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RESIDENTIAL BUILDING DESIGN & CONSTRUCTION CONFERENCE PROCEEDINGS

MAY 11–12, 2022

UNIVERSITY PARK, PENNSYLVANIA, USA

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UNIVERSITY PARK, PENNSYLVANIA, USA

Edited by
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PREFACE

While home builders are continuously challenged to consider various criteria such as affordability, energy efficiency, sustainability, serviceability, aesthetic, utility, and resistance to natural hazards among others, there are varying degrees of adherence to such objectives. The more efforts are made for technology transfer and providing the residential construction industry with the latest advancements in construction materials, tools, methods, and code requirements, the more receptive will be the mainstream builders to incorporation of technological advancements. As always, the Pennsylvania Housing Research Center (PHRC) at The Pennsylvania State University considers knowledge sharing and dissemination of the results of recent advancements in the field as one of its primary responsibilities and is pleased to continue organizing the Residential Building Design and Construction Conference series to serve the housing and residential construction industry for this purpose.

It is with great pleasure that we share the proceedings of the 2022 Residential Building Design and Construction Conference, which was held virtually on May 11–12, 2022. As in the past five RBDC Conferences, this sixth conference provided an opportunity for researchers, design professionals, manufacturers, builders, and code officials to exchange the latest advancements in research and practice and to discuss and share their own findings, innovations, and projects related to residential buildings.

The 2022 RBDC Conference hosted 85 attendees and included 61 papers, 60 presentations, and 10 posters on various issues related to residential buildings, which encompass single- and multi-family dwellings, mid-rise and high-rise structures, factory-built housing, dormitories, and hotels/motels. Papers and presentations related to the following areas and topics were invited in the conference call:

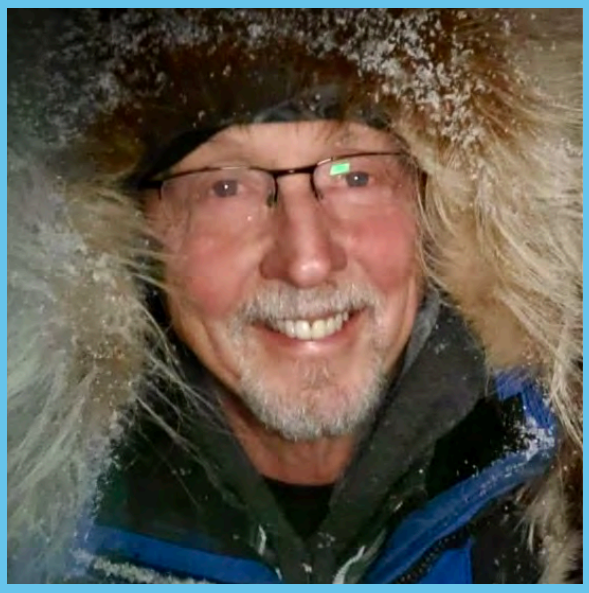
- Aging-in-Place and Senior Living Housing
- Alternative Renewable Energy Generating Systems
- Building Information Modeling (BIM) Application in Residential Construction
- Building Integrated Photovoltaic Systems
- Building Performance Assessment/Metrics/Verification Methods and Occupant Behavior
- Building Science and Building Enclosures
- Education of Residential Design & Construction
- Energy Efficient Building Components
- Fire Damage and Protection
- High-Performance Residential Buildings
- Indoor Air Quality
- Innovations in Green Roofs and Façade/Envelope Systems
- Innovations in Residential Architecture and Design
- Innovations in Modular and Manufactured Housing
- Innovative and Emerging Housing Construction Methods/Systems
- Innovative Wall, Floor, Roof, Window, and Siding Systems
- Learning from the Performance of Residential Buildings under Natural Disasters
- Low-Income and Affordable Housing
- Net Zero Energy Homes
- Panelized Building Components
- Passive House Design Approach
- Resilient New Design and Retrofit of Existing Buildings under Natural Disasters
- Retrofit of Existing Buildings for Energy Efficiency
- Rural Housing Materials and Construction
- Serviceability and Life Safety Damage Aspects
- Smart Home Technologies, Design, and Construction
- Sustainable Housing Construction Materials and Methods
- Temporary Housing for Disaster Situations
- Whole Building Design Approach

As the Table of Contents of these proceedings show, many of the above areas were among the papers and presentations at the conference. There was considerable interest in topics including building envelope, building in Alaska, building science education, disaster resilience, hemp, high-performance housing, innovative and affordable housing, mass timber and CLT, mechanical and lighting systems, occupant behavior, retrofits, and tools for homebuilders.

Two keynote speakers were invited for the conference: Wil V. Srubar III, Ph.D., associate professor at the University of Colorado Boulder and founder and managing director of Aureus Earth, Inc. and Rusty Smith, associate director of the Rural Studio at Auburn University's School of Architecture, Planning, & Landscape Architecture. Srubar discussed his presentation titled "Transforming Buildings into Carbon Sinks." Smith shared his presentation titled "Rural Studio: What Does Affordable, High-Performance Housing Truly Afford?" The conference also hosted a closing plenary session by Jack Hébert, founder of the Cold Climate Housing Research Center and senior research advisor at the National Renewable Energy Laboratory, entitled "Indigenous Wisdom and 21st Century Technologies: An Arctic Approach to Building Science."

We wish to thank the members of the International Scientific Committee of the conference for their contributions in promoting the conference. The support of the PHRC staff for logistics is gratefully acknowledged. Special thanks go to Rachel Fawcett for her contribution as the Conference Coordinator.

Proceedings Editors:
Ali M. Memari and Sarah Klinetob Lowe
May 2022



CONFERENCE SCHEDULE

WEDNESDAY, MAY 11

8:15am ET - 9:30am ET

Keynote: **Dr. Wil V. Srubar, III | Associate Professor, University of Colorado Boulder**
Title: **Transforming Buildings Into Carbon Sinks**
Opening Remarks by Dr. Ali Memari & Sarah Klinetob Lowe

9:45am ET - 10:15am ET — **Virtual Networking Session**

10:30am ET - 12:00pm ET — **Conference Sessions A**

	Innovative & Affordable Housing	Building Envelope		Building Science Education
10:30-11:00	**High-performing technologies for contemporary residential Rural buildings in the Pianura Padana territory** *Silvia Brunoro (University of Ferrara)*	**Multi-chamber Standardized Testing of Air-permeable Cladding Materials** *Oscar Lafontaine & David O. Prevatt (University of Florida)*		**Introductions, Overview, and Where Are We Now?** *Georg Reichard (Virginia Tech), Pat Huelman (University of Minnesota), & Sam Taylor (Energy & Resource Efficiency)*
11:00-11:30	**Catenary domes for housing: benefits and challenges** *Ryan Bradley (University of Witwatersrand)*	**Performance of OSB and SFS Shear Walls in Residential Building** *Shideh Shadravan (University of Oklahoma), Behnam Shadravan (Florida A&M University), & Chris Ramseyer (University of Oklahoma)*		
11:30-12:00	**THE USE OF ARTIFICIAL INTELLIGENCE TECHNIQUES FOR PREDICTING COMPRESSIVE STRENGTH FOR HIGH PERFORMANCE CONCRETE: A REVIEW** *Refilwe Lediga & Jefferey Mahachi (University of Johannesburg)*	**An Innovative, High-performance Shell Structure for Residential Construction: The SPS System** *Rolf Jacobson; Dan Handeen; Pat Huelman; Garrett Mosiman; Tom Schirber*		**Beyond Boundaries: Education to Advance the Transformation of the Architecture, Engineering, Construction, and Operations Industry** *Jonathan Bean (University of Arizona) & Sarah Truitt (NREL)*

12:00pm ET -12:30pm ET — **LUNCH BREAK**

12:30pm ET - 2:00pm ET — **Conference Sessions B**

	Disaster Resilient Housing	Mechanical & Lighting	Mass Timber & CLT	Building Science Education
12:30-1:00	**Observations and Analysis of wind pressures on roof overhangs and underneath walls of a low-rise building** *Karim Mostafa (Florida International University), Ioannis Zisis (Florida International University), & Ted Stathopoulous (Concordia University)*	**Balance Points are Changing – and That's Just Sensible!** *Pat Huelman (University of Minnesota)*	**Parametric Evaluation of Embodied Carbon within Design for Hybrid Mass Timber Floor Systems** *Samantha Leonard, Ryan Solnosky, Nathan Brown, & Corey Gracie-Griffin (Penn State)*	**Resilience and Social Justice as a Framework for Architectural Education, Research and Practice – The Design+Build Kunga ADU** *Jörg Rügemer (University of Utah)*
1:00-1:30	**Analysis of Complex Flow Characteristics from Field and Simulated Hurricane Measurements** *Jianing Wang & Chelakara Subramanian (Florida Institute of Technology)*	**Development of Smart Watering Algorithm To Improve Biowall Performance** *William Hutzel (Purdue University)*	**Structural Design of a Cross-Laminated Timber (CLT) Single-Family Home** *Anthony Jellen (Jellen Engineering Services) & Ali Memari (Penn State)*	**Facilitating Real-World Project-Based Service-Learning Opportunities by Participating in Department of Energy Race to Zero and Solar Decathlon Competitions** *Jeremy Farner (Weber State University)*
1:30-2:00	**CASE STUDIES OF BUILDING RESILIENCE IN HURRICANES** *Behnam Shadravan (Florida A&M University) & Shideh Shadravan (Oklahoma University)*	**Machine learning based surrogate model for faster daylighting estimation in building design** *Naveen Kumar Muthumanickam (NREL), José Pinto Duarte (Penn State), & Tim Simpson (Penn State)*	**Moisture Vapor Buffering and Latent Heat Effects of CLT Insulated with Wood Fiber Insulation Assembly on Energy Saving** *Ling Li (University of Maine), Jake Snow (University of Maine), Maitham Alabbad (University of Maine), Samuel V. Glass (Forest Service FPL), Benjamin Herzog (University of Maine), & Stephen Shaler (University of Maine)*	**Continued Experiences with the Solar Decathlon Design Challenge** *Tom Collins (Ball State University)*

2:15pm ET - 2:45pm ET — **Poster Session**
See Next Tab

3:00pm ET - 4:30pm ET — **Conference Sessions C**

	Innovative & Affordable Housing	Occupant Behavior	Hemp	Building Science Education
3:00-3:30	**Frame House System: An Open-Source Housing Design and Construction System** *Puja Bhagat, Celina Deng, & Benay Gürsoy (Penn State)*	**Case Study: The Effect of Homeowner Behavior on Energy-Efficiency in a High-Performance Home** *Lindsey Beates (Beates Properties) & Jason Lucas (Clemson University)*	**Use of Industrial Hemp and Bamboo Fiber in Construction** *Dan Hindman, Tom Hammett, & Jonas Hauptman (Virginia Tech)*	**Picking Favorites - A Building Science Education Showcase/Showdown Panel** *Georg Reichard (Virginia Tech), Jonathan Bean (University of Arizona), David Fannon (Northeastern), Walter Grondzik (Ball State University), Bruce Haglund (University of Idaho), Pat Huelman (University of Minnesota), Ulrike Passe (Iowa State University), & Brian Wolfgang (Penn State)*
3:30-4:00	**How to Make Zero Energy Ready Pencil Out at the Production Scale** *Eric Werling (US DOE), Kevin Brozyna (Insight Homes), & Theresa Gilbride (PNNL)*	**Impact of Occupant Characteristics on the Energy Performance of Multifamily Residential Building in the United States** *Debrudra Mitra, Yiyi Chu, & Kristen Cetin (Michigan State University)*	**Critical Review of the Characterization of Environmental and Mechanical Properties of Hemp Hurd and Hempcrete** *Hojae Yi, Corey Gracie-Griffin, & Ali Memari (Penn State)*	
4:00-4:30	**Discussion of Tiny Home Inclusion as a Concentric Diversification Strategy in Production Home Building to Address Housing Crisis** *Molly Smith, Wei Wu, Yupeng (Vivien) Luo, & Michele Randel (California State University, Fresno)*	**Development and validation of a post-occupancy evaluation model for LEED-certified residential projects** *Mohsen Goodarzi (Ball State University) & George H. Berghorn (Michigan State University)*	**Modeling of 3D printing Concrete based on Meshfree Explicit Galerkin Analysis Method** *Aleksandra Radlinska, Hanbin Cheng, Feihong Liu, & Michael Hillman (Penn State)*	

Thursday, May 12

8:15am ET - 9:30am ET

Keynote: **Rusty Smith | Associate Director, Rural Studio at Auburn University**
Title: **Rural Studio: What Does Affordable, High-Performance Housing Truly Afford?**
Opening Remarks by Dr. Ali Memari & Sarah Klinetob Lowe

9:45am ET - 10:15am ET — **Virtual Networking Session**

10:30am - 12:00pm ET — **Conference Sessions D**

	Innovative Housing	Retrofits	Tools for Homebuilders	Disaster Resilience
10:30-11:00	**A Multi-manufacturer Platform Approach to Modular Volumetric Construction – An Experiment in Cross-pollinating Design with Fabrication** *Carlo Carbone (Université du Québec à Montréal)*	**Application of refractive fluid flow imaging techniques for visualizing building exfiltration** *Philip Boudreaux, Emishaw Iffa, & Venkat Singanallur (ORNL)*	**Creating a Virtual Environment Data Collection Tool for Construction Safety** *Daniel Hindman, Leann Rhodes, Rafael Patrick, Alicia Johnson, & Todd Ogle (Virginia Tech)*	**Transdisciplinary Perspectives on Equitable, Sustainable, Resilient Housing: Panel Discussion & Moderated Q&A** *Stacey Connaughton (Purdue University), Mohamed Hilmi (InterAction) , George Foden (Loughborough University), & Esther Obonyo (Penn State)*
11:00-11:30	**Design Grammar of Scaffold-Free 3D Printed Shells** *Mahan Motamedi (ENSAPM, Laboratoire GSA), Shadi Nazarian (Penn State), Romain Mesnil (ENPC, Laboratoire NAVIER), Robin Oval (University of Cambridge), & Olivier Baverel (ENPC, Laboratoire NAVIER)*	**Drone-based scanning technology for characterizing the geometry and thermal conditions of building enclosure system for fast energy audit and design of retrofitting strategies** *Shayan Mirzabeigi (SUNY ESF), Parisa Eteghad (SUNY ESF), Mohamed Razkenari (SUNY ESF), Paul Crovella (SUNY ESF), & Jianshun Zhang (Syracuse University)*	**Likeliness to Recommend: A Mixed Methods Analysis of Consumer Perceptions of Home Builders** *Todd Usher & Jason Lucas (Clemson University)*	
11:30-12:00	**UTILIZING ARTIFICIAL INTELLIGENCE FOR DESIGNING CEMENT-BASED MATERIALS FOR 3D CONCRETE PRINTING APPLICATIONS** *Refilwe Lediga & Jefferey Mahachi (University of Johannesburg)*	**Energy Modeling to Determine Optimum Order of Component Installation in Stepwise Retrofit Towards EnerPHit Standard** *Sophia Welch, Esther Obonyo, & Ali Memari (Penn State)*		

12:00pm ET -12:30pm ET — **LUNCH BREAK**

12:30pm - 2:00pm — **Conference Sessions E**

	High Performance Housing	Retrofits	Building in Alaska	Disaster Resilience
12:30-1:00	**Site Net Zero Target Contemporegional Architecture – The Barn Haus in Utah** *Jörg Rügemer (University of Utah)*	**Comparing Affordable, Durable and Energy Efficient Wall Retrofit Systems** *Chrissi Antonopoulos (PNNL), Patti Gunderson (PNNL), Tyler Pilet (PNNL), Sumitrra Ganguli (PNNL), Jian Zhang (PNNL), Travis Ashley (PNNL), Pat Huelman (University of Minnesota), Antonio Aldykiewicz (ORNL), Garrett Mosiman (University of Minnesota), Harshil Nagda (PNNL), Cheryn Metzger (PNNL), Andre Desjarlais (ORNL), & Rolf Jacobson (University of Minnesota)*	**Design of homes for concrete printing in the permafrost regions of Alaska** *José Duarte, Gonçalo Duarte, Nathan Brown, Shadi Nazarian, & Ali Memari (Penn State)*	**Building for Energy Efficiency and Disaster Resistance: Complementary Goals, Most of the Time** *Edward Louie, Chrissi Antonopoulos, & Theresa Gilbride (PNNL)*
1:00-1:30	**The Intersection of Passive House and Affordability in Cold Climate Residential Construction** *Christopher Wingate (MSR Design) & Sean Sonnabend (AKF Group)*	**Hygrothermal simulation of exterior retrofits in a cold climate** *Antonio Aldykiewicz (ORNL), Andre Desjarlais (ORNL), Pat Huelman (University of Minnesota), & Garrett Mosiman (University of Minnesota)*	**Structural Evaluation of a proposed concrete 3D printed Habitat in remote Alaska** *Gonçalo Duarte, Ali Memari, Nathan Brown, José Duarte, & Zhengyu Wu (Penn State)*	**A parametric investigation of canopy heat islands mitigation strategies: A case study of a new residential development master plan of a U.S. north-eastern city** *Farzad Hashemi, Lisa D. Iulo, & Ute Poerschke (Penn State)*
1:30-2:00	**Reducing Interior Overheating of Residential Buildings by Passive Cooling Measures** *Michal Bartko, Abdelaziz Laouadi, & Michael Lacasse (National Research Council Canada)*	**Insitu Testing for PNNL/ORNL/UMN Deep Wall Insulation Upgrade Project** *Pat Huelman, Garrett Mosiman, Fatih Evren, & Rolf Jacobson (University of Minnesota)*	**A comparison of thermal insulation strategies for 3D printed concrete structures in cold regions** *Nathan Brown, Ali Memari, Ming Xiao, Zhengyu Wu, José Duarte, Shadi Nazarian, & Gonçalo Duarte (Penn State)*	**Small-Scale Testing of Air Barrier Systems Adhered on Sheathing Panels Under In-plane Relative Displacement Simulating Seismic Effect** *Karim Abdelwahab, Corey Gracie-Griffin, Ali Memari, & Lisa D. Iulo (Penn State)*

2:15pm - 2:45pm ET — **Roundtable Networking Session**

3:00pm - 4:30pm ET — **Conference Sessions F**

	Retrofits	Building in Alaska
3:00-3:30	**Siding Retrofits – Never a Better Time to Upgrade Wall Insulation and Windows** *Katherine Cort & Theresa Gilbride (PNNL)*	**Building Durability in Extreme, Changing Climates** *Zoe Kaufman, Robbin Garber-Slaght, Tanushree Charan, & Conor Dennehy (NREL)*
3:30-4:00	**Determining Energy Savings for Various High Performance Ventilated Attic (HPVA) Roof Retrofits** *Sam Meleika & Anthony Fontanini (NREL)*	**Addressing the Housing Infrastructure Challenges of Rural Alaska in a Changing Climate: Physical Characteristics of Residential Infrastructure** *Maria Millan (Michigan State University), Kristen Cetin (Michigan State University), Jessica Taylor (Iowa State University), & Cristina Poleacovschi (Iowa State University)*
4:00-4:30	**A Zero-carbon Bio-based Wall Panel as an Energy Retrofit Solution for Buildings** *Shaghayegh Kurzinski, Paul Crovella, Mohamad Razkenari, & William Smith (SUNY ESF)*	**Design, Construction, and Field Validation of a Blown-in Fiberglass Wall System in a Cold, Wet, and Windy Climate** *Vanessa Stevens, Robbin Garber-Slaght, Haley Nelson, Aaron Cooke, & Chan Charoonsophonsak (CCHRC - NREL)*

4:45pm ET - 6:00pm ET

Closing Plenary: **Jack Hébert| Founder - Cold Climate Housing Research Center (CCHRC)**
Title: **Indigenous Wisdom and 21st Century Technologies: An Arctic Approach to Building Science**
Closing Remarks by Dr. Ali Memari & Sarah Klinetob Lowe

POSTER SESSIONS

Multiple benefits through residential building energy retrofit and thermal resilient design *Shayan Mirzabeigi & Mohamad Razkenari (SUNY ESF)*	**Educating the Youth On Energy Literacy Through Virtual Reality** *Joseph James (Virginia Tech)*	**Practical Construction of 3D Printed Reinforced Concrete Members** *Zhengyu Wu & Ali Memari (Pen State)*	**Review of Mechanical and Structural Testing for 3D Printed Concrete** *Zhengyu Wu & Ali Memari (Penn State)*
Resilience in Modular Construction *Maryam Kouhirostami (University of Florida), Arezou Sadoughi (Appalachian State University), Mahtab Kouhirostami (University of Florida), & Robert Ries (University of Florida)*	**Use of Plastic Waste in Building Construction Industry** *Shahryar Habibi (University of Ferrara) & Ali Memari (Penn State)*	**Small-Scale Testing of Air Barrier Systems Adhered on Sheathing Panels Under In-plane Relative Displacement Simulating Seismic Effect** *Karim Abdelwahab, Corey Gracie-Griffin, Ali Memari and Lisa Iulo (Penn State)*	**Review of Structural Load Resisting Systems for Cross-Laminated Timber Multi-story Residential Buildings** *Nadia M. Mirzai and Ali Memari (Penn State)*
Literature review on triodetic foundation system for permafrost regions *Nima Aminpour and Ali Memari (Penn State)*	**3D Printing of Residential Houses by Adapting the Historical African Sustainable Housings** *Eden Binega and Ali Memari (Penn State)*		

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CONFERENCE SESSIONS B

PROCEEDINGS ONLY

High-performing technologies for contemporary residential Rural buildings in the Pianura Padana territory.

S. Brunoro[1]

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ABSTRACT

The paper illustrates the potentialities of designing high – efficient rural buildings, by introducing innovative methodology and techniques. Sharing of services and efficient building technologies represents a growing strategy that can fulfill the goal of the 20-20-20 EU energy policies. Rural housing - homes and services built with agricultural and farming purposes - is an historical heritage in Italy, are mainly diffused in the Emilia Romagna Lombardia and Veneto Region (area called Pianura Padana). The rural real estate in this territory is now not efficiently valorized, as economic, functional and cultural constraints generally rules the design phase. The theme of the residence is then particularly insidious as it collides with preconceptions that are difficult to overcome, this both on the front of the client and of the construction companies. The main aim of the paper is to investigate the possibilities to introduce experimental contents - both in architectural then in technical issues - in reconstructing rural settlements, besides of the opportunity to build efficiently while respecting limited budgets and keeping references to traditional typologies together with the most up-to-date technological equipment and construction systems. In this paper, small-scale high – efficient rural projects are analyzed. Realized examples of young Architects (KM429, MIDE architects) are presented, showing several residential interventions where sustainable construction systems, thanks to their design sensitivity, are well integrated into very delicate rural contexts.

INTRODUCTION

The ancient rural buildings represent a testimony of exceptional historical and cultural value in Italy They are disseminated along the Pianura Padana, an Italian territory comprehended between the Emilia Romagna Lombardia and Veneto Region (Figure 1). Today such complexes are most of all abandonment and/or damaged, for many reasons, most of all the shift between rural and industrial economy and the progressive migration from country to town.
The seismic events of 20 and 29 May 2012 in Pianura Padana caused considerable damages to the rural settlements, both to agricultural activities than to the agricultural sector, and to the built heritage as a whole.
In this area, which includes more than 30 municipalities between the Reggio Emila and the upper Ferrara province, agriculture has always played an important role in terms of surface extension agricultural used and economic level reached. The

earthquake has hit hard the activities and the scattered rural building fabric of the Emilian countryside. The greatest damage was recorded for historical rural courts: those complexes for which maintenance has not been continuous or that were even in a total state of decay. Moreover these complexes do not fulfil the recent standards in the field of energy efficiency [*Marangoni, 2013*].

Figure 1. An example of historical rural building in the Pianura Padana territory

The main purpose of the study is to investigate methods and examples to deal with rural architecture by introducing modern languages and efficient technologies for the reconstructing of rural settlements, respecting traditional typologies and at the same time using efficient sustainable technologies and construction systems.
The main objectives at the center of the work are :

- the management of the relationships between past and modern in the composition of the complexes buildings, linked to the agricultural landscape;
- the enhancement of the historical heritage language (re-interpretation of the preserved agricultural heritage) with new materials, methods and techniques;
- The control of the building quality, energy efficiency and budget limitations.

The study aims to suggest methods and best practices for the integration between landscape and modern rural architecture, pursuing a twofold objective: in the first place to interpret in a modern language the basic architectural and technical features of rural houses in the Pianura Padana landscape (from the typology to the landscape colors) then to upgrade to high – efficient energy standards. The use of a contemporary language and technologies do not distort the concept of rural house.

COURTYARDS AND RURAL COMPLEXES IN THE HISTORICAL CONTEXT

From the 1950s to today, the Pianura Padana rural landscape has undergone radical transformations. The evolution of the built complexes shows equally evident signs of change, legible in the growth and articulation of centers already present in the 1950s, and only more rarely in the creation of new functional nuclei for agricultural companies [*Baricchi, 1990*].
Building new settlements had more to do with the inclusion of incongruous functions, such as residential compartments and isolated production activities. The transformations have thus determined a gradual alteration of the structuring characteristics of the landscape, making homogenization inexorable with the margins

of urbanization and the trivialization of signs, tradition and memory linked to the agricultural world.

a. b. c.

Figure 2. Main basic typologies of rural architecture in the Pianura Padana a.Courtyard. b,c. Rural farming complex

Rebuilding can be an unmissable opportunity to improve the rural landscape in its original tradition settlement as a whole, an at the same time to upgrade it to new efficient standard by using sustainable construction systems such as dry technologies, eternal thermal insulation, high – performing windows etc..

Historical rural settlements can be defined in their historical asset by the following macro-categories [*Gambi, 2008*]:

Courtyard (Figure 2 a)

This is the elementary rural unit consisting of two buildings, one intended for the tenant's home and the other used as services and storage. Other secondary buildings may be present and play a service role.

Rural farming complex (Figure 2 b,c)

It is the evolution of the elementary unit, with the inclusion of recent buildings, diversified activities and functions which make the composition and the functioning of the court more complexes: a cattle shed, machinery storage buildings agricultural, warehouses.

The main typological variations of these two macro categories, depending on the territory, can be listed as follows:

- *Bolognese typology (separate buildings)*
  It consists of two principal buildings of similar size arranged in a chessboard or on a single axis, quadrangular floor and with hipped roofs, one for family house home and one stable;
- *Modenese typology (separate buildings)*
  Is a variation of the Bolognese court, for smaller size companies It is a court where dwelling and secondary rural building are arranged perpendicular. Dwelling is general rectangular floor and is three floors high with slope roof. Stable has large dimensions due to the intense dairy cow breeding, with grated openings that give air to the barn;
- *One-building typology*
  It is one of the oldest types spread everywhere in the area of Modena where house and secondary functions are settled under the same roof. Here the house is half-divided in vertical: a load bearing wall divides the house from the barn

for fire – safety. The rural building consists of a high roof with pillars, forming a porch in front of the entrance of the stable .

MODERN RURAL ARCHITECTURE DESIGN PRINCIPLES AND REALIZED EXAMPLES

In this chapter, small-scale high – energy efficient rural projects are analyzed. Realized examples of two young Architects companies (KM429 architects, MIDE architects) are presented, showing how a careful design can address and solve the main above-mentioned issues. four projects are presented, in different contexts, using sustainable - construction systems which, thanks to their design sensitivity, are well integrated into very delicate rural contexts.

Small rural architectures are diffused in the territory represented in Figure 3. The challenge is to approach to the architectural rural landscape using a modern language as well as, at the same time, respecting the typological characters, materials and colors of the tradition. The case studies analyzed are representative of a capillary network to rebuild the lost rural landscape. Most of the examples are built to replace existing rural houses severely compromised by the earthquake of May 2012.

Also it has to be highlighted that the new houses rises in one of the most evocative and characteristic areas of Italy, with a rare historical-landscape and naturalistic value, the result of the spontaneous fusion between nature and centuries-old human work. This landscape, consolidated over the centuries by a continuous rural use remained unchanged in forms and methods, has acquired a characteristic and unrepeatable aspect. [*Regione Emilia Romagna, 1986*]:

Figure 3. The Pianura Padana territory in which the modern rural settlements network is diffused.

Architectural principles and layout

The analyze projects, as representative of the above – mentioned re construction philosophy are: the 8-HOUSE located in Dosso di Sant'Agostino, the FLOWER HOUSE in San Posidonio (Mirandola, Modena), the HOUSE OF VALLEY in Novellara (Modena), HOUSE IN THE POPLAR in Scorzè (Venezia) (FIG 4,5). These are only a few group of amore diffused network of interventions spread all over the territory, with the same characteristics and intentions.

The first three houses are built on the ground of the old rural houses, destroyed by the earthquake of 2012. Behind the projects there is the desire to enhance the existing context, by re-interpreting the peculiarity of the rural buildings in a contemporary key. Design choices are made in order to respect the memory of the places, by assuming the peculiarities of the agricultural countryside, to conserve the typical image of the around landscape and at the same time to try to innovate the housing layout concept to modern requirements.

Figure 4. Case studies of modern rural buildings. 8 HOUSE, Flower House (KM429 Architects)

Figure 5. Case studies of modern rural buildings. House of Valley(KM429 Architects), House in the poplar (MIDE Architects).

Common principle is to valorize the rural typology by adopting an architectural language in line to the context, respecting design composition and the peculiar element of the rural architecture such as to have compact shapes with visual cones toward the countryside. The research of a visual deep continuity with internal and external spaces is very important, as represented in Figure 6,7,8. Other peculiar elements recalling shapes and suggestions of the tradition are the use of the porch, of large openings, of brick-clad basement, concrete or other materials of the tradition.

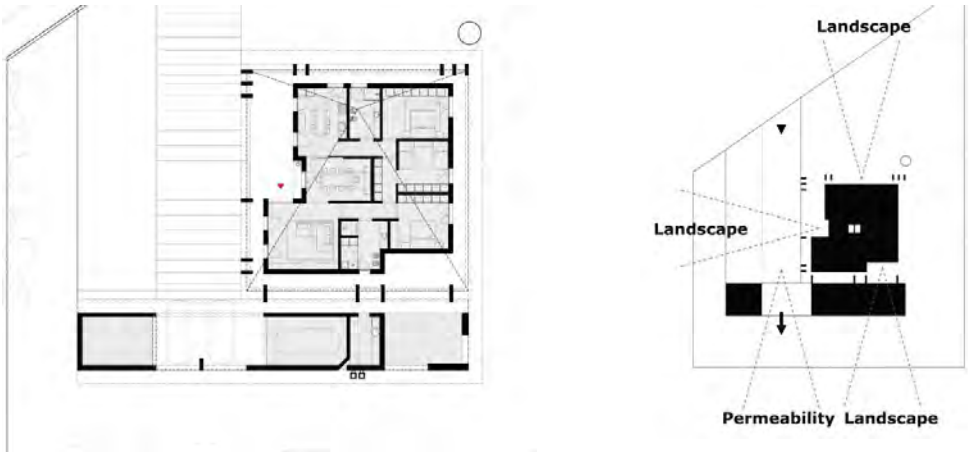


Figure 6. 8 House, Sant'Agostino –Ferrara (KM429 Architects). Floor plan and visual layout. The plan has been designed to try to recreate an intimate atmosphere of protection, and at the same time opening towards the countryside, framing it in reserved visual cones.

In the 8 HOUSE (FIG. 6), the entire architectural composition provides for an internal-external dialectical relationship without boundaries, surrounded by a porch that regulates the solar gains and visual comfort. The main livable spaces, such as the living room and the dining kitchen, overlook the porch that encloses all the rooms; it is punctually marked by the presence of exposed masonry pillars in memory of the typical columns of the "barchesse", a rural service building, typical of the rural architecture. Next to it and in close dialectical relationship, is the service block characterized by the use of concrete and exposed bricks. The house develops around the dining room located at the center of the ground floor. It is sized to accommodate the extended family gathering on weekends.

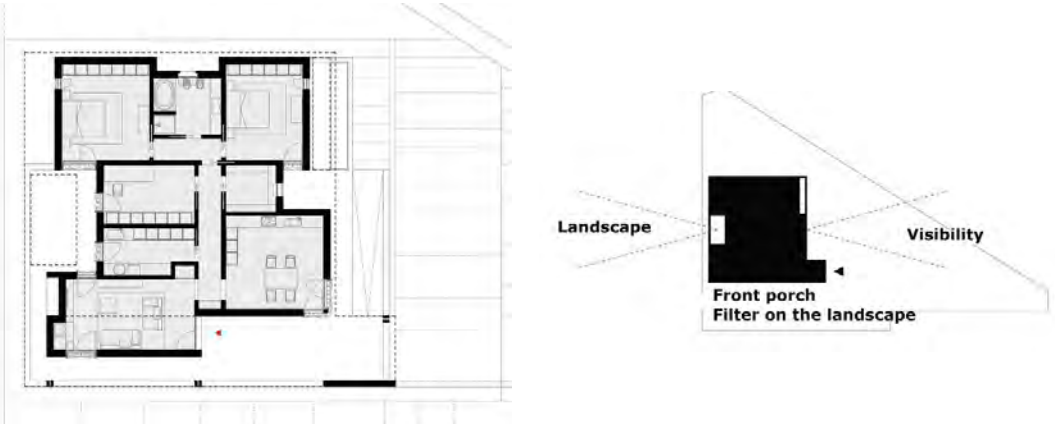


Figure 7: The Flower house, Mirandola, Modena, (KM429 Architects). Floor plan and visual layout. The house is spread on over one compact ground-floor, typical of the places. In addition to the porch on which the living room and kitchen overlook, two loggias have been created to the east and west, marked by the presence of green flowerbeds.

The FLOWER HOUSE for a family of three, consists of a living room, kitchen-dining room with pantry, boiler room-laundry, three bedrooms, a bathroom and porch. The layout comprehends dedicated views from the internal rooms to outdoor spaces, that makes the architecture changing during seasonal changes. In addition to the porch on which the living room and kitchen overlook, two "intimate" loggias have been created to the east and west, marked by the presence of green flower beds, where the property can stay in total privacy, giving itself emotions of peace and relaxation, during family banquets (FIG.7).

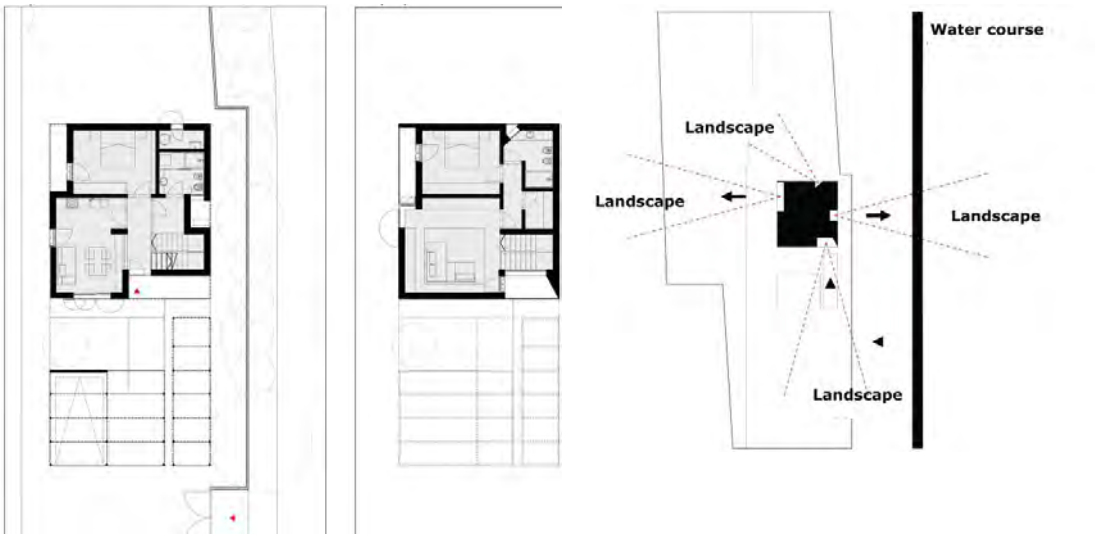


Figure 8. The House of valley, Novellara, Modena (KM429 Architects). Floor and first plan, visual layout. The house has a compact form where the functional distribution element is reduced to the minimum surface. This choice is due on the one hand to the containment of economic costs and on the other hand aimed at maximizing the effects of thermal and acoustic insulation. Landscape, light, water and wood are the project materials

The compact shape and volume of the HOUSE OF VALLEY is spread over an area of approximately 9.15 meters x 8.40 meters with a maximum ridge height of 8.80 meters, taking up the characteristics of two-pitched roof rural buildings typical of these areas (FIG.8).. To confirm the typology of the previous building and of the Reggio Emilia rural settlements, it is spread over two levels and an attic. The main services are located on the ground floor, such as the kitchen, the bathroom, the boiler room and the cellar with the addition of a bedroom, while on the second floor the living area and another bedroom with bathroom and closet.
For the HOUSE IN THE POPLAR design (FIG.9)., the wide plot of land, bordered by a watercourse, allowed to design a single-floor building with a double pitch roof. To reduce the visual impact of the new building, the project include a T-shaped floor plan, allowing for a better orientation of the rooms, each with a different destination. the large stained glass windows in the living room permit to further enlarge the space, constantly mutating during the day. Designing and building a house in the countryside of Veneto means to interact with the building techniques of the traditional rural constructions,

choosing specific materials and recalling shapes and suggestions Some typical agricultural components, such as the spontaneous vegetation next to the porch and the wooden overhanging roof are used as solar protection devices.

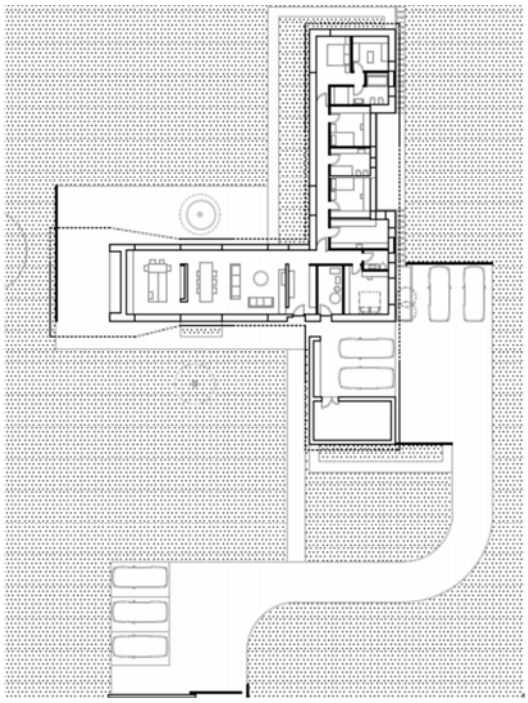


Figure 9. House in the poplar. To reduce the visual impact of the new building, the project include a T-shaped floor plan, allowing for a better orientation of the rooms. The house is characterized by a deep continuity between the internal and the external spaces and the generous natural lighting characterize the interior spaces.

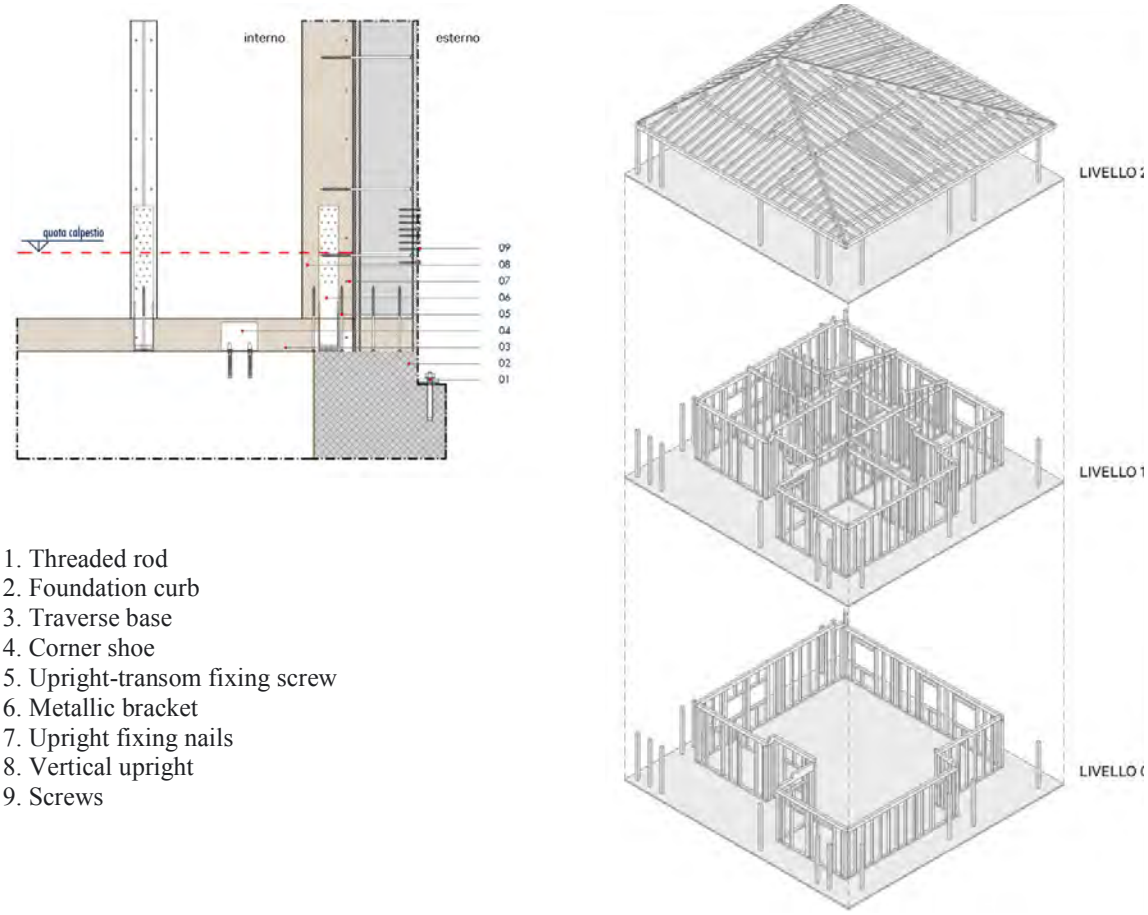
Technologies

A great attention is given to the use of high – efficient technologies both in terms of sustainability than in cost – benefit evaluation. Moreover the projects' materials and surfaces have been chosen from a careful study of the site, merging the traditional and the contemporary construction techniques.

Residential rural houses are built mainly using wooden dry – technologies, without the use of water in the assembly process, by layering materials on a resistant internal frame. This construction method, has very ancient origins, and this is the first reason of its employment, besides of the recycling, optimization and respect of times/costs, construction site safety, speed, lightness.

A first family of houses, such as 8 House, flower and house of valley houses are built with wooden frame structure (FIG.10), with wooden fiber coating insulation, reaching energy A - class. In these case studies, the envelope is designed to fulfill low U-value standards. A typical layer composition is internal insulation is 8 cm of rock wool, density 50 Kg / mc and an 8 cm panel of wood fiber density 140 Kg / mc. The wall is then closed and braced by wooden - flake panels (Fig.11). The external insulation, cladding, in high-density wood fiber, for a total thickness of 4 cm, completes the stratigraphy. Besides of its structural and thermal properties, the wall is only 190 cm

thick: this is one of the most advantages of using dry technologies such as platform frame where, the use of a high – efficient thermal insulation allows to reach optimum results with very small thickness. All the external walls are completed by internal metal frame and double wooden slabs, to constitute a technical compartment for the incorporation of electrical and plumbing systems.



1. Threaded rod
2. Foundation curb
3. Traverse base
4. Corner shoe
5. Upright-transom fixing screw
6. Metallic bracket
7. Upright fixing nails
8. Vertical upright
9. Screws

Figure 10. In the 8 House, the wooden fir lamellar wood frame is made of uprights and crosspieces with base beam 16x10 cm, upper beam 16x10 cm, uprights and crosspieces 16x6 cm.

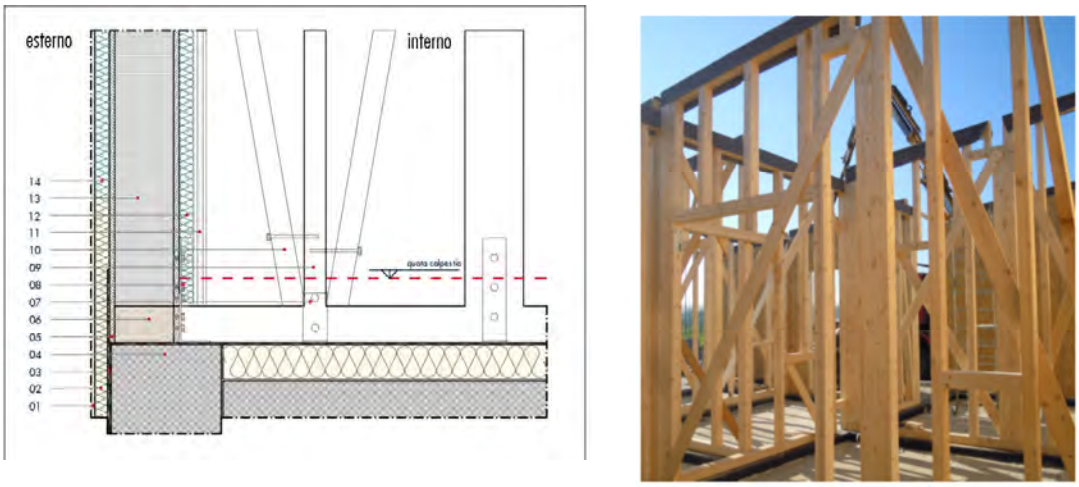


Figure 11. Flower House. High performing wooden – stratified layer envelope is made of: 01 External thermal insulation wooden fiber cm 4 Thermal coat in wood fiber with shaving 02 XPS insulation layer 03 Waterproofing sheath 04 Concrete foundation 05 OSB multilayer panel 06 Lamellar starting crosspiece 07 L shaped metallic stirrups 08 Torx screws 09 Upright 10 Bracing 11 Double plasterboard panels 12. Internal rock wool insulation layer 13. Insulation inside the frame 8+8 cm wood fiber and rock wool.

The roof structure (Fig. 12) is primary beams and secondary joists in fir lamellar wood, laminate, sanded and finished with water varnish. Roof external thermal insulation is double layer of wooden fiber panel, medium density 160 mm and high – density 40 mm.

Figure 12. 8 House. The roof structure.

A second group of case studies is made by concrete technologies. As it can be seen from the section (FIG 13) a high – efficient envelope both in terms of thermal insulation and in thermal inertia is designed.
Designing and building a house in the countryside of Veneto means to interact with the building techniques of the traditional rural constructions, choosing specific materials and recalling shapes and suggestions.. The project's materials and surfaces have been chosen from a careful evaluation of the site. The building reminds the

atmospheres of these places and the chromatism of the surrounding environment. The external concrete walls are characterized by a rough surface obtained with a special formwork that has the print of a typical cane field that can be found in the countryside of Veneto.

The roof of the living space is realized with timber beams recovered from the demolition of the decks of ancient villas.

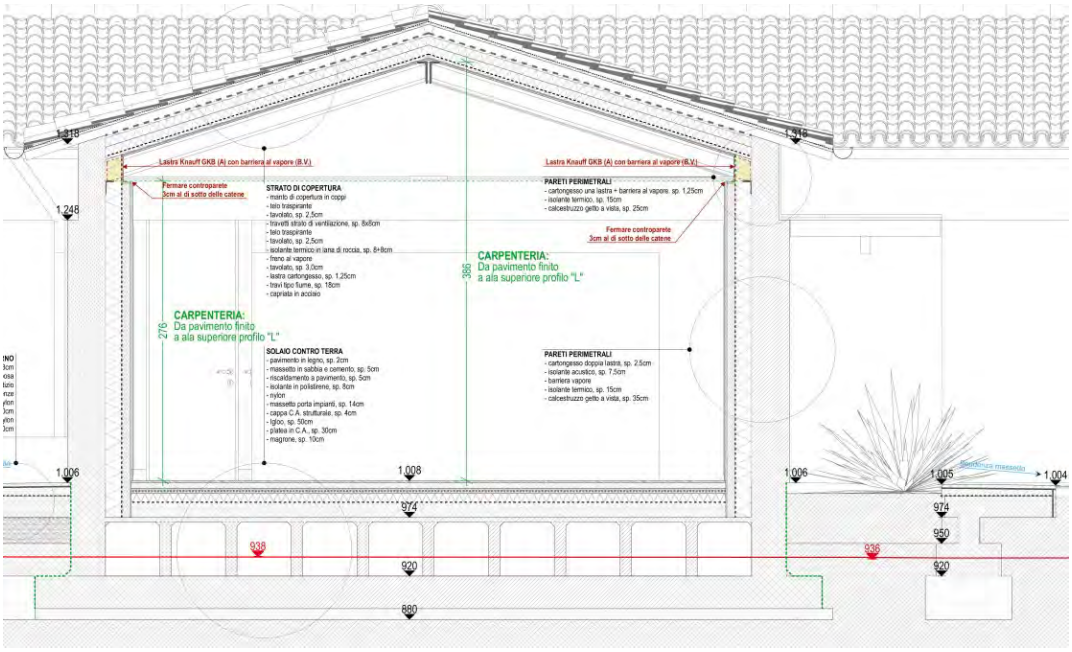


Figure 13. House in the poplar (MIDE Architects). And construction section. The external envelope is, from internal to external, ma de of: double drywall slab 2,5 cm, thermal insulation rock wool 7,5 cm, vapor barrier, thermal insulation rock wool 15 cm, exposed concrete wall 35 cm.

Energy efficiency

All the case studies are labelled in A4 class that means the most performant energy class according to Italian energy efficiency standards. The estimated annual overall

energy consumption ranges between 23,13 (House of poplar) and 41,54 Kwh/m^2/year (8 House). In wooden frame buildings (8 house, flower house, house of valley) the electricity production is made through photovoltaic installation, with a peak power of 3.00 kWp. The system is on the roof, exploiting the favorably exposed pitch, and consists of 1 photovoltaic generator and 12 polycrystalline silicon photovoltaic modules distributed over an area of 21 square meters. The production is estimated at 3300 kWh per year.

CONCLUSIONS

Designing high – efficient rural buildings, by introducing innovative methodologies and techniques, allows to introduce experimental contents - both in architectural then in technical issues - in reconstructing rural settlements.
In this paper, innovative residential architectures has been presented, showing how a modern language can be integrated into very delicate rural contexts and rural identity can be re- interpreted with sustainable -construction systems.
The research was carried out to investigate possible methods, addresses and examples for the valorization, enhancement and reconstruction of the rural landscape in the lower Pianura Padana, pursuing a twofold objective: on the one hand to orient the transformations by new languages , on the other hand promoting a "landscape vision" of the rural territory with integration between modern architecture and agricultural world.
A reconstruction cannot be limited to re-propose the pre-earthquake or historical state of affairs, but must seize the opportunity to offer to improve the rural landscape as a whole: improve the heritage from the point of view of seismic safety and energy efficiency.
Designing small rural architectures might be seen above all as a possible opportunity for the redevelopment and recreation of new rural landscape in the portion of the territory included in the network.
Starting from the concise and expeditious analysis of the characteristics of the landscape, of the heritage and of the resources that constitute the identity of the territory, the individuation of upgraded architectural and technical requirements has been the starting point of the design concept.

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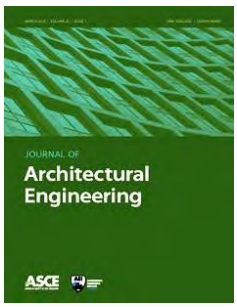

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