

# Sustainable Identities in the Technological Esprit of Architecture

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**Abstract:** Innovation and energy efficiency are the essential paradigms of the new technology and design culture, in the sustainable economic and social development, highlighting the performance of new technologies, systems and intelligent materials, such as sustainable identities in architectural envelopes. Then, contextualized sustainable architectural objectives favor material and energy flows, pointing to the constructive flexibility, identity and compatibility of technological innovation, which contrasts with climate change. So sustainable use of natural resources, renewable energy, in line with the principles of the 2030 Agenda for SDGs (Sustainable Development Goals). The well-being of the community with the valorisation of places and the environment, indicates the technological excellence of architecture, synchronous with territorial metamorphoses. Thus, vision glass principles in the environmentally responsive wall, and engineered wall, in external awareness, cellular flooring for eco-efficiency. The methodologies indicate the applications of new design models for new constructions and regeneration, with dynamic, efficient and integrated envelopes integrated with renewable energy storage technologies, neomaterials and high performance insulating. Then HPP (high performance polymers) nanotechnologies are based on efficient pigments, intelligent bioPCM (PCM for phase change material) nano technologies, thermoregulators with high thermal inertia. The goal is towards an escalation of sustainable architectures that contrasts with climate change and pollution of anthropic origin, for smart and sustainable growth.

**Key words:** Architecture, technology, sustainability, energy storage, intelligent materials, nanotechnologies, quality.

## 1. Introduction

The constructive iter, consolidated by emerging sustainable systems, integrates into new spatial articulations marked by a dialectics of identity and highlighted the technological excellence of architecture. It is synchronous with territorial metamorphoses and the work in progress of innovation and building production by highlighting efficient technological and material systems. For this reason, it is necessary to apply new and exclusive operating models with the realization of sustainable architectures, low environmental impact, through a metaproject of a framework and user activities, focusing on material and energy flows, across the cycle of the life of the building. They distinguish a pyramidal optimization of morphological,

technological and functional choices and where the nature becomes the protagonist of building transformations.

In these, we distinguish the physiognomic and landscaping aspects of a modern public garden, in the synthesis of an anthropic space. It represents the ideal fulcrum of socio-economic and political development with contextual architectures that highlight the excellence of sustainable technological systems, intelligent materials and components, and new nanostructures based on natural pigments [1]. For this reason, an interaction between Genius Loci, efficient envelopes, served by different spatial infrastructures and aimed at valorization of the environment is generated, favoring the comfort and well-being of users in *Gemütlichkeit*'s performance [2], the continuity of fruition between indoor and external spaces. Highlighting dynamic façades and neomaterial with the different colors that camouflage, sustainably,

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in nature. It integrates architectures that distinguish technological excellence, interacting with the climate, with the rational use of environmental resources and context, as the focus of new design. So sustainable types, according to the UPDP (United Nations Development Program) and the New ONU (United Nations Organization) Summit of 2015 in NY, for the adoption of the 2030 Agenda for Sustainable Development, with its 17 SDGs (Sustainable Development Goals) [3]. These highlight the use of renewable resources with accessibility, the adoption of urgent measures against climate change with sustainable use of the earth ecosystem. In particular, the EC (European Commission) 2020 strategy (COM (2010) 2020 final) projects towards smart, sustainable and inclusive growth, fostering innovation, digital society and skills acquisition. So they point to a new integrated technologies in new design processes, with architectures aimed at territorial valorization and natural resources with sensory perception and environmental visibility. And then they evoke feasibility, compatibility and technological quality with the use of natural and ecological materials according to prescriptions, to improve asset values subordinate to management policy of transformation, depending on economic and productive needs and dynamic/anthropic and fixed/natural interrelations. To this end, European standardization organizations develop the technical specifications of various types of processes, materials, products and services, CEN (European Committee for Standardization), CELENEC (European Committee for Electrotechnical Standardization) for Electrotechnics and ETSI (European Telecommunications Standards Institute) for ICT (Information and Communication Technologies), ensuring the interoperability of digital technologies, like the WHO (World Health Organization) and US.EPA (United States-Environmental Protection Agency) recommendations, also focusing on efficiency, energy saving, ecosystem quality, clean air, EEA

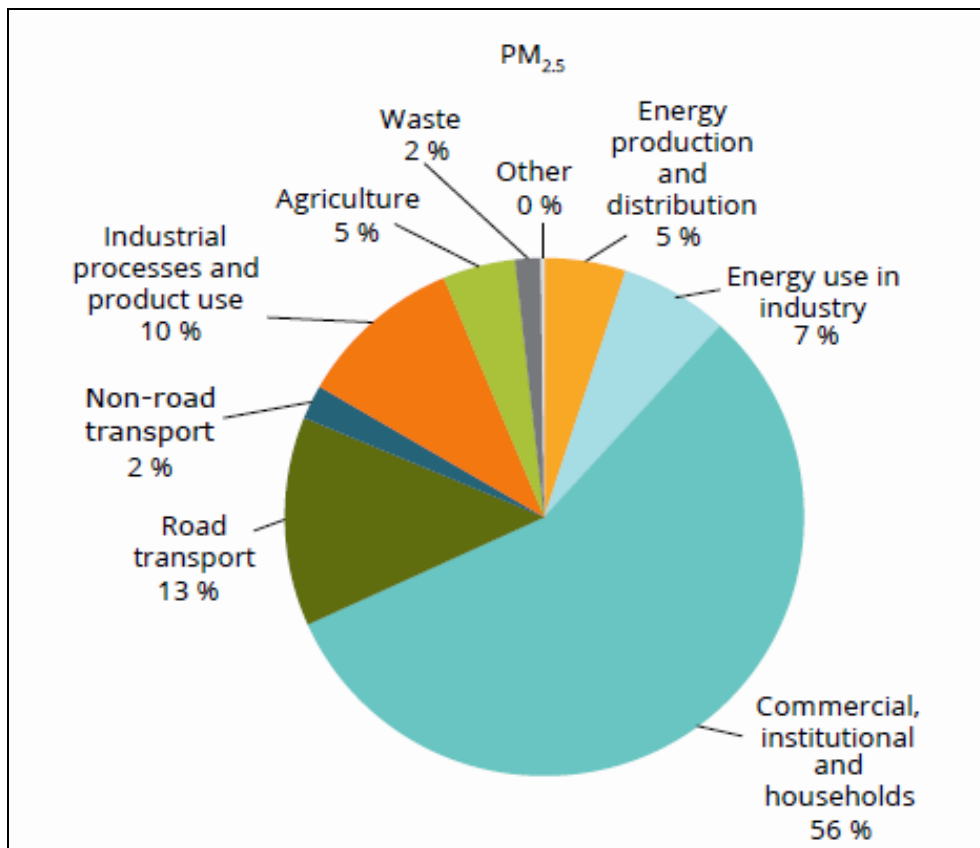
environment (European Environment Agency). In line with COM (2013) and the new EU 2016/2284-NECD (National Emission Ceilings Directive), for new air quality limits, with emission reduction targets up to 2029 and from 2030 onwards, for the protection of public health, to this end, European Community strategies become more stringent for the ecological and bioclimatic sectors for sustainability, CO<sub>2</sub> reduction, polluting factors both human and environmental, adopting measurements against the emission of particulate-thin powders (PM<sub>10</sub>, PM is short for particulate matter) (Fig. 1). In Europe, it is noted that the management of inefficient domestic installations, which dissipate in the PM<sub>10</sub> or PM<sub>2.5</sub> environment through combustion, becoming the main cause of environmental pollution and silk building.

So, sustainability and eco-efficiency in the growing media debate and in IPCC (Intergovernmental Panel on Climate Change).

## 2. Sustainability in Architecture

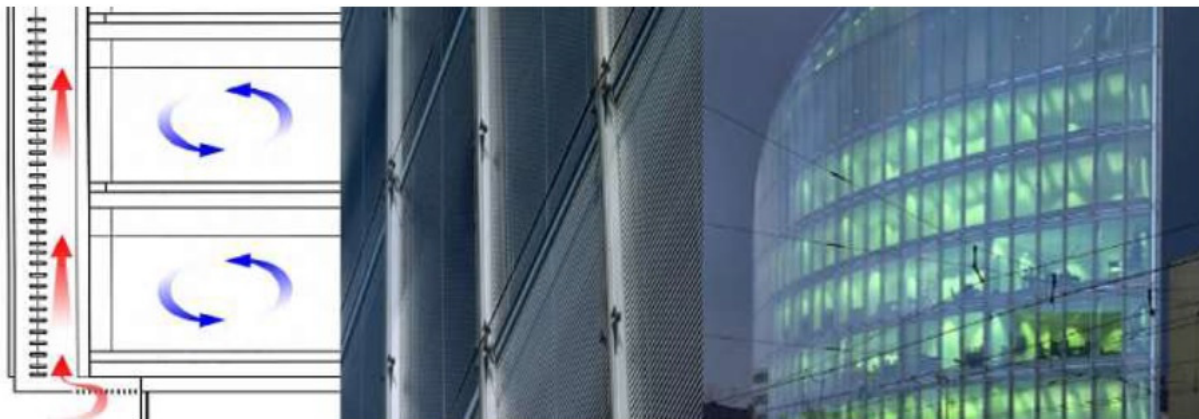
### 2.1 *BioPCM Technologies and High Performance Materials*

The identification of sustainable design criteria for a new construction process, according to a demanding and performance-based system, is based on the quality requirements of interior environments, contextualization and lifecycle of the building, with reduction and containment of resources, in a productive increase in climatic resources. For this reason, selective and dynamic control criteria [4] are developed for the regulation and conveying of the climatic and environmental flows, through the adoption of clean construction technologies, components and devices capable of interacting with light, air and thermo/hygrometric stresses. Vertical enclosures, for example, typically characterize vision glass through glass curtain wall systems, unit systems (cellular), double or triple skin façades, and so on. They are designed according to the design criteria of the environmentally responsive wall, in interaction with



**Fig. 1** Emission of PM<sub>2.5</sub> in housing, in Europe.

Source: Ref. [5].



**Fig. 2** Buffer DSF (double skin façade) zones with blind system.

Source: Ref. [6].

context and environment, through a perceptive and organic contact, with the dual function of transmitting the heat of air to the cavity (Fig. 2), in the interior, in winter, instead of removing the heat of the indoor outdoors, in the summer. In addition, the same vertical enclosures are also carried out according to the criteria

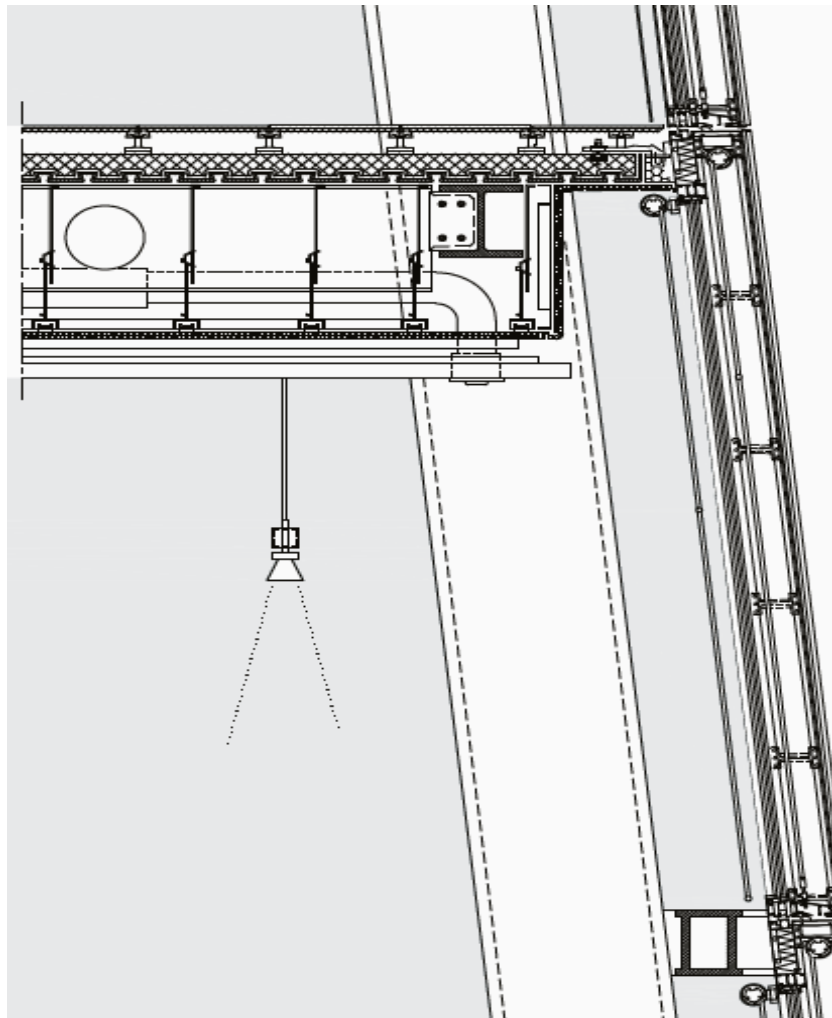
of engineered wall, for hygrometric thermo control, passive natural ventilation for the interior, light transmission and heat. They have the absorption and control function for the compatibility of external noise, reduction and increase of radioactive heat exchangers, between user and surface, control of the dominant

summer and winter winds, and so on. Additionally, sustainable design criteria for external awareness and cellular floor planning for eco-efficiency are used. So in solar planning and relationship with the user, in building systems, it is indicated by a reduction of about 20% for shading, orientation with the adoption of innovative low-E, passive and active technological systems, high tech, innovative quality criteria, right/product/right, level/right, costumer, and the use of bio-materials, with high energy efficiency. These façade systems are integrated with the management of BMS (building management system) systems, to control solar radiation, lowering the darkening (for

example, if solar radiation is greater than  $200 \text{ W/m}^2$ , leaving the transparency of the glasses) and to reduce the energy consumption, in many works, among which, in the architectural envelope of The Shard, by arch. Renzo Piano, in London (Fig. 3).

In these principles of efficient façades, is also highlighted the application of nanostructured intelligent materials and thermoregulators PCMs (phase change material). PCM materials are considered as melting latent heat storage (referred to the building).

They include the cement, plexiglass, wood, such as the laminate used, with its various aesthetic-functional



**Fig. 3** The Shard, London. Detail of façade with extra clear glass, triple glass DFS, “cellular”system: external with single layer laminated glass, in middle-ventilated space with a roller blind (controlled by BMS system), interior with double insulating glass. BIM (building information modeling) design.

Source: Ref. [7].

performance and ecological characteristics, high antisismic, plasterboard, glass, plaster, building materials, prefabricated blocks, bricks, etc. In some cases for interiors, PCM plaster panels are realized where, depending on the requirements, the amount of thermal accumulation performance of the components can be controlled, according to the thicknesses of the layers. While for prefabricated masonry, aerated green cement blocks are enhanced with latent heat storage capacity and with high thermal, and indoor humidity insulation, environmentally compatible and constant temperatures, as it has a low temperature of internal surface fluctuation, at the same U transmittance value. So their storage capacity does not depend on the thickness of the materials. Some types of PCM-based panels such as those produced in nanoPCM Micronal<sup>®</sup> PCM (micro capsules) are equipped with high thermal inertia and low transmittance with thermal conductivity values  $\lambda = 0.18 \text{ W/mk}$  with low thicknesses of about 15 mm. In addition, they exhibit high permeability performance in addition to the

latent heat storage (distributed with a certain delay), maintaining their temperature constant up to the melting point, accumulating heat until the complete transformation of the material, from solid state to liquid or from liquid to gaseous, using hydrated salts or paraffin. They are used as heat conductors usually contained in plastic modules, except for hydrates, which also require stainless steel for their corrosion, and also promote the integration between active and passive building systems. Therefore, the advantages of these materials for their use are those that are mainly adopted in the passive technology of bioclimatic architectures, as they reduce the internal temperature peaks of the environments and consequently, energy consumption, for air conditioning. In fact, having capacity to absorb thermal energy and use latent heat (Fig. 4), they can eliminate or reduce the internal conditioning by mitigating the daily temperature thermal fluxes in buildings. In these, because in winter, the insulation reduces thermal dispersions, through the walls while, through glazing enclosures, it increases

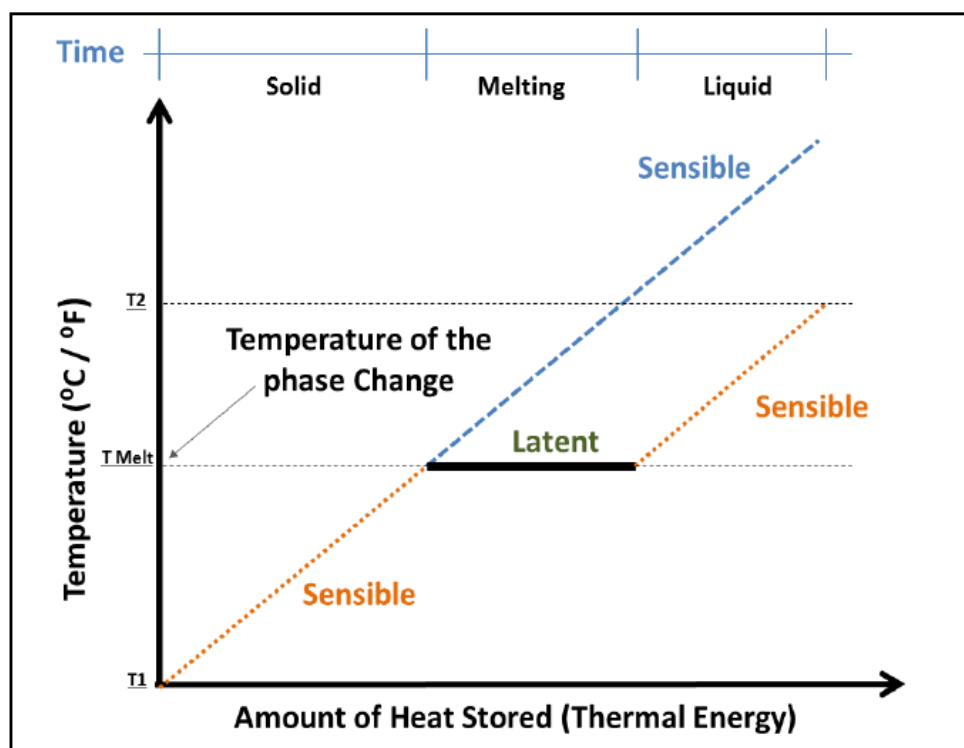


Fig. 4 Graph with temperatures of sensible and latent heat.

Source: Ref. [8].

the flow of solar radiation, with the passive integration of these PCM heat storage materials [9], we can get results of energy efficiency and indoor temperature control. In fact, this is achieved mainly through thermal insulation, latent storage heat, shading, and nighttime ventilation. But to optimize the performance of the envelope, improving the durability of the system [10], the main requirements that PCMs should have, are that they are not hygroscopic, inflammable, toxic or corrosive, with a melting temperature of ca. 25 °C, from the solid/crystalline to the liquid/viscous phase, of its phase change, and a relative high phase transition heat, from the liquid state to the solid state. They must also be equipped with greater management, for their use in the building, through low-cost availability on the market. PCMs are organic (paraffin compounds, non-paraffin compounds), inorganic (salt hydrate, metallics) and eutectic (organic/organic, inorganic/inorganic, and inorganic/organic). They apply to the following different components of the building system: wallboards, ceiling tiles, floor panels, interior wall constructions with micro-encapsulated paraffin wax, interior wall constructions, attics/drop ceiling plenum floor with bio-based (organic), and eutectic salt mixtures materials too. They were derived from paraffinic organic composites, such as heat conductors usually contained in plastic modules, except for hydrates that also require stainless steel for their corrosion, and some hydrocarbons, but also saline solutions (hydrate salts) derived from inorganic composites. The paraffin, biodegradable and non-corrosive material, microencapsulated in acrylate film or salt hydrate, is much more fluid than salt hydrate, requiring greater compensation space in containment modules due to radiation heat. So in summer, its thermal state remains unaltered, facilitated by prismatic glass plates that dampen the irradiation. According to the 2017 report by the Fraunhofer Institute for Solar Energy Systems ISE, paraffin dispersions such as PCM are stable for more

than 20,000 thermal cycles, according to which PCM dispersions are distributed between two plate heat exchangers, whereby the material crystallizes and melts once in the cycle. So a search for materials that significantly and safely reduce super-cooling, even for a large number of cycles, is experimental in several cooling applications in the building, in ceilings and storage units for cooling power, up to cooling of batteries for stationary and mobile applications.

## 2.2 Applications with Integration in Buildings

The flexibility of components of the architectural envelope provides opportunities for extending its lifecycle (for new or retrofitting), improving its sustainability, or increases the performance of the buildings. This condition occurs in the building as a function of new functional or commercial requirements by highlighting its identity values, in possible contemporary transformations with the adoption of innovative technologies and materials. The nPCM (nanoPCM) technologies, microencapsulated inorganic composites, distributed in powder forms, are integrated throughout the building envelope for both new construction and retrofitting operations, in which the coat-jacket in the façades is often adopted. Then they are applied in roofs, in double or triple façades that become thermodynamic, in the heating floor (Fig. 5) and in the interior walls, highlighting also plant solutions in heat exchangers, solar collectors and HVAC (Heating, Ventilating And Air Conditioning). In the sustainable project MESSIB (multi-source energy storage system integrated in buildings) financed by the European Commission [11], the accumulation systems are based on the distributed energy on “on time” and hybrid thermal-electric grids. A thermal, multi-technological energy storage system based on PCM materials, microencapsulated paraffin and fluid transmitting energy to the envelope building components, built into the GS (grund storage) thermal storage system, built-in ground energy storage radiant systems.





**Fig. 5 Underfloor energy storage with PCM materials.**

Source: Ref. [12].

The system becomes a backup for RESs in buildings, which increase EE (energy efficiency) and become more self-sustaining and intelligent (integrated in smart city and smart grid) through the integration of energy storage systems, that reduce energy consumption and environmental impact. Since RESs are variable and intermittent, MESS integration is needed, reducing CO<sub>2</sub> and primary energy demand, with greater market access. In fact, these nanomaterials are systems for energy efficiency and sustainability in buildings, with high thermal accumulation and thermal transmission, high thermal inertia, even with very low thicknesses with the benefit of volumetric and energy saving and low transmittance. The heat storage is obtained when the crystals are melted with their heating, while regaining solidity during the cooling. PCM technologies are therefore also used to alter accumulation masses of opaque envelopes, such as concrete, with a storage capacity of about 10 times lower than that of salt hydrates and favor the integration of active and

passive systems' building. In fact, as a passive system, a type of bioPCM technology operating at 20-24 °C, it will be able to maintain indoor climate comfort at the same temperature, without the use of conventional mechanical plants, but with automatic transfer of thermal accumulation, through cooling and natural ventilation, resulting in energy savings from 20% to 40%, and an investment ROI (return on investment) of 1 to about 7 years. Active systems integrate into the accumulated energy, some devices for the additional power supply of the heat and cold transmission process. Additionally, heat accumulators store certain temperatures from renewable energy and transmit them to the environment, depending on the needs, even for the supply of hot water. Recently, NASA (National Aeronautics and Space Administration) has developed a heat exchanger with a PCM HX (heat exchanger) that stores energy by thawing a phase change material based on wax, a device that can support smart grids and smart city. Integrations of PCMs in buildings can occur through heat mass

(passive heating system), and cooling (active systems). Finally, excellent aesthetic performances of façades cladding are identified in diffused translucent stone materials too, from new technologies with minimal thicknesses, laminated marble slabs and hybridized by glass reinforcement and polymer films and PCM integration with photovoltaic technologies.

Like the application of thin-film solar collectors on the south façade of the “Smart Material House”, by zillerplus Architekten, residences in Hamburg, Fig. 6 shows a passive building where the heat requirement is calculated by approx 19,250 KWh per hour, per year, or 12 KWh per m<sup>2</sup> per year (passive house guidelines). The building is heated, above all, by solar energy. Radiant floors, such as cold drinking water, are heated by means of a heat exchanger, two storage tanks of up to 2 m<sup>3</sup> containing solar energy passive and energy from the Wilhelmsburg Central network. An automated BMS system controls the intelligent

management of the distributed power generation, with its energy saving and access to the distribution local heat grid. Additional efficient technology applications are the BAT (best available technology), as indicated by the European IPPC (Integrated Pollution Prevention and Control) Strategy and the normative AIA (Integrated Environmental Authorization) of Directive 96/61/EC aimed at reducing the environmental impact of production processes.

So technological solutions in various sectors, include waste management, resources in industrial production, ICT (information communication technology). They follow the operating management tools including LCA (life cycle assessment), ecodesign, etc., and diagnostic tools for measuring environmental data. Particularly in the building sector, clean technologies are used, especially in the environmental management of the building to reduce greenhouse gas emissions, VOCs (volatile organic



**Fig. 6** Residences in Hamburg: (a) section; (b) perspective. PCM integration into façade and PV-vacuum tube collectors on the parapet wall.

Source: Ref. [13].



compounds) in indoor environments, but also to reduce energy (thermal and electrical) consumption, raw materials, water consumption, dangerous substances and waste, ect. For the treatment of pollution, we aim at “end of pipe” technologies. The same nano-pigments are innovative thermal energy-efficient materials used in construction, such as in the automotive industry. These HPP (high performance polymers), (polymers, paints and concrete) are added by colored pigments which, with

low cost production, avoid production process changes and the building has thermal performance that contributes to the reduction of thermal power plants. Daylighting technologies, prefabricated systems, with dry technologies, reducing thermal dispersion, and self-sufficient planting of active systems to complement passive (photovoltaic and solar panels), optimized by planimetric conformation and envelope configuration. Thus, dual leather envelops with technologies that focus on sustainable identities with



**Fig. 7 Musée D'Arts de Nantes: (a) suspended façade with portuguese white marble on metal frame; (b) Cube's inner perspective.**

Source: Ref. [14].

technological esprit with high performance levels. In fact, transparency, slimness and security are also essential parameters of excellent contemporary architectural envelopes, that integrate into the context, including within new sustainable upgrading plans, highlighting continuous, suspended façades (Fig. 7). As in the recent intervention of 2017, for the regeneration and extension by arch. Stanton Williams of the Musée D'Arts de Nantes in France, with works in three areas: the new Cube building, which represents the contemporary art gallery with circular areas, with a suspended façades, the transformations in the palais, and the appropriation spaces of the chapel. The Cube (Fig. 8), a monolithic space with a flexible layout and a simple façades to the north, without windows,

resembles the white color of the palais stone and the local *tuffeau nantais*. This new volume, compact and slender, has a suspended façade to the south, on a metallic structure with portuguese white marble, finishes and translucent stratified glass. Then, in the palais tunnel skylights, new daylight systems are introduced, on a pre-existing frame, with layered system of glass, woven fabric and adjustable blind shading.

Thus, high-performance sustainability is both perceptive and qualitative energy, with new design process models and open source envelopes. They exhibit glossy and opaque surfaces with tested and certified neo materials [15], with integrated façade to photovoltaic cells, thermotropic facades, facades with



**Fig. 8** Musée D'Arts de Nantes. The Cube with connection to the museum. Perspective to the south.  
Source: Ref. [16].

metal/glass/ceramic coating hybrid modules, fiber reinforced concrete panels, wood X-LAM, ceramic and clay, bricks, etc. The color also becomes dominant in the various texture, characterized by homogeneity and glossy and ultra-opaque alternations, integrating energy performance of façade and interior components.

In architecture, for the purpose of reducing energy dispersion, in the sustainable building, parameters are adopted, above all, of compactness and slimness, pointing to the most efficient distribution solutions. Compatibly with different energy responses, linear, central, radial, aggregates, variables in relation to their configuration S/V (exposed surface/envelope/volume) coefficients, depending on the size and the height/width ratio, not determining the degree of efficiency with respect to the energy flows. For exposed envelopes to the south with large surfaces,

the real S/V index, although high, does not affect the volumetric compactness. This changes itself under environmental conditions of isotropy, the absence of solar radiation, orientation and geometries that, if obliquely set, improves the compactness of the building with its relative thermal equilibrium, smaller envelope surface, and interchangeability with the outside.

### 3. Case Study

The Haute Ecôle building in Liège Province, Belgium, is currently being retrofitted (Fig. 9), started in 2015, within the European BRICKER (Energy Reduction in Public Building Stock) project, involving Belgium, Spain and Turkey [17]. The sustainable project aims at energy efficiency and low environmental impact with a 50% reduction in energy consumption through the retrofit of existing buildings



**Fig. 9** Haute Ecôle, Belgium. Retrofitting façade with replacement windows. Block No. 6, patio, perspective. Source: Ref. [18].





**Fig. 10** Haute Ecôle, Belgium. Ceiling insulation with PCM materials, perspective.

Source: Ref. [19].

of public property. The building indicates a high demand for heating of  $180 \text{ kWh}/(\text{m}^2\text{y})$  for a  $23,600 \text{ m}^2$  conditioned area. Thus, retrofit interventions concern hybrid cogeneration with ORC (organic rankine cycle) boiler with biomass of 1.5 MW, which uses thermal oil, the main façade curtain, thermal insulation of PMC material, insulation façade heat, fixtures and decentralized ventilation.

In it are distinguished the efficient passive and active systems technologies that reduce the energy consumption. The former aims, above all, at reducing demand for heating, the latter, instead, using thermal and electrical energy from the biomass source. In particular, for passive systems, the interventions are characterized by thermal insulation (Fig. 10) of  $1,045 \text{ m}^2$  of shells for blocks No. 1 and No. 6. These roofs are the first in the world to handle temperatures, through an innovative thermal insulation system, with PCM technologies based on polyurethane foam integrated with PCM microcapsules. This system was installed by the Department of Technological Innovation at ACCIONA (Agua, Concesiones, Construcciones, Industria y Servicios) Construction. This type of technology contributes to the integration of others through the replacement of  $1,155 \text{ m}^2$  of main

curtain wall in Block No. 1, the isolation of  $2,486 \text{ m}^2$  of façade with the replacement of  $1,293 \text{ m}^2$  of high-performance thermal windows integrated into the system, decentralized ventilation and aimed at reducing energy consumption. For electricity, the reduction is 86%, while for gas, it is 75%. In the classrooms, offices and laboratories, 22 prototypes of decentralized ventilation units are installed. The investment costs of new technologies would account for 20% of the total cost over a 7-year of ROI with PCM insulation.

#### 4. Conclusions

The disamina indicates sustainable architectures that highlight flexibility with technological compatibility and feasibility, such as the identity of its environment related to the context, the environment and the metamorphoses of the places. Therefore, it is essential to promote various interdisciplinary strategies and approaches to reduce the complexity of fragmentation, territorial atrophy and improve planning, community and environmental well-being. To this end, the socio/political/economic and managerial platforms are indispensable, with objectives, methodologies and intervention measures

on various scales. Since many buildings are responsible for high pollution rates in the world, sustainable and environmentally friendly construction and regeneration [20] is needed, with retrofitting and building recovery with the adoption of clean technologies, intelligent components and materials and bio-building, awareness of several causes including planetary carrying capacity. In this respect, technological innovation that represents the esprit in sustainable design, highlights transformational performances, type morphological and distributive, focusing on efficient envelopes, zero environmental impacts that contrast the climate change. So they, often, use the environmentally responsive wall and engineered wall criteria and the natural and intelligent neo materials, such as bioPCM nano technologies, HPP nanopigments, etc. The challenge is to create sustainable architectures, new frontiers for the building's climate control, energy management and the "neu Sachlichkeit" (new objectivity) of a harmonious elegance between functionality and essentiality with the places.

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