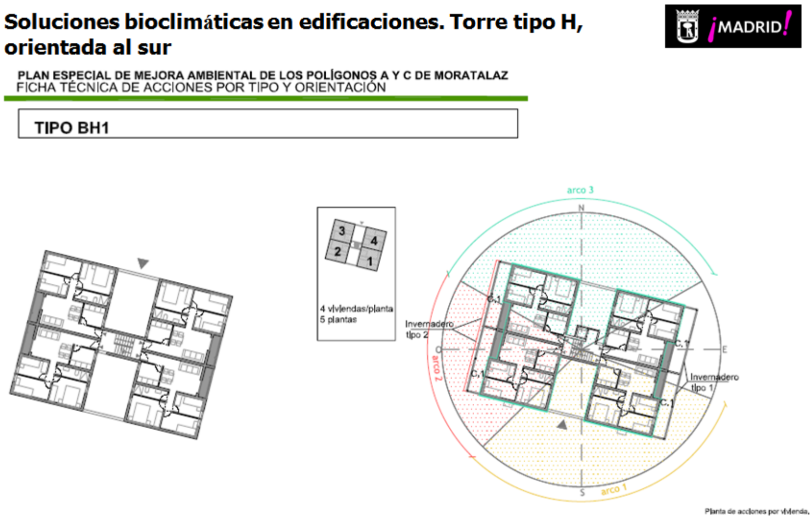

Figure 3: Plan for Block “H” typology. On the left the actual situation of the building; on the right the bioclimatic proposal with new balconies and terraces in order to improve bioclimatic strategies on the envelope renewal.

4 Proposal for nanotechnology and innovative construction systems for rehabilitation of existing buildings

Table 2 summarizes the objectives and examples of these neighborhoods in seeking both lower energy consumption and a drastic reduction in pollution levels using nanotechnology and nanomaterials.

Some European neighborhoods have seen innovative rehabilitation and regeneration become a new reality. Some of them, extracted from the proposal by Williams [11], are the national programs of the UK and Sweden for new housing, while the programs proposed for solar houses in the UK and Germany are for both new and existing homes and, in addition to this process of renewal, as necessary from a holistic perspective of sustainability.

To the list of actions proposed by Jo Williams (Technical Systems), we can add nanotechnology systems in solving the envelopes of the current buildings, as a truly timely and efficient system that should be taken into account to obtain the expected results.

For residential neighborhoods to become a new reality and be defined as eco-neighborhoods, they need innovative management measures and concrete planning to be pursuing these objectives. This is a big challenge, because it requires new deal making and urban planning, but this is where you should make the effort of initial transformation to convert these ideas into an urban reality.

Table 2: Definition of standards for low or zero-carbon homes (Williams [11]).

Definition of standards for low or zero carbon homes					
Standard	Definition	Aims			Examples
		Lower energy consumption	Generate more energy than consume	Reduce CO_2 emissions	
Zero carbon homes	A zero carbon home will produce zero-net emissions of carbon dioxide from all energy on use (excludes emissions generated from fabrication, construction or demolition processes)			Yes	Bed ZED UK
Low energy homes	Will consume less energy than required by the Building Code	Yes			Germany Sweden
Passive houses	Total primary energy consumption must not be more than 120 kWh/m^2 annum and heat load must be less than 15 kWh/m^2 /annum	Yes			Germany Sweden
Energy-plus homes	Will generate more energy than they consume during operation	Yes	Yes		Freiburg, Germany
Zero-net energy	Will consume no net energy during operation	Yes	Yes		G Solar USA

Table 3: Summary of innovation housing programmes (Williams [11]).

Summary of innovation housing programmes				
	Zero Carbon homes programme. UK	Solar homes programme UK	Mijonprogrammet Sweden	German energetic programme
Technical systems	Complex	Energy efficiency and solar technologies	Energy efficiency	Energy efficiency
Motivation	Targets for CO_2 reduction, energy security, industrial innovation	Energy security, growth of new industry, lower energy process	Comfort, cold climate, energy security	Targets for CO_2 reductions, energy security
New/existing stock	New	Both	New	Both
Deployment	A few demonstration projects	8000 homes	25% of current housing stock	Over 600.000 since 2006
Policy instruments of development	New housing programme, targets, building code, subsidies and planning	New housing programme, targets, building code, subsidies, training programmes, expedited planning process	New housing programme, targets, building code, subsidised loans	Building code, subsidised loans, training programmes, accreditation schemes
Impact on industry	Very significant for energy and house-building industries	Very limited-similar model but develop supply chains	Significant change supply chains and construction process	Limited-similar model but develop supply chains

Table 4: Authors' adapted for technical systems (Williams [11]).

Technical systems to achieve zero carbon standard		
	Definition	Technical systems
Energy efficiency	Energy efficiency of the dwelling unit: 39 kWh/m^2/year for apartments and mid terrace homes 46 kWh/m^2/year for end terrace semi-detached and detached homes It is 20% reduction on CO_2 emissions compared with a standard house	1. Insulation 2. Airtight shell 3. Passive solar technologies 4. **Nano technology materials to improve building envelope**
Carbon compliance	Carbon compliance – a 70% reduction in CO_2 emission required on-site and/or through direct connection to LZC heat	1. Micro generating technologies in the fabric of the building 2. CHP systems 3. Direct connection to a near-site LZC heat network 4. **Nano technology materials to improve building envelope**
Allowable solutions	Residential emissions can be dealt with either by off-site solutions or by house-builders contributing to a buy-out fund-allowable solutions: LZC heat exported to existing proprieties on the surroundings or for micro generations connected by private wire to a LZC energy source off-site or contribute to an energy infrastructure fund	1.Energy efficiency technology off-site 2. Micro generating technology off-site 3. LZC heat network feeding off-site proprieties 4. LZC electricity supply linked by private wire to homes 5. **Nano technology materials to improve building envelope**

The use of nanotechnology in construction is strongly linked to sustainability. It is the declared aim of many nations to improve energy efficiency and reduce greenhouse gases. According to the Kyoto Protocol, CO_2 emissions across the world must be halved by 2050 and this is only possible with resolute and, above all, immediate action. Energy efficient construction is therefore imperative, particularly as construction is a major producer of CO_2 emissions.

The most relevant nanotechnologies on the new envelopes on these buildings are thermal insulation by vacuum insulation panels and solar protection by angles, that should be placed on the correct orientation.

Table 5: The roles of planning in delivering zero carbon developments (Williams [11]).

The roles of planning in delivering zero carbon developments			
Role of planning	Mechanism	Benefits	Example
Strategic coordination	Combine strategic resources and development plans Combined development energetic and economic strategy	Identify options for achieving zero carbon development Identify the benefits of a low carbon economy and provides rationale for zero carbon development	Freiburg and Stockholm Freiburg
Development control	• Zoning and design codes • Solar access ordinances • Expedite planning process • Linking new development to LZC infrastructure	• Specifies sites for zero carbon development and provides indications of design standards. • Perpetuates the integrity of design standards • Reduces overall development costs • Reinforces the integrity and viability of existing systems	RMLUI, Denver Freiburg Codes Boulder San Diego Stockholm
Facilitation	Patterned ships between key players, learning and dissemination processes, community consensus building	Share expertise and risks between players, raising awareness of technical options; building community support for zero carbon development	Malmö Stockholm

4.1 Thermal insulation: vacuum insulation panels (VIPS)

Vacuum insulation panels (VIPs) are ideally suited for providing very good thermal insulation with a much thinner insulation thickness than usual. In comparison *with* conventional insulation materials, such as polystyrene, the thermal conductivity is up to ten times lower. This results either in much higher levels of thermal resistance at the same insulation thickness, or means that thinner insulation layers are required to achieve the same level of insulation. In other words, maximum thermal resistance can be achieved with minimum insulation thickness. At only 0.005 W/mK, the thermal conductivity of VIPs is extremely low. The historical precursor to vacuum insulators is the thermos flask, which functions according to the same basic principle: low thermal conductivity is achieved, not, as usual, by enclosing pockets of air but by evacuating the air entirely, i.e. the creation of a vacuum (Leydecker [12]).

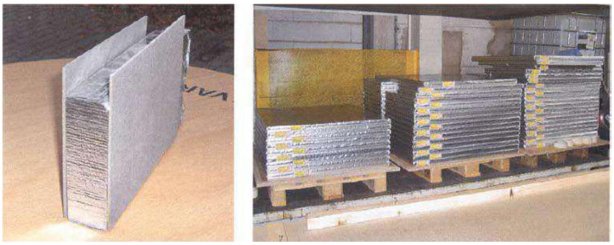

Figure 4: Vacuum insulation panels with a protective encasement source: (Leydecker [12]).

In thermos flasks the air between the twin-walled glass vessels is evacuated, whilst the cylindrical form withstands the high pressure created by the vacuum. This approach is more difficult for flat insulation layers as they are unable to withstand the pressure. The solution to the problem is the use of an extremely fine fill material with a nanoscalar porosity of around 100 nm. The thickness of these VIPs ranges from 2 mm to 40 mm. Vacuum insulation panels can be used both for new building constructions as well as in conversion and renovation work, and can be applied to walls as well as floors. Vacuum insulation panels offer great potential in the general context of improving energy efficiency through better insulation, and accordingly contribute to reducing the amount of CO_2 emissions. The lifetime of modern panels is generally estimated at between 30 and 50 years, with some products exceeding 50 years. Humid environments reduce the overall lifetime of the product. The panels can be recycled (Fig. 4).

4.2 Solar protection: (KALWALL + NANOGEL)

Solar protection against heat gain from solar radiation is offered by two kinds of self darkening glass. The advent of nanotechnology has provided a new means of integrating electrochromatic glass in buildings. The primary difference to the earlier product is that a constant electric current is no longer necessary. A single switch is all that is required to change the degree of light transmission from one state to another, i.e. Fig. 5. (Leydecker [12]).

Another one does the change from transparent to dark and a third one changes it back. Different levels of light transmission with various darkening effects are also possible, as smooth gradient or clearly differentiated. The electrical energy that is required to color the ultrathin nanocoating is minimal. The range of panel sizes currently available is relatively limited as the products have only recently come onto the market – the maximum size at present is 120 × 200 cm.

Photo chromatic glass is another solution for darkening glass panels. Here the sunlight itself causes the glass to darken automatically without any switching. Glare-free light and shading is particularly important for office interiors with computer workstations. Both variants also provide partial shading rather than complete closure so that a degree of visual contact to the world outside always remains. Nanotechnology has made it possible to provide an energy efficient means of solar protection that can also be combined with other glass functions.

Table 6: Comparison between old and new material.

Properties	Old materials (GT.1)	New material (solar protection)
Light transmission index	Minimum 50%	9–12%
Shading coefficient	Even or lower than 45%	Even or lower than 45%
Reflection	Max. 10 %	Max.10%
Total solar radiant heat transmission factor	Max. 40%	0.08–0.11%
Colour rendition	96	95
UV reduction factor	Minimum 85%	Minimum 95%
U value for this glazing	1.35 (W/m^{2}k)	0.28 (W/m^{2}K)

Figure 5: Components of solar protatction.

5 Conclusions

The research presents the opportunity to use nanotechnology for the rehabilitation of residential neighborhoods built after the Second World War, and which combine a number of advantages among which the following stand out:

- Nanomaterials as its associated technologies, are materials of low weight and high performance for thermal, acoustic and PV isolation and therefore make them ideal for skin overlap as a new high technological benefits, existing buildings, improving quality of life and the thermal comfort of its users.
- The repetition of building types on these residential complexes, with very large machining solutions, as well as the implementation of the advantages of economy of scale that will lower the cost of rehabilitation of these neighborhoods. However, one must consider the differences of each bioclimatic façade, first according to their orientation, and secondly according to the numbers of floors and the real urban obstructions facing buildings, so that these new enclosures can solve differences of radiation, lighting and sunlight situations.
- There is a great opportunity for using nanotechnology in Mediterranean countries as thermal conditioning benefits are required in winter conditions (increase the inertia of the walls and reduce thermal bridges) as well as for

summer (by preventing overheating of the façades and allowing the ventilated façade). These innovative constructive systems will improve indoor comfort and will reduce energy consumption in winter and summer. These situations and particular bioclimatic requirements can be part of manual solutions and techniques that can serve as models in a large number of urban buildings with these conditions.

- Finally, the massive use of these nanomaterials and technologies will result in a significant reduction in consumption of polluting energies in both heating and cooling homes that will mean a clear and significant reduction in CO_2 emissions in the Mediterranean cities. In addition, they will be able to better manage security challenges and the agreements signed by these countries in the Kyoto Protocol.

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