The Future of Research and Experimentation in Technological Design of the Relationships between Architecture, Energy and Environment

Fabrizio Tucci*

Department PDTA, Faculty of Architecture, University of Rome "La Sapienza", Rome, Italy

Abstract: The problematic nature of the centrality of the focal core formed of the Technological Design/ Energy / Environment relationship has never been so evident as at the present time, together with the need to tackle it urgently. Humanity has been directly interfacing with the energy issue and the "non-renewability" of resources on the one hand, and the question of harmful and climate-changing emissions on the other part for other for at least thirty years. This is the reason why it is our principal scientific and ethical duty to focus a major part of our attention and efforts on research – as proved in Italy by a significant part of the activities of PhD Program in "Planning Design Technology" of Sapienza University of Rome, by "NZEB" cluster of SITdA Italian Society of Technology of Architecture and by National Work Group "Green Economy for Architecture and Cities" of CNGE National Council on the Green Economy – in order to take significant steps forward. And to provide incisive answers for the emergency situations represented by, to use the two iconic terms of the much larger set of questions, the Climate and Energy problems. On the other hand, if it is true that the Nearly Zero Energy Building slogan specifically alludes to the scale of action, what is certain is that, at an international level, this is not the sole correct level on which we can and we must operate in order to have a chance of success, effectiveness and obtainment of that efficiency referred to in the first European directive 2002/91/EC through to the most recent 2010/31/EU "Energy Performance of Buildings" and 2012/27/EU "Energy Efficiency" which, inter alia, establish the concept of NZE architecture. So the working dimension becomes primarily "a-scaleable", in its need to oscillate constantly, with ongoing feedback, between actions at various leveles. Research related to the broad areas of Nearly Zero Energy Architecture developed in recent years fits into Technological Design in this sense and in this light, mainly in relation to regeneration of the existing architectural heritage, technologies for new building projects, process governance, the systemic approach on an urban scale, environmental and energy sustainability protocols, smart communities and cultural heritage.

Keywords: Near Zero Energy Architecture, Technological Design, Ecoefficiency, Built Environment, Green Economy.

GENERAL OBSERVATIONS: FOUR CHALLENGES

When exploring the complex relationship between energy, architecture and the environment in terms of its prospects for development in an informed way, at least from a Western and, above all, European point of view, we cannot help but start by seriously considering a number of trans-continental challenges that are the inevitable framework for the creation of a critical scenario that the future and innovation of such a trilateration will have to tackle, today and tomorrow. Here I propose at least four such challenges out of the many that are possible.

Firstly, the most unmistakable and inescapable observation which needs to be intelligently acknowledged rather than adopting positions which ignore it on the one hand, and which fight it without understanding it on the other: the number of inhabitants living in urban areas – currently already equal to half the Earth's population compared to a quarter one century ago – will experience a major increase over the next twenty-five years, reaching six billion people which will be equal to about two-thirds of the world's population in just a quarter of a century's time [1]. Faced with such growth, we are aware that tangible and intangible resources – and particularly those that meet the human race's energy, water and nutritional needs – will continue to diminish and will be increasingly inaccessible and unavailable [2].

The truth is that we will be well aware of the consequences of this first series of problems well before the worrying targets scheduled for 2030 and 2050. In this sense, the speed and scale of the urbanisation process and increase of "metropolitan areas" are already creating new problems as regards resource and infrastructure management and institutional capacity to support the growth of cities, on difference scales – yet still a cause of major concern – in both industrialised and emerging and developing countries [3].

Secondly, there are observations that bring to light how the urban transport and physical infrastructure development systems are on the verge of collapse, in many countries worldwide at the same time, especially in Asia and Latin America. This is due to the quick

*Address correspondence to this author at the Department PDTA, Faculty of Architecture, University of Rome "La Sapienza", Via Flaminia 72, 00196 Rome, Italy; Tel: +39-6-49919014, +39-6-70474625; E-mail: fabrizio.tucci@uniroma1.it

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spread of individual motorised means of transport, the decline of collective transportation systems, the gradual marginalisation of feet and pedals as means of transport on a global scale, and the failure to grasp the major opportunities and potential of intangible infrastructure development systems [4]. The latter represent the meaning of well-known terms such as *smart grid* and *smart cities* which are, at the present time, appearing on contemporary scenarios in an explosive and innovative manner, yet one that is too fast and technologically advanced to be absorbed and endorsed by the increasingly complex urban governance management processes [5]. Instead, they could make an enormous contribution, even as regards their consequences on aspects such as the infrastructurisation of "physical" as well as "intangible/energy" connections [6].

There is a third set of observations for which the built environment and in particular the city, which represents human society's largest, most important work of art, which has been the heart of all civilizations for centuries, the driving force behind all thought processes, progress and social conquest, has transformed itself in recent decades into a place – a metropolitan place where all problems are radicalised to the hilt – characterised by harsh contradictions: social intensity is risking becoming suffocating congestion, cultural incentive, frustrating and bland provocation, civil and creative dialogue is inevitably becoming social antagonism while business opportunities are becoming exploitation [7]. We can find marginality, alienation, poverty, drugs and increasingly widespread criminality alongside major achievements in the field of artistic expression and communications. In this sense, the challenges that are threatening to squash today's metropolis are the extremely radicalised ones that were, in essence, already present in 20th-century urbanisation: the challenges of being safe, equal and fair, of offering work, of providing open spaces, places for recreational activities, meeting people and entertainment, of granting economic opportunities and of ensuring compliance with the Lynchian meta principle of accessibility [8], which now seems to represent, when present, the greatest wealth; physical and immaterial accessibility to all parts of the metropolis, accessibility to community comforts and services, accessibility to education and healthcare, accessibility to drinking water and clean air and – a central concern in these observations – accessibility to energy, bioclimatic and environmental resources [9].

Then there is a fourth and last category of problematic observations, the energy-environment category [10], which undoubtedly represents the key issue of today's built environment; a category of problems that, what's more, have inevitably been mentioned in each of the earlier three series of observations because they permeate any point of view one wishes to adopt when attempting to tackle, in an informed way, the momentous challenge posed by the trilateration of Energy/Architecture/Environment [11], even more so when it concerns an exceedingly developed context like that of Europe.

A DETAILED ANALYSIS OF THESE ISSUES

Firstly, we need to see what problems an Italian or European urban entity may encounter in a contemporary scenario characterised by longing for generalised "sustainability" (at least in its three-fold notion, in other words environmental, social and economic) and, given these, try to make some critical observations regarding the opportunities that arise for developing a "balanced", "sustainable", "adaptive" and" resilient" built environment which can use the Italian or European situation as reference parameters such as highly significant and connotative factors, even given the major differences that exist.

It can be said that there are mainly two categories of observations that concern the future of a balanced and sustainable Italian built environment.

The first refers to an updated concept of living that involves what we can call the "transition time to a responsible city" [12].

Indeed, if the 20th century was the century of urbanisation par excellence, the 21st century will be that of the transition from city to sustainable city: all-important battles for the quality of life will be fought in cities, the results of which will have virtually definitive effects on the environment and human relations [13]. Some of today's intellectuals describe the urbanised world using apocalyptical scenarios where cities become hopeless spaces where you cannot even breathe due to the excessive number of cars and inhabitants. But we must not give in to the total pessimism of this vision; cities are not *problems*, they are *solutions*, and must be conceived, lived and designed as such, focusing more on their amazing transformation potential rather than on desperately attempting moves to curb their negative aspects [14]. One of the key elements in the pro-active vision of a

transition of Italian cities to a status of "greater responsibility" is to think of the city as an integrated structure where the concept of *green economy* and the vision of *circularity of resources* used take shape, where life and work come together, as well as physical-material structures and informative-immaterial infrastructures [15].

If we think of the developed or developing territory of a large urbanised area in Italy, we can envisage development that is aimed at going beyond the "physical saturation" that is typical of the seamless metropolises our planet is full of. Development that aims at achieving an updated vision – a more responsible one as regards the quality of life in its three-fold meaning of environment, mobility and solidarity – where, first and foremost, the very perception of the metropolis prevails, where perception of the key elements characterising balanced contribution to improving the quality of life is based on concepts such as reduction, separation, conservation and reuse [16]. In contrast to the prevailing principles that are typical of the "non-responsible" metropolis, which are *increase* (of consumption, population, density...), *saturation* (of spaces, buildings, services...), *profligacy* (of energy, resources, the economy...) and *wastage* (of materials, refuse, primary resources...) [17].

Some examples of how the aforelisted principles can be put into being are reduction of the use of cars, of the distances between homes and workplaces, of energy consumption and management costs; rationalised sorting and collection of material waste in general and of the lifecycle phases of a component, a building, an urban complex; reuse of recycled materials and building closure materials or site surpluses; research and maximisation of clean energy, bioclimatic comfort and environmental wellbeing in a broader sense [18].

The second category of observations necessarily and actively leads to the quest for a an updated concept of sustainability – environmental, social and economic – which looks upon the issue of energy-environmental efficiency as one of the cornerstones on which to build the framework of the green economy vision and one of the momentous key issues to be tackled and resolved, including by adopting a totally new way of thinking, conceiving and perceiving the city which brings into play the opportunities offered by the concept of green and smart cities as well as zero energy and zero emissions [19].

Tackling the question of environmental quality and eco-efficiency in the urban transformation of any Italian city inevitably involves referring the key issues of the speculative tradition to areas of application [20]. These direct the centre of scientific and experimental interest onto the assessment and design of living spaces and housing in the urban environment, in full compliance with resources, economic costs and eco-systemic balances within the broader man-made/natural relationship [21]. An interest which assigns new value to design, giving it back a central role compared to any other legislative action, and hence legitimising the role of architecture as a mediator between specific needs and continuant answers, between society and decisive places [22]. In other words, a role which is the very premise of architecture and which acts in a decisive manner within the complex field of the major synergies at play in the urban ecosystem.

The concept of urban ecosystem implies awareness of the fact that attention needs to be focused on interaction processes, on moving towards an eco-efficient approach to the assessment, design, upgrading and management policies of an urban situation undergoing transformation [23].

An innovative idea of the metropolitan setting presents itself in this way, in its privileged relationship with the established historical centre and with upgrading of its polycentric suburbs; concepts that are closely linked to the new cultural, social and technological processes involving cities and that tend to highlight the need for new ideas, models and examples carried out that lead to an experimental and totally updated type of vision of governance of a metropolis: *from expansive city planning to transformational city planning* [24]. It is a vision that considers human, natural and environmental resources to be an integral and energising part of the development of a socially, environmentally and energetically accessible and balanced territory [25].

The vision of a kind of energy-efficient development that is technologically balanced and geared towards improving access to tangible and intangible services in a European city cannot help but take its cue from this framework of considerations and aim to solve problematic situations that have now arisen in many of the world's metropolitan areas [26], proving how enormously difficult it is to solve these problems, given the short amount of time that the 2030 and 2050 targets impose [27].

THE METHODOLOGICAL APPROACH

The problematic nature of the centrality of the focal core formed of the Technological Design/ Energy / Environment relationship has never been so evident as at the present time, together with the need to tackle it urgently. Humanity has been directly interfacing with the energy issue and the "non-renewability" of resources on the one hand, and the question of harmful and climate-changing emissions on the other part for other for at least thirty years.

This is the reason why it is our principal scientific and ethical duty to focus a major part of our attention and efforts on research in order to take significant steps forward, as proved in Italy by "NZEB" cluster of SITdA Italian Society of Technology of Architecture [28], by National Work Group "Green Economy for Architecture and Cities" of CNGE National Council on the Green Economy [29] and by a significant part of the activities of PhD Program in "Planning Design Technology" of Sapienza University of Rome. And to provide incisive answers for the emergency situations represented by, to use the two iconic terms of the much larger set of questions, the *Climate* and *Energy* problems.

On the other hand, if it is true that the *Nearly Zero Energy Building* slogan specifically alludes to the scale of action, what is certain is that, at an international level, this is not the sole correct level on which we can and we must operate in order to have a chance of success [30], effectiveness and obtainment of that efficiency referred to in the first European directive 2002/91/EC through to the most recent 2010/31/EU *"Energy Performance of Buildings" and* 2012/27/EU *"Energy Efficiency"* which, inter alia, establish the concept of NZE architecture [31].

So the working dimension becomes primarily "a-scaleable", in its need to oscillate constantly, with ongoing feedback, between actions at various levels [32]. Research related to the broad areas of Nearly Zero Energy Architecture developed in recent years fits into Technological Design in this sense and in this light, mainly in relation to regeneration of the existing architectural heritage, technologies for new building projects, process governance, the systemic approach on an urban scale, environmental and energy sustainability protocols, smart communities and cultural heritage.

The main aims shared by the scientific community - pertaining to the three institutions above mentioned of Sapienza's PhD, SITdA's NZEB cluster and CNGE's work group, all directed by the author - are: to focus research activities on issues related to procedural and design aspects in order to achieve the best standards of energy efficiency with regard to the given context; to improve the building's passive bioclimatic aspects; to reduce, streamline and optimise primary energy consumption by acting on the building's technological and environmental system; to produce, share and network renewable energy sources; to define innovative technological solutions and make innovative use of traditional technological solutions; to obtain maximum integration of design with active plant engineering solutions within an all-encompassing *building-plant* vision; to promote the use of audit, monitoring, control and management systems in relation to the architecture's energetic and bioclimatic behaviour.

As regards the framing of a technological-environmental design approach, in line with the vision and aims of the "NZEB" cluster of SITdA Italian Society of Technology of Architecture and of the National Work Group "Green Economy for Architecture and Cities" of CNGE National Council on the Green Economy, interpretation and analysis of the many activities included therein seem to indicate a change in the focus of research and design experimentation. The latter is shifting onto the six-level combination, that can be split into five points (actually five interconnected approach methods), the innovation of which lies not only in the points taken individually, but in how they are combined at a scientific and design level:

1. an approach that pursues the reduction of energy consumption in building and urban organisms, together with an increase of the level of energy efficiency;

2. an approach which seeks maximum "dynamic" interaction between architecture and microclimatic and environmental factors and optimises passive bioclimatic behaviour;

3. an approach that favours techniques, technologies, parts and materials that are increasingly able to support a clean, non-polluting, zero-emission, high energy performance, with a high ecological value;

4. an approach that looks for forms of self-production of energy from renewable sources that are increasingly integrated within building organisms, hence generated on site;

5. an approach that tends to promote the distribution, sharing and networking of self-produced, clean, renewable energy for our common future, with dynamic management as regards demand and requirements;

6. an approach that makes assessment of energy-bioclimatic-environmental performances an integral part of the conception and design of activities during simulation prior to design and monitoring subsequent to project performance.

THE FUTURE OF RESEARCH AND PROJECT DESIGN

Adopting the methodological approach described here, the three national institutions I supervise in Italy – "NZEB" cluster of SITdA Italian Society of Technology of Architecture, National Work Group "Green Economy for Architecture and Cities" of CNGE National Council on the Green Economy and PhD Program in "Planning Design Technology" of Sapienza University of Rome – have been mainly working on the following six thematic areas for many years now:

1. Energy Efficiency and Efficiency Improvement

Topics: Research of the best relationship that can be achieved in new construction, compared to contextual environmental, cultural social and economic data, between resources used and energy-environmental performance, as an all-encompassing product of the architecture-technology-environment system. Research of the maximum effectiveness of action to improve the energy-environmental performance of the existing architectural stock, in the balance between characteristics of existing buildings to be maintained/optimised and pursuit of efficiency improvement targets.

2. Bioclimatic Design and Passive Systems in Architecture

Topics: Optimisation of passive bioclimatic behaviours of architecture and use of technological systems aimed at interaction with microclimatic and environmental factors, for the dual goal of improving environmental comfort and energy behaviours, linked especially to fluid dynamic and luminous thermal aspects. Design technological experimentation in the field of architecture of concepts that can be obtained and transferred from the study of Nature in its “passive” management of energy, bioclimatic and biophysical aspects.

3. Reduction of Energy Requirement, Low Cost and Resource Management

Topics: research of ways to reduce energy requirements as from the design phase and of actual energy consumption of architecture in its real life cycle, for the transition from the concept of *Nearly Zero Energy* to that of *Net Zero Energy Building*. Design technological studies, research and experimentation focusing on the balance between low energy targets and financial budget contexts, firstly with regard to social housing, for extremely reduced construction and management/maintenance of the architecture.

4. Renewable Energies and Smart Grid

Topics: optimisation of the integrated use in architecture of forms of energy production from renewable resources (solar, wind, geothermal, biomass, hydro, passive kinetic, etc.) for total doing away in our society of production from fossil sources. Studies and research for network sharing of various forms of energy produced (*smart grid*), with focus on local dimensions (*smart district*) of testing of distribution and “intelligent” exchange aimed at managerial optimisation of different production at different times of the day and year.

5. Technological Innovation of Systems and Components, and Grey Energy

Topics: studies and research of so-called “hidden energy” in systems, components and materials used in architecture and in the artificial environment, aware of the centrality of considering the overall quantity of energy which the use of those materials and components brings to their whole life cycle. Design research and experimentation aimed at the use of materials and components with high capacities of transmitting an improvement in overall energy-environmental performance to the architectural and artificial context.

6. Evaluation of Energy-Environmental Perfor-mance

Topics: innovation of methods and instruments for analysing and evaluating energy performance in three cases: prior to action on the existing construction (energy audit), after action has been completed (energy certification), during its life (energy monitoring). Innovation of methods and instruments for simulation and evaluative forecast of energy, thermos-physical, fluid dynamic (etc.) behaviours of a project, of a virtual context not yet a reality.

Given the significant innovative repercussions on the built environment's structure, we should take a closer look, particularly at the aspect of the energy infrastructurisation of our complex built environments, a matter that is complementary to the six thematic areas listed above.

As regards the "intangible" infrastructure development of a responsible and sustainable Italian metropolis, the frontrunners are proposals involving intelligent use of smart grids as electrical network systems which — by definition – are able to cleverly integrate the actions of all connected users – producers, consumers, prosumers – in order to distribute energy in an efficient, sustainable, financially advantageous and safe way. On the other hand, the most recent European directives clearly show how the core of the development matrix for an innovative energy infrastructure is based on ICT, able to manage the metabolism of a complex body such as a metropolis and to configure "intelligent" (an overused term) cities given that it would potentially interact with the three currently largest energy-consuming systems: the buildings-city system, the transport system and, obviously, the energy procurement system [33].

As a result, various research and design questions come to the fore for cities tackling the development of a new energy-technology infrastructure based on a widespread large-scale distributed energy resources (DER) system which allows for evolution of the urban system as regards its tangible and intangible characteristics. Also in this case the term "evolution" seems to be the most appropriate (rather than "reform" or "revolution") since this evolution programmes longstanding strategic action priorities regarding the urban environment: polycentric rebalancing, regeneration of the city, environmental control of the urban metabolism, optimisation and protection of local resources, incentivisation of participation, inclusive and decision-making processes. All of these are priorities which start to be endorsed worldwide, mostly by cities that have effectively embraced a development policy focused on including the environment, sustainability and the green economy as structuring factors of urban transformation processes that cannot help but systematically include an "Italian smart city".

It is of crucial importance, in relation to the scale of the crisis the world is currently facing, in a development model where the relationship between energy use and cultural evolution – looked at during the last thirty years of the 20th century by White, Odum, MacCurdy, and intensely re-examined and re-proposed since the early years of this century by Rifkin, among others. And as regards the prospects offered by technological innovation, it is indeed the latter – if used and applied in a responsible manner – which paves the way for a new energy infrastructure model based on distributed generation (DG) which entails a new relationship between energy use and cultural evolution [34]: this is why the vision of the polycentric, network-distributed system of the future Italian metropolitan area can lend itself to development in this sense, which is, moreover, very similar to the cultural development model based on the autopoietic system theories introduced by Maturana and Varela.

This type of vision is based on the scenario where integration of DER (distributed energy resources) will become the solution for the future energy infrastructure, becoming a safe and sustainable energy procurement system. In this perspective, bringing together the set of energy production resources from small-scale renewable natural resources (combined, if necessary, with specific loads and/or categories of other kinds of energy procurement) into a virtual production unit known as a virtual power plant (VPP) is one of the most advanced concepts for development. The goal is to maximise their contribution to the primary procurement system through to them being gradually replaced (in the long-term) by the latter. The question of virtual power plants is of key interest and introduction of the new infrastructure model will have major knock-on effects on numerous areas of urban life [35].

As specifically regards energy production technologies, Distributed Generation (GD) will play a key role since it is able to cover a wide range of technologies (wind, solar, geothermal, biomass, etc.), renewable technologies which provide energy on a suitable scale and at locations near users. A technology which minimises transmission losses since it works on-site, also minimising distribution baskets, increasing the level of self-management of the local demand.

CONCLUSIONS

If we are to re-examine the observations from a broader viewpoint which also takes in the numerous effects that knowledgeable trilateration of technological design can have on built environment morphological organisation, with 'responsible' and 'balanced' urban

life and with serious examination of the deepest meaning of circularity of the use of resources and green economy, implementation of this development scenario marks a radical change of process from a methodological-technological viewpoint, both with regard to planning and design [36]. Knowledge of the local geographical condition is no longer an aspect related to occasional individual sensitivity, but rather collective and structural sensitivity for the complete urban set-up.

Indeed, as regards the urban set-up, solar access, wind configuration, geological mapping, the hydrographic grid, control of specific local humidity, the orographic trend, vegetative characteristics and all the 'natural infrastructure' [37] are involved in defining the most appropriate energy sources to be connected to the Distributed Generation system as initial potential offered by the specific climatic-geographical condition.

But also the anthropic infrastructure, in other words the constructed environment, from large, compact complexes to the widespread city, from public to private buildings, from urban voids/non-places to structured and structuring parks, can all be potentially declined in an energy-environmental interpretation and circular vision of the green economy. Volumetric configuration, physical size, habitational density become parameters to be reprocessed using logics in agreement with the new vision. This applies for new settlement areas just as for the more widespread regeneration, upgrading and recovery projects.

It will most definitely represent an opportunity to innovate personal building regulations and to re-organise individual design processes based on a set of real, diversified action proposals, that can be adjusted and systematically connected to specific tangible and intangible local characteristics, for the "responsibly controlled" Italian built environment.

NOTE

Fabrizio Tucci is Director of PhD Program "Planning Design Technology", Sapienza University of Rome; Director of Cluster "Nearly Zero Energy Building", Italian Society of Technology of Architecture; Director of National Work Group "Green Economy for Architecture and Cities", National Council on the Green Economy, Italy.

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