HABILITATION THESIS

Different Approaches of Energy Efficiency, Applied to the Built Environment

Domain: Architecture

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This thesis represents the main results of more than a decade of research on energy efficiency, in various approaches: architectural projects and interventions, analysed and detailed through scientific works; standards and legislation introspection, on international and national level; student involvement in competitions related with sustainable issues and built environment; possible future directions of applied technical solutions. Even if it seems a one-person work, there are many people in the backstage, influencing and supporting it, with useful advice that inspired and motivated me.

My first thanks go to Dragos Bocan, long life partner, best friend and colleague, for infinite constructive dialogues on all levels (professional, scientific and academic), transforming visions and ideas into qualitative design projects (most of them built), articles, competitions and students experiences.

Secondly, I owe a big thank you to Alexandra Keller, my very good friend and colleague, for her never-ending support and overwhelming kindness. Perseverant and always open for new introspections, she continues to be a constant help in my academic work, assisting me in all disciplines. The common participation to many conferences meant an enriched experience and multiple new connections.

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If I forgot to mention someone, I apologize.

And finally, to my family, for understanding me with enduring patience, endless thanks!

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SYMBOLS & ABBREVIATIONS

SYMBOLS

^{0} C – temperature (degree Celsius)
CO_{2eq}/m^2/year –Carbon Dioxide Equivalent per square meter per year
CO_2 kg/m^{2}a – kilograms of Carbon Dioxide emissions per square meter per year
g-value – total solar energy transmittance through glass factor
h – duration, time (hours)
lx – illumination (lux)
λ (W/mK) – lambda, the material's thermal conductivity (Watts per meter-Kelvin)
J/kg*K – heat capacity (Joule per kilogram-Kelvin)
kg/m^3 – density (kilogram per cubic meter)
kWh/m^2 – energy or heat demand (kilowatt-hour per square meter)
kWh/m^{2}a – energy demand / consumption (kilowatt-hours per square meter per year)
m^2 – area (square meter)
m^{2}K/W – R-value, thermal resistance (square meters Kelvin per Watt)
m^3 – volume (cubic meter)
m^3/h.p.p – air consumption (cubic meters per hour per person)
$q4 < 0{,}6\ m^3/(h\ m^2)$ – air permeability in French regulation, for a passive house
W/m^{2}K – U-value, heat transfer coefficient (watts per square meter Kelvin)

ABBREVIATIONS

AH – Active Jouse
AHA – Active House Alliance
AI – Artificial Intelligence
ASC – Architecture Student Contest
BREEAM – Building Research Establishment Environmental Assessment Method
CCUA – Centrul de Cercetare în Urbanism și Arhitectură (Research Center on Architecture and Urban Planning)
CHP – Combined Heat and Power
CLT - cross-laminated timber
CO_2 – carbon dioxide
COP – Conference of the Parties
DF – Daylight Factor
DGNB – Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council)
DIN - Deutsches Institut für Normung (German Institute for Standardization)
EN – European Norm
EEWärmeG – Erneuerbare-Energien-Wärmegesetz (Renewable Energies Heating Act)
EnEG – Energieeinsparungsgesetz (Energy Saving Act)
EnEV – Energieeinsparverordnung (Energy Saving Ordinance)
EGD – European Green Deal
EPBD – Energy Performance of Building Directive
EPC – Energy Performance Certificate
EU – European Union
ETICS – External Thermal Insulation Composite System
FAST – Festival for Architecture Schools of Tomorrow
GBC – Green Building Council
GHG – Greenhouse Gas
HVAC – Heating, Ventilation, and Air Conditioning
ICSA – International Conference on Structures and Architecture
ISO - International Standard Organization

IT – Information Technology
KfW - Kreditanstalt für Wiederaufbau (Credit Institute for Reconstruction)
LCA – Life Cycle Assessment (or Analysis)
LCC – Life Cycle Cost
LCCA – Life Cycle Cost Analysis
LEED – Leadership in Energy and Environmental Design
MOPA – Multi-Objective Parametric Analysis
NP – Normativ de proiectare (Design Norm)
NZEB – Nearly Zero-Energy Building
OAR – Ordinul Arhitecților din Romania (Romanian Order of Architects)
PH – Passive House
PHI – Passive House Institute
PHPP – Passive House Planning Package
PROHITECH – Protection of Historical Constructions
PV – Photovoltaic
PVC – Polyvinyl chloride (synthetic polymer of plastic)
RUR – Registrul Urbaniștilor din România (Romanian Registers of Urban Planners)
SAHC – Structural Analysis of Historical Constructions
SDG – Sustainable Development Goal
SG – Saint-Gobain
STAS – Standard de stat (State's Standard)
VIP – Vacuum Insulation Panel
UN – United Nations (organization)
ZEB – zero-emissions buildings
WMCAUS – World Multidisciplinary Civil Engineering, Architecture, Urban Planning Symposium

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A1. ABSTRACT

Started in 2001, the academic activity of the candidate represents a continuous evolution of the university studies, related with her interests on a popular topic, rehabilitation of the built environment, with a large-scale applicability and considering a sustainable framework. The PhD Thesis of the candidate, defended in October 2013, was developed under the coordination of professor Valeriu Stoian, proposing a light concrete attic solution for prefabricated housing blocks, along with their rehabilitation, in line with the European good-practice examples. An appropriate attic solution with rapidly assembled modular solution, light and performant materials was low-cost implementation was submitted, based on thoroughly analysis of similar interventions, including even a laboratory experiment on the connection between the new column and existing building.

Through design and several other actions, the candidate's post-doctoral activity consists of her perpetual involvement into the energy efficiency field and current legislation, along with the membership to the most important professional associations and representation in different boards / committees. The most relevant and original research works on the buildings' energy efficiency applications and specific norms is presented in Chapter B, while future directions of the candidate's scientific, professional and academic career represent Chapter C.

The experience acquired in the field of urban planning, architecture and interior design was the main support for the academic itinerary, considering a multitude of projects for different functions, urban plans and competitions. Regular trips to the most important international fairs related with her interests were methods to keep up with latest trends and technological progress in the domain. Multiple disciplines such as Architectural Design Studio, Urban Planning, Legislation, Construction Materials, Building Physics, NZEB and certification systems, along with diploma projects, dissertations and PhD thesis guidance represents the teaching activity. Other specific educational activities are summer practices, student contests, exhibitions, admission and graduation committees, partnerships and Erasmus+ mobilities, grants, scientific conferences and publications.

The built environment and its sustainability represent a major influence on human existence and the living conditions on this planet, the industrialisation period being a starting point for groundbreaking discoveries, economic and social development. Energy issues are strongly connected with the building industry, leading to inhabitants' comfort and its many ties with the indoor and outdoor climate. Thermal comfort, building envelope, building services, construction materials – all of them mean consumption of resources and the new concepts like recycle and reuse, life cycle assessment, passive / active measures are the new field's directions.

Starting from the leading companies in construction and their capacity to involve students in research and experimental projects, during the last decade the candidate developed many partnerships through presentations, demonstrations and students' competitions, the most innovative ideas being presented into scientific conferences and awarded on national and international stages. The BAUMIT partnership' s competitions continued the candidate's PhD research on prefabricated blocks thermal rehabilitation, related with Building Physics disciplines, reaching four different editions. The annual international architecture student contest, connected with multiple disciplines within the 4th year of Architectural studies, organized by the Saint-Gobain company, within their sustainable pillars, specific technical parameters and judging criteria, have reached the third participation from the candidate' students under her teaching team supervision.

While common buildings were studied throughout the previously mentioned activities, the built heritage interventions were more connected with the professional practice of the candidate, also concluded in scientific papers. A historical classic style monument, real-life project, was a perfect case-study for energy-efficiency analysis. A brutalist educational construction was another introspection done within the academic framework, with students, presenting different, but all possible approaches on this typical design.

The close relation between thermal rehabilitation and structural strengthening, especially for older buildings, was surveyed during a PhD thesis development (author Dragos Bocan), including laboratory tests on masonry specimens, comparisons between different types of insulating materials, cost scenarios, proper reinforcements and even a closed pattern building block energy analysis as an urban scale intervention.

The second part of this thesis focuses on the specific regulations, applied on energy-efficiency, with multiple analyses on different levels, the candidate does several comparisons. The first one presents the more general actions taken from global to national level (with Europe and Germany as intermediate steps), being followed by specific norms on the thermal

transmittance limited values for the envelope's components. Then, the European successive EPDBs and third-party certification systems are shown, along with the contemporary strategies, from passive to active concepts, applied in Germany.

The candidate's involvement into this continuous evolution of policies, "green" developments and various constraints is reflected in designed and built projects, within her professional studio. Optimised solutions, energy calculations, analyses with specific software became subjects of scientific research and public visibility, through presentations in conference and architectural competitions. Built examples of passive houses were visited, during their execution, with her students, while the active house principles became a major focus for the candidate.

A difficult relationship between national standards and daylight criterion from the previously detailed certification systems was presented as a future subject for profound studies connecting the urban planning, sunlight provision and sustainability. Digital tools from different window providers offer support for designers (specialists and students) during preliminary phases of any project to improve the lighting conditions.

Countless possible studies on energy-efficiency issues, applied on different scales, are listed in the final chapter by the candidate: urban layouts, high performance construction components and materials (including recycled ones), retrofits of existing buildings, passive and active means, higher quality standards, guidelines, methodologies and digital tools, innovative modular homes, step-by-step approaches and large-scale solutions, off-grid ready, renewable energy-efficient solutions and systems, valuable architecture with built-in equipment and technology, accessibility for all to co-exist.

As a practitioner architect and a dedicated teacher, the candidate will carry on experimental and theoretical academic approaches on design, sharing her expertise to the students, academic community and other interested people. The real value of the performed studies and research projects is revealed through her publications.

A2. REZUMAT

Începută în anul 2001, activitatea academică a candidatei reprezintă o evoluție continuă a studiilor universitare, corelată cu interesele ei asupra unui subiect bine-cunoscut, reabilitarea mediului construit, cu aplicabilitate la scară largă și luând în considerare un cadru mai amplu, sustenabil. Teza de doctorat a candidatei, susținută în octombrie 2013, a fost elaborată sub coordonarea profesorului ing. Valeriu Stoian, propunând o soluție de mansardă din beton ușor pentru blocuri de locuințe prefabricate, împreună cu reabilitarea acestora, în conformitate cu exemplele de bune practici europene. A fost dezvoltată o soluție adecvată de mansardă cu soluții modulare asamblate rapid, materiale ușoare, performante și implementare cu costuri reduse, bazată pe analiza amănunțită a unor intervenții similare, experimentând în laborator un sistem de prindere a bazei noul stâlp de clădirea existentă.

Prin proiectare și alte câteva acțiuni, activitatea post-doctorală a candidatei constă în implicarea sa perpetuă în domeniul eficienței energetice și al legislației actuale, împreună cu apartenența la cele mai importante asociații profesionale și reprezentarea în diferite consilii / comisii. Cele mai relevante și originale lucrări de cercetare privind aplicațiile eficienței energetice a clădirilor și legislația specifică sunt prezentate în Capitolul B, iar direcțiile viitoare ale carierei științifice, profesionale și academice reprezintă Capitolul C.

Experiența dobândită în domeniul urbanismului, arhitecturii și amenajărilor de interior a constituit principalul suport pentru parcursul ei academic, având în vedere multe proiecte cu diferite funcționalități, planuri urbanistice și concursuri. Deplasările regulate la cele mai importante târguri internaționale legate de interesele candidatei au fost metode pentru a fi la curent cu cele mai recente tendințe și progrese tehnologice în domeniu. Discipline multiple, precum Proiectarea de arhitectură, Proiectele de urbanism, Legislație, Materiale de Construcții, Fizica Construcțiilor, NZEB și sisteme de certificare, alături de proiecte de diplomă, disertații și îndrumare de teze de doctorat, reprezintă activitatea didactică. Alte activități educaționale specifice sunt practicile de vară, concursurile studențești, expozițiile, comisiile de admitere și absolvire, parteneriatele și mobilitățile Erasmus+, contractele de cercetare, conferințele și publicațiile științifice.

Mediul construit și sustenabilitatea acestuia reprezintă o influență majoră asupra existenței umane și a condițiilor de viață de pe această planetă, Revoluția industrială fiind un punct de plecare pentru descoperiri inovatoare, dezvoltare economică și socială. Problemele legate de energie sunt strâns legate cu industria construcțiilor, ducând la confortul locuitorilor și la numeroase relaționări ale acestuia cu climatul interior și exterior. Confortul termic, anvelopa și instalațiile clădirii, materialele de construcție – toate acestea implică consum de resurse, iar noile concepte precum reciclarea și reutilizarea, evaluarea ciclului de viață, măsurile pasive/active reprezintă noile direcții în acest domeniu.

Pornind de la companiile de top din construcții și capacitatea lor de a implica studenții în proiecte de cercetare și experimentale, în ultimul deceniu candidata a dezvoltat numeroase parteneriate prin prezentări, demonstrații și concursuri studențești, cele mai inovatoare idei fiind prezentate în cadrul conferințelor științifice și premiate la nivel național și internaționale. Competițiile in parteneriat cu compania BAUMIT au continuat cercetarea doctorală a candidatei privind reabilitarea termică a blocurilor prefabricate, relaționată cu disciplina Fizica construcțiilor, având patru ediții diferite. Concursul internațional anual pentru studenții la arhitectură, conectat la mai multe discipline în cadrul celui de-al IV-lea an de studii de arhitectură, organizat de compania Saint-Gobain, plecând de la pilonii declarați de sustenabilitate, parametri tehnici și criterii de jurizare specifice, a ajuns la a treia participare a studenților, sub coordonarea cadrelor didactice conduse de candidată.

În timp ce clădirile comune au fost studiate pe parcursul activităților menționate anterior, intervențiile asupra patrimoniului construit au fost mai mult legate de practica profesională a candidatei, concluzionându-se și prin lucrări științifice. Un monument realizat în clasic, proiect real, a fost un studiu de caz perfect pentru analiza eficienței energetice. O construcție educațională „brutalistă" a fost o altă introspecție realizată în cadru academic, studenții prezentând abordări diferite, dar toate posibile, asupra acestui design tipic.

Relația strânsă dintre reabilitarea termică și consolidarea structurală, mai ales la clădirile istorice, a fost analizată amănunțit pe parcursul dezvoltării unei teze de doctorat (autor Dragoș Bocan), incluzând teste de laborator pe mostre de zidărie, comparații între diferite tipuri de materiale izolatoare, variante de cost, armare adecvată și chiar analiza energetică a unui cvartal construit închis ca intervenție la scară urbană.

A doua parte a acestei teze se concentrează pe reglementările specifice, aplicate în domeniul eficienței energetice, cu analize multiple pe diferite niveluri, candidata efectuând mai multe comparații. Prima prezintă acțiunile mai generale întreprinse de la nivel global la nivel național (cu Europa și Germania ca niveluri intermediare), fiind urmată de norme specifice privind valorile limită admise ale transmitanței termice pentru componentele anvelopei. Apoi, sunt prezentate EPDB-urile europene succesive și sistemele de certificare de la terți, alături de strategiile contemporane, de la concepte pasive la active, aplicate în Germania.

Implicarea candidatei în această evoluție continuă a politicilor, dezvoltărilor „verzi" și a diverselor constrângeri se reflectă în proiectele create și realizate, în cadrul biroului său profesional. Soluțiile optimizate, calculele energetice, analize cu programe digitale specifice au devenit subiecte de cercetare științifică și expunere publică, prin prezentări la conferințe și concursuri de arhitectură. Exemple construite de case pasive au fost vizitate, în timpul execuției, împreună cu studenții săi, în timp ce principiile casei active au devenit un punct central de interes pentru candidată.

O relație dificilă dintre standardele naționale și criteriul luminii naturale din sistemele de certificare detaliate anterior a fost prezentată ca un subiect viitor pentru studii amănunțite care conectează planificarea urbană, însorirea și sustenabilitatea. Instrumentele digitale de la diferiți furnizori de ferestre oferă sprijin proiectanților (specialiști și studenți) în fazele preliminare ale oricărui proiect pentru îmbunătățirea condițiilor de iluminare.

Nenumărate studii posibile legate de eficiența energetică, aplicate la diferite scări, sunt iterate în capitolul final de către candidată: amenajări urbane, componente și materiale de construcție de înaltă performanță (inclusiv cele reciclate), reabilitări ale clădirilor existente, mijloace pasive și active, standarde mai bune, ghiduri, metodologii și instrumente digitale, case modulare inovatoare, abordări treptate și soluții aplicate pe scară largă, independente energetic, arhitectură de calitate cu echipamente și tehnologie integrată, accesibilitate pentru toți.

În calitate de arhitect practicant și dascăl dedicat, candidata va continua să abordeze în mediul academic, experimente și teorii privind proiectarea, împărtășindu-și expertiza cu studenții, comunitatea academică și alte persoane interesate. Adevărata valoare a studiilor și proiectelor de cercetare efectuate se reflectă prin publicațiile sale.

B. SCIENTIFIC, PROFESSIONAL AND ACADEMIC ACHIEVEMENTS

"Designing means dancing in shackles" architect Walter Gropius, founder of the BAUHAUS movement

1. INTRODUCTION

Becoming a teacher right after graduating the university studies, meant a continuous progress and necessary research to educate other students. Two years later, the candidate became a PhD Student under the coordination of Professor Valeriu Stoian from the Civil Engineering Faculty. The first chosen subject, about architectural and structural rehabilitation of existing water towers, was changed few years later due to the growing interest of the candidate on another current topic, regarding the possible sustainable rehabilitation of prefabricated housing blocks with a light concrete attic solution. The thesis was defended in October 2013, at Polytechnic University of Timisoara ([1]).

Starting from a problem of a construction stock built mostly between 1960-1990 that needed improvements, the PhD thesis proposed a solution for the rehabilitation of these "communist" blocks completely different from the current practice in Romania, but in line with what other European countries started as experiments and good-practice examples.

A great number of cities from our country have significantly increased their population during the communist regime, due to many prefabricated blocks, quickly erected, most of them with five or eleven stories. Even today, they are still in use, representing an important part of the 20th century urban history. Before the 1989 Revolution, their aspect was quite uniform, due to a single national institute for design and industrialized execution. After this important moment, along with the ownership transfer from State to individual, the desire to improve private comfort became an issue, starting from punctual interventions to more general ones (ETICS systems, pitched roofs, attics). At a larger scale, the "grey" image (original concrete panels) changed, but not always considering the common interest. Different roof shapes, colours and materials appeared on the same building (Fig. 1-1). The National Rehabilitation Program through financial involvement in envelope refurbishments was meant to bring cheaper living costs. Another possibility to minimize the occupants' expense on these construction works was to create new apartments above the existing terrace by the real estate developers, usually through a maximum saleable area and very cheap execution, regardless of the final architectural image.

Fig. 1-1 Existing examples of prefabricated blocks with added pitched roofs (candidate's photos ©)

An alternative vertical extension came as a completely different solution for one of the most popular types of "commieblock", with comfortable open space penthouse apartments complying with legal constraints – structural resistance, lightweight elevator, energy efficiency, fire safety, all together with a better appearance. A large-scale operation on all similar buildings could be developed with the proposed materials (modulated, prefabricated, energy efficient and light), along with the flat roof shape to support solar power equipment (Fig. 1-2).

Fig. 1-2 The existing and proposed facades, for the studied block and ensemble into the PhD thesis (candidate's images ©)

The structural innovation consisted of a concrete frame with 3 columns and 2 beams, all having a small trapeze section and placed exactly on the below concrete panels grid. The outside elements (2 inverted L columns), visible from the street level, gave a dynamic rhythm on the upper part of the construction and were covered with an extended roof shadowing the surrounding terrace (Fig. 1-3).

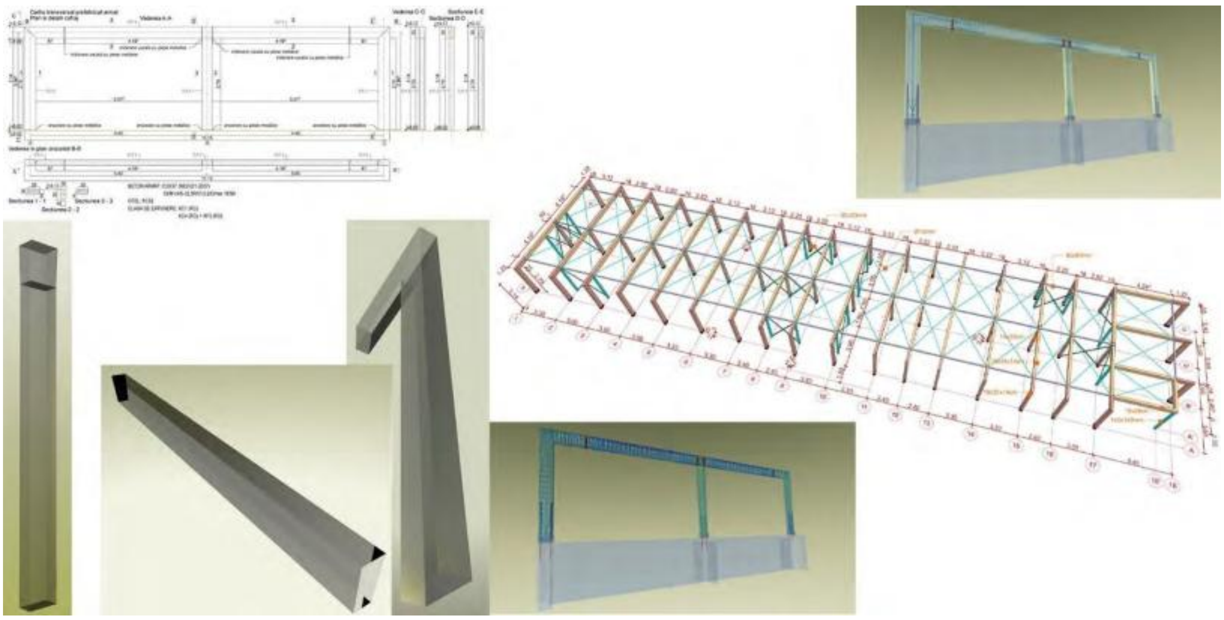


Fig. 1-3 The prefabricated frame proposed into the PhD thesis (candidate's images ©)

The connection between the existing building structure and the new elements was made through a special metallic piece, placed on the lower part of the new columns, with shoes and two chemically fixed bolts for 45 cm depth in the inner walls from the story below, leading to a rigid node, non-monolith and gaps filled with special effusive cement. Similar detail was used for the connection between the new five structural elements, to minimize thermal bridges (Fig. 1-4).

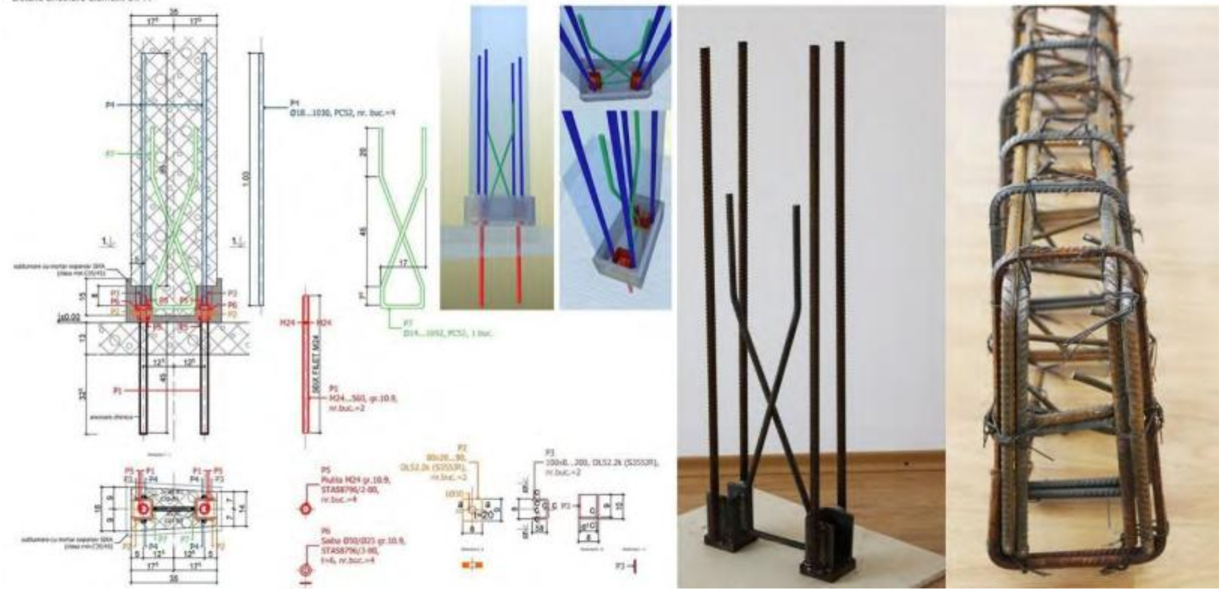


Fig. 1-4 The connection of proposed prefabricated columns from the PhD thesis (candidate's images ©)

Regarding the concrete reinforcement studied solutions, the classic one with steel bars was completed with a mixture of steel bars and corrugated steel fibres and only corrugated steel fibres. The experimental tests done in the laboratory focused on the behaviour analysis of the rigid and non-monolithic node joint between old and new elements, with a partial column and concrete bolsters replacing existing structure. 6 tests were performed on a closed metallic frame stand with 2 strain stamps and 3 deformation captors to measure the cyclic loading of each column to forces up to 11000 daN, showing a better performance of the classic and mixt reinforcements than the only fibre one. But all of them yielded at a higher level than anticipated, proving the opportunity for a solution with minimum interference for exiting building and inhabitants living in over 85000 prefabricated constructions (Fig. 1-5).

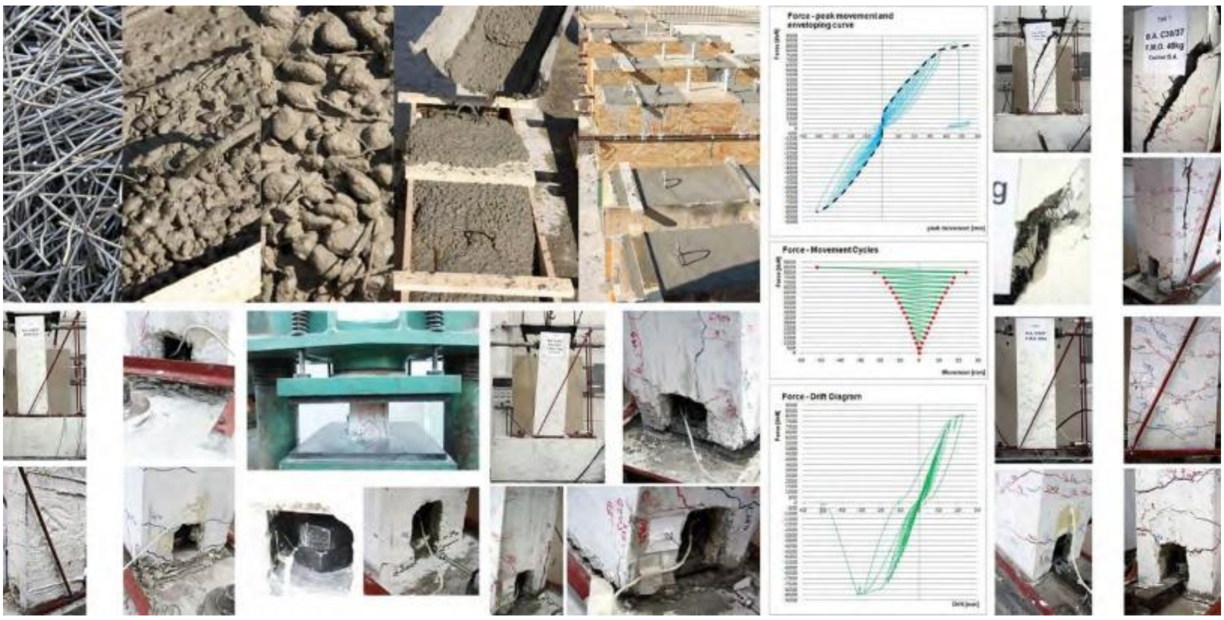


Fig. 1-5 Images and captions from the experimental works performed during the PhD thesis (candidate's images ©)

After defending the PhD Thesis, the candidate elaborated a conclusive article summarizing the entire research, its following main contributions being listed here, showing that the candidate's focus remained in the same field, of energy and efficiency for the existing constructions:

- highlighting the importance of rehabilitating blocks of flats from large, prefabricated concrete panels based on the analysis of similar intervention works
- a new holistic (urban, architectural, structural) appropriate attic (overstorey) solution with rapidly assembled and energy-efficient prefabricated building materials, offering a completely different aspect from the usual solutions

- a lightweight precast reinforced concrete structure with a rigid base, non-monolith concrete and specially created fastening parts, allowing high repeatability and low costs of implementation
- laboratory experiments on the column-base joint system, with three reinforcement options and the interpretation of the results.

The present document summarizes an important part of the research done by the candidate after this date. The selected post-doctoral activity considered to be relevant and original was developed within the main theme of energy efficiency applied on built environment, also considering national or international specific regulations (as presented in Chapters 2 and 3).

The academic activity was constantly supported by the professional projects and actions, all of them representing a full package of knowledge on energetic field and current legislation. The involvement in representative structures of professional association is also very important for the interests of the candidate.

The candidate is member of the most important professional associations in the field of architecture and urban planning: Romanian Order of Architects (OAR) and Romanian Registry of Urban Planners (RUR). For the first organization, the candidate was chosen representative in the territorial subsidiary for eight years and another eight in the national council. During the first mentioned period, a brochure and two books were published together with other fellow architects for practicing members and investors, as author of some chapters (Exercising the profession of an architect, 2005 & 2006). Also, representing the Faculty of Architecture and Urban Planning, the candidate is an active member of Technical Commission for Territorial and Urban Planning from Timisoara town hall (since 2013) and from Timiș County Council (2016-2025).

The professional activity of the candidate evolved simultaneously with the academic itinerary, offering support to acquire experience in the field of urban planning, architectural and interior design. After a two-year internship at one of the most renowned design offices in Timisoara, she started a small design studio, together with her life-partner Dragos Bocan, called Atelier CAAD Ltd, where several projects were developed, such as:

- New individual and collective houses, health and sport facilities, industrial halls and commercial centres

Interventions on existing buildings – also for housing, health care, industry and commerce

- Interior design for living, offices, selling and eating spaces
- Different scale urban plans for residential and complementary functions, industrial and deposit warehouses, commercial and services areas
- National or international competitions.

Some of the projects mentioned above were exhibited in national or regional events, sometimes awarded with prizes and nominations, their value being recognized and appreciated.

The candidate organised regularly excursions to some of the most important architectural fairs, considering them viable methods to keep up with the new trends in her interests' domain and international actions:

- **BAU**, the World's Leading Trade Fair for Architecture, Materials and Systems, held every two years in München. Architects, planners, investors, representatives of the industrial and commercial sectors, the building trades involved in the international community for planning, building and designing buildings come together to find out the latest techniques, materials and applications that can be used in actual practice.
- **Salone del Mobile** (known as Milan Design Week), the largest and most prestigious furniture and design fair, held annually for over five decades, showcasing the latest innovations and trends in furniture, lighting, textiles, and decorative items. The festival includes exhibitions, installations, product launches, open showrooms, tours, talks and parties along with Fuorisalone ("outside design week") – interconnected events over the entire city.
- **Mostra di Architettura di Venezia** (Venice Biennale of Architecture), an international exhibition of architecture from nations around the world, held every two years in Venice. Architectural solutions for contemporary issues concerning society, people and technology are proposed and showcased in the national pavilions in the Biennale Gardens and Arsenale, along with other local sites where new projects are presented.
- **World EXPO**, a global event that started in the 19th century showcasing symbolic buildings and innovative products from science & technology, arts & crafts, related with a historical moment and held every five years, in different places all around the planet, latest editions having designated locations. It promotes education and cooperation while reflecting each period's humankind efforts.

During 2011 - 2023 the candidate obtained the following professional certifications, attested by State:

- Energy Auditor for the Ministry of Development, Public Works and Administration (from 2011)
- Project verifier for the Ministry of Development, Public Works and Administration (from 2021) B1, Cc, D1, E, F.

Considering the continuous teaching activity since graduation, the candidate had very serious implications in different fields of education (architecture, furniture and interior design, urban planning and territorial administration) and different years of study, some of them being mentioned below:

- Architectural Design Studio (bachelor students from 3rd, 6th, 5th and 4th year of Architecture speciality), today being responsible for the whole 4th year of Architecture studies
- Urban planning projects (4th and 5th year bachelor architecture students, 1st year master students)
- Course, seminar and project on Building Physics (4th year bachelor architecture students, previously 2nd year for about five years)
- Seminar and Course on Construction materials (still teaching it, for the 1st year bachelor architecture students)
- Mechanical equipment in architecture (4th year bachelor architecture students)
- Urban planning legislation (5th year bachelor architecture students)
- Architectural legislation (5th year bachelor architecture students)
- NZEB and certification systems – theory (optional, 5th year bachelor architecture students, recently introduced)
- License design studio, unit for specific sport functions, leisure and health, (final year bachelor architecture students)
- Legislation and firm management (3rd year bachelor for Furniture and interior design students)
- Studies and documentation of urban planning and territorial development (1st year master student).

Multiple diploma projects and dissertations were guided over the last decades.

It must be mentioned that the candidate already guided three doctoral students for obtaining their Ph.D. degree at the Polytechnic University Timisoara, while other two are still developing their subjects, as listed below:

- Iasmina Apostol (Onescu), architect, PhD in Civil Engineering – research related with the earthquake vulnerability of the historic masonry buildings in the Iosefin and Fabric neighbourhoods of Timisoara
- Alexandra Keller, architect, PhD in Civil Engineering – an assessment methodology suitable for historic timber roof structures, possible to use to determine their value and vulnerability and as a decision-making tool for the planning and hierarchisation of future interventions
- Ciprian Maties, architect, PhD in Civil Engineering – research related with aspects of the buildings' energy efficiency and their impact on the environment, focusing on the European and national context, connected with the nZEB constructions criteria
- Simona Daciana Danci (Pasca), engineer, architect, PhD student in Architecture – a study on preservation of architectural heritage from traditional to modern technics
- Ioana-Antonia Tanase, interior design specialist, PhD student in Architecture – about inclusive design and the synergy of human perceptions in tangible implementations.

Along with teaching activity, more other academic duties (some of them related to the positions of head of Architecture Department and vice-dean of the Faculty of Architecture and Urban Planning) like summer practices, student architectural contests, exhibitions, partnerships, conferences, Erasmus+ mobilities, admission and graduation committees complete the educational activities.

The involvement of the candidate in several contracts and grants as director and or member developed her abilities and competences to manage future similar projects, like urban planning documentations within the Architecture Department's Research Centre CCUA and Poli-linia design studio.

More recent activities focused on the promotion of the faculty through specific publications and exhibitions regarding students' projects, anniversary and statistics for the local school of architecture, like: "Student trend" brochures, "The School of Architecture in Timisoara at the Age of 50" book, FAST event – Festival of Architecture Schools for Tomorrow.

The candidate's numerous publications and their presentations on several scientific conferences or journals show the international recognition of her activity until now, combining the academic and professional interests on the built environment and specific issues like energy efficiency and different scale possible applications for tomorrow's neutral-climate sustainable buildings, while keeping the imposed standards. The relevance of this holistic performance reflects on the candidate's teaching perpetual improvements.

The importance of the scientific activity and the recognition of the national and international activity in the field of Architecture is emphasised by the publications of the candidate.

Relevant Publications

The list of the most important 10 publications, considered to be relevant for the academic and professional achievements obtained by the candidate for the postdoctoral period, sustaining her activity presented in the Habilitation Thesis, are listed below:

1. **Bocan Cătălina**, „An "old" and new elements special joint for concrete prefabricated panel blocks" 2nd International Conference on Protection of Historical Constructions PROHITECH, Antalia, Turcia, 2014, ISBN 978-975-518-361-9, p. 877-882 ([2])

2. **Bocan Cătălina**, Bocan Dragoș, „Urban and thermal rehabilitation for concrete prefabricated panel apartment blocks - student ideas", MODERN TECHNOLOGIES FOR THE 3RD MILLENNIUM, WOS:000491484600032, ISI Proceedings, ISBN 978-88-87729-49-8,2018, -, p.185-190 ([3])

3. Bocan Dragos, **Bocan Cătălina**, Keller Alexandra, RILEM Bookseries (RILEM Bookseries, volume 18), SAHC 2018 Cusco, Structural Analysis of Historical Constructions, „Possibilities of Using Fiber Reinforced Mortar and Textile Reinforced Mortar for Strengthening Masonry Columns in Rehabilitation Projects", DOI: 10.1007/978-3-319-99441-3_177, Springer, Cham, ISBN 978-3-319-99440-6, 2019, 2518 pag., p. 1651-1660 ([4])

4. **Bocan Cătălina**, Bocan Dragoș, Keller Alexandra, „Effects of Current Sunlight Exposure Regulations on New Housing", IOP Conference Series-Materials Science and Engineering 3rd World Multidisciplinary Civil Engineering, Architecture, Urban Planning Symposium (WMCAUS Praga), DOI10.1088/1757-899X/471/8/082056, WOS:000465811804001, ISI Proceedings, ISBN 17578981, 2019, vol. 471, issue 8, 10 pag. ([5])

5. Dragos Bocan, Alexandra Keller, **Cătălina Bocan**, Iasmina Apostol, Marius Mosoarca,„Potential Results of Using Current Thermal Rehabilitation Techniques on a City Block of Timisoara and their Structural Strengthening Opportunities", IOP Conference Series-Materials Science and Engineering 3rd World Multidisciplinary Civil Engineering, Architecture, Urban Planning Symposium (WMCAUS Praga), DOI10.1088/1757-899X/471/8/082056, WOS: 000465811802088, ISI Proceedings, ISBN 17578981, 2019, vol. 471, issue 6, 7 pag., ([6])

6. **Bocan Cătălina**, Bocan Dragos, Keller Alexandra, „Energy efficiency study applied on a monumental building", Structures and Architecture-Bridging the Gap and Crossing Borders: Proceedings of the Fourth International Conference on Structures and Architecture (ICSA 2019, Lisabona), WOS:000670758600035, ISI Proceedings, ISBN 978-1-315-22912-6, 2019, vol. 1, p. 288-295 ([7])

7. Bocan Dragos, **Bocan Cătălina**, Keller Alexandra, „Adaptation of a monument building for accessibility of disabled persons, a case study", Structures and Architecture-Bridging the Gap and Crossing Borders: Proceedings of the Fourth International Conference on Structures and Architecture (ICSA 2019, Lisabona), WOS:000670758600066, ISI Proceedings, ISBN 978-1-315-22912-6, 2019, vol. 1, p. 556-562 ([8])

8. **Bocan Cătălina**, Bocan Dragos, Truta Mihnea, RILEM Bookseries (RILEM, volume 47), „The Rehabilitation and Extension of the Old Arad's Casino–Case Study" SAHC 2023 Kyoto, International Conference on Structural Analysis of Historical Constructions, DOI: 10.1007/978-3-031-39603-8_37, Springer, Cham, ISBN 978-3-031-39449-22023, 1451 pag., p. 449-462 ([9])

9. Bocan Dragos, **Bocan Cătălina**, Keller Alexandra, Gruin Aurelian, „Analysis of Thermal Rehabilitation and Seismic Strengthening Solutions Suitable for Heritage Structures", Journal of Sustainability, 2024, 16(13), 5369 Section Green Building, https://doi.org/10.3390/su16135369, 2024, vol. 16(13), 17 pag. ([10])

10. **Bocan Cătălina**, Bocan Dragos, Keller Alexandra, Springer, Cham, volume 2, „Brutalist University Building Energy Refurbishment – Case Study" 5th International Conference on Protection of Historical Constructions, PROHITECH 2025 Napoli,, WOS:001484831500063, DOI10.1007/978-3-031-87316-4_63, ISI Proceedings, ISBN 978-3-031-87315-7, 2025, 606 pag., p. 521-528 ([11])

2. ENERGY EFFICIENCY APPLIED THROUGHOUT BUILT ENVIRONMENT

"Demolition is a waste of many things – a waste of energy, a waste of material, and a waste of history", architect Anne Lacaton, winner of Pritzker Architecture Prize 2021 (together with Jean-Philippe Vassal)

2.1 Introduction

Living meant, throughout history, to develop interior spaces while protecting humans from exterior adversary conditions. The fundamental right of having a place to live is defined in the United Nations Charter, along with other basic needs like food and clothing. The level of protection offered by a building increased since the first forms of houses, with single leaf roof and wood or stone walls, without windows. The notion of personal comfort and inner habitable conditions within constructions lead to more use of energy natural resources ([12], p. 17).

From a historical point of view, the industrialisation era might be the start of energy topic, considering that around 1700 the first calculations for the heating requirements were made (before that, the Roman ducts were used in bathing facilities and floor heating) A first crisis appeared in the same century in Europe, owing to the scarcity of coal. During the 19th century the term of thermal conductivity was used, along with temperature gradient, thermal transmittance. In the same period, the photovoltaic effect was discovered by 1839, the predecessor of today's heat-pump was invented, and the first solar high-performance system was presented at the 1878 World Exhibition in Paris. The insulating glazing was patented and marketed, while at the beginning of 20th century, solar thermal collectors had a boom in USA. The first specific standards were developed (for heating requirements, boiler and radiator sizes), considering climate data and thermal insulation values for various building components. At the beginning of first world war, the energy subject was introduced in the university education of future architects and MIT developed a solar house in a research project with integral collector roof with long term storage. Trombe wall application appeared before 1960 and in the building industry sophisticated machinery for conditioning interior air regardless of the external condition, the photovoltaic panels being used by satellites. The major oil crisis from 1973 acknowledged the dependence of energy supplies on fossil fuels, the need to reduce costs and to use better construction materials and technology for building systems. Passive-houses and self-sufficient houses were introduced as viable solutions at the end of the previous century, along to more standards, directives and regulations ([13], p.111).

Along with energy issues, the term of sustainability appeared in the 18th century and since then, it was used in connection with continuous exploitation of Earth natural resources and environmental catastrophes. A milestone in the sustainability debate was in 1972 at the UN Environment Conference in Stockholm where the "Limits of Growth" study was presented, preceded by "Silent Spring" ten years before. In 1987, the Brundtland report "Our Common Future" followed by the 1992 Earth Summit in Rio de Janeiro – Agenda 21 and 1997 Kyoto Protocol Resolution (climate conference) were the main triggers that connected sustainability objectives with energy used in building. After each main historical event (natural or human caused disaster), a new sustainable concept was developed, with topics on assessments in building plus health and safety measures. Starting with construction materials, different components or equipment, spaces or functional units and even an entire building with its form and surrounding context, each of these can influence the sustainable design ([14], p. 6, 12).

Nowadays, there are some interconnected strategies that can lead to the philosophy of lifestyle and contribute to a sustainable development: sufficiency (the opposite for more & more), eco-effectiveness (about the use of resources compatible with the environment) and efficiency (less resources with more benefits) (Fig. 2-1, p. 27).

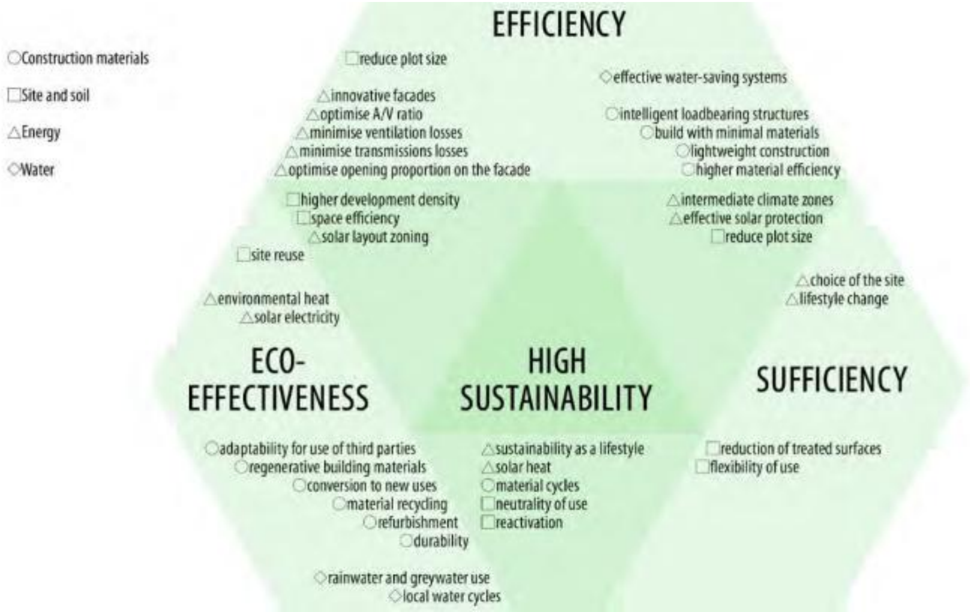


Fig. 2-1 Sustainability diagram: strategies of building to preserve resources, (candidate's image, interpreted from original source)

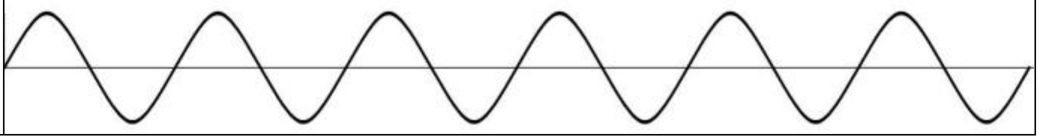
Efficiency is, first, an economic category. But, increasing efficiency and lowering costs (at the workplace, in the building and on the buildings site, in taxes, in risks, through long-term cost security and strategic competitive advantages) relate to less environmental damage by minimizing energy consumption, use of materials, toxic emissions, waste and scrap along with closing material cycles and increasing the use of renewable resources ([13], p.25).

Energy efficiency refers to consistent saving measures needed to prevent the global climate change. Strategies that can reduce the greenhouse gas emissions, increase the renewable energy sources and limit the mean temperature on Earth are proposed for implementation to diminish the melting of Alpine, Arctic and Antarctic glaciers along with the rise of the sea level and imminent floods of populated areas ([15], p. 126).

The building sector is responsible, especially in developed countries, for almost 50% of the CO_2 emissions through construction and operation of the building, some in production and transportation, the rest in its conditioning (heating / cooling, ventilation, lighting). Also, the building industry uses about 50% of the raw material processes, while producing more than 60% of the total waste. The existing building stock needs more capital invested in its refurbishments than a new building to comply with all imposed regulations ([16], p. 6, [13], p.26).

A theory developed by N. Kondratiev relates successive 50 years supercycles of economic and social development (starting the industrialisation period), covering basic needs achieved by ground-breaking innovations. The 6th wave – in progress, is dealing with global aging issues, artificial intelligence and virtual reality (Table 2-1, [13], p. 25).

Kondratiev cycle	1st cycle steam engine, cotton	2nd cycle railways, shipping, steel	3rd cycle electricity, chemistry	4th cycle mobility, petroleum, electronics	5th cycle information technology, ecology	6th cycle health-related
	analysis					**Projection*?**
peak in development	1825	1873	1913	1966	2015?	2060?
fundamental needs	making work easier	making resources available worldwide	making urban life worthwhile	fostering individuality and mobility	solving problems for our contemporaries	the human healing
comprehensive networks	trade networks	transportation networks	energy networks	communication networks	knowledge networks	virtual reality networks
groundbreaking applications	machines	locomotives, railway stations	lighting, cinema	telephone, car, television, data processing, missiles	intangible goods, information equipment and databases	general-purpose technologies
groundbreaking technologies	steam	steel	electricity	electronics	multimedia	artificial intelligence (AI)
synergy applications	consumer goods	shipping	chemistry, aluminium	petroleum products	ecological problem solutions, traffic systems	increased life expectancy opportunities, tourism

technology applications	mechanics	large drives	large-scale plants	weapons systems	security and environment technologies	biotechnology in medicine, agriculture and food, building and energy industry, environment
the grands supercycles of social and economic development						

* candidate's opinion

Table 2-1 Successive Kondratieff cycles of social and economic development (candidate's compilation from the original source)

As it is shown in the previous table, the world progress is based on a constant change in a variable context, while the built environment is developing in larger urban areas, through the largest mass migration. Inconvenient things drive to innovations and eliminating unpleasant conditions stimulate people to discover new ways of living together. The sustainable use of planet's resources may lead to surpass the habitable boxes with walls and lids ([13], p. 10).

Energy relates, without a doubt, with economic growth. The most populated countries have the lowest gross domestic products and the lowest energy consumption per individual, while the greatest energy consumers are using nearly all its resources. In the energy supply chain, more than half of it is lost during conversion and distribution. From fossil fuel to nuclear and renewable, the entire energetic system needs major changes while dealing with environmental interference (from tectonics extractions to water, air and even atmosphere's emissions). If the first ones have a longer route from point of extraction to the power station and then to the final consumer (petroleum, coal, gas, uranium), the newest ones (biomass, raw materials, renewable energies need to be stored and compatible with the existing systems. Therefore, political initiatives to support and speed up the transition are required, considering that some processes for concentration and monopolisation are technically impossible. The natural energy, coming from the sun, with its derivates – wind, waves, water and biomass – covers 15000 times more needed energy per day than what it's used from fossil fuels and atomic. In the construction sector, new building materials and methods can ease the transition to solar construction, if suited to local topographical and bio-climatic conditions. Personal and common advantages can be acquired in a shorter period, if influential players (on fields like politics, economy, culture and health) decide to be a part of this energy change ([13], p. 15, 16).

The relation between sustainability and architecture can be difficult, even if measurable local indicators can be used locally in separate buildings. Urban planning or ecology means a lot more and sometimes it is not enough to apply two or three measures like solar panels, green facades, thermal insulation that can optimise a single construction. If, the act of moving from a large city to the surrounding countryside can be seen as a personal benefit decision, inevitably supplementary costs appear from extended infrastructure, more traffic, real urban planning. A self-sufficient, decentralised construction must relate to the complexity of human behaviour and, its architectural design needs to include more than just partial aspects (photovoltaic, passive-energy building standards, heat recovery) keeping the final image in front ([13], p. 18-19).

The term "more quality of life" refers nowadays to the living space growth over the decreasing trend (in square meters) of the households. This has a great influence on the 21st century town, with an existing valuable building stock, very hard to be reproduced. Architects, property developers, residents and businesspeople must be aware of what already exists and should be preserved, by implementing sustainable strategy for adaptability, reusability and upgrades as a second chance to revive it. If the technical knowledge already exists, the decision factors (experts, upper education institutes) should be more committed and enthusiastic for the "ecological architecture".

The Earth system with its incident solar radiation as main supplier, can achieve the necessary energy only if simultaneously components from different places are put together. The built projects that can lead to a change in people's mentality are represented by simple examples, correlated with their willingness to accept the changeover of old habits actions. Plus, from an economic point of view, the possibility of saving more happens only if higher investments are made, starting with the building costs. The interest to reduce the running costs of any space (especially the living ones) is greater for the future tenants and smaller for the real property owners. But the primary discussions between the architect and the investor can foresee limited involvement (mostly financial), even if materials and technology are available, unconditioned by the local or regional context. This is why the architecture remains responsible for the spatial system in which contemporary society lives, along with its challenges.

Actions to be taken into the building industry should cover the following aspects (Club of Rome, [17]), to reach comfort, architectural quality and financial benefits with the smallest quantity of resources and energy (Fig. 2-2, [13], p. 39):

- climate protection (large percentage of greenhouse gases resulted from construction and buildings' use; operating these buildings means lots of energy consumed, including materials' production and transportation)
- resource saving (fewer building materials extracted; less generated waste; less new areas for urban planning; less average living space requirement)
- supplies preservation (lower dependencies for energy and material sources; limiting the global energy consumption)
- operation costs decreasing (for heating especially; in the rented housing sector, a raised rent doesn't mean a higher income due to expensive operation costs)
- valuable building stock (major capital investment are in housing market, with just a third of its possible profit through actual refurbishment measures)
- incentives (for balanced investment between the existing and new buildings)
- comfort and health (the indoor environment possible syndromes).

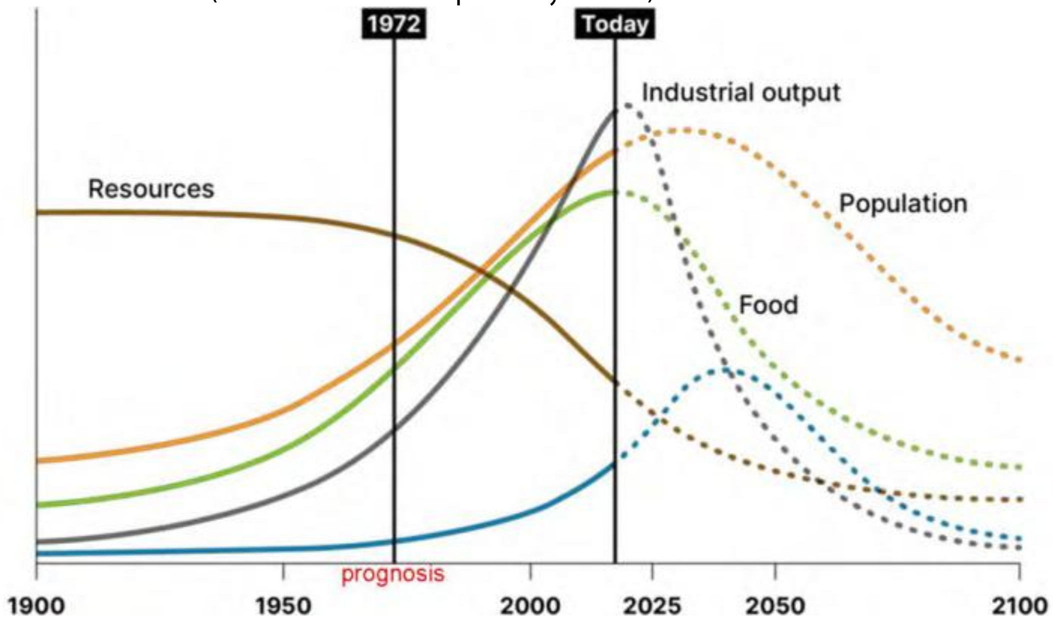


Fig. 2-2 Club of Rome prognosis on Limits of growth ([18]), updated

Comfort is a subjective perception of external parameters influencing specific conditions on the human well-being. It cannot be accurately determined, but it can offer values for the environment considered pleasant. There are physical conditions, like thermal (interior air temperature, mean enclosing surface temperature, interior air humidity, air movements), acoustic (frequencies, noise level, reverberation times), visual (lighting, contrast, angle of light, glare and luminance distribution, colours and colour rendering, reference and view of the outside surroundings), olfactive (smells, CO_2 and other gases, dust), other like air pressure and interior air static load. Intermediary conditions refer to individual aspects like clothing, activity, adaptation, acclimatisation, daily and annual rhythms, room occupancy and psycho-social features. The physiological conditions relate to gender, age, constitution, physical fitness, state of health, food intake and ethnic influences. Through vision, as the main human sensor, everybody perceives almost everything all around and completes the image with touch, hearing and smell, the feeling of hot or cold. The architecture of any specific space can create long lasting memory by stimulating many senses ([13], p. 55).

The **thermal comfort** is the most important component because it affects the human heat balance and the energy consumption of a building. A temperature of 37^0 C is needed for wellbeing, efficiency and metabolic purposes. To adjust the body temperature thermodynamics mechanisms are needed: convection, conduction, radiation plus evaporation and perspiration through a continuous exchange with the environment. While performing different types of activity (from a physical perspective), the human organism generates different levels of heat output, influencing the indoor comfortable parameters: temperature, humidity, air velocity, oxygen and CO_2 levels.

Developed algorithms, based on empirical data, can make predictions on occupants' thermal environment satisfaction in different conditions, by using two indices: predicted mean vote PMV and predicted percentage of dissatisfied PPD ([16], p.14).

The **indoor climate**, in which people spend 90% of their lifetime, must provide a superior air quality. Due to the increased airtightness of the buildings, the reduced rate of natural air exchange is compensated with mechanical ventilation. Therefore, the inner environment might present increased levels of pollutants, especially after 1950, due to the use of specific materials (volatile organic compounds VOC, solvents, formaldehyde, volatile gases, etc.) that can affect the human health. Also, very small particles and fibres (mineral, asbestos) might cause damage with minor to carcinogenic results. High values of moisture (as relative humidity parameter) favours mould and mites, while low values lead to respiratory problems. Radiation, even in small doses, represent a health hazard. For all these possible causes, imposed reference values are settled ([16], p.17).

The **outdoor climate**, connected with the occupants demands on thermal comfort, affects the technical equipment necessary to provide conditions for a comfortable space. The geographical coordinates (latitude, longitude and altitude) influence the outside air temperature, the exposure to solar radiation and its angle of incidence, the amount of precipitation. The local natural environment – ground characteristics, vegetation, the presence of water – helps also to define the outside parameters. Knowing detailed climate conditions can be very useful during early design phases when "climate responsive" criteria for different part of the world are set ([16], p.20).

There are three main parameters of a building design considered to be relevant for the energy demand in operation ([16], p. 24):

- the building form through its compactness. Although there are different definitions of this term, the building envelope enclosing, the heated or cooled volume, the net floor area, the usable area or conditioned living area must be known. A reduction of envelope area saves energy by minimising the heat loss transmission during the operation period and leads to less energy for its manufacturing.
- the building functions – a residence is used 24 hours, while the non-residential buildings operate on timetables and different interior conditions during a day, a week, a month or the whole year. The different types of uses have specific criteria to be taken into consideration like room temperature, lighting, number of occupants, occupation period, type of activity, interior heat sources.
- the inner spaces' orientation, with different effects in summer or winter, due to heat-gains, urban noise, daylight. It is recommended to place functions with internal occupancy heat-loads related with the solar radiation (so the two factors don't overlap). The window surface area and proportion have a major influence on daylight, heat-gains, heat-loss and energy efficiency, especially in well insulated buildings.

The energy consumption starts from specific requirements due to boundary conditions and user-related terms, connected with relevant energy services, independent from architectural features (Table 2-2, [13], p. 60, 61).

Requirement	Boundary conditions	Service
comfortable temperature	external temperature (^{0}C)	heating and cooling
Comfortable brightness	Brightness (lx)	Lighting
Good air quality	Air consumption (m^3/h.p.p)	Ventilation
Comfortable humidity	Humidity (%)	Humidification / dehumidification
Hot water provision	Drinking water (^{0}C)	Heating or drinking water
Electrical equipment operation	Efficiency of equipment	Electricity provision
Heating / cooling processing	Efficiency of process	Heating / cooling production process

Energy themes	Minimising energy requirement	Optimising energy supply
heating	maintaining heat	efficient heat gains
cooling	avoiding overheating	efficient heat dissipation
ventilation	natural ventilation	efficient mechanical ventilation
lighting	use of daylight	optimising artificial daylight
electricity	efficient use of electricity	decentralised electricity generation

Table 2-2 Synthesis of requirements, boundaries conditions & services energy related (candidate's compilation from the original source)

The **building envelope** plays a major role in architecture, being the connection between inner and outer space. From an artistic point of view, is defined by appearance, proportions, materials and culture. Technically, this shell protects the interior activity from exterior agents, like water (precipitations), air (wind) and sun (radiation). The growing comfort requirements, along with energy consumption has led to a big focus on the envelope, especially facades and roof. Choosing different materials, with consideration for architecture and technology, means respect for sustainability principles, not just during the construction, but also for durability and deconstruction possibilities ([13], p. 82).

There are several factors that determine the envelope design concerning energy issues (Table 2-3, [13], p. 83):

- its usage, through mandatory distinctive rules
- climatic aspects, related with a specific location
- construction configuration (loadbearing, enclosing, insulating elements and building services integration)
- legislation (international, European, national).

External influencing factors	Building envelope	Internal influencing factors
Light - intensity and angle of solar radiation - illuminance - horizon - surrounding buildings and vegetation **Air** - temperature and humidity, even precipitation - velocity and wind direction - quality - sound **Ground** - temperature, moisture and thermal mass	**Properties** - transparency, translucency, opacity - thermal conductivity, total energy transmittance, heat capacity - weight - sound reduction - vapour diffusion resistance **Protective functions** - moisture control - wind - wintertime / summertime thermal performance - sunshine and glare - noise - privacy and intruders **Supply functions** - lighting - view out / view in - passive / active heat gains - solar generated electricity	**Thermal** - interior air temperature and humidity - average temperature of enclosing surfaces - surface temperatures - temperature, humidity and velocity of incoming fresh air - air movements **Acoustic** - noise level, acoustic loads - reverberation times **Visual** - direct radiation - angle of incoming light - illuminance - luminance distribution - contrast and glare - daylight factor and autonomy - colour rendering - contact with the outside world, view out **Olfactory** - air change rate and air quality

Table 2-3 Buildings envelope with influencing factors and properties

From a historical point of view, older buildings envelope was adapted to climate conditions: warmer zones had wooden loadbearing structures and enclosing elements made from animal skins. In cold and temperate areas, solid brick external walls with small openings gave a large thermal mass. In the 19th century, technical and physical aspects led to new functions for the envelope, considering the interior comfort. While the connection with the sky and the earth were designed mostly for their functional role, the facade has always represented the architectural image of a building, communicating the author's ideas and experience. Glass and other materials development are exhibited in iconic buildings of the 19th and 20th century, while thermal insulation and proper energy consideration, with their economic and ecological aspects, appeared only after the Second World War. Experimental houses (with solar architecture, passive and active principles) along with software programs for simulation (energy balance, heat transfer, thermodynamic system, etc.) blossomed at the end of last century. The current trend for an efficient envelope, including upgrades for existing buildings, is to optimise this skin through several concepts on the five energy themes presented before (Table 2-4, [13], p. 85).

Energy theme	Concepts	Measures
heating (maintaining and gaining)	envelope geometry and surface optimising	compactness, zoning, thermal envelope
	opaque elements thermal insulation	choice of materials, insulation, thermal bridges
	transparent components thermal insulation	proportion of glazing, quality of glass
	solar radiation passive use	thermal mass and insulation, buffer zones
	heat losses through ventilation	heat recovery, preheating incoming air, airtightness and air's change rate
	active solar gains	roof and / or façade collector
cooling (avoid overheating)	heat transfer reduction	thermal insulation, surface temperature
	reduced incoming solar radiation	special glasses, sunshades, construction stage measures
	thermal mass and ventilation	incoming air preconditioning, stored thermal energy release
(decentralised) ventilation	natural ventilation	ventilated windows (based on wind and thermal currents)
	mechanical ventilation façade mounted units	panel elements, frame ventilation, underfloor convectors
lighting (daylight use)	geometry optimising	building or room form, glazing proportion, glazing arrangement
	daylighting systems	transparent, translucent, reflective, redirecting of transporting the light
(generated) electricity	photovoltaic panels envelope	façade, roof, shading elements
	solar technology	incorporated, separated or mixed
	architectural solar technology	integrated, added or adapted

Table 2-4 Envelope's optimisation Synthesis (candidate's compilation from the original source)

A thermal balance between **heat losses and gains** is important in temperate and cold zones, by keeping as much heat inside when outside temperatures are low. Therefore, an optimised envelope can help the heat flows throughout the year. The degree of compactness is better when the heated volume increases – a housing unit in an apartment block has a much lower transmission heat losses than a detached house with the same floor space. Considering different temperature requirements of internal spaces (within climatic conditions and room orientation), the areas with high temperature need should be located on the south side of the building, while those unheated or with low temperature demand should be located on the north side. Still, the most important heat loss transmission through **opaque elements** is determined by the thermal conductivity of their components, according to the U-value as a parameter for any building element (measured in W/m^2K). The thermal performance of any element is better when its U-value is smaller. An average U-value of less than 0.15 W/m^2K is required in passive house, for example. The **external walls** usually represent the largest area of the building envelope, even more in higher buildings. Therefore, their insulation influences considerably the transmission heat losses, while the inner or outer position of insulation must comply with building physics regarding vapour flow and moisture control. Widely used, the ETICS (external thermal insulation composition system) and ventilated facades (air space insulation), along with cavity, interior and frame/panel insulation are encountered in the built environment. Heavyweight slab (flat) **roofs**, purlin (pitched) roofs and lightweight (steel structure) roofs are major zones for heat loss, especially in low-rise buildings. Even here, the position of thermal insulation can vary (inside or outside of the structural elements), while considering the correct position of the vapour barrier. Unheated spaces have the boundary elements with reduced thermal insulation, as well as the elements connected to the soil. Thermal bridges cause heat losses, and they lead to moisture or condensation risk due to lower surface temperature on the inside. Thermographic images help to properly design for preventing later damage with continuous or higher insulation. **The transparent components** of the envelope have more rules to comply, not just for heating, but for lighting, ventilation and even cooling. The size and proportion of glazing area influence the heat losses and interior heating is needed nearby as a countermeasure (when the transparent area exceeds 30% in residential and 50% in non-residential buildings). The glass quality varies considerably, from single to double, triple or quadruple glazing with low U-value to 0.3 W/m^2K. A double-leaf façade, with a second glass leaf and ventilated cavity increase the thermal quality of the element, even in refurbishments with the reuse of existing glazing and frames. Shutters (sliding, folding, insulated roller) and louvres placed in front or behind a transparent component offer temporary reduced thermal insulation. The passive use of solar radiation through transparent surfaces is available, but depends on the orientation, size and geometry of the windows. Buffer sunny areas are intermediate spaces between interior and exterior, heated only from the sun. Recently discovered, transparent thermal insulation allows the use of solar radiation through opaque components. Active use of solar thermal energy with efficient storage technology lets an independent usage from the moment of incident solar radiation, with the opportunity to generate heat. Facades or roofs collectors have a major aesthetic potential to be architectural integrated. **Cooling** from excessive hot temperatures, during summer periods (considering the climate change and global warming) has the same importance as heating in cold season. Humans can protect themselves better against low values than higher temperatures, due to their own effort (small or big) to adapt to the physical conditions of the interior environment. To avoid overheating means to reduce the heat transfer through the building envelope, while controlling the internal thermal loads from people, lighting and appliances. The incoming solar radiation depends also on the proportion of glazing (compared with the opaque wall), on different types of glass and sunshades and on supplementary ventilation. A decentralised system of **ventilation** can be natural, mechanical or a mix between them. A natural ventilation has economic advantages, but it might lead to difficulties in extreme weather conditions, noise pollution, wind pressures, all depending on external climate and urban context. To improve the fluctuations of air change rate, a mechanical solution with integrated façade mounted units can secure a regular air flow rate. The **daylight use of natural light** offer visual comfort, stimulates several body functions and influences the work efficiency. Also, by reducing the artificial light (that can increase internal heat gains), less electricity is needed. But more glazing means good thermal performance of the envelope and a balanced energy consumption between the reduction of excessive incoming daylight heat and the operation of a shorter period for artificial lighting. Several parameters, such as glazing's features, geometry and position, interior space layout, daylight factor, light transmittance, reflection, sun shading system influence the perception and the availability of natural daylight. The last, but nor least concept on optimizing the building envelope is through its capacity to generate **electricity**, while using the sun endless energy. The photovoltaic panels can be used above a classic roof (flat or pitched) or directly replacing the waterproof layer. Facades (or other vertical parts) and shading elements, exposed directly to solar radiation are ideal for integrating a photovoltaic installation. The solar technology is strongly connected with architecture, due to the possibilities to develop a specific architectural design or building envelope while adding, integrating or adapting new energy components to supply the classic energetic system ([13], p. 86).

Construction materials, as main components of any building, represent the smallest component, but with major influence on the environment and energy system, starting from the consumption of resources. The selection of a specific material is related with its aspect, properties (physical, chemical), dimensions, costs. Above these primary specifications, other factors define their use for architectural purposes: the perception (with all our senses), the functional or technical performance (related with human protection – health, fire, sound, thermal, moisture) and their life cycle (usage-related, ecological and economic requirements) ([13], p. 147).

Before the Industrial Revolution, materials were selected considering the proximity to supply them and local sources (wood, stone, clay). Under the idea of "anything is possible", and the opportunities offered by the technological progress, innovative materials (optimal forms, large scale use) played a key role in rapid constructions with high performance (steel, glass, concrete, etc.). Prefabrication and later industrialisation were terms used for low-budget, variable, reusable, lightweight, transportable and extreme weather conditions buildings, while separate functional requirements (loadbearing, waterproofing, thermal insulating) led to the introduction of new and experimental materials in the construction field. Any building material has a major influence over the energy performance of a building:

- by minimising the heat flow and reducing the energy consumption, with ecological consequences (CO_2 emissions, for example)
- by transferring or storing energy (through thermal mass, related with its density)
- its production, maintenance and deconstruction (the embodied energy) generate irreversible environmental impacts
- its thermal conductivity, density related, is essential in any energy-efficient measure regarding building materials.

The primary energy input (PEI) for building materials relates the material production with its weight and, from a sustainable point of view, materials with lower proportion of grey energy are recommended. Their transportation contributes also to this choice. Therefore, raw renewable materials are considered better than others, and the environmental product declaration (EPD) together with the life cycle assessment (LCA) of any material can be used for the entire lifespan of a building material, building component or the whole building.

In the recent years, LCA – as a tool – had a major influence on the building industry, with its specific principles to be considered: decision-making processes, selection of materials, calculation of material energy flows, waste and produced emissions, all related with the term "functional unit" (mass or volume building material / area unit of a component / total building). The four successive phases of an LCA approach – goal and scope definition, inventory analysis, impact assessment and interpretation - help architects and planners to go further with any certification system for sustainable or green building (Table 2-5, [14], p.24).

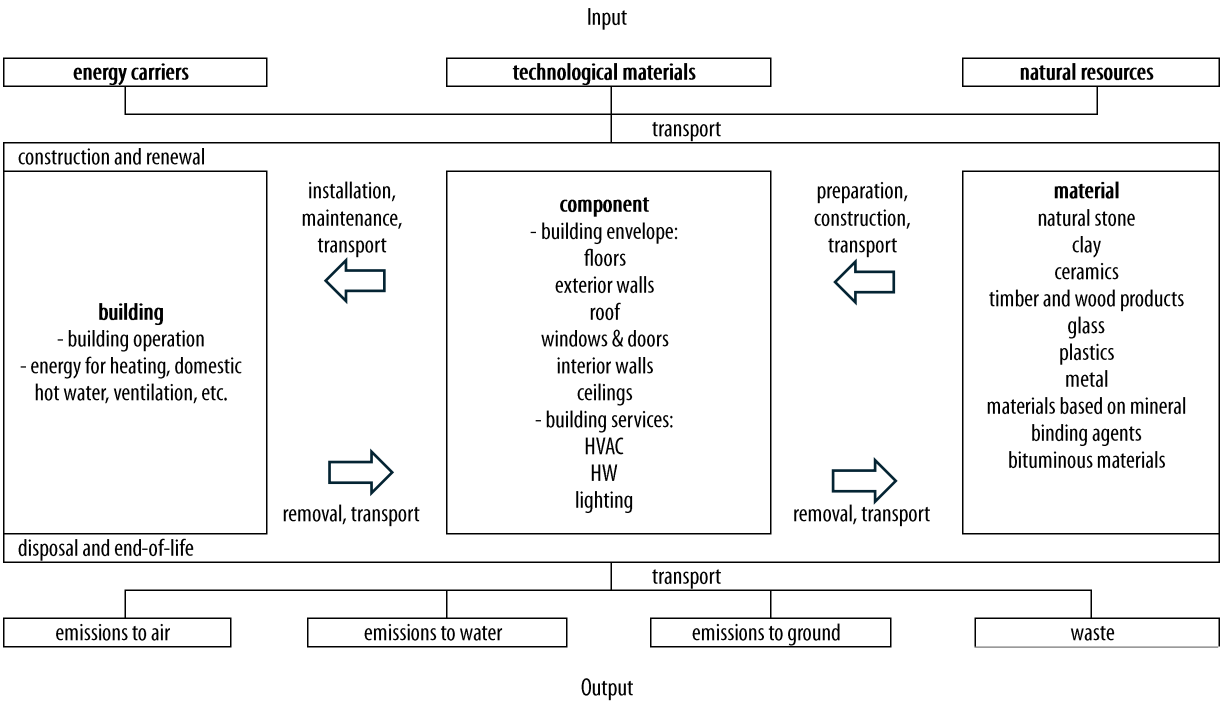


Table 2-5 Life cycle assessment from building to material (candidate's compilation from the original source)

By **reusing and recycling** the building components, resources can be saved. Some materials (wood, plastics, steel) are more suitable than others to be reintroduced into a circular cycle and used again. Prefabricated elements, especially from concrete, worth far more when rebuilt than their disposal cost. Pre-sorting waste on the construction site (mineral, recyclable, mixed, hazardous, asbestos containing materials) increase the reuse potential of building components from low to high, related with the type of recycling technology (mechanical, thermal or just landfill disposal). Components that fulfil the technical and legal requirements for a new building or for an existing one provide more possibilities to be reused than those still working properly but no longer up to date ([14], p. 53).

Moreover, new concepts like **Cradle to Cradle**, seems to surpass the recycling, since the latter begins at the end of a building's life. The idea C2C aims to introduce a steady circulation of materials, considering that "less bad" is not enough and materials can be reused in a different context. "Digital material passport" provides the nature of each individual material, how and where it is used in the building, easing the demolition process ([19], p. 47). Companies that collect and manufacture for reuse recycled building material appeared in northern Europe, offering economical viable solutions compared to the use of new products when building a new construction. Concrete elements, windows and other dismantled components can become the "urban mines of the future" by their introduction at the beginning of a new building life cycle, after fulfilling necessary requirements (fire, pollution, etc.) ([19], p. 60). This kind of circular economy might reorganize the sustainability system, long associated with reduced energy consumption and high tech. The emissions of greenhouse gases can be reduced even during construction, not just during the operation period of a building. The "zero emission" term is harder to achieve than a "neutral climate" one, considering the energy balancing (with primary energy different sources and factors, greenhouse gases, energy costs).

The accomplishment of a comfortable building with minimum energy use is a key issue of energy efficiency by using constructional measures. This can be achieved through the building design, building envelope, construction materials and main principles regarding energy balance (losses, consumption, solar radiation, gains, etc.), related with **passive** or **active concepts** (as described in chapter 3) and not without **building services** (to supply the previous energy themes). To provide interior comfortable conditions, they should perform independently of envelope's quality, specific climate and personal demands. Because their equipment requires lot of energy for production, operation and maintenance, a sustainable approach is desirable ([13], p. 110):

- on every technical system and its ecological consequences (fossil fuel, renewable source, technology, material embodied energy)
- the influence on the building's architecture (integrated concept, user behaviour through intuitive control options)
- optimisation of the entire life cycle.

All this introduction was made to emphasize the importance of all energy issues, starting from general meaning of the terms and concluding with specific measures within the architectural field and the candidate's interests. The chapter presents some of the most important activities developed by her during the last ten years, related to the existing building stock and its possible future development.

Experimental studies and exercises on energy efficiency were developed by the candidate with her students, regarding possible interventions on existing building stock, to comply with new regulations and personal comfort topics.

2.2 Common buildings rehabilitation

Energy saving potential means also saving costs. And the economic part is very important, from construction to operation and demolition. Life cycle cost (LCC) of the building refers to everything (initiation and planning, realisation, usage and maintenance, demolishing and disposing) with a major influence on the energy efficiency measures pack, no matter where the money come from (public, private, mixed partnership investments). Usually, the running costs are not very well predicted from the design phase – considering not just the needed utilities, but also administrative and security, cleaning, interventions on machines or buildings. The construction materials used in a building do not age all the same, therefore their replacement happens irregularly. Still, there is the possibility to foreseen shorter or longer cycles to replace various number of components at a different financial scale ([13], p. 32).

From a sustainable point of view, the usage period is one of the most important preconditions on a building's economy, related to volume changes (new buildings and interventions) that entail a higher consumption of energy and resources. The adaptability, flexibility and variable layout possibilities of a building will substantially materials, fuels and money. This is the main reason for the current general trend in building industry, even in state policies, for the re-use of existing constructions.

The renovation of actual building stock (with or without heritage values), considering the large number of edifices in need for (at least) comfort improvement measures, has become a major theme in Europe.

One of most important companies in the construction market, **Schüco**, known as a leader for developing and selling building envelope solutions from aluminium, steel and PVC-U, presented at the BAU 2025 its latest theme: **Value up** ([20]), in accordance with EU Green Deal framework. Starting from the idea "responsible handling of existing buildings, retention and increase of their value", it presents the key challenges of today aiming the neutral climate in 2050. Cost effectiveness, comfort and aesthetics are required for long term values. There are four phases to be considered in the renovation processes (Fig. 2-3):

- analyse to upgrade: transparent investment decisions (apartment and non-residential buildings) through three flexible service packages – inventory of existing building, energy efficiency and technical specific solutions for renovation measures on windows, doors and facades, ranging from minimum invasive intervention to complete renovation; carbon footprint and recycling values are incorporated, along with eligibility for national funding programs
- plan to upgrade: reducing complexity of the planning phase considering the sustainability of raw materials cycles, environmentally friendly and economical recycling; specific cloud-based calculation tool (Building Physics Solver BPS) to avoid damage of the building; renovation guidelines to clarify the responsibility of the client and the contractor, from consultancy to execution
- rebuild to upgrade: security and efficiency in execution – with reliable and economic implementation, without any interruptions of the building in use; modularity represents maximum flexibility and adaptability; windows and doors, balconies, ventilated facades with BIPV or double skin facades, even non-ventilated areas are eligible methods for results without additional costs due to loss of a rent or labour time
- maintain to upgrade: greater functionality and efficiency of the building operation; innovative systems to increase comfort, improve energy efficiency and reduce costs; different components retrofitting and repairing information digitally stored, related with their maintenance history and recyclability.

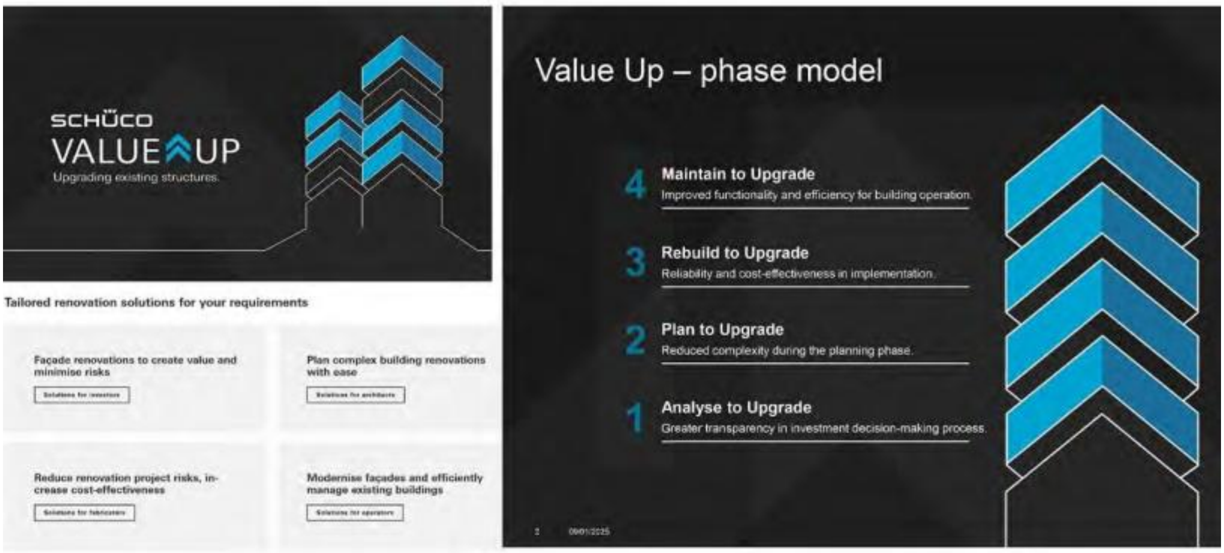


Fig. 2-3 Maintaining and increasing value – Schüco Value Up (candidate's compilation, image credits Schüco International KG ®)

Saint-Gobain company launched the "sustainable construction observatory", in 2023, as a leader, that brings together specialists, institutions and communities to accelerate their contribution to a more sustainable built environment ([21]), in certain directions: decarbonization, circularity, renovation ([22]), quality of living, urbanization, politics and economics. International "talks" organized frequently as major events in different places, approach subjects related both with new and existing constructions ([23]). An online magazine presents experts' opinions on solutions, cultural revolution and frameworks.

Kerakoll SPA ([24]) is another multinational group, renowned as a green company leader, providing a wide range of eco-friendly products and high-performance solutions, including restoration and systems for living wellbeing, repair, structural and anti-seismic strengthening, thermal insulation systems ([25]). Innovation, research and development performed in the Italian GreenLab ([26]) are key elements to support its "building better together" motto.

These are just few of many demonstrative examples on the amplitude of the rehabilitation subject, showing that building materials or solutions providers majorly influence the construction field, contributing to a continuously updated technology.

The architecture students, as future young professionals within the building sector, can be easily involved in different experimental or practical activities.

Along with punctual presentations / demonstrations at specific disciplines, the academic environment is a valuable resource to produce innovative ideas through students' competitions. By doing this, sometimes, the learning process becomes more attractive, and the positive results can be promoted in the media, having a greater impact on other actors (large public, authorities, politicians).

2.2.1 BAUMIT competitions

A continuous introspection into the energy domain is shown by the academic evolution of the candidate, underlined by a very specific discipline – Building Physics – with new courses, seminars and projects to be done. This started in 2011, after following the postgraduate course "Thermal and energy rehabilitation of existing buildings – constructions and mechanical equipment", ended with a new professional certificate for Energy Auditor, obtained from the Ministry of Public Works and Buildings.

The opportunity of introducing the fourth-year students of architecture into proper knowledge about interior comfort and energy issues regarding was maximum exploited throughout the applications themes developed together. The seminar consisted of calculation of necessary thermal insulation on small houses, related with national norms and methodology used by energy audits.

The most interesting part was another discipline, Building Physics Project, where the candidate connected the research done for the PhD thesis with real life rehabilitations, proposed for Timisoara. To increase the students' implication on the project, a prize competition was organized with BAUMIT (one of the largest companies that produces construction materials for ETICS systems), as external partner of the university.

The contest, as discussed and agreed with BAUMIT, started in 2015 using the motto "innovation, design, integration", and was named **Thermal rehabilitation of a blocks' rectangular plot**. It was about the selection of best architectural ideas, with good quality and great respect for the existing building stock, during the achievement of the following objectives:

- exterior uniform aspect for the entire blocks' ensemble from the given plot, after the proposed thermal rehabilitation with Baumit insulation systems (PRO with expanded polystyrene or mineral wool, OPEN with vapour-permeable polystyrene, STAR with graphited polystyrene)
- contemporary architectural solution respecting the restrictions imposed by the constructions' chromatic identity from Timisoara, with tones selected from BAUMIT Life colour chart and facades' decorative textures from BAUMIT CreativTop range. The local norms for chromatic identity of non-historical buildings required no more than 2 colours for the base (background) and some accents in other colours, but less than 20% of the facade surface (palettes in NCS codes). Baumit offered a free software to balance their colour palette with the imposed tones from the municipality regulation. Even more, at the final exhibition, Baumit provided panel 1:1 with finishing samples executed in the structures and colours indicated in the projects (Fig. 2-4)
- technical solution for maximum durability and long-term use with minimum maintenance costs, transposed in a calculation exercise on energy efficiency.

Fig. 2-4 Exhibition of the competing projects, (candidate's photo ©)

Specific districts around the Timisoara city centre were endowed almost 50 years ago with blocks of flats, organized in rectangular plots or closed patterns. Most of them were built after standard project types, but various interpretations on urban volumes, balconies and roofs have altered (during the last 20 years) the original design, with punctual thermal rehabilitation for a single apartment or a single staircase in a building having 2/3/4 entrances. The general appearance was chaotic, with pitched roofs or lofts or just thermally insulated with expanded polystyrene using ETICS system (Fig. 2-5).

Fig. 2-5 Romanian blocks with punctual thermal rehabilitation (candidate's photos ©)

The selected block for this task, project type 770-83, was one of the most used in our country, having 12 subtypes, 6 types of apartments (with 2, 3 and 4 rooms), same width of 11.2 m to couple different subtypes, small cellular structures and height (basement and 5 storeys), rectangular form and seismic area use (Fig. 2-6).

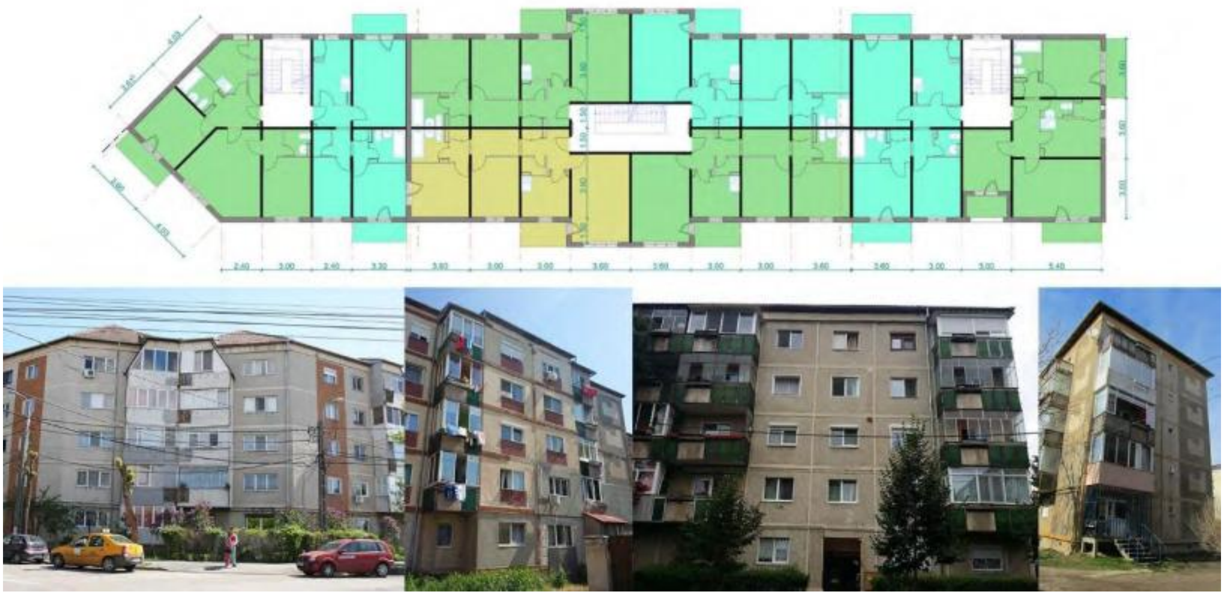


Fig. 2-6 Plan and images of the project type 770-83 (candidate's images ©)

The students' competition site was placed in Lipovei district from Timisoara, with many prefabricated panel blocks type 770-83, organized in square plots and without too many subsequent significant interventions. They worked in pairs for the technical part of the project, on a single staircase unit, with thermal rehabilitation measures and energy efficiency recommendations, the results being concluded in an Energy Performance Certificate. After that, they regrouped in teams of 4-6 people to develop the more interesting part of urban design with the facade's rehabilitation for the whole site (Fig. 2-7).

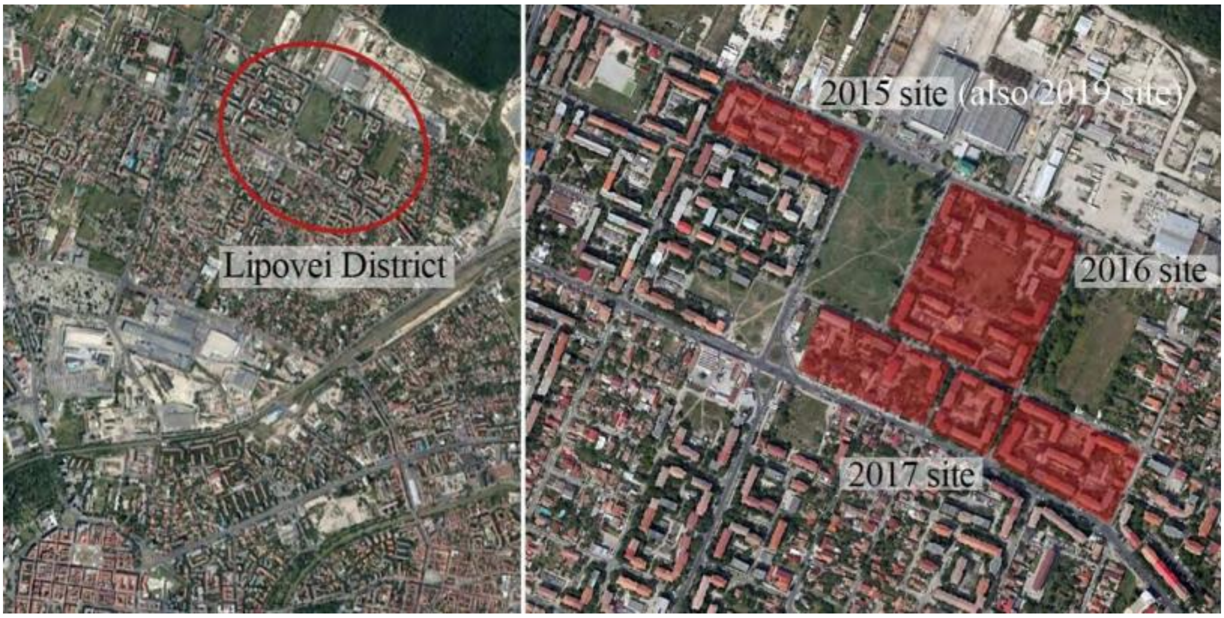


Fig. 2-7 Competition sites (candidate's completion on Google maps ® images)

The Jury included members from the university (architects and engineers), BAUMIT company (technical staff) and Timisoara Cityhall (urban planning department) and their selection for the best projects were done considering the exemplary features that could constitute a model for approaching this type of contemporary interventions. A common element found in all solutions was the demolition of the pitched roof, considering the expressed intention to reestablish a geometrical image, in line with the original aesthetic. There were 4 editions of this competition, the first three being presented at the 17th edition of International Technical-Scientific Conference of Modern Technologies for the 3rd Millenium, held in Oradea, 2018.

The first year (2015) had the most diverse proposals, but with the general idea of treating the balconies as unifying elements. The best project was appreciated for its fifth façade used as common green space, lighting filter through irregular green "wall" in front of the balcony, the great "background" yard as social gathering space and underground general parking. The second prize had a different approach, the interior spaces being related with the chosen colour of the outside façade (red for living, grey for sleeping) together with windows or balconies accents in a pattern for the long frontage (Fig. 2-8).

Fig. 2-8 2015's best solutions (images from the students' projects ©)

In 2016, the white was chosen as background to amplify the other coloured elements (pastel or dark). The green roof terrace remained a key element, while different volumes generated around the balconies marked some individual accents on the facades. Wooden elements and thin metallic wires for climbing plants defined the winning solution (Fig. 2-9).

Fig. 2-9 2016's best solutions (images from the students' projects ©)

"Unity through diversity" was the motto for the first prize in 2017, the focus being to allow individual intervention and to create dynamism by the various use of accent colours, while the common elements (access area and staircase zone) had a neutral tone. An improvement of life quality was offered by extended balconies and enlarged outside space, in a wooden frame that unified all the blocks represented the second-best project (Fig. 2-10).

Fig. 2-10 2017's best solutions (images from the students' projects ©)

The 2019th edition of this project emerged on the same site from 2015, but with different teams, of course. The main idea of the winning design was the use of green areas: in the inner courtyard, with playground zone and small parks; on the flat roof as thermal component; on the main facades as vertical gardens. The yellow accompanied the natural green on a neutral light background to gather people in an urban jungle. Another appreciated solution was developed around the notion of small community, with wooden elements on the open balcony interpreted as traditional porch, with new social areas on the flat roofs (Fig. 2-11).

Fig. 2-11 2019's best solutions (from the students' projects ©)

This whole exercise revealed some significant targets when dealing with large scale rehabilitation while upgrading the architectural image and the individual comfort: the fifth façade (roof terrace) as extra green or public common space; balconies as intermediate area between inside and outside; coloured or volumetric accents to distinguish similar blocks; the inner courtyard refurbished for underground parking and limited access public or playground zone. The streets' quality in these "new" districts can also be improved while reducing the number of parked vehicles. The following table (Table 2-6) reveals the number of participating students and teams, throughout the years.

Year	Number of students involved	Number of teams	Prizes
2015	39	8	3 prizes, 3 mentions
2016	57 (2 Erasmus+ incoming students included)	12	3 prizes, 2 mentions
2017	57 (5 Erasmus+ incoming students included)	12	3 prizes, 2 mentions

2019	48 (7 Erasmus+ incoming students included)	10	2 prizes, 1 mention

Table 2-6 Synthetic info on BAUMIT competition

2.2.2 Architecture student contests organized by Saint-Gobain

Another didactic exercise started in 2023, when the candidate decided and accepted to involve (also) the 4th year students from architecture specialization in another contest, this time internationally, launched by Saint-Gobain (SG) company ([27]). The first edition of **Architecture Student Contest** (ASC) was organized in Serbia in 2004, by Saint-Gobain Isover, becoming international in 2005. The 2022-2023 edition (held in Lisbon) had more than 1600 students coming from 220 universities, 30 participant countries and 5 international awards, addressing to students of architecture, design and construction engineering. Based on company's vision of sustainable buildings, with annual contest, the 19th edition of ASC 2024 had 2 phases (first national and then international) and one real architectural task: to provide building ideas and solutions of an area located in Viikki (northeast of Helsinki), through a combination of temporary housing for students and researchers or permanent housing for residents as part of the new Viikki district, and nearby outdoor functions. The project involved the renovation and change use of an existing building to residential function for visiting researchers or students, as well as the construction of a new residential building. Another challenge was to design the interconnection of the buildings by exterior public green space, along with circularity and potential reuse of building parts and materials was encouraged. All the new proposals would have to be innovative, sustainable and comply with the technical guidelines prepared by Saint-Gobain (Fig. 2-12).

Fig. 2-12 Helsinki's competition site and its limits (image from ASC 2024 Contest task brochure ©)

The general framework of Saint-Gobain contest relied on two main pillars and their drivers:

- **better for the planet** through Energy & Carbon (increased energy efficiency, increased use of renewable energies, reduced embodied carbon emissions) and Resources & Circularity (reduced use of non-renewable resources, reduced freshwater consumption, increased lifetime and use rate, reduced amount of non-recovered construction & demolition waste)
- **better for people** through Health & safety on jobsites (reduced builders' exposure to hazardous substances during installation, improved working conditions for builders) and Health & wellbeing indoors (improved indoor air quality, better acoustics, better thermal comfort, improved access to natural light).

The technical parameters required for the competition were:

- thermal comfort: a good internal environment (thermal comfort must be achieved during summer and winter periods – range between 19-23 °C), all around the year through both passive measures like sun-shading, light colours for exterior surfaces, green roofs and facades and active measures like ventilation; also, the energy independence from the grid was desirable with renewable energy and heating systems fitted to the city strategy
- acoustic comfort: SG recommendations for airborne noise (wall between units and ceiling between floors) and for impact noise (ceiling between floors) forced to higher values than technical parameters of Finnish standards on acoustic

classes of dwelling; the windows' relevant acoustic quality had to be taken into consideration along with solutions proposed to reduce the noise generated by the technical equipment

- indoor air quality: low levels of CO_2 inside the apartments through a minimum ventilation rate of 30 m^3 per hour per person, and a general strategy to achieve an excellent door quality
- fire safety: non-combustible materials for all products in the facades and the roof; specific measures were necessary for evacuation paths, fire sections between stories and apartments, material's reaction to fire, fire resistance of system selection
- natural daylight: an autonomy of 60% to achieve a minimum level of natural light should be achieved (300 lux threshold), together with a window/floor ratio no lower than 1/8 and optimal orientation, high performance glazing products
- carbon emissions & energy consumption: a highly energy efficient building with the following levels of performance: annual energy demand for heating less than 15 kWh/m^2 (passive house standard); roof U value<0,07 W/m^2K; external wall U value<0,14 W/m^2K; floor on the ground U value<0,10 W/m^2K; windows U value<0,70 W/m^2K with g-value around 50%; air tightness as specified in Finnish regulation for building envelope. More, a calculation of the energy demand should be done for one year and another calculation of the carbon emissions over the whole building life cycle should be carried out through the OneClick'LCA tool provided for free during the competition
- resources & circularity: design for longevity (flexibility in use, easily adaptable over time, allowed possibility for usage reorientation, durable and resource efficient materials, products and systems, easy to repair, maintain or replace and to reuse or recycle at their end of life; a minimum use of non-renewable primary raw materials; off-site prefabricated building elements, modular construction and lightweight systems (in particular for facades and internal partitions); renovation and extension of existing buildings shall be preferred over demolition/deconstruction and new built; selective deconstruction shall always be preferred over demolition at buildings' end of life.

Judging criteria: two main themes were established to be evaluated by the jury during the National Stage, and during the International Stage to select the winners, reflected in the table below (Table 2-7):

New construction 60%	Renovation 40%	Criteria
Architecture (30%)	Architecture (20%)	• Design excellence, functional concept, adapted to context, and building information. • Master plan, interconnection of the buildings to the exterior public green space.
Sustainable construction (30%)	Sustainable construction (20%)	• Design clearly addresses sustainability criteria: - Carbon & energy: solutions and strategies to reduce the energy consumption and reduce the embodied and operation carbon (construction U value, passive/active measures, etc.) - Resources & circularity: solutions addressing the reduction of non-renewable resources, extend the end of life of product, and promotes recycling / reuse of products. - Health & wellbeing: strategies to achieve thermal, lighting, acoustic and indoor air quality comfort (sound protection, ventilation type, natural daylight strategy, etc.). - Quality and consistency of the proposed construction details with regard to building physics (thermal and acoustic bridges, airtightness, and moisture management). • Correct usage and mentioning of Saint-Gobain products and solutions in the project in their different applications (criteria evaluated during National Stage and must be fulfilled if considered for International Stage).

Table 2-7 Projects' evaluation criteria weights (from ASC 2024 Rules, Organization and Legal terms brochure ©)

Considering the amplitude of this competition and the numerous requests on multiple issues, the candidate involved more disciplines from the architecture 4th year (1st semester) while she coordinated the main one, Architectural Design Studio 7, along with another five architects and two engineers (structural and mechanical), through the 2023-2024 academic year. The disciplines were Landscape design – project, Interior Design – project, Envelope aesthetics, Sustainable buildings and Computer aided design.

90 students have been organized in pairs of two, another team being formed with three Erasmus+ incoming students, all of them working the whole semester to develop architectural solutions, the selected projects to compete in the National stage being selected at the end of this semester. The introductory multi-criteria analysis phase was done all together, later moving to the more technical stages developed on the individual solutions of each team, up to a scale of 1:200. The specific competition requirements (technical part, LCA, Saint-Gobain materials, circularity) were later detailed by the 8 best teams, selected by the coordinating teachers.

The National Stage had 21 entrance projects, our students winning three prizes, unfortunately without going at the International Stage. All of them used CLT as main construction material and offered many housing units for students and researchers, while respecting the contest technical parameters and using Saint-Gobain products. The national jury was formed by members from different universities and technical staff from the organizer.

“The Line” project, winner of the 2nd prize, stated as a key element an orange storey as a physical connection for the proposed buildings, also creating a good context for social interactions. The existing building circular pattern was extended to the new construction, as a filter for the natural environment, protected from the urban vicinity of the competition site. The public spaces, designed as “green oasis” were accessible from different sides of the plot, extending the existing Japanese garden (Fig. 2-13).

Fig. 2-13 “The Line”, 2nd place national stage prize (images from the students' project ©)

The “Evergreen views” project won the 3rd national prize and proposed a succession of ground floor public spaces, under a common frontage to unify the site. While focusing on the connection between the city and nearby natural reserve, it consisted of different height volumes oriented for maximum natural light, with the biggest one marking the street corner. Rain gardens were used as landscape elements to collect and use the water, along with the prevention on floodings and improvement on local biodiversity (Fig. 2-14).

Fig. 2-14 “Evergreen views”, 3rd place national stage prize (images from the students' project ©)

“Vertical garden” solution won the first special prize, by coming up with a different concept of a student house organized around a green atrium, with natural light and social purposes. The biophilic design promoted as a primary issue meant a great sustainability, through wellbeing and energy efficiency. Two larger new buildings were composed at the street corner, where the main access into the campus was intended to be. The renovation of the existing building used the same envelope with modular perforated metallic sheets (Fig. 2-15).

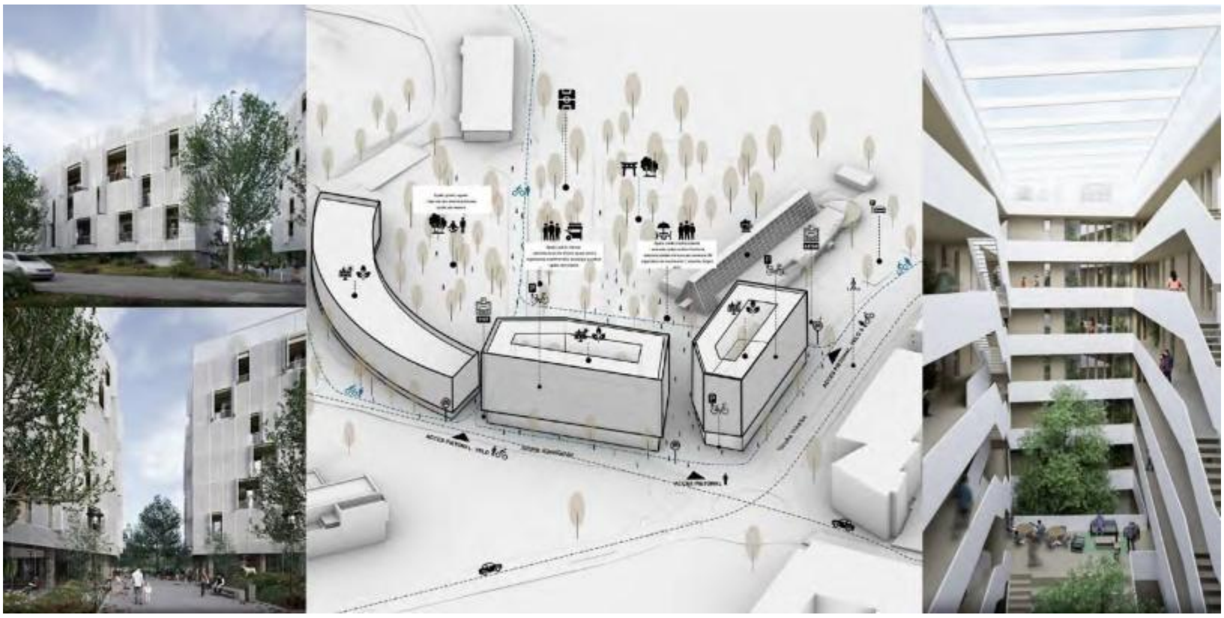


Fig. 2-15 "Vertical Garden", 1st special prize, national stage (images from the students' project ©)

The candidate was invited and participated as a guest teacher to the International Phase, acquiring experience and necessary information for the next year competition. There were 1300 students from 29 countries, the national stage winners competing in Helsinki. The following important conclusions can be underlined:

- sustainability and economic efficiency are more appreciated than the architectural value of the presented solutions, together with its compactness
- clear and simple representation are necessary for the project's success
- the Saint-Gobain products used in the project must be detailed through diagrams and schemes.

The latest completed competition (started in 2024) represented the **anniversary 20th edition of ASC** and the candidate continued to pursue at least the participation at the international stage, by winning the 1st prize at the national level (in the spring of 2025). More than 200 universities from 33 countries participated under the theme of "Attracting Youth". The Contest Task covered two sites from Nord-Isere region in France: the village of Chimilin and Les Grands Ateliers in Villefontaine (Fig. 2-16).

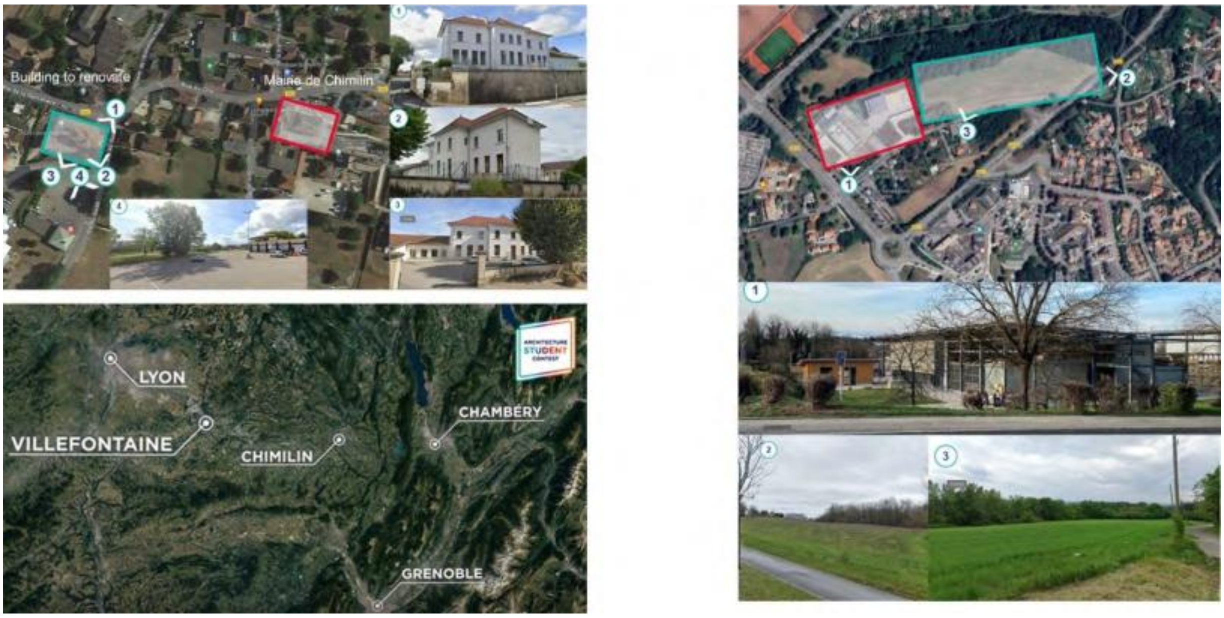


Fig. 2-16 Nord-Isere's competition site and its limits (images from ASC 2025 Contest task brochure ©)

The challenges were:

- to renovate and change the use of an abandoned school building in Chimilin into a building that provides space for multi-use activities for many local associations and organizations

- to design a new residential building for students in Les Grands Ateliers and propose a volumetry of uses for the rest of the site (20000 m^2)
- to create a link between the 2 distinct places through a common identity and possible synergies between their proposals, revitalizing the territory and offering attractivity beyond its frontiers.

The requirements were mostly the same (technical parameters), based on Saint-Gobain's Sustainable Construction Guidelines, adapted to French legislation and with few new/modified elements:

- on thermal comfort: how could monitor the building and energy consumption/production of the building
- on acoustic comfort: SG recommended that technical parameters should be designed in line with requirement of French Acoustic Regulation, A1 level
- on carbon emissions & energy consumption: average U value for all opaque constructions (roof, external wall, floors on the ground) <0,15 W/m^2K; windows U value<0,80 W/m^2K with g-value around 50%; air tightness q4 < 0,6 m^3/ (h m^2). The calculation of the energy demand should refer to low carbon energy supply – solutions such as locally produced renewable energies – geothermal / photovoltaic or heat pump). The other calculation carried out through the OneClick LCA must explain how they have been able to reduce/optimize the embodied carbon while progressing in their project design – lightweight constructions, wood construction, product reuse, considering the French regulation (RE2020) thresholds for carbon of 490 kgCO_{2eq}/m^2/year.

The general judging criteria, from the 2-phase competition, needed to consider the following aspects:

- the sustainability considerations
- the respect of minimum requirements, correct usage of Saint-Gobain products and solutions in the project, and the quality and consistency of the proposed construction details with regard to building physics.

The last generation of 4th year students formed 30 small groups with 3 members each, including one Erasmus+ students from Italy and Spain, coordinated under the Architectural Design Studio 7 teachers during the first semester. Each team had additional work done for the same solution, but in other disciplines, as mentioned before. At the end of the architectural proposal stage, 7 teams were selected to go further at the National Stage and detail the SG specifications.

All of them continued with the required sustainability features for the first half of the second semester, offering more support to their architectural concepts. Considering the last year experience, this time more adequate approach and the use of recommended software led to better appreciation from the national jury, three of them winning important prizes.

The "Yellow" project, with the best academic evaluation, had multiple very good ideas, starting from an innovative concept that connected the two separated sites: from rural pitched roof to industrial shape, new and existing buildings were linked through a sinuous coloured pathway. A simple, repetitive and modular metallic structure (5 x 5 m grid) was used for the three main functions in Villefontaine: the first one, for prototyping activities, closer to the existing educational centre (Astus), with outdoor dedicated platform; the second one, for students housing, in the middle of the site, incorporating a greenhouse and supporting biodiversity and social fabric; the last one, for offices and meeting spaces, to attract the public, being opened for the community. The geometry of a pedestrian path had several add-ons such as outdoor amphitheatre, campfire and sitting areas to relax, socialize and enjoy the natural surrounding views. Similar features were integrated in Chimilin, giving a fresh look to the old school, while accommodating interactive spaces and a better outside connection within the village context. The yellow colour, borrowed from Les Grands Ateliers logo ([28]) became the main idea of the entire solution. All of these were completed with active and passive sustainable strategies, showing a comprehensive solution, most appreciated by the national jury, winning the 1st prize and furthermore, representing Romania into the international stage (Fig. 2-17).

Fig. 2-17 "Yellow", 1st national stage prize (images from the students' project ©)

„Sous le collines" had a landscape design solution, with the declared intention to extend Villefontaine image through contemporary small houses, settled half visible – half hidden into the natural context. A red footbridge was introduced to connect the built sites with different functions. The existing natural slope played a key role in the architectural concept, reducing the visual impact of volumes and organizing the spaces efficiently, while offering great views of the ensemble. Controlled earth excavations and additions generated artificial hills, extending the neighbouring forest. The different interior functions, under similar and all visible pitched roofs offered great architectural qualities and dynamism throughout their great skylights. A vertical symbolic chimney completed the general aspect of the site. A similar new volume was proposed instead of demolished small annexes in Chimilin, connecting a cafeteria with the old school, where other multiple community spaces were introduced. The attic was also opened and used for social purposes, connected through a red metallic stair with the ground level. This project won the 3rd prize (Fig. 2-18).

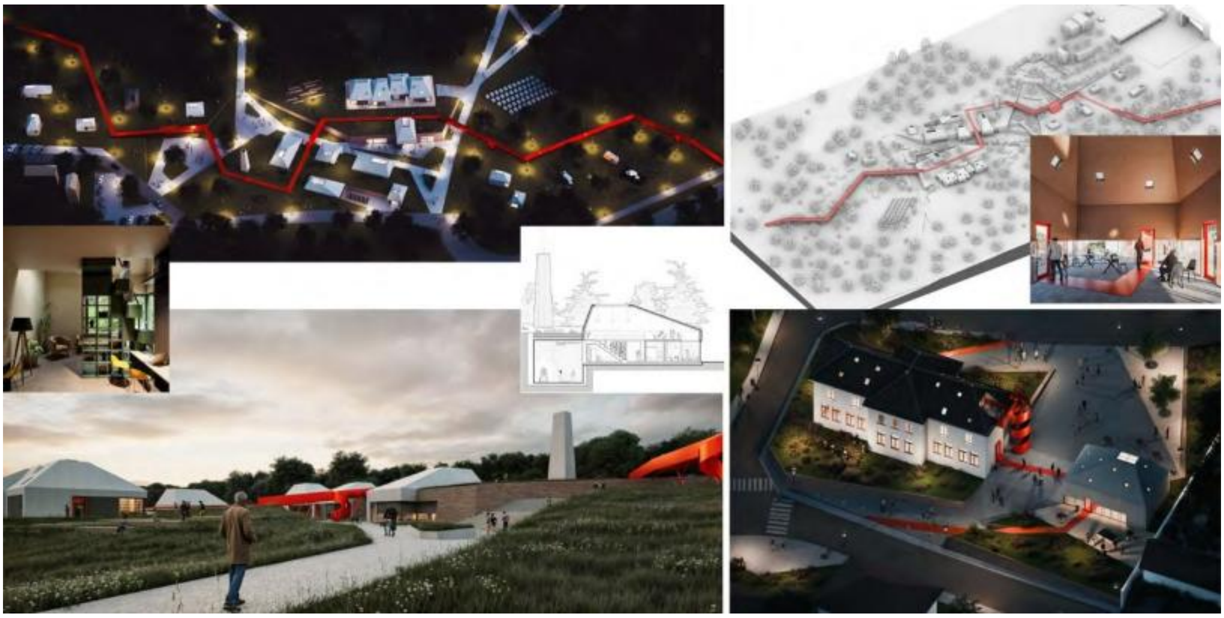


Fig. 2-18 "Sous le collines", 3rd place national stage prize (images from the students' project ©)

Another good project was „La bande jaune", winning the 1st special prize. A more compact solution, well adapted to the natural slope and offering very good connections with the existing buildings, was placed to let future and sustainable complementary developments. A more geometrical landscape design positioned all the required functions, two large rectangular volumes with movable shading elements and yellow horizontal accents were related with the ASTUS platform and two linear exterior pedestrian stairs and ramps. The largest volume contained laboratories and working spaces, while the second included the students' accommodation facilities. Thin yellow metallic elements connected and defined the entire ensemble, even the landscape design (recreation, sitting, camping areas). The space in between was the main idea for the small village, where the simple transformation of the old building into a multi-use edifice related to a new social space through an outer carefully designed environment (Fig. 2-19).

Fig. 2-19 "La bande jaune", 1st special prize, national stage (images from the students' project ©)

The international stage, held in Lyon, was managed by the Saint-Gobain International team and all the winners from the National stages exhibited and short presented their projects in front of the International Jury. The candidate, as the coordinating teacher of the students, authors of the "Yellow" project, sustained them and participated together in this event. A very coherent presentation from the team, a bold colour in historical context, a clear connection between the two sites, a recognizable architectural motif (pitched roof) along with the reinterpretation of local architecture into new typologies, polyvalent spaces with a simple structure and an elaborate landscape design were the reasons why this solution was rewarded with the Student Prize (one of the five prizes), receiving the most number of votes from all the other students, participants in the international stage ([29]). For this exquisite performance, the candidate proposed and the three girls received from our university an Excellency Award for Internationalization in the year 2025 (Fig. 2-20).

Fig. 2-20 The international and university awards (candidate's photos ©)

The 2025-2026th edition of this competition returns to Serbia, under the same criteria and circumstances, for a well-positioned site and sport-oriented function, along the Sava River. Teams from the current 4th year of study, managed by the candidate and her colleagues, compete in the national stage with students from three other architectural schools. The advantage of being relatively close to Belgrade was transformed into a student one-day documentary trip, supported by our university and organisers. These kinds of visits, done in an early stage of design concepts, help both scholars and teachers to a better perception of the urban context and contest requirements, later developed into innovative projects.

The whole experience and knowledge acquired during these academic and professional exercises show the candidates interest to teach future architects how to deal with a specific task and to transform consciously the built environment, while competing with other educational institutions. The multidisciplinary team from specific subjects (Architectural Studio Design, Landscape Design, Sustainable Buildings, Computers Aided Design) of the 4th year can offer the necessary support for outstanding projects, highly appreciated by external evaluators. Another previous discipline taught by the candidate, Building Physics, gives the students useful technical information related with energy efficiency and sustainable development.

2.3 Energy interventions on built heritage

2.3.1 Introduction

The importance of existing buildings with historical value amplifies the problem of their energy efficiency issues, due to the increasing role of the urban image as testimonial for the past. The twentieth century represents the largest percent of existing building stock, especially built after the second world war with prefabricated technologies, new materials and, sometimes, complicated structural and decorative elements. Many representative constructions (classic or modern styles) were erected before the first imposed requirements for minimum thermal protection. Their energy performance is, from the start, lower than the efficiency of a new building that complies with today's standards, these representing only recommendations for valuable old buildings.

The topics of energy on heritage buildings are:

- minimum invasive measures with maximum impact on the desired effects, along with costs' optimization and compatibility
- no outside walls thermal insulation, where important design features might be destroyed; efficient insulation materials placed on the inner side of the wall, related with humidity and moisture control
- decorated surfaces treatments and special plasters, thinner insulation
- relevance of moisture control, considering that some of the new materials used to improve interior comfort have no water vapour diffusion, being waterproofed or airtight sealed
- required ventilation and indoor air pollution control
- optimal upgrades of the glazing and sunshade devices, while maintaining the original aspect and using integrated ventilation systems with humidity control; roller shutter boxes (related with heat sinks) to be included in energy refurbishment
- reduction of thermal bridges, especially on concrete interventions (for structural reasons); reveals for windows / doors and mounted substructures for ventilated facades to avoid linear or punctual
- roofs / terraces insulation (connected also with thermal bridges); similar wall's problems given by the exterior aspect or form that must be maintained leading to inside insulation on pitched roofs, even if the attic loses the usage possibility; keeping original chimneys as building's identity mark
- insulation on horizontal surfaces (ground floor, floor above basement, protruding slabs), related with structural intervention
- the potential of building services, newly introduced or replacing the existing ones with more efficient ones, even renewable (heating boilers, heat pumps, cooling systems, solar and electrically powered).

The following subchapters present the candidate's continuous focus on the subject, in two different situations, starting from the existing state and nature of intervention.

2.3.2. Classic style building rehabilitation ([7], [9])

A historical building from Arad, built in 1872, known as "The old Casino", listed as a monument of local importance (identified through its national code LMI AR-II-m-B-00498), with its neoclassic and neo-baroque architectural elements, was the main subject of a real project, commissioned by the current owner who wanted to revive the old attraction of the city. Under the influence of the Austrian empire, the entire western part of Romania was transformed, enriched with new architectural specific elements in residential and non-residential constructions: neoclassic decorated main facades with gypsum molds, ironwork, roller shutters, tinware, stairs – for almost half a century around the 1900s.

The Casino (Baross Park Kioszk), set into a park near the Mures river, offered a summer panoramic garden and an ice-skate terrace during winter, gathering important local people and tourists of the northern riverbank. A variety of mural artistic details applied on lime and sand plasters, as well as on stucco decorative elements were found on the four-storey squared building, with its central event space surrounded by two rows of thick vertical pillars. At the beginning of the 20th century, the first outdoor skating rink and a perimetral closing fenestration were the first interventions to the original building (Fig. 2-21).

Fig. 2-21 Old Casino building (images from the cited articles ©)

Several transformations were carried out on different political periods of the last century, the most important (structural and architectural) being done in 1980s: intermediate concrete floors added at the mezzanine level and between ground and first floor, with anti-seismic strengthening role. The exterior image was altered with visible pipes, installations, improper closing of the upper terrace and various colour for same decorative elements on different facades. Its current condition (being abandoned for almost ten years) at the beginning of this project showed a partial greenhouse with metallic frame and simple glass, missing windows, lots of graffiti, water infiltrations, mould and moss, exfoliated successive layers of plaster and paint, detached ornaments, compromised insulation, covering and waterproofing, along with minor structural damages (Fig. 2-22).

Fig. 2-22 The Casino building around the year 2000 (images from the cited articles ©)

The previous owners' lack of interest to preserve this building is found in the rapid deterioration of the monument due to successive interior partitioning interventions. The actual owner wished to create a contemporary and attractive destination, through an event hall with all necessary secondary spaces, also bringing some economic profit and public benefits for the image of city's central park. Actions were initiated concerning repairs, consolidation, protection, restoration, preservation with an emergency building permit to secure and stop degradation of exterior and interior components: facades, roofs, terraces, decorations. Later, a revival of the whole site was proposed, with a catering building containing two levels of event halls, meeting rooms, services, offices, administrative functions. A separate volume for vertical circulation and toilets and an underground extension for kitchen spaces completed the design theme of a fair approach to the monumental character (Fig. 2-23).

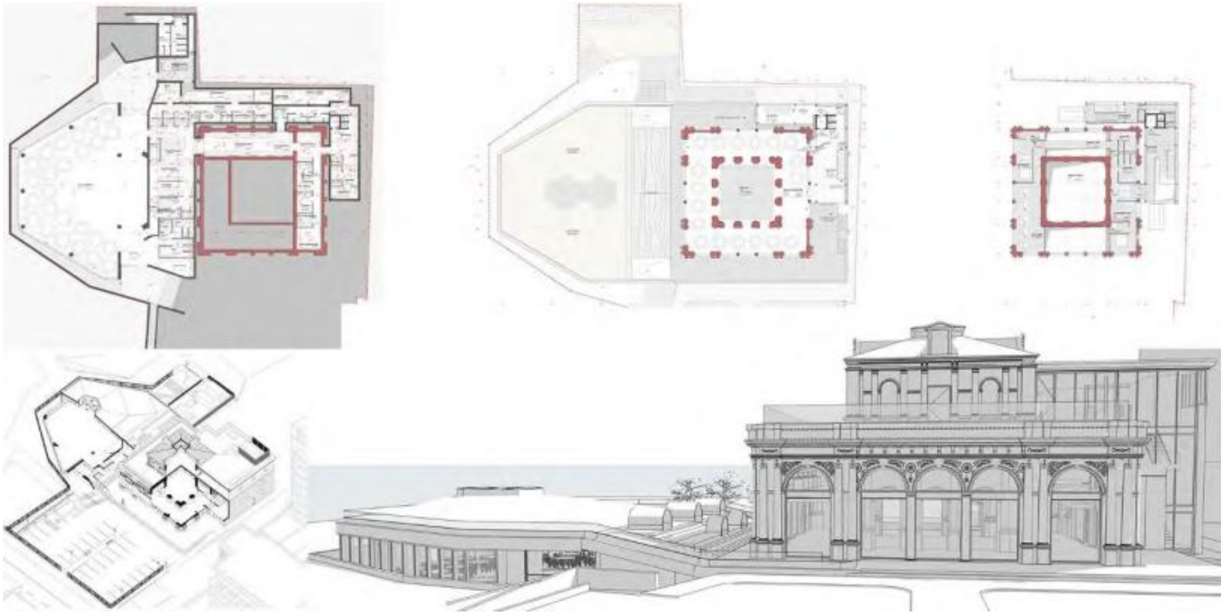


Fig. 2-23 First proposed solution (images from the cited articles ©)

The national legislation concerning monuments protection requires approval from the Local Monuments Committee and at least three solutions were discussed, the final one leading to a large horizontal extension of a demi-basement level with large windows to the park, accessible green terrace with a big skylight near a genuine image of the old Casino. A buffer between the heritage construction and the 10th stories Parc Hotel erected less than ten meters in the vicinity sheltered secondary spaces, stairs and elevators. The whole complex comprised three event halls (for 150/100 people on the ground /first floor of the old building, 300 people in the demi-basement extension), two apartments, administrative office, restroom, kitchen, storage, technical and staff spaces, together with outside arrangements for visitors and supplies (Fig. 2-24).

Fig. 2-24 Final solution outside photos (images from the cited articles ©)

The historic decorations were restored, including the missing elements according to the original context, even with golden leaf proposed by expert restorers. Colours were chosen based on the stratigraphic analysis, with decorative plasters and silicate paints. The external wooden fenestration was replaced with an oak and heat-insulating glass, while the previous dormers four windows were restored with laminated wood frames, all preserving the historical design. Iconic iron details added more value to this monument's refurbishment (Fig. 2-25).

Fig. 2-25 Final solution interior photos (images from the cited articles ©)

An energy performance study was developed on the Casino, even if, it was not compulsory, given its heritage character and no energy certificate needed to be issued. The minimum energy performance requirements do not apply on historic buildings, if by applying the requirements, their character or appearance would alter unacceptably. Still, for this type of buildings, restaurants with discontinuous occupancy (usual, not monuments), specific legal requirements for the building's envelope referred to the minimum thermal resistance of the opaque components (vertical walls, upper roof and terrace) and of transparent walls (opening) in contact with the exterior space. The energy evaluation of the building was carried out, considering the on-site found existing materials and the newly proposed solution. Values referring to the energy balance, consumption, class and CO_2 equivalent emission index, resulted within the ArchiCAD 21 (Graphisoft) specific software.

Even if the thermal rehabilitation was not compulsory by the law, the minimal changes of exterior elements features done because of deterioration and aesthetical aspects significantly improved the envelope's energy performance, while reducing energy cost and giving an up-to-date architectural restored image (Table 2-8).

	Existing	Proposed
Thermal resistance of component features R' [m²K/W]	- Masonry walls and columns, 51 cm (brick masonry, without any insulating material) - 0.79 - Exterior windows and doors, wooden frame, simple glazing - 0.14-0.20 - Greenhouse metallic frame, simple glazed - 0.14-0.20 - Roof over main building, without any insulating material - 1.37	- Masonry walls + insulating plaster (4 cm on each side of the wall), 59 cm thickness 1.88 - Exterior triple glazed windows and doors 1.23 - Greenhouse metallic frame and double glazed 1.23 - Roof over main building, with additional 20 cm mineral wool 7.19 - New flat roof, including 20 cm mineral wool over self-sustainable metal sheet 6.13
Heat transfer coefficient values U [W/m²K] Normed values - - 0.25 - 0.625 - 2	- Building Shell Average - 2.71 - Floors- 2.66 - External - 1.25 - 2.66 - Openings - 4.94 - 6.99	- Building Shell Average - 0.36 - Floors - 0.18 - External - 0.13 - 0.54 - Openings - 0.67 - 18.72
Specific Annual Values [kWh/m²a]	- Net Heating Energy - 217.46 - Energy Consumption - 271.38 - Primary Energy - 329.78	- Net Heating Energy - 12.47 - Energy Consumption - 49.20 - Primary Energy - 94.69
Energy class	C	A
CO_2 Emission Annual Values [kg/m²a]	63.85	11.20

Table 2-8 Energy performance of the Casino (candidate's compilation from the article ©)

A multidisciplinary strategy was developed considering separate interventions such as:

- Consolidation and repair of the exterior walls, finishes and roof
- Replacement of exterior windows, doors, balconies and attics

- Rebuild or repairs of ornaments, profiles, architectural profiles, indoor and outdoor frames.

This case-study analysis showed that contemporary interventions, if done with great care, considering all aspects of comfort, safety, energy efficiency and constraints given by regulatory acts, will lead to great benefits for everyone.

2.3.3 Brutalist buildings' energy refurbishment – case study ([11])

The Polytechnic University of Timisoara (UPT) has a building fund heritage including more than 100 constructions, most of them erected during the 20th century. After the First World War, the first western superior education establishment from Romania appeared in our city, by a royal decree stipulating the foundation of superior technical school (Fig. 2-26).

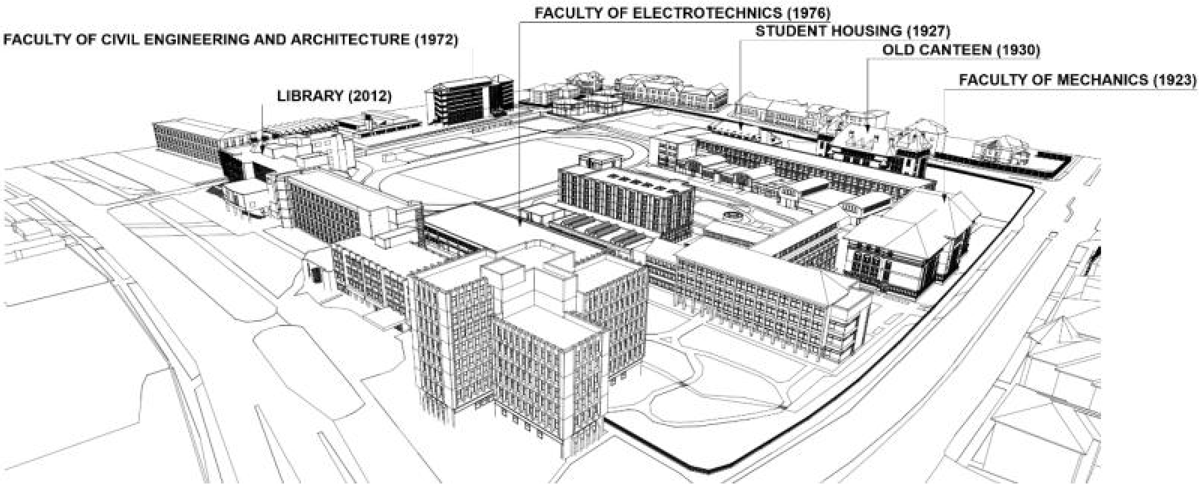


Fig. 2-26 Aerial view of the campus (image from the cited article ©)

The campus layout started its development with 3 important buildings: the Faculty of Mechanics, the first dormitory and the first canteen, all of them designed by the Romanian modernist architect Duiliu Marcu, with specific brick facades and decorative elements, along with pitched roofs, typical for the neo-romanian style – representative for that interwar period (Fig. 2-27).

Fig. 2-27 The first three building from the campus, designed by the architect Duiliu Marcu (images from the cited article ©)

Later, after the Second World War, another superior school was founded nearby the Polytechnic Campus, The West University of Timisoara, with its main building designed at the beginning of the 1960's by another famous architect, young at that time, but with great visionary ideas: Hans Fackelmann – an open building, with semi-pavilion shapes and open or closed precincts, modular, repetitive and landscape oriented. A similar Romanian complex was The Bucharest Polytechnic Institute (1962-1972) (Fig. 2-28).

Fig. 2-28 Post Second World War Romanian educational buildings (images from the cited article ©)

Regarding the UPT campus, new buildings completed the first proposal for the site, the Faculty of Electrotechnics being the most representative and becoming an iconic figure for the Brutalist style, recognizable even today. Started in 1974, it was designed after the plans of the Romanian architect Peter Swoboda, previously working at the Bucharest Polytechnic Institute project. It has four buildings interconnected, marking the street corner between two main boulevards near the Bega River: the highest one has eight stories being a vertical accent, while the other three low rise buildings are linear and with simple articulated volumes, all of them offering varied spaces – lecture theatres and classrooms for theoretical education, laboratories and design workshops for applied learning, office space for administration and teachers. It was opened in 1976 to accommodate 1650 students, within a total built area of 21350 sqm. With its multiple connected pavilions, the technical details were specific for that period: prefabricated elements used for more than 82% of the building, including floor slabs and modular standard frame-type repetitive façades. The exterior load-bearing structural elements generated a very pronounced relief and served as lost formwork for the monolithization process (Fig. 2-29).

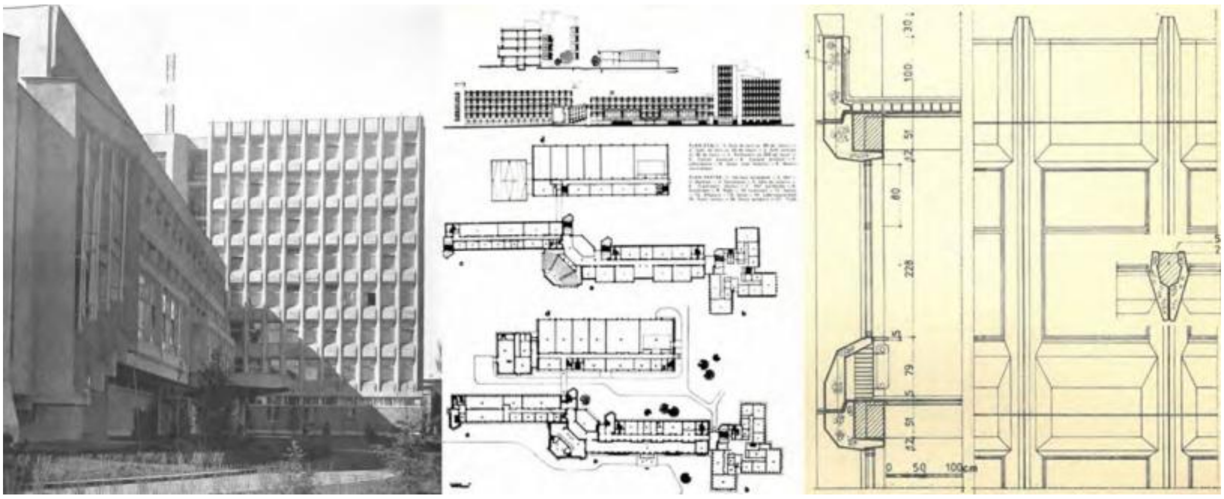


Fig. 2-29 The Faculty of Electrotechnics built in 1974 (images from the cited article ©)

Since the original construction was designed at the very beginning of thermal insulation issues, over the last three decades, several large-scale interventions have taken place, both internally and externally. Outside works meant the replacement of wooden windows with white PVC frames and yellow and orange paint (unfortunately) instead of the grey concrete elements, the pronounced volumes being hard to be more altered. The interior educational spaces were separately updated (new equipment included), each one with the help of a different company (Polytechnic's partner, usually employer of future graduates), but these actions came with limited free access to those classrooms. Today, the four pavilions are used by three major faculties and their 5424 students: Automation and computers (IT); Electronics, Telecommunications and Information Technologies; Electrotechnics and Electro-energetics. Like any other building built fifty years ago, it needs to be refurbished, considering both energy efficiency and comfort criteria, the envelope (exterior walls, windows, roof) being here, the most valuable to consider, regarding natural lighting, ventilation, solar radiation and energy (passive / active), heat gains and losses, different systems integration. The existing windows replacement is of the most efficient energy measures to be taken, due to the ultimate developments for improved qualities and much better specifications: glass thermal transmittance value (U), glass solar factor (g), window frame, and even shadowing system (Fig. 2-30).

Fig. 2-30 The Faculty of Electrotechnics in 2024 (images from the cited article ©)

The idea of a doing a study on the possible intervention regarding an energy efficiency refurbishment, applied on this representative ensemble, emerged in the spring of 2024 and was developed by the candidate with few students enrolled in the 4th year of architecture (members of the best teams that reached the National Stage of Saint-Gobain Architectural Student Contest – edition 2024 – as described in chapter 2.1.2). The main idea was to leave the interior space unaltered, while focusing on the envelope and keeping its original aspect.

The Brutalism movement emerged as architectural current in the mid of 20th century, being characterized by raw and left unfinished materials, mostly concrete to highlight its natural texture, plus geometrical block-like shapes with repetitive patterns and exposed structural prefabricated elements and mechanical systems. During 1950's to 1970's its specific architecture has been widely used in government buildings, educational institutions and public housing (l'Unité d'habitation in Marseille or the Barbican Estate in London). The public opinion was divided between those who supported it and debating about the preservation of the architectural value and the critics, who disapproved it, as constructions were considered uninviting, unattractive and overwhelming, without human scale. In the 21st century, architects and other people revived the popularity of this style that combined traditional features with innovative elements, appreciating the honesty and boldness of structural and geometrical shapes, promoted even more through Social Media photos to the new generation. Efforts to save iconic Brutalist buildings have increased, emphasizing their architectural and historical importance ([30]).

The Electrotechnics building's form was a big challenge for rehabilitation purposes, therefore the proposed measurements for energy efficiency issues were separated in several categories:

- doors and windows, with the least problems in disturbing the outside appearance, while bringing the biggest intake in the future energy class of the building
- roof, with additional external layers, including thermal insulation, vapour barrier, waterproofing and even green terrace system
- façade walls, with thin inner thermal insulation, to preserve the original exterior design and not to diminish the cubic capacity of the interior space air
- new ventilation systems, with air recovery, to prevent condensation and improve local thermal bridges
- an add-on might be the use of photovoltaic cell (PV) panels on the flat roof as renewable energy supply.

The first solution proposed to clean the outside yellow/orange paint from the prefabricated elements and to keep the revive the grey colour of concrete. New triple glazed windows, with timber aluminium green frames, from INTERNORM, model HF410 together with an exterior shadowing system FIXSCREEN 100 Atria replaced the existing windows. Inner 50 mm VIP (vacuum insulation panel) boards and a green terrace completed this project (Fig. 2-31).

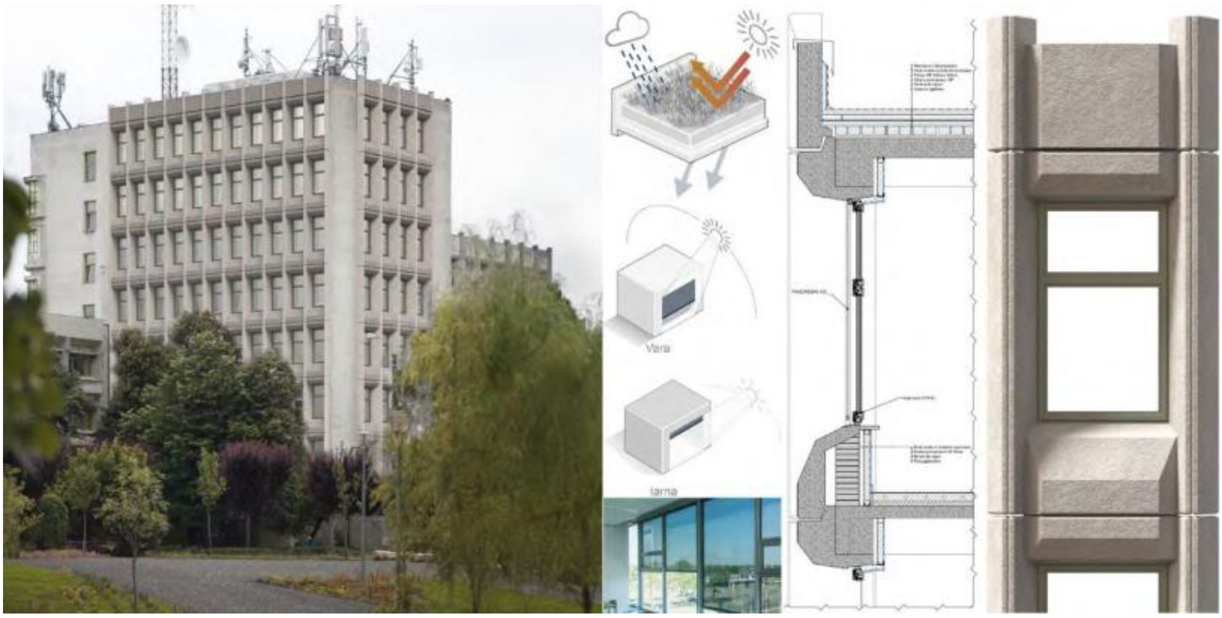


Fig. 2-31 1st proposed solution (images from the cited article, students' project ©)

The second solution related an architectural solution of a ventilated façade system applied on the opaquer volumes that connect the main four buildings with the main domain studied inside (IT and electronics), through a symbolic representation of electrical motherboard connection lines. ZOLA Thermo ALU90TM R-8 windows (with passive house characteristics), internal 50 mm efficient thermal insulation, recovery HVAC system and accessible green roof represented the new features of this proposal which leaves the longer facades monochrome (Fig. 2-32).

Fig. 2-32 2nd proposed solution (images from the cited article, students' project ©)

A sensible solution offered a new image of the main entrance, along with punctual different tones of green to frame certain prefabricated elements, pursuing a vertical dominance in the urban context. A grey and thin exterior thermal insulated plaster was applied to double the interior 50 mm VIP panels. Triple glazed windows with interior shading, from ALUMIL, model Supreme S91 were used to replace all the glazing area and, again, a green roof with PV panels was suggested for the existing flat upper terraces (Fig. 2-33).

Fig. 2-33 3rd proposed solution (images from the cited article, students' project ©)

The green elements became more present, within the last two solutions being used not only on the upper part, but also on the facades, as a filter and natural shadow. From linear roof pots, parallel with the vertical walls and near the edge, plants are coming down in front of the modulated elements, on thin steel cables and connecting exterior elements. Each prefabricated window frame received a flashing and a drip edge to avoid possible water infiltration while on the inside the UdiIN(R) System mold-free insulation was added (Fig. 2-34).

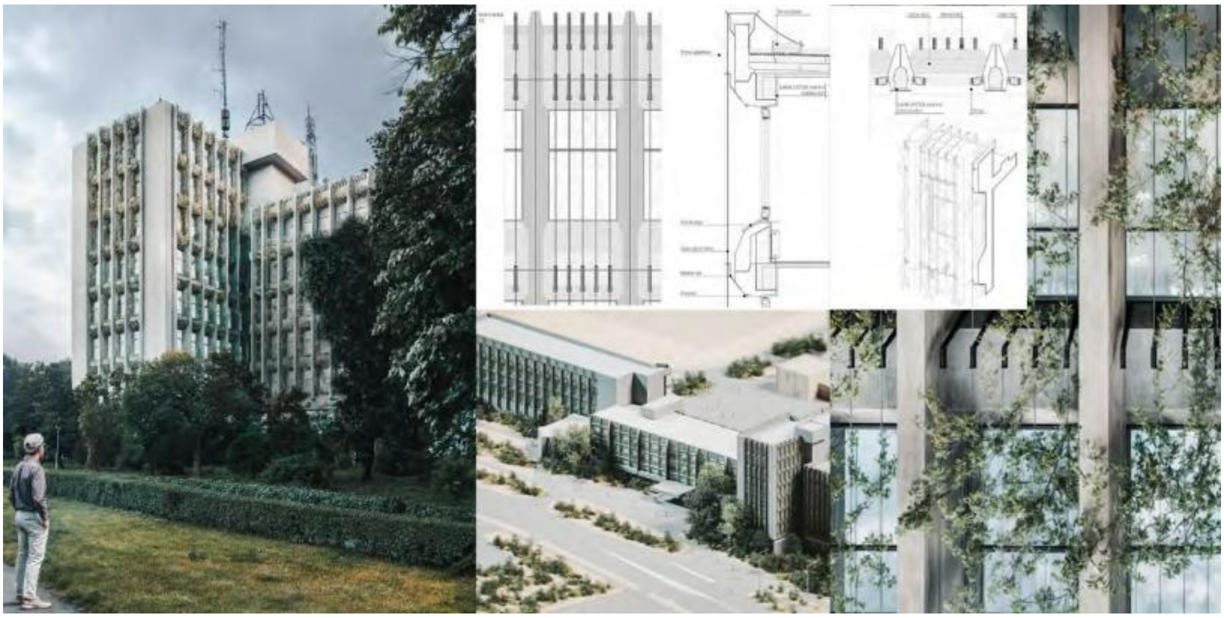


Fig. 2-34 4th proposed solution (images from the cited article, students' project ©)

In the fifth proposal, the most comprehensive, each prefabricated element received a ceramic or concrete individual pot for each window, a formal extension of the existing volumetric element. Small plants like ever green ivy (Hedera Helix) could be easily maintained from the inside, due to the gliding system of proposed windows. Triple glazed aluminium windows, STEICO internal wood insulation, HVAC recovery system and (another) green roof were even here taken into consideration for this intervention (Fig. 2-35).

Fig. 2-35 5th proposed solution (images from the cited article, students' project ©)

All the proposals were public exhibited and appreciated by the academic community, especially by the direct users of this symbolic building. Even if it was a case-study, the proposed solution can be applied on other similar construction with valuable architecture. Detailed measures to prevent cold bridges and condensation on critical interior surfaces should be further analysed, while taking into consideration the financial aspect of refurbishment.

2.4 Structural strengthening along with thermal rehabilitation

2.4.1 Introduction ([10])

The candidate participated, along with other colleagues, to different studies elaborated on this complex subject, related with a PhD thesis, "Structural Strengthening of Historic Masonry Buildings Using Mesh Reinforced Composite Materials", defended by the author, Dragos Bocan, in April 2025 ([31]). The novelty of using thin elements, beneath the decorated facades of the exterior wall (one-side or double side strengthening) is a subject thoroughly developed in the thesis, along with multiple scientific articles published during its elaboration period.

The thermal rehabilitation is, especially in older buildings, an opportunity given by structural strengthening, reflecting the importance of both aspects: envelope's energy efficiency can reduce the operational costs and necessary structural safety for the building inhabitants. Sometimes it is quite difficult to apply contemporary rehabilitation techniques on historical constructions, while preserving the heritage aspect when necessary. Ornamental features, highly decorated facades and construction materials compatibility are considered part of a complex problem while solving the structural integrity issue in seismic areas, like Romania.

Research on possible rehabilitation solutions developed on one side (inner or outer face) or two sides of an exterior wall was done through an extensive work and multiple articles, all realized over the last several years. The brick masonry constructions were widespread throughout the western Romanian cities, mostly erected under the former Austria-Hungarian Empire governance. Timisoara and Arad are offered a great opportunity for applied investigation, especially in the city centre, where many buildings were slowly brought to the original image, their facades showing the structural components during the execution works. An extensive inquiry concluded several possible solutions applicable to heritage structures, considering both thermal and structural retrofit, in a seismic area.

Most of the erected buildings around 1900 were made of masonry walls with fire brick and lime mortar, an underground level covered with masonry vaults and upper levels with wooden floors, progressively thinner walls and pitched roof with ceramic tiles, organized along the perpendicular streets as blocks enclosing inner courtyards. Neoclassic and eclectic decorations for public facades, contrasting with courtyards facades, just in painted lime render (Fig. 2-36, [32]).

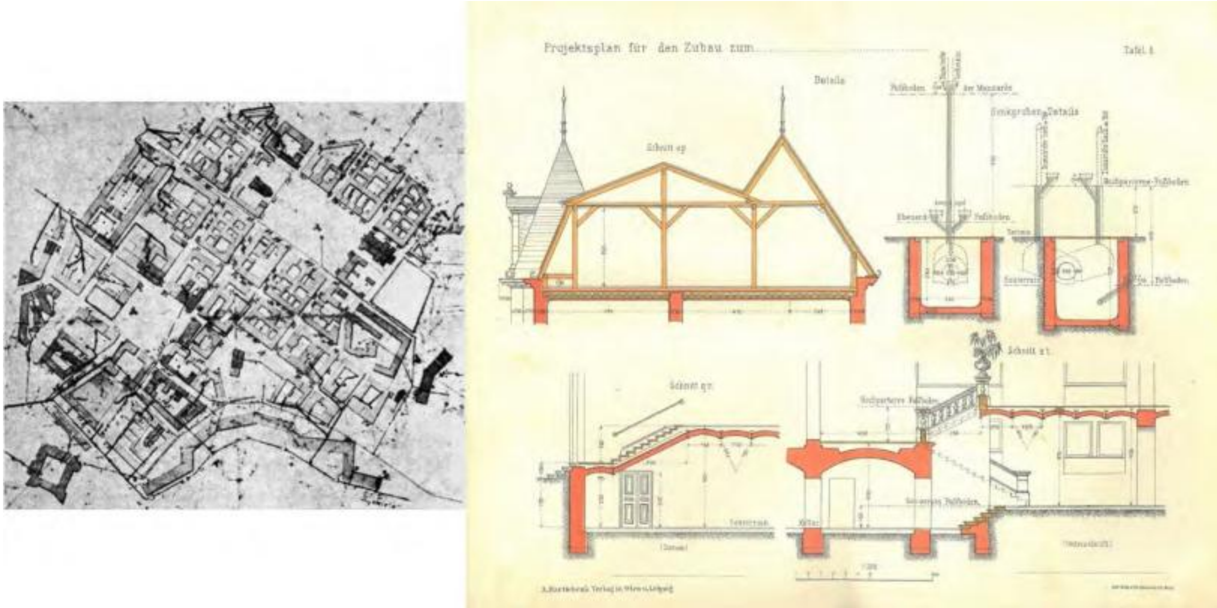


Fig. 2-36 Timisoara's City Centre and typical buildings' sections (images from the cited article ©)

The intervention decisions have to preserve the history of the building, considering its multiple values – architectural, cultural and even social. The solutions that can keep the structural integrity and improve the current needs were approached lately, on different scale (from construction materials to urban plots) and directions (from energy issues to longer functionality and life expectancy), showing the impossibility of an outside solution, especially where the façade decorations must be maintained.

A strengthening solution behind a thermal insulation from various natural-based materials was proposed and analysed, under several different scenarios (Table 2-9):

Insulating material / Characteristics	M1 (board)	M2 (plaster)	M3 (high performance plaster)
Physical properties	Lightweight, vapour permeable	Breathable, porous	Lightweight, highly porous
Composition	Mineral-based (sand, lime, cement and water)	Lime-based (natural lime, pumice stone) and cork	Aerogel-lime
λ (W/mK)	0.042	0.075	0.028
Thickness (mm)	20-300	20 /coating / Max. 80	Max. 80
Possible application	Inner side of the wall	Inner side of the wall (even outside)	Both sides of the wall
Est. cost / m2 (€)	8 (50 mm)	20 (20 mm) / 40 (40 mm)	90 (20 mm) / 230 (50 mm)

Table 2-9 Various thermal solutions (candidate's compilation from the cited article ©)

To determine an accurate context of this mixt proposal, the first steps were done by analysing some representative buildings and select those to be 3D-modelled and detailed in ArchiCAD, a specific design software. Its Energy Evaluation integrated module used all the on-site measurements for information on defined materials (envelope, walls and slabs), location climate data and environment setting together with the operational profile and building systems, showing geometry data, heat transfer coefficients, specific annual energy consumptions values and CO_2 emissions. Furthermore, the Ubakus application ([33]), with its large database of relevant technical details from manufacturers, determined the envelope's components U-values, heat-loss, moisture and initiative LCA analysis. The platform offered also financial references related with decreasing the heat costs to support the owners' refurbishment decision.

The seismic strengthening simulations were performed through tests on masonry specimens of 1200 x 1200 x 450 mm, reconstructed with burnt clay bricks, 1.5 English bond style. The 10 mm lime-based mortar, suitable for unreinforced masonry (URM), used to cover both sides of the wall, was completed with 2 perpendicular layers of unidirectional steel fiber sheets, strengthening only one side or both sides of the specimen (Fig. 2-37, [31]). The experimental investigations on historical masonry walls were realized as laboratory tests during the mentioned PhD development.

Fig. 2-37 Masonry tested specimens (images from D. Bocan PhD thesis ©)

By using the different solutions mentioned above, eight scenarios were analyzed and compared (Table 2-10):

Features \ Scenario	0 (no measures)	1	2	3	4	5	6	7
Interior insulation material	-	M1 50 mm	M2 40 mm	M2 40 mm	M3 50 mm	M3 50 mm	M1 50 mm	M1 50 mm
Outside insulation material	-	-	-	M2 20 mm	-	M3 20 mm	M2 20 mm	M3 20 mm
U-Value (W/m²K)	1.705	0.531	0.835	0.683	0.429	0.334	0.471	0.397
Heat Capacity (kJ/ m²K)	800	730	736	744	731	735	734	730
Condensation (kg/m²)	0.20	0.62	0.36	0.09	0.68	0.39	0.46	0.25
Drying time (days)	10	77	41	12	92	54	63	35
Heat energy annual demand reduction (%)	-	-42.60	-29.00	-34.60	-43.20	-46.30	-41.90	-44.30
Annual heat energy saving (kWh/m²)	-	76	54	65	84	91	81	86
Annual heating cost reduction (€/m²)	-	4.60	3.20	3.90	5.00	5.40	4.90	5.20
Energetic amortization (years)	-	0.2	0.1	0.1	0.2	0.3	0.2	0.2
CO_2 Emission reduction (%)	-	-12.40	-18.20	-14.70	-18.40	-19.70	-17.80	-18.80
CO_2 Savings (eq. kg CO_2/m²)	-	16.00	11.30	13.70	17.60	19.00	17.00	18.10
CO_2 Amortization (years)	-	0,2	0.3	0.3	0.6	0.8	0.3	0.5
Financial amortization (years)	-	1.6	8.2	9.4	17.6	19.8	4.6	10.8

Table 2-10 Energy efficiency relevant information in various scenarios (candidate's compilation from the cited article ©)

Significant differences between the presented scenarios, together with the thin layer of structural strengthening, showed that financial aspect may have a major influence on the design decision, while keeping the valuable external decorations, breathable wall structure, little mass added, small reduction of the internal area and increased seismic load-bearing capacity. The structural strengthening must be, just like the energy efficiency, adapted to regulations change and environmental condition. Our country has seismic activity, therefore the specific combined measures are usually more complicated than the ones applied in other regions, like Italy, where thermal rehabilitation is not an important issue. Considering the latest earthquake movements in Romania, a new seismic design code P100-1 might become compulsory soon.

2.4.2 Fiber and textile reinforced mortar used in structural rehabilitation ([4])

Another analysis and study performed as part of the same PhD thesis investigated the opportunity to use different meshes and fibres from Kerakoll Spa manufacturer while using 3muri software (from STA Data) and GeoForceone to simulate the wall behaviour on sites with different degree of degradation.

This possibility was explored through successive steps, aiming to provide a better solution to more than just concrete reinforcement, with thin lime mortar, reinforced with fibres or meshes. In the historical built environment, where a

rehabilitation deals with more than just structural issues, the compatibility with older materials is needed to avoid condensation or excess humidity, while keeping the architectural image and improving the thermal comfort.
Considering the large scale of similar buildings in the central part of the Hungarian Austrian Empire cities, due to a uniform education for designers and construction workers, a typical façade with rhythmic fenestration voids, limited masonry piers between them and continuous masonry connecting different stories was the object of this study. Furthermore, the seismic activity from Banat region, with its usual low depth earthquakes and repeated structural stress, lead to various scale interventions applied and simulated on an equivalent frame in 3muri, with or without reinforcement (Fig. 2-38).

Fig. 2-38 Buildings from Timisoara with similar features (images from the cited article ©)

The masonry reinforcement proposed in alternative simulations was selected from Kerakoll Spa, leading manufacturer in renovation materials:

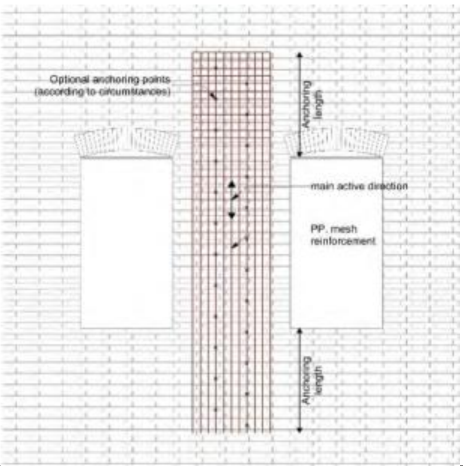
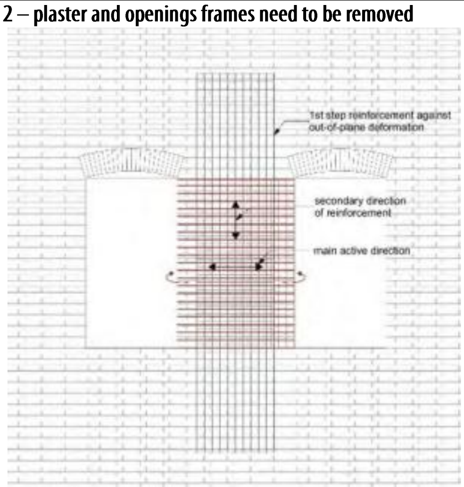
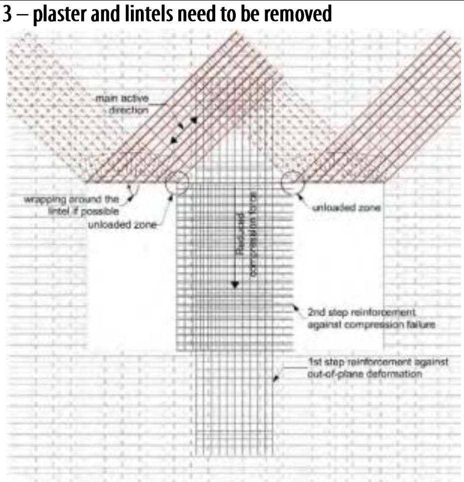
- alkali resistant glass and aramid fibres, forming a bi-axial mesh (Rinforzo ARV 100)
- a unidirectional sheet with ultra-high strength galvanized steel micro-cords (GeoSteel G600).

Other construction materials, from the same producer, were proposed optional, to get more strength consolidation or to obtain more thermal insulation, even to have a better interaction between different components:

- Lime based mortar matrix compatible with use as render on historic buildings (GeoCalce Fino Antisismico)
- Fiber reinforced mortar possible to use as higher strength consolidations (Kerabuild Eco Fix)
- Thermal insulation mortar, lime based with expanded clay aggregates (Biocalce Termointonaco)
- Wall anchors with terminal elements for better interaction with textile mesh reinforcements (Baumit Star Track Duplex).

The successive steps are synthetically presented below (Table 2-11):

Step	Main goal	Results during a seismic event through 3muri software:
0 – no reinforcement		Shear force for failure: 220 (kN); bending damage and shear failure affecting lintels and masonry pier

<table>
<tr>
<td>1 – plaster from the pier need to be removed

</td>
<td>Reinforcement against deformation, along the vertical direction of the pier (inside and outside); distanced from the window openings to limit the façade in-plane behaviour.</td>
<td>The damage state was reduced. Visible difference between the two types of reinforcements were noticed:
- with ARV100 shear force for failure was 257 (kN); the wall suffered only bending and shear damage, while only few elements of the wall had tension failure
- with GeoSteel G600 shear force for failure was 330 (kN); the wall presented also bending and shear damage failure in some of its composing elements.</td>
</tr>
<tr>
<td>2 – plaster and openings frames need to be removed

</td>
<td>Reinforcement against compression failure by wrapping the pier in mesh to avoid formation of vertical cracks due to compression; possible increase of the masonry units bending rigidity causing a larger impact of the in-plane behaviour.</td>
<td>Significant difference from the first step (one third), higher forces to cause first structural failures: with ARV 100 - 334 (kN) and with Geosteel G600 - 347 (kN), causing bending and shear damage.</td>
</tr>
<tr>
<td>3 – plaster and lintels need to be removed

</td>
<td>Reinforcement for lintel effort rerouting the discharged forces with oblique strips of mesh passed underneath the lintels and crossed above the pier; possible advantage given by the strips pretensioning to limit the deformation; use of anchors also</td>
<td>Less significant difference than before, but the structure became more secured, while the assembly resisted to a higher force Up to 375 kN for failure) with less deformation, most of the composing elements didn't suffer any damage.</td>
</tr>
</table>

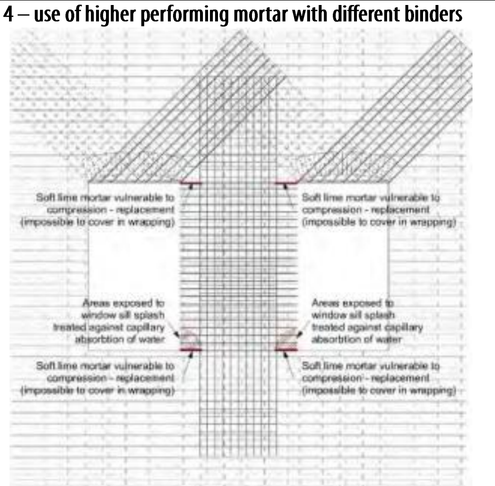
4 – use of higher performing mortar with different binders 	Additional protection against vertical stresses and weather effects, including impregnation agents for the sides of the window sills exposed to water splash during rain	Different types of intervention can be applied on sites with different degrees of masonry degradation.

Table 2-11 Reinforcements successive steps (candidate's compilation from the cited article ©)

By using these feasible solutions for strengthening the masonry columns the crack development was limited while gaining load bearing and flexural strength. A small mortar thickness can provide the opportunity to limit the heat transfer to keep the architectural appearance compared to a thicker concrete strengthening solution, especially for the historic buildings. When a major renovation is considered (by removing inner and outer plaster, exterior windows and even decorative lintels), the previous proposal can be applied.

2.4.3 Closed pattern building block combined intervention ([6])

An urban scale intervention for thermal and structural improvements of historical buildings was previously analysed on a city block within the old city centre of Timisoara through specific proposals only on their construction envelope. The streets highly decorated facades, as part of the heritage urban areas, cannot be refurbished using the usual nowadays energy rehabilitation techniques. The inner courtyards facades, on the other hand, with less decorations, can support more interventions, but also being restricted to compatible solution with the original materials used more than 100 years ago. The preservation of the external look, while minimizing the heat transfer, was the focus of three different approaches on the same edifices.

Classified monuments and common buildings formed a plot developed during the 18th and the 19th century, representing collective housing, a church, two educational buildings and a hotel. Different architectural styles can be found, from an eclectic neoclassic to Secession, having two to four storeys and forming a continuous façade towards the neighbouring streets and complex interior courts (Fig. 2-39).

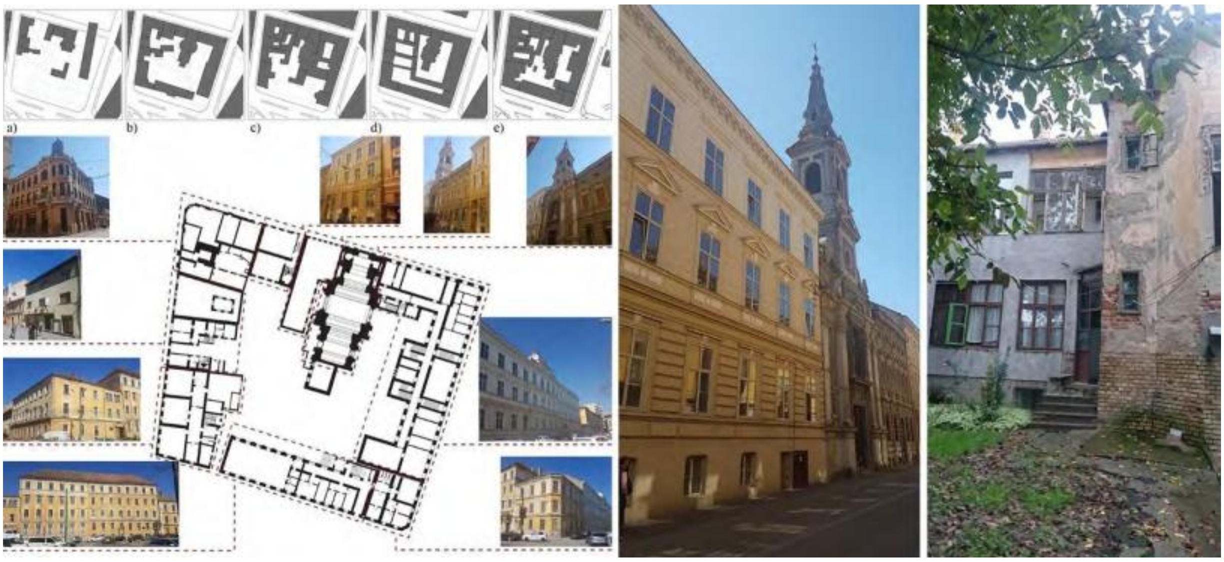


Fig. 2-39 Analysed plot – historical evolution (images from the cited article ©)

A detailed architectural 3d model, developed after the geometrical survey, represented the file support used in a specific tool, EcoDesigner, from the ArchiCAD special design software, to determine the energy efficiency evaluation, based on thermal zones defined by walls and slabs and on the context with its environmental features (climate, shading, wind direction, even used heating systems). The geometrical characteristics of the entire block such as external envelope area (12241.97 m^2), ventilated volume (50476.72 m^3) and glazing ratio (8%) were essential for the following output data, considering the proposed scenarios. The outer walls were proposed to be insulated with an insulating plaster from Kerakoll (Biocalce Termointonaco), containing only natural materials, with a low thermal conductivity (0,075 W/m*K), high porosity for a proper ventilation, low density (370 kg/m^3) and good heat capacity (1080 J/kg*K) (Fig. 2-40).

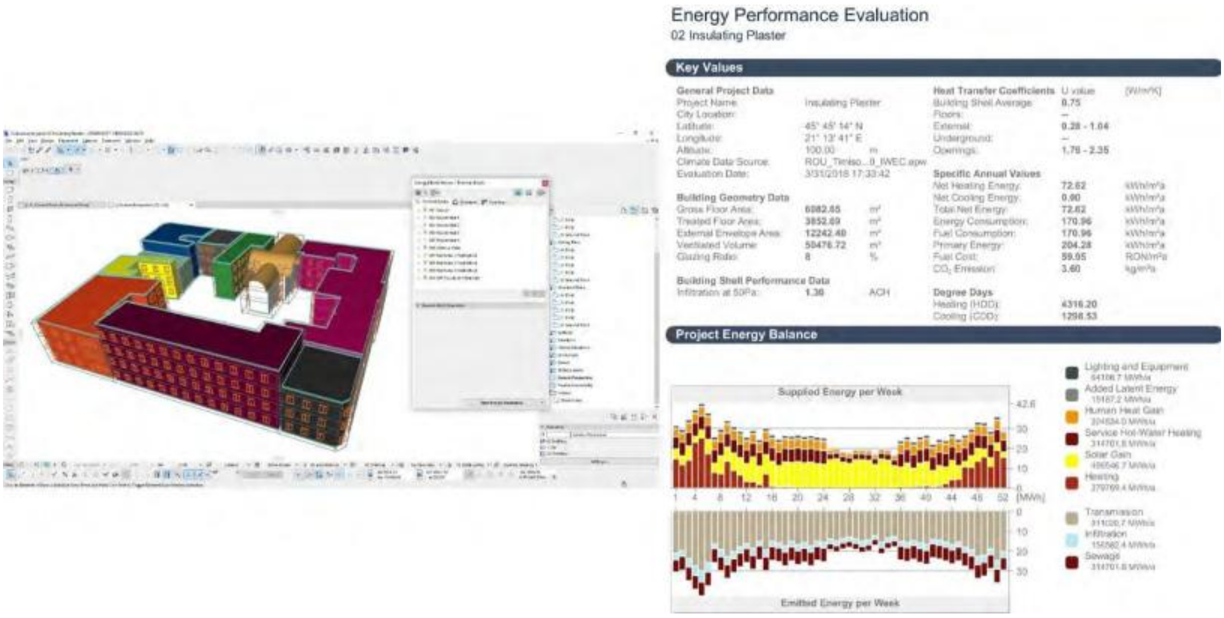


Fig. 2-40 Analysed plot – energy evaluation (images from the cited article ©)

The visible differences between the proposed solutions shown below (Table 2-12) proves that simple interventions like render replacement with breathable insulation and windows retrofit can lead to major improvements on energy efficiency, along with the necessary structural strengthening.

Comparative results / Scenario	Building Shell Average (W/m^2*K)	Net Heating Energy (kWh/m^2*a)	Primary Energy (kWh/m^2*a)	Fuel Cost (RON/m^2*a) (year2018)
1 (existing buildings) - no thermal rehabilitation - usage and heating scenarios according to reality	1.19	140.73	272.39	81.75
2 (only with insulated plaster) - both sides insulated facades with 2.5 cm insulating plaster on the inside and 4 cm insulating plaster on the outside walls - between buildings walls insulated only on internal side - church walls insulated only on the outside because of the decoration - 20 cm mineral wool on the floor towards attic space - 10 cm mineral wool boards on the floor towards the cellar - rehabilitated windows with double glazing, low-e glass on the inside, 4 Seasons external glass, argon in the cavity, existing frames with new sealing, U_{glass} = 1.3W/m^2*K, U frame unchanged	0.75	72.62	204.28	59.95
3 (with insulated plaster and mineral wool) - street facades with 2.5 cm insulating plaster on the inside and 4 cm insulating plaster on the outside - courtyard facades with 10 cm mineral wool based ETICS on the outside - between buildings walls insulated only on internal side - church walls insulated only on the outside because of the decoration - 20 cm mineral wool on the floor towards attic space, including over the church vaults - 10 cm mineral wool boards on the floor towards the cellar - rehabilitated windows with double glazing, low-e glass on the inside, 4 Seasons external glass, argon in the cavity, existing frames with new sealing, U_{glass} = 1.3W/m^2*K	0.67	62.38	194.04	56.68

Table 2-12 Different scenarios and their results (candidate's compilation from the cited article ©)

All these theoretical studies, along with the other experimental part of the PhD thesis mentioned at the beginning of the 2.4 chapter, showed that retrofit solutions integrating thermal and seismic benefits can be achieved with proper building materials. The option for both insulation and one-side strengthening, usually on the exterior part of the load-bearing elements, is more suitable for the inhabitants of the building, considering they don't have to move out during the whole intervention. It also provides a sufficient improvement for the building structural behaviour, even if the benefits are lower than the double-sided wall approach. This second solution might offer superior advantages on long term but influences the costs of the entire process significantly. Even more, the image of heritage buildings and historical urban areas can be preserved, with lesser impact interventions.

Furthermore, the PhD author continues to develop mixt solutions along with Architecture 4th year students on selected existing buildings through educational projects.

3. ENERGY-EFFICIENCY SPECIFIC STANDARDS, LABELS AND CERTIFICATIONS

"Doing the right things or doing the things right? "(leadership versus management), Peter Drucker

3.1 Introduction

As it was previously mentioned, the energy efficiency in building sector represents a very important issue for all nations, closely connected with the economic growth and people's wellbeing. To achieve specific tasks and to impose fair rules for each region / country means the necessity of an overall energy policy framework consisting of laws, directives, standards, technical regulations, official publications.

Many international institutions such as World Green Building Council (WGBC), European Climate, Buildings Performance Institute Europe (BPIE), along with United Nations Organization (UN) and European Union (EU) have developed strategies and objectives, continuously improved. Each major global event that affected the energy industry and, of course, the climate change was followed by specific rules to be transposed in continental and national legislation. Europe has, by far, the most complex energy requirements on buildings, and Germany is probably, the leading country. Romania, as part of the EU, had a good start, but it is hard to reach the western countries progress. In a table comprising the most important data from the post-war period (Table 3-1), the candidate illustrates, downsizing from international to national, these actions ([34], p. 18, [16], p. 36, [35], [36]):

Period	World	Europe	Germany	Romania
1950-1970	-	-	1952 Minimal Thermal Protection (DIN 4108:1952-07, today DIN 4108-3:2024-03) – maximal U-values (thermal transmittance) for specific envelope elements and moisture damage issues	1962-1968 National State Standard STAS 6472 -61, STAS 6472-68
1970-1975	1972 UNO conference "Environment" Stockholm 1973 Oil Crisis			1973-1975 STAS 6472/3-73 – Building Physics (thermo-technics and hygro-thermic)
1976-1980			1977 Energy Saving Law 1st Thermal Insulation Regulation (enEG 22.07.1976) – winter and summer thermal protection with specific U-values, dependent on surface area / heated volume ratio	STAS 6472/3-75
1981-1985			1984 2nd Thermal Insulation Regulation (enEG) – added the refurbishments with minimum requirements on building components	1982 Norm on design and execution of thermal insulation works for buildings (C107-82) 1984 Norm on the design of residential buildings (NP15-84), STAS 6472/3-84
1986-1990	1987 Brundtland Report	1988 EU directives for building products		NP15-87 STAS 6472/3-89
1991-1995	1992 United Nations Framework Convention on Climate Change (UNFCCC)– Rio de Janeiro Summit		1992 Building Act products 1995 3rd Thermal Insulation Regulation (enEG) – introducing heat demand on winter	
1996-2000	1997 3rd UN Climate conference – Kyoto Protocol (combating climate change by reducing greenhouse gas emissions)	2000 Lisbon Sustainable Development Strategy to make the EU "the most competitive and dynamic knowledge-based economy in the world" by 2010	2000 Renewable Energy Sources Act (EEWärmeG)	1997 Norm on thermo-technical calculation of building construction elements (C107/1,2,3,4,5), replacing STAS 6472/3 1996 Norm on the design of residential buildings (NP016-96)
2001-2005	2002 World Summit "Sustainable Development" Johannesburg	2002 Energy Performance of Building Directive (EPBD 2002/91/EG) – **Energy Performance Certificate** concept	2002 Energy Saving Ordinance (EnEV), revised 2004 – introducing the specific transmission heat loss in winter and solar insulation in summer; total energy balance refers to primary energy demand and differences in residential (heating and hot water) / non-	2002 Norm on design and execution of thermal insulation works for buildings (C107/0-02); Norm for calculating mass transfer (humidity) through building elements (C107/6-02)

			residential building regarding technical installations	2002 Norm on the design of residential buildings (NP057-2002, replacing NP016-96) 2005 Norm on thermo-technical calculation of building construction elements (C107-2005, /1, /2, /3, /4, /5 replacing those from 1997);
2006-2010	2009 15th UN Climate Conference – COP 15 Copenhagen (succeeding the Kyoto protocol)	2009 Europe Strategy 2020 (3x20) until 2020: - reduction of CO_2 emissions by at least 20% compared to the level as of 1990 - increasing the share of renewable energy sources (RES) in total energy consumption to 20% - increasing the efficiency of energy use by 20%. 2010 Revised EPBD 2010/31/EU – **Nearly Zero-Energy Buildings (NZEB)** concept	2007 Energy Saving Ordinance (EnEV) – separating residential buildings from the others, even in refurbishments; for non-residential buildings a reference building is used to limit the provision of heating, hot water, cooling, lighting, ventilation, humidification; Energy Certificate required for residential properties 2009 Energy Saving Ordinance (EnEV) – introduces renewable energy sources	2006 Calculation methodology for buildings' energy performance (MC-001/1-2006, /2-2006, /3-2006), to complete the 372 Law from 2005 on Buildings' energy performance 2009 Calculation methodology for buildings' energy performance (MC-001/4-2009 and /5-2009) regarding calculus breviary for buildings and apartments' energy performance certificate model
2011-2015	2012 UN Climate conference – COP 18 Doha (reducing greenhouse gas GHG emissions by 18% compared to 1990 levels) 2015 COP 21 Paris Agreement (limiting global warming to 1.5 ºC above pre-industrial levels until 2030) 2015 UN Sustainable Development Summit – New York (Transforming our world: the 2030 Agenda for **Sustainable Development** – 17 **Goals**)	2014 Climate and energy framework for 2030: - a target of at least 40% less GHG, compared to 1990 - a target of at least 27% renewable energy consumption - an indicative target of at least 27% improvement in energy efficiency	2014 Energy Saving Ordinance (EnEV) – reduce energy consumption for heating and hot water in buildings, raise the standard for new buildings by 25 % from 2016	2010 Norm on thermo-technical calculation of building construction elements (to complete C107-2005 with new values for thermal resistance) 2013 Calculation methodology for buildings' energy performance (MC-001/6-2013) – necessary climate parameters for energy performance of new and existing buildings, dimensioning of HVAC installations and hygro-thermic dimensions for building's envelope materials
2016-2020		2016 "Winter package", known as "Clean Energy for All Europeans" 2018 "Going climate-neutral by 2050 an economy with net-zero GHG emissions", long term low-carbon development strategy 2019 European Green Deal (EGD) – climate neutrality, decoupling economic growth from resource use, circular economy, sustainable finance, policy integration – through energy, transport, agriculture, industry and biodiversity	2017 Energy Saving Ordinance (EnEV) – nearly zero-energy standard for new buildings, from 2019 for public buildings and from 2021 for private buildings 2020 The Building Energy Act (GEG): the Law on saving energy and using renewable energies for heating and cooling in buildings (it replaces EnEG, EnEV, EEWärmeG); refers to buildings' energy performance, energy performance certificates and renewable energy	
2021-2025	2021 World Economic Forum on Sustainable Development Goals (SDG) – pandemic challenges, resilient recovery 2024 1st Buildings and Climate Global Forum – Declaration de Chaillot, to accelerate the climate change	2024 Revised EPBD EU/2024/1275, to be transposed into national laws until 29.05.2026 – aims to increase the rate of renovation in the EU, covers 4 main areas: renovation, decarbonisation, modernisation and digitalisation, financing and technical assistance; **zero-**	2024 The Building Energy Act (GEG): new heating systems to use at least 65% renewable energy from 2024 onwards and no more fossil fuels by 2045 starting with new buildings; gas boilers allowed only operated with renewable gas	2022 Calculation methodology for buildings' energy performance (MC-001/2022) – introducing nearly zero energy concept, renewable energy, more detailed types of buildings

		emission new buildings (ZEB) from 2030 2024 ECGT (Empowering consumers for the green transition) Directive EU/2024/825, to be transposed into national laws until 27.03.2026 – aims to help consumers make sustainable choices by receiving better information on product durability and repairability, and by strengthening protection against greenwashing and early obsolescence	2025 draft bill on "Act Against Unfair Competition (UWG)"	

Table 3-1 Post Second World War actions on energy efficiency (candidate's compilation from various sources ©, updated)

There are less than five more years to reach the 2030 Agenda for Sustainable Development established in 2015 ([37]), along with the 17 goals within the "5 Ps":

- **P**eople (1 – no poverty, 2 – zero hunger, 3 – good health and well-being, 4 – quality education, 5 – gender equality, 6 – clean water and sanitation)
- **P**rosperity (7 – affordable and clean energy, 8 – decent work and economic growth, 9 – industry, innovation and infrastructure, 10 – reduce inequalities)
- **P**lanet (11 – sustainable cities and communities, 12 – responsible consumption and production, 13 – climate action, 14 – life below water, 15 – life on land)
- **P**eace (16 – peace, justice and strong institutions)
- **P**artnership (17 – partnership for the goals).

All these interconnected goals are under permanent surveillance and analysis, yearly reports showing further needed actions. The last UN report from 2025 ([38]) reveals that, on energy and climate targets, acceleration is required, the visible progress being too slow. The connection between SDGs and European / national imposed legal framework can be seen in the entire built environment: from building materials selection to types of used energy, from energy performance certificates to green buildings rating systems, from residential sector to the public constructions, with a relevant consideration for social and economic aspects ([39]).

One of the most characteristic features for building materials, as envelope elements, was limited from the first energy requirements: the thermal transmittance or the rate of heat loss through a material (U-value) and its opponent R-value (meaning the thermal resistance) for different components (walls, roofs, floors). Throughout the years, this imposed value became lower, meaning more thermal insulation along with better humidity transfer control. Not just winter thermal protection, but summer thermal protection, refurbishments, specifications for technical installations, corrections for thermal bridges were introduced within each update of the specific legislation. The following table (Table 3-2) shows the parallel evolution of U-values in two countries, Germany and Romania, chosen by the candidate: ([16], p. 37-38, [36], [40], [41]):

Country	**Year**	**Norm**	**Maximal U value (1/R-value) of envelope component (W/m^2K)**				
			wall	roof	basement ceiling	floor above exterior space	window
Germany	1952	DIN 4108-2	1.56	1.56	1.16	0.8	-
Romania	1961	STAS 6472-61	1.32	1.04	1.22	-	-
	1968	STAS 6472-68	1.25	0.98	1.15	-	-
Germany	1974	DIN 4108-2	1.56	0.97	0.93	0.68	3.49
Romania	1976	STAS 6472/3-75	1.25	0.98	1.15	-	-
Germany	1977	EnEG	1.45*	0.45	0.80	0.45	-
	1981	DIN 4108-2	1.38	0.90	0.81	0.79	-
	1984	EnEG for refurbishment	1.20* 0.60	0.30 0.45	0.55 0.70	0.30 0.45	Double or insulating glazing
Romania	1984	STAS 6472/3-84	1.32	1.15	1.76	-	-
		NP15-84	0.83	0.65	0.93	-	-
	1989	STAS 6472/3-89	1.00	0.81	1.49	-	-
Germany	1995	EnEG for refurbishment	0.50 0.50	0.22 0.30	0.35 0.50	0.22	0.70 1.80
Romania	1996	NP016	0.83	0.50	0.91	0.33	2.50
	1997	C107 / 1, 3 ***	0.71	0.33	0.61	0.22	2.00
Germany	2002	EnEV, revised 2004					

		for refurbishment	0.35	0.30 0.25**	0.50	0.40	1.70
Romania	2003	NP057 ***	0.71	0.33	0.61	0.22	2.00
	2006	MC-001 / 1,2,3 *** for refurbishment	0.67 0.71	0.29 0.33	0.60 0.60	0.22 0.33	1.80 2.50
Germany	2009	EnEV 2007 revised, for refurbishment	0.24	0.24 0.20**	0.30	0.24	1.30
Romania	2016	MC-001 revised	0.56	0.20	0.35	0.22	1.30
Germany	2020	GEG For refurbishment	0.28 0.24	0.20 0.24	0.35 0.24	0.35 0.24	1.30 1.30
Romania	2022	MC-001 *** for refurbishment	0.25 0.33	0.15 0.20	0.29 0.40	0.20 0.22	1.11 1.20
Germany	2023	GEG	0.20	0.14	0.25	0.25	0.90

* windows and French doors included
** flat roof
*** values considering thermal bridges

Table 3-2 Evolution of maximal U values in Germany and Romania (candidate's compilation from various sources ©, updated)

Together with this constant reduction of U-values, in terms of better insulated building, the buildings requirements became increasingly specific, considering saving energy through other limited requirements: functionality (residential or not), usage period (all year, seasonal, weekly, daily), total primary energy demand, CO_2 emissions, percentage use of renewable sources, the main European goal to be achieved in 2050 being a self-sufficient built environment, climate-neutral, with zero energy consumptions and zero GHG emissions. The introduction of a compulsory Energy Performance Certificate (EPC), first for public edifices and any constructions / apartments on real-estate markets, and later to all built environment, sometimes even related with financial benefits (reduced taxes), led to an emerging building sector in areas such as infrastructure, circular economy, electrification and renewables, equipment and installations, operation, refurbishments of existing building stock, embodied carbon actions.

An EPC offers information on energy efficiency of the building, under several criteria, leading to a buildings' ranking similar with those of household products. Classes of efficiency (alphabetical, numerical, coloured, stared) are related with the primary / final energy consumption, usually given by unit of area per year. (replacing ISO 16343:2013 and ISO 16346:2013, ISO 52003-1:2017 Energy performance of buildings – Indicators, requirements, ratings and certificates, Part 1: General aspects and application to the overall energy performance – related with SDG 7 – Ensure access to affordable, reliable, sustainable and modern energy for all and SDG 11 – Make cities and human settlements inclusive, safe, resilient and sustainable). The next table (Table 3-3), synthesized by the candidate, shows the evolution of European Union's main legislation – EPBD:

Specific criteria	**EPBD 2002/91/EG** ([42])	**EPBD 2010/31/EU (recast of the previous,** [43]	**EPBD EU/2024/1275 (recast of the previous,** [44])
Transposition	National or regional methodology applied until 2006 (and three more years in case of missing experts in the field).	Several terms of application (2012, 2013, 2015) for different provisions.	Several terms of application (2025, 2026) for different provisions.
Applied definitions	Used terms: building, energy performance of a building, energy performance certificate of a building, CHP, air-conditioning system, boiler, effective rated output, heat pump	New terms: nearly zero-energy building, technical building system, primary energy, energy from renewable sources, building envelope, building unit, building element, major renovation, European standard, cogeneration, cost-optimal level, district heating / cooling	New terms: zero-emission building, public bodies, building automation and control system, metered, renewable and non-renewable primary energy factor, renovation passport, (staged) deep renovation, operational / whole-life-cycle greenhouse gas emissions, life-cycle global warming potential (GWP), split incentives, energy poverty, vulnerable households, recharging point, pre-cabling, roofed car park, micro-isolated system, smart / bi-directional recharging, mortgage portfolio standards, pay-as-you-save financial scheme, digital building logbook, useful / reference floor area, assessment boundary, on-site, energy from renewable sources produced nearby, EPB services, energy needs / use (consumption), calculation interval, delivered / exported energy, bicycle parking space, indoor environmental quality
Subject matter	Buildings' energy performance improvement, considering outdoor climate, location, indoor climate needs and cost-effectiveness		Buildings' energy performance improvement and reduction of greenhouse gas emissions (zero-emission building stock until 2050)
Objectives	Minimum energy performance requirements (EPR) for new / existing buildings and different categories of buildings: single-family houses, apartment blocks, offices, education buildings, hospitals, hotels and restaurants, sport facilities, wholesale and retail trade services buildings, other types of energy-consuming buildings.		
	Exceptions permitted for specific buildings: protected monuments,	Exceptions permitted for specific buildings: protected monuments,	Exceptions permitted for specific buildings: protected monuments, for religious activities, with temporary use, with

	for religious activities, with temporary use, with a total useful floor area < 50 m^2.	for religious activities, with temporary use, with a total useful floor area < 50 m^2, with an expected energy consumption <25% of a yearly use.	a total useful floor area < 50 m^2, with an expected energy consumption <25% of a yearly use and those serving national defence purposes (except living quarters or office buildings).
	Regular reviewed indoor climate conditions to avoid negative effects of inadequate ventilation		The optimal indoor environment should be adapted to climate change, fire safety, seismic risks, disabilities access, along with carbon (or other hazardous substances) removal / carbon storage in buildings.
	For **new buildings** with a total useful floor area > 1000 m^2, alternative systems should be considered, if they are environmental and economic feasible.	For all new buildings, the feasibility of high-efficiency alternative systems should be considered. All new buildings from 2021 and those occupied / owned by public authorities from 2019 must be **nearly zero-energy (NZEB).**	All new buildings from 2031 and those occupied / owned by public authorities from 2028 must be **zero-emissions buildings (ZEB),** with a lower energy-demand threshold and coverage of the annual primary energy from renewable / carbon-free sources, efficient district heating / cooling system.
	For large existing buildings (floor area > 1000 m^2) upgrades, minimum requirements set for the entire renovated building or renovated systems / components, only if they are feasible technical, functional and economical.	For all existing buildings under major renovation, (entirely / partially / building envelope elements retrofitted or replaced), minimum requirements are set only if they are feasible; high-efficiency alternative systems should be encouraged.	For all existing buildings under major renovation, minimum requirements are set only if they are feasible; high-efficiency alternative systems should be encouraged.
		National plans for more nearly zero energy buildings	National renovation plan – for all building stock, until 2050, with every five years revisions – template available.
			National database (or multiple integrated databases) for EPB must be created (connected to EU Building Stock Observatory), gathering: - Renovation Roadmap (with several options of intervention) - Building logbook for pilot buildings - EPC (with all necessary data) - renovation passport (showing the appropriate steps to a zero-emission building) - reports and inspections - smart readiness indicator (when is required) - one-stop shops (with technical and financial assistance facilities, dedicated services for vulnerable households). A direct access to the system's data must be provided for building owners, tenants and managers.
Energy performance requirements			Energy performance threshold for non-residential building stock, limited to 16% from 2030 and 26% from 2033, compared with 2020.
			National trajectory for a progressive renovation of residential building stock, the primary energy use set to decrease by at least 16% by 2030, 22% by 2035, etc., compared with 2020; 55% of this indicator should be achieved by the 43% worst-performing housing.
			Optimized solar energy in buildings: - for new public and non-residential buildings (useful floor area > 250 m^2) by 2027 - for existing public buildings by 2028 (useful floor area > 2000 m^2), by 2029 (>750 m^2), by 2031 (>250 m^2) - for existing non-residential buildings by 2028 (useful floor area > 500 m^2) - for new residential buildings by 2030 - for new roofed car parks by 2030
			Sustainable infrastructure mobility (recharging points, parking and bicycle places, pre-cabling installation) is set to be ensured subsequently for different categories of users. Guidance for fire safety in car parks will be provided.
	Regular inspections on boilers and air-conditioning systems	Detailed conditions for regular inspections of heating and air-conditioning systems	Separate inspection schemes established for residential and non-residential systems.
			Measuring, control, self-regulating devices for effective installation and operation of systems are required for a healthy indoor climate. In non-residential buildings, automation / control systems and automatic lighting are required, related with the value of the effective rated output (by 2025, for over 290 kW and by 2030, for over 70 kW). For residential buildings, specific equipment is required.

	Independent experts in the field	Independent experts and control system, with public information on training and accreditations	Independent experts and control system, public certification for professionals
		Energy performance requirements for building / building elements based on **cost-optimal levels**, related with climate and existing energetic infrastructure	Revised methodology until the mid of 2025 for cost-optimal levels, different for new / existing buildings and categories of buildings.
		Every three years updated national instruments for structural funds, **financial programmes**, stimulated investments should be provided.	Public-private partnerships may be promoted, together with EU programmes and packaged solutions. Priority for vulnerable categories and social housing and green loans / mortgages should be granted.
			EU taxonomy for sustainable investment: - 10% lower than national requirement for primary energy demand in new buildings - 30% improvement in primary energy compared to the actual state for renovation
Energy performance certificate (EPC)	- For buildings that are constructed, sold or rented out, for whole building or single apartment		- For buildings that are constructed, sold or rented out, for whole building or single apartment; that have undergone a major renovation
		- For buildings (useful floor area > 500 m^2 / 250 m^2 since 2015) occupied by public authorities frequently visited	- For existing building owned / occupied by public bodies
Validity	- Maximum 10 years		
Display	- Clearly visible displaced in buildings (useful floor area > 1000 m^2) occupied by public authorities and institutions, frequently visited	- Clearly visible displaced in buildings (useful floor area > 500 m^2 / 250 m^2 since 2015) occupied by public authorities and institutions, frequently visited	- Clearly visible displaced in buildings occupied by public bodies frequently visited or non-residential
Input data	- Thermal characteristics (shell, internal partitions, air tightness, etc.)	- Thermal characteristics of the building (thermal capacity, insulation, passive heating, cooling elements and thermal bridges	
	- For specific outdoor climate, position and orientation; natural lighting and ventilation		
	- For indoor climate conditions		
	- Heating installation, hot water supply, air-conditioning installation, ventilation, built-in lighting installation		
	- Passive / active solar systems, renewable energy sources for heating or electricity; CHP electricity, district / block heating / cooling		
			- Capacity of installed on-site renewable energy generation / storage (electrical or thermal)
Output data	- reference values (legal standards / benchmarks) to compare and assess the building's energy performance - recommendations for cost-effective improvements on EP - possible CO_2 emission indicator included	- reference values (minimum energy performance requirements) to compare and assess the building's energy performance - recommendations for cost-optimal or cost-effective improvements on EP (measures connected with major renovation – building envelope, technical building systems, individual building element); possible payback periods provided	- reference values for minimum energy performance requirements, minimum energy performance standards, nearly zero-energy building requirements and zero-emission building requirements - recommendations for the cost-effective improvement of the EP, the reduction of operational greenhouse gas emissions, the improvement of indoor environmental quality; possible payback periods / financial benefits provided
EPC Content	- classes of energy efficiency, ranging from maximum to minimum (usually labels from A – best to G – worst, coloured from green to red) - annual primary / final energy consumption (kWh/m^2year) - CO_2 emissions (kgCO_2/ m^2year) - real building data compared with a virtual / reference model with the same characteristics and minimal energy efficiency values		- classes of energy efficiency, ranging from maximum to minimum (usually from A – zero-emissions building to G – very worst-performing, coloured from green to red); A+ class possible - possible energy classes for CO_2 emissions - total, non-renewable and renewable, primary and final, annual energy use - operational greenhouse gas emissions produced in kgCO_2eq/m^2year - renewable energy ratio (%) - all new buildings (from 2031) and those with useful floor area > 1000 m^2 (from 2028) must have and disclose the life cycle GWP within the EPC, to achieve climate neutrality

Table 3-3 Evolution of EPBD legislation (candidate's compilation ©)

All these requirements, developed by many specialists from different countries / institutions and imposed by EU to be further implemented in national standards, were, at the beginning, tested and applied in residential buildings, where people spend most of their indoor time. Therefore, the housing sector, dynamic in the real-estate market, revealed the first analysis and offered specific information for the public. Later, other constructions, with public or private activity (administrative, office, financial, commercial, social, educational, etc.) were labelled through the mandatory EPC. Any building's energy performance can be explained in numerical indicators, leading to future actions for better and comfortable spaces, for less energy consumption and with money savings, on long term. Still, initial costs, related with all the necessary steps to obtain an Energy Performance Certificate, varied from one country to another, with significant influence on the public acceptance and openness for implementation. The increased complexity and distinctive demands of the three successive EPBD's had a different approach in European states. The most developed ones (financial and technological) represent following models for the rest of them, but different contexts usually lead sometimes to barriers at the national level, needed to be solved.

Meantime, the sustainability became more popular step by step, with "green standards" and certification systems for buildings. Considering the society sensibility to environmental issues and the long-time influence of construction materials on pollution-level, transparent methods for assessing in a simple and understandable manner were developed in the early 1990s. The economic feasibility was a major determinant for investors and clients; therefore, public and private institutions started to certify different components and entire systems or buildings ([34], p. 6).
Previous, green products standards were developed related with toxicity, children's health and indoor environment quality, followed by climate change, resource depletion, impact of manufacture, use and reuse of different components. Labels, certificates, product declarations, specifications, guidelines led to improved design and sustainable planning goals since early phases of the whole construction process. A green building is environmentally responsible, with an efficient use of resources during its entire life cycle, while creating healthy indoor spaces for occupants. The main international organization, World Green Building Council (WorldGBC, set up in 1998, comprising today over 70 independent nonprofit organizations), represents a global framework on building certification and supports the development of sustainability through standards, technologies, products, certification systems, without promoting a specific label. It endeavours relevant aspects at national levels with reference to local climatic, politic and cultural circumstances to attain a certain quality for the built environment.

BREEAM (Building Research Establishment Environmental Assessment Method), from United Kingdom, was the first among certification systems by publishing an assessment catalogue in 1990, followed by its French equivalent in 1996, **HQE** (Haute Qualité Environnementale). **LEED** (Leadership in Energy and Environmental Design) appeared two years later, in United States of America, managed by USGBC (United States Green Building Council) with ratings on new offices and administrative buildings. **CASBEE** (Comprehensive Assessment System for Building Environmental Efficiency) developed in Japan and **Green Star** assessment method in Australia materialized at the beginning of the 21^{st} century. All these are considered first generation labels, evaluating the "green" criteria and using GBTool (Green Building Tool). In 2007, the German Sustainable Building Council (**DGNB** – Deutsche Gesellschaft für Nachhaltiges Bauen) was founded, becoming today the Europe's largest network for sustainable building. As a second-generation assessment tool, other aspects were introduced and evaluated: site and economical features, socio-cultural and technological criteria, related with the entire life cycle of the construction: planning, erection, utilisation and demolition, through SBTool (Sustainable Building Tool) and LEnSE (Label for Environmental, Social and Economic Building) methodology.
Furthermore, new performance requirements for sustainable buildings were added in 2012:

- economic – focused on life cycle costs (LCC) through construction, operation, demolition or preservation values; EU taxonomy introduced in 2020, as part of the EGD, is now considered in several certification systems
- social – human comfort and health, achieved with all our senses through parameters like temperature, humidity, air and water quality, visibility, noise, accessibility.

Multiple attempts to develop a common and compatible assessment tool, to promote and compare at a global scale the sustainability of buildings, were initiated by independent organizations. Using the same starting point, the practical implementation at a national level, considering the climate, the legislation (laws, norms ad standards) and even the construction culture, led to different results. Still, the support for international standardisation in this domain was created. A comparative analysis shows that a similar procedure can be applied to most of the certification systems, even if each of them has a different methodology, distinctive terms and terminology ([34], p. 90). Following progressive levels (from 1^{st} to 6^{th}), a certain module defines the necessary steps in every certification to reach the specific grade or number of points through comparable units (Table 3-4):

Level	1^{st}		2^{nd}		3^{rd}		4^{th}		5^{th}				6^{th}
Module	Objectives (aspired assessment status	⇨	Qualities, categories (topic of criteria used	⇨	Criteria (features considered in the assessment)	⇨	Indicators (status quo, level of achievement,	⇨	Significance (for categories, criteria)	⇨	Weighting factor (%, points)	⇨	Rating result

	needed to be met): Regional / national safety goals, based on social values, trends and politics	for assessment)		quantitative / qualitative)			
		1.	1.1	1.1.1	x	%	Result
				1.1.2	y		
				…	…		
			1.2	1.2.1	a		
				…			
			…				
		2.	2.1	2.1.1	m		
				2.1.2	n		
				…			
			…				
		…					

Table 3-4 Certification system's general structure (candidate's compilation from the original source)

A comparison between these main three certification systems is present below, emphasizing the similarities and differences (Table 3-5):

Certification / Criteria	BREEAM	LEED	DGNB
Rating levels	Outstanding (≥ 85 %) Excellent (≥70 %) Very good (≥60 %) Good (≥40 %) Pass (≥25 %) Unclassified (<25%)	Platinum (≥80 points) Gold (≥60 points) Silver (≥50 points) Certified (≥40 points)	Platinum (≥80 %, min. 65% for each topic) Gold (≥65 %, min. 50% for each topic) Silver (≥50 %, min. 35% for each topic) Bronze (≥35 %)
Usage in Europe ([45]	65%	5.46%	6.46%
Different certification for:	- New construction residential v7 - In-use v6 - Refurbishment and fit-out v7 - Communities v6 - New construction v7 - Infrastructure v6	- Building design and construction (BD+C) v5 (New Construction and Major Renovation, Core and Shell Development) - Interior design and construction (ID+C) v5 (Commercial Interiors) - Operations and maintenance (O+M) v5 - Neighbourhood development (ND) v4 (Plan, Built Project) - Residential v4.1 - Cities and Communities (Plan, Existing, Design)	- Buildings new construction (v2023 in Germany, v2020 international) - Buildings in use v2020 - Buildings renovation v2022 - Buildings interiors v2018 in Germany - Buildings deconstruction - Buildings construction site - Urban districts - Business districts - Commercial areas - Industrial sites - Biodiversity-Promoting Exterior Space
Moment of certification	Pre-certificate (design-phase) Commissioning certificate (on completion)	Pre-certificate (optional) Commissioning certificate (on completion)	Pre-certificate (design-phase) Commissioning certificate (on completion)
Assessment categories (2nd level)	* 1. Ecological aspects (45% - 54.81%) - Energy - Water - Materials - Waste - Pollution 2. Economic aspects (9.43% - 12.43%) - Management (includes LCC) 3. Social aspects (13.3% - 22.63%) - Health and wellbeing (include Hazards) - Innovation *(extra 10%)* 4. Other aspects (17.25% - 29.26%) - Transport - Land Use and Ecology	** 1. Ecological aspects (60 points, 54.54%) - Water efficiency - Energy and atmosphere - Materials and resources 2. Economic aspects 3. Social aspects (24 points, 21.82%) - Integrative Process, Planning and Assessments - Indoor environmental quality - Project Priorities 4. Other aspects (26 points, 23.64%) - Location and Transportation - Sustainable sites	*** 1. Ecological aspects (environmental quality 22.5%) - Climate action and energy - Local environmental impact - Responsible resource extraction - Potable water demand and wastewater volume - Land use - Biodiversity at the site 2. Economic aspects (quality 22.5%) - Life cycle cost - Value stability - Climate resilience - Documentation 3. Social aspects (sociocultural and functional quality 22.5%) - Thermal comfort - Indoor air quality - Sound insulation and acoustic comfort - Visual comfort - Quality of indoor and outdoor spaces - Barrier-free design 4. Other aspects (32.5%)54.54% - Technical quality (15%) - Process quality (12.5%) - Site quality (5%)

Energy criteria (3rd level)	*** Energy criterion (Ene)** - Ene 01 Energy and carbon performance for regulated energy uses (9 credits + 3 exemplary) - Ene 02 Prediction of operational energy and carbon (12 credits + 4 exemplary) - Ene 03 Energy monitoring (up to 2 credits) - Ene 04 Low carbon design (up to 5 credits) - Ene 05 Energy efficient equipment (up to 5 credits) - Ene 06 Energy efficient systems (up to 9 credits) - Ene 07 Flexible demand response (2 credits) - Ene 08 Installed controls (2 credits)	**** Energy and atmosphere criterion – prerequisites and credits (EA)** - EAp1 Operational carbon projection and decarbonization plan (required) - EAp2 Minimum energy efficiency (required) - EAp3 Fundamental commissioning (required) - EAp4 Energy metering and reporting (required) - EAp5 Fundamental refrigerant management (required) - EAc1 Electrification (1-5 points) - EAc2 Reduce peak thermal loads (1-5 points) - EAc3 Enhanced energy efficiency (1-10 points) - EAc4 Renewable energy (1-5 points) - EAc5 Enhanced commissioning (1-4 points) - EAc6 Grid interactive (1-2 points) - EAc7 Enhanced refrigerant management (1-2 points)	***** Climate action and energy criterion (ENV1.1)** - Optimisation of the CO_2 balance in the planning process (max. 10 points) - Comparative values for life cycle CO_2 balance (max. 100 points) - Comparative values of other life cycle assessment indicators (max. 20 points) Key metrics: - Greenhouse gas emissions - Primary energy demand - Final energy demand - Renewable energy self-sufficiency rate - Building mass according to LCA - Life cycle assessment results **Life cycle cost (LCC) criterion (ECO1.1)** - Exemplary energy and climate balance in operation (max. 10 points) Key metrics: - Energy requirement value of GEG (German Buildings Energy Act) as a proportion of the reference value **Use and integration of building technology criterion (TEC1.4)** - Passive systems - Adaptability of the distribution system to suit operating temperatures to enable the use of renewable energy - Use of renewable energy sources and energy generation Key metrics: - Implementation of a passive building concept to reduce energy demand - Degree of coverage of final energy demand from the direct district/surroundings - Share of renewable energy sources in final energy demand - Minimum amount of renewable energy generated on the building or in the immediate vicinity
Energy weightings on the total ranking	* - 16.00% fully fitted; 7.87% shell only; 17.79% shell and core in non-residential buildings **(Ene)** - 13.91% partially fitted; 16.57% fully fitted in single residential dwellings **(Ene)** - 13.24% partially fitted; 15.71% fully fitted in multiple residential dwellings **(Ene)**	** - 30% new construction **(EA)** - 24.54% core and shell **(EA)**	*** 10.90% - 11.98%: - 9.6% - 10.4% **(ENV1.1)** - 0.083% (as part of **ECO1.1**) - 1.22% - 1.5% (as part of **TEC1.4**)

*Based on BREEAM New Construction International Version 7.0.0 [46]
** Based on LEED v5 Reference Guide for Building Design and Construction, November 2025 Edition [47]
*** Based on DGNB System, New buildings criteria set, version 2023 [48]

Table 3-5 Comparison of the three main certification systems (candidate's compilation from various sources ©)

The certification systems, as previously described, relate to multiple standards and technical norms, established by international organizations (ISO – International Standard Organization, CEN – Comité Européen de Normalisation, WHO – World Health Organization, UN, etc.) or national institutions (ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers, DIN – Deustches Institut für Normung, local GBC's, etc.). Therefore, most of the energy efficiency criteria are covered by any certification system. Technological improvements and innovations offer support for increased performances on different consumption and emissions, adapted to local conditions.

In terms of the economic aspect (as another pillar of sustainability), the certification systems have essential contributions to it, for all involved stakeholders: investors and occupants, construction materials and equipment suppliers, policies and strategies developers, researchers and standards issuers. Supplementary necessary costs to obtain a "green building" should be balanced during the life cycle of a building by lower operational costs and increased incomes. The decision to certify a sustainable building comes with extra effort and expenses given by certification fees (including auditor's service), aspired rating level, design optimisation, usually higher construction costs, operations optimisation, and even deconstruction. The direct benefits of the property value can vary from lower operational costs (due to energy and water efficiency, waste reduction) to an increased productivity (given by comfort, health and user satisfaction) and, for corporations, an improved image based on environmental protection issues. The end-users are attracted to this and, most of them usually being open to pay 1-5% to achieve several future profits.

A more popular term, the **lifecycle of a building**, is used now in most of the certification systems, starting from its first use. Below, the candidate presents how it is used in different contexts, but within the same large "umbrella" of sustainability:

- estimated economic lifecycle of a building (EPBD 2010), referring to a cost-optimal level for energy related investments (design, maintenance, operation, disposal)
- LCA – Life Cycle Assessment, (EN 15978:2011, Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method), referring to environmental, social and economic aspects, technical / functional characteristics and requirements, investor and regulatory demands, all related with different scenarios within the following stages of the system boundary: product, construction process, use and end of life
- Environment product declaration (EPD) for construction products and services (ISO 21930:2017 Sustainability in buildings and civil engineering works – Core rules for environmental product declarations of construction products and services), relating elements, assemblies, technical systems from construction works to life cycle stages, assessment and impact
- life cycle approach for new and existing building (EN 15643:2021 Sustainability of construction works. Framework for assessment of buildings and civil engineering works), offering a methodology that quantify how a construction can contribute to sustainable development, without benchmarks or performance levels
- whole-life-cycle greenhouse gas emissions (EPBD 2024), referring to emissions from production and transport of construction products, on-site execution activities, energy use and products replacements, demolition, waste management, reuse / recycling / disposal
- embodied carbon (or CO_2 footprint), decarbonisation and more recently sequestration of carbon dioxide ([49]), referring to a long-term storage of $C0_2$, similar to the natural processes like soil mineralization and photosynthesis. By using recycled aggregates, steel or other building materials components, technological wood-based products (CLT, Glulam), renewable biomaterials (bamboo, hempcrete, straw bales, timber), innovated materials or by creating chemical processes that lead to solid / stable carbonates (such as the cement matrix from the concrete production), the built environment can switch from emitting gases to carbon storing.

To conclude with this detailed analysis on what has or can be done to improve the energetic aspects of a certain building, while improving the built environment quality and satisfying its occupants, a "green" rating system contains the main indicators required in standards and methodologies ([39]). Long-term effects on energy efficiency and climate benefits result from several considered parameters (location, socio-cultural criteria, aesthetics, design methods, functional, technical and economic characteristics), suitable for an ecological and resource-saving investment ([34], p. 23).

The candidate developed some of these contemporary (and mandatory) information into her recently introduced course "NZEB and certification systems", a theoretical discipline for the 5th year bachelor architecture students (optional). The introduction of international framework and European goals is followed by a presentation of the national mandatory standards and the current "Calculation methodology for buildings' energy performance (MC-001/2022)" ([50]). The second part of the subject focuses on different types of the most used Certification Systems, in Romania and around the globe: BREEAM, LEED and DGNB, along with the LCA. Furthermore, a much-needed connectivity with specific construction materials and products was presented by external experts from the construction industry market, invited by the candidate in different lectures (twice until now):

- A specialist from the Schüco Group (including also Alukönigstahl & Jansen) for glazing systems: windows, doors, balconies and interior transparent, regarding thermal and acoustic properties, types of frames (and glass panes made by Saint-Gobain manufacturer), curtain walls, integrated shadowing system, controlled ventilation, façade fire spread limitation – all used in new and rehabilitated buildings.
- A second specialist from Saint-Gobain Company, for specific products: thermal wool insulation, multiple types of plasterboard (for drywall systems) – air-purifying, high-strength and impact resistant, non-combustible, light weight facades, interior modular spatial systems, acoustic –, airtightness and moisture management system, heating / cooling ceiling board, floors, plasters, water-proofing insulation.

- The third specialist from Xella Group, with their well-known wall-block products: Ytong (autoclaved aerated concrete with excellent thermal insulation, load bearing, fire resistant, good sound insulation, moisture regulating, eco-friendly), Silka (calcium silicate with high compressive strength, excellent sound insulation, good thermal mass, fire-retardant, regulating indoor humidity) and Multipor blocks (solid mineral insulation, non-flammable, vapor-permeable, energy-efficient internal and external wall insulation in both old and new buildings).

For a better understanding of the matter, each student had to use all this information in a study applied on the individual project from the current semester of Architectural Studio Design, as follows:

- Building's type classification and limited imposed values according to national legislation (MC 001/2022), for primary energy demand and CO_2 emissions
- Selected building's envelope materials from the previous mentioned manufacturers
- Simplified calculation for the envelope's components with Ubakus software ([33]) for complying with the referenced thermal resistance R'_{max} or thermal transmittance U'_{min}
- Simplified calculation of LCA within Ubakus software
- Simplified evaluation of the building with one of the presented certification systems, based on the provided manuals – with centralized criteria and points, resulting in a score and a classification.

The candidate appreciates that students successfully understood the importance of a proper design and selection of materials to obtain obvious benefits on the energy-efficiency issue. As future specialists, young professionals formed in the architectural school must acknowledge their responsibility on the built environment, being main dialogue-partners with clients, authorities and manufacturers, while becoming capable, through acquired practical experience, to positively influence the entire sustainability system.

Another practical introspection into this subject was done through an experimental case study, performed on a newly built small house, with two apartments and mixed structure. The development of this project, created in the architectural professional studio of the candidate (Atelier CAAD Ltd), has emerged from the desire to combine the newest (in 2010) trends in the construction field, a representative image for the two architects, beneficiaries and designers at the same time and under a limited budget. The narrow site (under 10 meters street wide), with no possibilities for lateral views on the north and south limits, leaded to a simple and rectangular shape, positioned on the northern property limit, leaving 3 meters access to the backyard and covered possible parking places nearby the ground level southern accesses (Fig. 3-1).

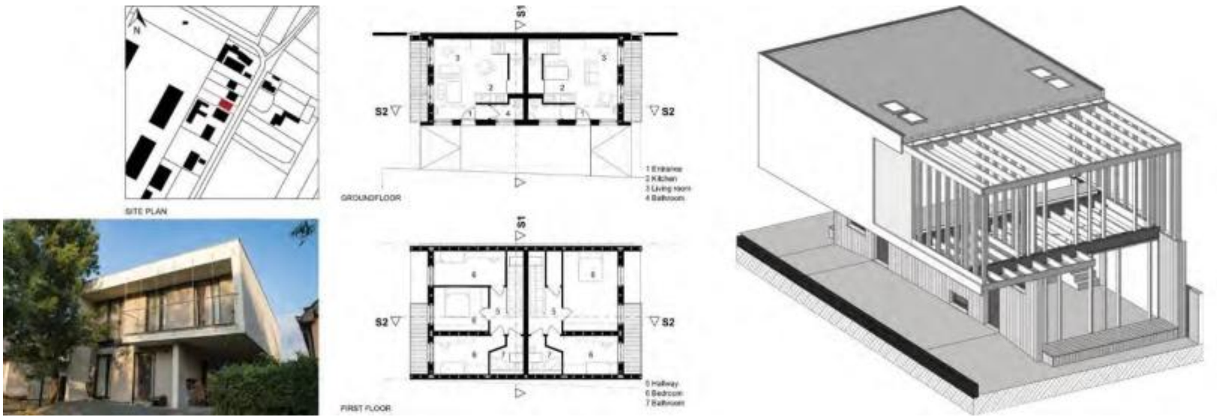


Fig. 3-1 Images of the house (project drawings and photo ©)

A combination of concrete foundations and ground-level structure, steel beams and wooden platform frame for the upper storey, partly visible on the outside and the inside, also considering seismic constraints, represented the aesthetic option of the owners. Eastern & western partial balconies plus generous canopies formed the ensemble image obtained with a large cantilever over the south two entrances (Fig. 3-2).

Fig. 3-2 Execution details (project drawings and photos ©)

The house envelope (Fig. 3-3) was quite well insulated with:

- 10 cm EPS for the ground floor
- Xella © inner rigid mineral insulation (8 cm of Multipor, λ=0,045 W/mK) that covered the outside visible concrete walls
- 16 cm mineral wool into the wooden panels
- 24 cm mineral wool into the wooden slabs (flat roof and first storey cantilever)
- 5 cm rigid mineral wool (Rockwool © Frontrock Max+) for the ETICS solution that doubled the wooden elements and diminished the metal beams thermal bridges
- 5 cm rigid mineral wool (Rockwool © Moonrock Max E) extra on the flat roof
- Internorm © plastic-aluminium frame for triple pane windows (argon filled, U_w=0,78W/m^{2}K, 35 dB sound insulation value) and entrance doors (48 mm foam panel U_p=0,6W/m^{2}K, U_d=0,89W/m^{2}K, 28 dB sound insulation value).

Fig. 3-3 Insulation details (project photos ©)

For almost a year, the interior climate of the house was monitored with one wire digital sensors (with a 0.5º C precision of the temperature measurements). They were placed on the first floor of the house, on the east façade, one on the outside, and two on the inside – one on the floor and the second one at 1 m above it. Subsequently, the recorded temperatures were analysed with Grafana open source ([51]), an interactive visualization multi-platform. The exterior temperature was also measured by a FLIR camera (Fig. 3-4).

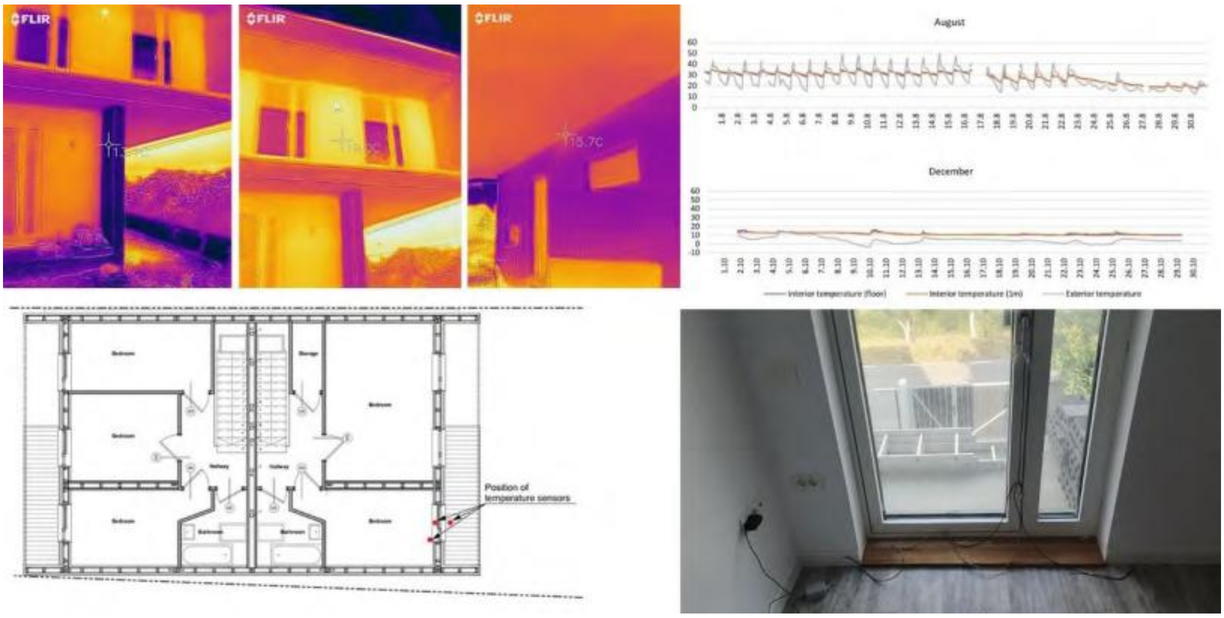


Fig. 3-4 Sensors and temperatures measurements (project images and photos ©)

Relevant differences were visible, considering that only one apartment was used and needed additional energy consumption, in certain moments during a whole day (24 hours), while the unused apartment, with an inner temperature set to 13º C, didn't require any extra energy (Fig. 3-5).

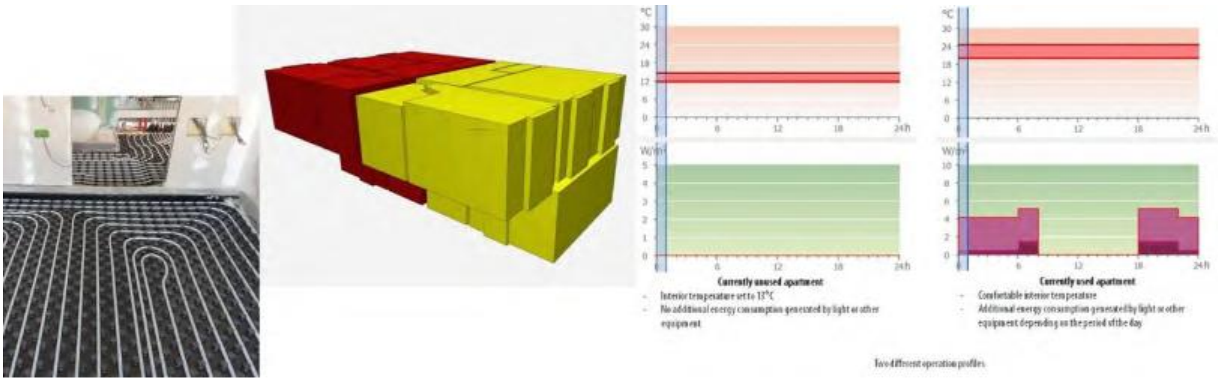


Fig. 3-5 Different usage in energy demand (project images and photo ©)

Two energy-efficiency simulations were performed: first, within the specific ArchiCAD © add-on software "Eco-designer", that considers the characteristics of the environment, the geometry of the house, the thermal properties of the used materials, the heat transfer coefficient of the windows and doors, used building systems, but also the way the owners were using the two apartments. The second, through a preliminary Energy Performance Certificate done for the Building Permit phase. The electricity was the main energy source, including underfloor heating and domestic hot water (Fig. 3-6).

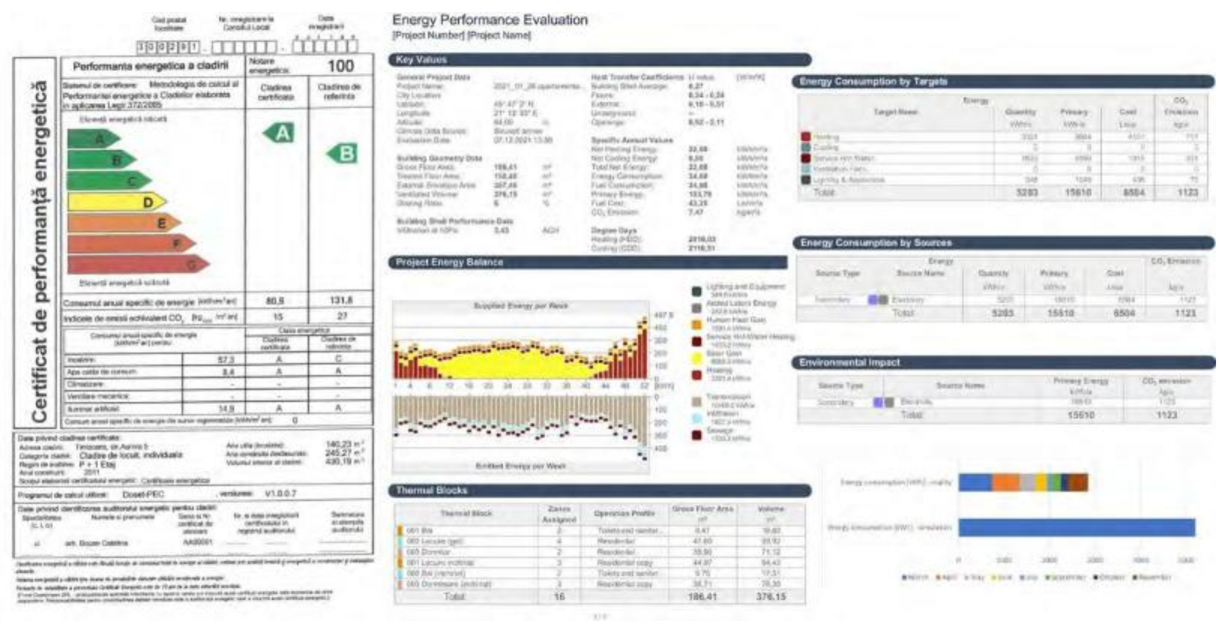


Fig. 3-6 Energy simulation (project data ©)

The analysed results were presented by the candidate in 2021, in a scientific conference, COHESION, along with her colleagues Dragos Bocan and Alexandra Keller, showing how an unusual aesthetic option and the selected structural solutions can influence the energy consumption of the house. In 2023, the construction received a photovoltaic system with 16 panels (Canadian Solar 435W), 1 inverter and 16 optimizers, one year later completed with a 48V battery and two years later with an air-air heat pumps from Daikin ©. Further energy efficiency analyses will be developed soon.

3.2 Building's energy strategies: from passive to active concepts

The general or particular interest to improve people's habitat and their comfort is not a recent matter, having an interesting evolution since the very first living spaces created by humanity. There are two main directions, separated, but somehow still connected: invention of technical solutions and development of several types of houses ([52]). The following table comprise the main discoveries related with the energy efficiency, from ancient times to this century, showing construction materials improvement and natural physics phenomena-based equipment (Table 3-6):

Technical solution	**Year & country of appearance**	**Specifics data on energy**
Badqhir (wind tower)	Approx. 4000 BC, Persia	Introducing outside fresh air inside through underground water canal
Thick brick wall & cavity wall	Approx. 3100 BC, Egypt	Thermal insulation
Solar chimney	Approx. 400 BC, Roman Empire, Middle East, Persia	Natural ventilation
Hot spring	Approx. 50 AD, Roman Empire	Heating and hot water
Geothermal spring	Approx. 400 AD, France	Water distribution
1st mechanical air cooler, 1st hygrometer, L. da Vinci	Approx. 1500, Italy	Cooling air by evaporating water
1st solar collector, H. de Saussure	1767, Swiss	Boiling water
Cast iron radiator, Franz San Galli	1855, Russia	Heating based on hot water
Double layer window, T. Stetson	1865, USA	Improvement on keeping the interior temperature and acoustic insulation
Electric fan with ice in front of the air current, N. Tesla	1882, USA	Increased comfort during summer
1st commercial solar water heater, C. Kemp	1891, USA	Climax Solar Water Heater
1st electric equipment for air-conditioning, temperature and humidity control, W. H. Carrier	1902, USA	
1st electric plant with geothermal source, P. G. Conti	1904, Italy	
Radiating floor system with pipes, -	1907, UK	Heating floor
VIP (vacuum insulated panel), -	1930, Germany	Compact, high insulation
"Critall" system, for heating and cooling in concrete slabs (ceilings and floor), R. Crittal	1930, UK	Water heating and cooling through steel pipes
1st ground-source geothermal pump, -	1946, USA	
1st silicon solar cell to produce electricity, R. Ohl	1946, USA	Predecessor of Photovoltaic panels

Air-air heat exchanger with recovery, Giese & Downing	1949, USA	Massive reduction of ventilation heat loss in winter
Air tightness on wall condensation, N. B. Hutcheon	1963, Canada	Requirements for exterior wall
Trombe wall, F. Trombe & J. Michel,	1967, France – based on the thermal mass wall patented by E. S. Morse in 1881	Sun thermal radiation captured during the day and released through the night
Blower window test Blower door test	1977, Sweden 1977, USA	Effective method to control air-leakage
1st low-E glass (heat mirror, transparent insulation), Southwall Technologies & MIT	1979, USA	Transparent thin coating on a double pane window, to reduce energy loss
Infrared plasm heating panel	2000, USA & Europe	Commercial use

Table 3-6 Energy-efficiency related discoveries through construction components (candidate's compilation from the original source)

Another synthetic table (Table 3-7, [52]) reveals the housing sector progress, directly related with the previously mentioned creations:

Name of the house, author	**Year & country of appearance**	**Specific data on energy, required indicators**
"bordei", -	Approx. 5500 BC, Romania (Dacia)	- ground built (partially/ totally)
Malqaf, -	Approx. 1300 BC, Egypt	- wind-catchers
Socratic House, -	Approx. 500 BC, Greece	- south oriented
Heliocaminus, -	Approx. 400 BC, Roman Empire	- south oriented room with windows covered with mica, trapping indoor solar thermal radiaton – greenhouse effect "Hypocaust" heating system – under floor
Turf house, -	Approx. 900 AD, Iceland	- thermal insulation with thick walls and roofs made of turf, stone and timber
Tulou house, -	Approx. 1200, China	- massive, rammed earth walls (1.5-2 m)
Polar ship "house", F. Nansen	1883, Norway	Thermal design principles matching to contemporary "passive house": - air tightness - thickness of the walls - triple pane windows - ventilation
Solar House #1, MIT University, H. C. Hottel	1939, USA	- solar collectors - water accumulator
The Autonomous House & Green Architecture, B. & R. Vale	1975, UK	Guide for houses solution: - energy-self-sufficient - traditional appearance - environmentally friendly - easy to maintain
Phillips Experimental House, Horster & Steinmuller	1975, Germany	- super-insulated - ground heat exchangers - controlled ventilation - solar and heat pump technology
DTH zero-energy-house, Technical University of Denmark, Esbensen & Korsgaard	1975, Denmark	- super-insulated 12-16 mm - air-air heat exchanger (80% efficiency) - double pane windows - solar collectors with water tank storage - envelope air-infiltration (sub-evaluated values)
Lo-Cal House (low calorie), University of Illinois, W. Schick	1976, USA	- super-insulation - double walls - triple pane windows - air tightness and air barrier
The Saskatchewan Conservation House, R. Desant, R. Dumont, D. Eyre, H. Orr	1977, Canada	- super-insulation - triple pane windows - ventilation with heat recovery - air tightness (0.8 h^{-1} at 50 Pa) - solar collectors
Leger house, E. Leder	1977, USA	- super-insulation - air tightness - air-air heat exchanger
Super-low-energy house, H. Aek	1985, Sweden	- highly-insulated - air tightness - mechanical ventilation with air-air heat exchanger - heating load 30 kWh/m^2/yaer
Schrecksbach House, M. Such	1987, Germany	1st German low-energy building - heating requirement of 59 kWh/(m^2a)
Passive house concept, B. Adamson, W. Feist	1988, Sweden & Germany	
Kranichstein Passive House, Darmstadt, architects Bott, Ridder & Westermeyer	1990, Germany	- thermal insulation (roof – 44.5 cm of mineral wool, exterior walls – 27.5 cm of EPS, basement ceiling – 25 cm of polystyrene

		- triple pane glazing with Krypton filling, U_g value 0.7 W/(m²K) and insulated framework - heat recovery ventilation (air-air heat-exchanger, 80% efficiency) - vacuum tube solar collector
The Autonomous House (Green house), B. & R. Vale	1993, UK	- recycled materials - PV panels
Self-sufficient solar house, Fraunhofer Institute of Solar Energy Systems	1994, Germany	- off-grid, PV panels and batteries (5 times more produced energy than needed) - solar collectors - earth-air heat exchanger - equipment for humidification / dehumidification
Heliotrope building, Freiburg, architect R. Disch, 1st **Plus-energy house** certificated	1994, Germany	- 4-6 times more produced energy than needed - zero CO_2 emissions - walls with phase changing materials, insulated with internal vacuum space - PV panels tracking the sun - vacuum tube solar collector - geothermal heat exchanger and CHP unit - U value
Expo 2000 project – Solarsiedlung am Schlierberg, R. Disch	2004, Germany	- 59 single-family houses and a commercial building complex - main facades U value 0.5 W/m²K - space heat demand 11-14 kWh/m²/y - decentralized ventilation with heat recovery - 445 kWp PV modules
Experimental solar houses – students' competition "Solar Decathlon"	From 2002, USA, From 2010, Europe	- only solar energy used for different ten disciplines
1st Efficiency-plus House with Electromobility, Berlin, University of Stuttgart's Institute for Lightweight Structures and Conceptual Design (ILEK) & W. Sobek (competition project); energy core concept ([53])	2010, Germany	- negative annual primary and final energy demand ($\sum Qp < 0$ kWh/m²a, $\sum Qe < 0$ kWh/m²a) - extensive building-integrated photovoltaics (BIPV) and solar thermal systems on facades and roofs - prefabricated timber panels, super-insulated walls & roofs - triple pane windows U-value 0.75 W/m²K - EV batteries and stationary house battery storage, powering electric vehicles - LED lighting with smart controls (dimmers, motion sensors) - complete disassembly and recycling
Sunlighthouse, VELUX – Juri Troy of Hein-Troy Architekten ([54])	2010, Austria	- first carbon-neutral single-family house in Austria - window area = 42% of the floor area - maximum passive solar energy gain - only renewable energy
Light **Active House**, 6 demonstration projects – VELUX Model Home 2020 ([55])	2010-2012, Denmark, Germany, Austria, UK, France	- experimental projects open for the public for 6-12 months, then sold and monitored during occupancy
Brighton Waste House, architect D. Baker-Brown & BBM studio ([56])	2012, UK	- thermal mass and waste insulation - recycled timber structure - triple pane windows - solar panels - primary energy consumption 22.5 kWh/m²/year
Prefabricated Accessible Technological Homes (P.A.T.H.), architect P. Starck & Riko prefabricated house specialist – 34 models ([57])	2013, France	- zero or positive energy (BEPOS) - PV, solar panels, heat pump, wind turbine / rainwater collector - 3 types of envelopes (wood, glass, and mixt), with insulation of 20-30 cm (mineral wool, glass fibre, cellulose) - triple pane windows
ZEB Pilot House, Snøhetta ([58])	2014, Norway	- solar collectors and PV panels (producing 19200 kWh/year) - thermal mass walls - earth-water & air-water heat pumps - 2 different grey water heat recovery systems - 13.2 kgCO_2 eq/m²/year - energy demand 86.1 kWh/m² (35.4 kWh/m² from PV) / year
Pop-Up House, Multipod studio ([59])	2014, France	- Passivhaus Standard
Prefabricated SOLACE House prototype, Warsaw, architect P. Pokorski ([60])	2018, Poland	- 24 PV panels (producing 6500 kWh/year) - energy demand 33 kWh/m²/year - energy positive based on renewable sources 108% - carbon neutral - OSB (Pfleiderer Living Board P5) with polyurethane foam - ventilation with heat recovery

Table 3-7 Energy-efficiency related discoveries through housing sector (candidate's compilation from the original source ©, updated)

Some of these prototypes are strongly connected (or even generated) with specific building standards and concepts, supporting the development of the entire domain. In fact, we can conclude that the energy demand decreased in time, while the requirements for achieving low values of energy consumption grew ([12], p. 32-33). The German evolution of national standards shows a continuous broadening of specific input parameters – from thermal insulation of components to heat demand, whole envelope, building systems, annual primary energy demand. A building is considered a source of energy transfers, losses and gains that must adapt to different uses, for having comfortable living conditions. The building operation building includes heating, cooling, domestic hot water, lighting and auxiliary energy, all meaning energy demand. Besides this, the life cycle of the building and the special energy involved in each person's habits are also important when a balanced energy is generated for each construction, considering not just the physical phenomena but also numerical and economical values. The evaluation of this whole balance is based on distinctive criteria, related with the construction and the operation phase, both with significant effects on the environment (not just emissions). A physical boundary, determined by the envelope, location and sources of energy is taken into consideration for the energy balance, while the time interval – annual / monthly / daily / hourly – of energy consumption is important for determining the peak loads, the buffer storage and optimisations.

Several programs and calculation methods, performed according to specific standards, technical rules and considered parameters, show comprehensive information on energy efficiency of a specific building, residential or not, very good for comparisons, certifications and public display. Possible secondary circumstances – economical high-efficiency, level of polluting emissions, domestic appliances efficiency classes, ecologically acoustic building materials, etc. – might improve the construction value, but usually with less control when evaluating the mentioned balance.

The climate and its change have a major impact when dealing with energy efficiency balance. While in colder countries the focus is more oriented in heating and in warmer countries in cooling, the buildings from the temperate regions have different demands throughout the year, from winter to summer, with transitory periods on variable conditions in spring and autumn. The European Union energy goals, mandatory norms, voluntary standards & labelling became role-models for other nations (mostly from America and Asia), beginning with similar climate conditions and ending with globalized technical development. A common trajectory can be found in the building energy standards at country level and voluntary labelling: gathered specific information on climate and technical / energy minimal requirements; certification process, costs, experts and training; compliance & penalties; public or private supporting measures / policies ([61]).

3.2.1 Germany's evolution and initiatives (one country's best practice example)

In Europe, Germany succeeded to combine the national framework of energy standards with other programs (including financial schemes) to facilitate an easier implementation while involving the citizens, raising their awareness and increasing their comfort. The following table presents the evolution of the main initiatives developed in this country and their main features (Table 3-8, [12], p. 45-51) and other sources:

German voluntary standards / initiatives	**Efficiency house** [62], [61] (KfW* state funding)	**Passivhaus** [63] (certified by PHI)	**Nearly zero-energy and zero-energy house** [40], [64]	**Efficiency house plus** [65] (EEWärmeG, federal initiave)	**Aktivhaus** [66], [61] (based on Active House Alliance principles)
	Lower values for Primary Energy Demand (kWh/m^{2}a) ⟹ **More requirements and input parameters involved, from passive to active principles**				
Balance scope	**Reducing energy consumption** Heating, cooling, domestic hot water, lighting, auxiliary energy	**Energy conservation** Heating, cooling, domestic hot water, lighting, auxiliary energy, domestic appliances – reduce energy demand	**Balanced energy** Heating, cooling, domestic hot water, auxiliary energy	**Producing energy** Heating, cooling, domestic hot water, lighting, auxiliary energy, domestic appliances	**Buildings that give more than they take** (based on open-source model), related with its economic viability: generate / remove heat efficiently, optimise artificial light, generate electricity locally – minimise energy supply
Classes and usage	- KfW several categories, each number representing the percentage of the reference new building's energy consumption, the lower values mean higher efficiency	- PH three categories: Classic, Plus & Premium (related with PER** values ≤60, ≤45, ≤30 kWh/m^{2}a) - for new & existing buildings	- nearly zero-energy (less than 55% of the reference building energy-demand) & zero-energy category - energy efficiency classes (from A+ to H)	- KfW category 40 Plus for new buildings - for single-family and semi-detached houses, apartment & educational buildings, districts - for renovated existing buildings	- 4 levels criteria system, from 1 (highest) to 4 (lowest): final energy demand: ≤40, ≤60, ≤80, ≤120 kWh/m^{2}a

	- 55 & 40 for new buildings - 115, 100, 85, 70 & 55 for refurbishments - 160 for monuments	- for buildings in regions, not optimal for PH standard - EnerPhit & PHI Low Energy Building			
Energy production	- fossil, renewable and mix	- fossil, renewable and mix	- more renewables than fossil fuels	- photovoltaic surface 0.33-0.46 $m^2_{PV\ area}/m^2_{floor\ space}$, larger than required - wind turbines, solar thermal collectors, heat recovery	- energy produced on site or in the system: ≥100%, ≥75%, ≥50%, ≥25%
Primary energy demand	- related with a reference building	<120kWh/m^2a	- relative to a reference building	- negative, <0kWh/m^2a (even for final energy demand) - self-sufficiency	- primary energy balance: ≤0, 0-15, 15-30, ≥30 kWh/m^2a for the building
Heating demand	- related with a reference building	<15kWh/m^2a (same for cooling and dehumidification) - heat load < 10W/m^2	>65% from renewable energy sources (RES) (15% solar thermal / PV, 50% geothermal / waste heat / biomass)	- different types of heat-pumps and	- solar thermal technology, heat pumps, biomass, thermal / cooling storage, heat recovery
Other specific requirements	- cold bridges taken into consideration - thermal insulation, glazing and airtightness according to standards	- minimized cold bridges - highly thermal insulated - blower-door test for airtightness - optimized glazing - mechanical ventilation with heat-recovery - compactness	- CO_2 emissions, as percentage of the reference building - total Energy Efficiency Factor - HVAC - benchmarks related with climatic zone	- user interface to control energy consumption - class A++ or better for appliances - thermal insulation quality approximately 40% better than the value of the reference building - compact building - ice & battery storage, charging station for electric vehicle	- Trias Energetica approach: 1st reduce energy demand, 2nd use sustainable energy sources, 3rd use fossil fuel efficiently - quantitative and qualitative parameters: **comfort** – daylight, thermal environment, indoor air quality, noise; **energy** – energy demand & supply, renewable energy, primary energy, validation on site; **environment** – environmental load, water consumption, ecological impacts, external context and accessibility, building management
Energy creation:	- solar and internal heat gains - on-site, for KfW 40 Plus	- gains from solar, internal and domestic appliances - on-site (Plus, Premium) and off-site (Premium)	- on-site or nearby	- electricity surplus of approximately 20kWh/m^2a for new buildings - electricity surplus of approximately 13kWh/m^2a for renovation projects	- solar PV, CHP, fuel cell, batteries
Used tools:	- EBS inspection tool - Energy Simulation Software (EnergyPlus, DesignBuilder), LCA, LCCA	PHPP	- open-source simulator (EnergyPlus) - structured methodologies (MOPA, LCC)	- [67]	Active House Radar

* (KfW meaning Kreditanstalt für Wiederaufbau)
** (PER meaning Primary Energy from Renewable)

Table 3-8 German initiatives' comparison (candidate's compilation from the original source ©, updated)

Minergie © standard from Switzerland ([68]) was developed in parallel with the German developments' standards, being primarily used in all cantons and some other foreign countries, but not so popular as the others presented above. It has four different levels, that can validate a low-energy, a nearly-zero-energy, a plus-energy or a supplementary green building standard combined with the others, for new and renovation projects.

3.2.2. Passive and Active Houses in Romania

Since its foundation, the **Passive House Institute** (PHI) succeeded to form a global community, an association with multiple national representatives, advocating its principles through all possible means. Approximately 50000 buildings were certified worldwide until the middle of 2025, the most of them being from Europe (Fig. 3-7, [69]). More than 6200 PH quality constructions are included in an open-source database, of which 39 are from Romania ([70]).

Fig. 3-7 Passive House certifications global distribution (images from PHI ©)

The Passive House concept is one of the most imported voluntary initiatives in Romania during the last decade, being promoted and somehow easier to understand by the large audience. The Passive House Institute acknowledges four organizations from our country that can provide accredited courses and exams, the Romanian Order of Architects being one of them. Therefore, several specialists can offer now their support and expertise, including consultancy, energy audits, blower door tests, visits to finalized constructions. Certified designers, architects, construction engineers, specific materials & components manufacturers, real-estate developers and contractors, along with social media influencers play a major role in more new homes projects for beneficiaries interested in contributions to a better living environment.

The candidate invited a former colleague at the Polytechnic University of Timisoara, PhD architect Miodrag Popov, who currently is involved in multiple studies and energy certifications in Germany, as another guest lecturer to exemplify the PassivHaus standard to the students of the same "NZEB and certification systems" course, previously mentioned.

She also organized planned visits with small group of students in passive houses before completion phase, erected by one of the regional building companies that designs and exports wooden-frame houses (IGHaus ©), Imperium Group Ltd from Timisoara (Fig. 3-8).

Fig. 3-8 Students' visits on execution sites of Passive Houses in Timisoara (candidate's photos ©)

The international partnership of different designers & planners, universities & research institutes, along with developers & builders, known as **Active House Alliance**, was founded in 2011, having today more than 40 members world-wide, national chapters and multiple agreements, now being an official partner of New European Bauhaus ([71]) and an example of valuable 17th SDG ([66]). The primary intention was to create a global framework with a holistic approach for a sustainable design, in new buildings and renovations, considering technical innovations, architectural quality, environmental impact and energy efficiency.

Around the globe there are more than 160 Active Houses online published that showcase the principles, from various types of homes to public buildings, with a formal labelling system introduced only in 2016, and projects submitted individually to obtain the quality stamp using Active House Radar. The 3rd edition of specifications' guidelines ([72]) was published in 2020, detailing the three main concepts with their several criteria:

- Comfort: daylight, thermal environment, indoor air quality, acoustic quality

- Energy: energy demand, primary energy performance, energy supply
- Environment: sustainable construction, freshwater consumption.

The qualitative aspect of each criterion is quantifiable from 1 (highest) to 4 (passing) level for each of these nine items. If the average score of all nine criteria is ≤2,5 (new buildings) / ≤3,5 (renovations), the evaluated building is considered an Active House. The specific design of it must go together with an effective management during the operational stage: users training for efficient behaviour, systems' check-up and monitoring, maintenance and continuous display of usage parameters.

In Romania, the Active House principles were introduced by the national alliance, called Active House Building Hub and Romanian Association of Energy Auditors for Buildings, most of the specialists being members of the last one. Still, there is more to be done in this direction, less developed or promoted than the Passive House.

A successful single-level house design, also developed as a project in the candidate's professional company was erected nearby Timisoara, under the first idea to be Passive House certified. The clients, specialists in HVAC design & built equipment, wanted from the start to have an energy-efficient environment. The site had the access south-oriented and therefore the general U-layout was organized around a north-facing greenhouse, placed in the middle of the house, with solar control glazed elements. High-performance installations (photovoltaic panels, air-water heat pump, ventilation with heat recovery, floor heating, smart home system) offered through comfort and geometrical parameters necessary adaptation to the users needs. Large interior openings due to a metallic structure, accommodated the day area on the eastern side, the night area on the western part, linked through the kitchen and dining zone nearby the main entrance (Fig. 3-9).

Fig. 3-9 "Living" Active House (candidate's image and photos ©)

All of the above info and the simple control of the inner comfort parameters remotely programmed / viewed / modified, along with black & white textile blinds for the large windows and focused skylights over important spaces contributed to the name of "living" home, under which this house was presented in December 2020 in the monthly newsletter and social media of the Active House Alliance ([73]).

3.3 Daylight criterion in different energy-efficient certifications and Romanian standards

The comfort of the indoor environment, where people spent most of their time, should offer best solutions for human health, considering all the above-mentioned criteria, according to the use of space. The **daylight** has multiple benefits and positive influence on well-being, such as scenery outside views, solar gains, reduced artificial lighting during the day and lower energy demand. The sun, as an infinite source of light radiations, offers also heat and electricity when proper equipment, systems and installations are used, in a close relation with the global position and the solar exposure of the built environment. Therefore, all energy-efficiency standards and certifications have references about the natural light / sunlight / daylight, related with specific international standards.

The latest EPBD and the related national methodologies consider the natural lighting, along with the local solar exposure conditions and passive / active solar systems, to have positive influence on the primary energy factors. The design, position and orientation of the building, the outdoor and the indoor climate, as well as solar protection and internal loads represent quantifiable parameters when general indicators such as primary energy use and greenhouse gas emissions ([44], p. 49). The Romanian methodology ([50]) references the EN ISO 52022 (about natural light properties of the building's components and elements), and details a lighting strategy along with shadowing solutions:

- Southern façade must have an optimum ratio of 25-35% glazed / opaque surface
- The different ratio between window area and floor surface area for different spaces and functions must be assured according to nation standard STAS 6221-89
- Glazed surfaces must ensure 50% daylight autonomy (for 300 lx), over a year
- Glazed solutions with the highest possible light transmission to allow a greater amount of natural light to enter, without increasing the size of the windows
- Shadowing exterior systems related with climate and geographical position, with different orientation for east / south / west side
- Optimum solar g factor, even variable, within dynamic glass, to control the solar radiation; recommended g_n values related with the climate regions and at least 0,50 value when exterior shadowing systems are present
- Different reference values R'_{min} and U'_{max}, for the exterior windows in new and rehabilitated, residential and non-residential buildings
- Technical solutions on existing windows for energetic refurbishment
- Influence of window size on solar / internal heat gains and natural ventilation.

The BREEAM Technical manual for new construction ([46]) includes in the "Health and wellbeing" category at least two assessment issues related with the natural light, Hea 01 Natural Light Hea and 03 Non-visual effects of light. The criteria to receive up to 8 credits are:

- vertical and/or inclined windows with a glazed area ≥ 20% of the surrounding wall area for at least 95% of all relevant building areas for daylight, or a glazed area as a percentage of floor area ≥ 7% for at least 80% of relevant building areas for daylight (in relation with the distance from window to workspace), to offer an adequate view out of building and landscape at seated level
- at least one relevant area of the building receives at least 3 hours of direct sunlight at windows on equinox day (21 March or 21 September), on a cloudless sky
- glare control strategy, with extra options
- equivalent daylight illuminance that produces circadian stimulation, at occupied see level.

In the November 2025 LEED v5 Rating System ([47]), the scorecard "Indoor Environmental Quality" includes a credit category, called "Occupant experience", Eqc2, where the Quality views and Lighting environment can receive up to 9 points for:

- 75% or 90% of all regularly occupied floor area offer a view of the outdoor natural or urban environment, through a visible light transmittance of 40%
- solar glare-control devices for all occupied spaces that receive direct / reflected sunlight
- at least 30% of the interior layout of the occupied area to be within 6 meters of the envelope glazing
- spatial daylight autonomy (for 300 lx and 50% annual sunlight) ≥40%.

The DGNB System and its current Buildings Criteria Set ([48]) presents the SOC1.4 Visual comfort criterion under the "Socio-functional and functional quality" topic, relating it with SDG 7 and 8:

- daylight supply (as per DIN EN 17037), a DF≥1.0% for a specific % of usable area (usually 50%), different for side windows or skylights
- annual exposure (as per DIN 5034) and translucent skylight portion of the roof surface
- visual contact with the outside (as per DIN EN 17037), percentage or quality level for direct visual link to the outside
- absence of glare in daylight
- exposure to daylight ≥ 1.5 h of at least one living space in residential unit or other percentages in hotels and healthcare buildings.

Passive House requirements for daylight are not very particular, but several component certifications are related with sunlight, all starting from the 7 different defined climates ([74]):

- transparent building envelope components, with defined PH efficiency classes for all glazed components, frame and glass thermal transmittance U-values, hygiene criterion (for mould)
- insulated glass units and solar control glazing, using the g-value and the light transmission in the visible spectrum, considering the type of glazing, the number of panes and the filling gas
- sun protection and window installation systems differs, considering the types of shading (roller, shutter, blind) and of window frame (metal, timber, plastic), as well as the position of installation and connections with structural opaque elements, to minimize the thermal bridges
- daylight simulations (DF, DA, optimisations)
- windows in a step-by-step retrofit, with well insulated Passive House frames, usually installed before the façade renovation.

Velux Group, one of the founding partners of Active House Alliance, is a Danish company with a rich history, starting with the first patented roof window Velux ® (1942), transforming attics into usable lightened spaces. After the economic postwar boom, the company evolved and developed multiple concepts, adapting to the market demand and technological evolution, along with a global widespread of its products. Multiple types of windows and accessories (with ventilation, insulation, electric control, sunscreen) received in the 21st century green energy and sustainable principles, being applied first in many demo-houses and later as usual components for an efficient envelope, from horizontal to vertical surfaces ([75]). The project Model Home 2020 was launched by Velux Group in 2009, as a vision for climate-neutral buildings and high living quality. The six full-scale experimental houses, with multiple awards, were used as best practice-examples to define the Daylight principle in the Comfort criteria of an Active House ([72]).

An optimal design, considering building geometry, natural surroundings and neighbouring buildings, contribute to assess the Daylight Factor (DF), as a main quantitative aspect. The Daylight Autonomy (DA) is more qualitative aspect, considering seasons, time of day, glazing orientation, location (latitude, variable sky), shading and glare management, functional requirements ([72]). The amount of daylight in a room is evaluated through levels of the DF on a horizontal work plane (from DF>5% for level 1 to DF >1% on average for level 4), using a validated specific simulation program. On habitable rooms, the provision of direct sunlight should be available between autumn and spring equinox at least 10 % for level 1 to at least 2.5% of probable sunlight hours for level 4 ([76]).

The candidate's interest into this important issue was reflected through an article, presented in a scientific conference in Prague, in 2018 ([5]). Subsequently standards on sunlight exposure were analysed in the housing sector, especially the real-estate market of the multiple-apartments buildings where an intensive activity flourished, especially in the 21st century.

From a historical view, during the Communist regime (before 1989) new large prefabricated concrete panel blocks were organized in closed patterns, aligned with access streets, showing no concern for living spaces orientation or their direct sunlight, but with a small density, less vehicles and no private property (everything was owned by the state). Political changes and the emerging capitalism led to continuous updates on legal standards in the construction field, with general rules for urban planning & building permits and more specific rules for different functions (e.g. housing) and specific criteria (accessibility, health, etc.), after 1989. New blocks of flats had more ground density, number of living units and obvious increased number of cars (Fig. 3-10).

Fig. 3-10 Prefabricated blocks of flats districts in Timisoara (images from the cited article ©)

The General Urbanism Regulation approved by the Government Decision no. 525/1996 established compulsory norms applicable on all terrain and buildings through national territory, regarding even positioning, accessibility, orientation, land occupancy percentage (LOP), orientation of specific spaces, necessary parking and green spaces. Regarding the housing function, the position shouldn't be near heavy traffic roads or polluting sources, and the north orientation of bedrooms is recommended to be avoided. The Building Permit Law (no. 50/1991) requires neighbours' legal approval when a new building close to an existing one may affect the latest hygiene, health or the environment by the level of direct sunlight for the existing construction, imposing a sunlight study to prove that the new building doesn't overshadow the vicinity.

The specific design norm for Housing Buildings (known as NP 052/2002) treated quality housing issues such as: structural stability, operational safety, fire safety, hygiene and environmental conditions, thermal and hydro insulation, noise protection. The human health was measured through technical conditions, including sunlight and lighting. The document stipulated that a housing unit should provide at least 2 hours per day with direct sun radiation (on 21st of February or October), under minimum 6° vertical incidence angle and minimum 20 ° horizontal incidence angle of direct sunlight, for at least one of its living spaces (bedroom or living room).

Still, the most strictly Romanian requirements regarding hygiene standards came from the Ministry of Health (the former Order no. 536/1997 being replaced by no. 119/2014), which demanded direct sunlight (through exterior windows) for a minimum of 1 ½ hours daily in the winter solstice of all living spaces, for the new building as well as for all the neighbouring ones. Furthermore, if the distance between two neighbouring buildings is smaller than the highest construction, a sunlight study is necessary. There are no strict regulations or specific software regarding this study, each designer (architect, engineer, etc.) doing his own advanced research on favourable orientation of the living spaces within the apartments (Fig. 3-11).

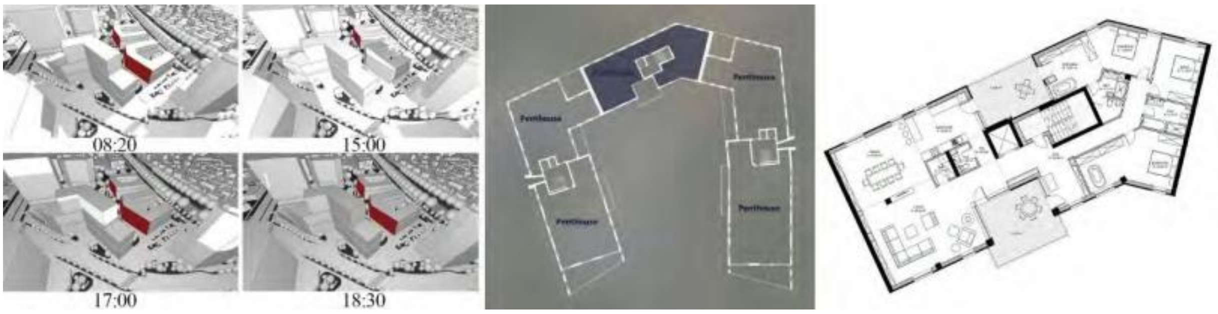


Fig. 3-11 Example of a sunlight study and north oriented apartment layout (images from the cited article ©)

Several case-studies, presented in the article, on Romanian collective housing developed for the real-estate market, revealed the constraints given by a correct positioning for the living spaces in a new building and in an urban context, with a valuable built environment. The facades oriented North-West, North or North-East cannot accommodate bedrooms or living rooms, just secondary spaces, according to these very strict rules (Fig. 3-11). Sometimes, the focus was just to create more saleable area, without any concerns for urban spaces, green facilities or parking areas. A similar example, from Vienna's new district Seestadt, showed more concern on social common areas and energy efficiency, instead of direct sunlight exposure of the habitable interiors (Fig. 3-12).

Fig. 3-12 Different approaches on contemporary collective housing – Bucharest and Vienna (images from the cited article ©)

The study conclusions were meant to signal that the co-existence of different rules regarding the same issue of sunlight exposure, all valid, but positioned on different steps of legal hierarchy, from the easiest (no. 525/1996) to the most severe norm (Order no. 119/2014) led to different interpretation and application, sometimes with consequences on the interior space functionality, but mostly with buildings that represents the clients' best interests and less abiding to the law, assumed by the designers.

In 2019, another scientific article, raised similar concerns on sustainability of urban planning for residential developments and the daylight provision requirements from the newest EN 17037, Daylight in buildings. The comparison of Slovenian rules of minimum solar exposure in hours for a certain time and date, along with a minimum window-to-floor ratio to the recently densely built urban layouts, with increased density and smaller distances between buildings led to an analytic methodology for urban planning guidelines in a preliminary phase of any residential project, that applied the criteria imposed by EN 17037, offering better indoor living conditions, sustainable use of land and less mutual shading of neighbouring buildings. The results showed that a very low value of FAR (floor area ratio – the ratio of a building's total floor area to the area of the site) is needed to fulfil the strict minimum daylight provision, related with buildings' typology and placement ([77]. Urban planning parameters are often set without too much care for the quality of interior conditions and further studies should include energy performance and other sustainable aspects.

One of the digital tools created by Velux, Daylight Visualizer ©, very useful for professionals, simulates the lighting condition and predictions during design stage. The candidate introduced this tool within a practical exercise to the students from the Buildings Physics discipline in the third year of study to help them better understand the importance of windows' position and their relevance regarding the sunlight exposure.

C. SCIENTIFIC, PROFESSIONAL AND ACADEMIC FUTURE DEVELOPMENT

"The good architect has three eyes, four ears and four hands at his disposal… what he has to say concerns the teaching of the past, observations of the present (and) foresight for the future" architect Philibert de L'Orme, 16th century

FORTHCOMING RESEARCH DIRECTIONS

Energy-efficiency is a widely used term today, its continuous development and changes shape our living environment, therefore results countless studies possible on this subject.

Further development plans consist of related issues, applied on different scales, such as **urban layouts**, new and existing built environment, **high performance construction components and materials (including recycled ones)**, techniques and suppliers' innovations, all linked with the constantly changing regulations from international to national level. The importance of this entire domain is highly emphasized by many actors involved into the building industry: investors, designers, builders, scientists, teachers and researchers, governments and NGO-s, manufacturers, producers, even regular citizens, becoming a specific goal for a better and long living on this planet.

The candidate will continue to pursue her interests in the already studied (and presented) fields in the previous chapters, through **retrofits of existing buildings** along with structural intervention when is possible, comparative studies on different standards, certifications, green labels, specific principles or guidelines and student competitions. Romanian building stock and some poor areas' living conditions represents a great opportunity for **significant upgrades to reduce energy demand and increase the inhabitants' comfort**.

European Union is, by far, the leader in energy-efficient applied technologies that must be shared with the rest of the world. The numerous examples of different building types, designed with less energy demand or, more recently, producing energy are spread all over the continent, adapted to their climate and geographical conditions. The voluntary certification systems, such as BREEAM, LEED, DGNB, Passive and Active House, play a major role for the entire society, by reducing bills for everyone and improved living conditions. **Proper passive and active means**, applied on a stable framework in the Romanian construction sector, **promoted by professionals** (architects, engineers, urban planners, craftsmen) will certainly bring more benefits to all users of the built environment.

The successive more stricter policies on energy efficiency standards, along with technology evolution on insulating and glazing, will most probably lead to greater demand in efficient built environment to achieve zero-emission and decarbonised building stock. Funding green and sustainable design, along with the public awareness on climate change combat and cleaner, renewable energy can be better supported within different standards (). [39].

The nowadays national legislation derives from international standards and norms, with thousands of pages and technical specifications. Their **improvement to high quality standards** but anchored in the economic reality and society's will to change should be considered, along with simpler **applied techniques**. Proper **guidelines, methodologies and digital tools** for practitioners and energy auditors can accelerate **skills development** and **implementation of energy goals**. The co-existence of general standards with those from certain entities (e.g. Ministry of public works, Ministry of Health) requires special studies on common subjects related with people's comfort (for outer and inner spaces). A possible debate is, for example, about the minimum distance between a parking place and the outside window of a living space, together with the implantation limit from of a new building from the street boundary: a 5-meter horizontal distance between a habitable-room window and the car, the latest usually placed in front of the house, leads to either a higher withdrawal of the construction from the street (at least 10 meters) or no bedroom/living-room facing the street. The same 5-meter distance cannot be applied with the existing residential building street fronts and the public parking lots along the street, the sidewalk often being narrower. Another specific case refers to classrooms' orientation (recommended east & south), considering the solar gains and internal loads from many children, that can lead to plus energy through heat recovery.

The 20th century cities, with a functionalist layout and separate areas for residences, working places, commercial and social activities, need to face this new millennium challenges: climate change effects, housing crisis, Covid 19 lockdowns, economic problems and technological transformation. New categories of habitants like seniors, gen Z and millennials, immigrants and digital nomads have different demands in this internet era, according with their lifestyle: co-living, co-working, shared transport, flexible and accessible buildings ([78]). Therefore, **innovative modular homes** or **micro-apartments**, with smart technology, **renewable energy-efficient solutions and systems** for quality housing might be developed through **step-by-step approaches and large-scale solutions, off-grid ready,** possible to be applied in different locations and climates.

The 21st century World EXPOs (Hanover 2000, Aichi 2005, Shanghai 2010, Milan 2015, Dubai 2021 and Osaka 2025) introduced sustainable technologies, recycled materials, hybrid and renewable energy related with climate change and waste reduction in demonstrative buildings as national pavilions or thematic constructions. Their **valuable architecture, with built-in equipment and integrated technology** could serve as best-practice examples for less representative constructions, with residential purpose or not. Equity and **accessibility for all to co-exist in the entire built environment** is another main issue promoted worldwide, downsized from global events to all day use buildings. The candidate already started this research direction in another relevant publication, presenting the adaptation of a monument building for accessibility of disabled persons, the Arad's Casino ([8]). The construction quality system in Romania includes mandatory "safety and accessibility in use" criterion. Still, the specific design norm on adaptation of civil buildings and urban space to the individual needs of people with disabilities, (no. 051-2012), is not compulsory for buildings with patrimonial value, even if their regular use brings together many people (tourists or visitors, employees or owners). The context of each heritage edifice differs from another and needs supplementary attention, but every application represents a step forward and an example for further application (Fig. C-1).

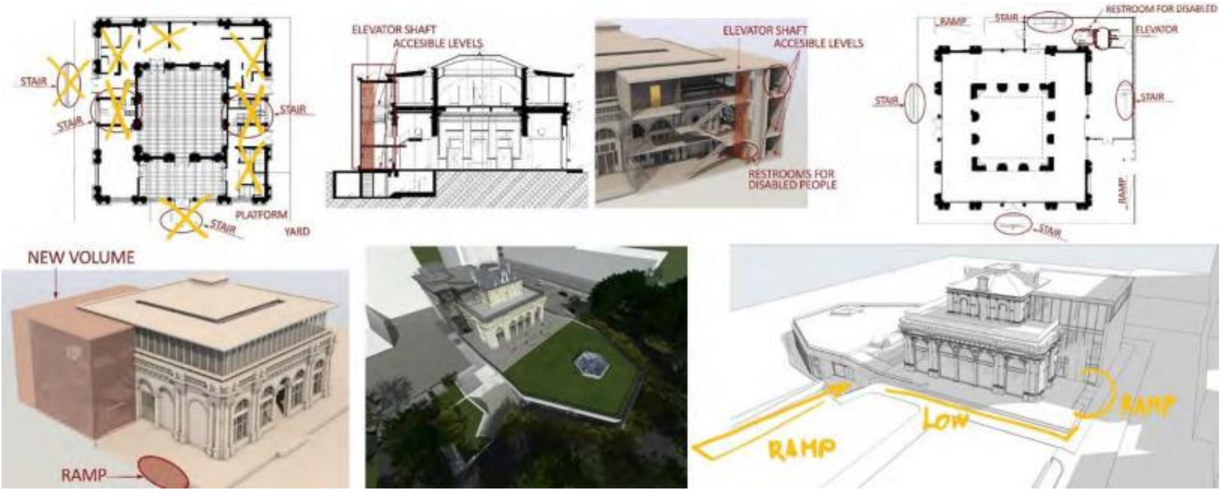


Fig. C-1 Accessibility on a monument building (images from the cited article ©)

C1. SCIENTIFIC PLANS

Right now, the candidate activates in the Faculty of Architecture and Urban Planning, within the Polytechnic University of Timisoara. The teaching staff from the department of Architecture is diverse and related with the main competences taught in this wide area: theoreticians and practitioners, architects, urban planners, interior designers, technical and artistic, equipment and structure specialists. Building a research team with interests in collective efforts is a main topic for the future, within people with similar ideas and desire for innovation. The existence of other departments, with more experimental practice can lead to new surveys or simulations on scaled models of built components.

Complementary urban, architectural and engineering solutions for the existing building stock refurbishment (all kind of buildings from the 20th century or even older) are possible subjects for investigations, considering their historical and monumental value, even adapted for new uses. The applied methodology and the precise moment of its implementation (related with the entire life-cycle performance) might lead to interesting conclusions on energy-impact. Publication of good-practice examples for exemplary cases increases the knowledge spread within academic community and to the interested public.

Also, construction materials (new, high-performance or recycled) along with various layouts and techniques, energy-related, can be thoroughly analysed within demonstrative designs and projects. Thermal and mechanical equipment, glazing elements and sun-shading solutions are potential themes for evaluation and control, within imposed parameters and continuous monitoring.

Scientific-based comparisons with others world-wide recently developed solutions, offer a better approach, especially in similar geo-political conditions. The new AI assistance will surely shorten the assessment time, while helping to produce clearer and synthetic conclusions.

C2. PROFESSIONAL PLANS

A substantial architectural and urban design practice was performed by the candidate simultaneously with the teaching activity through multiple projects, mostly done in her professional company, for over 20 years. By daily interaction with fellow architects and other specialists, state representatives, developers, suppliers and construction workers, she succeeded in forming an enriched expertise, intended to be continued. As energy auditor and project verifier, the possibilities to disseminate the accumulated knowledge and the right legal framework have spread among other architects and interested stakeholders.

Latest international trends and novelties will be acknowledged via regularly documentation trips to architectural fairs, as mentioned before. Newest technologies and energy-performance issues will be promoted by the candidate, for an improved living environment. From urban scale to interior spaces, former good and bad experiences become sources for better decisions. The most appreciated or successful solutions may be disseminated by the candidate in public presentations or become subjects for experimental and scientific research, presented in scientific conferences and journal articles. Continuous formation on applied legislation is also pursued by the candidate. Her increasing interest for Active House principles is intended to be incorporated into a verifier certification from Active House Alliance.

Preserving cultural, social and ecological values by reusing existing buildings along with the motto "yes to renovation <-> no to demolition" have been continuously advocated in the European space trying to maintain history and communities ([79]) by new generation of architects like Jonas Janke, Arno Brandlhuber, Olaf Grawert, and Roberta Jurcic in their collaborative architecture practice "b+" ([80]). The use of recycled materials, grey energy, cost-effective and adaptation methods is possible, when is campaigned to citizens by those convinced of its humankind benefits, like the candidate.

C3. ACADEMIC PLANS

Training future specialists in architecture means more than just teaching activity. The complexity of this field, with several actors, needs a team of very well-prepared experts to form characters and valuable professionals. The candidate's academic development represents a mix of scientific research, experimental work, projects design and practice expertise, all done together with other colleagues. Through constructive discussions and sharing opinions or new ideas, progress is inevitable. By respecting and supporting best values, the work environment becomes favourable for both didactic and managerial development of the collective's members.

The continuous changes of energy-efficiency related issues lead to yearly updates of the candidate's related courses, along with the proposal of new ones, if necessary. Possibilities of national cooperation and international agreements or Erasmus mobilities represent also candidate's further intentions.

The architectural design studio, as main discipline, is a prolific setup for several inputs from different teachers, bringing all together innovative and experimental projects. The candidate, as this team "manager", will carry on promoting contests among students, as powerful determining factor, for both educational and practical skills, being herself a competitive spirit. The opportunity to compare with other schools, while representing our university, strengthens the multidisciplinary approach of a complex subject.

The architectural and urban planning legislation represents another major subject, its permanent upgrade being under the candidate's radar, in her constant attempt to anchor the educational projects in the built environment's reality. By doing this, the knowledge transfer between research and practice happens in both directions.

Beyond regular educational interaction with our young scholars, the candidate perseveres in extra-curricular acts, involving them in team-building trips, encouraging their social and organisational skills.

The candidate's entire didactic activity reflects her capacity to develop, manage and guide research ideas along with interested people on improving our built environment through different types of actions. In the perspective of conducting PhD students, the candidate will try to include the best of them into the academic family of researchers, bringing fresh ideas into the system.

A FINAL WORD

" Think global, act local", Sir Patrick Geddes, urban planner and sociologist from the 19th century

Embracing the term "architectural flight simulator" used by Andrea Deplazes, the candidate is determined to continue this journey, as a practitioner architect and a dedicated teacher. She will carry on experimental and theoretical academic approaches on design, based on the experience gained through many interactions with investors, builders, authorities, construction materials suppliers, policy makers, local community and other specialists with great influence on the building stock. The students are among the main beneficiaries of her expertise, with their youth and openness to innovation as challenging determinants for new research topics. Architecture represents a field where creativity, inspired from the surrounding context, and applied technical skills form experts who make things, work for the wellbeing of entire society, often helped by knowledge creators.

REFERENCES

[1] C. M. Bocan, "Reabilitarea durabilă a blocurilor de locuințe tipizate din panouri mari – supraetajare ușoară cu structură în cadre prefabricate din beton armat," PhD Thesis, Polytechnic University of Timisoara, Timisoara, 2013.

[2] C. M. Bocan, "An "old" and new elements special joint for concrete prefabricated panel blocks," in *PROHITECH'14: International Conference on Protection of Historical Constructions*, Federico M. Mazzolani and Gülay Altay, Eds., Antalya, Turkey: Boğaziçi University Publishing, Istanbul, May 2014, pp. 877–882.

[3] Bocan C.M. and Bocan D.P., "Urban and thermal rehabilitation for concrete prefabricated panel apartment blocks-student ideas," in *17th edition International Technical-Scientific Conference: Modern Technologies for the 3rd Millennium*, G. A. P. Sorin Nistor, Ed., Oradea: EDITOGRAFICA s.r.l., Mar. 2018, pp. 185–190.

[4] D. Bocan, C. Bocan, and A. Keller, "Possibilities of Using Fiber Reinforced Mortar and Textile Reinforced Mortar for Strengthening Masonry Columns in Rehabilitation Projects," in *Structural Analysis of Historical Constructions*, Springer., vol. 18, Springer, 2019, pp. 1651–1660.

[5] C. Bocan, D. Bocan, and A. Keller, "Effects of Current Sunlight Exposure Regulations on New Housing," in *IOP Conference Series: Materials Science and Engineering*, 2019. doi: 10.1088/1757-899X/471/8/082056.

[6] D. Bocan, A. Keller, C. Bocan, I. Apostol, and M. Mosoarca, "Potential Results of Using Current Thermal Rehabilitation Techniques on a City Block of Timisoara and their Structural Strengthening Opportunities," in *IOP Conference Series: Materials Science and Engineering*, 2019. doi: 10.1088/1757-899X/471/6/062037.

[7] D. Bocan, C. Bocan, and A. Keller, "Energy efficiency study applied on a monumental building," in *Structures and Architecture: Bridging the Gap and Crossing Borders - Proceedings of the 4th International Conference on Structures and Architecture, ICSA 2019*, 2019. doi: 10.1201/9781315229126-35.

[8] C. Bocan, D. Bocan, and A. Keller, "Adaptation of a monument building for accessibility of disabled persons, a case study," in *Structures and Architecture: Bridging the Gap and Crossing Borders - Proceedings of the 4th International Conference on Structures and Architecture, ICSA 2019*, 2019. doi: 10.1201/9781315229126-66.

[9] C. M. Bocan, D. P. Bocan, and M. H. Truta, "The Rehabilitation and Extension of the Old Arad's Casino – Case Study," in *RILEM Bookseries*, vol. 47, 2024. doi: 10.1007/978-3-031-39603-8_37.

[10] D. Bocan, C. Bocan, A. Keller, and A. Gruin, "Analysis of Thermal Rehabilitation and Seismic Strengthening Solutions Suitable for Heritage Structures," *MDPI Sustainability (Switzerland)*, vol. 16, no. 13, Jul. 2024, doi: 10.3390/su16135369.

[11] C. M. Bocan, D. P. Bocan, and A. I. Keller, "Brutalist University Building Energy Refurbishment – Case Study," in *PROHITECH'25: 5th International Conference on Protection of Historical Constructions*, vol. 2, M. M. Federico, L. Raffaele, and F. Beatrice, Eds., Springer, 2025, pp. 521–528. doi: 10.1007/978-3-031-87316-4_63.

[12] Manfred. Hegger, Isabell. Passig, Caroline. Fafflok, and Johannes. Hegger, *Aktivhaus - the reference work: from Passivhaus to Energy-Plus House*. Birkhaüser, 2016.

[13] M. Hegger, *Energy manual: sustainable architecture*. Birkhaüser; Edition Detail, 2008.

[14] S. El. Khouli, Viola. John, and Martin. Zeumer, *Sustainable construction techniques: from structural design to interior fit-out: assessing and improving the environmental impact of buildings*. DETAIL, Institut fur̈ internationale Architektur-Dokumentation, 2015.

[15] Helmut. Bott, Stephan. Anders, and Gregor. Grassl, *Sustainable Urban Planning: Vibrant Neighbourhoods - Smart Cities - Resilience*. DETAIL, 2019.

[16] Clemens. Richarz and Christina. Schulz, *Energy efficiency refurbishments: principles, details, examples*. Institut fur̈ Internationale Architektur-Dokumentation, 2013.

[17] D. H. Meadows Dennis L Meadows J and rgen W. Randers William Behrens III, "THE LIMITS TO A Report for THE CLUB OF ROME'S Project on the Predicament of Mankind," 1972.

[18] "The science behind Earth4All," Club of Rome, Adaptation from The Limits to Growth. Accessed: Jan. 12, 2026. [Online]. Available: https://earth4all.life/the-science/

[19] "DETAIL 6.2021- Sustainability." Accessed: Jan. 12, 2026. [Online]. Available: https://www.detail.de/de_en/detail-6-21?srsltid=AfmBOooLiqE8ecPJYw_TfnO9jOg0zG5Vs_XNuJ1cbtG1udOPgqRSlP29

[20] Schüco Group, "Schüco Value Up." Accessed: Jan. 12, 2026. [Online]. Available: https://www.schueco.com/mn/company/press/schueco-value-up

[21] Saint Gobain Company, "About the contest | Architecture Student Contest." Accessed: Jan. 12, 2026. [Online]. Available: https://architecture-student-contest.saint-gobain.com/about-the-contest

[22] "Organisme de formation architecture, conception de prototype à échelle 1, maquette échelle 1," Les Grands Ateliers webpage. Accessed: Jan. 12, 2026. [Online]. Available: https://www.lesgrandsateliers.org/

[23] "SAINT-GOBAIN REVEALS THE 5 WINNERS OF THE 2025 ARCHITECTURE STUDENT CONTEST." Accessed: Jan. 12, 2026. [Online]. Available: https://architecture-student-contest.saint-gobain.com/sites/architecture-student-contest.saint-gobain.com/files/documents/asc-2025_press-release-eng.pdf

[24] G. Juhi, "Contemporary Brutalism: Reviving a Controversial Architectural Style - SMART.POV." Accessed: Jan. 12, 2026. [Online]. Available: https://smart-pov.com/contemporary-brutalism-reviving-a-controversial-architectural-style/

[25] D. P. Bocan, "Structural Strengthening of Historic Masonry Buildings Using Mesh Reinforced Composite Materials," PhD, Polytechnic University of Timisoara, 2025.

[26] D. P. Bocan, A. I. Keller, M. Mosoarca, and C. M. Bocan, "Experimental Investigation of One-Sided Strengthening Interventions on Historic Brick Masonry Walls," in *RILEM Bookseries*, vol. 47, 2024. doi: 10.1007/978-3-031-39603-8_40.

[27] "U-Wert-Rechner | ubakus.de," Ubakus webpage. Accessed: Jan. 12, 2026. [Online]. Available: https://www.ubakus.de/u-wert-rechner/?

[28] Thilo. Ebert, Natalie. Essig, and Gerd. Hauser, *Green building certification systems: assessing sustainablility, international system comparison, economic impact of certifications*. Edition Detail: Institut für international Architektur-Dokumentation, 2011.

[29] S.-A. Pescari, "STUDII ȘI CERCETĂRI PRIVIND PERFORMANȚELE ENERGETICE ALE CLĂDIRILOR PRIN PRISMA SUSTENABILITĂȚII," PhD, Polytechnic University of Timisoara, 2015.

[30] D. Dan, V. Stoian, T. Nagy-Gyorgy, and C. Dăescu, "GENERAL PRESENTATION Thermal insulation of old and new buildings in Romania." Accessed: Jan. 12, 2026. [Online]. Available: https://www.irbnet.de/daten/iconda/CIB11594.pdf

[31] United Nations (UN), "THE 17 Sustainable Development Goals." Accessed: Jan. 12, 2026. [Online]. Available: https://sdgs.un.org/goals

[32] United Nations (UN), "The Sustainable Development Goals Report," 2025. Accessed: Jan. 12, 2026. [Online]. Available: https://unstats.un.org/sdgs/report/2025

[33] B. G. Rebelatto, A. L. Salvia, L. L. Brandli, and W. Leal Filho, "Examining Energy Efficiency Practices in Office Buildings through the Lens of LEED, BREEAM, and DGNB Certifications," Jun. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/su16114345.

[34] "EnEV-online | GEG-info | WPG-info | GEIG-online | Energie-Regeln für Gebäude." Accessed: Jan. 12, 2026. [Online]. Available: https://enev-online.de/index.htm

[35] M.D.L.P.A., "LISTA REGLEMENTĂRILOR TEHNICE ÎN CONSTRUCȚII." Accessed: Jan. 12, 2026. [Online]. Available: https://www.mdlpa.ro/pages/reglementaritehnice

[36] P. Office of the European Union L- and L. Luxembourg, "DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 December 2002 on the energy performance of buildings," 2002. Accessed: Jan. 12, 2026. [Online]. Available: https://eur-lex.europa.eu/eli/dir/2002/91/oj/eng

[37] P. Office of the European Union L- and L. Luxembourg, "Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings," 2010. Accessed: Jan. 12, 2026. [Online]. Available: https://eur-lex.europa.eu/eli/dir/2010/31/oj/eng

[38] P. Office of the European Union L- and L. Luxembourg, "DIRECTIVE (EU) 2024/1275 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 April 2024 on the energy performance of buildings (recast) (Text with EEA relevance)," 2024. [Online]. Available: http://data.europa.eu/eli/dir/2024/1275/oj

[39] A. S. Cordero, S. G. Melgar, and J. M. A. Márquez, "Green building rating systems and the new framework level(s): A critical review of sustainability certification within Europe," Dec. 21, 2019, *MDPI AG*. doi: 10.3390/en13010066.

[40] BREEAM, "BREEAM-International-New-Construction-Version-7-Technical-Manual," 2025, Accessed: Jan. 12, 2026. [Online]. Available: https://breeam.com/breeam-newconstructionv7

[41] LEED, "LEED v5 BD+C Rating System_November 2025_clean," 2025, Accessed: Jan. 12, 2026. [Online]. Available: https://www.usgbc.org/sites/default/files/2025-10/LEED%20v5%20BD%2BC%20Rating%20System_November%202025_clean.pdf

[42] DGNB, "DGNB SYSTEM NEW CONSTRUCTION, BUILDINGS CRITERIA SET," 2025. Accessed: Jan. 12, 2026. [Online]. Available: https://www.dgnb.de/en/certification/buildings/new-construction

[43] "Embodied Carbon Sequestration → Term." Accessed: Jan. 12, 2026. [Online]. Available: https://prism.sustainability-directory.com/term/embodied-carbon-sequestration/

[44] M.D.L.P.A., "METODOLOGIE DE CALCUL AL PERFORMANȚEI ENERGETICE A CLĂDIRILOR, INDICATIV Mc 001-2022." Accessed: Jan. 12, 2026. [Online]. Available: https://www.mdlpa.ro/uploads/articole/attachments/63d8dccfe6ae8244797864.pdf

[45] C. Ionescu, T. Baracu, G. E. Vlad, H. Necula, and A. Badea, "The historical evolution of the energy efficient buildings," Sep. 01, 2015, *Elsevier Ltd.* doi: 10.1016/j.rser.2015.04.062.

[46] W. Sobek, "F87 – Plus-energy House." Accessed: Jan. 12, 2026. [Online]. Available: https://www.wernersobek.com/projects/f87/

[47] J. Troy, "Read about carbon-neutral Sunlighthouse in Pressbaum, Austria." Accessed: Jan. 12, 2026. [Online]. Available: https://www.velux.com/what-we-do/healthy-buildings-focus/demonstration-buildings/sunlighthouse

[48] "Visions for buildings of the future – Opening a 'Home for Life.'" Accessed: Jan. 13, 2026. [Online]. Available: https://press.velux.com/visions-for-buildings-of-the-future--opening-a-home-for-life/

[49] D. Baker-Brown and BBM Studio, "Brighton Wild House/ Waste House - ecological architectural design." Accessed: Jan. 12, 2026. [Online]. Available: https://www.brighton.ac.uk/research/research-news/feature/brighton-waste-house.aspx

[50] P. Starck and Riko prefabricated house specialist, "Starck with Riko." Accessed: Jan. 12, 2026. [Online]. Available: http://www.starckwithriko.com/

[51] Snøhetta, "ZEB Pilot House – Snøhetta." Accessed: Jan. 12, 2026. [Online]. Available: https://www.snohetta.com/projects/zeb-pilot-house

[52] Multipod studio, "Pop-Up House by Multipod Studio - Architizer." Accessed: Jan. 12, 2026. [Online]. Available: https://architizer.com/projects/pop-up-house/

[53] P. Pokorski, "SOLACE HOUSE-the First Prefabricated Plus Energy House," 2018. Accessed: Jan. 12, 2026. [Online]. Available: https://positive-energy-buildings.eu/fileadmin/user_upload/EXCESS_D1.2_Case_Study_SOLACE.pdf

[54] C. Moore, S. Dr. Shrestha, and S. Gokarakonda, "Building energy standards and labelling in Europe," 2019. Accessed: Jan. 12, 2026. [Online]. Available: https://www.switch-asia.eu/site/assets/files/2287/building_energy_standards_and_labelling_in_europe.pdf

[55] "Responsible Banking | KfW." Accessed: Jan. 12, 2026. [Online]. Available: https://www.kfw.de/kfw.de-2.html

[56] PHI, "Home PHI." Accessed: Jan. 12, 2026. [Online]. Available: https://passivehouse.com/en/home/

[57] C. Maduta, D. D'Agostino, S. Tsemekidi-Tzeiranaki, and L. Castellazzi, "From Nearly Zero-Energy Buildings (NZEBs) to Zero-Emission Buildings (ZEBs): Current status and future perspectives," *Energy Build*, vol. 328, Feb. 2025, doi: 10.1016/j.enbuild.2024.115133.

[58] B. and C. (BMI), D.-G. B. I. 3 German Federal Ministry of the Interior, "Brochure 'What makes an Efficiency House Plus?,'" 2018. [Online]. Available: www.bundesregierung.de/infomaterial

[59] "Active House." Accessed: Jan. 12, 2026. [Online]. Available: https://www.activehouse.info/

[60] "Effizienzhaus Plus Rechner." Accessed: Jan. 12, 2026. [Online]. Available: https://www.effizienzhaus-plus-rechner.de/

[61] "Minergie." Accessed: Jan. 12, 2026. [Online]. Available: https://www.minergie.com/en/

[62] PHI, "EN - Public share - Nextcloud - PHI-Cloud." Accessed: Jan. 12, 2026. [Online]. Available: https://univention.passiv.de/nextcloud/s/5S8DSqjidmtQ6R8?dir=/EN

[63] PHI, "https://passivehouse-database.org." Accessed: Jan. 12, 2026. [Online]. Available: https://passivehouse-database.org/index.php?lang=en#s_1c500a2cb67b45553cf89c7c2ac74bb1

[64] "Official NEB partners - New European Bauhaus - European Union," NEB webpage. Accessed: Jan. 12, 2026. [Online]. Available: https://new-european-bauhaus.europa.eu/community-core-new-european-bauhaus/official-neb-partners_en

[65] AHA, "THE ACTIVE HOUSE SPECIFICATIONS 3 rd EDITION Index-Specifications," 2020. Accessed: Jan. 12, 2026. [Online]. Available: https://www.activehouse.info/wp-content/uploads/2020/01/Guidelines_ActiveHouse_III_2020_Spreads.pdf

[66] D. Bocan, C. L. Cuc, A. Simonescu, and A. V. Lițiu, "Living home – Active House," Active House webpage. Accessed: Jan. 12, 2026. [Online]. Available: https://www.activehouse.info/cases/living-home/

[67] "Windows in the Passive House Portal component database." Accessed: Jan. 12, 2026. [Online]. Available: https://database.passivehouse.com/en/components/list/group_4?

[68] "VELUX History and Timeline," Velux webpage. Accessed: Jan. 12, 2026. [Online]. Available: https://www.velux.com/who-we-are/history

[69] K. E. Eriksen, C. Rode, and P.-A. Gillet, "REHVA Journal Active House Specifications - evaluation of comfort, energy and environment in buildings," rehva.eu. Accessed: Jan. 12, 2026. [Online]. Available: https://www.rehva.eu/rehva-journal/chapter/active-house-specifications-evaluation-of-comfort-energy-and-environment-in-buildings

[70] N. Šprah and M. Košir, "Daylight provision requirements according to EN 17037 as a restriction for sustainable urban planning of residential developments," *Sustainability (Switzerland)*, vol. 12, no. 1, Jan. 2020, doi: 10.3390/su12010315.

[71] P. Allard, "Present in time future: Challenges, Opportunities, and Trends for the Global Real Estate Industry," May 2023. Accessed: Jan. 12, 2026. [Online]. Available: ibanet.org

[72] J. Janke, A. Brandlhuber, O. Grawert, and R. Jurcic, "HouseEurope!" Accessed: Jan. 12, 2026. [Online]. Available: https://www.houseeurope.eu/

[73] J. Janke, A. Brandlhuber, O. Grawert, and R. Jurcic, "bplus.xyz adaptive reuse architecture." Accessed: Jan. 12, 2026. [Online]. Available: https://bplus.xyz/en/