Journal of Civil Engineering and Architecture 15 (2021) 217-228
doi: 10.17265/1934-7359/2021.04.007

New Building Typologies for Zero Energy Mass Custom Housing (ZEMCH) in More Sustainable Patterns of Development

Filiberto Lembo, Francesco Paolo R. Marino and Antonio Canosa
School of Engineering, University of Basilicata, Potenza 85100, Italy

Abstract: Conferences and publications on *Smart Cities* and self-styled ecological buildings such as "*Vertical Forests*", "*Biophilic*" building complexes and other similar are multiplying. But then, in reality, we continue to design as we have always done for the last ninety years: with the consolidated rules and formal solutions of international post-modern composition, in its various forms. The only attentions are (and not always) to super-insulate the envelopes, arrange photovoltaic panels on the roofs, make the systems *smart* and cover the facades and roofs with appropriate *green washing*. Even in the awareness that human settlements and cities are extremely complex phenomena, mostly determined by economic and social factors, rather than by conscious typological-settlement choices, perhaps the time has come to acknowledge that the traditional paradigms of design must be changed. First of all, the types of settlements must be renewed, because it is through their optimization that the greatest savings in terms of energy and sustainability can be achieved. The research presented here is the application of a ten-year study that involved the development of *net Zero Energy Mass Custom Housing (ZEMCH)* in specific context in southern Italy. The Innovation and Transparency of Tenders Environmental Compatibility (ITACA) Assessment Protocol, derived from the Green Building Challenge's GB*Tool*, was used as a design guide, which is normally used for the assessment and judgment of sustainability at the building scale and not of the urban design. The result is a settlement model in which network of pedestrian, cycle and public transport is fully integrated with adjacent urban areas; effective landscaping connects public and private green and kitchen-gardens/orchards everywhere; buildings are made with new semi-underground typologies; *net ZEMCHs* are made with local, recyclable materials with low impact or positive energy balance; wastewater and rainwater are collected, *in-loco* phyto-purified and reused; renewable energies (sun, earth, wind) satisfy remaining necessities, with a minimum of plant interventions.

Key words: Sustainable city planning, building typologies, semi-underground typologies, passive solar design, net zero energy buildings, ZEMCH.

1. Some Considerations on the State-of-the-Art of the Sustainable City Planning and the Research Objectives

Gianfranco Amendola wrote that "*the objectives of the Green New Deal (the European response to the emergency of Climate Change) ask us, among other things, to introduce new rules to enhance the spread of renewable energies…to promote biodiversity and the circular economy*" [1]. The new Italian minister for ecological transition Roberto Cingolani, in his first public speech after his appointment, declared that "*cities are a strategic laboratory for sustainable growth*" [2]. We now operate within the framework of international standards on *sustainable development in communities* (ISO 37101:2016), with precise *Indicators for city services and quality of life* (ISO 37120:2018), *Indicators for smart sustainable cities* (ISO 37122:2019), *Indicators for resilient cities* (ISO 37123:2019) and conferences and publications on *Smart Cities* are multiplying. We mainly work on the optimization of existing cities.

But, as for the plans for what is being built anew, it is necessary to note that the "*invention of the wheel*" contained in the building of Ove Arup Associates in

Corresponding author: Francesco Paolo R. Marino, M.Sc. Eng., assistant professor, research fields: architectural technology, building systems, construction techniques.

Fig. 1 Low energy building in Wittenberger Straße (Berlin, 1998), Arup GmbH & Assmann Salomon und Scheidt architect.

Wittenberger Straße in Berlin, published in 1998 [3] (Fig. 1) has been completely lost, and we continue to use the sled, like the American Indians when the settlers arrived in the Far West, with their carts with steering wheels. The "*Vertical Forests*" are all the rages (Fig. 2) which actually, apart from the size of the balconies, have plans not unlike those of the *mass housing* of the 60's and 70's of the last century, with apartments facing everyone the fronts, even to the north, where certainly "*free solar gains*" are not available.

Thus the "*biophilic*" complexes (Kengo Kuma in Milan) or the new Amazon Headquarters in Arlington (Fig. 3), are helical, and therefore with 360° facades, and more like that. Even "*eco-districts*" as Bjørvika Barcode in Oslo (2003-2016) (Fig. 4) when examined from the passive bioclimatic design point of view, which should be a basic requirement of a sustainable design, do not exhibit any of the characteristics they should have. The buildings are arranged in the North-South direction, in Oslo, as if they need to cool rather than heat; they shade each other; they do not use free natural supplies for heating or cooling. In addition, going back in time, if we analyse in the same way the buildings of the famous Vauban district of

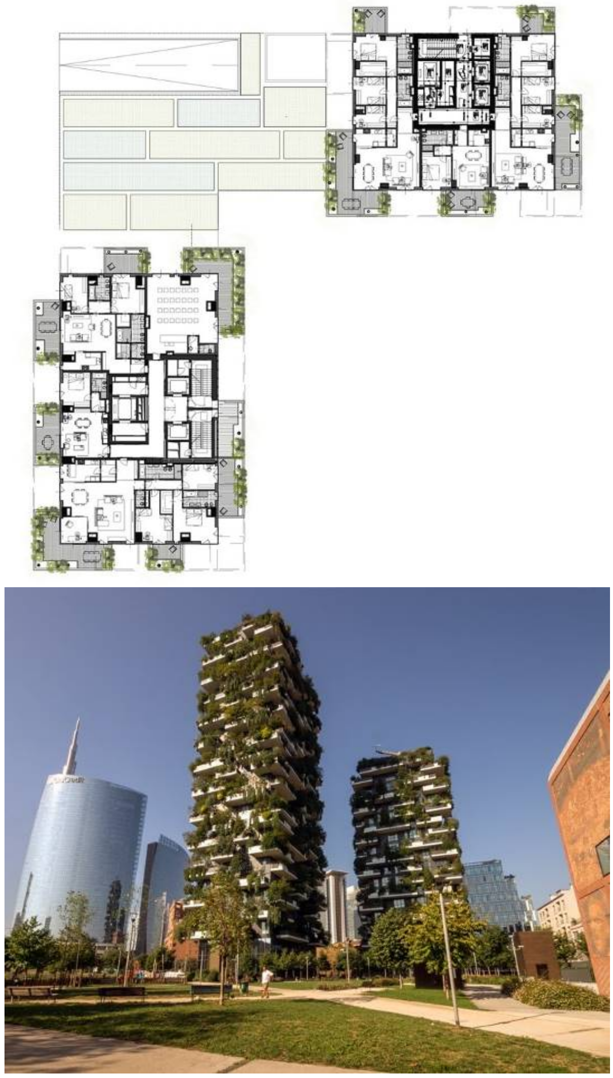


Fig. 2 Vertical forest (Milan, 2014), Stefano Boeri architects.

Fig. 3 The helix at Amazon's new HQ 2 (Arlington, Virginia USA), NBBJ—project photo render.

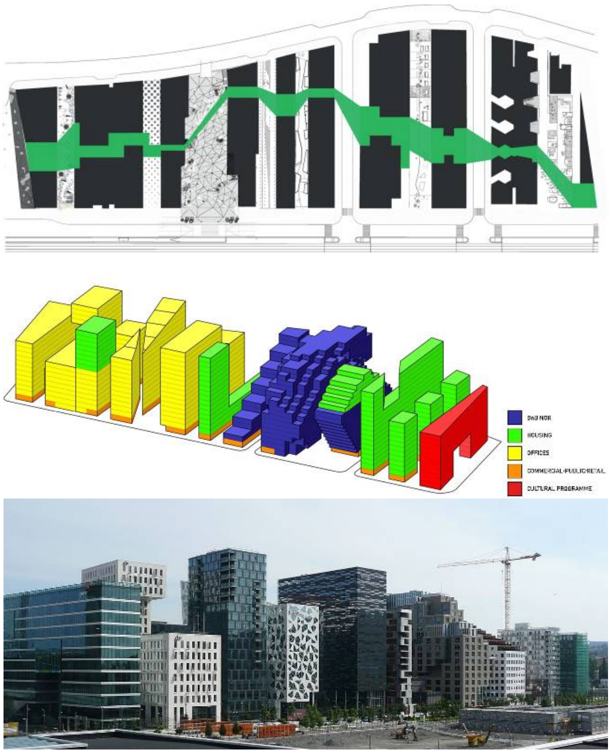


Fig. 4 Bjørvika Barcode (Oslo, 2016), MVRDV.

Fig. 5 Masdar city (Abu Dhabi, UAE), Foster + Partners—project photo render.

Fig. 6 Neom (Saudi Arabia), Foster + Partners—project photo render.

Friborg (1998-2003) [4], we find that they too have traditional typologies, with views on all sides and with all orientations. Except that they have photovoltaic panels on the roofs, they are super-insulated and with *smart* systems and heat recovery systems (*Passive Houses*). Just as the new cities that are designed by Foster + Partners (Masdar City, see Fig. 5 and Neom, see Fig. 6). It seems that to make a city *sustainable* it is enough to power it from photovoltaic panels on the roofs or solar power plants. For the rest, it continues to make them in the manner of the historical models that you prefer. Perhaps the time has come to acknowledge that the traditional design paradigms must be changed, and the first of all the types of settlement must be renewed, because it is through their optimization that the greatest savings in terms of energy [5] and sustainability can be achieved.

The decades-long research carried out, exemplified by the application presented here, concerned the development of *Zero Energy Mass Custom Housing (ZEMCH)*, on the basis of what was supported, among others, by the DETR already in 1998, in *Planning for Sustainable Development. Towards Better Practice*: "*New settlements will enjoy a high quality of urban and landscape design. As well as integrated open space, there should be habitat areas, and environmental gains such as energy efficiency measures introduced in layouts and individual buildings…A high quality of urban design not only represent a general objective of planning, but it is a specific requirement for sustainable development. Success of urban regeneration to higher densities, for example, will depend from skill of creating a more appealing environment.*" [6].

From the sustainability assessment point of view, international panorama offers methods both rating based (BREEAM, LEED, GB*Tool*, CASBEE, HQE), and analytical ones (EN ISO 14000 series, in particular 14025 on EPD and 14040 on LCA), which allows to evaluate in an objective manner sustainability of a building both at the design level, and as built. In Italy, the standard adopted is a rating based one, a GB*Tool* of Green Building Challenge version, named ITACA Protocol, which expresses the judgement on the basis of a series of criterions, from the site quality to the materials and constructive choices.

The challenge of the research was to adopt the ITACA Protocol not as an assessment criterion, but as a design method, and to structure up with its guidance the planning of a whole neighbourhood in Potenza, in central-southern Italy, from the town-planning level to the building and to the constructive one, with the target of checking possibility, in this way, of attaining the result of a settlement not only sustainable, but also appealing and delightful. According to Louis Kahn's lesson: "*What is measurable is in the service of what you can't measure*"; and to Kevin Lynch's one: "*It is necessary to learn what is desirable as much as to study what is possible: to act without target can be useless as much the idealism without power. Even the range of possible things can be extended by greater knowledge of what is desirable.*" [7].

2. The Site: Environmental and Town Planning Commitments

The research took place on the same site, already the subject of a similar study, presented at the SBE19 Helsinki Conference [8]. The site is a great area (Fig. 7), covering 128.057 m^2, named *Zone "C2"* in the Urban Regulations of Potenza Borough, at north border of the city, at an altitude between 815 and 880 m asl, with an average slope of 24%, 40°65' N, 15°79' E, and a good exposure to the sun toward south. Scheduled territorial density is of 0.50 m^3/m^2, which allows building 64.028 m^3, primarily dwellings, and also offices and shops. It is scheduled that buildings can have a maximum height of 10.50 m and a minimum distance from the vehicular roads of 7.50 m.

It is planned the realization of neighbourhood services, made up of primary school in an area of 3,170 m^2, common interest services (administrative and cultural) in an area of 2,000 m^2, public equipped green on 23,164 m^2 and public parking on 2,785 m^2. The soil is made of clay and silt grey-blue; it is stable, but it needs of foundation on piles. It is seismic zone I, with high dangerousness (acceleration with probability of exceeding of 10% in 50 years: $a_g \leq 0.25$ g). Potenza has a Mediterranean montane climate: cold and snowy in winter time, tepid in summer time. The coldest month is January, with average temperature of +3.5 °C, the hottest ones July and August, with average temperatures of 20 °C.

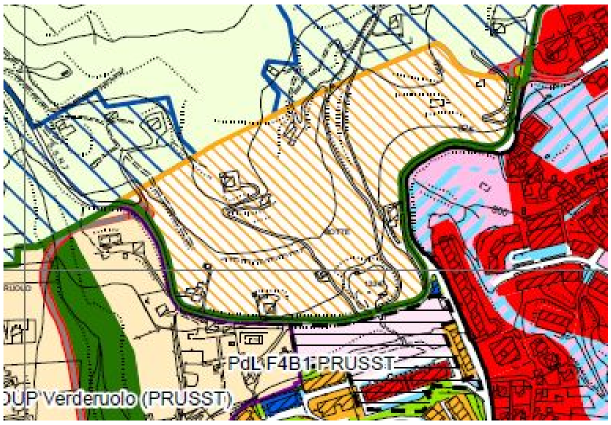


Fig. 7 Extract of the town planning regulations of the municipality of Potenza P-2C.

Average rainy condition of past decade has been of 753 mm/year, raising 100 mm with respect to the previous decade. Important is the relative average annual moistness, equal to 71%: for the most of months (but July and August) it seizes between 60% and 88%. Therefore, it is necessary to forecast systems of mechanical controlled ventilation equipped not only with heat recovery device, but also with dehumidifier. Winds in summer months come from 240° (West-South-West) and in the rest of the year mainly from 220° (South-West), with speed between 2 and 5 m/s. Solar radiation is high, thank to air clearness. It is climatic zone E, with 2,472 degrees-day (heating from October 15 to April 15, 14 hours daily).

Borough Administration has prearranged an Operative Plan [9] as guidance to the development of the area (Fig. 8), which presents all the defects typical

Fig. 8 Operative plan of zone "C2".

of urban contemporary extensions, meaningless and lacking of soul, but also of culture of sustainable planning, of which we wrote in the premise: it lacks an overall conception and the hierarchic organization of the areas; there is nothing about pre-arrangement of a public transport network; the development of the vehicular roads is excessive; green areas, despite great surface on which they stands, are not connected in an unitary logic and are not easy to enjoy; school (brown in Fig. 8) is set in the worse place as slope, exposure to the sun and accessibility; the Plan lacks an adequate mix of activities and an overall working logic; even though the buildings layout follows roughly contour lines, most of buildings are not exposed to South and scheduled building typologies are all "*not-passive-solar*" (little towers with two or four flats every floor, oriented to the four cardinal points).

This is the demonstration of the fact that also a site with good exposure can be badly utilized, and can be the Public Administration to stimulate disorder and fall out of love with the city, promoting the urban *sprawl*. As a matter of fact, it is impossible to understand why citizen must undergo the greater cost of being involved in a "planned" urban extension, if he can get a product similar (or probably worse) than that he would obtain building by himself a house in the country. Of the whole area, only the southernmost part was examined in this research, with an area equal to about a quarter of the total (Fig. 9).

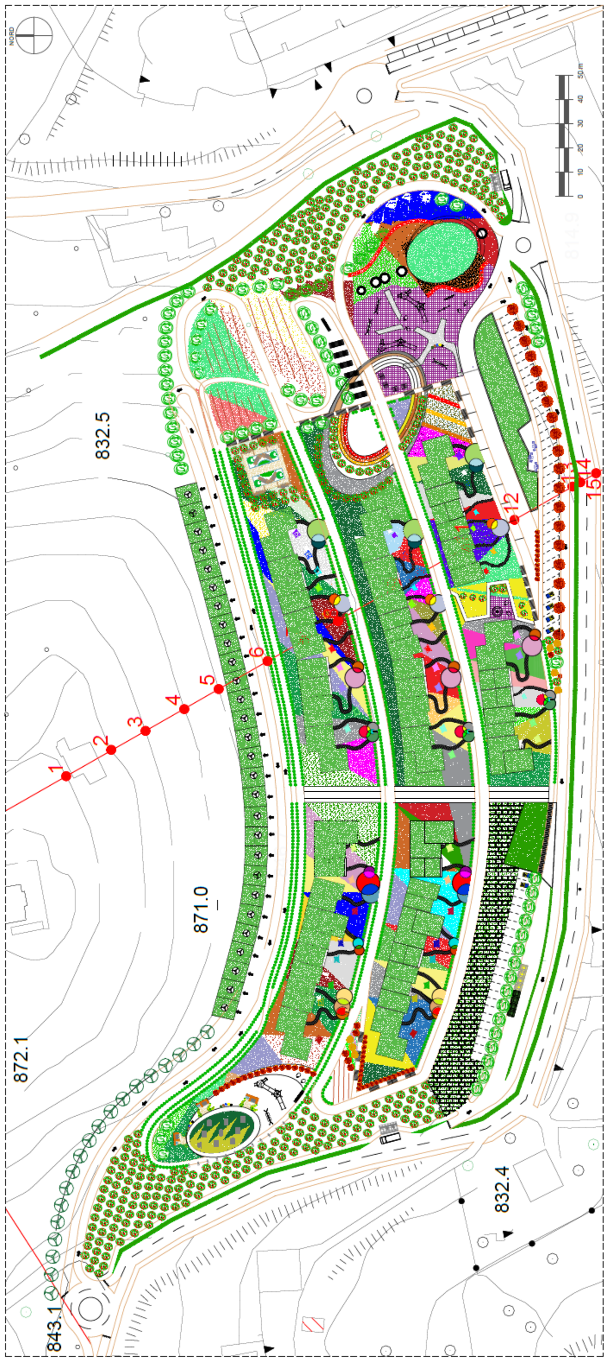


Fig. 9 General plan of the project.

3. The Use in Planning of the Assessment Criterions of ITACA Protocol

ITACA Protocol and its Standard Procedures [10-12] deal with five "areas" or significant macro-themes:

Table 1 ITACA Protocol criteria and related impact levels.

Criterion code	Criterion name **(Area A)**	Impact level P_k
A.1.5	Land re-use	18
A.1.6	Public transport accessibility	12
A.1.8	Functional mix of the area	4
A.1.10	Adjoining to infrastructures	6
A.1.12	Settlement sprawl	6
A.3.3	External equipped common use areas	4
A.3.4	Support to bike use	8
A.3.7	Use of local arboreal species	4
A.3.10	Incidence on the urbanized context	12
Criterion code	Criterion name **(Area B)**	Impact level P_k
B.1.2	Non-renewable primary energy	27
B.1.3	Total primary energy	27
B.3.2	Renewable energy for thermal uses	18
B.3.3	Energy in situ produced for electrical uses	18
B.4.1	Re-use of existing structures	27
B.4.6	Materials recycled / reused	18
B.4.7	Materials from renewable sources	12
B.4.8	Local materials	12
B.4.10	Materials recyclable or dismountable	18
B.4.11	Certified materials	12
B.5.1	Drinkable water for irrigation	18
B.5.2	Drinkable water for indoor uses	18
B.6.1	Thermal energy useful for heating	27
B.6.2	Thermal energy useful for cooling	27
B.6.3	Average global coefficient of thermal exchange	18
B.6.4	Control of solar radiation	18
Criterion code	Criterion name **(Area C)**	Impact level P_k
C.1.2	Expected emissions in exercise	27
C.3.2	Produced solid waste in exercise	12
C.3.3	Reuse of the soils	8
C.4.1	Grey water piped in sewage system	8
C.4.3	Permeability of the soil	8
C.6.8	Heat island effect	12
Criterion code	Criterion name **(Area D)**	Impact level P_k
D.2.5	Ventilation and air quality	9
D.2.6	Radon	9
D.3.1	Summer thermal comfort in air-conditioned rooms	6
D.3.2	Operative temperature in summer	6
D.3.3	Winter thermal comfort in air-conditioned rooms	6
D.4.1	Natural lighting	6
D.5.6	Acoustic quality of the building	6
D.6.1	Electromagnetic fields at industrial frequency (50 Hertz)	6
Criterion code	Criterion name **(Area E)**	Impact level P_k
E.2.1	Services equipment	6
E.3.5	B.A.C.S.	18
E.3.6	Domotic plants	6
E.6.5	Availability of technical documentation of buildings	6
E.7.1	Design for all	6

(A) site quality; (B) resources consumption; (C) environmental loads; (D) indoor environmental quality and (E) service quality (Table 1).

Following methodological order set by ITACA Protocol, in the settlement centre has been arranged a mechanized public route (cable railway with automatic control) which allows to link fast to the existing city, across intermediate and final stations, pedestrian and bike ways, set beside the contour lines.

The automotive traffic is confined to the border of the settlement and is linked to semi-underground parking, strategically settled to the south and north side, connected to the pedestrian and bike ways and covered by public urban vegetable garden and orchards and private ones.

The parking lots are intended for the most part to those residents in the neighbourhood, and hence are equipped with closed stalls, each for two cars, in addition to those open, intended to the visitors. Only one road, however paved with grating and grass, runs through the neighbourhood: it is intended to the security service (ambulance, Fire Brigade) and to the separate refuse collection.

Green fabric, structured on a wide range of local essences, both of first height (*Fagus sylvatica*, *Quercus cerris*), and medium/small ones, with permanent leaf or deciduous and flowering, makes a pervasive belt at the western and eastern edges and spreads on branches in horizontal matter, with a playground at the base and a stronger presence at the bottom, where is also a little artificial lake, connecting to the gardens and private vegetable gardens, set in front and upon the houses, becoming a zone for free physical activity and "*life course*" for fitness in the zone with the outmost slope, on the roof of parking. In the central bottom part are set out offices, shops and common interest services, you must cross for connecting with the existing city.

Building typologies (Figs. 10-14) forecast many sizes of dwellings, from 35 m^2 to 103 m^2, and are designed on the basis of established criterions of solar passive architecture, so that they warm themselves "at direct gain", and they get cold themselves with radiative passive cooling from the ground.

Some dwellings have only ground floor, partially under-ground, set following the slope of the hill, so that the roof of a dwelling is the garden itself. Some others are of the duplex type, in which on the roofs are set out thermal solar panels (producing hot water for sanitary purposes and supplement to heat pump heating) and PV panels. The interfaces with the ground and the retaining walls are in reinforced concrete (Figs. 15 and 16).

Buildings have been designed with structures pillar-beam in local glued laminated timber made of

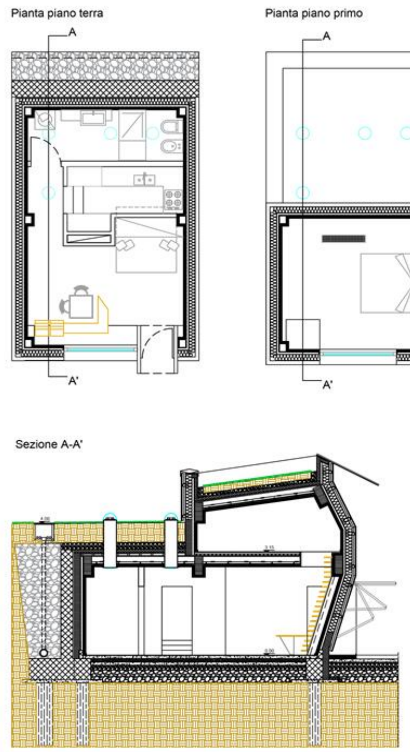


Fig. 10 Plans and vertical cross section of the dwellings of 35 m^2.

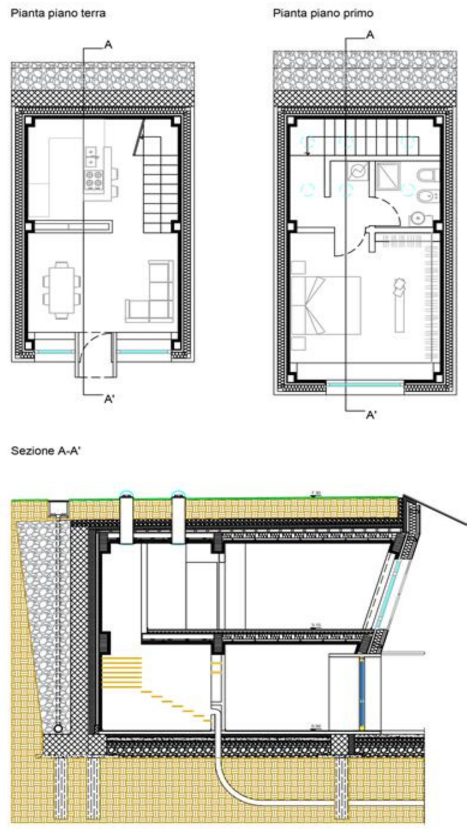


Fig. 11 Plans and vertical cross section of the dwellings of 55 m^2.

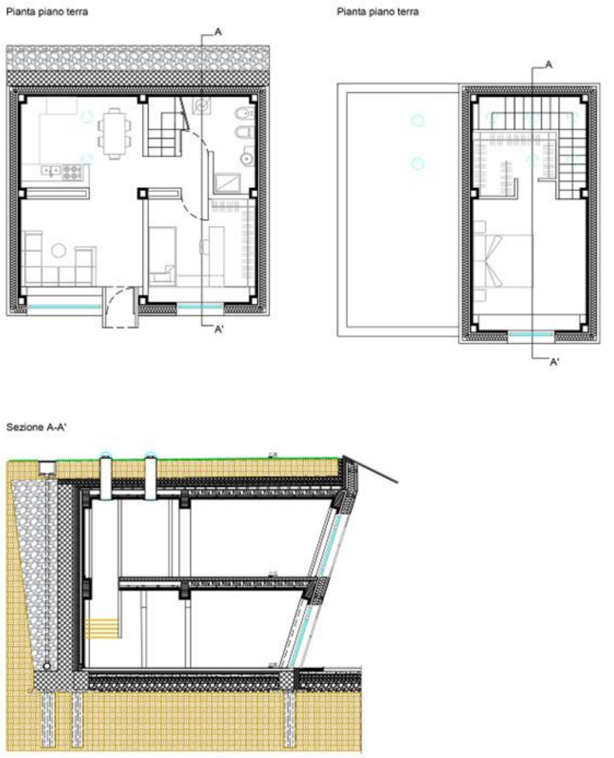


Fig. 12 Plans and vertical cross section of the dwellings of 67 m^2.

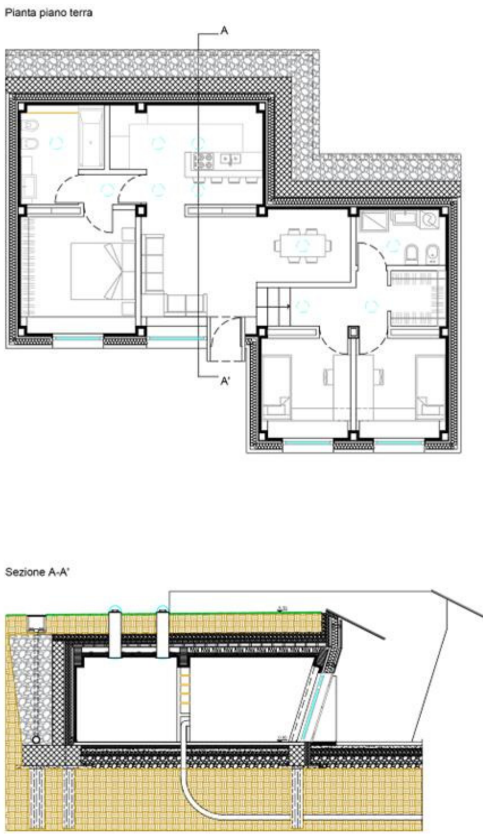


Fig. 13 Plans and vertical cross section of the dwellings of 85 m^2.

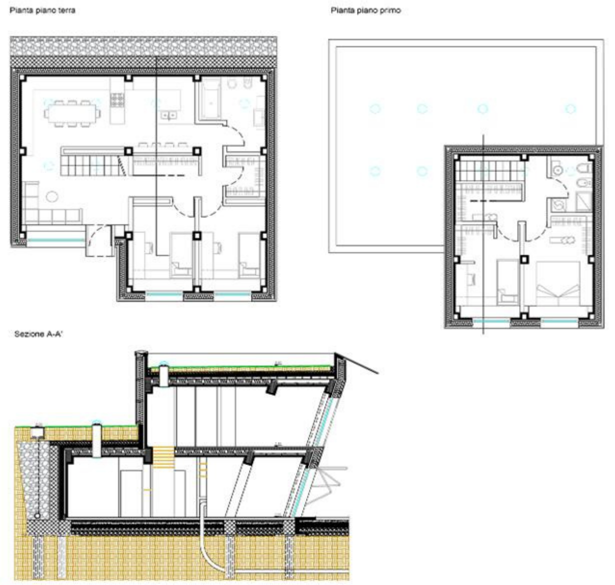


Fig. 14 Plans and vertical cross section of the dwellings of 103 m^2.

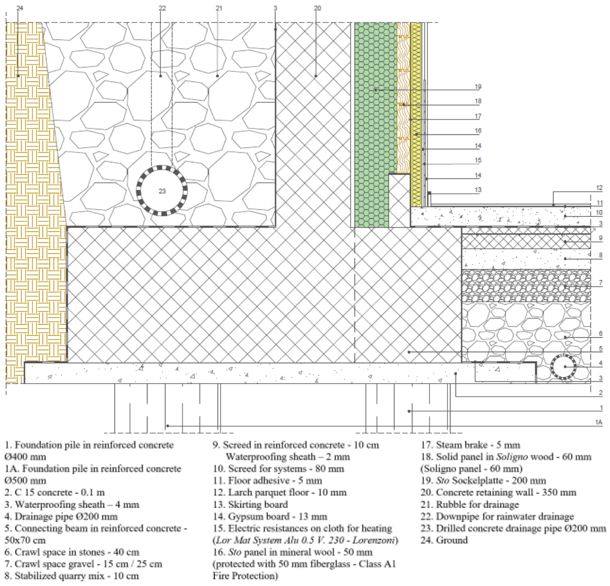
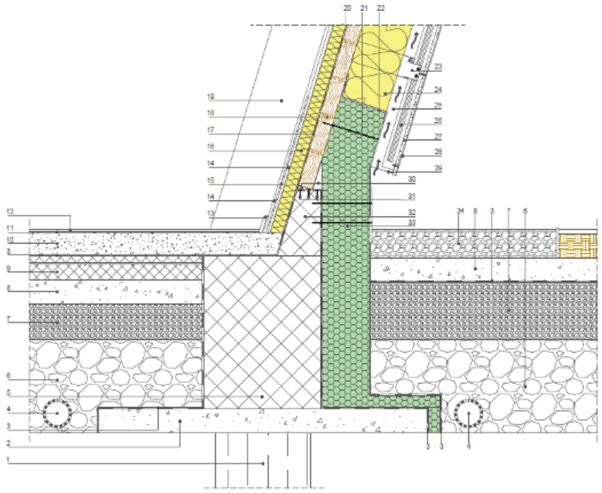


Fig. 15 Detail of retaining wall.

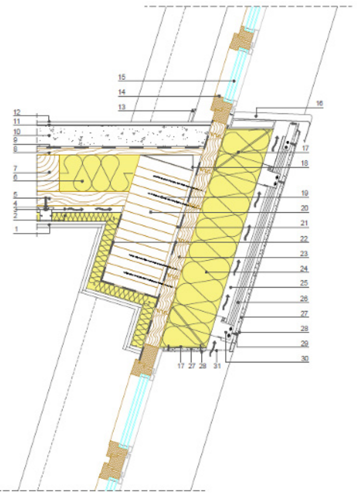
hardwood *Quercus cerris*, thermo-hydrometrically modified following procedure set by Marino et al. [13], with very high structural performances (it is a GL 42), with external walls highly insulated, 20 + 4 cm mineral wool, and ventilated rainscreen *StoVentec R* for maximum protection from the rain and from the sun (Fig. 17).

Dwellings offer the great part of the main rooms to the light, the air, the sun, even if they are covered by earth for reducing the ΔT. Insulating shielding with



1. Foundation pile in reinforced concrete Ø400 mm
2. Foundation lean-to - 1.2 x1.2x0.1 m
3. Waterproofing sheath - 5 mm
4. Drilled concrete drainage pipe Ø100 mm
5. Inverted beam in reinforced concrete - 50x70 cm
6. Stone for crawl space - 40 cm
7. Crawl space gravel - 15 cm / 25 cm
8. Fine aggregates for crawl space - 10 cm
9. Screed in reinforced concrete - 10 cm (electro-welded steel mesh Ø6mm)
10. Implant holder screed - 80 mm
11. Floor adhesive - 5 mm
12. Larch parquet floor - 10 mm
13. Baseboard
14. Plasterboard - 13 mm
15. Electric resistances on cloth for heating (*Lor Mat System Alu 0.5 V. 230 - Lorenzoni*)
16. *Sto* mineral wool insulation - 50 mm
17. Vapor check - 5 mm
18. *Soligno* solid wood panel - 60 mm
19. *Quercus cerris* glulam pillar – 24x20 cm
20. Aluminum coating layer
21. *Wurth ASSY PLUG VG* screw
22. Metal protection and stiffening square
23. Stainless steel *Sto* shelf
24. *Sto* mineral wool insulation - 200 mm
25. Air gap for ventilated wall - 40 mm
26. Profile *Sto Aluminum* – T
27. Plaster plate – 10 mm
28. Thin plaster reinforced with glass fiber mesh - 3 mm
29. Rodent-proof grid
30. Metal brackets for Soligno wall support
31. Screws for anchoring brackets
32. Trapezoidal base in precast reinforced concrete
33. *Sto Sockelplatte* panel – 200 mm
34. Splash protection – 120 mm

Fig. 16 Detail of ground connection.

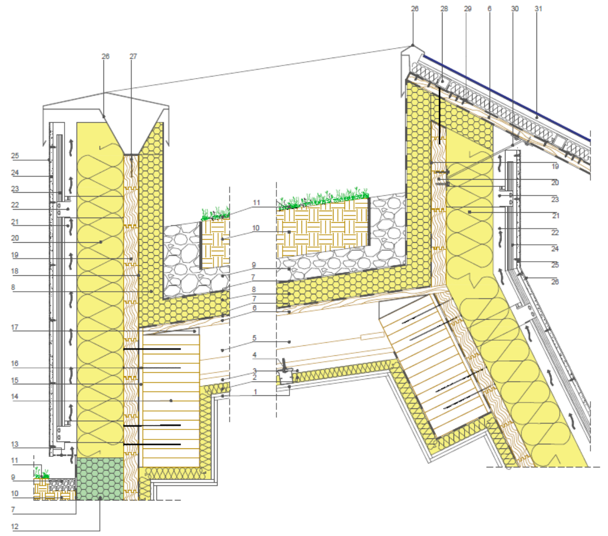


1. Gypsum board - 26 mm
2. *Sto* mineral wool panel - 40 mm
3. Air space for airborne and impact sound insulation - 20 mm
4. Elastic hanger
5. Wooden planking - 60 mm
6. *Sto* mineral wool panel - 160 mm
7. Joists - 16x10 cm
8. OSB - 30 mm
9. Waterproofing sheath - 2 mm
10. Screed for systems - 100 mm
11. Floor adhesive - 5 mm
12. Larch parquet floor - 10 mm
13. Baseboard
14. *Internorm* window frame in wood - aluminum
15. Triple glazing
16. *Sto Fentra* aluminum sill
17. Stainless steel square for laying the insulation
18. Stainless steel square for beam
19. Screw *Wurth ASSY PLUG VG*
20. *Quercus cerris* glulam beam - 56x24 cm
21. Drift joint - 20 mm
22. Vapor check
23. *Soligno* solid wood panel - 60 mm
24. *Sto* mineral wool panel - 200 mm
25. Air gap for ventilated rainscreen - 40 mm
26. *Sto* Alluminum T profile
27. Recycled glass plate *Ventec* - 12 mm
28. Thin plaster reinforced with glass fiber mesh - 3 mm
29. Sto stainless steel self-tapping screws - 5.5x24 mm
30. Stainless steel *Sto* shelf
31. Rodent-proof grid

Fig. 17 Rainscreen detail—vertical section.

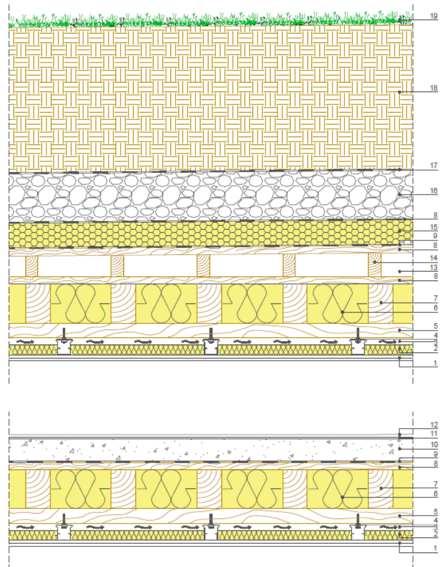
opening "to the knee" protects doors and windows from excessive solar radiation, isolates by night and protects against breaking and entering, given the layout at ground floor of the dwellings. Also, bathrooms and corridors, set toward the earth, are naturally illuminated, through solar chimneys.

Gypsum boards containing Phase Changing Material in microcapsules, boards for false ceiling with paraffin



1. Gypsum board - 26 mm
2. *Sto* mineral wool panel - 40 mm
3. Air space for airborne and impact sound insulation - 20 mm
4. Elastic hanger
5. *Soligno* wooden floor - 220 mm
6. OSB - 30 mm
7. Waterproofing sheath - 2 mm
8. XPS panel - 100 mm
9. Expanded clay layer for drainage - 100 mm
10. Topsoil layer - 200 mm
11. Turf
12. *Sto Sockelplatte* panel - 200 mm
13. Rodent-proof grid
14. *Quercus cerris* glulam beam - 56x24 cm
15. Drift joint
16. *Wurth ASSY PLUG VG* screw
17. Beam support device
18. Vapor check
19. *Soligno* solid wood panel - 60 mm
20. *Sto* mineral wool panel - 200 mm
21. Air gap for ventilated rainscreen - 40 mm
22. Stainless steel *Sto* shelf
23. *Sto* aluminum T profile
24. Recycled glass plate *Ventec* - 12 mm
25. Thin plaster reinforced with glass fiber mesh - 3 mm
26. Protective stainless-steel sheet
27. *TBS6800* stainless steel screw
28. *Zebra Solar Wurth* profile - 50x50 mm
29. *Zebra Solar W*urth profile anchor bracket
30. Inclined support bracket for photovoltaic panel
31. *OnyxSolar* Photovoltaic Panel

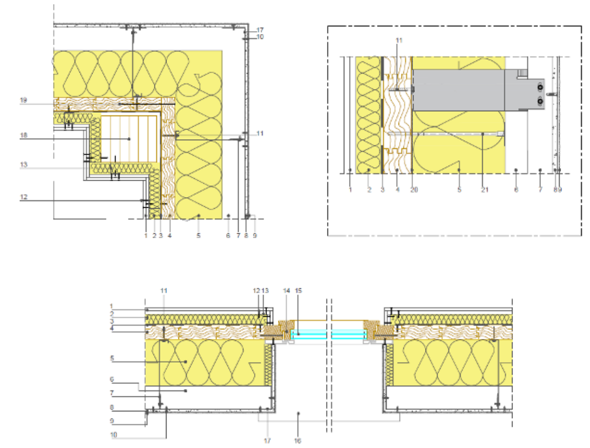
Fig. 18 Detail of the green roof and the crowning, with gypsum board containing PCM placed at the intrados of the *Soligno* floor.



1. Gypsum board - 26 mm
2. *Sto* mineral wool panel - 40 mm
3. Air space for airborne sound insulation - 20 mm
4. Elastic hanger
5. Wooden planking - 60 mm
6. *Sto* mineral wool panel - 160 mm
7. Joists - 12x16 cm
8. OSB - 30 mm
9. Waterproofing sheath - 2 mm
10. Screed for systems - 100 mm
11. Floor adhesive - 5 mm
12. Larch parquet floor - 10 mm
13. Air space
14. Rafter for roof garden slope Vapor barrier
15. XPS - 100 mm Waterproofing sheath – 5 mm
16. Expanded clay layer for drainage - 200 mm
17. Three-dimensional geotextile - 5 mm
18. Topsoil layer for cultivation - 600 mm
19. Culture

Fig. 19 Detail of the garden roof covering and of the suspended floor.

phase change material (PCM); insulation 20 + 4 cm thick in mineral wool in perimeter walls and 4 cm thick in wood fibres + 10 cm thick in extruded polystyrene foam (XPS) at roof; panels in local hardwood with dry joists, without glues, 60 mm thick



1. Gypsum board - 26 mm
2. *Sto* mineral wool panel - 40 mm
3. Vapor check
4. *Soligno* solid wood panel - 60 mm
5. *Sto* mineral wool panel - 200 mm
6. Air gap for ventilated rainscreen - 40 mm
7. *Sto* aluminum T profile and *Sto* stainless steel shelf
8. Recycled glass plate *Ventec* - 12 mm
9. Thin plaster reinforced with glass fiber mesh - 3 mm
10. *Sto* stainless steel self-tapping screws - 5.5x24 mm
11. *Sto Rahmendubel VF*
12. Screw for plasterboard
13. C profile for plasterboard support
14. *Internorm* wood - aluminum window
15. Triple glazing
16. *Sto Fentra* aluminum sill
17. *Sto Aluminum – L* profile
18. *Quercus cerris* glulam beam 56x24 cm
19. *Wurth ASSY PLUG VG* screw
20. Mineral wool insulation glue - 5 mm
21. *Sto-WdDVS Dubel*

Fig. 20 Ventilated rainscreen construction detail: corner (hor. sect.); typical (vert. sect.) and window (horizontal section).

at the perimeter and 120 mm thick for dividing internal spaces and wooden floors, 260 mm thick; maximize thermal inertia of the passive accumulation system (Figs. 18 and 19).

Flats are all *nZEB*, with U ranging from 0.141 $W/m^2 \cdot K$ of the external walls and roof garden, to 0.128 $W/m^2 \cdot K$ of the walls against earth. Windows and doors are in wood/PU/aluminum with triple glass, with U_w = 0.62 $W/m^2 \cdot K$ (Fig. 20). The insulation against earth is only perimetrical, extended 3.00 m outside the built contour. Sail sunshades for living external zones, controlled mechanical ventilation with heat recovery device and dehumidifier, heat pump air-water with very high efficiency. Local materials are used, that are also fully recyclable and reusable.

It is scheduled the recovery of meteoric water, collected, to be phyto-purified with a vertical submerged flow system and piped in accumulation reservoirs in the service of different buildings, re-used for feeding flushing cisterns of toilets, washing machines and irrigation of gardens and vegetable gardens. Grey waters originated from houses and from other activities (average 160 people in all) it is expected to be collected and piped to be phyto-purified in one plant of 160 m^2, able to handle 21 m^3/day of grey water, re-utilized not for vegetable gardens, but for decorative ones (Fig. 21).

Fig. 21 Photorealistic perspective of a glimpse of the neighborhood.

No. 28 vertical axis wind turbines of 5 kWp arranged on the car sheds in the north will supply energy to the housing and to recharge the batteries of the electric cars, also serving as reserve storage for the housing. No. 19 vertical axis wind turbines of 10 kWp each will provide energy for the common services and for the funicular. Public lighting installation rests on energy acquired by mini wind plants with vertical axis, integrated in the street lamp; their electrical production, more than demand by led light, it is scheduled to supplement common services.

4. Conclusions

Assessed with ITACA Protocol criterions, the settlement gains rating is of 4.63/5 (Fig. 22). It does not rank at full score only because it is placed on a virgin area, not before urbanized or polluted.

It is a neighbourhood in which it is possible to move walking or by bike, or by a mechanized public transport service; public and private green, orchards and vegetable gardens are everywhere, on the roof of the parking and of the homes too; the "heat island" effect is banned; buildings are *nZEB Mass Custom*, built with local materials, reusable, recyclable; meteoric waters and grey ones are collected, phyto-purified and re-used, as far as possible. Renewable energy available *in loco* (sun, hearth, wind) satisfies limited requirements that remain after using passive solar typologies for heating and earth's inertia for cooling.

PUNTEGGIO GLOBALE:

Punteggio	P. Pesato	AREA / CATEGORIA / CRITERIO	Indicatore
2,05	0,20	Strumento 1: SITO	
2,05	2,05	A. Qualità del sito	
2,05	2,05	A.1 Selezione del sito	
-1,00	-0,34	A.1.5 Riutilizzo del territorio	-0,65
1,03	0,24	A.1.6 Accessibilità al trasporto pubblico	6,09
5,00	1,15	A.1.8 Mix funzionale dell'area	371,00
5,00	1,00	A.1.10 Adiacenza ad infrastrutture	15,00
		Strumento 2: EDIFICIO	
5,00	0,25	A. Qualità del sito	
5,00	5,00	A.3 Progettazione dell'area	
5,00	0,80	A.3.3 Aree esterne di uso comune attrezzate	5,00
5,00	2,20	A.3.4 Supporto all'uso di biciclette	117,65
5,00	2,00	A.3.7 Uso di specie arboree locali	100,00
4,12	1,86	B. Consumo di risorse	
4,97	1,49	B.1 Energia primaria non rinnovabile richiesta durante il ciclo di vita	
5,00	1,75	B.1.2 Energia primaria per il riscaldamento	0,56
4,90	1,47	B.1.4 Energia primaria per l'illuminazione	51,04
5,00	1,75	B.1.5 Energia primaria per acqua calda sanitaria	23,81
5,00	0,50	B.3 Energia da fonti rinnovabili	
5,00	2,50	B.3.2 Energia rinnovabile per usi termici	100,00
5,00	2,50	B.3.3 Energia prodotta nel sito per usi elettrici	513,93
4,67	1,17	B.4 Materiali eco-compatibili	
3,50	0,77	B.4.6 Materiali riciclati/recuperati	35,00
5,00	1,40	B.4.7 Materiali da fonti rinnovabili	65,60
5,00	1,10	B.4.9 Materiali locali per finiture	100,00
5,00	1,40	B.4.10 Materiali riciclabili e smontabili	6,00
4,41	0,66	B.5 Acqua potabile	
4,09	2,61	B.5.1 Acqua potabile per irrigazione	81,70
5,00	1,80	B.5.2 Acqua potabile per usi indoor	74,29
1,52	0,30	B.6 Prestazioni dell'involucro	
-1,00	-0,58	B.6.2 Energia netta per il raffrescamento	158,80
5,00	2,10	B.6.3 Trasmittanza termica dell'involucro edilizio	46,09

Punteggio	P. Pesato	AREA / CATEGORIA / CRITERIO	Indicatore
4,79	0,96	C. Carichi ambientali	
5,00	1,50	C.1 Emissioni di CO2 equivalente	
5,00	5,00	C.1.2 Emissioni previste in fase operativa	5,68
4,90	0,74	C.3 Rifiuti solidi	
4,90	4,90	C.3.2 Rifiuti solidi prodotti in fase operativa	0,99
4,84	1,69	C.4 Acque reflue	
5,00	3,55	C.4.1 Acque grigie inviate in fognatura	100,00
4,44	1,29	C.4.3 Permeabilità del suolo	88,75
4,33	0,87	C.6 Impatto sull'ambiente circostante	
4,33	4,33	C.6.8 Effetto isola di calore	86,67
4,80	0,96	D. Qualità ambientale indoor	
4,00	0,80	D.2 Ventilazione	
4,00	4,00	D.2.5 Ventilazione e qualità dell'aria	4,00
5,00	1,50	D.3 Benessere termoigrometrico	
5,00	3,05	D.3.2 Temperatura dell'aria nel periodo estivo	1,37
5,00	1,95	D.3.3 Temperatura dell'aria e umidità relativa in ambienti riscaldati meccanicamente	0,18
5,00	1,00	D.4 Benessere visivo	
5,00	5,00	D.4.1 Illuminazione naturale	253,81
5,00	1,25	D.5 Benessere acustico	
5,00	5,00	D.5.6 Qualità acustica dell'edificio	5,00
5,00	0,25	D.6 Inquinamento elettromagnetico	
5,00	5,00	D.6.1 Campi magnetici a frequenza industriale (50Hertz)	5,00
		E. Qualità del servizio	
5,00	1,00	E.2 Funzionalità ed efficienza	
5,00	2,85	E.2.1 Dotazione di servizi	5,00
5,00	2,15	E.2.4 Qualità del sistema di cablatura	5,00
		E.3 Controllabilità degli impianti	
		E.3.5 BACS e TBM	
5,00	1,75	E.6 Mantenimento delle prestazioni in fase operativa	
5,00	3,35	E.6.1 Mantenimento delle prestazioni dell'involucro edilizio	100,00
5,00	1,65	E.6.5 Disponibilità della documentazione tecnica degli edifici	5,00
5,00	1,25	E.7 Aspetti sociali	
5,00	5,00	E.7.1 Design for all	100,00

Fig. 22 Overall score and partial scores for each performance of the settlement under study (note that commas in figure are an output of the Italian software and they stand for dots).

In order to take advantage of the free contributions of the sun to heat and of the earth to cool, the choices at the typological level are fundamentals. To warm up, it is necessary to open the windows only to the south, to shield from the high summer sun through the negative inclination of the facades and shielding systems; to cool down naturally in a humid climate it is necessary to attach oneself to the ground, insulate only the perimeter, cover oneself with earth, and control the entry of air through dehumidification devices.

This can only be done with some typological choices, and not with others. It is therefore necessary that *smartness* concerns not only the systems, but also the building types.

Contributions

Filiberto Lembo coordinated and provided the research objectives. Francesco Paolo R. Marino developed the various aspects of the research, the methodological and operational tools and verified the accuracy of the results achieved. Antonio Canosa carried out specific analyses in his Master degree thesis. The contribution of the authors in reviewing the manuscript, editing and writing the text of the paper was the same.

References

[1] Amendola G. 2021. "Il Fatto Quotidiano", March 5.

[2] Cingolani R. 2021. "Il Fatto Quotidiano", February 28.

[3] Cody, B. 1998. "Low Energy Apartment Building in Berlin." *The Ove Arup Journal* 3: 14-7.

[4] Spanu, S. 2017. *Città del futuro. Il modello di Friburgo in Breisgau*. Milano: Franco Angeli Editore.

[5] Steemers, T., and The ECD Partnership. 1991. *Solar Architecture in Europe. Design, Performance and Evaluation*. Bridport, Dorset: Prism Press.

[6] Department of the Environment Transport and the Regions (DETR). 1998. *Planning for Sustainable Development*. *Towards Better Practice*. London, 12.

[7] Galanti, A. 2010. *Forma urbana, sostenibilità, pianificazione*. Roma: Aracne Editrice, 30.

[8] Marino, F. P. R., Lembo, F., and Fanuele, V. 2019. "Towards More Sustainable Patterns of Urban Development." In *SBE19—Emerging Concepts for Sustainable Built Environment*. *IOP Publishing—IOP*

Conference Series: Earth and Environmental Science 297: 012028. doi: 10.1088/1755-1315/297/1/012028.

[9] Municipality of Potenza. 2007. *Operative Plan of the "C2" Zone (Contrada Botte) of the General Regulatory Plan 2007*. Technical Implementation Rules, Approved on April 13th, 2007 with City Council Resolution No. 24.

[10] ITACA/UNI. 2015. Reference Practice UNI/PdR 13.0. *Environmental Sustainability in Construction—Operational Tools for the Assessment of Sustainability—General Framework and Methodological Principles*. Published on Jan. 30, 2015 and Corrected on June 22, 2016, ICS 91.040.01.

[11] ITACA/UNI. 2015. Reference Practice UNI/PdR 13.1. *Environmental Sustainability in Construction—Operational Tools for the Assessment of Sustainability—Residential Buildings*. Published on Jan. 30, 2015 and Corrected on June 22, 2016, ICS 91.040.01.

[12] Italian Institute for Innovation and Transparency of Tenders Environmental Compatibility (ITACA). 2015. *ITACA Protocol, Nonresidential Buildings*. Published on Nov. 12, 2015.

[13] Marino, F. P. R., Lembo, F., Videtta, A., and La Notte, C. 2006. "Quercus Cerris Glued Laminated Timber: A Novel Material Derived from Wood. Tests on Thermoigrometric Conditioning, Wood Adhesives and Flexion Breakout Tension." Presented at *Sustainable Housing Design Emphasizing Urban Housing—XXXIV IAHS World Congress*, Napoli.