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nZEBox
PRODUCT INNOVATION TO REDUCE CARBON FOOTPRINT OF THE CONSTRUCTION SITE

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ABSTRACT
The sustainability issue in construction must take into account all the transformation processes that led to the final product. Although the construction phase is negligible in relation to the overall life cycle, it is responsible for large amounts of CO_2 emissions and has a negative impact on the carbon footprint of the construction industry. The paper illustrates the results of a funded research that has addressed the issue of energy retrofit of logistics services (site cabins), since from studies conducted in the United Kingdom, this appears to be the most relevant measure that can reduce the construction site's CO_2 emissions. The nZEBox system satisfies the need to optimise not only the energy-environmental quality but also the aesthetic and communicative quality of the traditional construction site cabin.

KEYWORDS
construction site, constraction site cabin, energy efficiency, carbon footprint, technological innovation

The nZEBox (nearly Zero Energy Box) system was developed to meet the market's need to improve the energy and environmental performance of logistics, in order to reduce carbon footprint of the construction site. The concept on which this system is based is to transform the traditional site accommodations into 'micro-architectures' (Perriccioli, 2016) which, even if temporary, are able to guarantee maximum comfort with minimum consumption of non-renewable sources and CO_2 emissions, at the same time satisfying all regulatory, design and architectural integration requirements. With the Clean Energy Package, the European Union sets new targets to reduce CO_2 emissions by at least 40% by 2030 relative to 1990. At the global level, strong action by governments, cities and businesses is needed to reduce the carbon footprint: a 'zero emission, efficient and resilient buildings and construction sector' (Global Status Report, 2018). This is a complex challenge, which to be met should involve all actors in the construction chain with a Life Cycle Thinking approach that takes into account all the life phases of the building organism, from cradle to grave.

To really reduce the carbon footprint of the construction industry, it is no longer sufficient to control energy and environmental impacts during the operational phase, but it is also necessary to reduce the embodied energy and carbon (Cannaviello, 2017). Building generates, in fact, impacts on the enviroment during the whole process, related both to the phases of raw material supply, production and transport (Hong et alii, 2014) and to the phases of demolition, decommissioning and final disposal. Some studies has shown, through a building LCA assessment, that the construction phase represents 3 to 9% of the total impacts (Delem et alii, 2013). According to the estimates of the UK Green Building Council, the CO_2 emissions generated during the construction phase can reach up to 10% of those generated during the entire life cycle. Carbon Action 2050 White Paper, Building in construction (Chartered Institute of Building, 2011) highlights the need for radical measures to reduce the large amounts of carbon emissions associated with construction processes.

Within the building process, the new challenge becomes to reduce the site's carbon footprint. This is also because the construction site has remained largely on the margins of innovation processes, perhaps because it is considered temporary and therefore negligible, while it plays a crucial role within the overall process and should be based on the same sustainability targets. The need to reduce CO_2 emissions on the construction site should be widened to all actors and processes involved (Fass and Elfsberg, 2017). In the United Kingdom, the Action Plan Carbon Reducing the Footprint of the Construction Industry (Carbon Trust & Strategic Forum for Construction, 2010) identified the energy efficiency of temporary prefabricated structures for the construction site (logistics) as the strategy that can have the strongest impact on CO_2 emissions due to the construction phase, as it has the greatest potential for reduction, precisely because of the very poor quality of these structures. «Referring to the idea of 'impermanence' in architecture has always meant to comply with a perspective that directly connects temporary constructions with housing emergency and provisional usage. The common perception of such buildings has always been associated with transitory, low-cost/low-building quality features and, often, with a sense of generality and unsuitability, both for the purpose they are realized for and for the environmental context they are put in» (Perriccioli, 2018, p. 5). This concept of temporary structures can also be extended to those for the construction site.

In this scenario, the paper illustrates the results of a research[1] that has focused on the issue of energy requalification of existing construction site cabins, which is an interesting niche market, in the global process of decarbonisation of the construction sector. The initial energy audit has shown that the cabins traditionally used on construction sites are not energy efficient, especially when compared with current legislative standards, and are, for most of the year and especially in summer, unable to ensure adequate conditions of thermohygrometric comfort for workers. The use of a high-performance portable cabins can lead to a reduction in CO_2 emissions of at least 50% compared to the entire construction process (Chartered Institute of Building, 2011) and in this direction the nZEBox system, consists of a set of components, to be applied to the traditional basic structure of the cabin, which are interchangeable according to specific needs (climatic conditions, surrounding context, type of building site) to optimize the performance of new or existing cabins. The research proposes a product innovation, relating both to the nZEBox system as a whole, and to the specific technological components, but also proposes a process innovation, relating to the control and optimization of the construction phase of the work.

Research methodology – In the more general context of sustainability of the construction site, the specific theme of the requalification of logistics services was examined, in order to identify technological design strategies capable of optimising not only the energetic-environmental quality but also the aesthetic and communicative quality of the traditional construction site cabin. The methodology sequence on which the research is based is as follows: Phase 1) Technological and energy analysis of the traditional cabin and identification of critical points; Phase 2) New concept for a high energy efficient construction site cabin: the nZEBox system; Phase 3) Setting objectives: requirements and performance to be achieved by the nZEBox system; Phase 4) Component stratigraphy design and energy performance assessment.

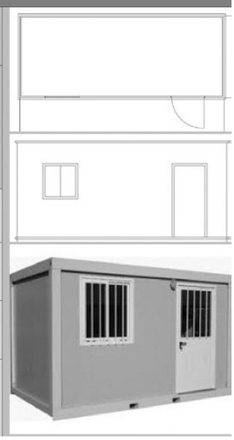
Technological and energy analysis of the traditional cabin and identification of critical points – Portable cabins have been widely used on the international market since many years, mainly in constrction industry as on site offices, with technical characteristics that have been nearly unchanged over time. Table 1 analyses the technical elements of the construction site portable cabin, which has variable dimensions[2] (especially in terms of length). To verify the energy quality of the traditional portable cabin, used as a construction site office, an assessment was made of the performance of the individual components, calculated with the software PAN 7.0, and a comparison with the reference values set by the Ministerial Decree 26/06/2015 (Tab. 2).

The most evident critical point is that portable cabins are generally the same in any context, with component characteristics that do not take into account the different climatic conditions, in contrast not only with the current legislative framework (which provides for different minimum requirements in relation to different climate zones), but also with the most basic principles of bioclimatic architecture. The comparison results between the performance of the cabin and the reference values set by the Ministerial Decree of 26/06/2015 show that the thermal insulation is inadequate, both for opaque and transparent components. The limit set for thermal transmittance is widely exceeded in any climatic zone where the cabin is located (in zone F the actual value is 250% higher than the reference value); the thermal inertia of the opaque components is very low and represents the most critical aspect in the summer season, both in terms of energy consumption and, above all, in terms of thermal comfort. As these are lightweight components, the requirement for surface mass cannot be met. However, the requirements regarding Periodic Thermal Transmittance, Decrement Factor and Time Lag are also not met; as regards the solar gain control in the summer season the critical issues concern above all the transparent components due to the absence of external shielding systems, but also the opaque components.

In order to verify the temperature trend (outside air temperature, external surface temperature and attenuated temperature), it has been assumed to place the cabin in a specific location (Naples, climatic zone C), using the climate data[3] of the place itself for the calculation (in particular the hourly values of temperature and irradiance). As shown in Table 3, the most critical aspect of the vertical wall and also of the roof is the low thermal inertia. The curve of the external surface temperature and that of the attenuated temperature practically overlap (as the time lag of the thermal wave is less than 1 hour), this means that the heat flow is immediately transmitted to the inside surface without any attenuation. As a result, the maximum summer indoor surface temperature is very high (see Tab. 3), with negative impacts on energy consumptions. The control of indoor thermal comfort conditions is almost entirely ensured by air conditioning systems, with high consumption of non-renewable primary energy throughout the year and production of large quantities of CO_2 emissions. Therefore, the influence of logistics services on the carbon footprint of the construction phase can no longer be overlooked, especially in the case of large and long-lasting construction sites.

New concept for a high energy efficient construction site cabin: the nZEBox system – The market for portable cabins for the construction site involves numerous companies at national and international level, which belong to different segments, from the production, assembly, marketing and rental. Few large companies can cover all market segments, but most only assemble the components. In recent years,

Classes of Technological Units	Technological Units	Classes of Technical Elements	Construction site cabin
Load bearing structure	Elevation structure	Vertical elevation structures	Uprights, consisting of welded and cold pressurized steel profiles, screwed to the roof and floor frame.
		Horizzontal elevation structures	Floor frame, consisting of welded and cold pressurized steel profiles and 4 welded corners. Floor cross members on the long side, floor cross members on the short side, load-bearing floor cross members (Ω profiles). Roof frame, consisting of welded and cold pressurized steel profiles and 4 welded corners. Roof cross members on the long side, Roof cross members on the short side. Folded galvanised sheet metal cover.
Envelope	Vertical Envelope	Vertical exterior walls	Constituted from panels with expanded polyurethane (density D=38-40 Kg/mc) between two galvanized and prepainted flat sheets. Thickness 40mm.
		Vertical exterior Windows	Double leaf window, extruded aluminium profiles complete with single glass (4 mm).
	Lower horizontal envelope	Ground floor	Steel profile frame, suitable for wall and floor support. Water-repellent chipboard panels with a thickness of approx. 19-20 mm are fixed to the frame, above which a vinyl sheet is glued.
	Overhead envelope	Roof	Constituted from panels with expanded polyurethane (density D=38-40 Kg/mc) between two galvanized and prepainted flat sheets, thickness 40 - 50 mm. The shaped perimeter profile is made of 1.5 mm thick galvanized steel, which also acts as an eaves channel.



Tab. 1 - Technological analysis of traditional site cabin components according to uni 8290.

Tabb. 2, 3 - Next page. *Energy analysis of traditional site cabin components and comparison with legislative reference values; Summer checks on the traditional site cabin.*

ENERGY PERFORMANCE ASSESSMENT OF CONSTRUCTION SITE CABINS				
Components	**Performance indicator**	**Unit of measure**	**Performance of site cabins**	**Reference limit D.M. 26/06/15**
Roof	Thermal transmittance (U)	W/m^2K	0,7	0,35 (Climate zone A –B)
				0,33 (Climate zone C)
				0,26 (Climate zone D)
				0,22 (Climate zone E)
				0,20 (Climate zone F)
	Periodic thermal transmittance (Y_{ie})	W/m^2K	0,56	0,18
	Decrement factor (f_a)	-	0,95	-
	Time lag (φ)	h	0h, 19m	-
External wall	Thermal transmittance (U)	W/m^2K	0,7	0,40 (Climate zone A –B)
				0,36 (Climate zone C)
				0,32 (Climate zone D)
				0,28 (Climate zone E)
				0,26 (Climate zone F)
	Periodic thermal transmittance (Y_{ie})	W/m^2K	0,69	0,10
	Decrement factor (f_a)	-	0,979	-
	Time lag (φ)	h	0h, 40m	-
Floor	Thermal transmittance (U)	W/m^2K	0,42	0,42 (Climate zone A –B)
				0,38 (Climate zone C)
				0,32 (Climate zone D)
				0,28 (Climate zone E)
				0,26 (Climate zone F)
	Periodic thermal transmittance (Y_{ie})	W/m^2K	0,18	-
Windows	Thermal transmittance (U)	W/m^2K	5,71	3 (Climate zone A –B)
				2 (Climate zone C)
				1,8 (Climate zone D)
				1,4 (Climate zone E)
				1 (Climate zone F)
	Solar Heat Gain Coefficient (with shading) g_{gl+sh}	%	0,8	0,35

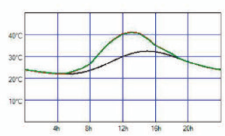
ENERGY PERFORMANCE OF OPAQUE ELEMENTS IN SUMMER:

- **effect of time lag and decrement factor**
- **trends of external and internal surface temperature**

Outdoor air temperature
External surface temperature
Internal surface temperature

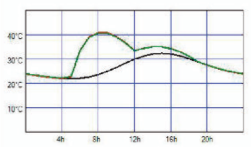
Construction site cabin location: Climate Zone C – Naples

SOUTH FACADE



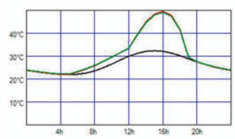
T_{max}= 40.89°C 1.00 p.m.

EAST FACADE



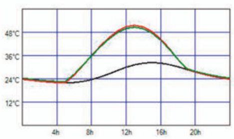
T_{max}= 40.72° C 9.00 a.m.

WEST FACADE



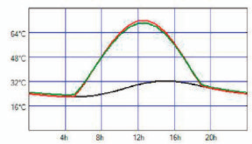
T_{max}= 49.19°C 4.00 p.m

Roof – Light colour



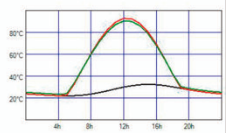
T_{max}= 50.63°C 1.00 p.m.

Roof - Medium colour



T_{max}= 70.27° C 1.00 p.m.

Roof - Dark colour



T_{max}= 90.73°C 1.00 p.m.

some producers, more responsive to energy and environmental aspects, have introduced production lines with more insulated components. However, no measures have been introduced to improve thermal inertia and solar control, or to provide for integration of renewable sources.

The concept behind the nZEBox system completely transforms the essence and image of a construction site cabin: from the traditional concept of the container, unchangeable over time, and always the same under any circumstances and anywhere in the world, to a new model of 'layered container', with the possibility to change the layout, case by case, in order to optimize performances and achieve the goal of nearly zero energy site accommodation (Cannaviello, 2017). The system provides for a load-bearing structure in metal carpentry, a sort of exoskeleton, to be adapted to the existing monoblock, with a series of prefabricated and modular components for the vertical perimeter walls and for the roof, adaptable to the needs (microclimatic context, site characteristics, etc.). The overall stratigraphy will thus be constituted by a support layer, consisting of the pre-existing cabin; by a thermal control layer (which represents the basic component), and by an exterior cladding layer. The components' aggregation logic is the same for both vertical walls and roofing.

The requirements for the thermal control layer, i.e. insulation and thermal inertia, must be guaranteed at all times, regardless of the others. For this reason, the 'basic component' foresees a stratigraphy capable of guaranteeing the expected performance (in terms of thermal transmittance, periodic thermal transmittance, decrement factor, time lag), which must be verified in relation to the specific climatic zone, without taking into account the finishing layer, which can therefore also improve overall performance. The external surface cladding is particularly significant, both in terms of comfort performance requirements and energy performance requirements, and in terms appearance requirements. It is believed, in fact, that the external surface of the monoblock, assumes a strategic role, not only from the energy point of view, meaning in terms of solar control and renewable energy production, but also in relation to the 'communicative' function that the cabin can assume with respect to the context, so as to become the distinctive element to highlight the commitment to sustainability of the company. The integration of renewable sources is a very important aspect, since both the external vertical wall and the roof of the cabin, as well as helping to reduce energy losses, can become energy producers, to meet the energy needs of the site cabins.

The external cladding layer can perform different functions depending on the specific requirements: solar control; energy production (integration of renewable sources); communicative function (advertising image for the company, visual integration with the context). The wall of the construction site cabin is therefore transformed from a 'simple wall', in which the technical element consists of a main layer that performs almost all functions, to a 'complex wall', that is, formed by the union of several technical elements that are assembled to perform multiple functions. The same can be said for the roof. For the external cladding, different solutions can be envisaged, applicable to one or more

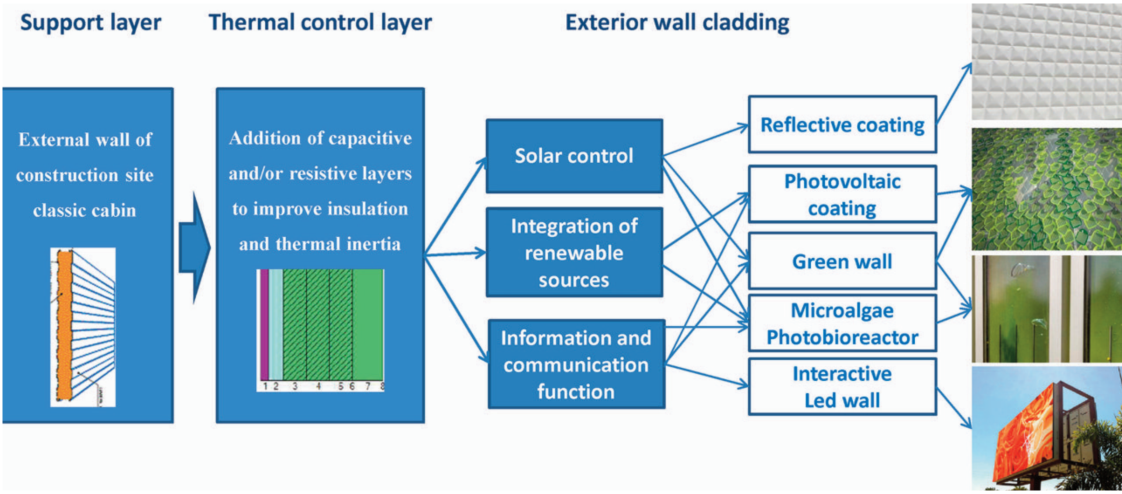


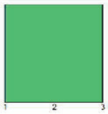
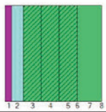
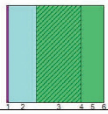
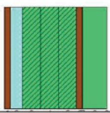
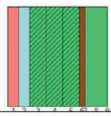
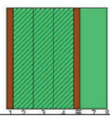
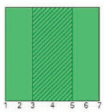
Fig. 1 - Diagram of the functioning of the external vertical wall of the construction site cabin.

ENERGY PERFORMANCE EXPECTED FROM nZEBox SYSTEM COMPONENTS				
Components	**Requirements**	**Energy Performance Indicators**	**Unit of measure**	**Expected performance**
Roof	Thermal insulation	Thermal transmittance (U)	W/m^2K	< 0,32 (Climate zone A - B -C < 0,26 (Climate zone D) < 0,2 (Climate zone E – F)
	Thermal inertia	Periodic thermal transmittance	W/m^2K	< 0,18 (*) < 0,3 (**)
		Decrement factor (f_a)	-	< 0,4 (*) < 0,6 (**)
		Time lag (φ)	h	> 8 (*) > 6 (**)
	Solar control	Reflectance	-	> 0.65 (Flat roof) > 0.3 (Sloping roofs)
External wall	Thermal insulation	Thermal transmittance (U)	W/m^2K	< 0,4 (Climate zone A-B) < 0,3 (Climate zone C – D) < 0,24 (Climate zone E – F)
	Thermal inertia	Periodic thermal transmittance (Y_{ie})	W/m^2K	< 0,1 (*) < 0,2 (**)
		Decrement factor (f_a)	-	<0,4 (*) <0,6 (**)
		Time lag (φ)	h	> 8 (*) > 6 (**)
Floor	Thermal insulation	Thermal transmittance (U)	W/m^2K	< 0,42 (Climate zone A-B) < 0,26 (Climate zone C – D) < 0,24 (Climate zone E – F)
Windows	Thermal insulation	Thermal transmittance (U)	W/m^2K	< 3 (Climate zone A-B-C) < 1,4 (Climate zone D-E) < 1,1 (Climate zone F)
	Solar control	Solar Heat Gain Coefficient (with shading) g_{gl+sh}	%	< 0,35

*Tab. 4 - Energy performance expected from the opaque and transparent components of the nZEBox system. * Where the average monthly value of horizontal irradiance in the month of maximum insolation is ≥ 290 W/m^2. ** Where the average monthly value of horizontal irradiance in the month of maximum insolation is < 290 W/m^2.*

fronts of the cabin: reflective wall (reflective ceramic materials); photovoltaic wall (integrated photovoltaic, Solar Ivy[4] type); green wall (with microalgae photobioreactors); Dynamic screen wall (videowall or Led screen type).

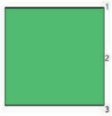
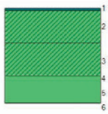
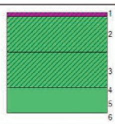
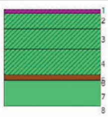
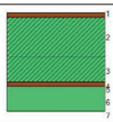
Figure 1 shows the block diagram with the layers of the vertical external wall of the site cabin and the functions and requirements for each layer. For transparent components, in addition to meeting the requirement for thermal insulation, it is necessary to ensure solar control, through the use of shielding systems or selective glass. The components of the Nzebox system are designed to be recovered for future and different reuse, with the aim of minimizing both assembly and disassembly times.

ENERGY PERFORMANCE OF EXTERNAL VERTICAL WALLS FOR DIFFERENT TECHNOLOGICAL SOLUTIONS							
Type of wall	Wall stratigraphy	Overall thickness	Superficial mass	Thermal transmittance	Periodic thermal transmittance	Time lag	Decremen factor
		cm	Kg/m^2	W/m^{2}K	W/m^{2}K	h	-
Classic construction site cabin		4	7.84	0.70	0.69	0h, 14m	0.979
Type 1		16,1	57.80	0.30	0.13	7h, 20m	0.42
Type 2		17,4	12.30	0.23	0.23	1h, 16m	0.99
Type 3		17,1	49,3	0.29	0.09	8h, 26m	0.31
Type 4		18,1	82.80	0.30	0.08	9h, 43 m	0.26
Type 5		15,1	53.3	0.30	0.09	8h, 8m	0.30
Type 6		14,2	42,1	0.29	0.08	7h, 4m	0.29

Tab. 5 - Energy performance of external vertical walls of the different proposed solutions.

Setting objectives: requirements and performance to be achieved by the nZEBox system – The nZEBox system's goal is to conform the site cabin to the law requirements (Ministerial Decree 26/06/2015), in relation to the specific climatic zone, so as to ensure suitable conditions of comfort throughout the year, with minimum consumption of non-renewable resources. Since the logic on which nZEBox system is based is to make the various technological elements of the system interchangeable, through the creation of countless configurations, the performance check must start from the assessment of the individual components. Each of them must meet the minimum requirements set out in Table 4. Three different levels of thermal insulation have been designed in relation to the climatic zone in which the construction site will be located (climatic zone A, B and C, climatic zone D, climatic zone E and F).

As for Periodic Thermal Transmittance, different limits have been set depending on the average monthly value of the horizontal irradiance in the month of maximum insolation of the location where the construction site will be located. Minimum values have also been set for the decrement factor and time lag of the thermal wave of walls and roof. These values, which do not currently represent a mandatory legislative require-

ENERGY PERFORMANCE OF ROOFS FOR DIFFERENT TECHNOLOGICAL SOLUTIONS							
Type of roof	Roof stratigraphy	Overall thickness	Superficial mass	Thermal transmittance	Periodic thermal transmittance	Time lag	Decrement factor
		cm	Kg/m^2	W/m^{2}K	W/m^{2}K	h	-
Classic construction site cabin		4	7.84	0.70	0.69	0h, 14m	0.979
Type 1		17,5	57.80	0.23	0.05	7h, 40m	0.22
Type 2		19,9	45.9	0.20	0.04	8h, 5m	0.21
Type 3		17,1	49,3	0.29	0.09	8h, 26m	0.31
Type 4		18,1	82.80	0.30	0.08	9h, 43 m	0.26

Tab. 6 - Energy performance of the roof for the different proposed solutions.

ment, derive from the 'Qualitative assessment of the characteristics of the building envelope designed to limit the need for summer air conditioning'[5], and are differentiated according to the average monthly value of irradiance.

Component stratigraphy design and energy performance assessment – Six different types of stratigraphies of the basic component have been studied to be added to the vertical wall (Tab. 5) of the traditional cabin and four for the roof (Tab. 6), to improve its energy performance, not only in terms of insulation, but especially in dynamic summer conditions. It is believed, in fact, that in Mediterranean countries the control of thermal and solar inputs in the summer season is the most important aspect to consider (Cannaviello, 2010). «The external wall will ensure a higher dynamic thermal insulation, i.e. the internal conditions of the room will be less bound to the external ones, as smaller is the dynamic thermal transmittance Y_{ie} (i.e. the decrement factor does) and as greater is the time lag f [1-2,3]. It is therefore very interesting to find, for a given wall, the optimal stratigraphy that minimizes Y_{ie} and maximizes f» (Galbusera et alii, 2010, p. 89).

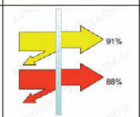
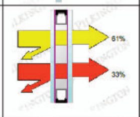
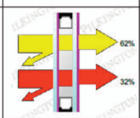
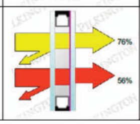
In order for the thermal control layer to guarantee the energy performance set out in the table in terms of thermal insulation and thermal inertia, the basic component must alternate resistance layers and capacitance layers[6]. The simulations carried out showed that the exclusive addition of resistance layers (8 cm of EPS with graphite), even if combined with a weakly ventilated air chamber of 5 cm (Type 2 solution), only meets the requirement for thermal transmittance in all climatic zone, but is not sufficient to improve the inertial behavior of the cabin (time lag 1h and 16m). For the layer with high thermal capacity, the use of wood wool panels mineralized with graphite has been tested. It is a natural mineral insulation characterized by very low thermal diffusivity (having a specific heat of 2090 J/kgK). These panels, in addition to ensuring excellent performance in the summer dynamic regime, are an environmentally friendly product as they are made with completely natural raw materials. They are also interesting in relation to the embodied carbon, as they derive from the use of only three materials, water, wood and magnesite, without chemical components, therefore they do not release any type of gas or harmful substance, and also the residues of production are biodegradable. For the resistive layer, the use of expanded polystyrene panels with graphite additive was investigated[7]. Inside these panels the EPS (Sintered Expanded Polystyrene) polymer is combined with a natural resource: graphite. This solution guarantees high thermal performance, even at low thicknesses, thanks to the graphite particles contained inside the insulating sheet. It guarantees dimensional stability, perfect flatness and safe gluing, even during maximum solar radiation.

In some of the proposed solutions additional layers have been included to improve dynamic performance and component stability. The different solutions have been designed to meet the requirements set out in Table 4, both in terms of thermal transmittance and thermal inertia, in relation to the specific location (climate zone and irradiance). They are therefore not always applicable, but depend on the location of the construction site.

For each technological solution, summer checks were also carried out to evaluate the inertial behaviour and the internal surface temperature. It is precisely in summer, in fact, that the cabin shows the greatest criticality, especially in the mediterranean countries.

In terms of energy, the window of the traditional cabin is one of the most critical elements of the envelope. It is inadequate both in terms of thermal insulation (Uw = 5.71 W/m^{2}K) and in terms of solar control (g_{gl+sh} = 0.8). The choice of technological solutions (Tab. 7) has been aimed at improving the energy performance of the windows in both aspects. For the glass, the calculation was carried out using the Pilkington Spectrum software, which verified the solutions proposed with respect to to solar control and light transmission. The energy performance of the window (glass + frame) was verified using the Termus software for calculating global thermal transmittance (U_{f+gl}). First two solutions aim to ensure solar control even without the shielding system, meeting the regulatory requirement only through the glass characteristics ($g < 0.35$). The Type 3 solution, on the other hand, has been designed for cases where solar control is not required for the glass, or because of the presence of shielding systems, or in the presence of shadows, or where the openings are located on the north front.

Conclusions – The technological and energy analysis of the traditional cabin has allowed to highlight the main criticalities and to develop specific strategies aimed at optimizing the energy performanceThe specific choices, however, must come from a careful

ENERGY PERFORMANCE OF WINDOW SYSTEM					
Window type		Thermal transmittance of glass	Total thermal transmittance (g+f)	Solar Heat Gain Coefficient	Light Trasmission
		W/m^{2}K	W/m^{2}K	%	%
Classic construction site cabin		5.8	5.71	88	91
Type 1		1.2	1.7	33	61
Type 2		0.9	1,2	32	62
Type 3		1.2	0.09	76	56

Tab. 7 - Energy performance of the window system for the different proposed solutions.

analysis of the climatic and microclimatic conditions and of the context: the construction site cabin must be transformed into micro-architecture contextualized and eco-efficient. Technological solutions therefore need to be assessed, in the context of the specific objectives, on a case-by-case basis. The site cabin, which over the years has remained one of the most obsolete elements of the construction process, can instead become chameleonic, transforming itself into a space for technical and formal experimentation to develop sustainable, resilient and high-tech solutions, also applicable in different contexts.

Placing such a product on the market can generate benefits for the company that uses it, not only in terms of reducing the consumption of non-renewable primary energy, but also in terms of image and greater comfort for workers. And, more generally, the benefits can concern the entire community, thanks to the reduction of the costruction site carbon footprint. The main limits are unfortunately related to the additional costs compared to the traditional site cabin. Only by understanding the added value of such a system could construction companies be prepared to invest in technological innovation and the environmental sustainability of the construction site. The concept behind the nZEBox system, designed to meet the construction site's sustainability requirements, could involve a wider market relating to all activities requiring temporary prefabricated structures for office use, emergency structures, refugee camps and event structures.

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NOTES

1) Research scholarship for Open Innovation processes within the priority technological ambits of RIS 3, financed by the Region of Campania for the period 2017-2018.
2) The module most commonly used as a temporary office on construction sites has external dimensions, length of 6 m ± 2 cm and width of 2.40 m x ± 2 cm. The minimum internal height is 2.30 m, but versions with an internal height of 2.40 m and 2.70 m are available. The monoblocks can be combined in different configurations, even on several levels.
3) UNI 10349-1:2016 – Heating and cooling of buildings – Climate data – Part 1: Monthly averages for the assessment of the thermal energy performance of buildings and methods for allocating solar irradiance to the direct and diffuse fraction and for calculating solar irradiance on an inclined surface.
4) Solar Ivy is a prototype of a photovoltaic panel, created by SMIT (Sustainably Minded Interactive Technology) and inspired by the climbing plant. It is, in fact, a series of photovoltaic cells printed with conductive ink to resemble leaves, which are anchored on a steel mesh.

5) Contained in point 6 of the Italian National Guidelines for Energy Certification (Ministerial Decree 26/06/2009).
6) i.e. layers with a low thermal diffusivity (m2/Ms).
7) The technical characteristics of the material are related to a product of the company Isolkappa Srl, partner of the research project.

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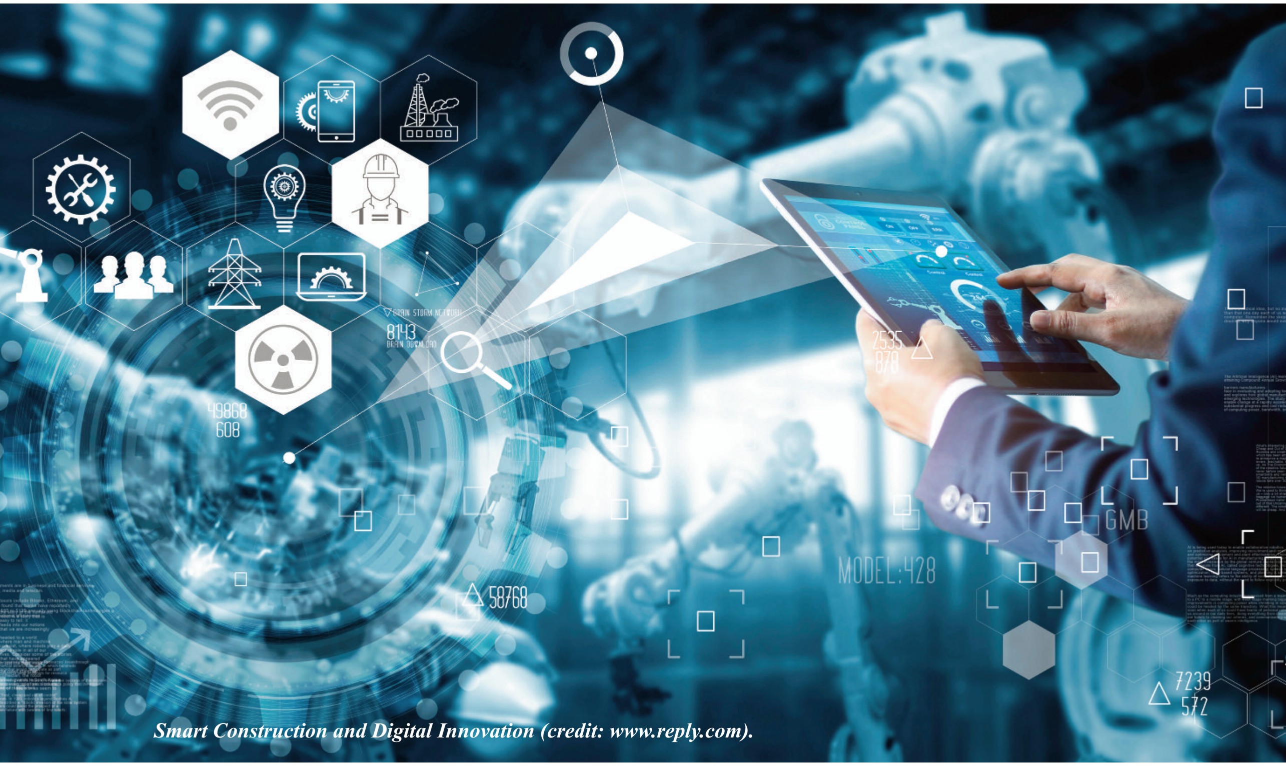

Smart Construction and Digital Innovation (credit: www.reply.com).