SUSTAINABLE SOLUTIONS FOR EXTENSIVE RETROFITTING OF RESIDENTIAL BUILDINGS

A Thesis Submitted for obtaining
the Scientific Title of PhD in Engineering
from
Politehnica University Timișoara
in the Field of Civil Engineering
by

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Foreword

This thesis has been elaborated during my activity in the Department of Steel Structures and Structural Mechanics of the Politehnica University Timişoara, Romania.

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MUNTEAN Daniel Mihai

Sustainable solutions for extensive retrofitting of residential buildings

PhD theses of UPT, Series X, No. YY, Editura Politehnica, 200Z, pages, figures, tables.

ISSN:
ISBN:

Keywords
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Abstract
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1. INTRODUCTION

1.1. Importance of research topic and objectives

Sustainable development is essential to managing the built environment and current architectural practice. The new perspective that buildings are complex systems with a significant impact on the environment in all phases of their life cycle, assuming the hegemony of high energy consumers worldwide, has led to the acceleration of research on renewable energy systems, and some construction practices ensure increased energy efficiency.

The complexity of the issues raised requires coordinated interdisciplinary efforts and initiatives to change how professional education, specialized research, and building design are carried out.

The chosen theme is not only current, being in tune with European concerns and national in the field of energy efficiency of buildings, but it is also a fertile ground for innovation, as will be seen during its elaboration. Therefore, it must be said that it constituted a real challenge, arousing the desire not only to identify the real issues that are circumscribed to him but especially that of responding with solutions concrete for solving these problems in line with people's needs.

I chose this topic firstly, because of the initially favourable context regarding subsidies granted by the government and local authorities for thermal wraps and interior installation upgrades, other programs and possibilities for funding, and the existing massive market for interventions like those addressed in the paper. The built-up fund to which I refer assumes the existence of tens of thousands of such blocks in Romania, not to mention the total of blocks built in Europe from the East, which is the order of hundreds of thousands.

Secondly, the idea and approach to this topic came from the fact that I participated in the RETROFIX Project as a member of team upTIM within the Politehnica University of Timisoara for two years, competing in the International Student Competition "Solar Decathlon Europe" Paris, 2014.

Block rehabilitation can be considered a national priority for Romania, considering its impact on the population and the commitments signed by the state regarding European energy policies.

In the opinion of the residents, the quality of life in these homes is inferior to today's demands, requiring substantial improvements. However, due to the high rate of owners (over 95% of the residents are also owners), any intervention at the building level requires a consensus from the neighbours, which is usually challenging to obtain.

The current thesis aims to define a strategy for rehabilitating blocks (housing made of large prefabricated panels) from a holistic perspective, starting from the quality-of-life parameters, placing the resident as the primary beneficiary and main focus.

The applied part was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0391 / CIA_CLIM - Smart buildings adaptable to the climate change effects, within PNCDI III.

1.2. Thesis structure

Chapter 1: Introduction

The present work begins with Chapter 1, within which the objectives of the thesis, the context in which the research was carried out, as well as the chapter organization of the thesis are specified.

Chapter 2: Energy efficiency of the built environment. Context. Policies. Laws

The second chapter addresses developments towards energy efficiency of the built environment. It details factors and decisions towards achieving this goal: life cycle assessment (LCA), urban planning, district-scale nearly zero energy buildings (NZEBs), smart grid scenarios, IEQ and TC, assessment of retrofitting actions, generative building design methods, thermal storage with phase change materials (PCMs), HVAC fluids (strategies and control), the importance of improving the use of renewables, the importance of end-users' behaviours and the need to use dynamic approaches.

Chapter 3: The existing collective housing stock in Romania. Then and now.

This chapter deals with the collective housing and the urbanization process in Romania after 1960, as this is the moment when, after almost 200 years from the industrial revolution, the context of the emergence of high-density collective housing is met. Developed under the influence of the USSR, collective housing was built according to standard projects, materializations of ambitious modernist visions, which had already shown their shortcomings since then. It is certain that the promising projects of neighbourhoods equipped with public facilities, intended to compensate for the shortcomings at the level of apartments, were in few cases completely built.

The result can be seen today: monofunctional neighbourhoods of blocks from standard projects, spread throughout the country, technically outdated and as living conditions offered, desperate to be rehabilitated. The study of the most widespread type 770 project built in Romania reveals fascinating details regarding the effectiveness of the constructive system, but also its limitations, from the perspective of national and European statistics that describe the quality of life, as well as of its inhabitants, interviewed within a broad sociological investigation. Instead of interventions that bring direct benefits to the inhabitants, they resort to their own interventions, most of the time at the limit of legality or, as one can say "unconsciousness".

Also, in this chapter an example of "good practice" is being analysed, with the author being a design team member.

Chapter 4: Test model and applied results

This chapter presents designing, building and monitoring a testing module, "Experimentarium" as part of the research project "CIA_CLIM –Smart buildings adaptable to the climate change effects". The project aims to address alternative building envelope systems that can adapt to different climate change effects, in the context of new or retrofitting existing buildings. The design and construction of the module was carried out over the span of two years, from 2018 till 2020 with monitoring and collecting data still ongoing.

Chapter 5: Extensive retrofitting of collective housing made of large prefabricated panels

In this chapter current options for thermal rehabilitation of collective housing in Romania are covered and the advantages and issues that these bring. It addresses the issue of the deep rehabilitation of these blocks, which are not even half of the life span for which they were designed, so as to obtain a substantial improvement in the quality of life, in all its aspects. Then, the concept of integrated rehabilitation is described, based on multidisciplinary and interdependent measures that focus on the resident. A set of common measures, intended for the whole community. Based on the result of the previous chapter the thermal balance and energy efficiency of different building envelopes are simulated using the 770 block as base model.

Chapter 6: Conclusions. Further study directions. Published results.

The final chapter concludes the thesis by listing conclusions, future directions of study, as well as the author's own contributions and the ways of disseminating the research results.

Annexes

At the end of the thesis, they provide additional information regarding the type 770 project, thermal and energy analyses carried out on the test module presented in Chapter 4 and the building envelope options from Chapter 5.

2. ENERGY EFFICIENCY OF THE BUILD ENVIRONMENT. CONTEXT. POLICIES. LAWS

2.1. Current advances in the energy and environmental performance of buildings towards a more sustainable built environment

The building environment has been the focus of energy and environmental debates and policies, and the need to reduce greenhouse gas emissions to meet targets by 2050 [1] and improve energy security has motivated a large body of studies on energy efficiency and environmental impacts associated with buildings. Improvement in energy and environmental performance requires innovative research, new policies and standard regulation, new materials and technologies, the integration of renewable energy sources, of increased awareness and outreach and people awareness (designers, practitioners, and end users). The operation of buildings has often been focused on the literature in conventional buildings, and this stage dominates energy demand and environmental impacts. Buildings have a long service life, during which end-user expectations should be met, including requirements for thermal comfort (TC) and indoor environmental quality (IEQ). As research and polices succeed in reducing the impacts of building's operation, the relative contribution of other life-cycle stages has increased, and integrated and holistic approaches are needed to avoid problem-shifting. Reducing the energy and environmental impacts associated with the built environment is a challenging task, which requires a comprehensive understanding of the dynamics and main drivers of energy demand and environmental impacts. In addition, ten topical questions are addressed for improving building energy performance: life cycle assessment (LCA), urban planning, district-scale nearly zero energy buildings (NZEBs), smart grid scenarios, IEQ and TC, assessment of retrofitting actions, generative building design methods, thermal storage with phase change materials (PCMs), HVAC fluids (strategies and control), the importance of improving the use of renewables, the importance of end-users' behaviours and the need to use dynamic approaches [2]. These follow two paths:

- The use of integrated and holistic approaches to assess and improve the energy and environmental performance of buildings, and
- the development of new solutions, technologies, materials, and dynamic methodologies.

2.1.1 LCA towards an improved environmental performance of buildings

Numerous studies focus on reducing overall operational energy demand and designing new low-energy buildings. However, if the operational energy is decreased, the embodied requirements are increased. The LCA methodology calculates potential environmental impacts that and associated with a material and its energy flows, through sequential life-cycle phases of a process (or product) from 'cradle to gate' or "cradle to grave". It is usually used in an industrial context and aims to improve the environmental performance of products. The LCA framework is defined by ISO14040 series [3] [4] and includes four iterative steps: definition of the goal and scope, inventory of the license cycle, of the life cycle, of the impact assessment and interpretation of results. Over the last 15 years, LCA has been used in the construction and building context to address trade-offs between different building life cycle and building components and to help identify the most effective opportunities to reduce impacts.

LCA studies in the building environment have increased rapidly in number, covering different scale, from assessment or comparisons of alternative construction materials (concrete, wood, brick, insulation materials) and building components [5][6](exterior walls, roofs, structures) to buildings as a whole (offices, schools, residential buildings: either conventional or low energy and refurbishments) Life-cycle impact assessment categories selected vary between studies: some cover only primary energy and greenhouse gas (GHG) emissions, whereas others include a wider range of environmental categories (abiotic depletion, acidification, eutrophication, land use change f.e) [2] presenting more comprehensive assessments. Review studies on the topic concluded that LCA can provide valuable information for selecting improved construction options and heating systems. Most research articles present specific case studies, with life-cycle modelling scenarios generally varying them (building type and shape; construction and climate; comfort levels and boundary conditions); thus, comparing different available studies is not easy. Many studies [7] [8] [9]conclude that the use phase is the main factor of the life-cycle loads of conventional buildings (representing between 60-90% of overall life-cycle in residential sector). Other point out that for low-energy buildings the construction phase, (including the embodied impacts) can sum up to half of the overall life-cycle impacts[10] [11]. Neglecting the need for a life-cycle approach when implementing and/or assessing the impact of new buildings could lead to problem-shifting; spending more energy upfront, in the beginning, than saving using energy efficiency measures; problem shifting is mostly to come by in new buildings that focus primarily on optimizing operational energy and costs[9], but also in places with lower operational scenarios. This is likely due to the prebound' effect of a users behaviour , and also mild climate conditions [12].

Life cycle assessment can, with great effect, support decision-making on selecting improved building options. The CEN TC 350 [13] group has been defining new standards for common rules towards environmental assessment of buildings [14]. In addition, the use of LCA as a support for building development is a recent topic, and several challenges were identified for future work.

Different LCI (life-cycle inventory) approaches were tested (process based; input-output; and hybrid)[15]. At a building level, the bottom-up method is the most used, because it relies on data at product level allowing the comparison between building options. This method however suffers from a truncation error. It underestimates indirect impacts or excludes steps along the process due to system boundary needs. The top-down / input-output approach is based on different activity sectors, energy intensity, and economic data. This method does not allow however easy disaggregation of impacts from products within the same sector. To overcome such limitations, hybrid approaches have been addressed [15]. Choosing the most adequate LCI approach should be ideally based on the scope and goal of the LCA study.

Buildings are complex systems. They incorporate multiple construction materials, processes, that come from different industries and producers. Although extensive international inventory data are available for energy production systems and construction materials (e.g., Ecoinvent database [2] [16] [17]), materials coming from local construction have a significant role in buildings, and the implementation of more accurate assessments could benefit from national databases, with data from local producer[2]. Natural materials (f.e wood) have a lower impact than others (e.g. concrete or brick) however their embodied impact depends on the entire production chain which includes wood growth, wood harvesting, and forest regeneration. These vary from place to place and go beyond the building scale. In contrasts to standardized products, a building is usually one-of-a-kind product. Therefore, it is not simple to draw general conclusions: a building has unique location (it is exposed to specific local features and climatic conditions) and is occupied by different users (different occupation and operational patterns) that significantly influence operational energy use. To compare the lifecycle performance of different buildings, ranges of similar assumptions can be used to draw conclusions. For example, to compare buildings under similar weather conditions (for a climatic region), with alternative occupational/operational patterns framing possible/typical user variation through scenarios and using local energy mixes. Thus, life-cycle studies of buildings should also refer to local contexts instead of making broad general assumptions, because the specifics of regional aspects can shift the conclusions of a study.[18]

LCA studies mostly use a static approach (they assume the same conditions over the entire life span). But, as long-lasting products, such an assumption may incorporate high uncertainty over time. Predicting and modelling future changes is challenging and requires further research efforts, namely for the following reasons:

- the total building service life is uncertain (usually between 50-100 years) and the schedule/ nature of maintenance activities can highly impact the life span;
- The service life of active systems is shorter than that of most building components. They will likely be replaced by more efficient systems as time goes on, which is hardly predictable;
- the electricity production mix changes over time, affecting operational phase impacts;
- Buildings will eventually be demolished or dismantled. However their EOL (end-of-life) and future construction waste treatment scenarios are uncertain.

2.1.2 Addressing the urban scale in the environmental assessment of buildings.

Although the environmental assessment of buildings significantly developed over last decades, the integration of urban scale in environmental research and policies is an important opportunity. Urban design is directly linked to the environmental performance of a building, as it is often related to typology and orientation [19]. However, less straightforward links play an important role and research is required for a better understanding and exploration of specific influences of urban form on energy, environmental requirements and emissions[2] [20]. Here, the connections between urban form and environmental impacts are addressed, associated with buildings by focusing on the following issues:

- accounting for urban microclimate effects;

- understanding how land use planning variables affect environmental performance of urban areas;
- how they affect travel demand.

T the need to integrate the urban scale in environmental assessment and policies and the potential of urban design is discussed and planning to contribute to a more sustainable development.

Previous research has addressed the connection between building environmental performance and the urban scale. A comprehensive review on the link between urban structure, energy demand, and GHG is provided. It covers how urban design, performance of buildings, and travel demand are connected [19]. It is concluded that two directions/ connections should be further tested, in order to understand and use the potential of urban planning in reducing energy demand: connection between the type of dwelling together with in-dwelling energy use, and the use of energy in dwellings and the link between urban structure and transportation-related energy use. Energy consumption requirements of urban and rural households has been compared in further researches, in Finland, for apartment blocks, row / terrace houses and detached houses [21]. The differences between urban and rural living have been explored, and between different types of housing. It was found that behavioural differences were significant between different housing typologies and that across all types of rural households had lower energy requirements [21].

Most debates on how urban form influences the environmental performance of urban areas have been focused on density, particular dwelling or resident population densities, and its influence on the performance of residential buildings or passenger transportation, separately[2]. Generally low density in urban zones has been associated with increased energy requirements and environmental impacts, while high-density living (apartment buildings) has often been considered to be a more sustainable living model [19]. For buildings, however, occupancy issues are likely to explain a large share of this evidence, in particular the current rapid increase in living space per person. Furthermore, although collective housing blocks may seem to have a better environmental performance (because they have a lower external envelope per square meter of living area), different operating requirements associated with common spaces and infrastructure, such as elevators, might narrow the difference between these and lower density housing typologies [22]. In regard to transport demand, lower energy requirements and environmental impacts associated with dense urban zones have been mostly related to better accessibility, shorter trips, and higher transit efficiency. However, density might increase congestion problems and commute time, particularly because of job centralization. Therefore, smart growth strategies have generally supported the development of higher density clusters linked by public transport networks. Other variables that characterize urban form have been addressed, although less explored, such as accessibility and land use mix [19] [23].

Urban context needs to be considered in the design stage is crucial to address urban microclimate effects, as well as public, street space, and accessibility, such as day lighting width and building height ratios, which strongly influence the environmental performance of buildings. For example, daylight and shading of buildings and public space have been explored [24]. It shows that oversized buildings offset does not necessarily mean significant decrease of energy use in dwellings, but they are likely to compromise walkability thus leading to higher transportation requirements. For the environmental assessment of new and existing buildings, addressing the urban scale is crucial to account for urban microclimate effects, such as considering urban form variables (building types and vegetation) to consider urban heat island effects [24] [25].

Generally, research has focused either on transport or in-dwelling energy and environmental impacts, but not both. However, the location of a building determines the transportation demand of its inhabitants, and, in order to support decision-making at the urban scale and avoid trade-offs, it is important that the two are also addressed together in integrated approaches. Few assessments have addressed both transport and building energy and environmental performance despite the fact that they are both strongly affected by urban design and planning policies. Bastos et al., which comprised a comparative life-cycle study for dwellings considering building construction, building use, and user transportation, included a brief review on nine previous life-cycle studies that integrated transportation and buildings.

Two issues that strongly affect research and comparative environmental assessments of buildings and urban areas should be highlighted: self-selection biases and functional units. Although a large body of research has shown strong correlation linkages between urban form and energy use or environmental performance (especially focusing on density), it is important to stress that it does not establish a causal link. The links between buildings and transportation environmental performance of transportation and urban form are complex and selection bias can hardly be controlled for. As an example, it is difficult to distinguish the demographic effects of the urban form on buildings' energy use and environmental performance of buildings (for example, denser areas in many cities are likely to have lower income residents). In addition, the results depend on the unit of analysis, most often being per floor area (square meter) or per capita.

In the last decades, significant progress has been made in monitoring, assessing and managing energy requirements and environmental performance of buildings; however, research has focused on isolated buildings and aspects, such as operational energy use, and there is an opportunity to expand to the urban scale, to support decision-making and guidelines for regional planning, urban and architectural design, which has great potential to achieve more sustainable growth and development. The design, location and local urban characteristics affect the environmental performance of a building, and focusing on the individual building, neglecting potential interactions with the urban scale, might shift impacts, have counterintuitive results, and overlook improvement opportunities for a more sustainable urban development. Future research should thus address the linkages of urban form, buildings, and transportation environmental performance with integrated and holistic approaches, to support design and decision-making and managing the building stock.

2.1.3 NZEB and urban context toward energy performance assessment

The European growth strategy for the present decade, known as Europe 2020, led to the Recast of the EPBD (Energy Performance of Buildings Directive) in 2010 [26], which brought the concept of NZEB to the forefront. This has been seen as a promising approach to minimize energy consumption and CO2 emissions in the building sector and, at the same time, to increase the penetration of renewable sources in energy production. However, and although relevant work can be found in the literature on the proposal of definitions and requirements[27], there is still

missing a comprehensive framework to characterize NZEB, namely in the urban context. Knowing that the building sector accounts for the largest energy consumption and that the world's population tends to concentrate in cities, it can be assumed that energy consumption is high.
Intensity in urban buildings will continue to increase, and more efforts are needed to counteract such a trend.

The recent interest on the district as an intermediate scale has brought a new emphasis to the study of both buildings and cities, whose energy efficiency has been studied distinctly, based on the= premise that buildings behave as isolated units that encapsulate all the requirements, neglecting the need to have shared resources and, particularly, the influence of urban scale phenomena. On the other hand, urban forms have been studied, for instance, on the design of a city as a whole, and a great deal of attention has been given to the sustainability in urban development, with the emergence of several assessment methodologies[28]. As a recent approach in the literature, the boundaries of this intermediate scale are not yet well defined; block, district, neighbourhood, or community are terms that reveal an attempt of understanding how buildings interact with near surroundings and how these affect their energy performance. The challenging mission of the NZEB concept lies in the goal of reaching a clear balance between energy consumption and production. For that, the elements that feature the design of these buildings are[2]:

- from the demand side – efficient opaque envelopes and glazing areas, efficient heating and cooling systems, good ventilation methodologies, efficient water heating systems, efficient lighting systems and appliances, etc.;
- From the supply side, technologies based on renewable energy sources and efficient building energy management systems.

These are very important and unquestionable factors; however, in an urban context, buildings' performance of buildings cannot be assessed individually. There are factors intrinsic to neighbourhood patterns that can play an important role in building performance, such as airflows and heat island effect generated by urban environment, buildings' shape, or even behaviour of the residents.

Among these factors, the urban morphology, namely through geometry, should also be considered in the energy performance assessment, and, in this topic, urban form and density assume an essential role, mainly due to the shading effect that buildings produce on each other, which can make some design strategies related to solar availability unfeasible. In the literature, the key solution for the energy efficiency of urban buildings and for achieving an NZEB on a district scale is related to the solar potential of urban areas, and how the shape can affect solar availability, energy demand, and energy supply[29].

The main advantage of studying the behaviour of buildings as a part of a quarter or a district is the possibility of sharing resources and systems, in order to optimize efficiency and cost investments, and this brings a special attention to the heating and cooling systems, as well as the energy production at a district scale. Some studies have shown that district heating and cooling systems are advantageous when compared to individual ones, in terms of environmental impact, investment costs, and services demand, depending on the urban density.

Moreover, they are referred as helping NZEB to have an important role in the construction of smart cities. Therefore, density can help delimitate this boundary of efficiency, and although several studies recognize this importance, a broad and consensus definition is still missing[2].

In this sense, it can be concluded that few studies have focused on an approach to the study of NZEB at a neighbourhood scale, and have concentrated in specific objectives. Taking into account that, for all European Member States, new private buildings must meet NZEB goals from 2020, it becomes increasingly important to enrich this field of studies, contributing to a consensus definition and congregation of all the influencing requirements in NZEB at the district scale, as well as several ways and methodologies to put them into practice. In this way, it will be possible to rule out effective urban policies guided by environmental and energy concerns, reflecting the goals of Europe 2050[2].

2.1.3.1 NZEB Requirements for existing buildings. Policies and laws

In Commission Recommendation (EU) 2016/1318 of 29 July 2016[30] on guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that by 2020 all new buildings will be buildings whose energy consumption is close to zero, for the renovation of the building stock, EU Member States are recommended to strengthen and further evaluate their adopted measures to stimulate in-depth and cost-effective renovations toward NZEB.

Law no. 372/2005 [31]on the energy performance of buildings, republished, defines a building whose energy consumption is almost equal to zero as a building with a very high energy performance, where the energy required to ensure the energy performance is almost equal to zero or is very low and is covered as follows:

- in proportion to a minimum of 30% with energy from renewable sources, including energy from renewable sources produced on-site or nearby, within a radius of 30 km from the GPS coordinates of the building, starting from 2021;
- Minimum proportions of energy from renewable sources, including renewable energy produced on-site or nearby, within a radius of 30 km from the GPS coordinates of the building, for the periods 2031-2040, 2041-2050, and after 2051, are established by government decision.

The conception, design, execution, and use of an NZEB building must be based on the conditions and performance indicators aimed at being achieved, as defined by the national legislation in force. Therefore, first of all, the thermal envelope of the building and all the installations must be correctly sized to fit the primary energy requirement, expressed in kWh/m2·year, within the maximum limits imposed according to the climate zone, the type of building, and its destination. Another condition that must be respected refers to reaching the minimum threshold of energy from renewable sources obtained on site or near (according to the rules in force), expressed in %. On the other hand, the lower the energy requirement, the easier it will be to achieve this percentage required to be made from renewable sources. Last but not least, the maximum accepted values for equivalent carbon dioxide emissions, expressed in kg/m2·year, must also be taken into account.

Therefore, the renovation of existing buildings at the NZEB level must comply with the limit values imposed by the legislation and norms in force at the design date, depending on the type of building and the climate zone, regarding the following performance indicators.

- The primary energy requirement (with values below the maximum imposed value);
- equivalent emissions of carbon dioxide (with values below the maximum imposed values); the energy requirement from renewable sources (with values above the legal minimum).

According to Law No. 372/2005 [31], republished, the minimum energy performance requirements of both new and existing buildings or building units, hereinafter referred to as requirements, apply differentiated by function types, as follows:

- residential - collective or individual;
- offices;
- education;
- health;
- hotels and restaurants;
- sports activities; trade;
- other functions.

Energy performance requirements do not apply to the following categories of buildings:

- Historical monument buildings and buildings that are either part of protected built areas or protection zones of historical monuments, according to the law, or have special architectural or historical value, which, if the requirements were applied, would be modified unacceptable character or external appearance;
- buildings used as places of worship or for other religious activities;
- temporary buildings intended to be used for periods of up to 2 years, in industrial areas, workshops and non-residential buildings in the agricultural field that require low energy consumption;
- residential buildings that are intended to be used less than 4 months a year;
- independent buildings, with a usable area of less than 50 square meters.

Annex 2 to Order No. 386/2016 [32] for the modification and completion of the Technical Regulation "Regulation on the thermomechanical calculation of the construction elements of buildings", indicative C107-2005 [33], approved by the Order of the Minister of Transport, Construction and Tourism No. 2.055/2005 defines the upper limit level of the primary energy requirement and CO2 emissions for buildings whose energy consumption is almost equal to zero, without differentiating between new and existing buildings. This differentiation will be established by subsequent technical regulations.

2.1.3.2 NZEB Requirements for existing buildings. Building renovations

Renovation is an important stage of the life cycle of a building, which allows ensuring the proper functioning of the building, increasing the life cycle perspective. The term renovation can be adopted to describe different stages of intervention. Renovation can refer to interventions to replace or modernize a single element or several parts of the building, as well as the installation of renewable energy sources.

The renovation of a building must be linked to an improvement in energy performance, and depending on the level of renovation, different performance requirements can be set for both elements of the building envelope and the whole building.

In the Commission Recommendation (EU) 2019/786 of 8 May 2019 [34] on the renovation of buildings, the following levels of scale of renovation were developed in the context of the EU Observatory of building stock based on primary energy savings:

- minor renovation (less than 30%);
- moderate renovation (between 30 % and 60 %);
- in-depth renovation (over 60 %).

Law no. 372/2005, republished, defines two types of renovation:

- in-depth renovation - a renovation that leads to the improvement of more than 60% of the energy performance of a building, estimated by calculation according to the methodology provided in para. (1) of art. 5 concerning the current state and normal use of the building;
- Major renovation - works designed and carried out on the building envelope and/or its technical systems, the costs of which exceed 25% of the building's taxable value, excluding the value of the land on which the building is located.

Renovation follows a route similar to that of new construction: it is linked to a new life cycle of the building and presents the same stages of design, execution, and operation. However, initiating the process is different, as the renovation process usually starts from one of the following issues:

- failures of construction elements and installations or equipment; one or more elements have reached the end of their life cycle;
- performance improvement (e.g., energy, safety, etc.);
- bringing the elements of the building back to the minimum performance requirements;
- different user needs.

Every design and construction process is affected by several challenges, which can be easily identified and solved in the case of new construction, but are more difficult to identify in the case of renovation. Uncertainties can lead to higher costs and a longer implementation period, affecting the estimated life-cycle costs (LCCs) of the intervention. The challenges and difficulties could be related to the following:

- Lack of original plans and drawings;
- the difficulty in identifying the characteristics of the construction elements (layers and materials);
- the compatibility between the proposed solutions and the existing resistance structure.

The decision to renovate a building or to demolish it and build a new one is a difficult choice for a property owner, as this decision strongly influences the life cycle cost of the building, as it is necessary to consider aspects related to the return on investment and energy savings. There are several tools and approaches to support the decision-making process and the main factors are related to the investment cost, the future market value of the existing building, the energy consumption and the environmental impact of the intervention measures.

The analysis of costs and benefits to support the decision refers to 4 main categories:

- **Planning** - Defining the expectations and objectives of the parties involved (essential activity in terms of decision-making); The destination of the building before and after the renovation is an important aspect to be analysed, as a consistent reconfiguration of the building may be necessary in case of a change of destination.
- **Plant systems and equipment -** The design of a new building would allow new equipment and technologies to be installed without being constrained by the existing structure, and materials, as well as HVAC and electrical systems, could be selected only based on life cycle profitability criteria, thus reducing maintenance costs.
- **Project requirements -**The requirements resulting from the building design codes are constantly changing and mean meeting ambitious objectives regarding the building as a whole, having a high impact on costs. In this regard, a detailed analysis of the costs of additional work is essential for making a decision; Structural safety of the building - assessment of the strength structure and an investigation of previous interventions is required. Materials used in existing buildings (e.g. asbestos, pollutants, etc.) no longer meet current requirements. Therefore, additional changes must be made, which increases the duration and cost of the renovation.
- **Location aspects -** Is the building in a location where the renovations will justify the investment? Renovating a store in an area where there is no economic growth is a good example of a consideration where location is considered important.

To optimise the process of the NZEB concept, the circuit of the process, the necessary technical qualifications, the actions to be carried out, and the role of each involved party must be established. Subsequently, the tasks and functions of the stakeholders will be known and assigned.

Building owners, investors, the construction industry, energy efficiency solution providers, designers, project verifiers, certified technical experts, building energy auditors, and contractors are involved in various phases of the building life cycle.

Each of the construction factors involved in the process of NZEB buildings is involved in various related activities over a certain period of time, which was indicatively illustrated in Figure 2.1 - Participation over time of the factors of interest, but also in a certain stage of the life cycle of a construction (Table 2.1).

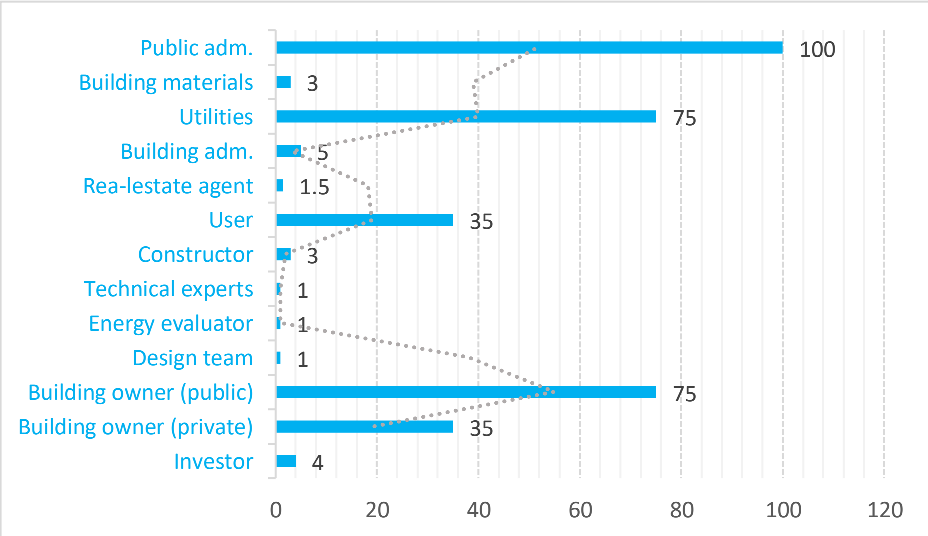

Figure 2.1. Participation over time of different factors of interest

	DESIGN PHASE	CONSTRUCTION PHASE	VALID PHASE	USE PHASE
INVESTOR	x	x	x	
BUILDING OWNER (PRIAVATE)	x	x	x	x
BUILDING OWNER (PUBLIC)	x	x	x	x
DESIGN TEAM	x	x	x	
ENERGY EVALUATOR	x	x	x	x
TECHNICAL EXPERTS	x	x		x
CONSTRUCTOR		x	x	
USER				x
REAL-ESTATE AGENT				x
BUILDING ADMIN.				x
BUILDING MATERIALS	x	x		
UTILITY SUPPLIER	x	x	x	x
NGO'S	x	x	x	x
PUBLIC ADMISTRATION	x	x	x	x

Table 2.1. Participation in a certain stage of the life cycle of a construction

While the user is primarily interested in the operational stage, the designer is most often involved only until the building is completed. If a property is financed and used by the building owner himself, he is interested in the entire life cycle until the user changes, if necessary. Depending on the approach, it can be between 25-30 years, after repayment of a possible bank loan, and up to 50 years, in case of full use.

Table 2.2 shows the benefits resulting from the process of building NZEB buildings, according to the interests of the different parties. For example, the user is interested in low operating costs, and thus being in a higher energy class and, therefore, low utility costs. The construction company is interested in keeping the execution costs low.

In the case of buildings where the owner is also the user, both components of the cost are important, both the initial investment and the costs of use. For public sector owners, the costs of each stage, throughout the life of the building, and also the effects of energy consumption, such as CO2 emissions, are important.

The benefits addressed refer to commercialisation, the possibility of renting, increasing the added value, comfort, durability, protecting the environment, or different local or national objectives such as energy autonomy. Where possible, direct and co-benefits should be considered in the decision-making process.

	BENEFITS					SIDE BENEFITS				
CONSIDERED FACTOR	COMERCIAL	RENT	INCREASE VALUE	COMFORT	DURABILITY	ASPECT / IMAGE	ENERGY SAVINGS	USER SATISFY	ECO FRIENDLY	ENERGY SELF-SUFFICIENT
INVESTOR	-	0	-	+	-	+	+	+	0	0
BUILDING OWNER (PRIAVATE)	+	+	+	0	-	+	0	0	-	-
BUILDING OWNER (PUBLIC)	+	-	-	+	+	+	0	+	0	-
DESIGN TEAM	-	-	-	-	+	+	-	0	-	-
ENERGY EVALUATOR	-	-	-	+	+	+	+	+	+	+
TECHNICAL EXPERTS	-	-	-	+	+	+	+	+	+	+
CONSTRUCTOR	-	-	-	+	+	+	-	-	-	-
USER	-	+	+	+	+	0	+	+	-	-
REAL-ESTATE AGENT	-	-	-	+	+	-	+	+	+	+
BUILDING ADMIN.	+	+	+	+	-	0	-	-	-	-
BUILDING MATERIALS	+	+	+	+	+	+	+	+	+	0
UTILITY SUPPLIER	+	+	+	+	+	+	+	+	+	+
NGO'S	+	+	+	+	+	+	+	+	+	+
PUBLIC ADMISTRATION	+	+	+	+	+	+	+	+	+	+

Table 2.2. Benefits resulting from the process of building NZEB buildings, according to the interests of the different parties: "+" – very interested; "0"- neutral; "-"- uninterested

2.1.4 Control of domestic energy resources in a smart grid scenario

As mentioned before, the buildings sector is one of the largest energy consumers representing 32% of global energy use, and special attention should be paid to this sector. Sustainable energy consumption comprises making a more conscientious use of electricity, including producing electricity locally based on renewables, and using it with the ultimate goal of reducing overall consumption.

Existing power systems are one of the main reasons for greenhouse or global warming effects which lead to environmental impacts by using fossil fuels, especially coal. In contrast to fossil fuels, renewable energy (RE) offers an alternative source of energy that is pollution free, from a technology perspective. There is a high focus towards using RE, particularly solar and wind energy, in return for electricity without generating carbon dioxide emissions. However, most existing transmission and installed distribution networks are considered "dumb" or inefficient systems as they cannot return the smart data required for a modern grid operation[35] [36]. The existing power grid cannot offer the necessary services in terms of energy efficiency, reliability and security, or possible integration of RE needed to meet the future clean energy demand [36]. Therefore, the introduction of smart grid technology is an essential step towards reducing overall greenhouse gas (GHG) emissions with demand management. Encourage energy efficiency, improves reliability, and has a more efficient and effective power plan. Smart grids bring centralized massive power plants and distributed power generators together, allowing a multidirectional power flow and information exchange. This two-way power communication system creates an advanced and energy-efficient advanced energy delivery network in contrast to traditional power systems where power flows only in one direction, i.e., from generators to customers through transmission and distribution relays [37] [38] [39].A smart grid is an advanced distribution grid that delivers electricity with flexibility, reliability, accessibility, and economy. Compared to today's power systems, smart grids are capable of digitally enhance power systems, where the use of modern communications and control technologies allows greater robustness, efficiency and flexibility [37] [38] [39] [36]. A brief comparison between the two grids is given in Table 1.

In the context of smart grids, power systems will be endowed with bidirectional communication, computing, control, and information technologies enabling the end-user to react in a near-real time environment to dynamic tariffs. Several studies have already shown that feedback on household electricity consumption can by itself act as stimuli for a more efficient behaviour and originate savings. Therefore, with the right incentives and technology, end-users may adopt a more active role, namely through the adjustment of energy demand aiming to reduce the electricity bill. Nevertheless, the adjustment of demand is not an easy task since it requires continuously monitoring demand and kWh prices, and simultaneously deciding when to decrease or even increase demand and how. The adjustment of demand should be done through the implementation of demand response actions. The range of demand response actions varies according to the type of load and includes deciding:

- when to turn on laundry machines, tumble dryers, dishwashers;
- the temperature to be set and/or the curtailments to be applied over thermostatically controlled loads, such as air conditioners and electric water heaters or even refrigerators and freezers;

- What to do with the energy produced locally (store/use/sell back to the grid); and
- How to manage electricity storage devices, including an electric vehicle that can be used in both grid-to-vehicle (G2V) and vehicle-to-grid (V2G) modes.

These decisions are not straightforward to the end-user due to all the inputs that have to be checked and the consequences directly arising from the demand response actions, which directly impact on the electricity consumption but also on the end-user perceived dissatisfaction. Additionally, there is the possibility of combining demand response actions according to the targeted load. For instance, one or more of the previous decisions may be assigned to thermostatically controlled loads, such as cold appliances, air conditioners, and electric water heaters, depending on end-user preferences, flexibility and level of comfort desired. Temperature settings can be reset, the working cycle can be delayed or anticipated, and short interruptions can be implemented. Therefore, taking into account the level of difficulty associated with the control of domestic energy resources, the adequate choice of demand response actions to be implemented on each manageable load can be done automately through decision support systems. These systems are supposed to simultaneously monitor demand, energy prices and local generation and trigger solutions which minimize the electricity bill and the dissatisfaction of the end user.

The control of domestic energy resources has been a topic of research for several years and the methodology selected depends on the targeted loads and on the final aim of the control. Furthermore, the potential flexibility has been assessed and some pilot studies have already been conducted. Evolutionary computation is one of the methodologies that can be used in this context to optimize the use of domestic energy resources through the selection of demand response actions specifically tailored to the end-user profile. It is important to emphasize that the cost of operation of a specific load may vary along the day due to a variable tariff structure, although the energy requested to the grid might be the same.

Therefore, if the end-user has some flexibility regarding load operation and temperature settings and is willing to accept a small degradation of the quality of the energy service provided if needed, then a decrease in the electricity bill can be obtained either by using electricity in periods of time in which the kWh price is cheaper or because less energy is needed (for the case of thermostatically controlled loads) or even by coordinating the use of storage systems.

Although the economic savings for each household may seem reduced, the aggregation of several houses can deliver substantial benefits at national level, impacting in the electrical energy chain and contributing to increasing overall efficiency, reliability, flexibility, and sustainability.

2.1.5 How much energy savings potential can be achieved by end-use energy behaviours.

Energy behaviours are seen as a important factor towards achieving energy efficiency in the residential sector. They also gain special relevance during the ongoing transition to smart grids. However, energy behaviours are still an underdeveloped resource because of the lack of adequate approaches to address their complexity and the difficulty of quantifying behavioural savings[40].

Energy behaviours represent people's actions that lead to energy consumption. These include investment, maintenance, usage patterns as and the management, provision of energy resources. While investment behaviours include new energy consuming equipment acquisition, maintenance behaviours contain actions for repairing, maintaining, and improving either the equipment or the building. Usage behaviours patterns are daily actions of users in buildings use phase and the installed equipment within. Particularly, in a smart grid context, energy behaviours also mean actions required for managing energy resources[41].

Energy behaviours are usually influenced by personal or contextual factors with different research disciplines defining them using distinct, yet complementary approaches. While the social sciences and humanities focus on exploring the personal and contextual factors that lead to the activation of energy behaviours, engineering explores energy consumption as a result of the technical characteristics of equipment and buildings. In Economics individuals are considered to be rational, the minimize cost and maximize utility in their daily activities, but the stream of behavioural patterns sees that each individual uses heuristics in order to make information processing easier[41].

Psychology addresses individual perspective. It identifies personal determinants and contextual influences. This in order to explain and/ or predict energy behaviours. Sociology together with other social sciences see energy behaviours / patterns as the outcome of social context and not as a consequence of individual decisions, accounting for energy behaviours as the outcome of the social organization in which individuals live, for example social rules and lifestyles[2].

Behaviour may greatly impact energy consumption in residential buildings. Modelling strategies like building energy performance simulation tools have estimated important savings potential that depends on the behavioural dimensions addressed. While adjusting Occupancy schedules can generate savings up to 21%, the combination of other behavioural dimensions related with TC (e.g., occupancy, set points, heated area schedule, ventilation and lighting practices, and use of blinds) can increase the savings potential up to 88%[2]. When considering other energy services used within residential environments (e.g., appliances, water heating), the savings potential can even increase. Usually, investment energy behaviour patterns have a more significant savings potential than usage behaviours, and the potential for behavioural savings per energy service is proportional to the breakdown of energy consumption[2].

Although major potentials for behavioral savings have been estimated through modeling approaches, it is difficult to realize these savings through implementation of behavioral change interventions. These, overall, usually generate savings up to 20%, but this value can significantly differ depending on the strategies used to promote them and on the social, political and economic context[42]. Using Europe as case study, the most effective interventions are feedback, community-based initiatives, energy audits, and a combination of multiple strategies, all having the possibility to generatw savings from 5% to 20%. However, these results may not be transferable since they have been achieved in the context of interventions with different characteristics (e.g., location, typology, scope, scale, and energy policy context). Furthermore, behavioral savings can also be partially cancelled by rebound effects, such as savings being potentially used by the household to increase the consumption of goods and services, including energy, and to a reduction of energy demand and lower fuel prices which, in turn, could increase the energy consumption. Rebound effects have been estimated to be around 5%-13% for improvements in electrical efficiency, 6% for lighting improvements, 15–

25% for improvements in space cooling and heating, and 9% and 14% for behavioral changes using electric appliances and heating, respectively Rebound effects also differ among geographic areas. For example, while in the USA rebound effect was estimated around 56– 80%, in Europe this value reaches only 18.3%[2].

In summary, end-use energy behaviors may significantly impact residential energy consumption therefore playing an important role in energy efficiency in buildings. However, behavioral savings may be limited by real-world constraints and rebound effects. [42]

2.1.6 Integrated indoor environmental quality assessment

Air Quality (IAQ) is a major environmental health concerns in Europe. It has great impact on the health of buildings users, mainly of children or elderly, these being the most sensitive groups. IEQ is tied to IAQ and it is defined as *"the complex of thermal, visual, acoustic, vibration and ergonomic comfort and indoor air quality"[2]*. TC also represents a decisive factor for health, comfort and work/ study proficiency of people and significant economic and social costs may arise when it is neglected. TC is defined as the state of mind which expresses satisfaction with the thermal environment[2]. It can be assessed by objective evaluation, and the main factors to be considered are the indoor air temperature, mean radiant temperature, humidity and air velocity. It is suggested that having improved indoor conditions and socio-economic protection might lead to a decrease in winter mortality in mild winter climates[43]. A good illuminance level also contributes to a suitable indoor environment. In fact, the payback of daylighting goes beyond energy savings. It has been suggested that daylighting improves learning up to 21%. Besides, from a psychological perspective, it effectively stimulates the human visual and circadian systems. For the mentioned reasons, it is mandatory that buildings ensure good IEQ to occupants[44].

The energy efficiency related to TC and IAQ embodies a great task in the buildings' operation and management field. Until recently, the IEQ issues have been approached separately from the energy efficiency issues in buildings. This is why many different case-studies are found in literature for each field, but few integrated studies are found. An integrated approach to reduce the energy consumption in school buildings while providing good indoor environmental conditions has been addressed, and the IAQ of homes is evaluated considering energy efficiency. In fact, it is proposed a reflection on the evolution of the reduction of useful floor space in dwellings and the air tightness and restricted air infiltration, which may see internal air change rates reduced by almost 90%. It is also mentioned that reducing ventilation rates to improve energy efficiency and reduce carbon emissions, without incorporating an effective ventilation strategy, leads to a poorer indoor environment, which is expected to have a long-term impact on public health. Although this was mainly addressed regarding housing, the same reasoning might be addressed for spaces where people spend most of their day, since offices or schools, where poor ventilation in classrooms may greatly impair children's attention and vigilance[2] [44].

Behaviors of end-users' should not be disregarded, as they are determinant for the use of energy. Buildings do not use energy, people do. Relating TC, besides environmental factors, end-users' behaviors (such as the activity and clothing insulation) also take part of the equation. For example, if the metabolic rate is somehow conditioned by the activity (e.g., seated in an office is seen as sedentary activity) and it cannot be easily changed, the clothing layers may correspond to a significant individual adaptation. Human adaptation should be seen as one of the main drivers to energy efficiency. Today, due to the increase of mechanical ventilated systems use in buildings, people seem to have tightened their comfort levels. In fact, in countries where HVAC systems are still not so imbedded, or where outdoor conditions go beside the "typical" European ranges, people feel more comfortable (i.e. people state to feel neutral or to accept the experienced conditions) besides the current comfort standards, such as ISO 7730[45], EN 15251[46], ASHRAE 55 [47] or the forthcoming EN 16798. The effort that the standards have been doing to incorporate TC adaptive models in a more sustainable building performance perspective is noteworthy. By enlarging the comfort boundaries, it has been unveiled that it is possible to reach comfort levels in non-mechanical ventilated buildings. Starting from the 70's approach on energy conservation through building tightness (that ultimately led to some of the problems such as increased concentration of pollutants indoors), moving forward a different attitude is needed. Besides adaptation, energy unenlightenment seems to be one of the main agents driving against energy efficiency in buildings[2].

Attention to "technological illiteracy or sins of emission" is drawn, relating the miss-control of building management systems in secondary schools, e.g. recalling the need for post-occupancy evaluation actions, vital analyses to identify opportunities for fine tuning of the systems operation. Basically, more efficient building management systems operation and scheduling are suggested, combined with passive measures towards IEQ when systems are turned off (due to energy constraints). Adaptive actions such as windows and/or doors opening are determinant, aiming at raising the ventilation rates and lowering CO2 concentration levels. The importance of different ventilation methods and control strategies on energy consumption and the importance of proper management of 'Building Automation and Control Systems (BACS) for performance optimization' are also to be addressed[2].

2.1.7 Different methodologies for the assessment of building retrofit actions

. The works involved in retrofit are usually of complex and heterogeneous nature that require various specialties to be integrated in highly variable conditions. Furthermore, a thorough building's retrofit evaluation is quite difficult to undertake, because a building and its environment are complex systems regarding technical, technological, ecological, social, comfort, esthetical, and other aspects, where every sub-system influences the total efficiency performance and the interdependence between sub-systems plays a critical role[48]. There are a number of models and methods developed to assess conditions and support decisions pertaining to building retrofit. These methodologies can be categorized into two main approaches: the models in which alternative retrofit solutions are explicitly known a priori and the models in which alternative retrofit solutions are implicitly defined in the setting of an optimization model[48].

The most common a priori approach is one in which the decision maker assigns weights to each criterion, the weighted sum of the criteria then forming a single design criterion. It is then possible to find the single design solution that optimizes the weighted sum of the criteria. A multicriteria analysis model to be used at the process of building design in order to explore the trade-offs between the building thermal performance and other criteria such as capital cost and usable area has been proposed [2]. More recently, other researchers have also employed multi-criteria analysis techniques to similar problems. Some [48]proposed approaches for the evaluation of retrofitting scenarios. In some cases, a multivariate design method and multi-criteria analysis for building retrofit, determining the significance, priorities and utility degree of building retrofit alternatives and selecting the most recommended variant. These lines of research have allowed addressing many problems as far as buildings retrofit is concerned. However, most of them consider that a list of predefined and pre-evaluated alternative variants of the building retrofit options is given. In case a small number of such solutions have been defined, there is no guarantee that the solution finally reached is the best one (from the decision maker’s perspective). On the opposite case, when a large number of solutions are defined the required evaluation and selection process may become extremely difficult to handle. Moreover, multi-criteria analysis-based methodologies do not provide the designer with information about how sensitive each criterion is to changes of the other criteria[2].

The second approach is based on multi-objective optimization. It allows to consider a large data-set of building retrofit options, set by the constraints that define search space and grasp trade-offs between objective functions helping to reach a satisfactory compromise solution. However, so far, relatively little attention has been paid to tackling building retrofit decision support with multiple objective optimizations.

Considering all the possibilities that the decision maker has available for building retrofit (e.g., HVAC systems and renewable energy sources), as well as all the objectives that one may wish to optimize (CO2 emissions, social objectives, etc.), it may lead to the combinatorial explosion of the decision problem, thus making the solving procedure extremely difficult and time-consuming. In such case, other optimization techniques, namely multi-objective genetic algorithms are necessary for tackling the problem. A multi-objective-genetic algorithm has been used to find the trade-offs between the energy cost and TC for the design of a single zone HVAC system[49]. A multi-objective optimization approach has been proposed based on genetic algorithms to tackle the problem of designing low-emission cost-effective dwellings, minimizing the carbon dioxide emissions and the investment cost for a two-story house and its HVAC system.

A main drawback of genetic algorithms is the high burden whenever it is necessary to make a large number of calls to an evaluation function involving a high computational cost. In building applications, these evaluations are generally estimated by an external simulation program such as Computational Fluids Dynamics or other simulation packages. If accurate results are required, each evaluation can be time consuming, and thus the complete computational process becomes extremely unattractive. Accordingly, building optimization studies using genetic algorithms generally tend to reduce the computational time by using two methods. The first method consists in using very simplified models instead of complex simulation software. However, this method presents a risk of over-simplification and inaccurate modeling of building phenomena. The second method commonly used is to select populations of very small genetic algorithms and / or a relatively small number of generations. Again, optimization can be significantly affected and may lead to narrow or nonoptimal solution sets[2].

One very efficient, yet not widely exploited, solution to reduce the computational time associated with genetic algorithms is to use a response surface approximation model to first mimic the behavior of the base building model, and then use this response surface approximation within individual genetic algorithms for the evaluation. By doing so, the computational time associated with each evaluation becomes negligible, while good accuracy is maintained in the results. Although there are several response surface approximation methods, there is no common agreement about which technique is best[2].

2.1.8 Thermal energy storage systems with PCMs

Thermal energy storage (TES) systems with phase-changing materials (PCMs) can be used to: reduce buildings' dependency on fossil fuels; make use of renewable energy sources; improve the thermal resistance and heat capacity of building's envelope; improve indoor thermal comfort; reduce heating and cooling energy demand; and reduce air-conditioning power needed for heating/cooling peak-loads. Compared to traditional materials used in construction, PCMs provide a large heat capacity over a limited temperature range (due to high energy quantities involved in the solid-liquid phase-change processes) and they could act like an almost-isothermal reservoir of heat. As the temperature increases and reaches the melting temperature, PCMs change phase from solid to liquid absorbing heat. When the temperature decreases and reaches the solidifying-temperature, PCMs change phase from liquid to solid releasing the stored heat. The PCM-based systems are commonly pooled into two main groups: passive and active systems. Here, "passive" means that the phase-change processes occur without resorting to mechanical equipments.

Regarding the problem of liquid leakage, several ways of [2]containment and different techniques for incorporating PCMs in construction materials have been studied. Two of the most well-known techniques are the microencapsulation and the macro-encapsulation techniques. In the former, the PCM is encapsulated within a micro-polymeric capsule. The final result is a powder-like material that can be mixed with other materials (*e.g.*, gypsum and cement mortars). In the latter, the microcapsule may be the only way of confinement. These macro-capsules are typically made of high-conductivity 20 materials in order to enhance the heat transfer to the PCM-bulk, as PCMs have typically low thermal conductivity [50].

The principles of PCMs' use are simple; however, optimizing the incorporation of PCMs within passive TES systems and evaluating the energy performance of the building with these elements is very complex and challenging. This entails including the use of the building and the typology of construction (high or low thermal inertia) and the major design parameters, namely the phase-change temperature of the PCM and its quantity. Moreover, such parameters need to be specified for given indoor loads and also for specific climatic conditions. Regarding the incorporation of PCMs in active systems, similar challenges are expected. However, in this case, the heat supply control may allow better control of phase-change processes[50].

The number of studies concerning the integration of PCMs in buildings has been increasing during the last decade. The research topics range from the most general to very specific ones, covering issues such as: the kind of PCMs and the main criteria for their selection; the thermophysical properties of different PCMs and the main techniques for their measurement; the long-term stability of PCMs; the hysteresis and subcooling problems; the different techniques for encapsulation and containment, including microencapsulation; the description of PCM emulsions and PCM slurries; the description of several impregnation; the main properties of shape-stabilized PCMs; the combination of thermal insulation and TES properties; the description of some heat transfer enhancement techniques; the mathematical and numerical modeling of phase-change problems; the description of several applications for buildings and their thermal performance Analysis; the dynamic simulation of energy in buildings with PCMs; the free-cooling of buildings with PCM-based systems; the design of ventilation and air-conditioning systems with PCMs and other active systems for buildings the integration of PCMs in domestic hot water systems; the latent heat storage in solar collectors and other solar systems; the thermal management of photovoltaics; the thermal control of electronic devices; the exergy assessment of PCM-based systems; the use of PCMs for cold storage applications and other TES applications[2].

It has been observed that the study of solid-liquid phase-change of PCMs is of great interest from the theoretical point of view and for the development of new TES systems. Moreover,[2] several research gaps were identified and some recommendations for future work were noted, such as:

- the design of new passive/active TES systems to take advantage of solar energy or other renewable sources;
- the assessment of the stability and convergence of numerical results, and the importance of validating the numerical predictions using appropriated experimental data (together with a suitable uncertainty analysis);
- the importance of the effects of hysteresis, subcooling and natural convection phenomena in
- the simulations and the challenging assessment of the thermophysical properties of PCMs
- and PCM-based elements in small, medium and large samples;
- the economic and the environmental life-cycle assessment of PCM-based systems; and
- the development of methodologies to couple dynamic simulation of energy in buildings techniques with multi-dimensional, multi-criteria and/or multi-objective optimization analysis to help decision-making in the optimization of the configuration of TES systems, their functioning and their location within the building.

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3. THE EXISTING COLLECTIVE HOUSING STOCK IN ROMANIA. THEN AND NOW

"The high-rate development of the national economy, the modernization of cities and labour centers, the increase of the number of workers and specialists, the continuous increase of the salary and other incomes of the working people, make necessary the development of housing construction and the improvement of their conformity. to the whole people.

In order to meet the growing housing requirements, the pace of construction of new homes will be intensified and measures will be taken to continuously improve comfort, in accordance with the pace of development of the national economy and according to the provisions of the state plan." [1]

After the end of the Second World War and the establishment of the communist regime, Romania experienced a period of massive economic recovery. Determined by the policy of forced industrialization over the entire sphere of influence of the Soviet bloc, Romania also suffered from a shortage of skilled labor for new industrial centers developed on the outskirts of cities or, in most cases, in new cities. built for this purpose. The result was a large migration from the rural to the urban areas during the period between 1948 and 1975, increasing the urban population by 147%. Therefore, it is fair to assume that the vast majority of people living in the socialist dwelling neighbourhoods came from a rural environment [2][3][4].

Here that, more than a century away from the first factories and working-class neighbourhoods during the Industrial Revolution, Romanian society faces the same premises that led to the development of high-density forms of collective housing in the modern period: new industrial cities that attract population rural as a labor force, causes an accelerated increase in the number of inhabitants in cities, generating, implicitly, a housing crisis [2][5].

In order to provide enough homes for the factory workers and their families, entire neighbourhoods of collective dwellings have been built, all based on the same recipe: prefabricated concrete panels. These panels ensured the production of a large number of neighbourhoods thanks to the rapid process of construction. The final product is a monofunctional and uniform space which lacks in diversity, a space where the emphasis is on providing the same conditions for everyone, hence on the equality between the residents.

For erecting these new neighbourhoods, the communist administration bought entire areas of houses and gardens located in the periphery. It soon led to the gradual demolition of the households, making space for the new apartment buildings. The blocks of flats were conceived in a great typological variety based on several typical architectural projects, thus obtaining repetitive mod- ules that could be assembled in many ways, depending on the limits of the existing urban tissues. In other words, a row of blocks could have been composed of multiple subtypes of the same building typology, allowing it to fit in the constrained boundaries of the demolished areas.

Even if the collective housing is present on the territory of today's Romania since the period of Austro-Hungarian expansion in the XVIII-XIX centuries, in the form of "Blockhaus" type housing, with living spaces for different social categories and organized around courtyards and corridors, the new apartment blocks built during the 60'-85 'had a much stronger impact on the country's population [2][6].

After the fall of the communist regime in 1989, as in many European Communist countries, the apartments have been purchased by the residents for a small amount of money. The growth of the inflation and the depression of the national currency led to the dramatic decrease of the apartment prices overnight. But prices soon exploded due to several factors, such as the flourishing economic context, and the late occurrence of new investments. The present recession led to a sudden drop in prices due to lack of bank financing and freezing of the housing market and the proposals of new residential projects, drawing attention upon new problems such as the need of improving existing housing stock that dominates the market.

3.1. Changes on private property

The development of collective housing in Romania, during the years 60'-85', is also linked, to a certain extent, to the evolution of the urbanization plan determined by the USSR policy. This evolution has largely retained its sequence of stages, being felt with some temporal delay.

In 2012 at Columbia University during the "The Fitch Colloquium: Why preserve public housing?" conference, describe the most important stages in the urbanization of the USSR and the satellite states, while following the emergence of constructive systems used in the construction of working-class neighbourhoods are described [7]. Key aspects are presented below:

- **1918:** Urban private properties are being nationalized
- **1920:** Collective housing experiments are being carried in the USSR. *Urban population at 17,9% with 8,2 sqm/capita available living space*
- **1931:** Stalin Period. During the Central Committee Meeting, Stalin criticises the failure utopic modernist ideas towards affordable housing; increased government authorities' involvement with detriment towards specialists. *Urban population at 33% with 6,9 sqm/capita available living space*
- **1952:** All residential buildings are to be designed according to State Committee for Construction. *Urban population at 40% with 7,4 sqm/capita available living space*
- **1955:** Hrusciov era. A decree is issued on "eliminating the excess in design and construction". The impact will be to simplify the design and execution of housing for economic reasons, to the detriment of quality and sometimes functionality.
- **1959:** First residential units using large prefabricated concrete panels are built in the GDR. This system will also be intensively used in Romania during the 70s. *Urban population in USSR at 47,9% with 9,2 sqm/capita available living space*
- **1965:** First buildings using frame structures. *Urban population at 52% with 10,3 sqm/capita available living space*
- **1991:** Fall of the USSR. *Urban population at 65.8% with 11,2 sqm/capita available living space*

- **1992:** Extensive privatisation

In Romania, the historical stages took place in the same succession until after 1963 when a series of divergences appeared between the Romanian and the Soviet authorities. At Khrushchev's proposal, the most industrialized communist states (GDR and Czechoslovakia) were to focus mainly on industry, while Romania had to specialize in agriculture, to the detriment of industry and inconsistent with the perspective of the Romanian Workers' Party. The position won by Nicolae Ceausescu's mediation of the conflict between the USSR and the People's Republic of China allowed a departure from the economic over-planning of the European communist states belonging to the Council for Mutual Economic Assistance (CAER) and, implicitly, from the political vision. in the USSR [8][2].

The new era of personality cult and communist propaganda born after Ceausescu's visit to Pyongyang in 1971 will mean the international creation of a state image independent of the USSR's influence, felt through political measures taken both externally and internally [9].

A number of measures of this independent policy have had a direct impact on private home ownership. It should be noted that in the ex-Soviet bloc, forms of ownership of liberal housing were non-existent, being replaced by the so-called "propiska" [10].

In the case of collective dwellings, they functioned as temporary or permanent residential permits, which could not be inherited or passed on to successors. For those who had the financial means to build a house in the urban environment, they were granted the right over the buildings themselves and the right to use the land in exchange for an annual rent, the land being owned by the state. The exceptions were rural households that were privately owned and could even carry out, under certain restrictions, even for-profit private activities. Contrary to the liberal view, Soviet forms had limited guarantees regarding the protection of private property, mainly due to ambiguously formulated laws. Privatization of property was possible only with the fall of the USSR, after the 1990s [11].

Some legislative initiatives, among which we mention law no. 9/1968 [12] and law no. 4/1973 [1] will make that, in Romania, private property over housing be allowed and guaranteed since the 70's, before many other states remained under the influence of the USSR until the end of the 80's. This legislative framework, revolutionary for consolidating the notion of private property in Romania, provided, as the title of the documents itself says, ways to "develop housing construction, sell housing from the state fund to the population and build personal property rest homes." Thus, a system of transferring state-owned to individual-owned housing was set up, with the help of loans granted by the authorities, which were particularly felt in the purchase of newly built apartments.

Although this new real estate market was still in its infancy, with no substantial capital from individuals, the true consequences of this policy will be felt much later, after the fall of the communist regime, as a result of a financial consequence.

The non-performing economic situation in Romania after 1989 [8] generated an exponential increase in inflation, the ratio of the national currency to international currencies occurring through a denomination that determined a significant devaluation of the leu. In this context, in the absence of a correlation with the new value of the national currency, housing loans, all related to the "leu", have become extremely affordable, generating a wave of apartment purchases unique in Europe.

3.2. The "Grey Neighbourhoods"

Today, more than half of the urban population in Romania lives in the blocks built during the communist period. It's not for nothing that these homes have were nicknamed "matchboxes", this because of their small space. Despite the fact that there are similarities between these constructions and several dwellings social from Western Europe, apartment buildings in Romania have characteristics and different motivations. For example, they were not designed for categories disadvantaged by people, but represented the only type of new housing. Besides, that's it urban development as well as architectural aspects were part of a system of general planning. This included the economic aspect, but also the stated purpose to create a new society. The general quality of these constructions has degraded, which leading to a decrease in the price of each apartment. In the long run, this could lead to the emergence of considerable social and economic problems. To prevent this, several measures have already been taken, for example, such as rehabilitation programs. But in addition to being insufficient, they promote partial and uncoordinated solutions. Figure 3.1 illustrates these neighbourhoods as they are today.

Figure 3.1. The "Grey Neighbourhoods"

It is important to see that the rehabilitation of these neighbourhoods does not it can only be based on solving technical problems, but it must have a holistic approach so that the end result can be a complex regeneration and efficient, a program that takes into account all aspects: spatial, social, local and economic.

3.2.1 Building statistics in Romania and Europe

The Studies carried out by the Building Performance Institute of Europe (BPIE) have highlighted the general situation in Europe regarding apartment buildings [13][14]. Figures 3.2 and 3.3 show a brief comparison between buildings in Europe and Romania.

Figure 3.2. Apartment building percentage in Europe

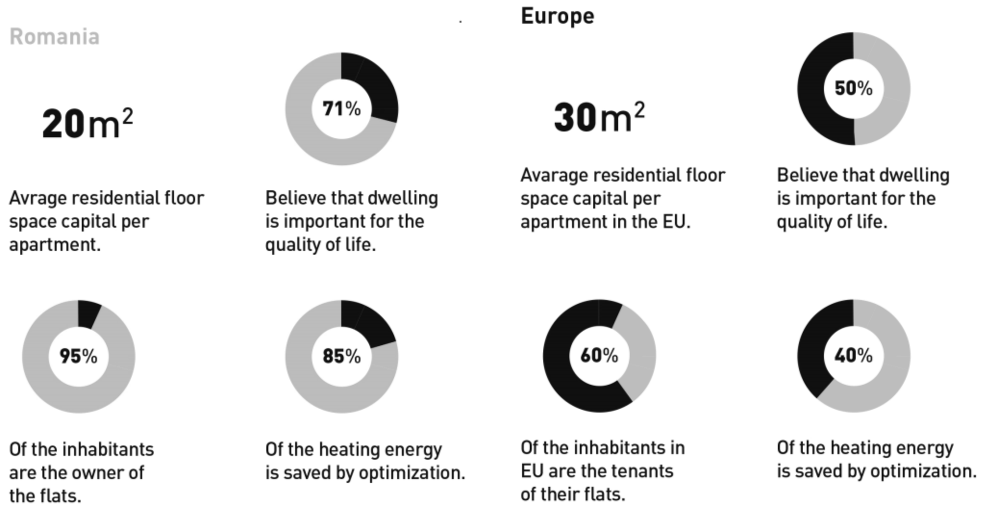

Figure 3.3. Statistic comparison of the collective housing stock between Europe and Romania

Compared to the highest percentage of residential construction completed between 1961 and 1990, of 81%, by Estonia, the lowest rate being in Ireland (32%), the percentage in Romania is quite high (60%). In addition, if it is about the number of owner-occupied apartments, Romania ranked first, with around 96% Only 4% of the inhabitants are renters, while in Switzerland the percentage of renters is 65%. Beyond these, however, regarding the area allocated for each person, Romania is at the bottom of the list, with only 20 sqm/person, while

Southern Europe allocates 31 sqm/person and North-West Europe leads the way with 36 sqm/person [13][14].

With regard to CO2 emissions per useful built area, Romania places somewhere in the middle of the list, producing only 57 kg CO2/m2. The smallest amount of CO2 emissions is in Norway, 5 kg CO2/m2, while in Ireland is the highest (122 kg CO2/m2) [13].

Rehabilitation of old buildings is one of the most important issues for the European Commission, in its commitment to reduce emissions of CO2 and greenhouse gases (GHG) and energy efficiency. According to statistics Eurostat, in 2009, European households were responsible for approx. 70% of the total final energy consumption in buildings, space heating requiring the more energy than end-use in EU homes. It is obvious that policies in the field aimed at retrofitting are crucial in this area of consumption. One of the most debated issues today is to find measures adapted to the level local that can be taken to ensure commitment to the EU policy "20-20-20" and to find alternative and innovative solutions for energy performance at a cost optimum of buildings, adapted to the local market.

3.3. Collective housing typologies. Project 770

3.3.1 Large prefabricated panels collective housing characteristics

The increased urbanization in Romania has led to rapid and economic construction of new housing neighbourhoods.

Among the construction systems that met the requirements, the best option was using large prefabricated reinforced concrete panels that had the following edges for design and implementation:

- **industrialization:** large reinforced concrete panels were prefabricated in industrial sites according to standard projects, being transported to locations for installation;
- **rapid production:** the prefabrication in industrial lines of a limited number of elements, which could be combined in different ways, allowed the process to proceed quickly;
- **mobility and transport:** the prefabricated buildings were dimensioned with maximum weights so that they could be easily transported and handled on site with the help of cranes;
- **repeatable:** conceived in this way, the type projects of residential buildings were repeatedly built on a large scale, multiplied, drawing the new image of the working districts;
- **quick construction:** unlike the traditional masonry systems used until the 60's, this system allowed the rapid erection of buildings, the only operations on site being those of binding the panels by monolithization;
- **economic efficiency:** industrialization opportunities, short construction times and limited site operations led to increased economic efficiency by reducing construction material losses, reducing labor costs and, by improving the system, detailed knowledge and prevention from the design phase of construction problems. building.

This construction system has been used since the 60's, gaining popularity in the 70's. An important moment in its evolution was the earthquake in Vrancea, in March 1977, leading to the abandonment of the construction of projects with high height regime (GF+8 - GF+10). This generated an increase in the construction of projects with 5 levels (GF+4) [13].

Among the project types built in Romania, the most common are:

- **Type 1013-1168:** three or four stories, built between 1960-1970;
- **Type 744:** GF+4 in height;
- **Type 944 and 1400:** GF+3, designed for areas with high seismic activities;
- **Type 1340:** GF+4, with large constructive cells;
- **Type 770:** GF+4, the most used typology in the country.

3.3.2 Project 770

One of the most common types of blocks in Timisoara are the 5-storey 770 and 1340 model, built between 1970- 1985 and 1980- 1990 respectively, the first offering the lowest living standards. All of these apartment blocks were created to be combined in different ways in order obtain a variety in the erection of new neighbourhoods. However, the repetitive pattern can still be perceived, producing a sense of confusion, as the neighbourhoods have no visual identity. The retrofitting and refurbishment of these blocks of flats can be seen as an opportunity to develop an identity to the neighbourhood. To narrow the field of research to the study of the most spread model in Timisoara, the 770 has been chosen.

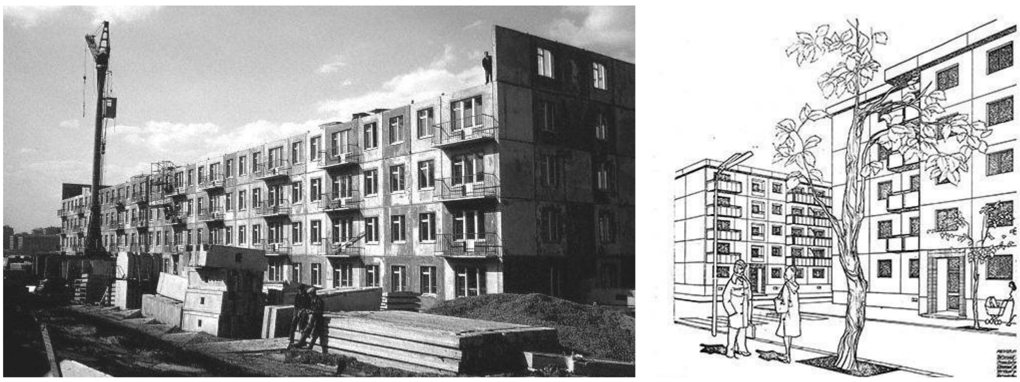

Figure 3.4. Building a Type 770

The model has been built extensively throughout the entire country during the 70s and the beginning of the 80s. We can find this model in almost all the neighbourhoods erected during that period from cities such as Arad, Cluj, Brasov, Bucharest, Iasi and Ploiesti. The great dispersion of such typical projects developed throughout the country lies in an efficient strategy oriented towards industrialization, affordability, transport and speed in execution. Every project type was developed starting from precise and rationally dimensioned prefabricated building components that would be shipped to the building site and assembled in the shortest time possible. In the case of the 770, 68 different components were used, ranging from vertical exterior and interior walls, ceilings, to staircases and even bathrooms. The particularity of this model is represented by the 5 possible bay dimensions measuring 2.40, 3.00, 3.30, 3.60 and 5.40 meters [16].

Based on the prefabrication strategy, three subtypes of the 770 model were identified: Pa, Pb and Pc, all differentiated by planimetry. Furthermore, the results show that the Pa subtype is most present in the West and Center of the country, while the Pb in the South and East. The Pc subtype is spread across the country, but less compared to the other two subtypes [17].

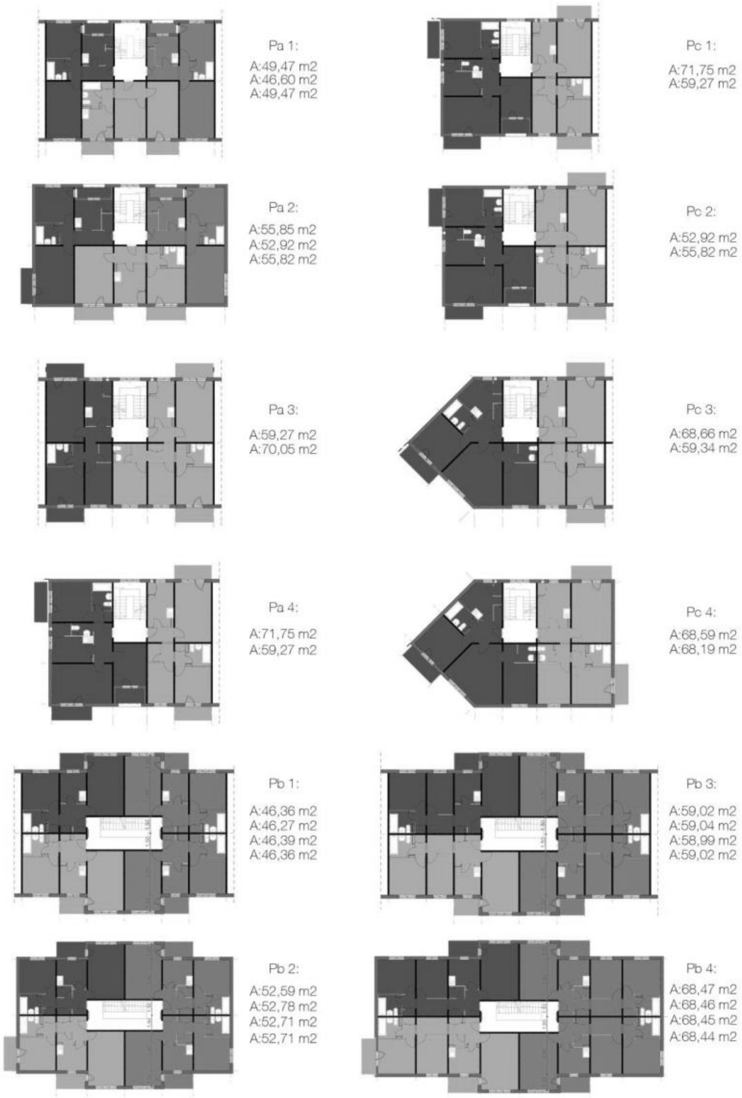

Figure 3.5. Subtypes of Model 770

The Pa typology has 5 bay openings, double orientated apartments, and a staircase with two flights of stairs. This typology has 4 subtypes: Pa1, Pa2, Pa3, Pa4. The first subtype, the Pa1, has two bay dimensions (3,30m and 3,00 m). This type has three apartments on each floor, each with just two small rooms. Two of the apartments are double orientated, and only the middle apartment has two balconies only on one side. The living areas of the apartments are 65,67sqm (ground floor apartment with 3 rooms), 49,50 sqm, and 46,60 sqm. The Pa blocks are placed N-S and the apartments have double orientation [16].

The Pb typology has 6 or 8 bay openings, but the dimensions are the same as the Pa (2.60, 3.00, 3.30, 3.60, 4.00, 5.40). This type of block has 4 apartments on the floor, all of them been single orientated. The staircase is made of a single flight of stairs, with no natural lighting [16].

The Pc typology has only 4 bay openings with the same dimensions as the other types of blocks (2.40, 3.00, 3.30, 3.60, 4.00, 5,40). These blocks are used for making the cvartal corners. On each floor they are only two double orientated apartments, but the plan isn't symmetrical like the Pa [16].

In Timisoara, the building apartments realised with prefabricated panels represent 40% of the entire built background. From all these, 1102 blocks were identified as the 770 model, out of which 473 are Pa (43%), 390 Pb and 239 Pc. However, only 27% of these blocks are in their original condition and just 4% of the buildings are thermic rehabilitated. Furthermore, the blocks on which the inhabitants intervened on the initial terrace with a two-slope roof dominate the background and represent 69% of the total number. In case of Timisoara, these interventions are most numerous in the Soarelui neighborhood, where 80% have this kind of intervention [17].

Each of the twelve subtypes represents one block of flats ranging from 10 to 20 apartments that are bound together to form a building row. Several connection types are defined, determining different positions of the blocks in the row [16].

The connections imply changes in the position of balconies and in few cases the modification of the floor plan (D and F, for Pc1 and Pc2 subtypes).

Thus, there are blocks that can function as individual buildings (CC 'end-end'), blocks that represent the end of a building row (MC, CM 'end-middle'), intermediary blocks (MM 'middle-middle') or corner continuation of the rows (LM, LC) [16].

By taking into account all possible types of connections that can be applied to the 12 subtypes, we get 88 different blocks of flats, all starting from the same 68 prefabricated building components [16].

Analysing the three subtypes (Pa, Pb and Pc), several problems have been identified, such as the staircase, the lack of elevators, or the apartments dimension, especially those with the loggia.

The apartment layout is also deficient according to present living standards, because they were conceived for people that spent a lot of time in the kitchen (cooking for the whole family) as a gathering place. The contemporary living has shifted towards a more dynamic lifestyle, where cooking has become a more sporadic activity.

The 770 block typologies main issues are: insufficient natural lighting, the lack of space and the low level of comfort especially in narrow bay configurations, emphasizing that these dwellings were realized for a population with a general low financial status, which owned small number of belongings. In the present, the number of belongings is continuously growing, and the old storage spaces are unable to support the new needs of the inhabitants.

Despite these, a study upon Timisoara's real estate market has proved the still existing attractiveness towards these collective dwellings. The result shows that the greatest apartment demands are situated on the intermediate floors (2nd and 3rd) from three main areas: Lipova, Soarelui and Giroc districts.

3.3.4 Structure assessment

The infrastructure is made of continuous foundations of plain concrete B75 (C4/5) for the current sections, under the walls at the joints, a superior concrete recipe B100 (C6/7.5). In the case of a large section, such as Pb3 or Pb4, the dimensions of the foundations are a maximum of 90x45 cm for the intermediate diaphragms, reaching a maximum of 110x60 cm for the perimeter diaphragms. They determine a spatial assembly with high rigidity in both directions [16].

The walls of the technical basement of 1.70 m, constituting the elevations, are made in -situ of concrete B150 (C8/10) with a thickness of 20 cm. It is recommended to make the lower and upper belts in the thickness of the basement walls, through additional reinforcement. The degree of reinforcement of the infrastructure is determined locally, depending on the conditions on each site.

Special attention was paid to the installation of the slab over the basement. Being the first prefabricated panels to be installed on the site, the correctness of the structural connections at this level determined a good cooperation between the building infrastructure and the superstructure of the prefabricated panels.

The suprastructure was almost entirely made of prefabricated elements, both load-bearing and non-loadbearing. On the construction site, only the monolithization works between the prefabs were carried out. All prefabs were made exclusively according to the standard project, obtaining an identical level of structural parameters in the case of all the built blocks. At the same time, all prefabs are limited to a weight of up to 5.1 t, in order to be handled using the MT110 crane.

The load-bearing outer walls are made of reinforced prefabricated concrete panels, with a total thickness of 30 cm. The 13 cm resistance layer, as well as the 6 cm protection layer, are made of reinforced concrete B250 (C16/20), having an 8 cm thermal insulation layer of BCA.

The load-bearing internal walls are 14 cm thick, being prefabricated from reinforced concrete B200 (C12/15) for seismic grades 6 and 7, respectively B250 (C16/20). They had semi-finished faces from the factory.

The slabs are made of reinforced concrete B250 (C16/20), 13 cm thick, and are also used over the technical basement.

The reinforcement of all precast concretes is made with 4 mm STNB concrete steel mesh (type S490) and longitudinal and vertical reinforcements from PC52 bars of 10 mm and 14 mm, respectively.

The other prefabricated elements were made up of non-load-bearing exterior panels, in the case of loggias (21 and 25 cm, with 8 cm BCA thermal insulation), attics and access hatches to the terrace, prefabricated landings and ramps, fully concrete bathroom cabins equipped and finished and ventilation chimneys.

The joints between the prefabs made on the site involved the welding of accessible reinforcement whiskers at the edge of the panels, using additional reinforcements and the monolithization of the joints with plain concrete B300 (C18/22.5) with fine aggregate. The thermal insulation of the joints, mainly for the purpose of correcting thermal bridges to condensation, is ensured by a 2.4 cm layer of polystyrene. The joints between the panels were insulated with C895 putty.

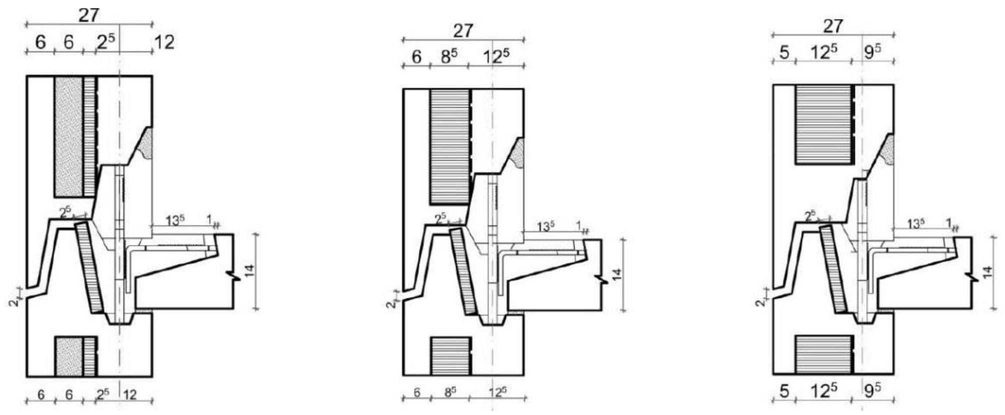

Figure 3.6. Connection details

3.3.5 Apartment characteristics

The types of apartments obtained within the project type 770-83 comply with the new provisions of the decree 216/1981 regarding "establishing the limit prices of houses that are built from state funds, the contract prices of privately owned houses and the sale prices of houses from the fund state housing" [2]. Along with the development of the means of selling apartments, it was resorted to the imposition of some minimum surfaces of the apartments, which must be covered by all standard projects.

Project 770-83 presents 3 major types of detached apartments (type 2, 3 and 4, defining the number of rooms), having several subvariants given different useful surfaces (I, II), but keeping the same functional configuration [16]. All benefit from a separation of the day and rest areas. Loggias or balconies are present in all cases. Bathrooms and sanitary groups do not have windows, being naturally ventilated, through eaves.

Type 2 is represented by two-room apartments, consisting of living room, bedroom, kitchen, bathroom and vestibule, with useful surfaces between 43.0 and 50.3 m2. The orientation of the living rooms is double, in the case of type a apartment and simple for type b apartments. Reaching a percentage of 44% of all the sections of the 770 projects, they remain specific to the Pa variants.

Type 3 are the apartments with 3 rooms, having a bedroom and an additional service bathroom and surfaces between 55.0 and 64.2 m2. The orientation of the rooms is double. Type 3 composes all the Pc sections, being found in 51% of all sections of the 770 projects.

Although they have the largest usable areas (between 67.7 and 77.9 m2), type 4 apartments are specific to the 8-bay sections Pb3 and Pb4 and sections Pa3 and Pa4 (only 5% of all possible apartments). In addition to the living room, kitchen and vestibule, the apartments benefit from 3 more bedrooms, an access hall and 2 full bathrooms. The living rooms are all simply oriented.

The usable area per capita at the level of the entire project 770, calculated as a weighted average, indicates the value of 21.76 m2/person.

Type	Building	Freq. [%]	People	Liveable area [sqm]	Surface area [sqm]	[sqm / pers.]
2.1	Pb1	12%	2	26.7	44.8	22.38
2.1.a	Pa1	5%	2	25.7	43.0	21.5
2.1.b	Pa1	2%	2	25.2	43.0	21.5
2.2	Pb2	16%	2	30.8	51.7	25.86
2.2.a	Pa2	5%	2	29.1	49.3	24.65
2.2.b	Pa2	2%	2	30.2	50.3	25.15
Type 2 Total		**44%**	**2**	**28.5**	**47.9**	**24.96**
3.1	Pb3	21%	3	34.8	55.0	18.33
3.2	Pb4	26%	3	40.4	64.7	21.57
3.2.a	Pc2,Pc4	4%	3	41.4	64.2	21.40
Type 3 Total		**51%**	**3**	**38.1**	**60.6**	**20.21**
4.1	Pa3	2%	4	43.8	67.7	16.91
4.2	Pa4	2%	4	49.3	77.9	19.48
Type 4 Total		**5%**	**4**	**46.5**	**72.8**	**18.19**
770 Total		**100%**				**21.76**

Table 3.1. Apartment units in model 770

3.4. The quality of life

3.4.1 National statistics

An assessment of the existing built stock in Europe shows the predominance of buildings built after the Second World War, in most European states. Romania is in the leading positions, with 45% of the existing built stock built in the period 1961-1980. Approximately 75% of them are residential buildings [18].

The TABULA report [19] made on the basis of data provided by the National Institute of Statistics in Romania, highlights the existence of three types of residential buildings: single-family, multi-family and collective housing blocks. Although they represent only 1.8% of all residential buildings, the blocks housed more than 39% of the total number of apartments in Romania, at the time of the 1992 Census [20]

A comparative study at the level of Timiş County using data from the last 3 censuses (1992, 2002 and 2011) [21] reveals the existence of 131,270 dwellings, with an average living area of 41.48 m2/dwelling and 17.58 m2/ person. At the same time, the ratio between collective and individual housing is 71.3% to only 28.7%. In the case of the first ones, over 87% are blocks from large prefabricated panels.

Among all the built type projects, among the most widespread are the 770 model, taken as a case study in this thesis for a detailed understanding of the aspects of this fragment of the existing built fund.

The popularity of the 770 project throughout the country is demonstrated by the typological identification study carried out during the Solar Decathlon Europe 2014 competition, by the UPTIM team, the researcher being a member of it [17]. Using a series of images provided by Google Maps, a survey of the existing built stock in the apartment blocks of several cities in Romania with the aim of determining the spread of the 770 model. We resorted to the identification and marking of the major sections Pa, Pb and Pc starting from the characteristics of the parts and their dimensions.

3.4.2 Urban space

Apparently, these prefabricated houses seem to fulfil the desired "living machines". However, as will be seen below, the abandonment of the "excess from design and construction" was achieved at the expense of the comfort and quality of private spaces, as well as of all public spaces of social interaction, representing the very essence of the vision of the modernists and of the Russian avant-gardes.

Even if the standard of living offered by these buildings at the time of their construction was superior to the majority of rural households (bathroom in the house, constant running water, etc.), with the passage of time they could no longer satisfy contemporary living conditions.

From the very beginning, what was an advantage from the point of view of the efficiency of the constructive system made of large prefabricated panels, used in the construction of working-class neighbourhoods (repeatability, mobility and speed of execution), ends up being relatively weak points today, when it is taken into account consider the quality of the urban space [17]:

- the repetitive use of the same type projects, throughout the country, regardless of the context in which they were built, creates a sense of confusion due to the lack of visual identity;
- the rigidity of the honeycomb cellular structure in allowing subsequent adaptations of the apartments to people's needs often generates small and overcrowded living spaces;
- the spaces between the blocks, initially defined as green areas, were gradually occupied by constructions of garages or cars parked or misused by some tenants, all being due to a poor management of the public space;
- the degradation over time of the prefabricated buildings, as well as the repair/refresh interventions at the level of the facades of the non-existent blocks up to the thermal rehabilitations have generated in people's perception the image of "grey neighbourhoods".

A comprehensive study, carried out in the light of the phenomenological and anthropological theories of Christopher Alexander [22], provides a complete analysis of living in the blocks of the Soarelui neighborhood and identifies the need for people to compensate for the small size of the apartments with a transposition of their activity in the public space (extensions of apartments, transformation of garages into additional rooms, occupation of free space with private gardens).

During the years of industrial development of the country (60'-85'), the collective housing districts were based on the micro district theory, hierarchical structural units, in which residential buildings were organized according to the principles of functional interconditionality with the socio-cultural buildings, maintaining an appropriate proportion between the built space and the arranged public space.

The neighbourhood school represented an element of the dimensioning of the micro district, around which the whole neighbourhood was organized. At that time, the ability of the residential complexes program to contribute to the economic development of the country, by raising the standard of living of the people, was positively appreciated. However, the micro district theory proved inadequate in the economic context of the 80s, due to the new urban densification policies that transformed the urban spaces of the neighbourhoods into valid sites for new blocks [2].

Looking at the urban development of Timisoara through the prism of the studies carried out within the Faculty of Architecture [4], 3 stages in the construction of residential neighbourhoods, characterized by different urban densities, can be found. If between the years 1962-75 and 1982-89 a densification of up to 70-80 units/ha was achieved, at the same time the socio-cultural infrastructure and apartments with large living areas were created, in the period 1975-82 the density level reached 300 units/ha, with small apartments.

Figure 3.7. Residential district development and project type distribution stages in Timisoara: 1962-1975, 1975-1982, 1982-1989

At the same time, the construction of social spaces is abandoned. The non-existence of neighbourhood cores and complementary functions, in many cases in Romania, foreseen in the plans of the micro-districts, but not yet built, prevents the achievement of community cohesion between the residents of the neighbourhoods. In extreme cases, these neighbourhoods turn into ghettos, due to perceived poor living conditions.

Although in the 90s there were initiatives and programs aimed at improving the quality of the urban space in the neighbourhoods, no significant changes were identified. Even the thermal rehabilitation projects do not seem to bring anything extra in favour of public spaces, being focused only on energy consumption aspects. Moreover, the achievement, in most cases of the rehabilitation of attics, of additional living spaces, generated an increase in density by adding a new level, increasing the pressure on the common spaces and the minimal infrastructure used by the inhabitants.

The different ways in which the attics were made (financed directly by tenants' associations, without expertise, financed by third parties - real estate developers or subsidized), the refusal of some tenants to allow the thermal rehabilitation works, the lack of quality of the works carried out or the very lack of recommendations regarding the aesthetic criteria of the works (colours, textures, proportions, materials used) generated exaggerated solutions, which do not contribute to the improvement of the urban aspect of residential neighbourhoods

3.4.3 Individual touches

In many cases, the lack of interventions on a global scale to improve the standard of living in the residential neighbourhoods has led the residents to resort to a series of modifications made individually and independently of the other roommates, often located at the limit of the legal provisions.

Figure 3.8. Personal touches and interventions throughout the neighbourhoods

Continuing the analysis of the Soarelui neighbourhood in Timișoara, made up mainly of residential buildings made of large prefabricated reinforced concrete panels and built according to project type 770, a series of current changes were documented, briefly detailed below [17]:

- enlarging the gaps on the ground floors and creating new accesses, allowing functional changes of residential apartments, commercial or service spaces;
- fenced private gardens: individual layouts in the spaces between blocks and abusive appropriations of public space (most of them penetrate far into the public domain, exceeding the 90 cm strip around the block considered indivisible common property of the tenant association);
- specific works at the level of the facade: many unauthorized, such as the specific thermal insulation of the external walls next to some apartments, generating the hygrothermal imbalance of the envelope of the entire building, or the closing of balconies and the installation of air conditioning systems in dissonance with the appearance of the facade;
- works to repair the waterproofing or to add coverings on the slope (tiles, sheets) with the plugging of the existing ventilation shafts;
- cantilever extensions of the apartments, in order to increase the usable area of the dwellings

The impact of the high rate of owners, residents of the apartments, led to a whole series of changes in the interior configuration of the homes, often unauthorized. The consequence of these unauthorized works is the lack of a clear record of their number and impact on the entire building, many of them being carried out arbitrarily and in some cases affecting the structural elements of the building.

As part of the UPTIM team's activity in the Solar Decathlon Europe 2014 competition, an attempt was made to probe these changes, by visiting private homes and interviewing the owners. However, the small number of cases in which we were allowed access to the interior makes the results obtained irrelevant.

However, several types of interventions that appeared periodically during the 70's, 90's and 2000s will be presented, explained through the prism of lifestyle changes between these eras. The evolution of the first generations of inhabitants is followed, along with the coexistence with those that appeared later. The following conclusions are intuitive and justified from several visits made in residential apartments in 2013.

- **The years 75'-85'. Generation 1. The first tenants.** most of them coming from the countryside, enjoy better conditions than country life. Centralized heating, running water and hot water replace a substantial effort that had to be made in the countryside to satisfy a minimum level of comfort. Gardens appear in front of the block, reminiscent of rural occupations in the urban environment. Life in the city is easy.
- **The years 85'-90'. Generation 1 (+0)**. The appearance of the children will bring a new member who comes to take care of the little ones before the nursery/kindergarten (or during it): the grandparents (in turn from the countryside who periodically stay with the children). In other cases, the children are taken to their grandparents to be raised, separating the family until the age at which schooling begins. As interior changes, only redesign is frequent. The child's crib appears in the living room. Additional storage spaces are arranged throughout the house (cupboards). The balcony turns into a workshop, storage space and plant area. At the level of installations, towards the end of the period, electric boilers are sometimes installed.
- **The 90s-2000s. Generation 1+2**. Increasing the share of owners. The massive sale of apartments, after the revolution, leads to the extremely high percentage of owners. Pandora's box is opened regarding the

demolition of non-bearing walls and interventions on structural elements. The ground floor apartments are being expanded to accommodate the new neighbourhood businesses. The child starts school. Thus, the living room becomes the child's room, acquiring a new function. The child's office appears either in the living room or on the newly closed balconies, where, at the same time, toys and books are stored. The corner sofa is extremely popular as a piece of furniture. PCs appear and washing machines are purchased. The kitchen becomes open-space - a new living space is defined, as a result of Hollywood culture - the houses shown in movies with large kitchens. Apartment heating plants are starting to enter the market.

- **The years 2000-2015. Generation 2 (+3**). Children at maturity start their own families, either in new houses and in new residential complexes, or in the same apartments. In some cases, the first generations, having reached retirement age, return to the countryside or move to houses in suburban areas. As for the arrangement of the apartment, advanced technologies are replacing old equipment - PCs with laptops and cathode-ray TVs with LED TVs, stoves are replaced by electric stoves. There is an increase in electricity consumption [17]. The issue of energy consumption and thermal rehabilitation is under discussion. The apartment's own central heating systems are currently being installed. Consumerism determines the increase in the volume of storage spaces. Wardrobes with sliding doors, fitted between the walls, are in fashion, making use of the enclosed space along its entire height. Otherwise, the reorganization of spaces in apartments is done with minimal furniture.

Comparing the changes regarding the functional use of the available space between these apartments in the 70s and 90s, with current newly built apartments in Timisoara and with similar examples from Western Europe, the 2000s notes variations between the different functions, due to changed lifestyles.

The rigid frame of the blocks of large panels generates considerably smaller spaces of the apartments of the 70s or 90s compared to the contemporary standards of use, shown by the other examples. It is worth noting the importance that the bathroom and the terrace/balcony acquire at the expense of the other spaces. The space for the kitchen is shrinking, a sign of reduced importance given to cooking.

Erroneous estimates are observed, regulated by the laws specific to housing [23] the surfaces for certain activities associated with housing, in the conditions of an overcrowding of apartments, being oversized compared to foreign examples, in detriment of the living areas.

3.5. The neighbourhood in a deeper perspective

Urban living is treated at length by P. Derer, A.M. Zahariade, M. Opris or T.O. Georghiu [6][24][25][26]. The present work seeks to treat, however, a specific problem characteristic of Romanian society, starting from an approach systemic, integral, and integrated, namely, that of the quality of life in the block districts. Buildings Performance Institute Europe (BPIE) [14] European statistics show that the spaces outside the collective housing blocks are almost entirely occupied with parking spaces or garages. This means that green spaces and places of play are missing. Starting from Gerrit Scwalbach's "Basic Urban Analysis" [27] the city, in our case, the neighbourhood of Soarelui, is defined in three different ways of perception: of the visible, of the invisible and another rational.

These modes of perception do nothing but increase the palette of knowledge and deepen the study. The resulting image is one based on careful, precise observations with a unique character specific to the studied area. Around these analyses and a contextual map that illustrates in a more way takes shape or less personal neighbourhood experience. Activities, the connection with the outside, the centres of interest, the places of collective memory, all show in the way residents perceive the neighbourhood, but also in the way they act.

3.5.1 The visible city

The visible city is like an urban x-ray showing human activity concentrated in active nuclei. This x-ray is contoured around dominants that may differ in function: the school, the dispensary, the church, the park, the square or the mundane street corner. Regarding the Soarelui district, visible city analysis helps to determine the location of the dominants of the neighbourhood. Secondary school no. 30, the square, the park, and the Customs building. Apart from these, the analysis showed that a corner of the square between blocks is also an important meeting point for residents. The image result is particularly reflected in the attitude of the inhabitants towards the public place and its importance. Even a mundane block entry changes its function.

In terms of architectural style, the predominant type is 770 blocks, with subtypes Pa, Pb, and PC, all built between 1982 and 1985. Their facades were designed from a combination of materials: decorative brick applied to a wide section of wall or arranged in frames, along with simple painted walls and with metal parapet on balconies (the oldest version) or with parapet made of concrete, with decorative plaster with sand and gravel, or with glass panels. The area presents a series of degradations at the neighbourhood level but also at individual buildings. The chaotic city and the complete non-realisation of projects led to problems that include abandoned spaces, unfinished or unfinished buildings, rust on the frame balconies, black spots caused by thermal bridges formed between the joints between prefabricated panels, or large areas with missing decorative bricks. The school area has in the vicinity most functions as well as most shops can be found here. Traffic is heavy on the main arteries that define the area, while within the neighbourhood the roads are very narrow and poorly lit. Parking is available in the inner courtyards of the block squares, which suffocates the existing green space, and on one side of the roads. Parking vehicles also appear in the grass of the premises or on alleys.

The most "lively" areas, where people usually gather, are on the street, in front of the school, where most of the shops are, in the parking lot in the area, or in the nearby park. The neighbourhood market, on the other hand, is constantly empty, with only a few traders choosing to sell their products here. The market problem is the location, because recently she was moved to an inner courtyard of a square, being isolated from the main route. Children play in the park, on the street, in front of the school and in the courtyards of the blocks, near the garages, in the places where the mothers can supervise them.

3.5.2 The invisible city

The invisible city is determined by the multitude of spaces with a ritual role that is constantly taking place since the population of the neighbourhood. These places are important for collective consciousness, as they fulfil the basic functions of the community and create personal characters. The quality of space is extremely important in defining the invisible city.

Positive sites were identified as "personal spaces". These are green areas, surrounded by fences, where residents have mounted swings and other improvisations for play. They denote the existence of a mentality remaining from the rural life of the great majority of the inhabitants from which they come. How the space between the blocks is a common one and maintenance should be done by community, often they are taken care of by the tenants on the ground floor, who, by they also made extensions with a separate entrance directly into the apartments
In addition to these positive places, there are also others with potential (for example: the square, the inner courtyards of the blocks with the parking spaces) and, as they exist, also negative places (for example, abandoned areas). There are also spaces residual, such as those between garages, but those too are transformed, being places only good for old games.

Figure 3.9. Personal space

Residents focus on adapting their private space on their own and the non-existent urban life, which caused the transformation of the old uniform space in veritable vertical villages. Moreover, the stairs are another place where it is very easy to see the need for more space for tenants.

Hidden from people outside the block, the staircase is actually a space personalised, in which there are flowerpots, dried bouquets, pictures or icons religious, placed in front of each apartment door.

3.5.3 The rational city

The description of a rational city starts from the infrastructure, defining accessibility in the studied area, but also its connections with the environment that surrounds it.

Therefore, there are three public transport routes in the neighbourhood with a total number of five buses stations, of which only one is also a transfer station. Since all these routes are located on Bulevardul Sudului, they are an advantage for the west part of the neighbourhood. The access to the Soarelui neighbourhood is through one of the two main perimeter roads (Bulevardul Sudului or Bulevardul Mareșal Constantin presence). From there, the inner streets leading to the blocks can be accessed and they are very narrow.

3.5.4 Apartment extensions

Access to the square of the blocks can be done either through the space between the buildings, according to their configuration or through the free space resulting from constructions abandoned from the site. When it comes to the block itself, tenants on the ground floor have expanded rooms or kitchens. From the entire studied area, it follows that 28% of the residents from the ground floor developed extensions. In the case of the Pa subtype of blocks, only 17.5% of them have this type of intervention. The study recorded 66% extensions towards the square inside, while towards the street the expansions are up to 34%.

Figure 3.10. Apartment extensions in the district

3.5.5 Building and apartment orientation

There are two types of block orientation: N-S and E-W. Due to the fact that blocks PA1 have apartments which are double oriented with rooms facing both N and S, the living space in each apartment is positioned on one side (either toward N or to the S), while the night area is on the opposite side. From Figure 3.13 we can observe the actual distribution of the blocks, relative to the two major axes: the axis N-S and E-W. The resulting ratio of 60% orientated N-S and 40% E-W comes to strengthen the idea that the distribution of buildings on the site was not done according to the requirements architectural orientation of living spaces to obtain natural lighting correct, but rather, from a spatial consideration influenced by access conditions, by the planimetry of the plots or the distribution of the sortotypes.

3.5.6 Landscape assessment

Although the reminiscence of rural life is still present in psychology residents, we have analysed the landscape quality of urban spaces. This analysis led to the creation of possible solutions for further improvement of the existing premises. After visiting the housing blocks and analysing the surrounding green spaces,

I was able to draw a set of conclusions. They were taken into account when formulating them how these spaces are used and maintained by the local community and also the general aesthetics of the area. Cardinal points, the whole project of traffic, pedestrian and car, shaded spaces, and sources of noise pollution were all considered for this study.

In the second stage, the flora, species and distribution of plants in the green spaces between the blocks. The importance was also noted that the locals attribute to these plants. The conclusion of the local green cadastre is the fact that every square metre of land is currently exploited. Also, the changes that could be made to improve the site resulted (explanations and details are presented below). One solution to free up the land would be to move the current parking spaces from the surface to the underground. Through this, the site can undergo a series of positive changes, such as:

- The possibility that the land between the blocks (which is currently used for parking) is used as a green space by the riverside population;
- improving the general quality of life from an aesthetic, ecological, and social point of view;
- increasing the number of parking spaces;
- increasing the area of green spaces.

The possibilities of improving the transitional spaces, of the alleys between the buildings towards the socialising areas and solutions for arrangement were proposed. Solutions for the collection and accumulation of water, as well as the contribution of rainwater to the maintenance of green spaces.

The local flora will be maintained and enriched by adding several plant species indigenous, which are resistant and do not require demanding maintenance. I propose that the roofs of the blocks be transformed into designed green spaces combining several strategies such as the use of photovoltaic panels, promoting urban agriculture and designing spaces for socialisation and recreation on the roofs. They will be located in such a way that they co-exist and do not affect each other. A more detailed view of this strategy involves:

- how the spaces mentioned above can be used in unfavourable weather conditions;
- how open spaces with vegetation can be combined with urban agriculture;

- how can plants intended for consumption be combined with ornamental ones for creating the most pleasant atmosphere?

3.6. Example of good practice. Project RETROFIX by UpTIM

Most of the common spaces in the neighbourhoods are occupied by cars, which denies the development of community facilities, while, at the same time, the unused terraced roofs of the blocks of flats remain unexploited. The project implies add-on structures, which house the community spaces on top of the blocks. Connections between these generate a public rooftop promenade, a new and attractive city skyline! A reconfigured staircase will provide barrier-free access, both to the inhabitants and potential visitors [17].

The standard typology of the existing apartments does not satisfy the needs of the Romanian contemporary society. At the same time, the vast population living in these buildings determined us to define the interior configuration of the apartments based on the specific lifestyles of three end user profiles: tenants, single-child families and retired couples. Additional space is made possible through independent plug-in extensions that each individual can buy as an end product [17][2][8].

Figure 3.11. Aerial rendering of RETROFIX project

A passive house standard retrofitting and an improvement of the daylight conditions lead to a consistent energy reduction. Furthermore, solar and other renewable energy systems cover part of the remaining energy yield [17].

The heating was improved by reusing the District Heating System along with solar heating for domestic water. Radiant floors ensure the comfort conditions inside the apartments as well as a reduction in fuel consumption and operating price [17].

Hybrid ventilation system that mechanically provides fresh air is also responsible for free cooling during the intermediate seasons by activating the thermal inertia of the structural concrete walls. Additionally, passive adiabatic cooling provides a new feature the current blocks of flats do not have. Furthermore, reusing and treating the rainwater as domestic water, reduces the water consumption by 20% [17].

The top extension roofs are a support for hybrid thermal and photovoltaic panels. A distributed photovoltaic powerplant generates electrical energy, covering the common facilities energy yield, while the surplus is being introduced into the local electricity grid [17].

Because the main idea is based on "the kit of parts" quality, the types and sizes of the windows vary depending on the kit characteristics. The type of extension defines the type of window, which provides enough light for the interior spaces. The project aims to improve residents' comfort by controlling the quality of the air in interior spaces. For example, there will be movement in each apartment as well as heat storage in walls. In addition, the microclimate around the buildings will be improved through bioclimatic design of the exterior spaces and of the build environment. The extensions work in different ways depending on the season. Having mobile openings, it can be quickly transformed from a closed green house to an interior alcove, a loggia or even a completely open balcony [17].

Figure 3.12. Axonometric view of RETROFIX project

The cubicles vary also due to different orientations the existing block might have. Situated on the southern façade, it becomes a passive solar system and a support for the active technologies that can also drop shades. The eastern and western extensions have vertical shading systems, while a northern cubicle becomes a buffer zone preventing heat loss [17].

The retro-house (the top extension) performs as the social hub of the project. Based on the "cloud village" concept, it generates a network of gathering points for the social environment. With three sides entirely out of glass, the house offers panoramic views towards the surrounding neighbourhood and a better interaction with the outside environment [17].

To prevent heat loss and to ensure complete airtightness highly efficient glass panels was used consisting of three layers facing the south and two layers against east and west with hardwood framework and metal joints [17].

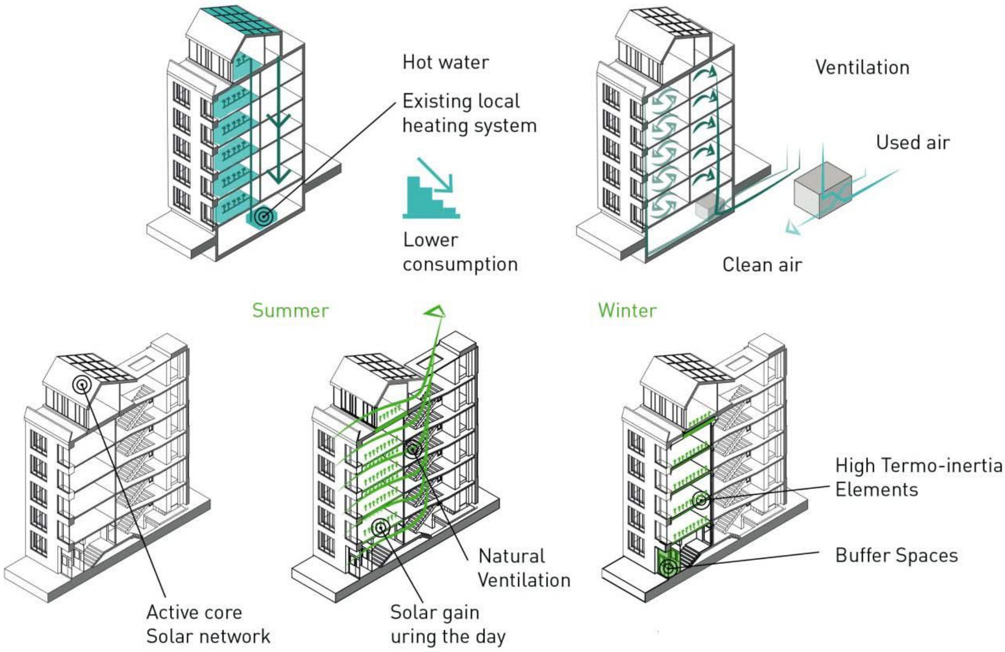

Figure 3.13. RETROFIX operation system diagrams

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4. TEST MODEL AND APPLIED RESULTS

4.1. General Project Description

The building sector focuses on surpassing challenges related to energy efficiency and lowering or reduction of greenhouse gas emissions; therefore, it needs to improve building performance to decrease the impact on the environment[51]. Buildings with reduced long-term operating cost, environmentally friendly and moderate construction costs can be reached only by multi-object optimisation and cross-disciplinary analysis, embodying a holistic approach. According to the principles of a holistic sustainable design approach, the research model presents a sustainable experimental modular laboratory that involves various strategies concerning sustainable building, such as resource, cost and material efficiency, health and well-being, environmentally conscious design, life cycle design, modular design, reusable/recyclable element, environmentally friendly demolition method, safety design, consideration of life cycle cost, materials cost and waste disposal cost [52]. In addition to installing renewable energy sources and the conservation of energy, the holistic construction of the laboratory also included an integrated design with consideration towards technology, operation, and maintenance, which involved implementing a monitored energy management system. The system provides an accurate overview of performance during operational phase.

Figure 4.1. CIA_CLIM testing model

The main objective of the project is the energy efficiency of new and existing buildings. The project has four components with two main research directions: (1) intelligent facade use, with low heat transfer that actively contributes to increasing indoor comfort, with passive control passive energy through the use of solar energy; (2) intelligent energy efficiency through automated systems and energy collectors. The resulting system, the intelligent building, is designed to minimise the energy required for maintenance.

The first project aims to determine the mechanical properties of cellular materials used as thermal insulation in smart facades, through mechanical tests of compression, bending, and toughness of cellular materials. The objectives pursued within the project are as follows:

- Determination of the mechanical properties of cellular materials (polystyrene, polyurethane foams, etc.) used as insulation of smart facades, through mechanical compression tests, bending, etc.
- Determination of the fracture toughness of cellular materials used in smart facades.
- The study of the behaviour of cellular materials under the action of dynamic stresses (shock behaviour, respectively to fatigue).
- Determining the response to mechanical stress of sandwich structures with a material core cell-phone. Construction of failure diagrams of sandwich-type structures.
- Experimental identification of the failure mechanisms of cellular materials and structures sandwich using the digital image correlation method and the thermography method.
- Determination of micromechanical material models to predict the mechanical properties of cellular materials.
- Calibration of material models for the numerical simulation of the behaviour of typical structures sandwich.

The second project aims to obtain, characterise, and test some materials with superior properties used in smart facades such as: heat insulating materials (glass cellular obtained from waste glass) and support for layers of materials with special properties (composite materials with natural and synthetic fibres with high mechanical resistance, flame retardant character, a good thermal insulation, resistance to freeze/thaw cycles, and exposure to solar radiation), materials with properties photocatalytic used for the degradation of pollutant compounds from the ambient air, and absorbent materials reduced/reflexion of UV-VIS-IR radiation.

The third project has as its main objective the theoretical and experimental study, of the implementation of the distribution of electricity in a smart direct current grid, with the integration of some source, with completion on an experimental platform. The objectives pursued in the framework project are as follows:

- Study on the requirements, performances, and technical particularities necessary for implementation of direct current electricity distribution for a neighbourhood microgrid.
- Realization of sub-system models of generation, conversion, storage and micro-grid tasks considered.
- Design and building a neighbourhood-type microgrid model with current energy distribution continuously.

- Implementation and testing of an experimental neighbourhood-type microgrid model with direct current energy distribution.

As a member of the design team for the fourth project this part accumulates brings the prior tree together through a mobile modular laboratory named EXPERIMENTARIUM. The project will carry out a global study of the influence of facades and energy input on the interior comfort in the building, through the analysis of different facade systems and, respectively, the realisation of a smart-grid type system. The results focus on the optimization of indoor comfort conditions: temperature, humidity, indoor air quality as well as the efficiency of energy consumption. The smart grid system will achieve the efficiency of internal electricity users (ventilation, cooling, etc.) and storage energy.

4.2. Design Phases

The development of the project has been carried out in four design phases[53]. The main objectives of the first phase are:

- The architectural optimization of the EXPERIMENTARIUM mobile modular laboratory, through the ideal orientation to the cardinal points and finding the optimal roof pitches to maximize the energy input given by the photovoltaic panels;
- design of the resistance structure for the EXPERIMENTARIUM mobile modular laboratory. The structural solution was chosen in frames made of elements made of light cold-formed profiles. The solution presents multiple advantages, including rapid and easy assembly, without the need for heavy machinery. In addition, the system transmits reduced loads to the foundations and the ground;
- The design of the infrastructure was carried out through innovative foundation systems, on prefabricated foundations in the shape of a pyramid trunk, inserted into the soil by vibropressing. Within the stage, they were carried out and soil research through geotechnical studies;
- studies on facade systems. They were considered solar absorbing systems, on which they performed optimization studies based on finite element analyses for integration into the experimental model; numerical models to optimise the existing experimental prototype of the solar facade (collector solar) to be validated with the existing prototype. An elementary model was created for analysis of air flow through the collector perforations. The model made allows the subsequent study to carry out the parametric studies necessary to optimise the perforated solar collector, for integration later in the experimental model;
- the integration of measurement sensors for temperatures, humidity, and CO2 concentration, as part component of the monitoring system (SCADA) and the development of related software elements for data acquisition, including energy conversion;
- testing the monitoring system;

4.2.1 The first design phase

In stage I/2018, the light demountable metal structure project was carried out (experimental laboratory) which was located in the courtyard of the Research

Institute for Renewable Energies. Laboratory experimental, with plan dimensions of 5x5m and height regime P+1E, is designed in the form of a compact volume. The structure was made of cold-formed thin-walled steel profiles. For the creation of the prefabricated foundation foundations, the system with quick assembly was chosen. A sun study has been carried out to determine the best placement of the module within the Institute of Renewable Energies courtyard. Three possible locations have been identified which are presented below. Out of the three, position 1 has been chosen as being ideal.

Figure 4.2. Possible locations resulted in the sun study

Figure 4.3. Simulations with the module in position1

In this phase, the types of facades existing on the economic market were analysed, for which they were carried out thermal transfer analyses, including phase change analyses, attenuation calculation amplitudes and temperature amplitude ratio. The study was completed by calculating the balance energy, calculated for the model building, considering the various facades analysed [54]. The systems are presented below in Table 4.1 in function of their stratification and thicknesses, the resultant thermal resistance (R) or the U value (R = 1 / U)[6].

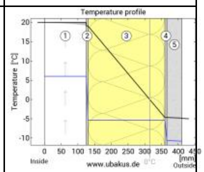
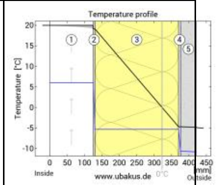
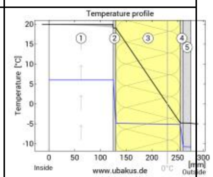
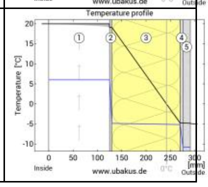
Façade system	Layer configuration (inside – outside)	d [mm]	R [m²K/W]	U [W/(m²K)]	
Mineral wool 1 (MW1)	1. Steel profiles C120 – support	120	5.943	0.168	
	2. Inner Hot-dip galvanized steel sheet	0.6			
	3. Mineral wool	232			
	4. Polyurethane adhesive	-			
	5. Outer Hot-dip galvanized steel sheet	0.6			
Mineral wool 2 (MW2)	1. Steel profiles C120 – support		6.193	0.161	
	2. Internal steel sheet - G, g, s, v, v2, m2 - profile (galvanized and painted)	0.5			
	3. Mineral wool	240			
	4. External steel sheet - G (smooth) - profile (galvanized and painted)	0.7			
PIR insulation 1 (PIR1)	1. Steel profiles C120 – support	120	5.850	0.171	
	2. Profile of the inner ribbed steel sheet profile	0.5			
	3. PIR insulation	125			
	4. Outer ribbed steel sheet profile	0.6			
PIR insulation 2 (PIR2)	1. Steel profiles C120 – support		6.001	0.167	
	2. Inner precoated steel sheet	0.5			
	3. PIR insulation	140			
	4. Outer precoated steel sheet	0.6			

Table 4.1. Façade layer configurations.

All proposed systems are sandwich panels, easily adapted to a steel structure made of thin-walled cold-formed structural members. The choice of such integrated systems contributes to modern buildings based on sustainable characteristics both in the fabrication and in End-Of Life (EOL) stages:

- system modularity;
- adaptability to different building systems;
- Prefabrication of both structure and envelope systems;
- rapid building erection;
- ease of dismantling and selection of wastes in EOL;
- reuse and recycling of materials.

Thus, the system allows for the total dismantling of original components with different EOL scenarios: while structural steel elements could be easily recycled and even reused, the final scenario for envelope systems is more complex, as steel sheeting and. As a consequence, the further study is focused on the performance analysis of heat transfer and the environmental impact of the envelope systems.

The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity of the elements. Other factors involved in the energy balance proved to be important, such as:

- phase shift: the time after which the peak afternoon temperature reaches the interior side of the component;
- amplitude attenuation: the attenuation of the temperature wave when passing through the façade system: a value of 10 implies that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26°C;
- temperature amplitude ratio (TAV): the reciprocal of the amplitude attenuation.

As mentioned above the building model used for simulations is a base unit of 5x5m, representing a two-floor open space, with a pitched roof on the second floor that benefits and uses the sun for both natural light and PV panels. The south façade is a glass curtain that offers lightning on the first floor but is shaded by external photovoltaic lamellae. The angle and the orientation of the pitched tip allow the disposition of the solar PV panels on the roof.

Figure 4.4. Building model used for simulation – 3D view

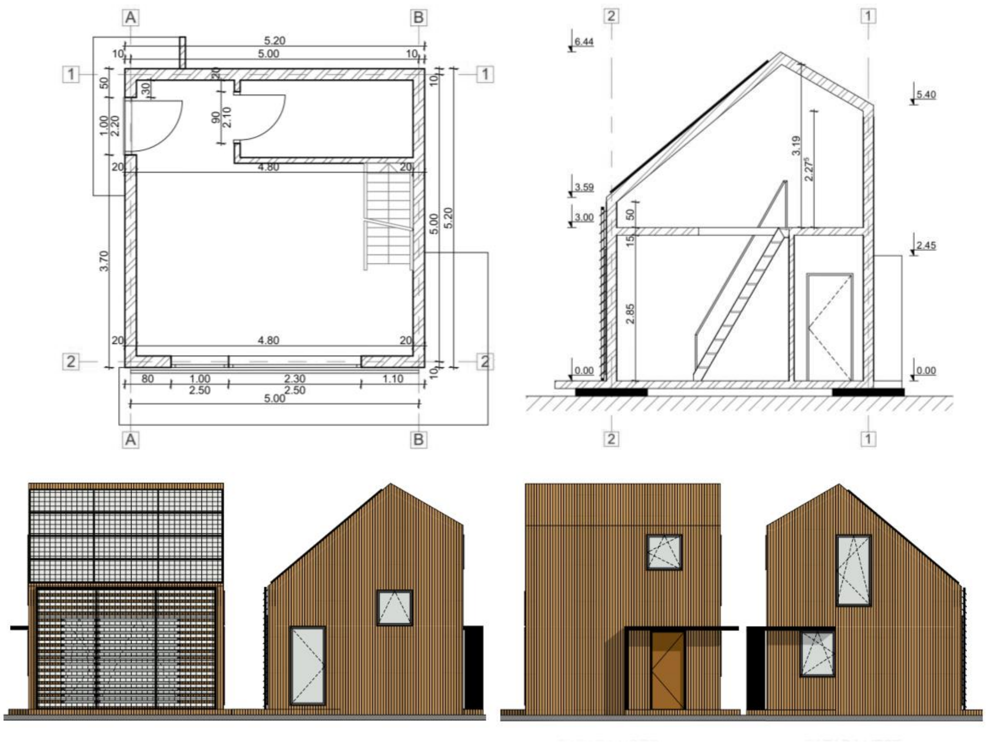


Figure 4.5. Building model used for simulation – **Top:** plan and cross-section, **Bottom:** test model facades

At the time of evaluation, the thermal analysis was carried out using an online U-value calculator (Ubakus) [55] and the Graphisoft Archicad 21 energy evaluator add-on [56]. For the simulations the following data have been considered and applied on a base model located in the city of Timisoara, Romania:

- Inside temperature: 20 °C and 40% humidity;
- Outside temperature -5°C and 60% humidity;
- Gross Floor Area: 30.37 m²;
- Treated Floor Area: 24.60 m²;
- External Envelope Area: 120.93 m²;
- Ventilated Volume: 124.44 m³;
- Glazing Ratio: 6%.

In the case of MW1 - Fig. 4.6, the simulation proves that the thermal protection is U=0,168 W/m²K. Furthermore, the heat storage capacity of the element is 47 kJ/ m²K with the thermal capacity of the inner layers at 19,7 kJ/ m²K and the overall thermal resistance of 5,943 m²K/W. This value is more than three times greater than the current values according to current Romanian norms. Phase shift is achieved after 6,7 hours with an amplitude attenuation of 7,9 and TAV 0,126 [6].

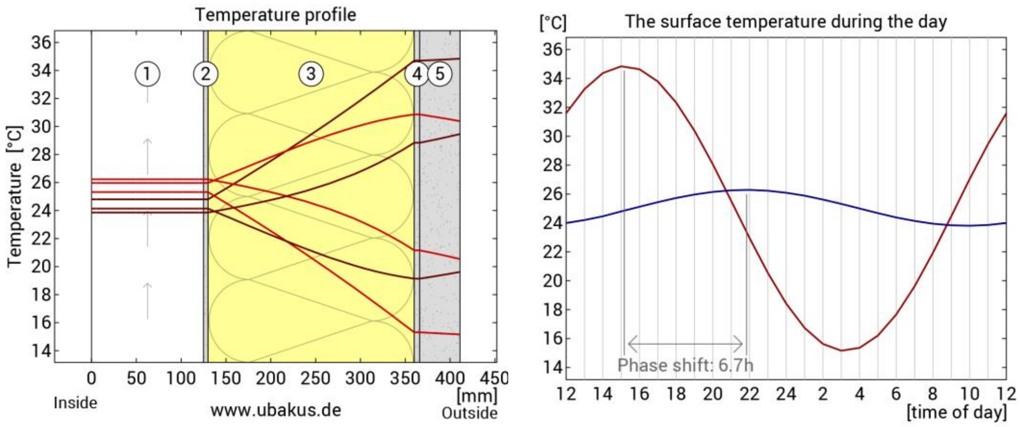


Figure 4.6. Component temperature profile (dark - temperature at 3pm, 11am and 7am; light - temperature at 7pm, 11pm and 3am). Component phase shift *(red-outside temperature; blue – inside temperature)*

The second analysed system MW2 (Fig. 4.7) proves after the simulation a thermal protection U=0,161 W/m²K. The element heat storage capacity is 47 kJ/ m²K with the thermal capacity at 19,8 kJ/ m²K and the overall thermal resistance is 6,193 m²K/W. The phase change is achieved after 6,7 hours with an amplitude attenuation of 8,3 and a TAV of 0,12 [6].

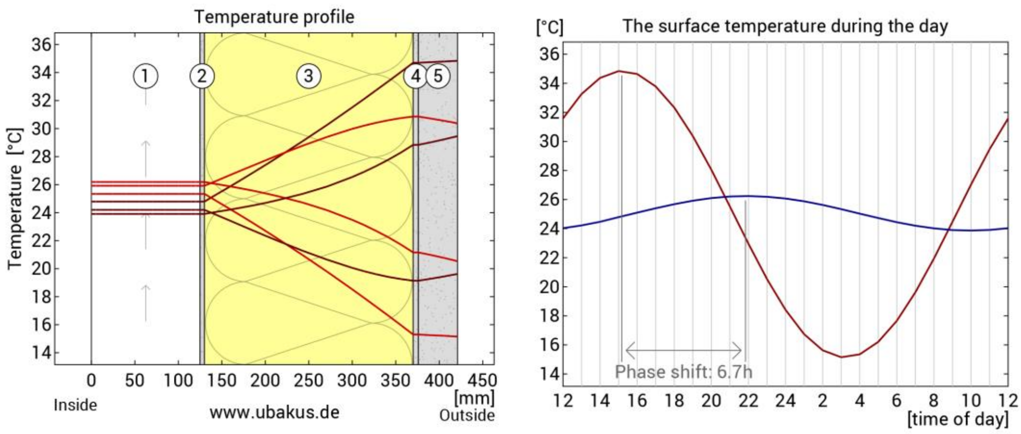


Figure 4.7. Component temperature profile (dark, temperature at 3pm, 11am and 7am; light, temperature at 7pm, 11pm and 3am). Component phase shift *(red, outside temperature; blue – inside temperature)*

For the PIR1 system (Fig. 4.8), thermal protection is U=0,171 W/m²K. The heat storage capacity of the element is 46 kJ/ m²K with the thermal capacity of the inner layers at 21 kJ/ m²K and the overall thermal resistance is 5,850 m²K/W. Phase shift is achieved after 6,8 hours with an amplitude attenuation of 8,2 and TAV 0,122. The advantage of using PIR core insulation is the overall reduced thickness of the component [6].

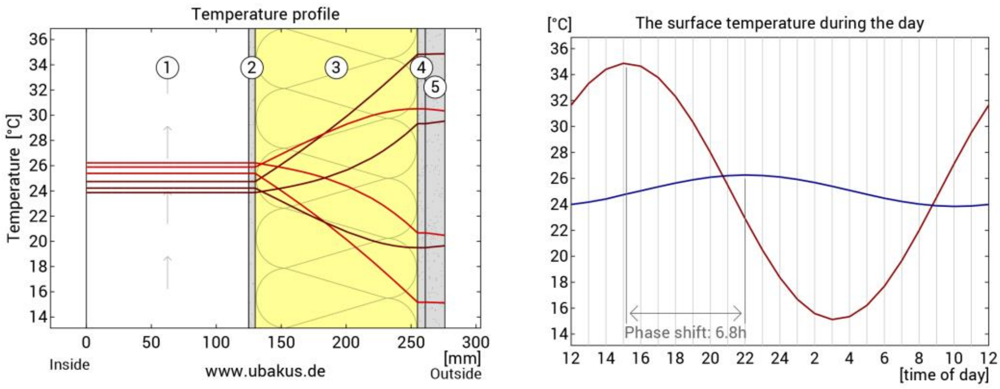


Figure 4.8. Component temperature profile (dark - temperature at 3pm, 11am and 7am; light - temperature at 7pm, 11pm and 3am). Component phase shift *(red- outside temperature; blue – inside temperature)*

The PIR2 system (Fig 4.9), has a protection capacity U=0,167 W/m²K. The heat storage capacity of the element is 46 kJ/ m²K with the thermal capacity of the inner layers at 21 kJ/ m²K and the overall thermal resistance is 6,001 m²K/W. Phase shift is achieved after 7,2 hours with and amplitude attenuation of 8,5 and TAV 0,117 [6]

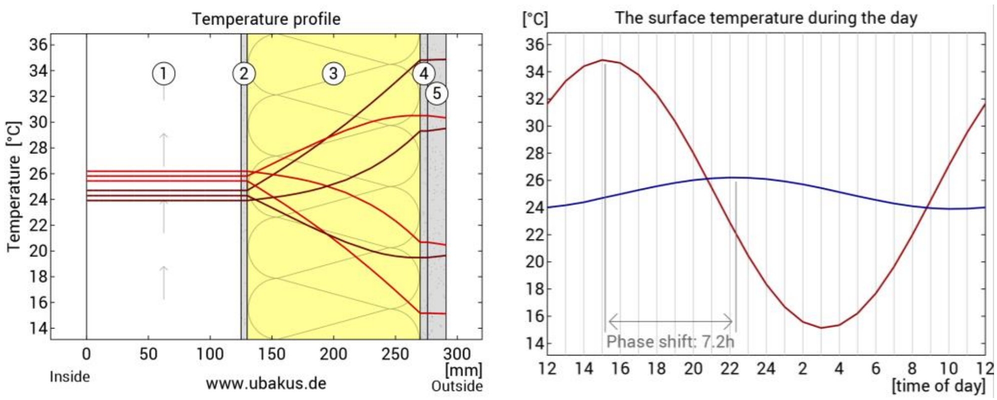


Figure 4.9. Component temperature profile (dark - temperature at 3pm, 11am and 7am; light - temperature at 7pm, 11pm and 3am). Component phase shift *(red- outside temperature; blue – inside temperature)*

In order to basic evaluate the energy balance of the four systems the following operation profiles have been introduced:

- human heat gain: 70W per user;
- service hot-water load: 60l/day per user;
- humidity load: 2g/day per user;
- usage rate: 6264hours/year;
- lighting: LEDs;
- heating: 1500W nominal capacity electric space heater. Service hot water heating included Control type: temperature controlled with indoor sensors.

The energy-balance results are presented below in Table 4.2. The graphs (Figures 4.10-4.13) show the amount of energy the building emits (bottom part), as well as the energy supplied energy: the amount of energy it absorbs from the environment and its own internal heat sources (top part), by month (in this case) or week, depending on user preferences.

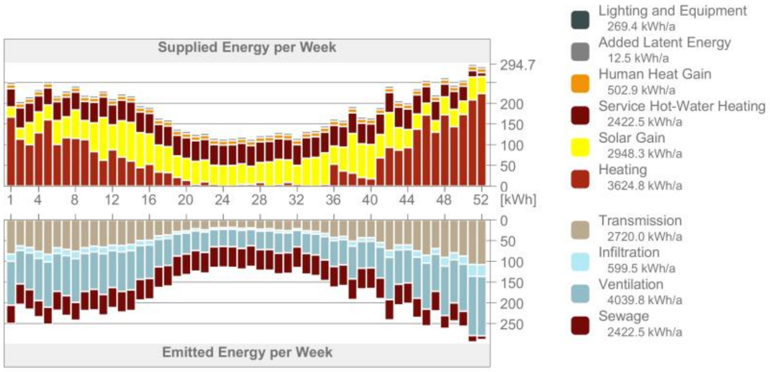


Figure 4.10. MW 1 energy graph (147,34 kWh/m²a)

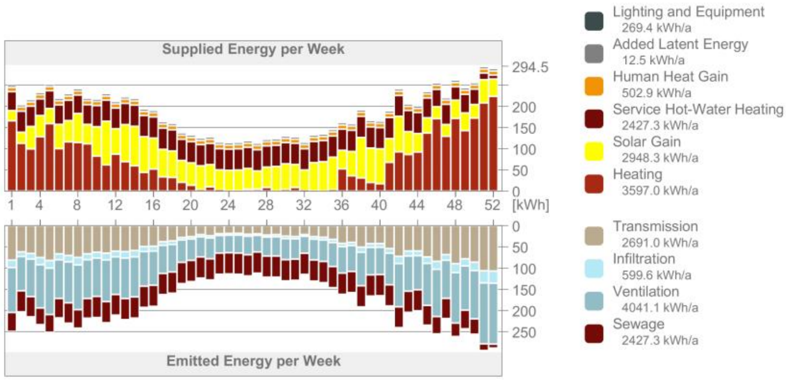


Figure 4.11. MW 2 energy graph (146,21 kWh/m²a)

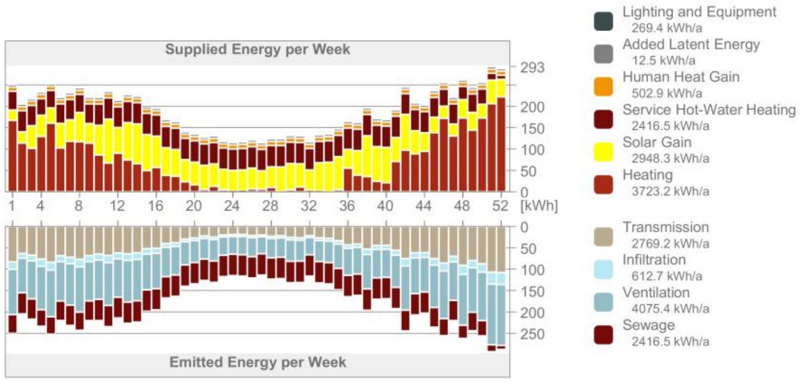


Figure 4.12. PIR 1 energy graph (151,34 kWh/m²a)

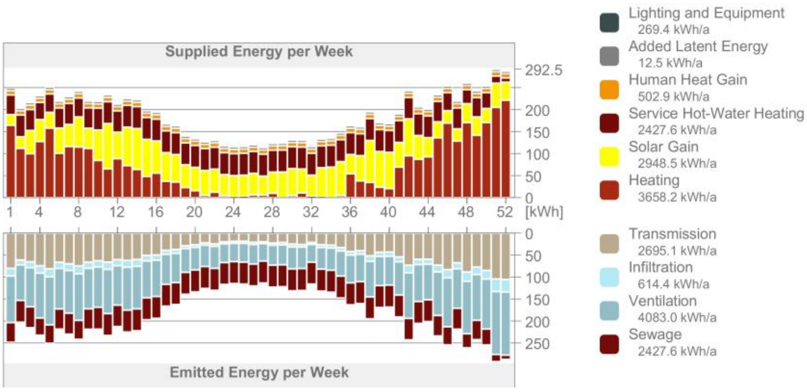


Figure 4.13. PIR 2 energy graph (148,70 kWh/m²a)

According to the energy balance equation, the energy and Supplied energy bars must be equal every month. The vertical axis of the chart shows an energy scale. Along the horizontal axis, the twelve months of the year are shown.

In a general overview, the supplied energy relies on heating (more than 50% of total amounts), solar gain and hot-water preparation. Other input energies are less than 7% of the total amount. The energy emitted from the building is based mainly in transmission - 30%, ventilation - 45%, and sewage systems – 10%. These percentages indicate also the ways by which the energy balance could be optimised. In this view, heat ventilation regulators or energy sewage recovery systems can lower the overall energy balance, leading to smaller amounts of input energy.

It can be observed that MW2 has the lowest net heating energy balance, needing 3597 kWh/a (annually) for space heating compared to the highest, PIR2 with 3658,2 kWh/a. In addition, the mineral wool cores (MW1 and MW2) are more airtight than PIR, allowing less infiltrations and heat transmissions between the inside then the outside environments.

Facade System	Overall thermal resistance [m²K/W]	Lowest net heating energy balance [kWh/a]	Heat storage capacity [kJ/ m²K]	Thermal capacity of inner layers [kJ/ m²K]	Phase shift [hours]	Amplitude attenuation	TAV
MW 1	5,943	3624,8	47	19,7	6,7	7,9	0,126
MW 2	6,193	3597	47	19,8	6,7	8,3	0,120
PIR 1	5,850	3723,2	46	21	6,8	8,2	0,122
PIR 2	6,001	3658,2	46	21	7,2	8,5	0,117

Table 4.2. Façade system performance

Table 4.2 presents the performances of the façade systems. The conclusion of the study is that all the parameters have similar values, the variation being of 5-6% among the studied cases. The MW2 solution having the highest thermal resistance (smallest U value) also results in having the net heating energy balance and the lowest TAV value. On the contrary, the highest amplitude attenuation and thermal capacity of inner layers are obtained for the PIR2 solution.

An environmental impact analysis was carried out through the Life Cycle Approach of facade systems (LCA), taking into account all the stages a product goes through until it reaches the end of its life cycle (starting with the extraction of raw materials, production, commissioning and reaching disassembly, waste processing and disposal after dismantling/demolition of the building) [6].

The LCA analysis for the facade systems was performed using the SimaPro [57] software program (8) starting from certain boundary conditions such as identical thermal insulation materials or with identical properties:

- Indoor temperature: 20 °C with 40% humidity
- Envelope systems are made of sandwich panels with the same transmittance value of 0.17 W / m2K;
- energy used during the construction process (for example, the energy from the fuel consumption of machines and technological equipment) is excluded from the calculation;
- the energy consumption due to the transport of sandwich panels (from the manufacturer to the construction site) and their installation on the structure are also excluded from the calculation;
- the calculation of long-term emissions is considered.

The Life Cycle scenario includes as input the same component materials and the same quantities used for in the heat transfer analysis [6]. The data related to the End of Life Cycle phase, representing the scenario for recycling, reuse and disposal of waste at the end of the building's life cycle, were evaluated according to the current conditions in Romania for the disposal of closing materials for structures [6]. Table 4.3 shows the components of each facade solution analysed, as well as the related quantities and the scenario of removing each component layer from the sandwich panels.

Façade system	Layer configuration (inside – outside)	Surface [sqm]	d [mm]	Kg/sqm	kg	EOL
Mineral wool 1 (MW1–23,8 kg/sqm)	1. Steel profiles C120 – support	137,34	120	5.943	0.168	100% Recycling
	2. Inner Hot-dip galvanized steel sheet	85,41	0.6			90% Recycle / 10% Waste
	3. Mineral wool	85,41	232			70% Recycle / 30% Waste
	4. Polyurethane adhesive	85,41	-			100% Waste
	5. Outer Hot-dip galvanized steel sheet	85,41	0.6			90% Recycle / 10% Waste
Mineral wool 2 (MW2-32,8 kg/sqm)	1. Steel profiles C120 – support			6.193	0.161	100% Recycling
	2. Internal steel sheet - G, g, s, v, v2, m2 - profile (galvanized and painted)	85,41	0.5			90% Recycle / 10% Waste
	3. Mineral wool	85,41	240			70% Recycle / 30% Waste
	4. External steel sheet - G (smooth) - profile (galvanized and painted)	85,41	0.7			90% Recycle / 10% Waste
PIR insulation 1 (PIR1-15,5 kg/sqm)	1. Steel profiles C120 – support		120	5.850	0.171	100% Recycling
	2. Profile of the inner ribbed steel sheet profile	85,41	0.5			90% Recycle / 10% Waste
	3. PIR insulation	85,41	125			90% Recycle / 10% Waste
	4. Outer ribbed steel sheet profile	85,41	0.6			90% Recycle / 10% Waste
PIR insulation 2 (PIR2-15,17 kg/sqm)	1. Steel profiles C120 – support			6.001	0.167	100% Recycling
	2. Inner precoated steel sheet	85,41	0.5			90% Recycle / 10% Waste
	3. PIR insulation	85,41	140			90% Recycle / 10% Waste
	4. Outer precoated steel sheet	85,41	0.6			90% Recycle / 10% Waste

Table 4.3. End-of-Life scenarios of envelope systems[6]

The impact on the environment is expressed by eco-points, defined by the method for LCA, Eco-indicator 99 [58] and presented in Tables 4.5 and 4.6.

Façade system	Environmental impact in production stage[eco points]	Damage category		
		Human Health	Ecosystem	Resources
Mineral wool 1 (MW1–23,8 kg/sqm)	232	72.3	25.47	134.15
Mineral wool 2 (MW2-32,8 kg/sqm)	203	62.94	19.79	120.38
PIR insulation 1 (PIR1-15,5 kg/sqm)	231	45.52	16.02	169.52
PIR insulation 2 (PIR2-15,17 kg/sqm)	212	41.46	12.09	158.76

Table 4.5. Production stage – Environmental impact[6]

Façade system	Environmental impact in EOL [eco points]	Damage category		
		Human Health	Ecosystem	Resources
Mineral wool 1 (MW1–23,8 kg/sqm)	232	72.3	25.47	134.15
Mineral wool 2 (MW2-32,8 kg/sqm)	203	62.94	19.79	120.38
PIR insulation 1 (PIR1-15,5 kg/sqm)	231	45.52	16.02	169.52
PIR insulation 2 (PIR2-15,17 kg/sqm)	212	41.46	12.09	158.76

Table 4.6. EOL stage – Environmental impact[6]

The results demonstrate that, as a whole, all four facade systems have similar scores, in both production as well as EOL stages. However, the facade system with the lowest environmental impact is different for the production phase and for the end of the life cycle of the analyzed solutions, due to the reuse and energy recovery of the component materials of the systems. It can be seen that for the production phase the solution with the minimum eco-points is the MW 2 solution, followed by the PIR 2 solution. The results recorded[6] following the analysis of the facade systems throughout their lifetime, also taking into account the End of Life Cycle, shows that the PIR 2 solution is ranked last in terms of environmental impact, having the most significant environmental impact among all four facade systems analyzed. However, the MW 2 solution (based on a mineral wool thermal insulation) remained the solution that added up the minimum eco-points also following the LCA analysis, thus proving that it is the facade system that has the lowest impact on the environment, in relation to the other analyzed solutions, from the production phase to the End of Life Cycle[6].

Regarding the impact category, all four solutions, both in the production stage and in the end-of-life stage, have a higher impact on natural resources, which translates into the high level of manufacturing of the component products by using energy.

4.2.2 The second design phase

During this phase three main targets were set:

- construction of the modular laboratory, by realising the execution project a metal structure, contracting an execution company, and making the resistance structure. On the other hand, during 2019, the Urban Planning Certificate was obtained for the building construction and the approvals of various public entities, requested by the Urban Planning Certificate;

- Design of facade systems with solar collectors. The studies focused on the construction and most efficient operation of glazed solar collectors with perforated absorbent plate, to integrate them into the facades of the buildings. Based on the results obtained (both experimental and numerical), it is possible to recommend the construction of a prototype of a glazed solar collector with a plate perforated absorbent (basically determining the main parameters) that can be tested in the conditions actual operation by integrating it into the facades of the buildings. The proposed configuration follows the integration of phase-change materials in solar collector construction for growth its performances;
- Experimental tests on fast foundations. Based on a geotechnical study carried out in phase 1 of the project, the study included three characteristic geotechnical tests, one of which was a test experimental with the modulus of plate, to determine the deformation of the land from site and two experimental tests on truncated pyramid foundations that allowed evaluation of the bearing capacity and settlements of this type of foundation. Studies of parametric numerical simulations.

4.2.2.1 Construction. PET insulation and starting simulations

During 2019 (stage II) and partially 2020 (stage III), the installation of the module was carried out. The slope of the roof on the southern facade is set at 42 degrees, to optimise the performance offered by the mount of the photovoltaic panel system. The structural elements allow the assembly of several types of facade walls. The facade system for the CIA-CLIM project study was chosen and consists of a sandwich system with fibre wool insulation obtained from PET plastic bottles. In the south façade, a curtain window with the dimensions of 3.30x2.80m, triple layer (Ug=0.6 W/m2K) is installed which provides interior lighting of the space and passive heating of the space during the day.

Figure 4.14. Steel structure assembly

PET insulation

Thermal insulation materials are catalogued in numerous forms in literature, but mainly in two groups: inorganic and organic, in agreement with the origin of the raw materials from which they are created. Each of the two groups is split into natural and synthetic insulation materials, depending on the production process. In addition, other composite products and new technology materials are in lasting improvement and progress [59][54].

Recently, the environmental perspective of thermal insulation products is considered, and the use of secondary raw materials is increasingly in the spotlight. Thermal insulation wadding produced with polyester fibers made from the recycling of post-consumer PET bottles is one such insulation material developed in the last decade [60].

The manufacture of polyester fibers begins with recycling post-consumer PET bottles from differentiated waste collection. After washing, grounded to flakes, these are used in fibre production [8]. Next, the layers of raw material for thermal insulation wadding are obtained by guiding the polyester fibers mechanically in the same direction. Eventually, the thermal insulation wadding is obtained by overlapping and thermal bonding (ca. 180ºC) two or more layers of raw material wadding with the desired density and thickness [61].

Figure 4.15. PET insulation boards

Thickness [mm]	Density [kg/m3]	Thermal conductivity λ [W/mk]	Thermal resistance R [m2K/W]
15	15	0.058	0.638
20	30	0.052	0.383
37	55	0.046	0.323

Table 4.7. Performance of PET insulation [61]

Further simulations have been carried out for the same model in order to test different PET insulation thickness behaviour[52] compared to a standard mineral wool solution. The goal was to reach similar thermal results considering the two different material qualities. These are shown below in Table 4.8 and 4.9.

Component	d [mm]	R [m²K/W]	U [m²K/W]
Walls v1 – MW100	100	2.65	0.38
Walls v2 – PET120	120	2.00	0.50
Walls v3 – PET150	150	2.93	0.34
Bottom slab	296	4.84	0.21
Middle slab	248	3.22	0.31
Roof	200	5.19	0.19
Openings	-	1.38	0.72

Table 4.8. Façade system input [52]

Façade system	Glazing ratio [%]	Lighting and equipment [kWh/a]	Solar gain [kWh/a]	Heating [kWh/a]	Cooling [kWh/a]	On-site energy PV energy generation [kWh]
MW100	6	694.6	2275	894.5	1571.4	1269
MW100	8	694.6	2797	792	1839.6	1269
MW100	10	694.6	3528	662.8	2230.4	1269
PET120	6	694.6	2275	1095.5	1566.3	1269
PET120	8	694.6	2797	982	1815	1269
PET120	10	694.6	3528	841	2184	1269
PET150	6	694.6	2275	841.3	1574.1	1269
PET150	8	694.6	2797	741.6	1847.6	1269
PET150	10	694.6	3528	616	2244.6	1269

Table 4.9. Façade system results with different glazing ratio [52]

Material	Thickness [mm]	Net weight [kg/sqm]	U [W/m2K]	Thermal resistance R [m2K/W]
MW 100	100	9	0.4	2.5
PET 150	150	3597	0.36	2.77

Table 4.10. Mineral wool vs PET technical performance [52]

Figure 4.16 shows the greenhouse gas (GHG) emissions for each thermal insulation per 1 kg of material produced. 'Production stage' assessment refers to stages A1 (extraction of raw materials), A2 (raw materials transport to the manufacturer), and A3 (production of thermal insulation), being run on GaBi Product Sustainability Software [62], using Environmental Product Declarations (EPD's) [63] and Technical Approval for Wadding Mattresses for Thermal and Phonic Insulation [61].

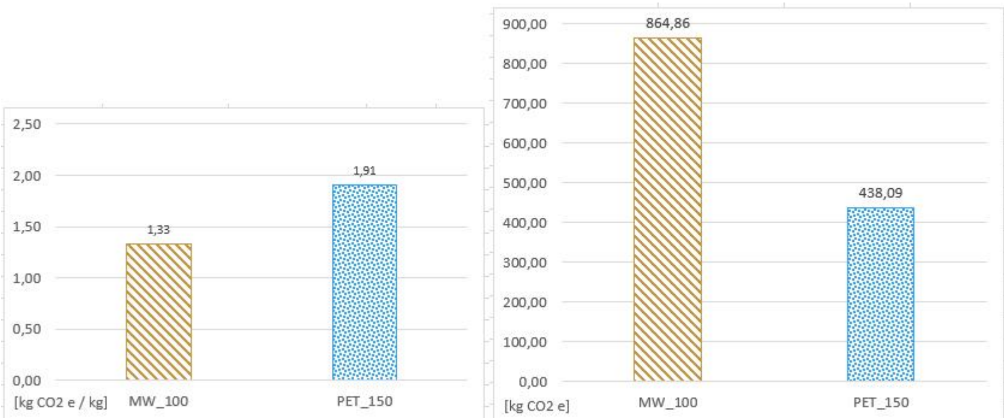


Figure 4.16. Environmental impact: left – potential impact of thermal insulation materials in the production stage; right – total impact of insulation materials in production stage

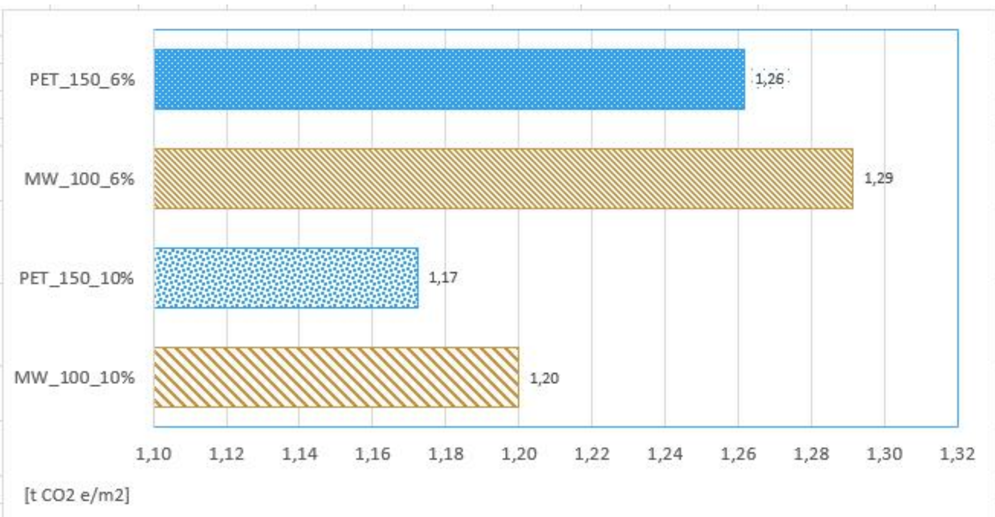


Figure 4.17. Life cycle impacts (stages A-C) / m2 [t CO2 e / m2]

4.2.2.2 Construction and final details of the building envelope

Figure 4.18. Steel structure / roof component assembly

The roof structure

The roof structure is formed out of 25 cm light-weight steel profiles. In between there are four layers of 5cm PET insulation boards, 20cm total. Towards the outside the roof if closed with 10cm SW panels that offer support for the PV installation on the roof. Towards inside a roofing membrane is placed and closed with a double layer of OSB3 boards. A double OSB board layer is sufficient to act as a vapour barrier under normal conditions. Because of the direct contact to the steel profiles, however, there is a risk of condensation forming on the inner side of the SW panel. The phenomenon is minimal, however additional roofing membrane has been used to prevent it. Figure 4.16 shows a detailed cross-section of the model in the join area between the room and wall elements.

The PET insulation boards have standard sizes. In order to minimize potential heat loss do the gaps between the boards during assembly, the boards were cladded and interlaced. Thus, most of the gaps could be covered.

The overall performance of the layers using Ubakus is shown below:

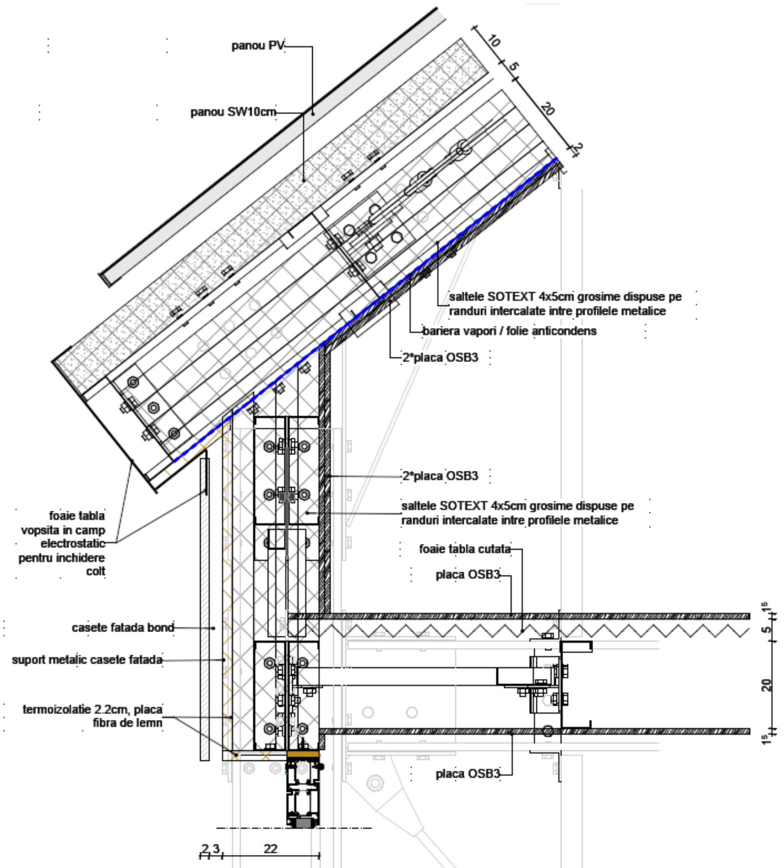


Figure 4.19 Construction detail – Joint area of the roof with the wall layers

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m^2K/W]	Temperatur [°C] min	max	Weight [kg/m^2]
		Thermal contact resistance*		0,130	17,7	20,0	
1	1,2 cm	AGEPAN OSB 3 PUR	0,130	0,092	16,8	19,2	7,2
2	1,2 cm	AGEPAN OSB 3 PUR	0,130	0,092	15,6	18,9	7,2
3	0,025 cm	BauderVAP DB	0,170	0,001	15,6	18,7	0,3
4	0,025 cm	BauderVAP DB	0,170	0,001	15,5	18,6	0,3
5	20 cm	TIZ SOFTEX	0,054	3,704	7,3	18,6	8,0
	25 cm	Steel (Width: 0,06 cm)	50,000	0,005	7,7	15,5	1,9
	0,06 cm	Steel (Width: 7 cm)	50,000	0,000	7,4	7,5	0,5
	0,06 cm	Steel (Width: 7 cm)	50,000	0,000	16,1	16,4	0,5
6	5 cm	Stationary air (unventilated)	0,278	0,180	6,8	8,8	0,1
7	0,1 cm	roof panels 026: Innenseite	50,000	0,000	6,8	7,7	7,8
	6,9 cm	roof panels 026: Dämmkern	0,026	2,654	-4,8	7,7	2,1
	5 cm	roof panels 026: trapezoidal sheet	10,000	0,005	-4,8	-4,8	5,0
		Thermal contact resistance*		0,040	-5,0	-4,8	
	39,45 cm	Whole component		5,446			40,9

Figure 4.20. Thermal performance of layers. *Thermal contact resistances according to DIN 6946*[64] *for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3* [65] *were used for moisture proofing and temperature profile.*

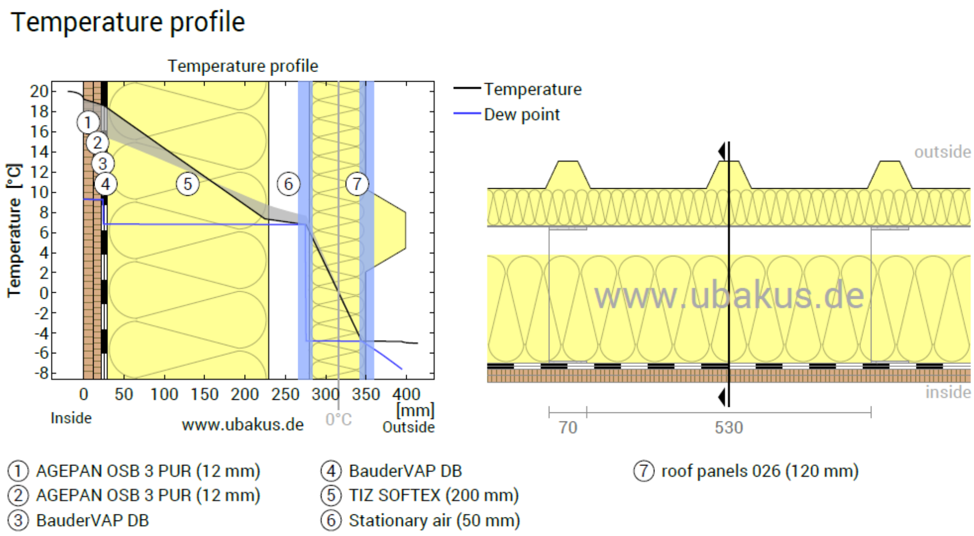


Figure 4.21 Roof structure temperature profile - ***Left:*** *Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.* ***Right:*** *The component, drawn to scale.*

The wall and bottom slab structure

Figure 4.22. Wall element assembly.

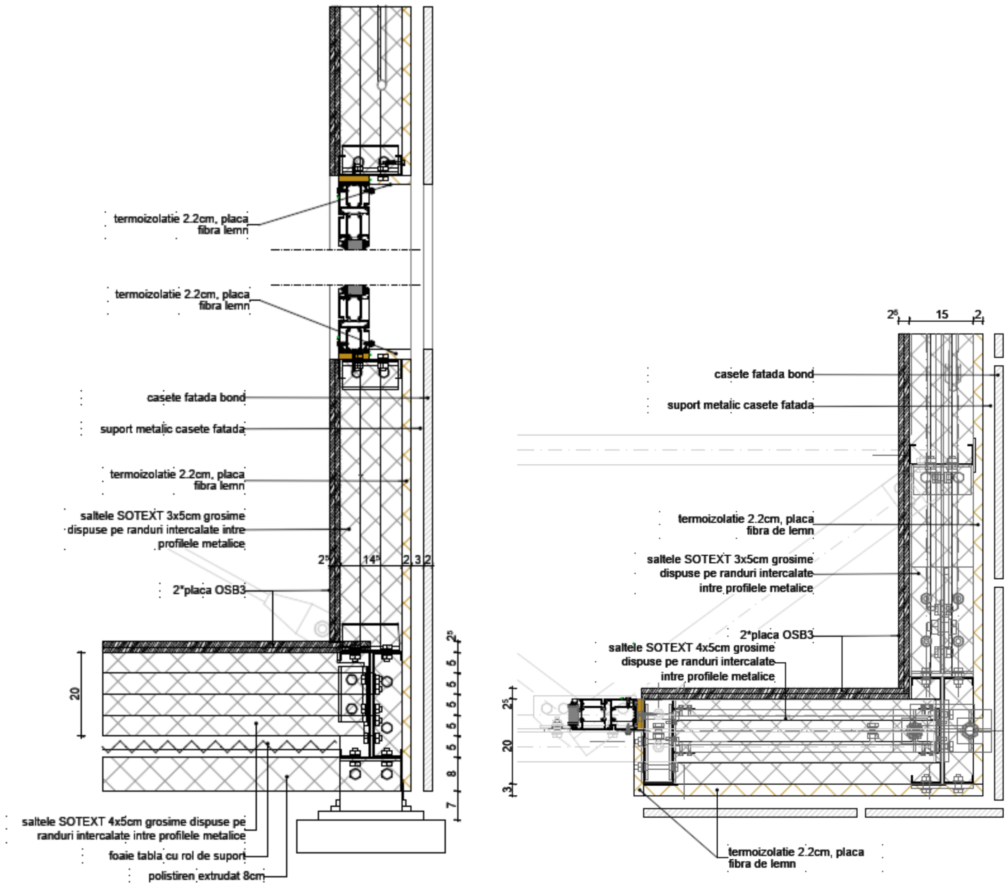


Figure 4.23. Construction detail – **Left:** Vertical section. Wall and bottom slab layer elements. **Right**: Horizontal section

Similar to the roof element, the thermal insulation for the wall and bottom slam components is made of four layers of 5cm PET boards. In order to prevent forming of thermal bridge within the element, the wall component has an additional layer of wood fibre insulation boards towards the outside fastened on the steel structure. On top of these the façade component is finished with bond (steel) cassettes on a secondary lightweight structure, thus acting as a ventilated façade system. The bottom slab has an additional XPS (extruded polystyrene) layer glued to a steel support sheet. Towards the inside both components have a double OSB board layer which also works as a vapour barrier.

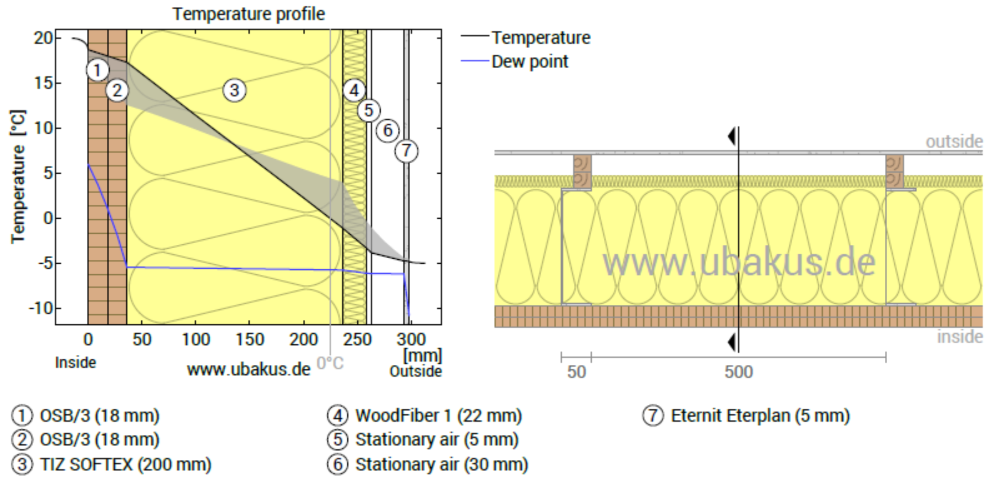


Figure 4.24. Wall structure temperature profile - ***Left:*** *Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.* ***Right:*** *The component, drawn to scale.*

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,130	17,0	20,0	
1	1,8 cm	OSB/3	0,130	0,138	15,1	18,7	11,2
2	1,8 cm	OSB/3	0,130	0,138	12,6	18,0	11,2
3	20 cm	TIZ SOFTEX	0,054	3,704	-1,1	17,3	4,0
	20 cm	Steel (0,11%)	50,000	0,004	4,0	12,6	2,2
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	3,0	4,0	0,6
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	12,6	13,5	0,6
4	2,2 cm	WoodFiber 1	0,050	0,440	-3,3	4,0	5,1
	3 cm	Profilholz (Fichte/Tanne) (Width: 3 cm)	0,140	0,214	-1,5	3,5	0,9
5	0,5 cm	Stationary air (unventilated)	0,045	0,110	-3,8	-0,5	0,0
6	3 cm	Stationary air (unventilated)	0,167	0,180	-4,8	-1,5	0,0
	3 cm	Rafter (spruce) (5,7%)	0,130	0,231	-4,4	-1,1	1,0
7	0,5 cm	Eternit Eterplan	0,580	0,009	-4,8	-4,4	8,3
		Thermal contact resistance*		0,040	-5,0	-4,5	
	29,8 cm	Whole component		3,539			44,8

Figure 4.25. Wall structure- Thermal performance of layers. *Thermal contact resistances according to DIN 6946*[64] *for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3* [65] *were used for moisture proofing and temperature profile.*

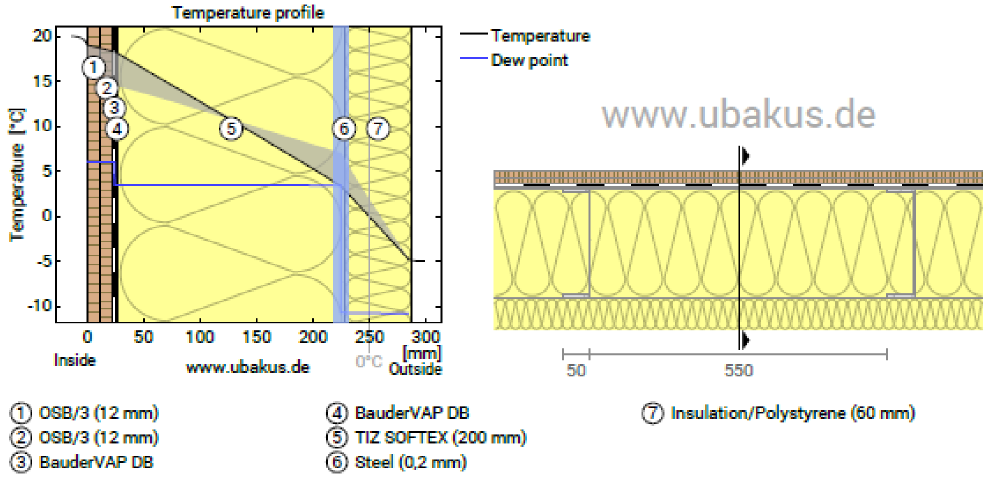


Figure 4.26. Bottom slab temperature profile - ***Left:*** *Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.* ***Right:*** *The component, drawn to scale.*

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,170	17,2	20,0	
1	1,2 cm	OSB/3	0,130	0,092	16,1	19,0	7,4
2	1,2 cm	OSB/3	0,130	0,092	14,6	18,6	7,4
3	0,025 cm	BauderVAP DB	0,170	0,001	14,6	18,3	0,3
4	0,025 cm	BauderVAP DB	0,170	0,001	14,5	18,3	0,3
5	20 cm	TIZ SOFTEX	0,054	3,704	3,4	18,3	4,0
	20 cm	Steel (0,10%)	50,000	0,004	7,1	14,5	1,6
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	6,5	6,7	0,4
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	15,0	15,2	0,4
6	0,02 cm	Steel	50,000	0,000	3,4	7,1	1,6
7	6 cm	Insulation/Polystyrene (EPS 035)	0,035	1,714	-4,8	7,1	1,8
		Thermal contact resistance*		0,170	-5,0	-4,7	
	28,47 cm	Whole component		4,663			25,1

Figure 4.27. Bottom slab. Thermal performance of layers. *Thermal contact resistances according to DIN 6946*[64] *for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3* [65] *were used for moisture proofing and temperature profile.*

4.2.3 The third design phase

The third phase focused on monitoring the model data. For monitoring the characteristics of facades under various atmospheric conditions, the module was equipped with 14 humidity sensors, 53 temperature sensors and 3 CO_2 concentration monitoring sensors (Fig.4.26). For data transmission a station with 12 relays (IR) was mounted. Each IR can integrate 8 sensors and can provide digital inputs and outputs that can be used for building automation. Currently, information is transmitted over an Ethernet network to a server located at distance, information monitoring is ongoing [52].

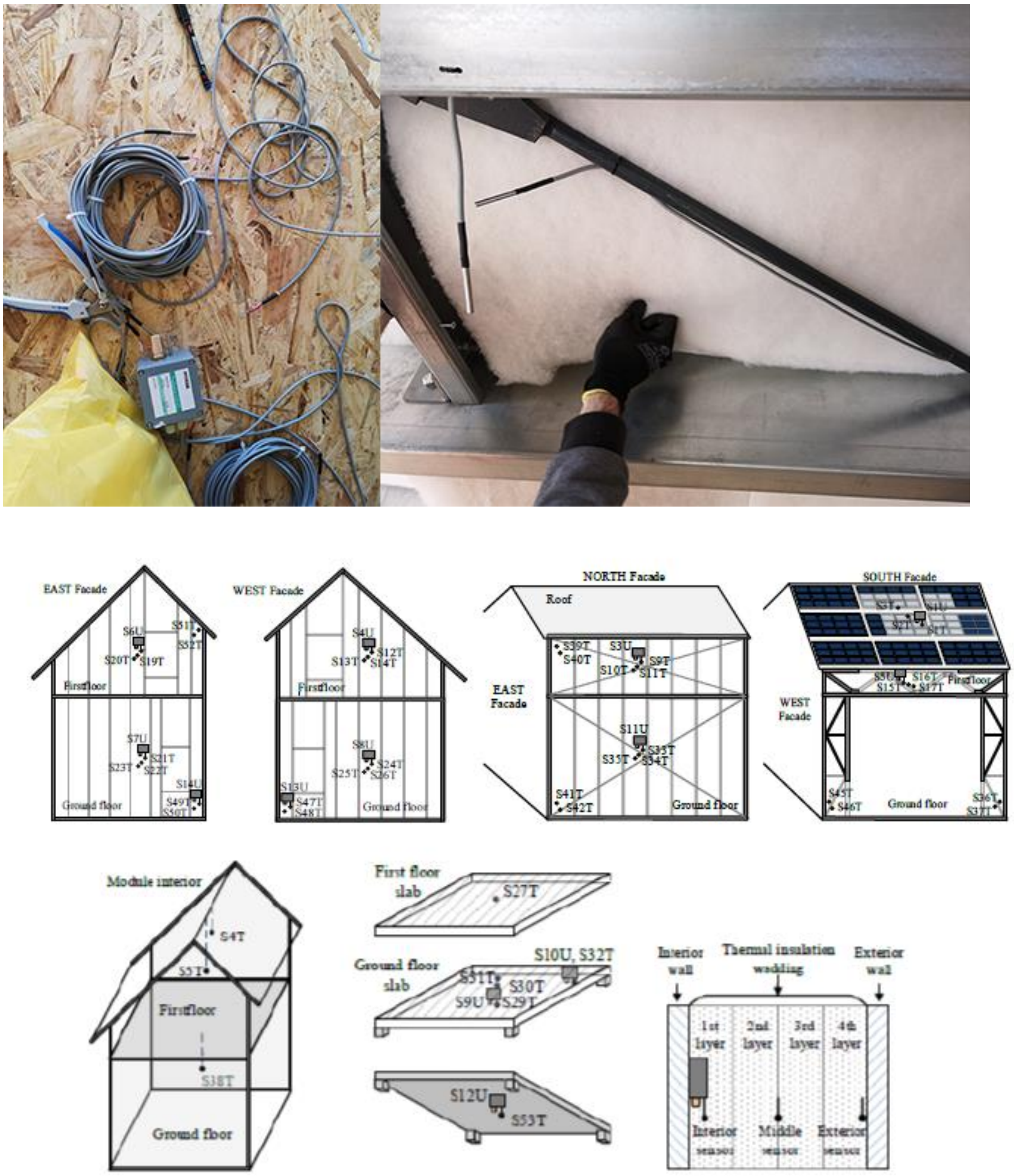


Figure 4.28. Monitoring sensor placement within the building envelope components

The LCA analyses on the types of facades analysed demonstrated that the clearance and the end-of-life cycle of these systems plays an important role in the impact analysis of the systems analysed, being able to reverse the scores obtained in the production phase. LCA analyses performed on quick foundation elements have shown that due to their reuse the impact on the environment is minimal, although in the production phase the impact on the environment is much higher than of a similar cast-in-situ foundation [54].

4.2.4 The fourth design phase

The final phase further detailed the prior with the following events: In stage IV/2020, the assembly of the wind turbine and the supporting structure and the photovoltaic slats was carried out in the model. For the proper functioning of the wind turbine, tests were carried out on a model experimental microgrid with direct current energy distribution integrated into the "smart" type system grid". Monitoring of the experimental data was continued to follow the variations given by temperature, humidity, and CO2 concentration sensors. The production of energy was also monitored because of the production of photovoltaic panels on the roof. Once the systems have been coupled of the wind turbine [66] and the photovoltaic blades it was be possible to monitor the energy production given by these systems.

4.2.4.1 Electric energy distribution network

The electricity distribution implemented in the experimental model is represented by a network of direct current (DC) and is similar to a "smart nano-grid" network. In the experimental model two types of renewable energy sources (solar and wind) are integrated, elements of conversion and storage of electrical energy the control system is also integrated and energy management through a SCADA type system. Because this model is proposed for residential type applications, common electrical equipment used in the home are adapted to operate in direct current.

The network architecture is composed of two DC networks. A network of high voltage (350V DC) and a low voltage network (24 V DC). Also, a classic network of alternating current with the effective voltage of 230 V is present in the experimental model. Solar energy is converted into electricity using twelve photovoltaic panels connected to the network of 4V DC through a specially designed converter to be able to take over the maximum energy generated by to the panels. Power is stored in four lead-acid gel batteries, specially designed for the application with photovoltaic systems. 10kWh of energy can be stored in the batteries, which, for an ordinary house it is enough for 2-3 days of operation without charging. The connection between the 350V DC network and the 24V DC network is made through a bidirectional converter with switched capacities, this being presented above. The connection to the alternating current network is made through a hybrid converter which has the DC voltage output connected to the 24 V DC network. A SCADA type system oversees and controls the entire flow of electricity and ensures data acquisition of all parameters.

The "smart nano grid" type architecture implemented uses a decentralized control, based on the voltage of the two direct current networks, on the power circulated through the BHCC converter and the hybrid inverter. The hybrid inverter offers two modes of operation: on-grid (connected to the grid national alternating current) and off-grid (isolated from the national grid).

Figure 4.29. Solar panel relay

Figure 4.30. AC and DC distribution network

In on-grid mode, if there is not enough energy produced by renewable sources and batteries are at a low voltage level, the hybrid inverter will supply power from the mains alternatives and will deliver it to consumers, charging the batteries at the same time. In case the sources of renewable energy produce too much energy, which is not consumed locally, it is introduced in the national alternating current network.

In off-grid operation mode, when renewable energy sources do not produce sufficient energy, consumers are fed according to a certain degree of priority. On the other hand, when the energy produced by these sources is greater than the energy required, each source can reduce the amount of energy delivered to the grid.

4.2.4.2 Wind turbine

Considering installed power in the test module and the available area, a wind turbine with a vertical axis with a power of 600W at the 24V voltage was chosen for this purpose. It operates over a wide range of angular speeds, starting from the starting speed of 1m/s, up to the maximum speed of 65m/s, with a low noise of less than 25dB (speed of 7m/s, measured at a distance of 10m). It can work in diverse environmental conditions and over a wide range of temperatures. The generator is a three-phase one, and the controller makes a short-circuit connection to brake the turbine [66].

Figure 4.31. On-site wind turbine

4.2.4.3 Lighting design

To reduce the energy consumption required for lighting, the lighting efficiency and the maintenance cost of the lighting fixtures, LED lighting was used. For the same lighting, they emit a reduced amount of heat compared to incandescent lamps, do not produce the stroboscopic effect present in fluorescent

lamp lighting, and are much more efficient than both types. The content of toxic substances is also reduced, compared to the latter, mercury vapor discharge lamps.
Considering the high characteristics of LED lighting, two types of LED strips powered by the 24V network were used for the two rooms of the experimental module. Due to the direct supply to the 24V network, the reliability, efficiency and cost of the lighting decreases, because their electronic power circuits are eliminated, which are usually integrated in each lighting fixture.

Two different types of tapes were used in order to compare their different characteristics. In the first case, a conventional strip using SMD2216 discrete LEDs was tested, obtaining an average light efficiency, and a light beam angle with a commonly encountered value of 120 degrees. Due to the dimensions of the LED of 2.2 x 1.6 mm, the size of the strip turns out to be 4 x 1.95 mm.

In the second case, a strip of COB (chip on board) LEDs was chosen, which can achieve better characteristics in terms of dimensions, light efficiency, light diffusion and cost. Thus, with a reduced height of 1.2mm, this strip produces 50% more power and 10% better light efficiency. Due to the angle of the light beam and the high density of LEDs on the surface, this LED strip can be used without the need for a diffuser/light diffuser. In addition, it also has an increased color rendering index of over 94.

Other accessories required for mounting these strips are visible LED profiles and profile ends made of anodized aluminum. In order to further reduce consumption, a microwave presence sensor is used.

Figure 4.32. Installed lighting system – LED strips

4.2.4.4 SCADA monitoring system

System architecture

The system design functions as an "open architecture" type. This allows integration of all equipment, from different producers, used in the framework of the experimental model. It is a two -way system, which allows both the monitoring, acquisition and storage of data from the measurement station, as well as the control of the execution elements and the energy flow. A standardized communication protocol is used, Modbus TCP/IP [67], using the Ethernet network, which allows the cooperation with other applications made on open systems that have the same implemented communication protocol or by using an OPC server.

The SCADA interface was developed using the SIEMENS - Logo Web Editor V1.0 platform [68]. The application runs on two intelligent relays used within the measuring station. Data storage is done internally on smart relays using multiple micro-SD cards, separate from the SCADA application. Thus, if for some technical reasons the SCADA application stops, the data storage is not affected. In this configuration, access to the SCADA system is done through a web browser, accessing the IP address assigned to the relay on which the SCADA application is running. The data is stored and indexed in files with the extension .csv, with a maximum length of 20000 rows, after which another file is created. The file name is composed of the IP address of the relay, the date and time it was created. Stored data can be downloaded using the intelligent relay programming interface, LOGO! Soft Comfort V8.2 SP1. The connection is made on the ethernet network without the need for a direct connection, on a dedicated cable, between the PC and the served relay. If more files are created, to download them, it is necessary to remove the micro-SD card from the relay and insert it into a PC. Only the last created file can be accessed from the programming application.

Considering the above aspects and given the fact that the intelligent relay operates on 16-bit, integers, a new SCADA application was developed that allows the integration of various mathematical functions for data processing. The application runs on a dedicated desktop drive. Data is acquired using the same standardized protocol, Modbus TCP/IP, Ethernet communication network. The data is acquired from the measuring station and stored in txt files on the hard drive of the PC. At the operator's request, they can be accessed, depending on the set time period, and can be exported in excel files. The SCADA application developed on the previous platform has been preserved. SCADA applications are separate, and their operation is not conditioned by the interruption of one of them, thus ensuring redundancy.

Graphic interface

The graphic interface of the SCADA II application was designed on the same platform used for development (Ni Labview). The interface is made up of several viewports which can be accessed from the menu by browsing them, located for each window on the left side. In the figure below, the "Home" window is presented (Fig 4.33), which opens at the first access of the SCADA application. This window displays the energy flow of the module and the daily production for each renewable energy source. For each consumer, the distribution equipment and energy source are displayed instantaneous active power.

The "Human Presence" area indicates the active presence of a person in the experimental laboratory. The "Light Control" area allows the remote control of LED lighting, distributed on the ground floor and floor. The blue color of the button confirms the transmission of the information and its execution by the final equipment. On the right side of the viewport, the following are displayed, separately for each source:

- daily electricity production;
- the percentage power level compared to the nominal value;
- ON/OFF status, signaled by the green or red led located in the upper left.

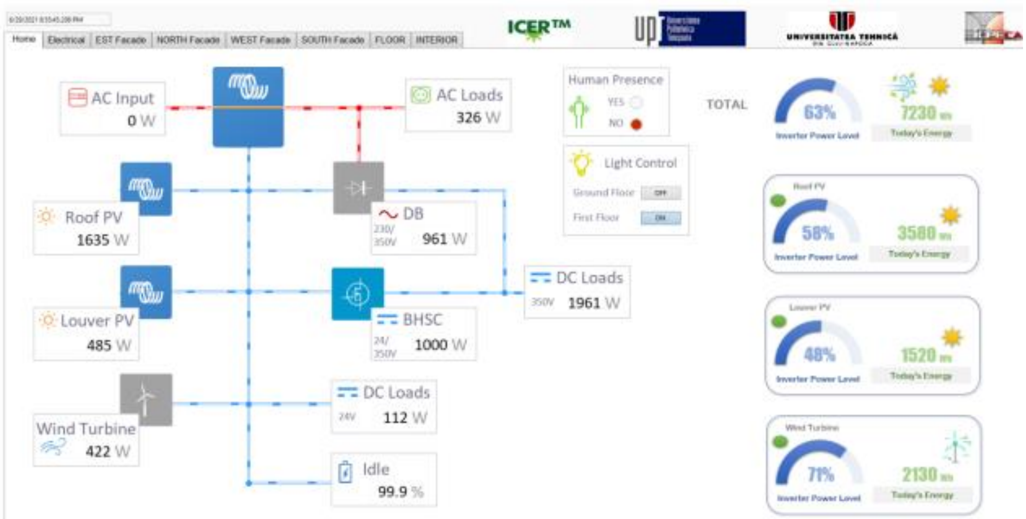


Figure 4.33. SCADA "Home"- Labview

The "Electrical" viewport (Fig 4.34) shows the electrical diagram of the testing module, and the actual current and voltage values related to each equipment, energy source and distribution networks. The status of each device is also indicated: Active, Standby or Inactive.

- Active – the equipment is in working condition and the current value is greater than 0.05A;
- Standby – the equipment is in working condition, but the current value is lower, in the mode, than 0.05 A;
- Inactive – the equipment is off or there is no communication with it.

The HBDC Control area is intended for the bidirectional DC converter, between the low voltage network (24V, DC) and the high voltage network (350V DC). The ON/OFF button allows the converter to be inserted or withdrawn from operation. The Mode button selects the operating mode of the converter, Manual/Automatic. In automatic mode, the converter will take the voltage references set for both networks from the SCADA interface and will be processed by the internal regulators within its nominal power limit. For example, if the references are set, the converter will supply energy to the high voltage network if the voltage value on the low voltage network is greater than 24.5V and the voltage value on the high voltage network is below the value of 350V. Otherwise, energy will be sent to the low-voltage network, as it is considered a priority.

The area in the lower-right part of the window is intended for the graphical representation, over a defined period, of the parameters of interest. It is possible to import the history and its graphic representation as well as export the data to an excel file.

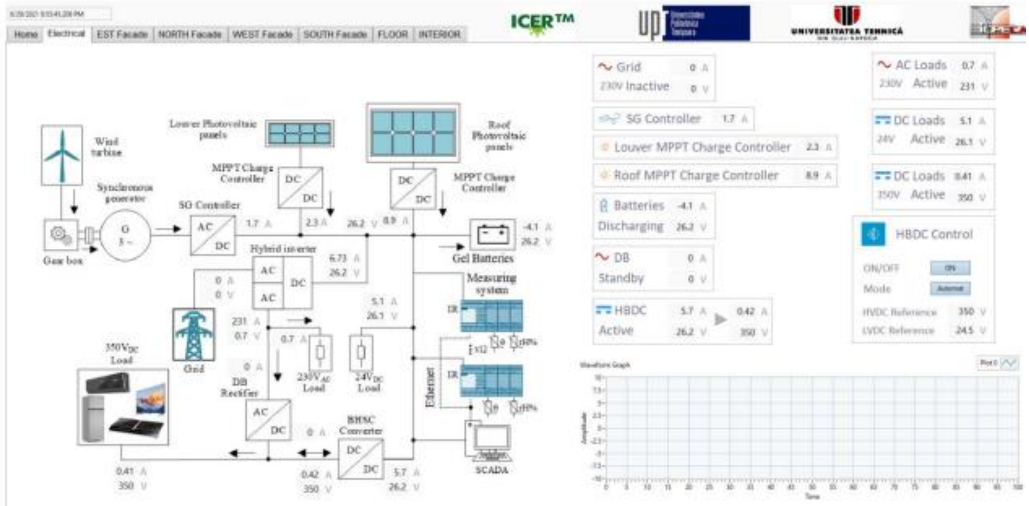


Figure 4.34. SCADA "Electrical" - Labview

Below are some viewport examples intended for the measuring station for temperature, humidity and carbon dioxide sensors. In addition, the option of graphical representation of the measurement history and its export to an excel file has been introduced. The trend also displays the current sensor values. The selection is made using the icon at the top right of the trend.

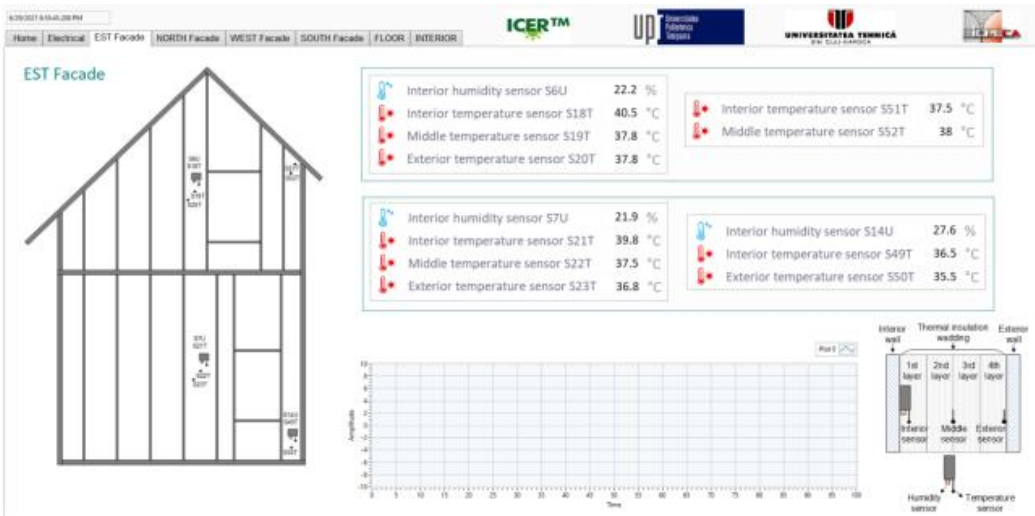


Figure 4.35. SCADA "EAST Facade" – Labview

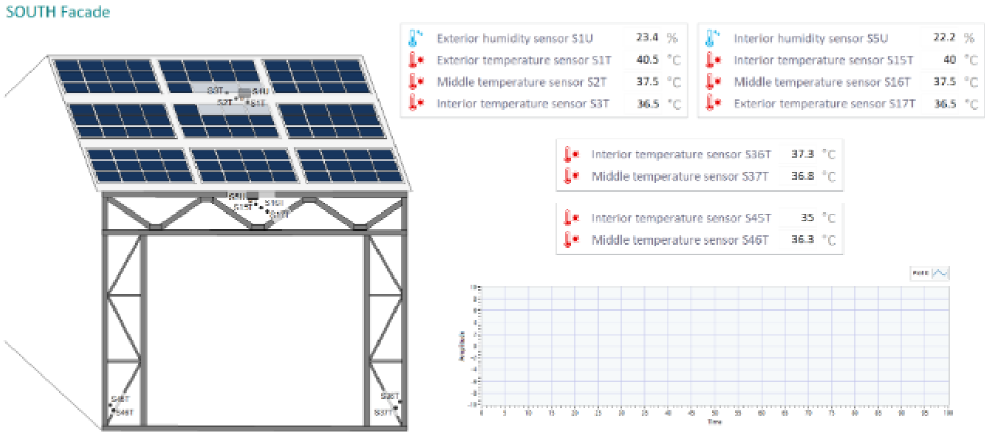


Figure 4.36. SCADA “SOUTH Facade” – Labview

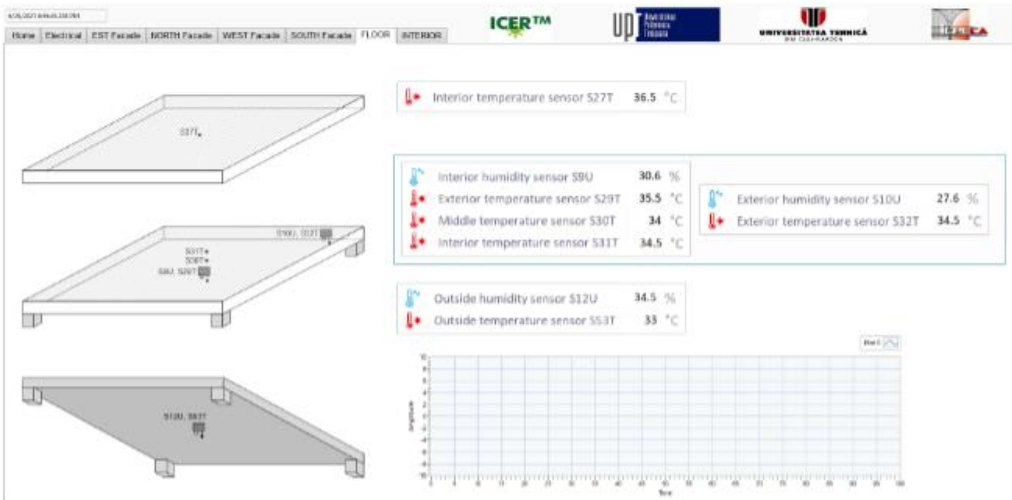


Figure 4.37. SCADA “SOUTH floor” – Labview

Figures 4.38 – 4.41 show the information provided by the monitoring management system, recorded for a monitoring interval of 6 months (01 December 2020 – 15 May 2021).

The recordings transferred by the sensors show the envelope behaviour of the experimental module and interior comfort conditions. At the time of the recordings the indoor temperature was influenced only by solar input, electrical devices and human interactions during interference by maintenance and observation, HVAC indoor comfort adjustment systems (heating-cooling, air conditioning) not being connected.

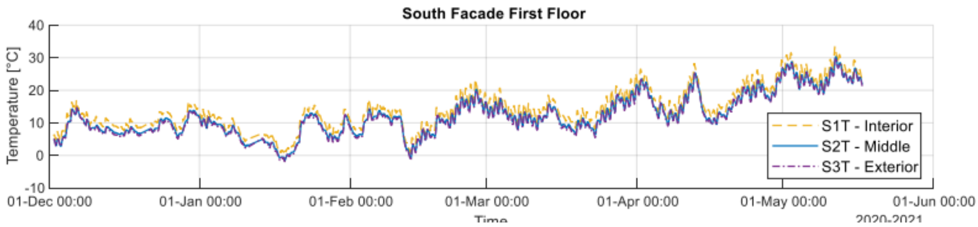


Figure 4.38. Temperature information provided by sensors on the south facade (floor) (top) respectively ground floor (downstairs).

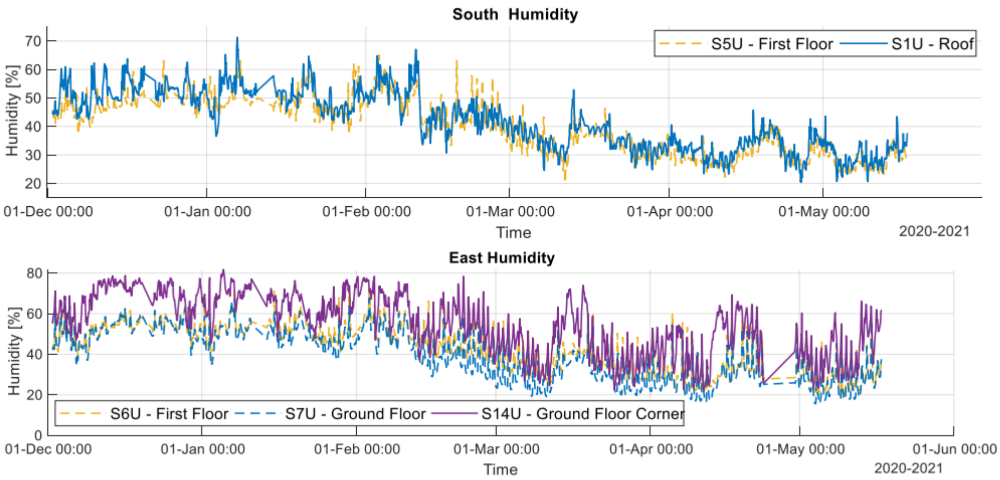


Figure 4.39. Humidity sensor data

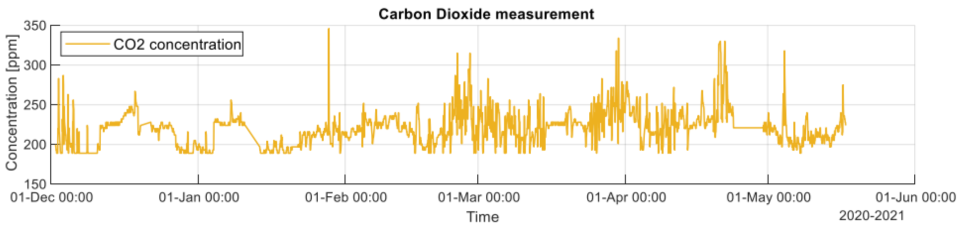


Figure 4.40. Variation of CO2 concertation inside the test model

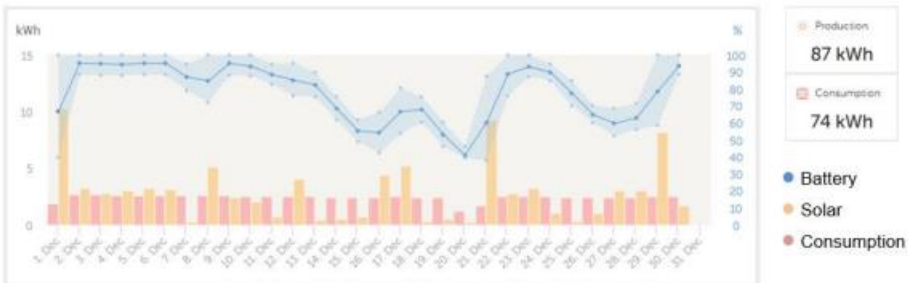


Figure 4.41. Winter energy production report

The energy production was monitored based on the data provided by the production photovoltaic panels on the roof. The recorded data shows that there are load periods with energy of up to 10kWh / day, which compensates for cloudy or snowy days, in which the energy is provided by batteries. In the natural operating conditions of the module, the consumption is constant approximately 2.6 kWh/day.

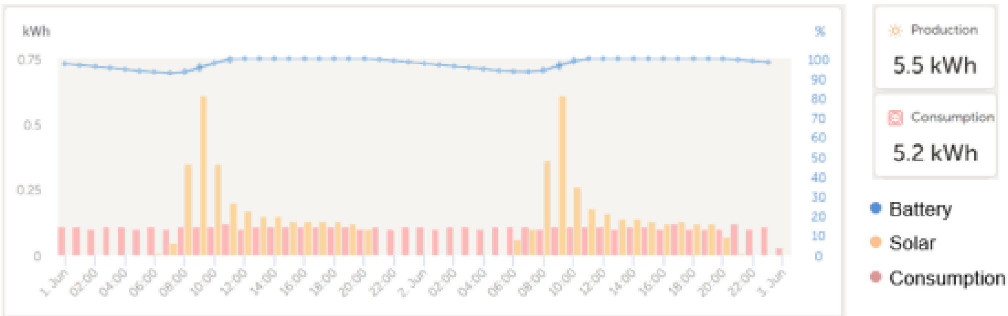


Figure 4.42 Energy production for a 2-day measurement within the test module

To illustrate the environmental benefit of the thermal insulation system obtained from recycled PET batting, in this phase an additional LCA type analysis was carried out, comparing the results obtained with the results obtained for a classic mineral wool system. The results indicate that the total impact of the insulation system PET_150 (438.09 kg CO2eq) is less than the environmental impact given by MW_100 (864.86 kg CO2eq) by approximately 48%[54].

The main conclusions of project 4 show that in order to obtain buildings with a low impact on environment and moderate construction costs, a holistic approach that integrates analysis is needed interdisciplinary and multi-object optimisation. The holistic approach to experimental module design involved the adoption of various criteria for sustainable building such as resource efficiency, efficiency materials, environmentally conscious design, life cycle design of buildings, use of reusable/recyclable materials, modularity and standardisation in design, methods of ecological demolition, recycling and reuse of waste, considering the cost of construction in the life cycle, cost of materials, health and welfare of occupants[52] [54].

The project was funded by a grant of the Romanian Ministry of Research and Innovation, CCCDI - UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0391 / CIA_CLIM –Smart buildings adaptable to the climate change effects, within PNCDI III.

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5. EXTENSIVE RETROFITTING OF COLLECTIVE HOUSING MADE OF LARGE PREFABRICATED PANELS.

5.1. Context and requirements.

The rehabilitation of collective dwellings built using large prefabricated panels has become national priority for Romania, considering the impact it can have on the urban population and the commitments assumed at the national level regarding the European energy objectives.

If at the time of their construction they were presented as the viable solution to the urgent problem of housing the newly arrived urban population, the four decades of exploitation have shown that they present a series of problems determined by factors ranging from physical wear and tear, poor execution on the construction site, results from the demands imposed by the political regime (regarding economy, speed of execution and high density of housing units).

Thus, the inhabitants of these blocks are faced with problems such as poor interior comfort and the reduced possibilities of adapting the interior of the apartments to contemporary living needs. Furthermore, due to the massive densification imposed by the political regime, the social infrastructure in these neighbourhoods is often deficient and there is a great lack of parking spaces, doubled these days by bad public space management. Added to this is the fact that the average available living space per capita places our country at the bottom of the European ranking (according to the BPIE Report) [1].

In this chapter, we try to answer to what extent the collective housing made of large prefabricated panels can be transposed in today's society, through a substance rehabilitation strategy, which responds to the real needs of the inhabitants, at the same time defining a high standard of living, in resonance with matrix of contemporary housing.

According to the national census of 1992[2], in the so-called "grey districts" finds approximately 1.8% of the total stock of residential buildings. These neighbourhoods of collective housing were built until the 70s during the period of industrialization accelerated during the communist regime. Despite this number of buildings, approximately 60% of the urban population in Romania lives in these neighbourhoods. Although these buildings are less than half their normal lifespan, many no longer meet contemporary living conditions. The building stock standard needs modernization, adaptation, and strategies that could benefit Romania's urban population. There is an obvious need to refurbish buildings, which is a necessity for existing communities who live in these "grey neighbourhoods".

The traditional way of life of the communities will slowly disappear with most of the current owners of housing in collective blocks. Living in collective housing must be maintained as it is a necessity and a reality. These communities must be encouraged to define their identity and appropriate social behaviour. Own initiatives or collectives should be present at every step, being the social promoter.

Because the intervention objectives target the urban environment, which has a relatively homogeneous population, the differentiation between social categories is based on criteria of age, income and lifestyle. The defined categories are:

Young people aged 18-30

The project mainly aims at young people between the ages of 18 and 30, married or not, who have jobs and seniority of six to seven years of field of activity. The average income in Romania for a young beginner begins with the minimum gross salary of 700 lei (in 2012) [3]and if that person is ambitious and eager to be promoted, this income can increase, in the first years, by approximately 15% annually.

The lifestyle for this type of person is dynamic; young people party quite a bit of time indoors and therefore household consumption is low. The main activities carried out in the apartment are rest and entertainment: the sea most prefer to invite their friends at least once a week.

Financially, young people present significant job risks uncertainty and lack of experience, counterbalanced by openness to new things and technology.

Adults with children between the ages of 30 and 65

The second social category to which the project is addressed is the formed family of two adults and one child. At this age there is some stability and responsibility in terms of income and level of consumption. Income increases they arise with the accumulation of experience. At the mature age of 30-65, the income monthly average in Romania, in 2012, was 1,743 lei. During this period, the study shows that Romanians have approximately four hours of free time during the week and nine hours during the weekend. The same study reveals that 80% of these people prefer to spend their free time from working days at home [3].

The elderly over 65 years old

The main source of income for this social category is the pension. Into the 2012, there were 5,480,000 pensioners in Romania, with an average monthly income of 773 lei (National Institute of Statistics). Although energy costs in Romania are the highest small throughout the European Union, many Romanians have problems paying their bills electricity. The reasons are various: low incomes, inadequate buildings' insulation, and increasing prices. Therefore, almost 17% of the monthly income is allocated for electricity, gas or water bills. Regarding electricity, prices increased by 10% on January 1, and natural gas prices will be increased from July 1.[3] On the other hand, the economic map and the business environment show the development discrepancy between the regions in Romania and a gap between counties in the same development region. Timiș County, for example, it holds 42% of the total workforce in the Western Region and has an index of productivity (GDP / capita) of 8,700 euros, 30% above the average of the region and 83% above that of Caraș-Severin county.[3] [4] Given these conditions and the relatively large amount of time spent indoors during the week, increase electricity, gas or water bills, how they also increase due to price increases.

5.1.1 Urban strategies.

Most common spaces in the neighbourhood are occupied by cars, which hinders the development of community amenities while at the same time the terraced roofs of the apartment blocks remain largely unexploited.

The adopted solution involves the extension of the structure on the terrace with intended constructions to create community spaces. The connections between them will generate a public place of promenade overlooking the city. The reconfigured staircase will provide access unfettered, both for tenants and potential visitors. The configuration standard of existing apartments no longer meets the needs of contemporary Romanian society. At the same time, the large population living in these buildings require the redefinition of the interior configuration of the apartments, taking into account of the specific lifestyle of various categories of end users: tenants, families with single child and retired couples. Supplementing the space is not only that necessary, but also possible. As a direct consequence, the intervention assumes the reorganization of the public domain to accommodate new functions and improve the existing ones. From the point of view of the street, since the street profile is quite small, and the number of parking lots is insufficient, parking insurance will be required do in common parking lots, either underground with a green roof, or multi-storey above-ground set up in residual spaces or on land near homes.

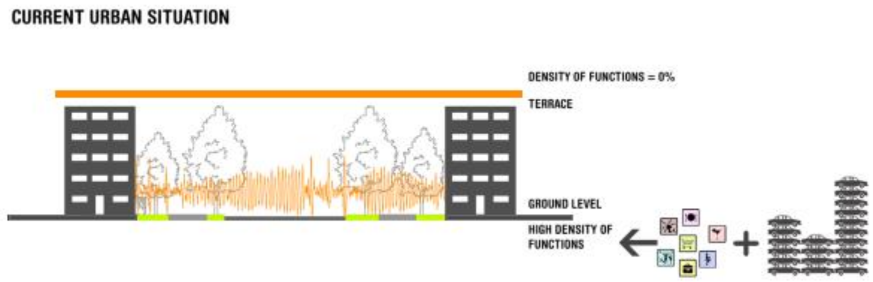

Figure 5.1. Current urban situation diagram

The space left free after clearing the inner courtyards of garages and parking lots it will turn into spaces for playing, socializing, or green promenades wit state seats. Also, the resulting spaces will be connected to each other by pedestrian networks and tracks of bicycles. Lighted, open and vegetated alleys will ensure security and the feeling of trust. The network can also accommodate small plots of urban gardening or agriculture, ideal for eliminating everyday stress. Gardening is possible it can also be done at block level on its terrace, the resulting products can be used generating income. Regardless of the investment threshold, urban redevelopment also allows for rapid human connection that will be capitalized on of the small initiatives that can start from within the community.

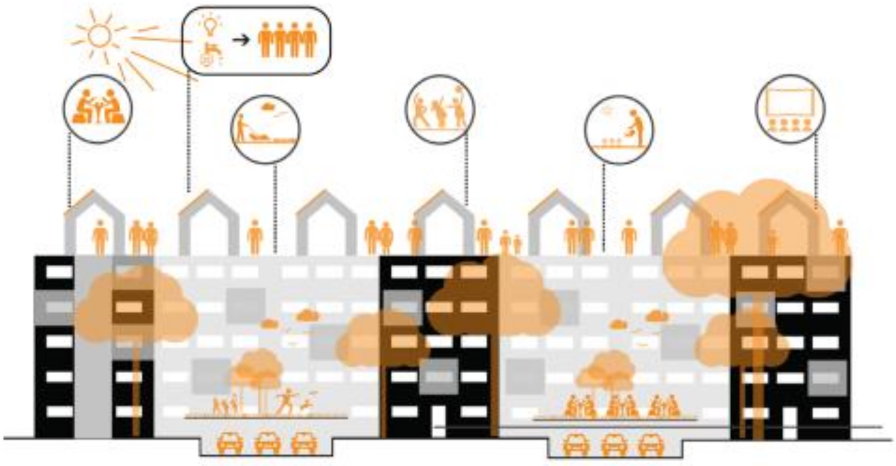

Figure 5.2. Holistic rehabilitation concept

It is not enough to recreate the negative space, it is also necessary to create one itinerary of activities to create its own identity, but also to enliven the space result. Like the garden city concept, the neighbourhood will be divided into cores of activity to create diversity and ensure small oases of peace. This way, the community will be in close contact, both with its members, but also with the other entities such as: the administration, the economic environment, the academic environment or NGOs. Public space becomes a platform through which the community communicates, remanifests and reacts in a responsible way towards its members, towards the environment, against all the factors that influence it.

A major importance is given to the implementation of a grounded electrical network on photovoltaic panels arranged on the terraces of the blocks or on the roofs of the premises which will partially ensure the energy consumption of the common spaces (elevator, staircase, the entrance to the block, the multifunctional space, but also of the public lighting in stations of bicycles, bus, etc.). To these are added water collectors arranged in the spaces on the terrace of the block or in public places. The collectors will be used for water reuse rainwater for bathrooms or for irrigating green spaces [5].

5.1.2 Existing architecture as support for retrofitting.

The most common typology of blocks in Timisoara is the one with a ground floor and four-story types 770 and 1340, built between 1970-1985 and 1980-1990, respectively, which, however, only offer minimal living conditions. All these constructive types were created to be combined in different ways in order to achieve variety apparent in, at that time, the new neighbourhoods. But the repetitive pattern is still perceived, producing a sense of confusion as the neighbourhoods have no identity visual.

Therefore, upgrading of these housing blocks can be seen and as an opportunity to develop a neighbourhood identity. On the occasion of the research, I narrowed the field to the most widespread model in Timisoara, of course, the 770.

Figure 5.3. Model 770 distribution in one of the major neighbourhoods in Timisoara

This type of block was widely used throughout the country in the 70s and at the beginning of the 80s of the last century. That's why we find it everywhere - in Arad, Cluj, Brașov, Bucharest, Iași or Ploiesti, etc. This great dispersion of such model project throughout the country was part of an effective targeted strategy towards industrialization, accessibility, transportation and speed of execution. Every type of project was developed starting from precisely and rationally dimensioned prefabricated components to be delivered to the construction site to be assembled in the shortest possible time with possibility. In the case of block type 770 there were 68 subtypes, varying through panels exterior and interior verticals, through the type of ceilings, stairs and bathrooms.

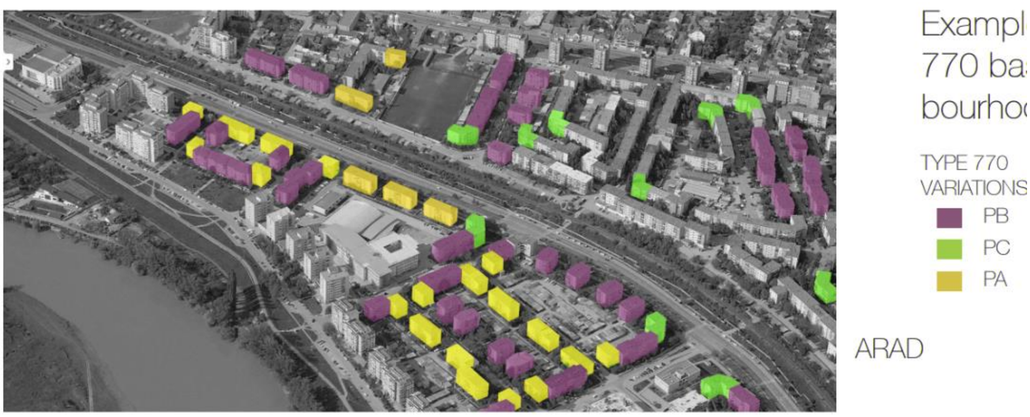

Figure 5.4. Model 770 distribution in Arad

Figure 5.5. Model 770 distribution in Brasov

Figure 5.6. Model 770 distribution in Bucharest

Figure 5.7. Model 770 distribution in Cluj

Figure 5.8. Model 770 distribution in Iasi

Figure 5.9. Model 770 distribution in Ploiesti

Five types and sizes of prefabricated panels were available for this model, respectively of 2.40; 3; 3.30; 3.60 and 5.40 meters long. Starting from existing prefabricated building elements resulted in a development strategy organically, also through industrialization, of new components for modernization apartments, blocks of flats, blocks of flats and entire neighbourhoods. Into the based on the prefabrication strategy, three subtypes of the 770 model have been identified: Pa, Pb and PC, these being differentiated by planimetry [5].

The typology studied in this work is Pa which has four subtypes: PA1, PA2, PA3, PA4. The first subtype, PA1, has two span sizes of 3.30 m and 3 m. This model has three apartments on each level, each with only two small rooms. Two of the apartments are double facing and only the middle apartment it has two balconies only on one side. The useful surfaces of the apartments are of 65.67 m (ground floor apartment with three rooms), of 49.50 sqm and 46.60 sqm. blocks of the Pa subtype are placed N-S and the apartments have a double orientation [6].

However, only 27% of these blocks are in their original state and only 4% of these buildings are thermally rehabilitated [3] [7]. Moreover, the blocks on which the residents intervened on the original terraced roof, replacing it with a gable roof slope dominate the landscape and represent 69% of the total. In the Soarelui District of Timișoara, this type of interventions is the most numerous, with around

80% of them having this type of intervention. Blocks were run with each of the twelve subtypes of homes with a number of apartments ranging from 10 to 20, blocks linked between them and forming rows of buildings. Several types of connections are defined, these causing different positions of the block in the row of blocks [6].

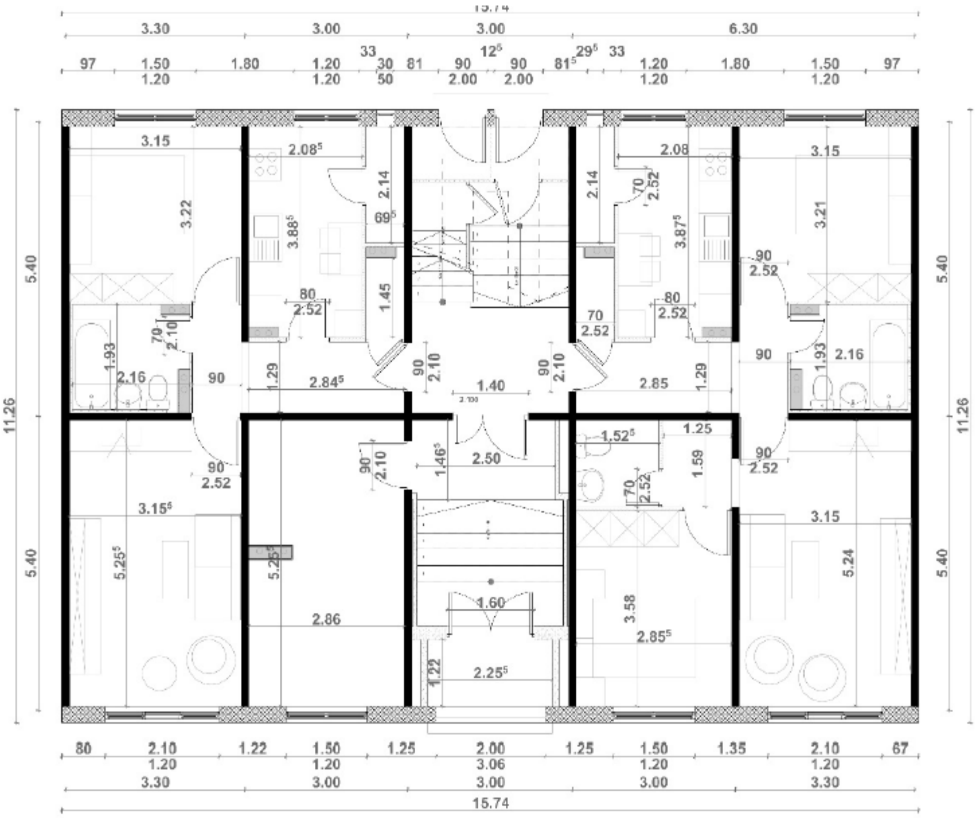

Figure 5.10. Model 770 ground floor plan

Several issues have been identified, such as the staircase, the lack of an elevator or the size of the apartments, especially those with loggias. The layout of the apartments also shows deficiencies in compliance with modern living standards, because they were designed for people who spent a lot of time in the kitchen (cooking for the whole family) and conversing. Nowadays the public is reoriented towards a much more dynamic lifestyle, cooking becoming a rather sporadic activity. The main problems of model 770 are:

- insufficient natural light
- lack of space and
- the low level of comfort, especially in narrow bay configurations.

It should be noted that the dimensions of these homes were made for a population with a generally low financial situation who owned a small amount of goods. Currently, the number of goods is constantly increasing, and the spaces of old storage are not enough for current needs.

If we consider current housing standards, major changes are observed regarding the importance of rooms related to its dimensions. More than that, new equipment has appeared that requires space, but also the behaviour of the user has changed over time. In 1975 the apartment under consideration was sized according to the rules in force on that date for two people with an area of 44 sqm, of which 27.1 sqm are useful and habitable. On this surface we consider the bathroom with 4 sqm., the kitchen with 7 sqm. and the hall with 3.70 sqm., the rest being either installation spaces or storage rooms.

Today, the Housing Law [8][5] states that the minimum area for a 2-room apartment inhabited by two people is 52 sqm, of which delimits: 2 sqm storage area, 4.5 sqm sanitary rooms, 18 sqm living room, 12 sqm bedroom, 8 sqm kitchen and dining area. From these figures we give note that the standards to which these apartments were designed and executed do not more correspond to reality. For this reason, the biggest challenge is to modify an existing structure without massive intervention so that you respect the standards current housing issues. Moreover, a minimum volume of 15 is also required cubic meters of fresh air for each person using the apartment. This thing translates into the need for additional ventilation that provides a minimum air exchange of 0.5 of the total volume per hour. In the current conditions this is almost impossible to achieve because ventilation is provided manually and depends on everyone's behaviour.

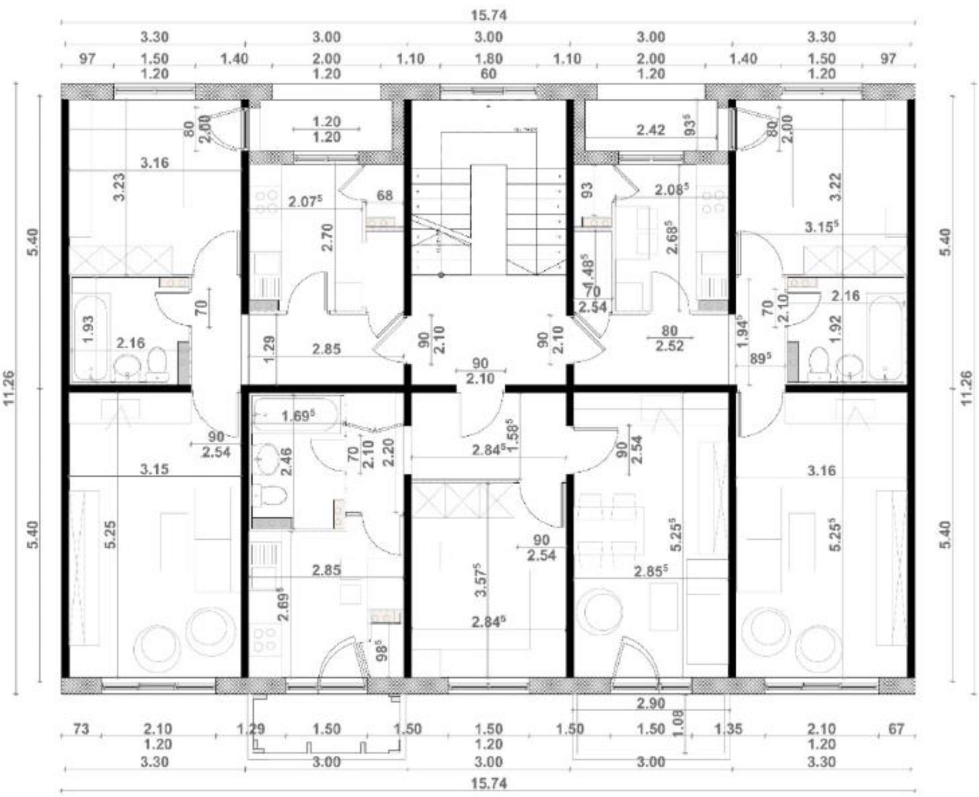

Figure 5.11. Model 770 typical floor plan

Figure 5.12. Model 770 elevation and section

Before detailing the solution below architectural, interventional limitations due to costs should also be mentioned, and namely: enlarging the openings in the facade, staircase redesign to accommodate a elevator, redesign of the apartments to be able to use the useful space to the maximum available through multifunctional furniture, horizontal extensions to the level of the balconies with the limitation of the protruding surfaces in the console, the complete retrofit of thermal insulation and the introduction of the walkable terrace. The ultimate challenge is, however, the acceptability of using alternative heating systems, under the conditions of a market in smaller and smaller of the central heating agent.

The architectural solution touches on three main elements, the first relates to the building envelope with the new thermal insulation and finish, the second refers to the redesign of vertical circulation with the differentiation of access and the last to the functional interior of the apartment.

The weak points of the model presented above can be seen as opportunities for new ideas. That's why an example of good practices in a city like Timișoara can change significantly the residents' perception of the possibilities of the existing housing stock.

After analysing a 770 model (the one that offers the poorest living conditions regarding space and energy efficiency) can be said, as a conclusion preliminary, that only an integrated design system can offer solutions to these problems to such a building. But the intervention can be done step by step, with cheap means and with the passive systems most suitable for the local context (Romania is a country in development course with low per capita income and low level of knowledge high tech). The solution is adapted to local conditions and is based on a system integrated that takes into account a strategy that involves the use of materials of construction. The project improves the energy efficiency of the building, using interventions innovative in its thermal envelope and which are in harmony with the environment as well as a local source of renewable energy, through the integration of solar panels and photovoltaics. The situation on the real estate market affected the strategy which was more focused on the technical aspects involved in achieving energy efficiency, as well as on the social needs and the quality of life of individuals and communities in general. Thus, the attention has focused on several different aspects [5] [9].

5.1.3 Reducing the energy demands

A first step towards lower consumption can be achieved by overall reduction or limitation of energy demands. This will be reached by reducing the amount of energy consumed for heating, cooling and lighting. Specifically, for a better heating and cooling, improving energy performance will focus on improving thermal transfer of the existing concrete wall, by adding an insulating layer of mineral wool which will bring the total U value opaque walls to approximately 0.15 Wm2k - according to passive renovation standards, in our case enerPHIT [10].

By replacing existing windows with more energy efficient ones and creating a new thermal envelope, more efficient, which will help reducing the consumption of energy by reducing heat transfer to the environment. They will increase the gaps of the windows, to allow more sunlight to enter apartments and, at the same time, in their possible enlargement. By using retractable shading devices, the rooms will benefit from more sunlight during the day thus reducing artificial lighting. In order to improve the lighting during the day, materials will be used and paints with highly reflective colours for floors and room interiors.

A second step is given by the introduction of equipment and appliances energy-efficient household appliances that have low consumption and that are purchased on the principle of the most efficient technology at the most affordable price on the market.

5.1.4 Active and passive solar systems

By installing combined solar panels, for heating and photovoltaics, thermal energy will be supplied for heating, at a lower temperature, due to of the adopted system, respectively underfloor radiant system and electricity for to cover part of the requirement for the pumps and fans used in the system of ventilation. The rest will be used for common and tenant spaces. [11][12][13][14]. To reduce and more electricity consumption will be provided for automatic lighting with presence sensors and LED lighting fixtures and appliances will be used energy efficient.

5.1.5 Addressing accessibility issues

The existing staircases and access routes were not designed for use and residents with disabilities. To allow a high degree of accessibility a new staircase was designed. The new staircase will replace the existing ones made of two prefabricated ramps. The new staircase will have a 1.2m wide ramp as well as an elevator added to the outside of the building in a cabin made on a frame with a light-weight steel structure. To achieve higher construction speed and reduced impact on tenants, all new elements are made of steel prefabs [13].

The construction process will be managed in such a way as to allow tenants to remain in apartments during construction. This will be achieved through the construction of the elevator car before the demolition of the staircase. Temporary stairs will be used which will allow vertical movement during the demolition of the staircase and facade panels existing. Demolition will be done by cutting the concrete with disc devices cutting out small pieces to eliminate any risk of injury to this operation [13].

The process will be carried out in two stages on each level and will consist of removing the facade element, allowing connection to the temporary scale, when the two landings of the staircase between the 3rd floor and the landing between the 3rd and 4th floors will be eliminated. During this process the tenants on the 4th floor will use for access to apartments the temporary staircase and the stairs up to the 3rd floor. This process will be repeated for all four levels. After the demolition of the old staircase, the new flights will be installed of prefabricated stairs. They will rest on the existing floors and beams link mounted next to the removed facade panels. When all new stair flights will be put in their position, the temporary stair will be dismantled, to make room the elevator [13].

The safety of tenants will be ensured by controlling access to stairs and elevators magnetic cards, not allowing foreigners access to the intermediate levels, but only to possible public rooftop extensions [13].

5.2. Thermal rehabilitation in Romania.

The thermal rehabilitation of residential buildings is not only a problem Romania [15]. And in the other ex-communist countries of Eastern Europe, but also on the whole territory of the former USSR, there are the same issues, although the approach is different. Today, the whole world is concerned with saving energy, regardless of the place or position he is in. Old buildings constitute a heritage in all countries the world, and for several years there has been a start to improve the existing fund and not for its demolition. Specialist calculations show that it is cheaper to rehabilitate a building, rather than demolishing and building a new one. The rehabilitation process of an existing buildings, however, requires complex interventions aimed at improvement general of it. It involves a redefinition and implicitly a redesign of the building, starting from its existing structure, installations, functionality, comfort and aesthetics, natural and created space, indoor and outdoor environment, materials and products used, the efficiency of the interventions, the amortization of the investment, etc. Intervention costs they will always be a major decision factor. The existing housing bock is outdated in terms of the demands of life now, both for builders (architects and engineers), administrators, researchers and users. But no one it cannot afford to demolish them in order to build new ones, subject to the conditions of current comfort. And if we did, tomorrow they would also be outdated, the world evolving [3] [15].

The process of rehabilitation involves different stages and approaches. There are general interventions, complex involving functional and structural changes, modernization is necessary installations, thermal and acoustic rehabilitation of the envelope, environmental rehabilitation and aesthetic rehabilitation of the building. Most of the time, however, a holistic approach is not possible, and the reason is financial. Therefore, only certain rehabilitations are done points of view, partially of each data[3].

From and architecture and design perspective there are still issues that are not addressed, by the anonymous aspect of these blocks [15], but also the tire that seems to be a lot too thin for what is needed. There are still some ways to solve the problem balconies, individual interventions transforming the buildings into something very heterogeneous from this point of view. Thermopane windows seal, but in turn generate others internal problems. Then there is the issue of roofs to be discussed. Beyond these aspects are also the seismic ones, so the structural aspects, of which any intervention by rehabilitation should take into account. Unfortunately, there is no financial support program from this point of view. By applying thermal protection, we also covered the damage caused by the major earthquake of 1977. Another aspect not to be neglected is the one related to fire safety [16].

In general, the methodology is followed without problems, but it is limiting the possibilities of using mineral wool as an insulator and metal windows, a thin plaster, natural and artificial stone. But this solution increases costs. There are also aspects related to noise protection, but also hygiene and environmental protection. During the execution of the thermal rehabilitation works, they were found various deficiencies, especially in finishing, their quality leaving much to be desired. Replacing windows is also not an easy thing. If we are talking about roofs, there is also something to discuss here what do we do with the multitude of devices, equipment and advertising structures on them, or with the frames executed without a secure anchorage in the existing structure.

It is good that this process of rehabilitating the collective housing blocks has started, because, in this way, a cultural dimension is also preserved, of which it does not seem to no one takes into account when talking about rehabilitation, in general.

5.2.1 Thermal rehabilitation or a new attic

After 1990, until the appearance of Government Ordinance no. 18/2009[17] on increasing the energy performance of housing blocks, attics, overstory and the construction of truss roofs with the arrangement of bridges unheated were considered urban regeneration measures and at the same time by thermal rehabilitation of these buildings. In a way, it is. The attic was born due to problems arising in connection with the waterproofing of roofs terrace, as a solution to these. The attic is defined as a room or assembly of habitable rooms, placed immediately under the roof (having the ceiling and slanted walls or irregular); floor located immediately under the roof of a building [18]. Basically, it is the attic, or the top floor of a house, placed under the roof, with the ceiling pitched and arranged as a house. A home made with an attic can not only represent an advantage, offering, through the construction system and the materials used, a comfort, both thermally and acoustically, much superior, but it can also represent an alternative for those who decided to buy an old apartment on the real estate market.

Its main characteristics are:

- it is a light construction (from light non-combustible structures) that will lean against the walls of the block;
- it has its own platform, built above the last floor top slab;
- the electrical, water, heating, drainage and gas installations of the attic they will be connected to the common installations of the block through the space between the terrace of the block and attic

- the attic will have a level or one and a half, according to the structural expertise assessment;
- the attic roof is of the classic roof frame type.

Sure, the attic is a thermal rehabilitation solution, but a partial one, for that it only touches the terraced roof it replaces. The thermal rehabilitation process is much more complex, primarily aiming at the achievement of an energy savings, but also comfort and environmental factors. From a technical point of view, the attic is very well set up, there being a developed technical norm [19].

5.2.2 Law issues

Although there are currently a large number of attics made, the legal problems related to them have not been overcome, despite efforts to resolve or remove them. Thus, in addition to the poor quality of the executed works, co-ownership on the common parts is the main cause that generated these problems.

Local authorities have been overwhelmed by the number of requests for authorization of such of works, which is why they developed, in order to keep the phenomenon under control, local town planning regulations. With however, there are quite a few attics built without being authorized. In 2012, Ministry of Development, Public Works and Housing (MDLPL), to go over the reality of co-ownership and the problems it generates for the business itself, that of attics of collective housing blocks, amended Law 230/2007 regarding the establishment, organization and operation of owners' associations, stipulating that the works of over-storing and/or attic of a building can be carried out by the association of owners, if the decision is approved by two thirds of the members the association and all the owners of the houses on the top floor of the building.

The legislative change was motivated by the need to allow works to be carried out of rehabilitation and attic of residential buildings, and regulates the decision of initiation of the works, as well as the alienation of the undivided share of the properties individual from the terrace of the block. Eventually these provisions were introduced at Law of cadastre and real estate advertising no. 7/1996, through an amendment from 2010 [20] and generated numerous litigations, contravening the provisions of the Civil Code. Through Decision of the Constitutional Court no. 1514/2011 regarding the admission of the exception of unconstitutionality of the provisions of art. 45 para. (3) - (6) of the Cadastre Law and a real estate advertisement no. 7/1996., starting from 12.01.2012, it returns to the situation in advance, and the attic can only be done with the express consent of all the owners. All this legislative instability is due, first of all, to the pressure of the construction companies that made the attic of the blocks a business, but also the fact that the political decision-maker has adopted this type of attitude, under pressure being also the effects of the economic crisis and the need to unlock the economy, the sector constructions being among the most affected by the effects of the crisis that started in 2009 [21].

5.3. Rehabilitation solutions for the existing building. Thermal and energy simulations.

In the following, three scenarios for extensive retrofitting are presented, considering implementation difficulties and costs.

The first scenario and the most accessible consist of an upgrade to the existing building envelope with new insulation materials and more efficient window elements.

In addition to a new thermal envelope, the second option offers a secondary building façade made out of lightweight steel structure. The structure is fastened to the existing reinforced prefabricated concrete panels and provides support a possible horizontal extension of the apartments.

The final scenario, and the most challenging is the redesign of the current staircase and the addition of an elevator to solve accessibility issues. Due to the significant implications of the solution the terrace roof is also transformed into a public space with different functions. These functions also serve as support for installing renewable energy systems.

The results are compared with the C107 [22] norms for thermal resistance of building components of residential buildings. These base values are presented below.

Component	$R'_{min}[m^2K/W]$	$U'_{max}[W/m^2K]$
Outer walls	1.80	0.56
Windows	0.77	1.30
Top slab/Roof	5	0.20

Table 5.1. Building envelope elements thermal resistance values

5.3.1 Simulation process and input data

The thermal behaviour of the building's envelope, existing and new, is studied using the online U-calculation platform Ubakus [23]. The platform is easy to use and it allows generation of building components using either existing embedded materials or creation of new ones for further use.

The energy simulations are carried out with ArchiCAD's Energy Evaluation option [24]. The calculations were carried out on the middle apartment of the 770 model. The way it works is a base model of the building is generated. Using the Zone tool, thermal blocks are defined within the model and added into the interface. Also following data have been considered:

- Inside temperature: 20 °C and 40% humidity
- Outside temperature -5°C and 60% humidity
- Gross Floor Area: 52.60 sqm
- Treated Floor Area: 46.40 sqm
- External Envelope Area: 124.50 sqm
- Ventilated Volume: 133.12 sqm
- Glazing Ratio: 3%
- human heat gain: 70W per user;
- service hot-water load: 60l/day per user;
- humidity load: 2g/day per user;

- usage rate: 6264hours/year;
- lighting: LEDs;
- heating: 1500W nominal capacity electric space heater.
- Cooling: 12000 BTU wall-mount cooling system
- Overall window U-value 4.93 (2.11 opaque / 5.20 glazing)

5.3.2 Current situation. Collective housing unit before thermal rehabilitation

The load-bearing outer walls are made of reinforced prefabricated concrete panels, with an average total thickness of 27 cm. The 12.5 cm resistance layer, as well as the 5 cm protection layer, are made of reinforced concrete B250 (C16/20), having a 7.5 cm thermal insulation layer of aerated concrete and EPS granules. The overall thermal performance is presented below. The complete thermal assessment is presented in Annex 4 -5.

770 Existing outer wall, R=1,35 m²K/W

Temperature profile

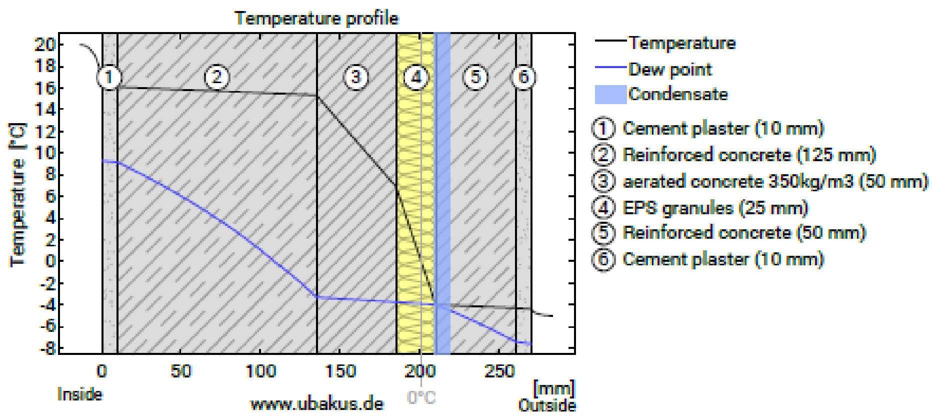

Figure 5.14. Temperature profile of the existing building envelope

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,130	16,2	20,0	
1	1 cm	Cement plaster	1,400	0,007	16,1	16,2	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	15,3	16,1	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	6,9	15,3	17,5
4	2,5 cm	EPS granules	0,035	0,714	-4,0	6,9	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	-4,3	-4,0	120,0
6	1 cm	Cement plaster	1,400	0,007	-4,4	-4,3	20,0
		Thermal contact resistance*		0,040	-5,0	-4,4	
	27 cm	Whole component		1,524			478,0

Figure 5.15. Thermal performance of layers. *Thermal contact resistances according to DIN 6946*[64] *for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3* [65] *were used for moisture proofing and temperature profile.*

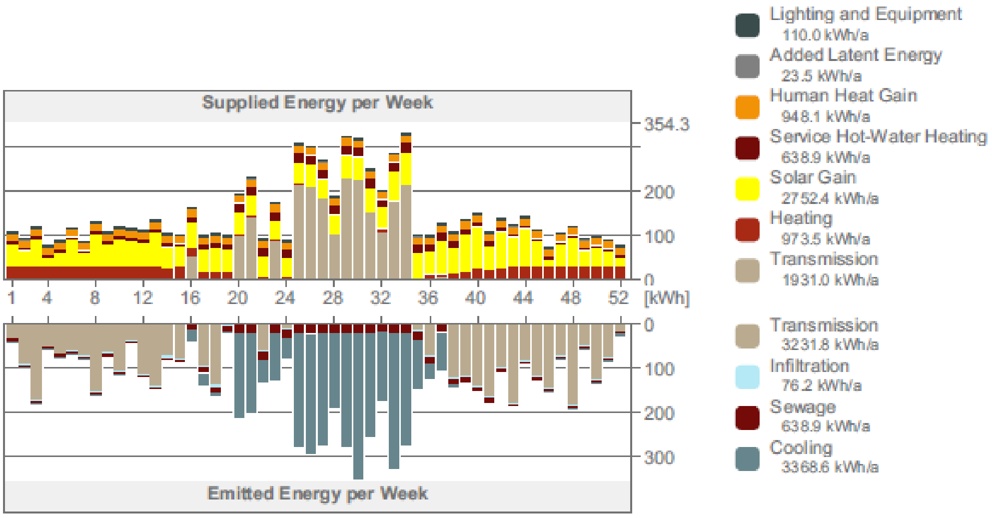

Figure 5.16. Existing building energy balance

5.3.3 First scenario. Current situation. Collective housing unit after standard thermal rehabilitation

The current thermal rehabilitation program ensures a minimum of 8 cm thermal insulation XPS boards (extruded polystyrene) on top of the existing prefabricated panels. At the floor slab area these boards are replaced with a 60 cm mineral wool strip to prevent fire from spreading on the façade of the building. The upside in this case is a shorter execution. The downside, however is the execution process. In most cases the small gap is formed between the insulation boards and the building façade due to improper installation. This leads to formation of mould on the inner side of the board and in time those gaps can widen and compromise the entire envelope.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,130	18,4	20,0	
1	1 cm	Cement plaster	1,400	0,007	18,4	18,4	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	18,0	18,4	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	14,5	18,0	17,5
4	2,5 cm	EPS granules	0,035	0,714	10,0	14,5	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	9,8	10,0	120,0
6	8 cm	Extruded polystyrene (XPS 035)	0,035	2,286	-4,7	9,8	2,8
7	1 cm	Cement plaster	1,400	0,007	-4,7	-4,7	20,0
		Thermal contact resistance*		0,040	-5,0	-4,7	
	35 cm	Whole component		3,810			480,8

Figure 5.17. Thermal performance of layers. *Thermal contact resistances according to DIN 6946*[64] *for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3* [65] *were used for moisture proofing and temperature profile.*

770 Existing outer wall - Classic thermal rehabilitation, R=3,64 m²K/W

Temperature profile

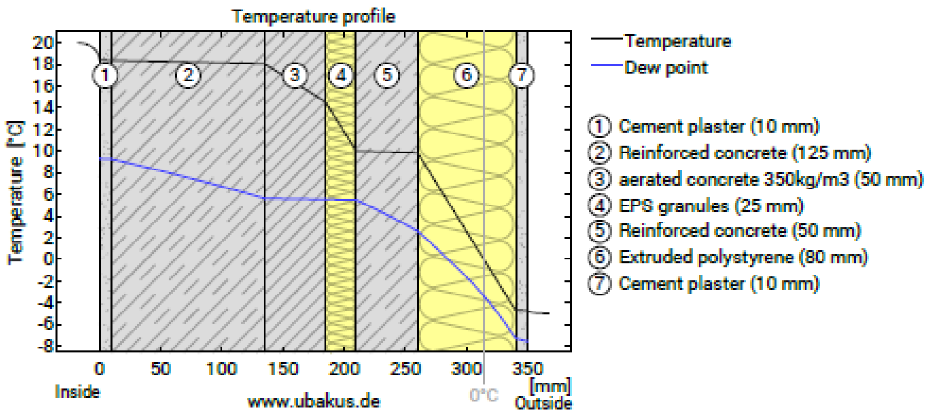

Figure 5.18. Temperature profile of the building envelope for the standard thermal rehabilitation option

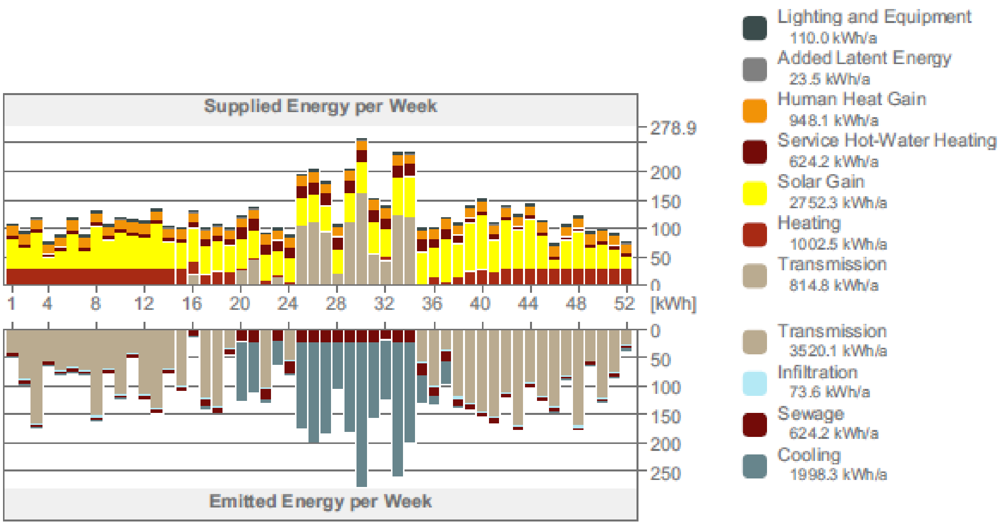

Figure 5.19. Existing building energy balance - standard thermal rehabilitation option

The total energy consumption resulted from the simulation is 3735 kwh/year out of which 1002 kwh/year are for heating, 1998 kwh/year for cooling and 110 kwh/year for lighting.

5.3.4 First scenario. New situation. First option

This thermal envelope option replaced the standard polystyrene layer with mineral wool. It results in a more environment friendly system from and LCA point, more performant due to the increased thickness (10 cm) and thermal properties of the material. It results in total energy consumption of 3684 kwh/year, out of which 1001 kwh/year for heating, 1948 kwh/year cooling and 110 kwh/year lighting.

770 Existing outer wall - Proposed rehabiliation v1, R=4,21 m²K/W

Temperature profile

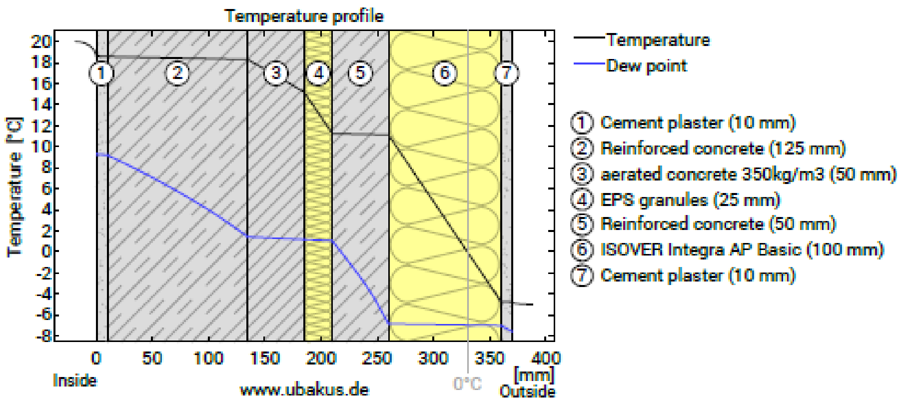

Figure 5.20. Temperature profile of the building envelope for the first thermal rehabilitation option

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,130	18,6	20,0	
1	1 cm	Cement plaster	1,400	0,007	18,6	18,6	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	18,3	18,6	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	15,2	18,3	17,5
4	2,5 cm	EPS granules	0,035	0,714	11,2	15,2	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	11,1	11,2	120,0
6	10 cm	ISOVER Integra AP Basic	0,035	2,857	-4,7	11,1	no inform ation
7	1 cm	Cement plaster	1,400	0,007	-4,8	-4,7	20,0
		Thermal contact resistance*		0,040	-5,0	-4,8	
	37 cm	Whole component		4,381			>478

Figure 5.21. Thermal performance of layers. *Thermal contact resistances according to DIN 6946*[64] *for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3* [65] *were used for moisture proofing and temperature profile.*

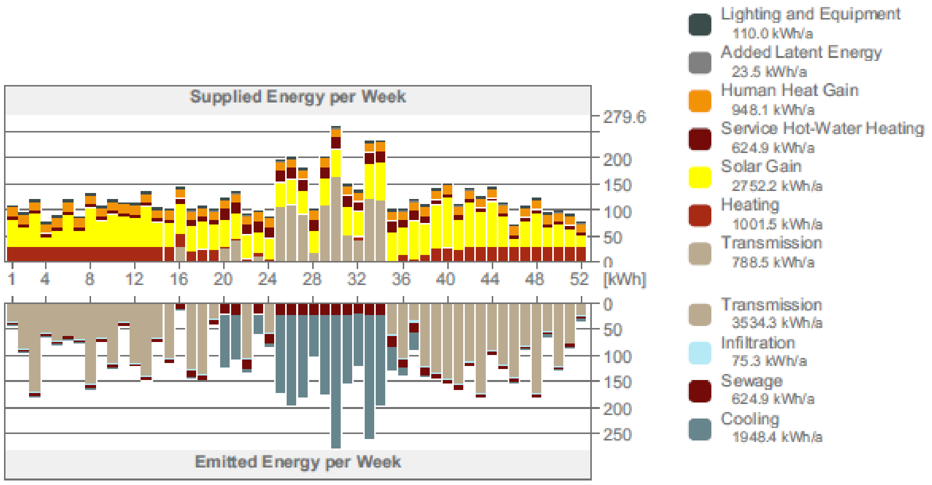

Figure 5.22. Existing building energy balance - first thermal rehabilitation option

5.3.5 First scenario. New situation. Second option. An alternative to standard insulation materials

This option is based on the PET insulation boards study carried out in the previous chapter. In this case the total thickness of the boards is 15 cm in order to achieve similar results as the mineral wool option. The total energy used is 3732 kwh/year, with 1002 kwh/year being for heating, 1995 kwh/year cooling and 110 kwh/year lighting.

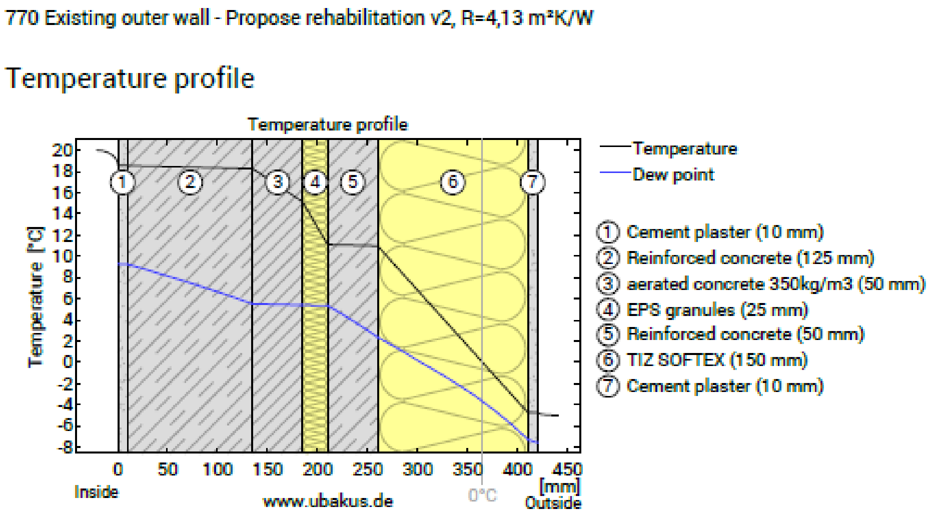

Figure 5.23. Temperature profile of the building envelope for the second thermal rehabilitation option using alternative insulation materials

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	18,6	20,0	
1	1 cm	Cement plaster	1,400	0,007	18,5	18,6	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	18,3	18,5	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	15,1	18,3	17,5
4	2,5 cm	EPS granules	0,035	0,714	11,1	15,1	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	11,0	11,1	120,0
6	15 cm	TIZ SOFTEX	0,054	2,778	-4,7	11,0	3,0
7	1 cm	Cement plaster	1,400	0,007	-4,8	-4,7	20,0
		Thermal contact resistance*		0,040	-5,0	-4,8	
	42 cm	Whole component		4,302			481,0

Figure 5.23. Thermal performance of layers. *Thermal contact resistances according to DIN 6946*[64] *for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3* [65] *were used for moisture proofing and temperature profile.*

The overall results for heating and cooling are summarized in the table below:

Evelope	Overall energy [khw/year]	Heating [khw/year]	Cooling [khw/year]	R'_{min} [m²K/W]
Existing building	5090	973	3368	1.35
XPS 8 cm	3735	1002	1998	3.64
Mineral wool 10cm	3684	1001	1948	4.21
PET insulation 15cm	3732	1002	1996	4.13

Table 5.2. Summarized result of thermal envelope solutions

5.3.6 Second scenario. Secondary building façade. Possible apartment extension

This option proposes creating a secondary façade detached to the existing building, replacing the existing balconies and offering structural support for a possible future horizontal extension of the apartments.

The new main structural elements are HEA 180 beam and column profiles which are, welded to steel endplates and connected to the existing prefabricated panels of the building.

Figure 5.25. Concept image of the additional structure

The first stage of the construction process involves mounting the counter pieces of the assembly inside the apartments, consisting of four 230*160*25 L-profiles. They are connected in pairs by one M16 threaded rod that crosses the internal diaphragm, having the role of preventing axial forces that could cause tearing of the panels in the monolithic area. At the same time, the corners act as a template for making the holes that will pierce the facade panels. Another 4 M16 threaded rods, perpendicular on the facade, are mounted in the previously made holes, being fixed with mortar or chemical anchors to the concrete core of the exterior prefabricated panels.

The second stage involves the factory welding of the 580*580*25 stee plates (end plates) at the end of the 4 beams of the new structure perpendicular on the building envelope. These will distribute part of the crushing forces on the surface of the concrete facade. The large dimensions are justified by the desire to avoid monolithic areas among the 8 prefabricated ones (4 facade panels, 2 transverse diaphragms and 2 floors). It should be mentioned that all the other connections between the elements that make up the new structure are thought to be rigid connections to compensate for the non-rigid character of the connection on the face of the block.

The third stage, the connection with the counter pieces begins with transport of the factory-made elements to the site and their positioning on the intended place on the facade, with the help of a crane. The end plates of the beams are aligned with the M16 rods perpendicular to the facade, the oval holes at the level of the plate take and correct any deviations/ error that might result during fixing of the rods. The module is aligned in the final position, and the unevenness of the facade is corrected with mortar (poured after fixing the element). Thus, the apparent structure allows an easy handling of the prefabricated module on site (the connection to the crane does not affect the thermal envelope or the finish) and accessibility when making the connections.

The final stage involves connecting the closures and adding the new building thermal envelope.

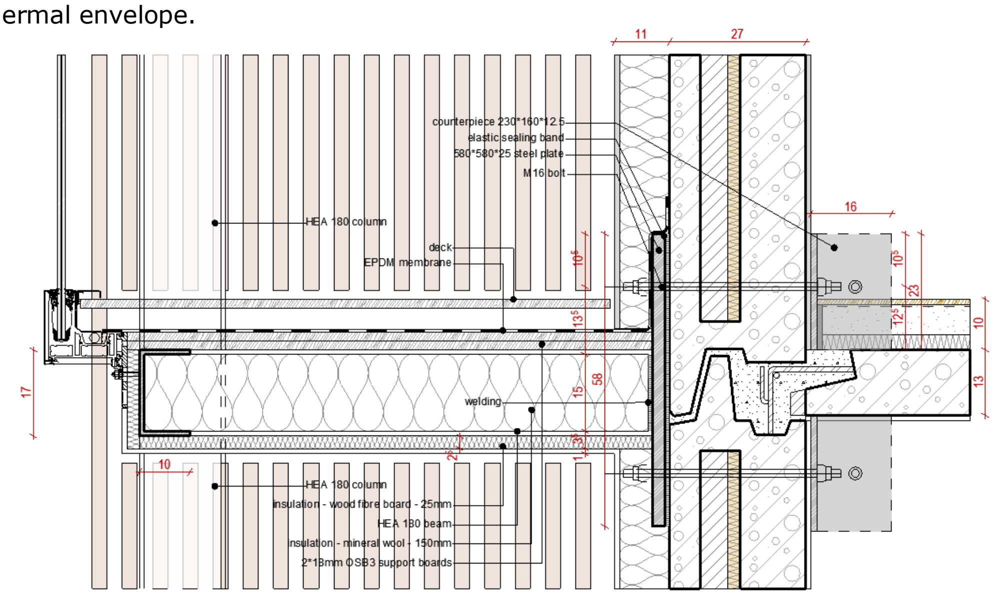

Figure 5.26. Structure detail

To prevent thermal bridges mineral wool hardboards are placed between the steel beams and closed with a 25mm thick wood fibreboard on the bottom face. At the top part, a double layer of OSB boards acts as support for the flooring system: composite decking for the outside, and for continuing the already existing indoor system if required.

5.3.7 Third scenario. New staircase and elevator

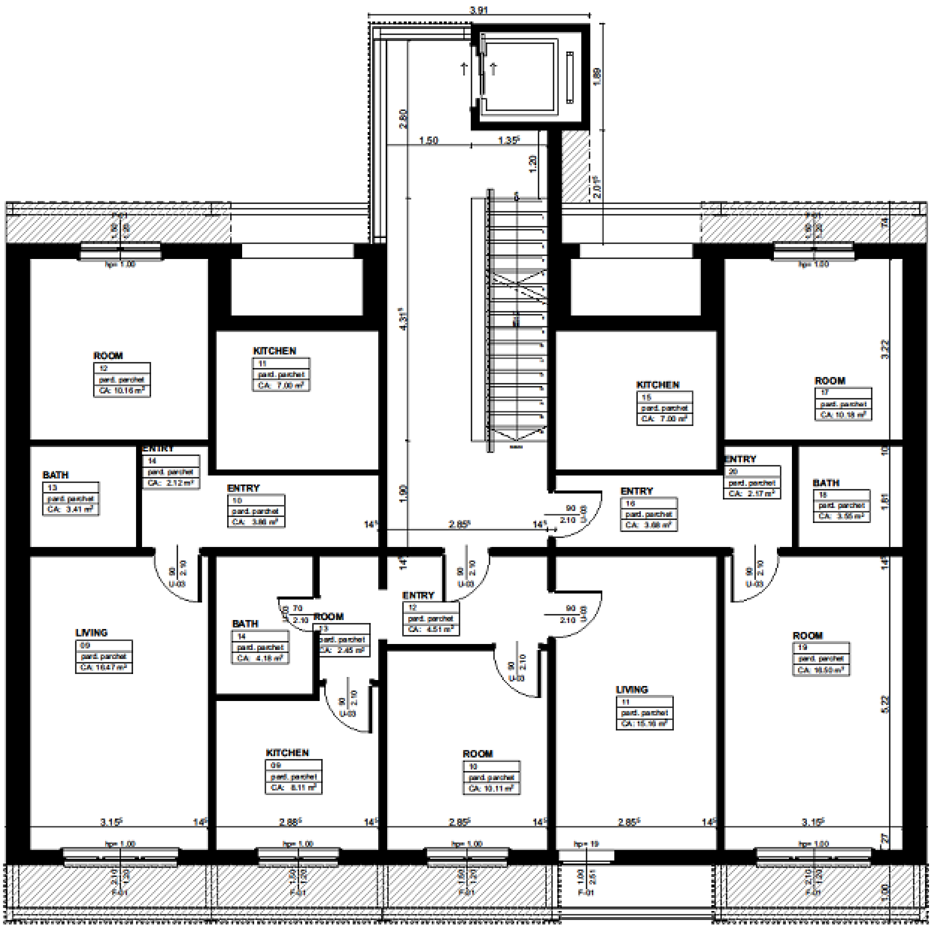

Figure 5.27. New general floor plan of the 770 model

As mentioned above the final additional option for the thermal rehabilitation process is redesigning the existing staircase and adding an elevator to improve accessibility for the tenants.

The existing staircases and access routes were not designed to accommodate disabled inhabitants. In order to allow for a high accessibility level a new staircase was designed. This new staircase will replace the existing stairs made of 2 prefabricated ramps. The new staircase will have one 1.2 meters wide ramp, and an elevator added on the exterior of the building within a metallic structure with lightweight enclosures. In order to achieve high construction speed and low impact on the inhabitants all the new elements are made out of steel prefabricates. The building process will be managed to allow the inhabitants to stay in their homes during the construction period. This will be made by building the new elevator shaft before the demolition stars. The shaft will support a temporary stair that will allow vertical circulation during the demolition of the existing stair and the façade panels. The demolition will be made with concrete cutting devices which will create small pieces that are less dangerous to handle. This process will be a 2 stages operation for each floor:1 the façade element on the 4th floor will be removed, allowing the connection to the temporary stair, 2 the stair ramps between the 3rd and the 4rd floor will be removed. During this process the inhabitants of the 4th floor will be accessing their homes through the temporary stair and those on the 3rd floor on the existing one (that stopped on their floor). This process will be repeated for all the 4 floors. After the demolition the new prefabricated stair ramps will be added. They will be supported on the existing floor slabs and on the new connected beams added in place of the façade panels removed. When all the new stair ramps will be in position the temporary stair will be disassembled in order to make way for the elevator.

It is important to mention that the biggest problem with the new staircase is user acceptability, since the degree of intrusion in the common space, but also in the intimate one, is high. This makes this scenario a holistic one with low chances of implementation. In order to accommodate and elevator within the 770 model the least invasive method would be to extend the intermediary landings of the existing staircase and connect them to the shaft. However, this option solves the problem only halfway.

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6. CONCLUSIONS. FURTHER STUDY DIRECTIONS. PUBLISHED RESULTS

6.1. Conclusions

The post-war period of forced urbanization led to mass migration, millions of people from the countryside to the industrial centers developed in the new one city. Quick and efficient solutions were sought for building housing for the citizens coming in such large numbers to the cities. That's how we got to making block built from large prefabs. Model projects were developed and disseminate throughout the country, giving rise to the so-called "grey districts", in which today almost 60% of Romania's urban population is living. Chapter three shows that these types of repetitive flats and the constructive system used everywhere generates the same image of neighbourhoods and of monotonous public spaces with little scope for improvement. More than that, the small area of the apartments and the restrictive placement of the walls makes it difficult for any architectural intervention.

The construction sector as shown in chapter two, generates a considerable volume of waste every year, which can reach up to 40% in industrialized countries, almost all of which comes from the rehabilitation or demolition of buildings. Therefore, this waste is a key issue and changing the way we manage the use of construction materials is crucial.

This is where the circular economy comes in, a system that aims to make resource use more efficient and reduce environmental impact, while not neglecting people's well-being. In short, when thinking about a product, we need to consider its entire life cycle, from the design phase to the moment it can no longer be used. According to the linear model, at the end of a life cycle products were usually thrown away, but the circular economy proposes a new approach, in 3 steps: reduce-reuse-recycle. Therefore, the famous motto "Nothing is lost, everything is transformed" valid in science can easily be applied in the circular economy as well. All over Europe, architects consider the reuse of materials by other users and the recycling of waste as the main qualities of a circular building economy. A third of them even expect to achieve a fully circular construction economy by 2030.

Chapter 4 shows that alternative thermal insulation solutions using recycled material (in this case PET boards) can perform similar to standard systems, considering thermal performance of layers and indoor air quality, and with a significantly better impact in the end-of-life scenario. Based on the simulations carried out on a test model, the thermal system was applied in Chapter 5 on an apartment building with similar results.

The analysis of one of the most widespread type projects built in Romania (project 770) seeks to reveal the problems that this particular built fund generates at the level of the inhabitant's habitat. National and European statistical data show a housing quality below the European average.

In this context, the commitments undertaken by Romania, regarding the increase in energy performance, are mainly found in the thermal rehabilitation projects of the blocks, due to the great impact they have on the population. Despite all the efforts made, the Thermal Rehabilitation Program is not applied on a large scale and only partially solves the improvement of the quality of life of the residents of the block. In the absence of other alternatives, they resort, as shown at the end of chapter 3, to individual interventions, often at the limit of legality or the safety of their own lives.

6.2. Further study directions

As a result of the research work carried out, the following research directions, not explored within this thesis, must be specified:

- a complex assessment of energy consumption on an entire block extended to the neighbourhood level, rehabilitated in an integrated manner, according to the proposed measures;
- Life cycle assessment of the integrated rehabilitation method;
- Further applied experimental study using modular test models;
- Based on the model design strategies, a second participation in the Solar Decathlon Competition, involving students from different fields of study.

6.3. Published results

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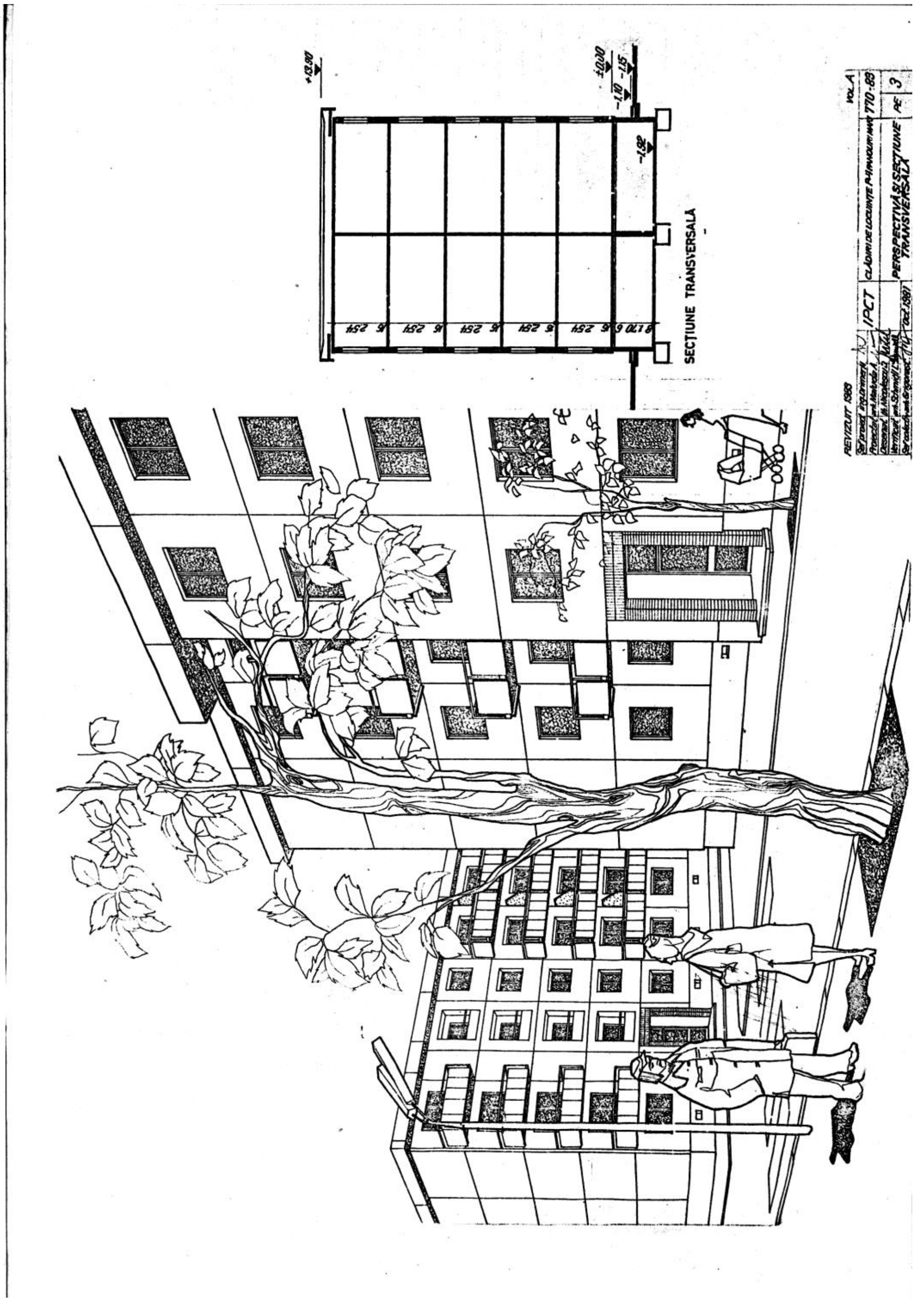
ANNEX 1 – PROJECT T770-83 – DRAWING SELECTION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PROIECT 770 - 83 CONFORM DECRET 216

Secțiunea Decret 216	Secțiunea 770-81	Număr apartamente Tip I 2 cam	Tip I 3 cam	Tip I 4 cam	Tip II 2 cam	Tip II 3 cam	Tip II 4 cam	Total	Caracteristicile apartamentelor: Tipul	Nr.	Al m²	Au m²	Arii pe secțiune (m²): A loc.	Au proiect	Au maxim decret 216	Adc maxim decret 216	Adc/Ac: MM	CM MC	LM ML	LC CL	CC	MD DM	CD DC	MF FM	CF FC	MT TM	CT TC	Valab. seismică
P2a1	Pa1	13				1		14	2I 2I 2I 3II	8 4 1 1	26,7 25,2 26,7 36,9	43,0 43,0 46,5** 61,1	378,0	623,6	630,2	972,0	905,4 175,6 ●	938,8 178,2	918,4 178,2	947,8 180,8	964,2 180,8							6,7
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P2a3	Pa3		7	3				10	3I 4I	7 3	34,8 45,0	55,0 69,0	378,6	592,0	592,0	916,0	870,8 162,1 ●	884,1 163,7	869,6 163,7	882,9 166,3	897,4 166,3							6,7,8
P2a4	Pa4					7	3	10	3II 4II	7 3	40,4 48,4	64,8 77,0	428,0	684,6	686,0	1064,0	978,0 182,4	991,0 185,0 ●	974,5 185,0	987,6 187,6	1004,0 187,6							
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P2a8	Pb4					18	1	19	3II 4II	18 1	40,4 50,2	64,5 78,8*	777,4	1239,9	1247,0	1937,0	1665,4 320,6	1694,8 323,2	1678,4 223,2	1707,8 225,8	1724,2 225,8 ●							
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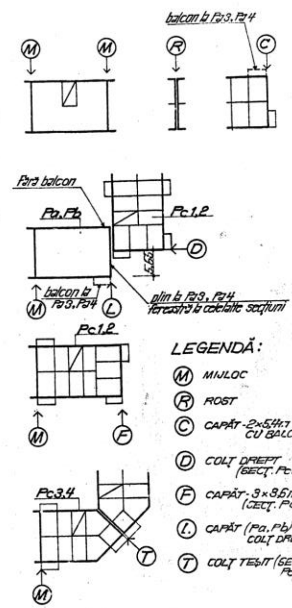
P2a10	Pc2				2	8		10	2II 3II 3II	2 5 3	30,2 40,4 40,7	53,0* 64,8 63,5	384,5	620,5	622,0	966,0						923,5 171,5 ●	936,5 174,1	923,5 171,5	936,5 174,1			6,7,8
P2a11	Pc3		5		2	3		10	3I 2II 3II	5 2 3	34,8 31,8 42,0	55,0 50,5 64,9	363,6	570,7	572,0	886,0										831,5 157,0 ●	844,5 159,6	6,7,8
P2a12	Pc4				2	8		10	2II 3II 3II	2 5 3	31,8 40,4 42,0	50,5 64,8 64,9	391,6	619,7	622,0	966,0										884,7 167,1 ●	897,7 169,7	6,7,8

*) Se compensează pe secțiune.

**) Se justifică prin suprafața corespunzătoare logiei.



LEGENDĂ:

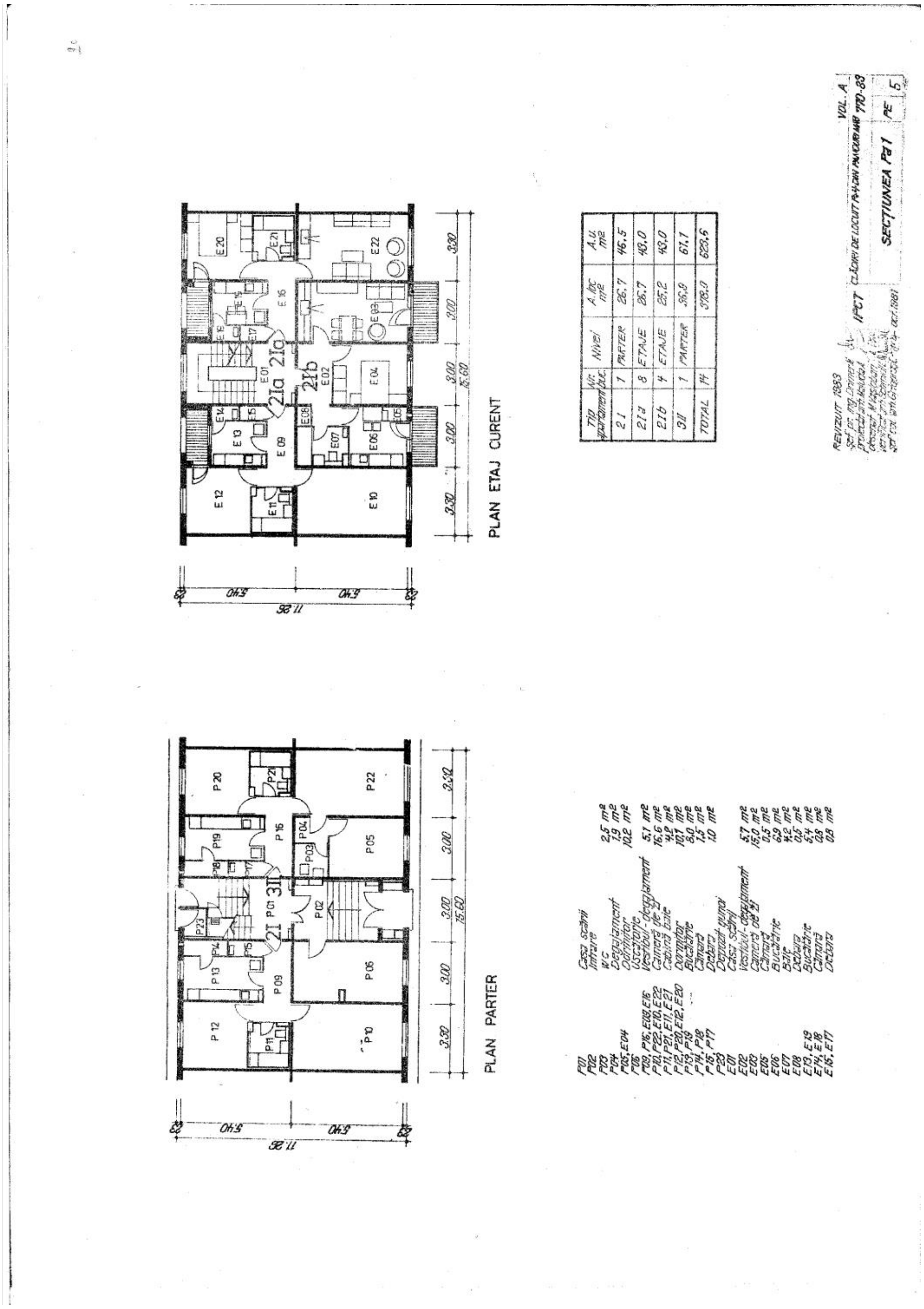
- Ⓜ MIJLOC
- Ⓡ ROST
- Ⓒ CAPĂT - 2×5,4 m CU BALCON
- Ⓓ COLȚ DREPT (SECȚ. Pc1, Pc2)
- Ⓕ CAPĂT - 3×3,6 m (SECȚ. Pc1, Pc2)
- Ⓛ CAPĂT (Pa, Pb) PENTRU COLȚ DREPT
- Ⓣ COLȚ TEȘIT (SECȚ. Pc3, Pc4)

NOTĂ:

- În loc de M se poate realiza R; în această situație, Adc. crește cu 11,2 m² pentru R.9 și cu 5,6 m² în celelalte cazuri.
- Realizarea tronsoanelor dintr-o singură secțiune (RR, RC, LC, CC etc.) este posibilă doar pe baza verificării structurii la acțiunea forțelor seismice.
- Secțiunile marcate cu ● corespund secțiunilor prezentate în „Catalogul de proiecte tip - vol. P"; celelalte tipuri (LM, LC, CD, MF, CF, CT, etc.) sînt variante ale acestor secțiuni.
- În toate cazurile, suprafețele construite pe apartamente sînt mai mici decît limitele maxime prevăzute în Decretul 216/1981; pentru calculul suprafețelor construite, vezi pl. 2 din prezentul volum.

VOL. A

REVIZUIT 1983 Șef pr. ing. M. Drimer Proiectat arh. A. Melcida Desenat tehn. Y. Codrea Verificat arh. P. Mihăilescu Șef col. arh. C. Grigoraș	IPCT oct. 1981	CLĂDIRI DE LOCUIT P+4 DIN PANOURI MARI. PLANȘĂ SINOPTICĂ SECȚIUNI	770 - 83 PE 4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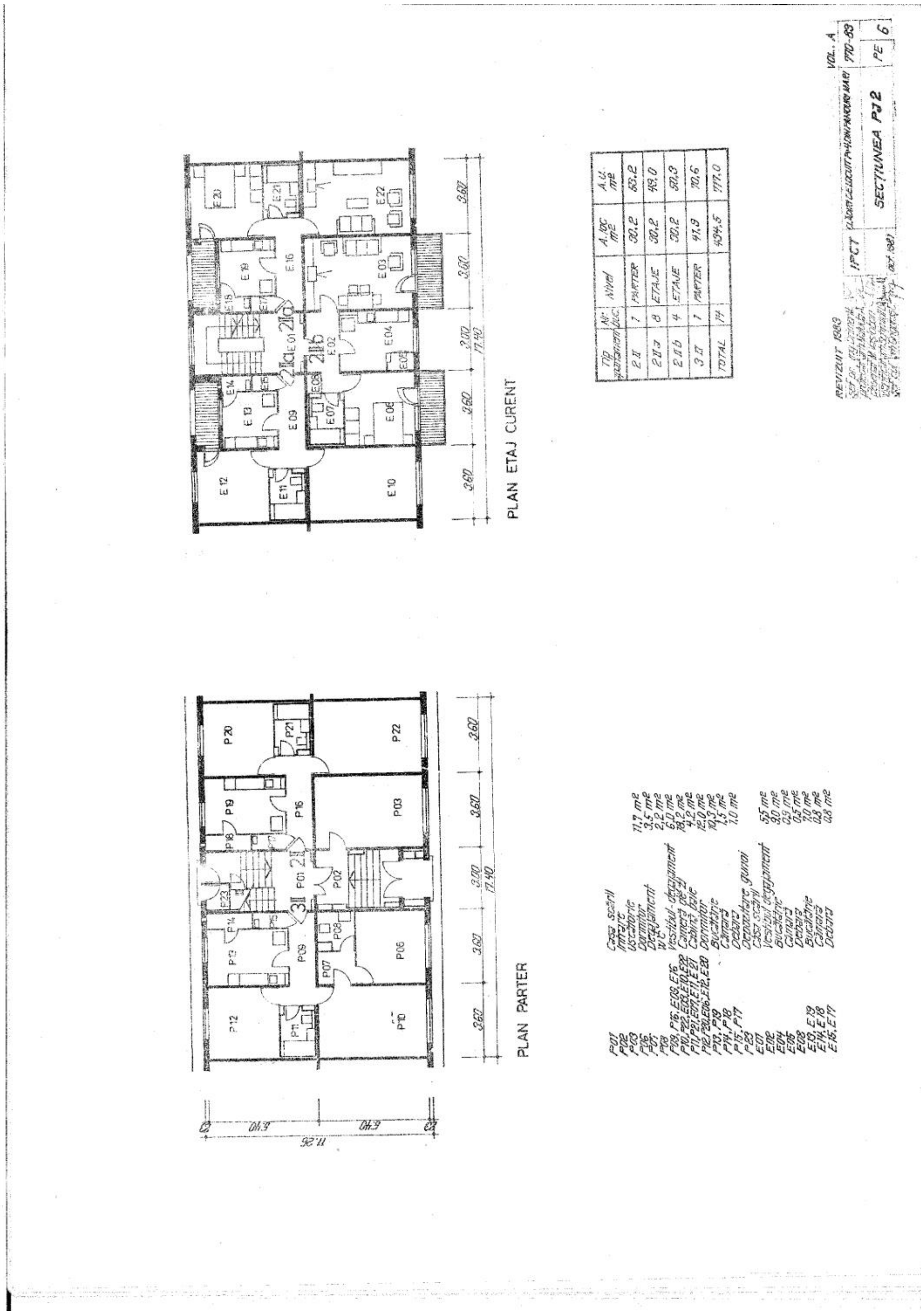
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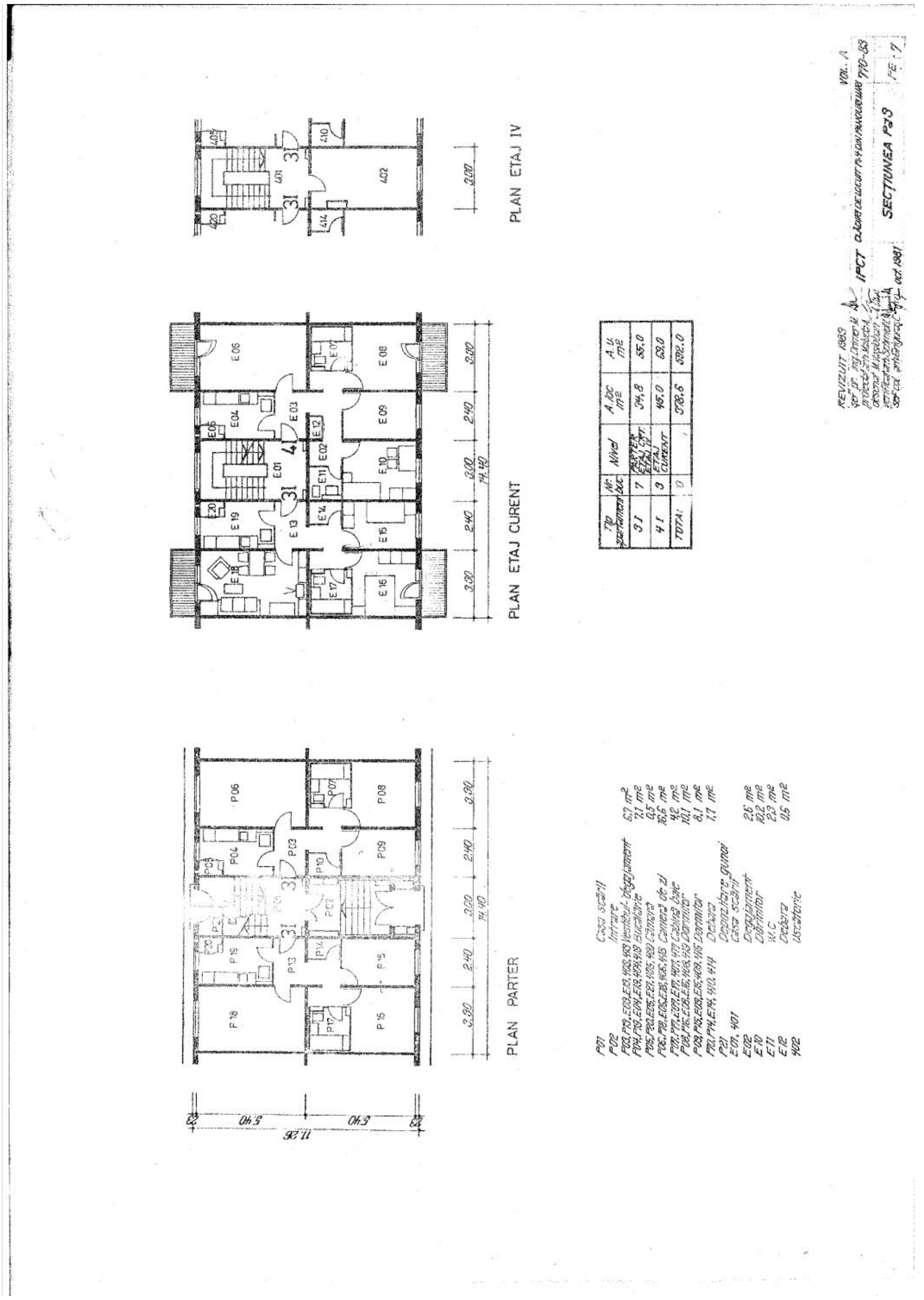
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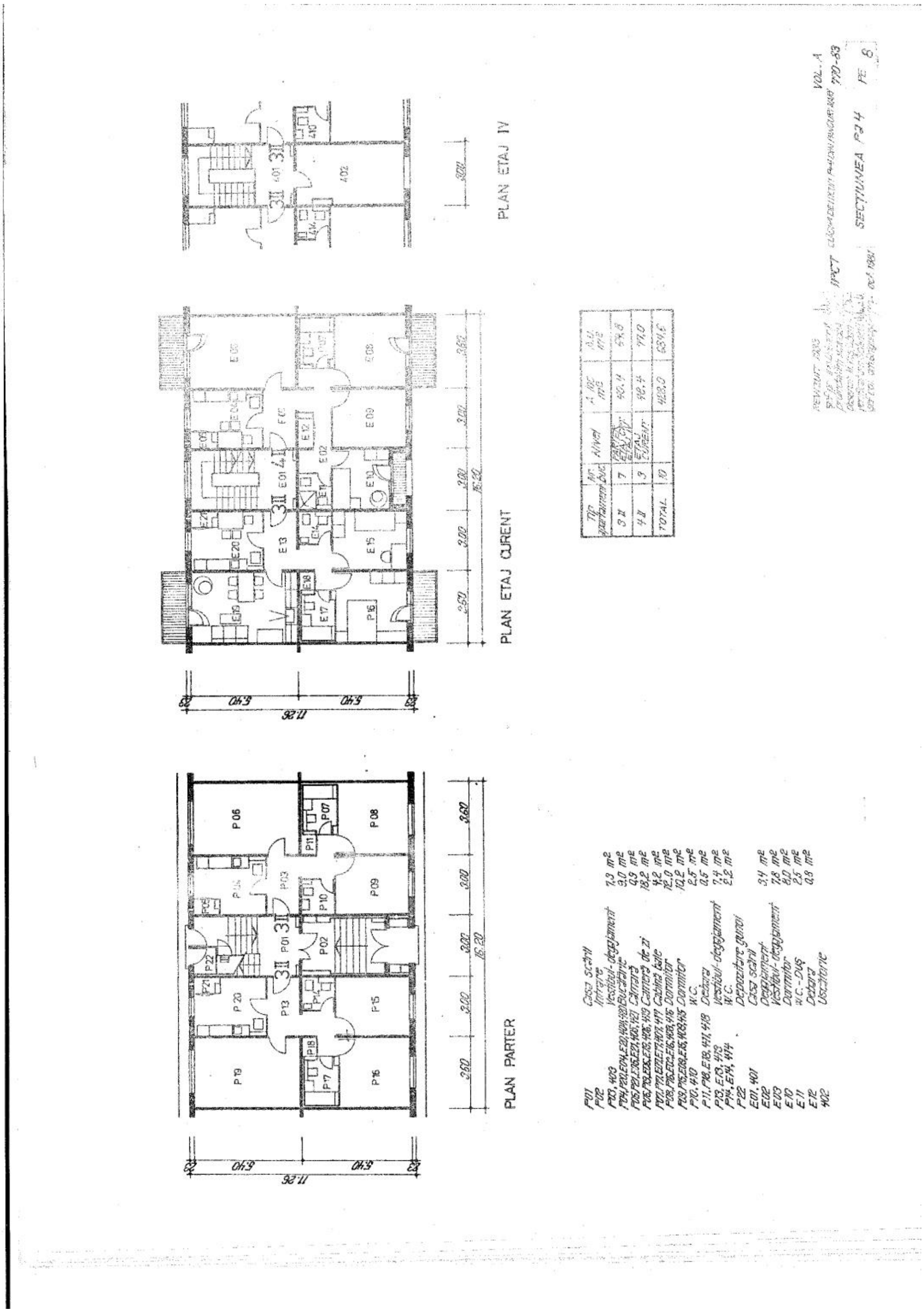
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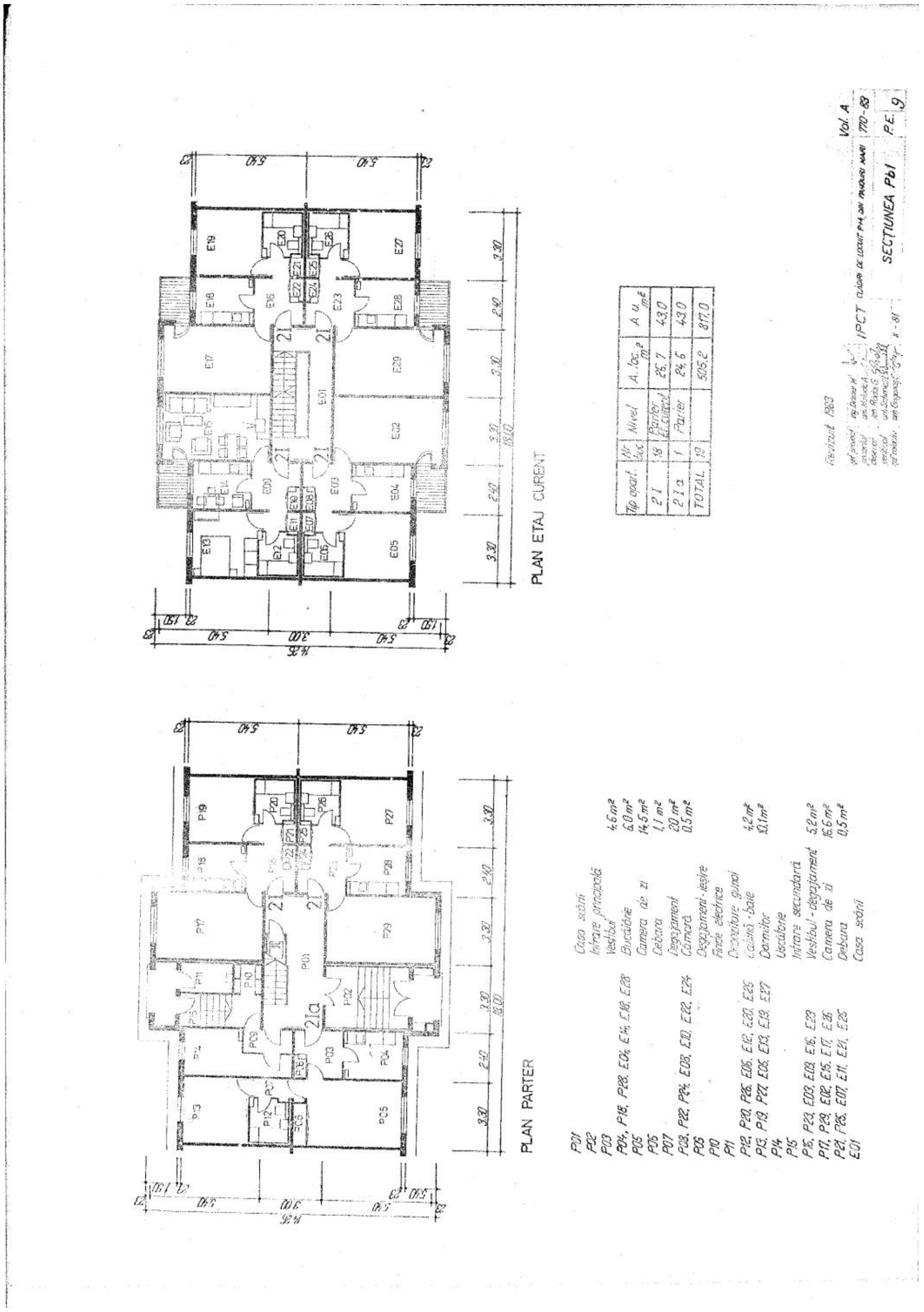
PLAN ETAJ IV
SECTIUNEA P24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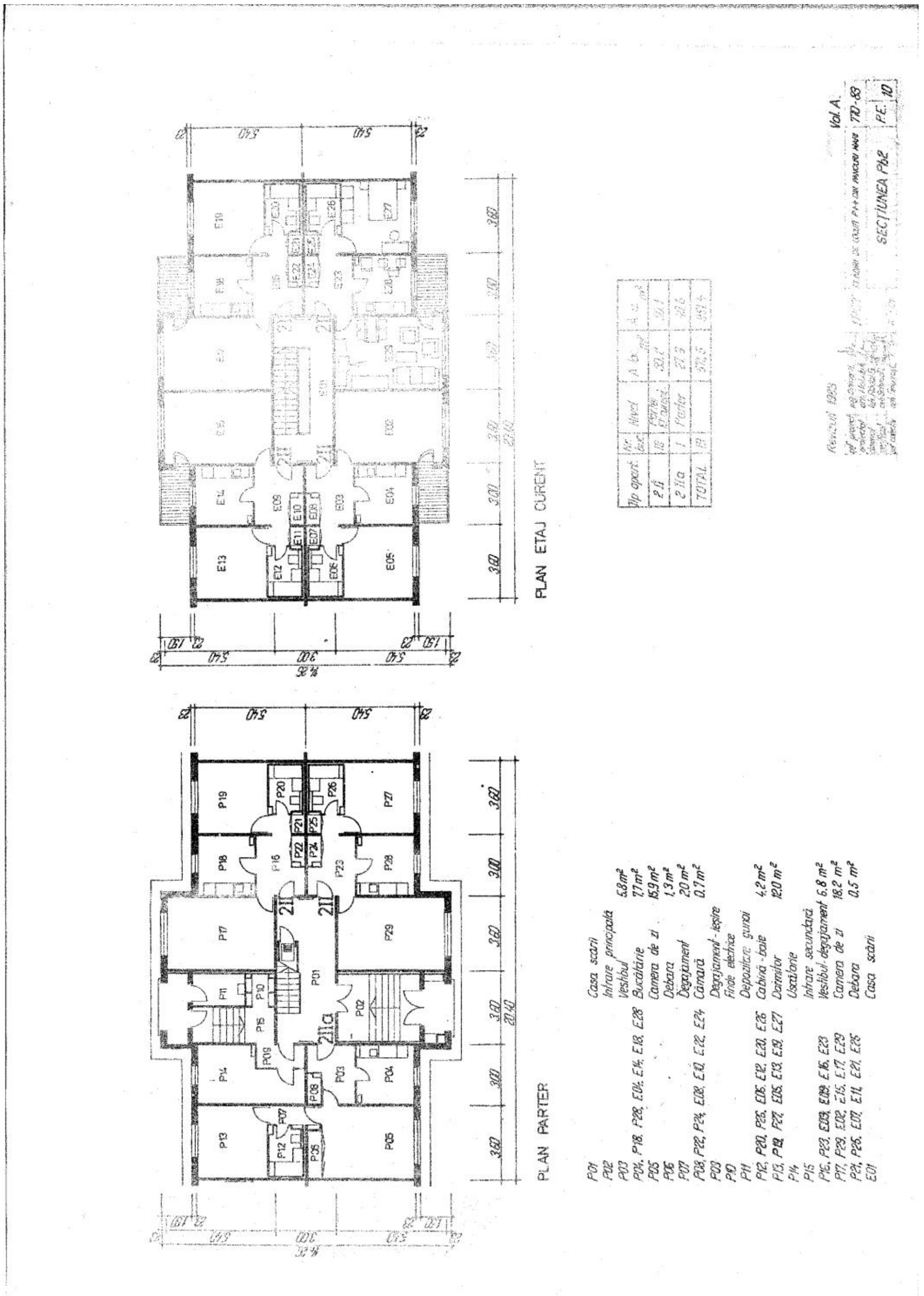
PLAN PARTER
SECȚIUNEA Pb1
IPCT
Vol. A
P.E. 9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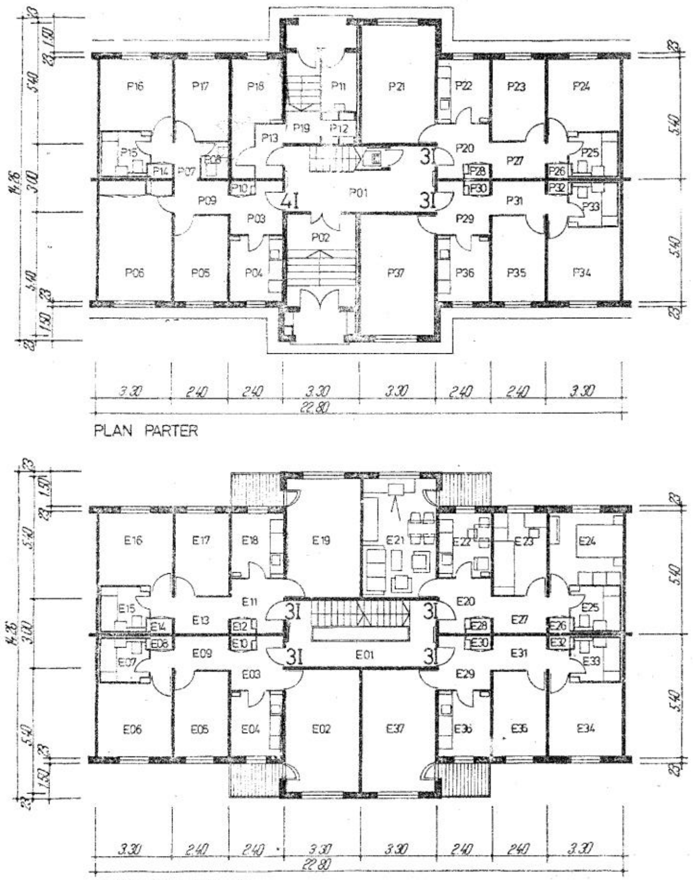
SECTIUNEA P+2
Vol. A.
PE. 10



PLAN PARTER

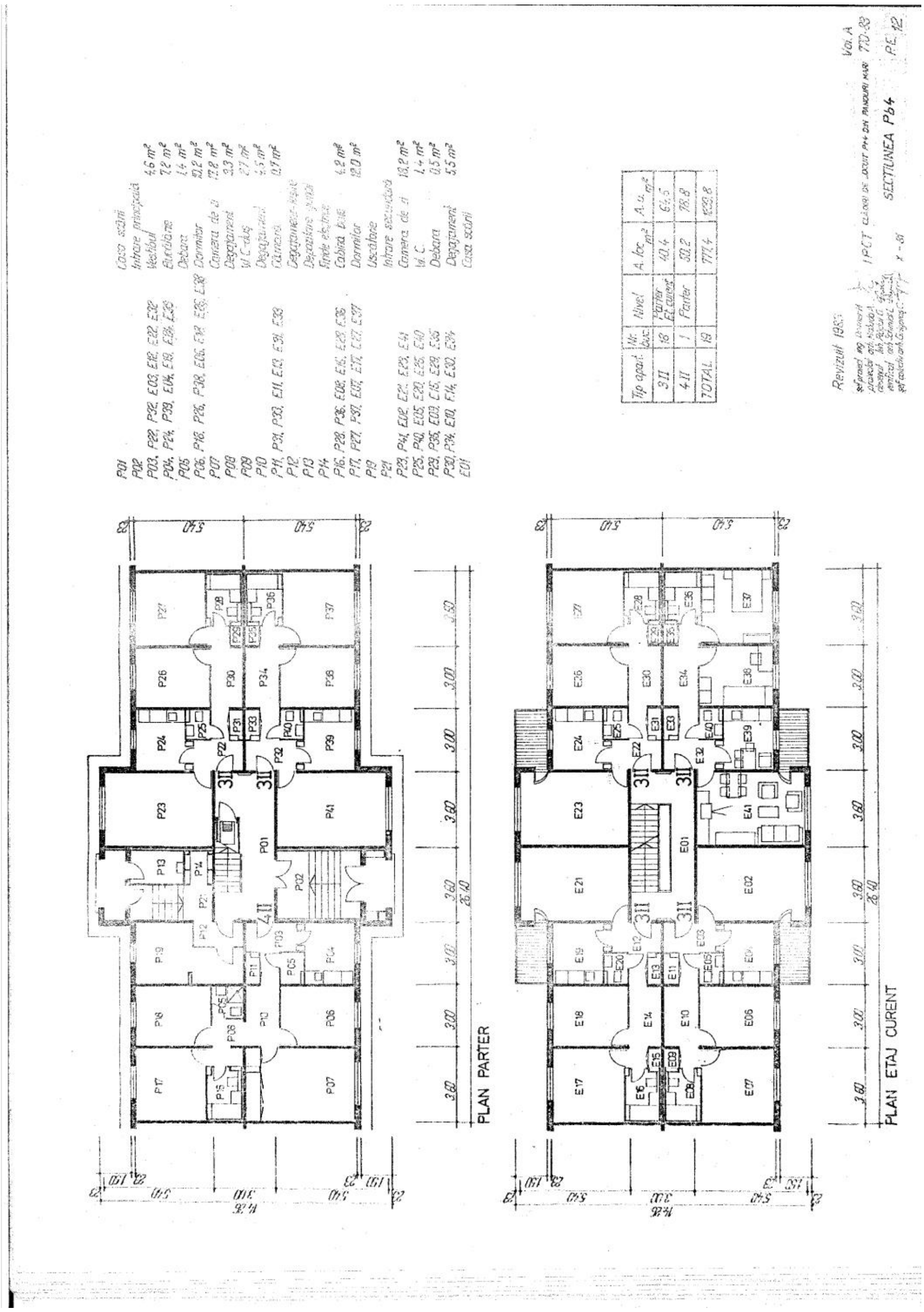
PLAN ETAJ CURENT

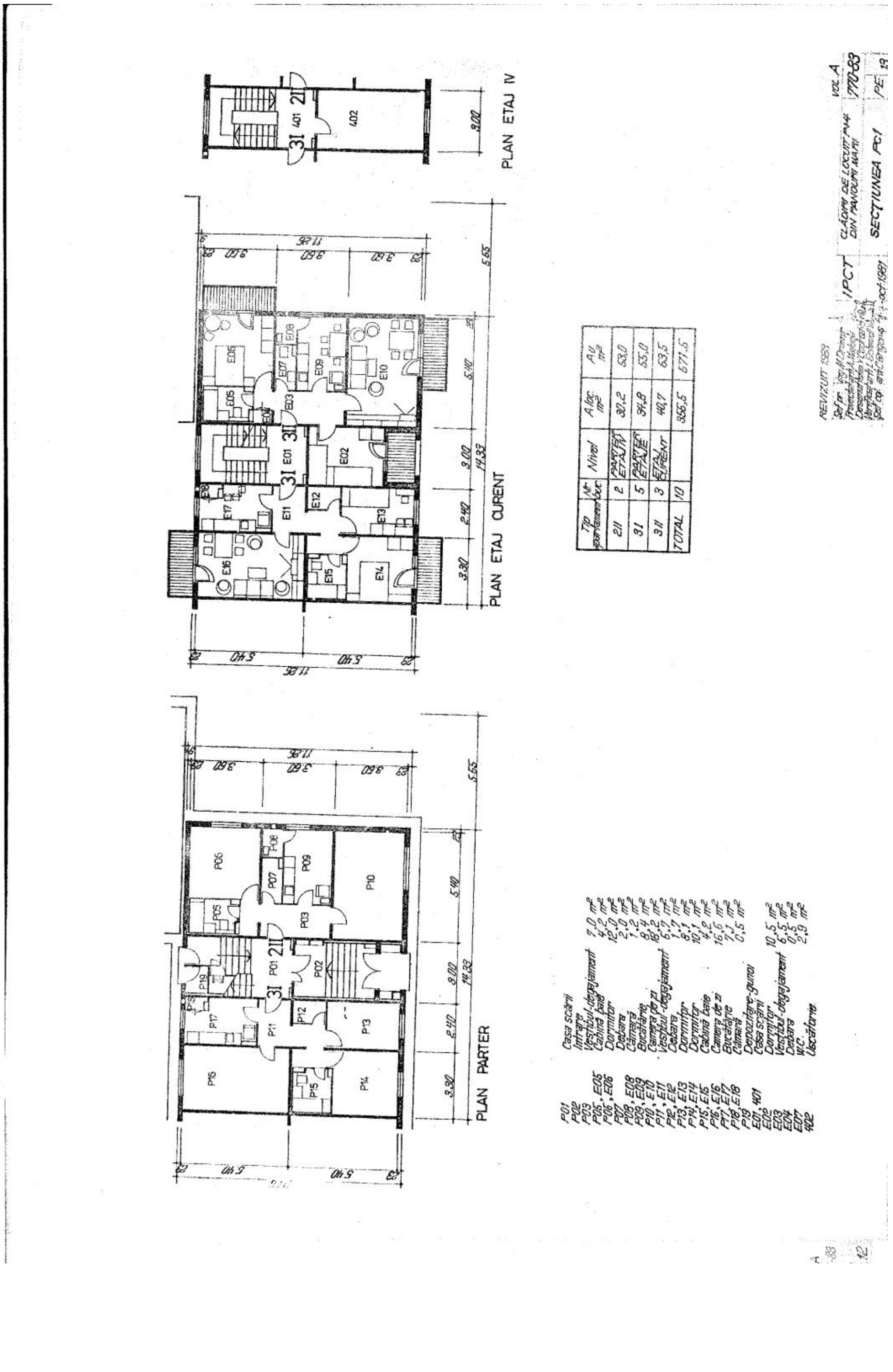
P01	Casa scării
P02	Intrare principală
P03, P20, P29, E03, E11, E20, E29	Vestibul 4,6 m²
P04, P22, P36, E04, E18, E22, E36	Bucătărie 6,0 m²
P05, P17, P23, P35, E05, E17, E23, E35	Dormitor 8,1 m²
P06	Camera de zi 16,2 m²
P07	Degajament 2,7 m²
P08	W.C. 1,7 m²
P09	Degajament 3,6 m²
P10, P28, P30, E10, E12, E28, E30	Cămară 0,5 m²
P11	Depozitare gunoi
P12	Firide electrice
P13	Degajament ieșire
P14, P26, P32, E08, E14, E26, E32	Debara 0,5 m²
P15, P25, P33, E07, E15, E25, E33	Cabină baie 4,2 m²
P16, P24, P34, E06, E16, E24, E34	Dormitor 10,1 m²
P18	Uscătorie
P19	Intrare secundară
P21, P37, E02, E19, E21, E37	Camera de zi 16,6 m²
P27, P31, E09, E13, E27, E31	Degajament 4,4 m²
E01	Casa scării

Tip apart.	Nr. buc.	Nivel	A. loc. m²	A. u. m²
3I	18	Parter Et. curent	34,8	53,0
4I	1	Parter	42,5	66,3
TOTAL			638,0	1056,3

Revizuit 1983

șef proiect ing. Drimer H. proiectat arh. Maluda A. desenat teh. Rădoi G. verificat arh. Schmidt L. șef colectiv arh. Grigoraș C.	IPCT X - 81	CLĂDIRI DE LOCUIT P+4 DIN PANOURI MARI SECȚIUNEA Pb3	Vol. A 770-83 PE 11


PLAN PARTER
PLAN ETAJ CURENT
SECTIUNEA Pb4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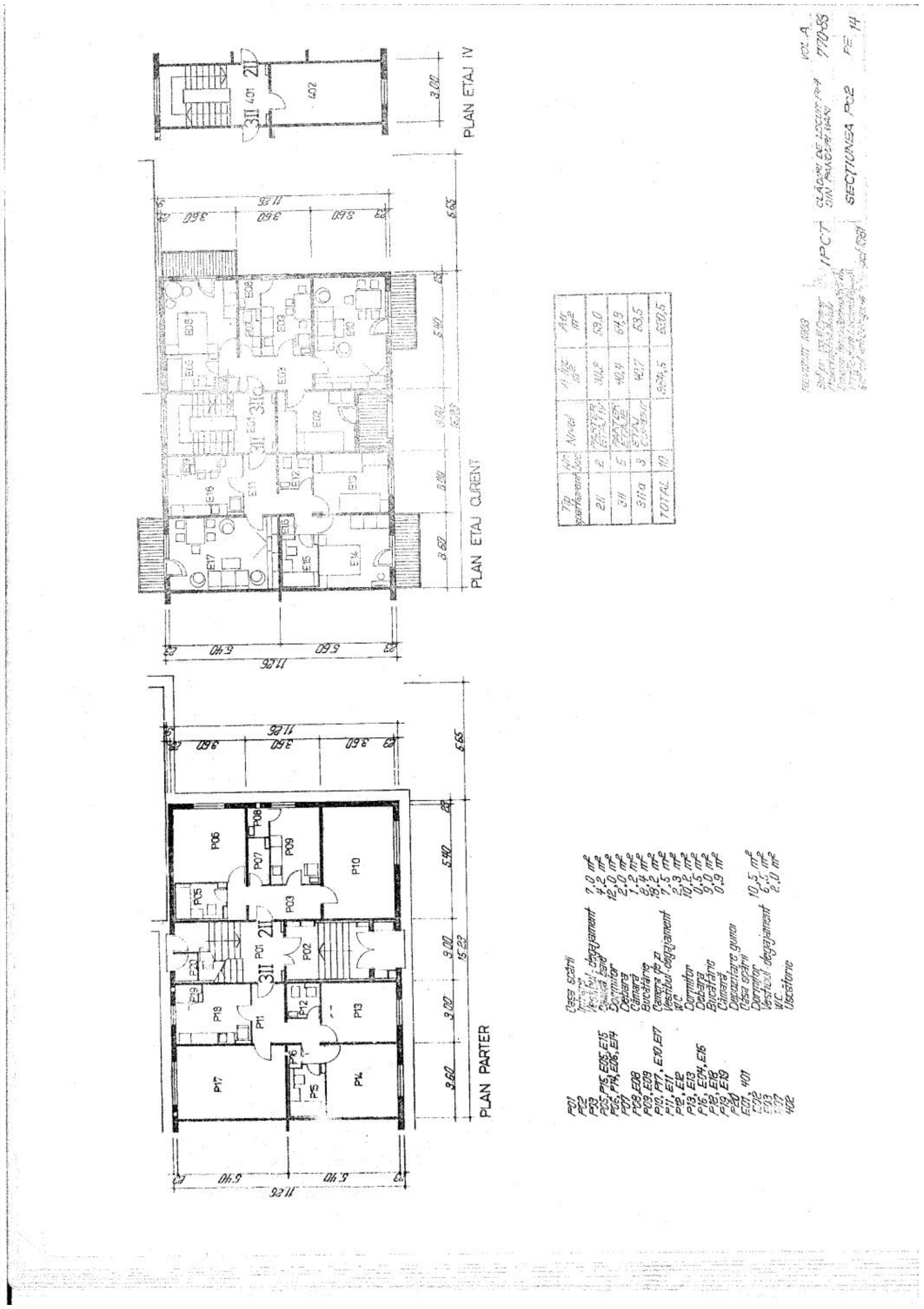
PLAN ETAJ CURENT
PLAN ETAJ IV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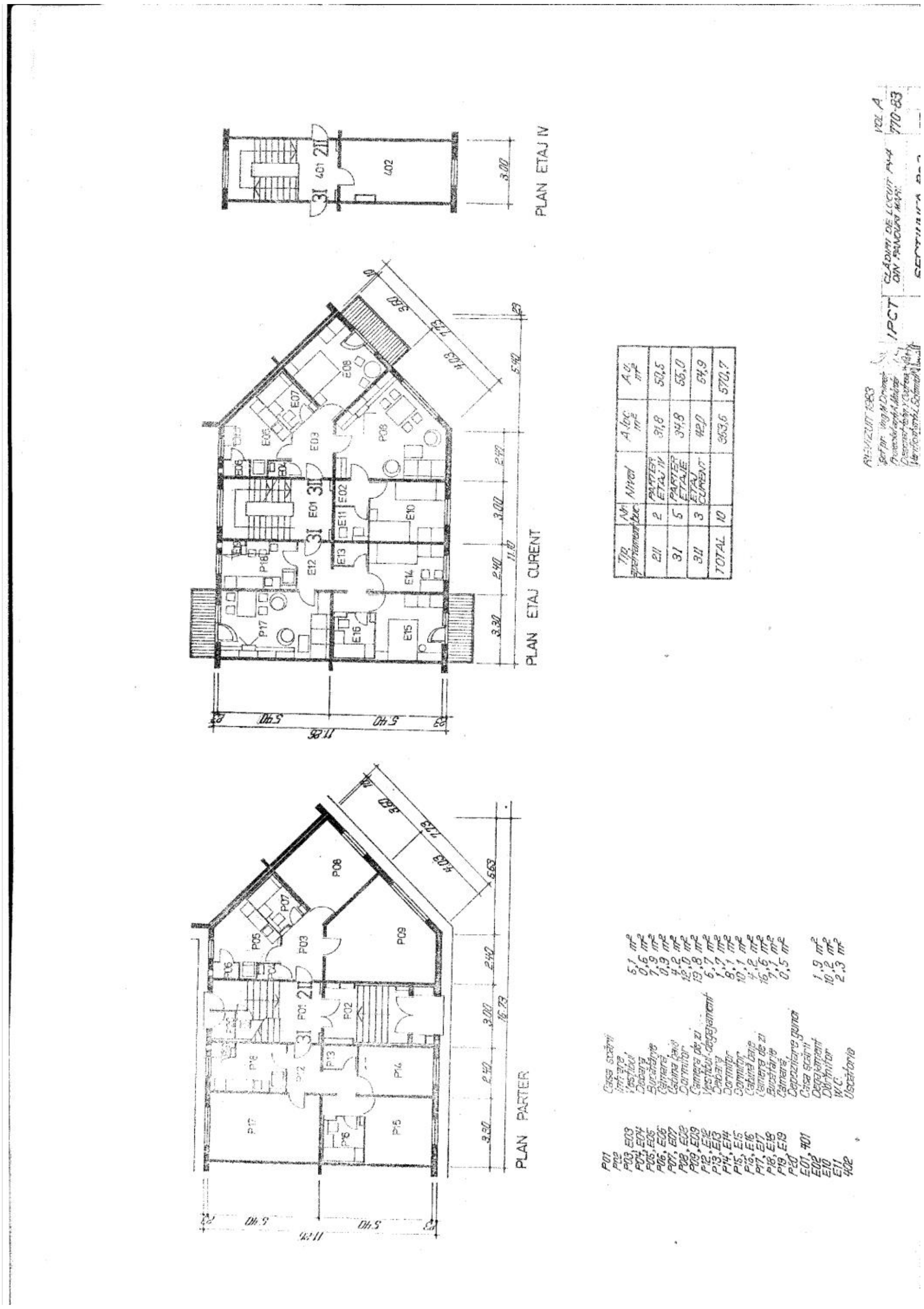
PLAN ETAJ IV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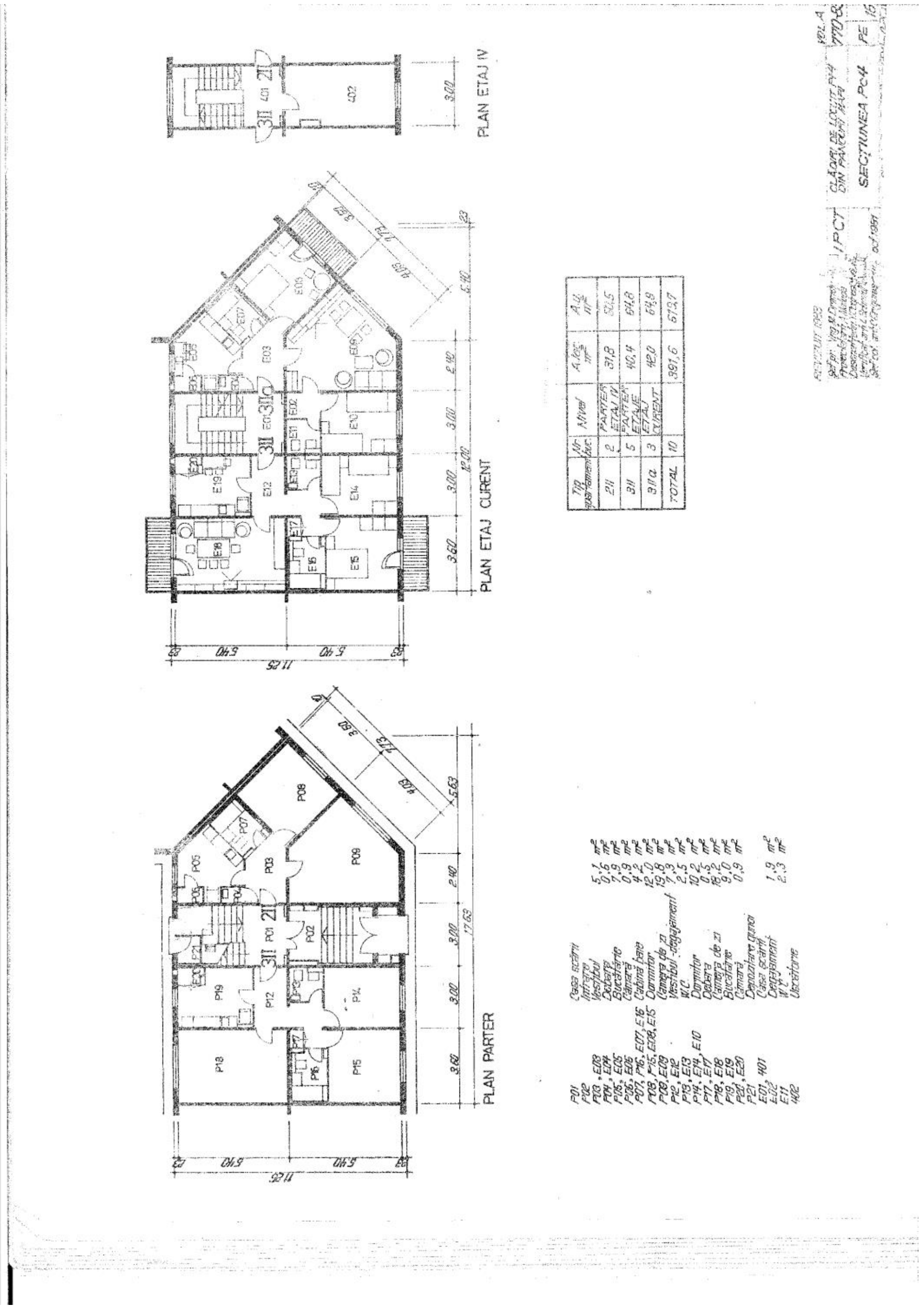
PLAN ETAJ IV


PLAN PARTER
PLAN ETAJ CURENT
PLAN ETAJ IV
SECTIUNEA Pc-4

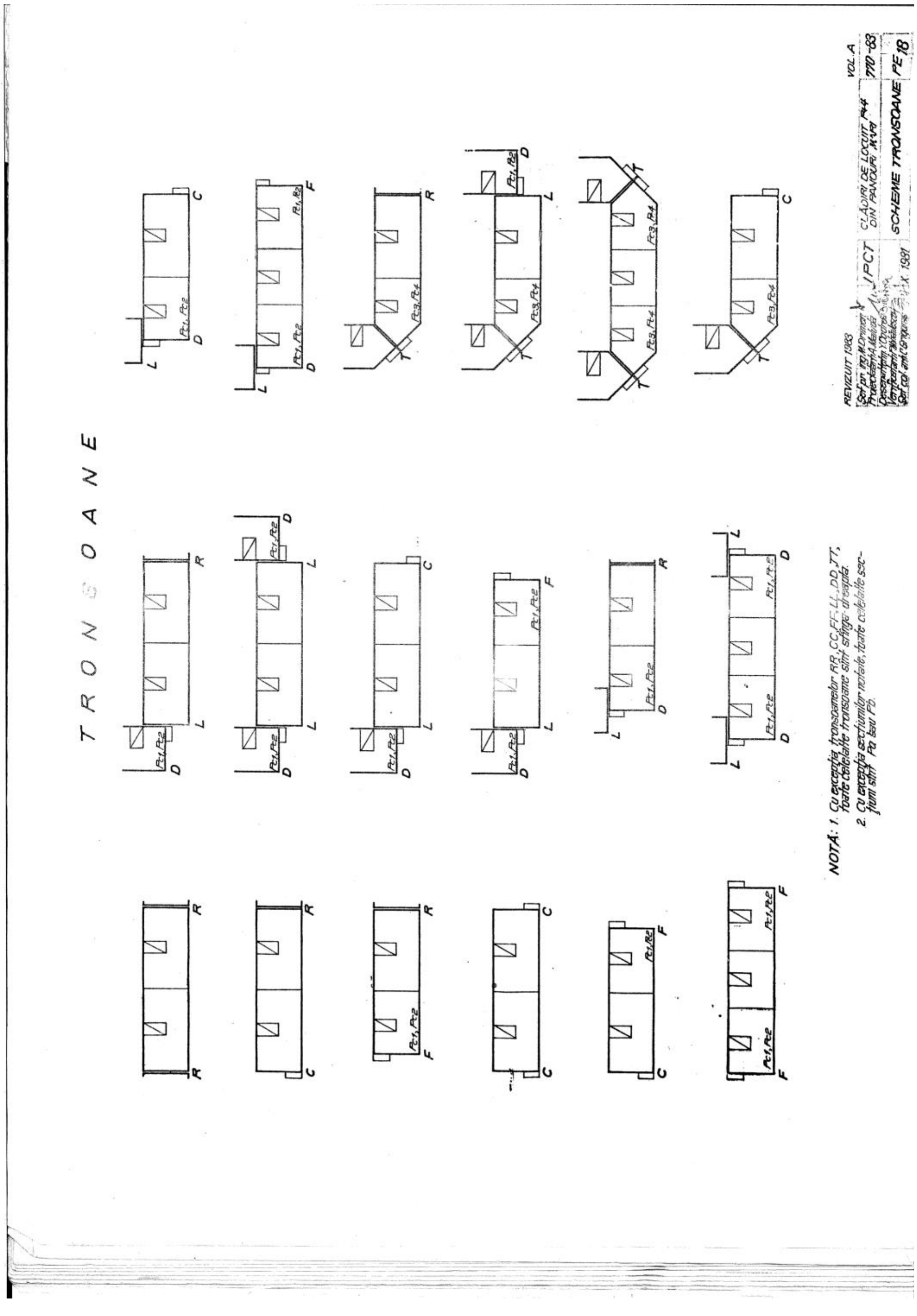
T R O N S O A N E

Nr. tronson	Alcătuire (secțiuni) P				Lungime (interax) m	Tronsoane curente: mijloc RR	capăt RC (CR)	capăt FR (RF)	independent CC	independent FC (CF)	independent FF	Tronsoane adiacente colțului drept: mijloc LR (RL)	mijloc LL	capăt LC (CL)	capăt FL (LF)	Tronsoane de colț drept: mijloc DR (RD)	mijloc DD	capăt DC (CD)	capăt DF (FD)	Tronsoane de colț teșit: mijloc TR (RT)	mijloc TL (LT)	mijloc TT	capăt TC (CT)	Valabilitate seismică max.
1	a_1	a_1			31,2	o	o		o			o	o	o										7
2	a_1	a_1	a_1		46,8	o	o		o			o	o	o										7
3	a_2	a_2			34,8	o	o		o			o	o	o										7
4	a_2	a_2	a_2		52,2	o	o		o			o	o	o										7
5	a_3	a_3			28,8	o	o		o			o	o	o										8
6	a_3	a_3	a_3		43,2	o	o		o			o	o	o										8
7	a_3	a_3	a_3	a_3	57,6	o	o		o			o	o	o										8
8	a_4	a_4			32,4	o	o		o			o	o	o										8
9	a_4	a_4	a_4		48,6	o	o		o			o	o	o										8
10	a_1	a_3	a_1		45,6	o	o		o			o	o	o										7
11	a_3	a_1	a_3		44,4	o	o		o			o	o	o										7
12	a_2	a_4	a_2		51,0	o	o		o			o	o	o										7
13	a_4	a_2	a_4		49,8	o	o		o			o	o	o										7
14	a_1	a_3	a_3	a_1	60,0	o	o		o			o	o	o										7
15	a_3	a_1	a_1	a_3	60,0	o	o		o			o	o	o										7
16	b_1	b_1			36,0	o	o		o			o	o	o										7
17	b_1	b_1	b_1		54,0	o	o		o			o	o	o										8
18	b_2	b_2			40,8	o	o		o			o	o	o										8
19	b_3	b_3			45,6	o	o		o			o	o	o										8
20	b_4	b_4			52,8	o	o		o			o	o	o										8
21	b_1	b_3	b_1		58,8	o	o		o			o	o	o										8
22	a_3	b_1	a_3		46,8	o	o		o			o	o	o										8
23	a_4	b_2	a_4		52,8	o	o		o			o	o	o										8
24	a_3	b_3	a_3		51,6	o	o		o			o	o	o										8
25	a_4	b_4	a_4		58,8	o	o		o			o	o	o										8
26	b_1	a_3	b_1		50,4	o	o		o			o	o	o										8
27	b_2	a_4	b_2		57,0	o	o		o			o	o	o										8
28	b_3	a_3	b_3		60,0	o	o		o			o	o	o										8
29	c_1	a_1			29,7			o		o					o	o		o						7
30	c_1	a_1	a_1		45,3			o		o					o	o		o						7
31	c_1	a_3			28,5			o		o					o	o		o						7
32	c_1	a_3	a_3		42,9			o		o					o	o		o						8
33	c_1	a_3	a_3	a_3	57,3			o		o					o	o		o						8
34	c_2	a_2			32,4			o		o					o	o		o						7
35	c_2	a_2	a_2		49,8			o		o					o	o		o						7
36	c_2	a_4			31,2			o		o					o	o		o						7
37	c_2	a_4	a_4		47,4			o		o					o	o		o						7
38	c_1	b_1			32,1			o		o					o	o		o						8
39	c_1	b_1	b_1		50,1			o		o					o	o		o						8

Nr. tronson	Alcătuire (secțiuni) P				Lungime (interax) m	Tronsoane curente: mijloc RR	capăt RC (CR)	capăt FR (RF)	independent CC	independent FC (CF)	independent FF	Tronsoane adiacente colțului drept: mijloc LR (RL)	mijloc LL	capăt LC (CL)	capăt FL (LF)	Tronsoane de colț drept: mijloc DR (RD)	mijloc DD	capăt DC (CD)	capăt DF (FD)	Tronsoane de colț teșit: mijloc TR (RT)	mijloc TL (LT)	mijloc TT	capăt TC (CT)	Valabilitate seismică max.
40	c_1	b_3			36,9			o		o					o	o		o						8
41	c_1	b_3	b_3		59,7			o		o					o	o		o						8
42	c_2	b_2			35,4			o		o					o	o		o						8
43	c_2	b_2	b_2		55,8			o		o					o	o		o						8
44	c_2	b_4			41,4			o		o					o	o		o						8
45	c_1	c_1			28,2						o						o		o					7
46	c_1	a_1	c_1		43,8						o						o		o					7
47	c_1	a_1	a_1	c_1	59,4						o						o		o					7
48	c_1	a_3	c_1		42,6						o						o		o					7
49	c_1	a_3	a_3	c_1	57,0						o						o		o					7
50	c_2	c_2			30,0						o						o		o					7
51	c_2	a_2	c_2		47,4						o						o		o					7
52	c_2	a_4	c_2		46,2						o						o		o					7
53	c_1	b_1	c_1		46,2						o						o		o					8
54	c_1	b_3	c_1		51,0						o						o		o					8
55	c_2	b_2	c_2		50,4						o						o		o					8
56	c_2	b_4	c_2		55,4						o						o		o					8
57	c_3	a_1			32,1															o	o		o	7
58	c_3	a_1	a_1		47,7															o	o		o	7
59	c_3	a_3			30,9															o	o		o	7
60	c_3	a_3	a_3		45,3															o	o		o	8
61	c_3	a_3	a_3	a_3	59,7															o	o		o	8
62	c_4	a_2			34,8															o	o		o	7
63	c_4	a_2	a_2		52,2															o	o		o	7
64	c_4	a_4			33,6															o	o		o	7
65	c_4	a_4	a_4		49,8															o	o		o	8
66	c_3	b_1			34,5															o	o		o	8
67	c_3	b_1	b_1		52,5															o	o		o	8
68	c_3	b_3			39,3															o	o		o	8
69	c_4	b_2			37,8															o	o		o	8
70	c_4	b_2	b_2		58,2															o	o		o	8
71	c_4	b_4			43,8															o	o		o	8
72	c_3	a_1	c_3		48,6																	o		7
73	c_3	a_3	c_3		47,4																	o		7
74	c_4	a_2	c_4		52,2																	o		7
75	c_4	a_4	c_4		51,0																	o		7
76	c_3	b_1	c_3		51,0																	o		8
77	c_3	b_3	c_3		55,8																	o		8
78	c_4	b_2	c_4		53,2																	o		8

NOTĂ:
La unele tronsoane, în gr. 7 și 8 seismic, sînt necesare armături suplimentare în centuri și stîlpișori (față de barele indicate în planșele R71 și R81 din volumele de secțiuni); acestea se introduc la adaptare de către proiectantul investiției, conform precizărilor din pl 28.01 vol. B

REVIZUIT 1983
Șef pr. ing. M. Drimer
Proiectat [illegible]
IPCT
CLĂDIRI DE LOCUIT P+4 DIN PANOURI MARI
PLANȘĂ SINOPTICĂ
VOL. A
770-83


TRONSOANE
SCHEME TRONSOANE PE 18
IPCT
VOL. A
REVIZUIT 1983

GRUPA	TIPODIMENSIUNI	SORTOTIPODIMENSIUNI			DIMENSIUNI (cm)			GREUTATE (t)
PERETI EXTERIORI	E18	E18	1		178	283	30	2,3
			2					2,3
	E24	E24	1		238			3,1
			3	S/D				2,7
			3b	S/D				2,7
			4					2,6
			4p					2,6
	E24-4 *		43	S/D	231			2,6
			43b	S/D				2,6
	E30	E30	3	S/D	298			3,5
			4					3,4
			4p					3,4
			10					2,9
			14					3,3
			25					2,8
			25b					2,8
			30					3,4
			36					3,8
	E30-4 *		43	S/D	291			3,3
			43b	S/D				3,4
	E30-6		60		298		47	4,0
	E33	E33	4		328		30	3,7
			4p					3,7
			6					3,4
			6p					3,4
			14					3,7
			16					3,4
			25	S/D				3,3
			26	S/D				3,1
	E33-5 *		50	S/D	358			3,3
			56	S/D				3,6
			56p	S/D				3,6
	E33-7 *		71	S/D	352			4,8
	E36	E36	4	S/D	358			4,1
			5					3,9
			5p					3,9
			7					3,6
			7p					3,6
			15					3,9
			17					3,6
			25	S/D				3,6
			27	S/D				3,3
	E36-5 *		50	S/D	388			3,4
			57	S/D				3,9
			57p	S/D				3,9
	E36-6		60		358		47	4,5
	E36-7 *		71	S/D	382			5,0
	E *	E	8	S/D	418		30	4,2
			8p	S/D	418			4,2
PERETI INTERIORI	I24	I24	1		210	260	14	1,9
			3					1,2
	I24-8		8		195			1,7
	I30	I30	1		270			2,4
			1a					2,4
			1S					2,4
			2					1,3
			2S					1,7
			3					1,7
			4					1,2
	I30-8		8		255			2,3

GRUPA	TIPODIMENSIUNI	SORTOTIPODIMENSIUNI			DIMENSIUNI (cm)			GREUTATE (t)
PERETI INTERIORI	I33	I33	1		300	260	14	2,6
			1a					2,6
			3					2,1
	I33-67		6		322			2,8
			7					1,7
	I36	I36	1		330			2,9
			1a					2,9
			1r					2,9
			3					2,3
	I36-67		6		352			3,0
			7					2,0
	I39	I39	1r		360			3,2
	I54	I54	1		510			4,5
			1b					4,4
			1r					4,5
			2					3,8
			2a					3,8
			2b					3,8
			2c					3,8
			2d					3,8
			2e					3,8
			3					3,9
			5					3,1
			5a					3,3
			5b					3,3
	I54-8		8		495			3,7
PLANSEE	P1	P	1		182	182	13	0,6
	P2		2		352	352		2,0
	P3 *		3	S/D	332			5,1
	P24-1	P24	11	S/D	232	532		3,6
			15					3,6
			17	S/D				3,5
			18	S/D				3,4
	P24-3 *		37	S/D		452		2,9
			37r	S/D				2,9
	P24-4		47	S/D		242		1,3
	P30-1	P30	10		232	532		4,4
			12					4,6
			13					4,4
			14					4,6
			15					4,3
			16					4,5
			17	S/D				4,5
			18	S/D				4,5
			19	S/D				4,5
	P30-3 *		37	S/D		452		3,8
			37r	S/D				3,8
	P30-4		47	S/D		242		2,0
	P30-5		51			496		4,3
			53					4,1
	P30-6		63			172		1,4
	P33-1	P33	11		322	532		5,0
			12					6,0
			12r					5,0
			13	S/D				5,0
	P33-5		51			496		4,8
			53	S/D				4,7
	P33-6		61			172		1,6
			63					1,5

GRUPA	TIPODIMENSIUNI	SORTOTIPODIMENSIUNI			DIMENSIUNI (cm)			GREUTATE (t)
PLANSEE	P36-1	P36	11		352	532	13	5,1
			12					5,1
			12t					5,1
			13					5,1
			18	S/D				5,1
			19	S/D				5,1
	P36-2		23			352		3,6
	P36-5		51			496		5,1
			52	S/D				5,1
			53					5,1
			54	S/D				5,1
	P36-6		61			172		1,7
			63					1,6
	P36-7		72	S/D		466		4,9
SCARI RAMPE	S123	S	1		292	130	27	1,3
			2		322			1,5
			3		352			1,6
	S4		4		466	113		1,9
	S567		5		298	100		1,1
			6			130		1,4
			7			190		1,9
	S8		8		466	232	13	3,7
			8t					3,5
	R1	R	1		541	109	40	2,3
	R2		2		353	141	159	2,2
	R3		3				150	2,2
CABINE	K12 *	K	1	S/D	255	179	253	4,7
			2	S/D				4,5
	K34 *		3	S/D	225	203		4,7
			4	S/D				4,5
ATICE	A	A	1	S/D	199	35	50	0,3
			2	S/D	258	109		0,9
			3	S/D	421			1,4
			4	S/D	268			0,9
			21		208			0,8
			24		238			0,9
			27		268			1,0
			30		298			1,1
			33		328			1,2
			36		358			1,3
			54	S/D	569			2,1
VENTILATII	V1	V	1		68	52	85	0,3
	V		4		44	26	254	0,4
			4a					0,4
			7	S/D	67			0,5
			8	S/D	79			0,5
CHEPENGURI	H1	H	1		158	138	85	1,3
	H2		2		144	144	145	1,6
PERETI LOGII	L1	L10	1	S/D	98	254	21	0,4
			2					0,6
		L13	1	S/D	129			0,6
			2					0,9
	L3	L30	3	S/D	282		25	2,2
			5					1,7
		L36	4	S/D	342			2,6

RECAPITULATIE SERIA 770-81

NR. CRT.	GRUPA	TIPODIMENSIUNI	SORTOTIPODIMENSIUNI
1	PERETI EXTERIORI	21	71
2	PERETI INTERIORI	11	37
3	PLANSEE	22	67
4	SCARI	7	12
5	CABINE	4	8
6	ATICE	1	1F
7	VENTILATII	2	7
8	CHEPENGURI	2	2
9	PERETI LOGII	2	11
	TOTAL	72	231

* TIPODIMENSIUNI „STINGA - DREAPTA"

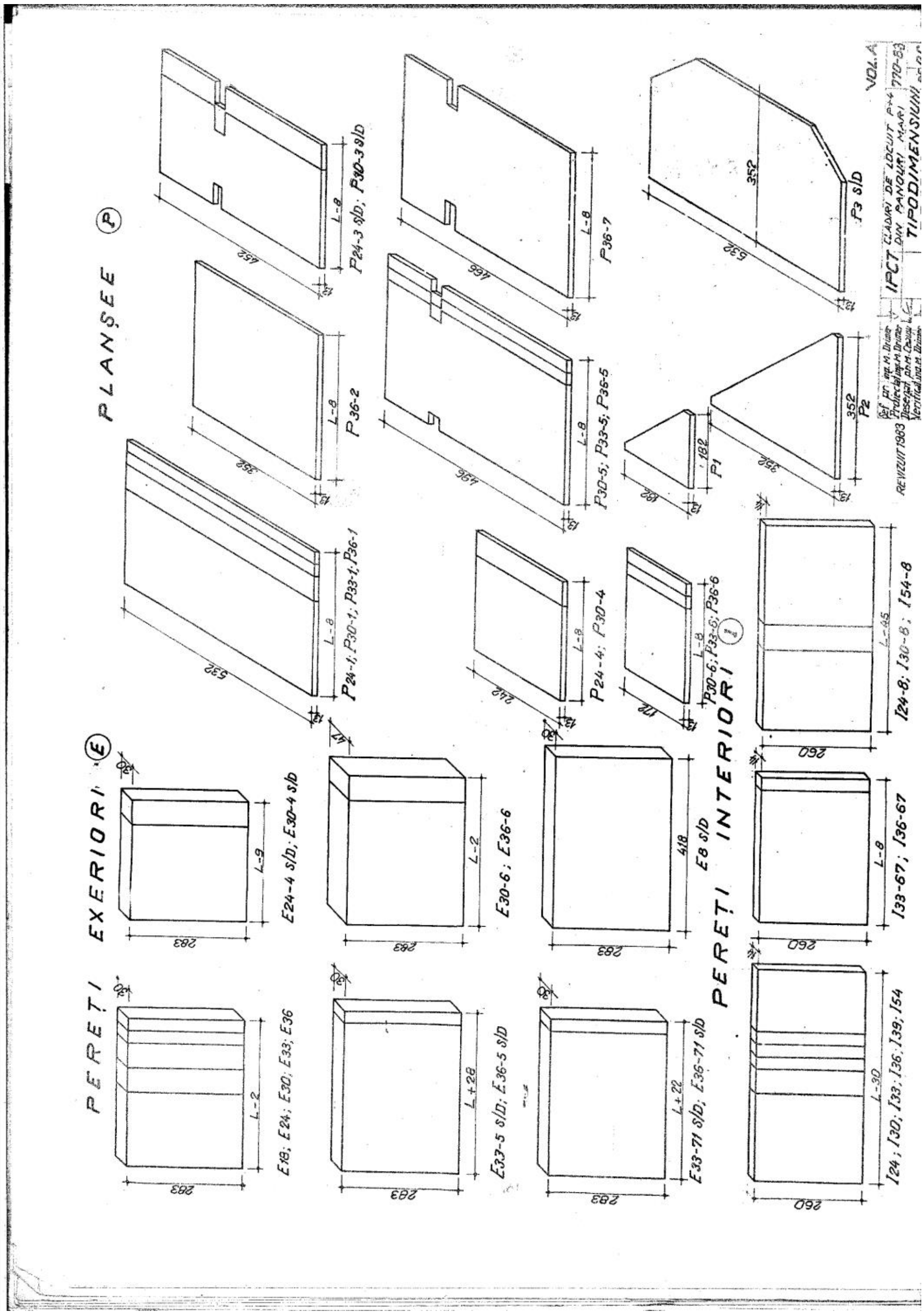
REVIZUIT 1983
SEF PR. ING. DRIMER
PROIECTAT ING. DRIMER
DESENAT STANESCU A.
VERIFICAT ING. DRIMER
SEF COLECT. ING. DRIMER

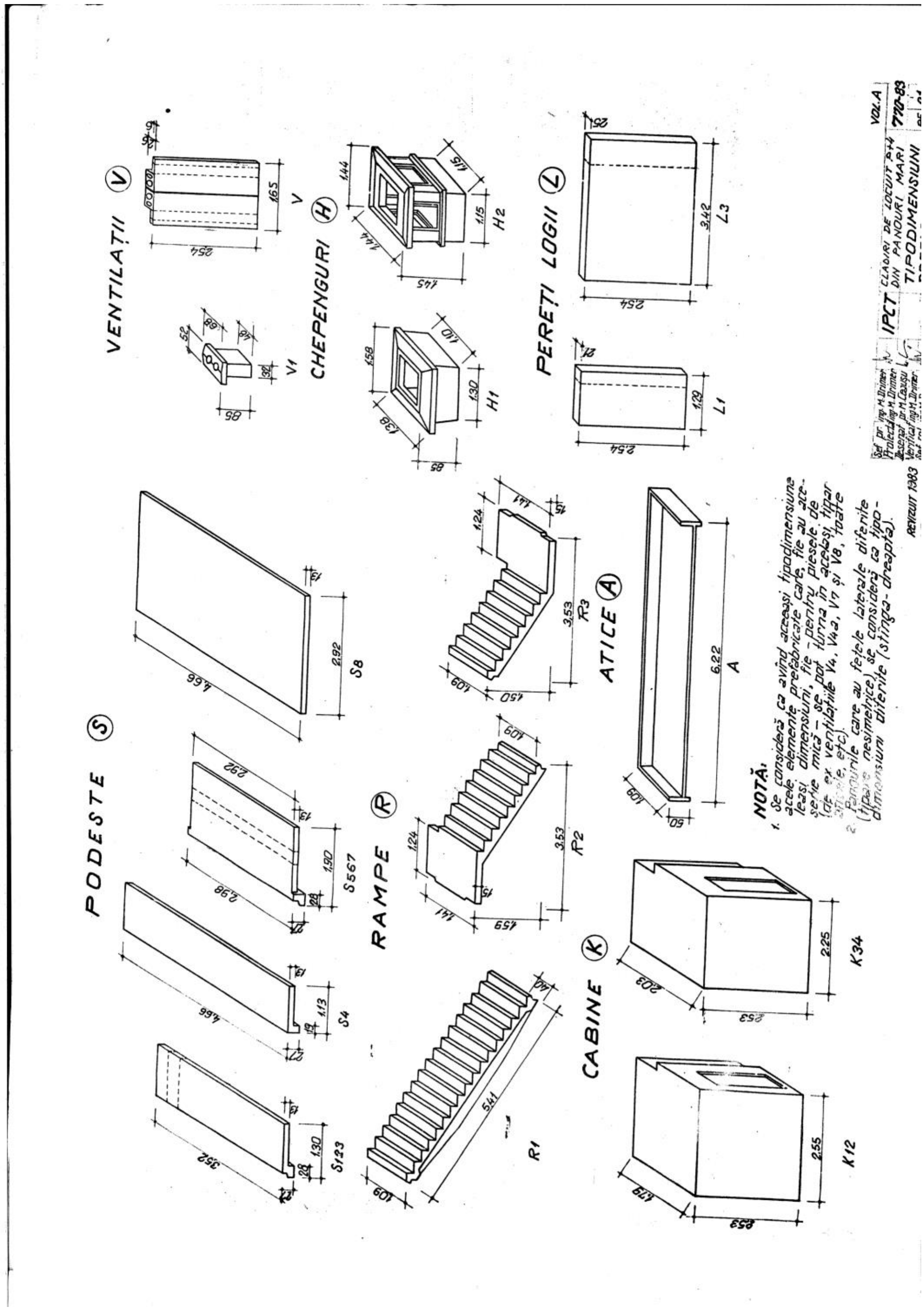
IPCT X-1981

VOL. A

CLADIRI DE LOCUIT P+4 DIN PANOURI MARI — 770-83

TIPO SI SORTOTIPODIMENSIUNI — PE 13


PLANȘEE
PEREȚI EXERIORI
PEREȚI INTERIORI


PODESTE (S)
RAMPE (R)
CABINE (K)
ATICE (A)
VENTILAȚII (V)
CHEPENGURI (H)
PEREȚI LOGII (L)

DENUMIREA SORTOTIPODIMENSIUNILOR PENTRU PANOURILE DE PEREȚI ȘI PLANȘEE E, L, I, P

PRIMELE 2 CIFRE INDICĂ INTERAXUL MODULAT L (ÎN dm)

PEREȚI EXTERIORI (E) — PEREȚI LOGII (L) — PEREȚI INTERIORI (I) — PLANȘEE (P)

E — CIFRA 3-a INDICĂ

–	ℓ=L-2	panouri curente
1	ℓ=L-2	la parter sub balcoane și la intrări
2	ℓ=L-2	la balcoane et. curent și et. IV
3	ℓ=L-2	la casa scării
4	ℓ=L-9	la decalări (colț intrînd)
5	ℓ=L+28	la decalări (colț ieșind)
6	ℓ=L-2	la logii (vezi nota 3)
7	ℓ=L+22	la colț (vezi nota 4)

E — ULTIMA CIFRĂ INDICĂ

0	portal intrare	
1	panou plin	
2	panou cu fereastră sau ușă+fereastră cu lățimea de:	60cm
3		90cm
4		120cm
5		150cm
6		180cm
7		210cm
8		240cm

L — ULTIMA CIFRĂ INDICĂ

3	ℓ=L-18	cu fereastră de 90 cm
4	ℓ=L-18	cu fereastră de 120 cm
5	ℓ=L-18	cu ușă+fereastră de 150 cm

I — CIFRA 3-a INDICĂ

1	ℓ=L-30	panou plin
2	ℓ=L-30	panou cu gol de ușă în cîmp
3	ℓ=L-30	panou cu gol de ușă la margine
4	ℓ=L-30	panou cu 2 goluri de ușă la margini
5	ℓ=L-30	panou cu un gol de ușă în cîmp și cu unul la margine
6	ℓ=L-8	panou plin la casa scării
7	ℓ=L-8	panou cu gol de ușă la casa scării
8	ℓ=L-45	panou plin sau cu gol de ușă

P — CIFRA 3-a INDICĂ

1	ℓ=L-8	b= 532 cm
2	ℓ=L-8	b= 352 cm
3	ℓ=L-8	b=452 cm (cu balcon)
4	ℓ=L-8	b= 242 cm
5	ℓ=L-8	b=496 cm (cu balcon)
6	ℓ=L-8	b= 172 cm
7	ℓ=L-8	b=466 cm (cu balcon)

P — ULTIMA CIFRĂ INDICĂ

1	la cameră de zi
2	la cameră de zi
3	la dormitor+baie sau + bucătărie
4	la dormitor+degajament, cămară, debara sau grup sanitar
5	la dormitor+degajament, cămară, debara sau grup sanitar
6	la dormitor+logie
7	la bucătărie + vestibul
8	la bucătărie + vestibul
9	la bucătărie + vestibul+logie

PANOURI NEMODULATE (E)

E8	panou cu L=4,18 cm cu fereastră de 240 cm

LITERA INDICĂ

P	fereastra are ochi de ventilație
b, c, d, e, f, g	panouri cu unele diferențe față de tipurile de bază

PANOURI NEMODULATE (L)

L10	1	ℓ= 98	panou cu gol de ușă
L10	2	ℓ= 98	panou plin
L13	1	ℓ= 129	panou cu gol de ușă
L13	2	ℓ= 129	panou plin

LITERA INDICĂ

a, b, c, d, e	panouri cu diferite poziții de uși în cîmp, mustăți verticale și trasee de instalații electrice
r	panouri de rost
s	panouri la casa scării

PANOURI NEMODULATE (P)

P1, P2, P3	panouri de forme speciale

LITERA INDICĂ

t	panouri la terasă

DENUMIREA TIPODIMENSIUNILOR

a. Panourile E și I de dimensiuni efective curente ℓ=L-2 (pentru E) și ℓ=L-30 (pentru I) - se denumesc cu literele majuscule respective urmate de 2 cifre ce reprezintă interaxul modulat al panoului (în dm).

b. Panourile E avînd cea de a 3-a cifră 4,5,6 și 7 (pentru E) și 8 (pentru I) se denumesc cu cele 2 cifre de la pct. „a", urmate de această a 3-a cifră.

c. Panourile I avînd cea de a 3-a cifră 6 și 7, avînd aceleași dimensiuni, se denumesc cu cele 2 cifre de la pct. a, urmate de cifrele 67.

d. Panoul E8 de dimensiune nemodu- [illegible]

e. Panourile de planșeu modulate se denumesc cu litera majusculă **P** urmată de primele trei cifre.

f. Panourile **P** nemodulate au aceleași denumiri ca sortotipodimensiunile respective.

g. Panourile de scări și cabinele spațiale de baie se denumesc ca sortotipodimensiunile respective cu excepția elementelor care se pot turna în același tipar, care se denumesc cu litera majusculă respectivă urmată de toate cifrele panourilor care se toarnă în același tipar.

h. Aticele, putîndu-se turna într-un unic tipar - au o singură tipodimensiune, denumită A.

i. Ventilațiile (cu excepția lui V1) - putîndu-se turna într-un unic tipar - au o singură tipodimensiune, denumită **V**.

j. Ventilația V1 și chepengurile H1 și H2 au denumirea tipodimensiunilor la fel ca a sortotipodimensiunilor.

k. Pereții neportanți de la logii au 2 tipodimensiuni:
- L1 - pentru panourile L10 și L13
- L3 - pentru panourile L30 și L36.

REVIZUIT 1983

DENUMIREA SORTOTIPODIMENSIUNILOR

1. La toate panourile, indicativul „s" și „d" reprezintă panouri stînga sau dreapta (în oglindă); stabilirea elementelor „s", respectiv „D" se face arbitrar.
2. La panourile **E** și **L** modulate, ultima cifră reprezintă numărul de module de 30 cm a lungimii modulate a golului de fereastră sau ușă+fereastră.
3. Panourile E de la logii (cifra 3-a =6) au ultima cifră 0, 1, 2 ... 9, în funcție de forma și modelul acestora.
4. Panourile E de colț (cifra 3-a =7) au ℓ=L+22 pentru pereți de 30 cm grosime; la pereți de grosime „d" (cm) ℓ=L+d-8.
5. Elementele de scară (podeste S și rampe R), cabinele (K) și chepengurile (H) se denumesc cu litera majusculă respectivă urmată de cifrele 1, 2, 3 ... etc.; la podeste, litera „t" indică folosirea elementului la terasă.
6. Elementele de atice de lungimi modulate se denumesc cu litera majusculă A urmată de 2 cifre care indică interaxul modulat L (în dm); lungimea efectivă a acestor atice este:
   ℓ = L-2 - pentru A21 ... A36
   ℓ = L+49 - pentru A54.
   Elementele de atice nemodulate, de forme speciale sau cu teșituri se denumesc cu litera majusculă A, urmată de cifrele 1, 2, 3 ... etc.
7. Elementele de ventilații (normale sau cu aripi de pereți despărțitori) se denumesc cu litera majusculă V urmată de o cifră care reprezintă lungimea (rotunjită) în dm a elementului; cifra 1 indică ventilația de pe terasă iar litera „a" - unele particularități față de tipul curent de aceleași dimensiuni.

LEGENDĂ.

L = interaxul modulat al panourilor (cm)

ℓ = lungimea efectivă a panourilor de pereți (cm)
  = lățimea efectivă a panourilor de planșee (cm)

b = lungimea efectivă a panourilor de planșee (cm)

S = tipo sau sortotipodimensiune „stînga"

D = tipo sau sortotipodimensiune „dreapta"

Șef pr. ing. M. Drimer; Proiectat ing. M. Drimer; Desenat pr. M. Ceaușu; Verificat ing. M. Drimer; Șef col. ing. M. Drimer	IPCT XII-1981	CLĂDIRI DE LOCUIT P+4 DIN PANOURI MARI — DENUMIREA ELEMENTELOR PREFABRICATE	VOL. A 770-83 PE 22

CATEGORIA	ELEMENTUL			Pa																			
				1					2					3					4				
				MM	CM	MC	LM	ML	MM	CM	MC	LM	ML	MM	CM	MC	LM	ML	MM	CM	MC	LM	ML
PERETI EXTERIORI	E18	1			5	5	10	10		5	5	10	10		5	5	10	10		5	5	10	10
	E18	2			5	5				5	5				5	5				5	5		
	E24	1																					
	E24	3	S											5	5	5	5	5					
	E24	3	D											5	5	5	5	5					
	E24	3b	S																				
	E24	3b	D																				
	E24	4												8	8	8	8	8					
	E24	4p												2	2	2	2	2					
	E24	43	S																				
	E24	43	D																				
	E24	43b	S																				
	E24	43b	D																				
	E30	3	S	1	1	1	1	1											5	5	5	5	5
	E30	3	D	1	1	1	1	1	4	4	4	4	4						5	5	5	5	5
	E30	4		4	4	4	4	4						3	3	3	3	3	8	8	8	8	8
	E30	4p												1	1	1	1	1	3	3	3	3	3
	E30	10		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	E30	14		2	2	2	2	2															
	E30	25		4	4	4	4	4															
	E30	25b		4	4	4	4	4															
	E30	30		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	E30	36		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	E30	43	S																				
	E30	43	D																				
	E30	43b	S																				
	E30	43b	D																				
	E30	60		8	8	8	8	8											3	3	3	3	3
	E33	4		8	8	8	8	8															
	E33	4p		2	2	2	2	2															
	E33	6		8	4	4	4	4									4	4					
	E33	6p		2	1	1	1	1									1	1					
	E33	14												2	1	1	2	2					
	E33	16												2	2	2	1	1					
	E33	25	S											4	4		8						
	E33	25	D											4		4		8					
	E33	26	S											4		8		4					
	E33	26	D											4	8		4						
	E33	50	S																				
	E33	50	D																				
	E33	56	S																				
	E33	56	D																				
	E33	56p	S																				
	E33	56p	D																				
	E33	71	S			5		5								5							
	E33	71	D		5		5								5								
	E36	4	S						1	1	1	1	1										
	E36	4	D						1	1	1	1	1										
	E36	5							8	8	8	8	8										
	E36	5p							2	2	2	2	2										
	E36	7					4	4	8	4	4	8	8									4	4
	E36	7p					1	1	2	1	1	2	2									1	1
	E36	15													1	1			2	2	2	2	2
	E36	17			1	1			2	3	3	2	2						2	2	2	1	1

CATEGORIA	ELEMENTUL			Pb																			
				1					2					3					4				
				MM	CM	MC	LM	ML	MM	CM	MC	LM	ML	MM	CM	MC	LM	ML	MM	CM	MC	LM	ML
PERETI EXTERIORI	E18	1			1		10	10		1		10	10		1		10	10		1		10	10
	E18	2			9	10				9	10				9	10				9	10		
	E24	1																					
	E24	3	S																				
	E24	3	D																				
	E24	3b	S																				
	E24	3b	D																				
	E24	4												16	16	16	16	16					
	E24	4p												4	4	4	4	4					
	E24	43	S	8	8	8	8	8						8	8	8	8	8					
	E24	43	D	8	8	8	8	8						8	8	8	8	8					
	E24	43b	S	2	2	2	2	2						2	2	2	2	2					
	E24	43b	D	2	2	2	2	2						2	2	2	2	2					
	E30	3	S																				
	E30	3	D																				
	E30	4																	16	16	16	16	16
	E30	4p																	4	4	4	4	4
	E30	10																					
	E30	14																					
	E30	25																					
	E30	25b																					
	E30	30																					
	E30	36																					
	E30	43	S						8	8	8	8	8						8	8	8	8	8
	E30	43	D						8	8	8	8	8						8	8	8	8	8
	E30	43b	S						2	2	2	2	2						2	2	2	2	2
	E30	43b	D						2	2	2	2	2						2	2	2	2	2
	E30	60																					
	E33	4		16	12	12	12	12						16	12	12	12	12					
	E33	4p		3	3	2	3	2						3	3	2	3	2					
	E33	6																					
	E33	6p		1		1		1						1		1		1					
	E33	14																					
	E33	16																					
	E33	25	S																				
	E33	25	D																				
	E33	26	S																				
	E33	26	D																				
	E33	50	S	1	1	1	1	1						1	1	1	1	1					
	E33	50	D	1	1	1	1	1						1	1	1	1	1					
	E33	56	S	8	8	8	8	8						8	8	8	8	8					
	E33	56	D	8	8	8	8	8						8	8	8	8	8					
	E33	56p	S	1	1	1	1	1						1	1	1	1	1					
	E33	56p	D	1	1	1	1	1						1	1	1	1	1					
	E33	71	S			5		5								5		5					
	E33	71	D		5		5								5		5						
	E36	4	S																				
	E36	4	D																				
	E36	5						4	16	12	12	12	16					4	16	12	12	12	16
	E36	5p						1	3	3	2	3	3					1	3	3	2	3	3
	E36	7					4					4					4					4	
	E36	7p					1		1		1	1	1				1		1		1	1	1
	E36	15				1					1					1					1		
	E36	17			1					1					1					1			

CATEGORIA	ELEMENTUL			Pc											
				1				2				3		4	
				DM	MD	FM	MF	DM	MD	FM	MF	TM	MT	TM	MT
PERETI EXTERIORI	E18	1		10	10	5	5	10	10	5	5				
	E18	2				5	5			5	5				
	E24	1										5	5	5	5
	E24	3	S	5		5						5			
	E24	3	D		5		5						5		
	E24	3b	S										5		5
	E24	3b	D									5		5	
	E24	4		4	4	4	4					4	4		
	E24	4p		1	1	1	1					1	1		
	E24	43	S												
	E24	43	D												
	E24	43b	S												
	E24	43b	D												
	E30	3	S					5		5				5	
	E30	3	D						5		5				5
	E30	4						4	4	4	4	3	3	7	7
	E30	4p		1	1	1	1	2	2	2	2	1	1	2	2
	E30	10		1	1	1	1	1	1	1	1	1	1	1	1
	E30	14													
	E30	25													
	E30	25b													
	E30	30		1	1	1	1	1	1	1	1	1	1	1	1
	E30	36		4	4	4	4	4	4	4	4	4	4	4	4
	E30	43	S												
	E30	43	D												
	E30	43b	S												
	E30	43b	D												
	E30	60		3	3	3	3	3	3	3	3				
	E33	4													
	E33	4p													
	E33	6													
	E33	6p													
	E33	14		1	1	1	1					1	1		
	E33	16		1	1	1	1					1	1		
	E33	25	S	4		4						4			
	E33	25	D		4		4						4		
	E33	26	S		4		4						4		
	E33	26	D	4		4						4			
	E33	50	S												
	E33	50	D												
	E33	56	S												
	E33	56	D												
	E33	56p	S												
	E33	56p	D												
	E33	71	S												
	E33	71	D												
	E36	4	S		5		5		5		5				
	E36	4	D	5		5		5		5					
	E36	5													
	E36	5p													
	E36	7													
	E36	7p													
	E36	15		1	1	1	1	2	2	2	2	1	1	2	2
	E36	17		1	1	1	1	2	2	2	2			1	1

* REVIZUIT 1983

SEF PR. ING. DRIMER PROIECTAT ING. POPESCU R. DESENAT STANESCU A. VERIFICAT ING. DRIMER SEF COLECT. ING. DRIMER	IPCT V-1983	CLADIRI DE LOCUIT P+4 DIN PANOURI MARI NOMENCLATOR PREFABRICATE P.E.	VOL. A 770-83 23

ANNEX 2 – TEST MODEL THERMAL AND ENERGY SIMULATIONS BASED ON DIFFERENT ENVELOPE SYSTEMS

ubakus

All statements without guarantee

MW 1

Exterior wall
created on 13.2.2019

Thermal protection

U = 0,17 W/(m²K)

EnEV Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

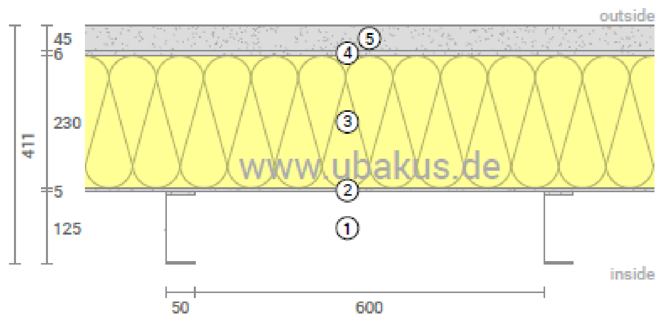
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 7,9
phase shift: 6,7 h
Thermal capacity inside: 19,7 kJ/m²K

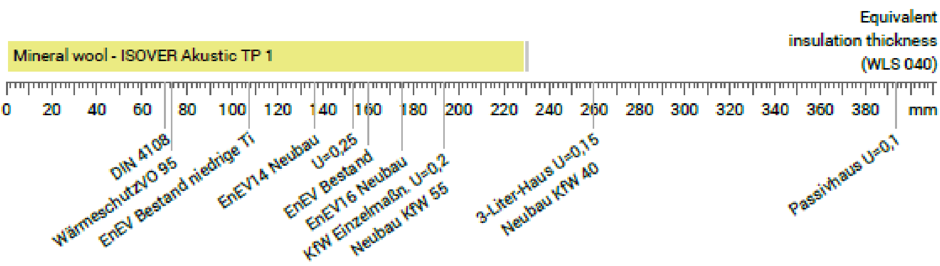
excellent insufficient



1. Steel (125x0.6)
2. Internal steel sheet (5 mm)
3. Mineral wool - ISOVER Akustic TP 1 (230 mm)
4. External steel sheet (6 mm)
5. Cladding elements with fastening clips (45 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,040 W/mK.



Inside air :	20,0°C / 40%
Outside air:	-5,0°C / 60%
Surface temperature.:	19,9°C / -4,8°C

sd-value: 2030,6 m

Thickness:	41,1 cm
Weight:	0 kg/m²
Heat capacity:	47 kJ/m²K

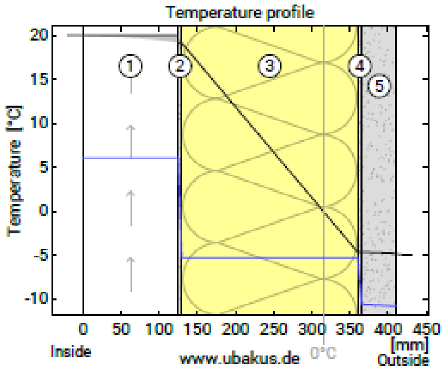
*Comparison to the maximum U-value according to the german EnEV 2014/2016 for first-time installation or renewal of Außenwänden (Anlage 3, Tabelle 1, Zeile 1).

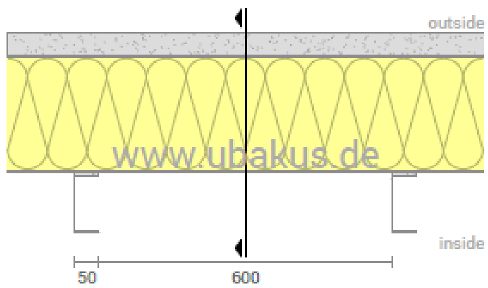
ubakus

All statements without guarantee

MW1 U=0,17 W/(m²K)

Temperature profile





① Inside air (125 mm)
② Internal steel sheet (5 mm)
③ Mineral wool - ISOVER Akustic TP ...
④ External steel sheet (6 mm)
⑤ Cladding elements with fastening c...

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	19,9	20,0	
1	12,5 cm	Inside air			19,1	20,0	
	12,5 cm	Steel (0,092%)	50,000	0,003	19,2	19,9	0,9
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	20,0	20,0	0,0
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	19,2	19,2	0,0
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,2	19,2	0,4
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,9	20,0	0,4
2	0,5 cm	Internal steel sheet	50,000	0,000	19,1	19,2	38,5
3	23 cm	Mineral wool - ISOVER Akustic TP 1	0,040	5,750	-4,7	19,2	no information
4	0,6 cm	External steel sheet	50,000	0,000	-4,7	-4,7	46,2
5	4,5 cm	Cladding elements with fastening clips	1,200	0,038	-4,8	-4,7	5,4
		Thermal contact resistance*		0,040	-5,0	-4,8	
	41,1 cm	Whole component		5,943			>92

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max):	19,9°C	20,0°C	20,0°C
Surface temperature outside (min / average / max):	-4,8°C	-4,8°C	-4,8°C

ubakus All statements without guarantee

MW1, U=0,17 W/(m²K)

Moisture proofing

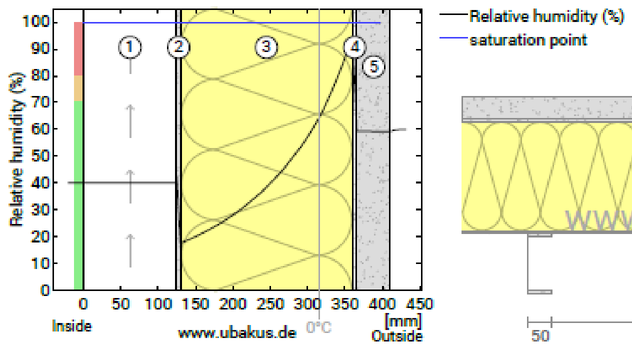
For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 40% Humidity; outside: -5°C und 60% Humidity (Climate according to user input).

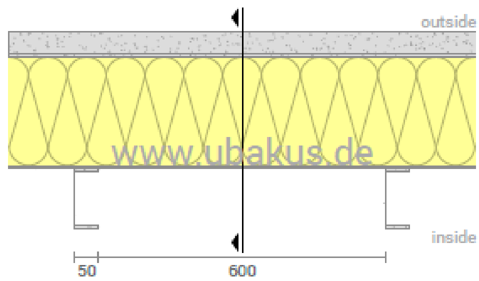
This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	Condensate [Gew.-%]	Weight [kg/m²]
1	12,5 cm	Inside air		-		
	12,5 cm	Steel (0,092%)	7,20	-		0,9
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
2	0,5 cm	Internal steel sheet	1500	-		38,5
3	23 cm	Mineral wool - ISOVER Akustic TP 1	0,23	-		no information
4	0,6 cm	External steel sheet	450,00	-		46,2
5	4,5 cm	Cladding elements with fastening clips	13,50	-		5,4
	41,1 cm	Whole component	2.030,57			>92

Humidity

The temperature of the inside surface is 19,9 °C leading to a relative humidity on the surface of 40%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.





① Inside air (125 mm)
② Internal steel sheet (5 mm)
③ Mineral wool - ISOVER Akustic TP ...
④ External steel sheet (6 mm)
⑤ Cladding elements with fastening c...

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

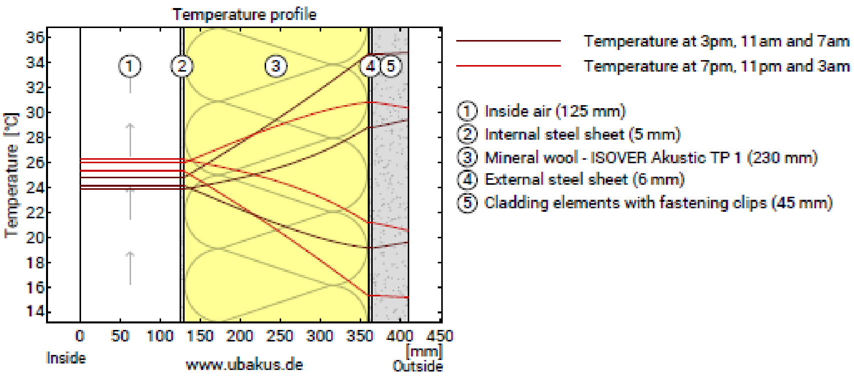
ubakus

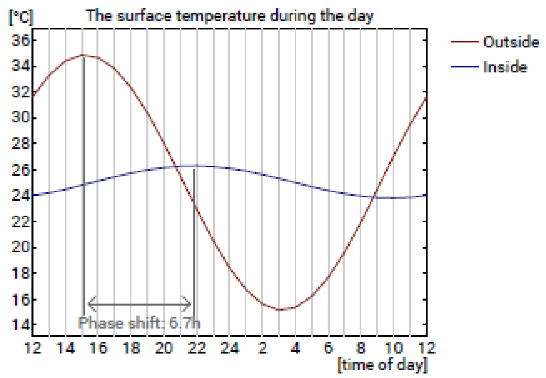
All statements without guarantee

MW1, U=0,17W/(m²K)

Heatbprotection

Thebfollowingbresultsbarebpropertiesbofbthebtestedbcomponentbalonebandbdobnotbmakebanybstatementbaboutbthebheatbprotect ofbthebentirebroom:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	6,7 h	Heat storage capacity (whole component):	47 kJ/m²K
Amplitude attenuation **	7,9	Thermal capacity of inner layers:	19.7 kJ/m²K
TAV ***	0,126		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

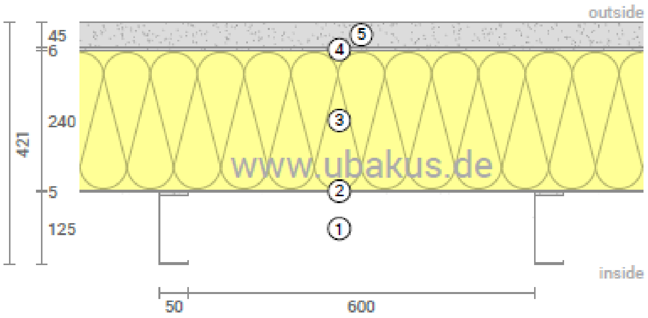
The calculations presented above have been created for a 1-dimensional cross-section of the component.

All statements without guarantee

MW2

Exterior wall
created on 24.2.2019

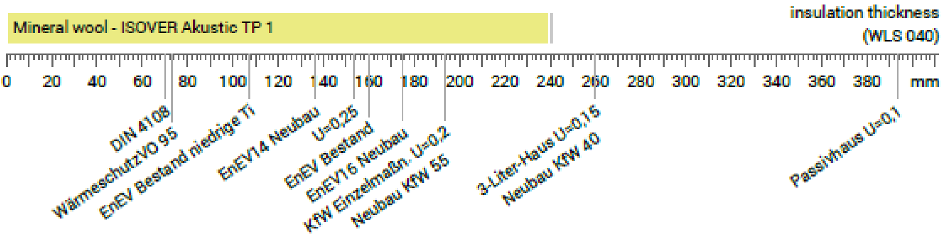
Thermal protection	Moisture proofing	Heat protection
U = 0,16 W/(m²K)b	No condensate	Temperature amplitude damping: 8,3
EnEV Bestand*: U<0,24 W/(m²K)		phase shift: 6,7 h
		Thermal capacity inside: 19,8 kJ/m²K
excellent — insufficient	excellent — insufficient	excellent — insufficient



1. Steel (125x0.6)
2. Internal steel sheet (5 mm)
3. Mineral wool - ISOVER Akustic TP 1 (240 mm)
4. External steel sheet (6 mm)
5. Cladding elements with fastening clips (45 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,040 W/mK.



Inside air :	20,0°C / 40%		Thickness:	42,1 cm
Outside air:	-5,0°C / 60%	sd-value: 2030,6 m	Weight:	0 kg/m²
Surface temperature.:	19,9°C / -4,8°C		Heat capacity:	47 kJ/m²K

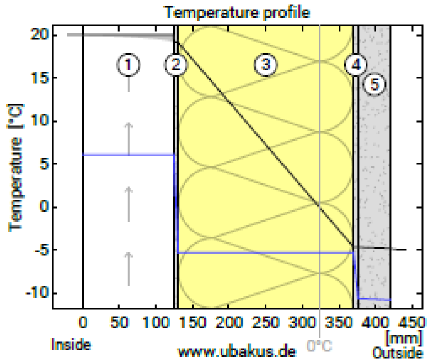
*Comparison to the maximum U-value according to the german EnEV 2014/2016 for first-time installation or renewal of Außenwänden (Anlage 3, Tabelle 1, Zeile 1).

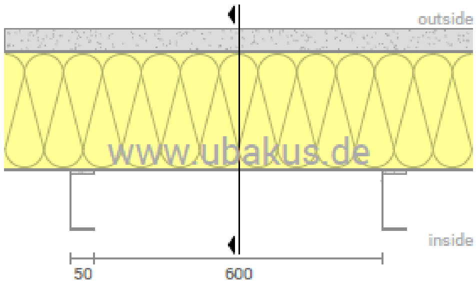
ubakus

All statements without guarantee

MW2, U=0,16 W/(m²K)

Temperature profile





① Inside air (125 mm)
② Internal steel sheet (5 mm)
③ Mineral wool - ISOVER Akustic TP ...
④ External steel sheet (6 mm)
⑤ Cladding elements with fastening c...

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	19,9	20,0	
1	12,5 cm	Inside air			19,1	20,0	
	12,5 cm	Steel (0,092%)	50,000	0,003	19,2	19,9	0,9
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	20,0	20,0	0,0
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	19,2	19,2	0,0
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,2	19,2	0,4
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,9	20,0	0,4
2	0,5 cm	Internal steel sheet	50,000	0,000	19,1	19,2	38,5
3	24 cm	Mineral wool - ISOVER Akustic TP 1	0,040	6,000	-4,7	19,2	no inform ation
4	0,6 cm	External steel sheet	50,000	0,000	-4,7	-4,7	46,2
5	4,5 cm	Cladding elements with fastening clips	1,200	0,038	-4,8	-4,7	5,4
		Thermal contact resistance*		0,040	-5,0	-4,8	
	42,1 cm	Whole component		6,193			>92

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max): 19,9°C 20,0°C 20,0°C
Surface temperature outside (min / average / max): -4,8°C -4,8°C -4,8°C

ubakus All statements without guarantee

MW2, U=0,16W/(m²K)

Moisturebproofing

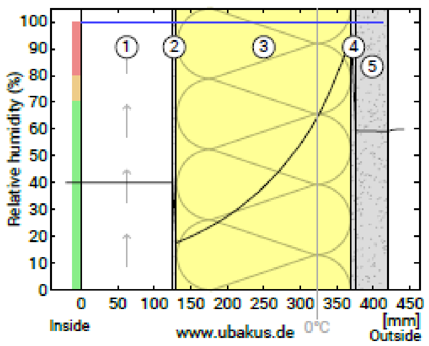
Forbthebcalculationbofbthebamountbofbcondensationbwater,bthebcomponentbwasbexposedbtobthebfollowingbconstantbclimatebf(
90bdays:binside:b20°Cbundb40%bHumidity;boutside:b-5°Cbundb60%bHumidityb(Climatebaccordingbtobuserbinput).

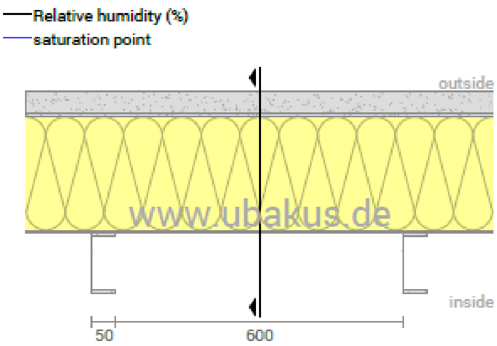
Thisbcomponentbisbfreebofbcondensatebunderbthebgivenbclimatebconditions.

#		Material	sd-value [m]	Condensate [kg/m²]	Condensate [Gew.-%]	Weight [kg/m²]
1	12,5 cm	Inside air		-		
	12,5 cm	Steel (0,092%)	7,20	-		0,9
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
2	0,5 cm	Internal steel sheet	1500	-		38,5
3	24 cm	Mineral wool - ISOVER Akustic TP 1	0,24	-		no information
4	0,6 cm	External steel sheet	450,00	-		46,2
5	4,5 cm	Cladding elements with fastening clips	13,50	-		5,4
	42,1 cm	Whole component	2.030,58			>92

Humidity

The temperature of the inside surface is 19,9 °C leading to a relative humidity on the surface of 40%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



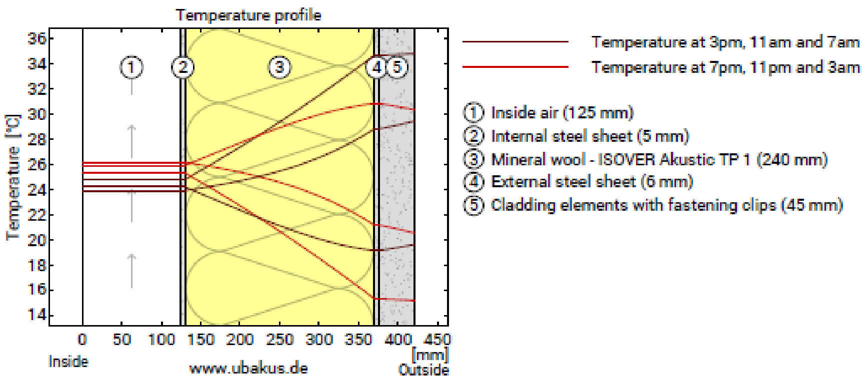


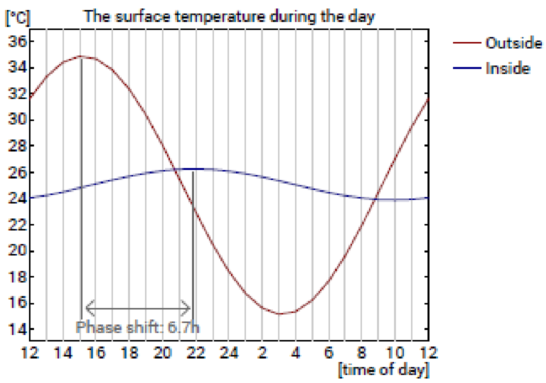
① Inside air (125 mm) ② Internal steel sheet (5 mm) ③ Mineral wool - ISOVER Akustic TP ... ④ External steel sheet (6 mm) ⑤ Cladding elements with fastening c...

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

Heatbprotection

Thebfollowingbresultsbarebpropertiesbofbthebtestedbcomponentbalonebandbdobnotbmakebanybstatementbaboutbthebheatbprotec ofbthebentirebroom:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	6,7 h	Heat storage capacity (whole component):	47 kJ/m²K
Amplitude attenuation **	8,3	Thermal capacity of inner layers:	19.8 kJ/m²K
TAV ***	0,120		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

The calculations presented above have been created for a 1-dimensional cross-section of the component.

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All statements without guarantee

PIR 1

Exterior wall
created on 13.2.2019

Thermal protection

U = 0,17 W/(m²K)

EnEV Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

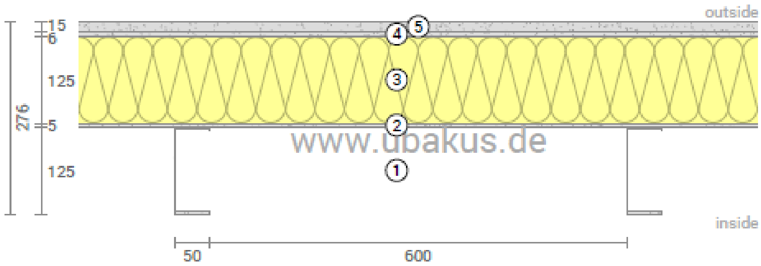
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 8,2
phase shift: 6,8 h
Thermal capacity inside: 21 kJ/m²K

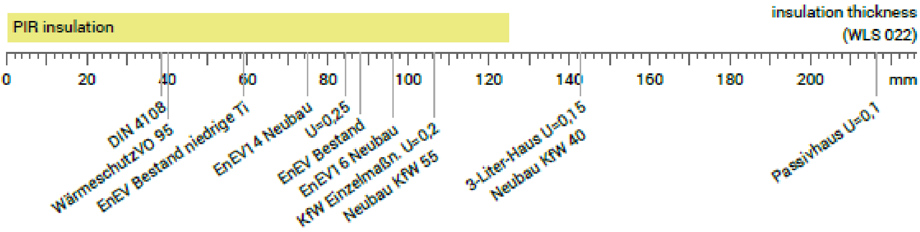
excellent insufficient



(1) Steel (125x0.6)
(2) Internal steel sheet (5 mm)
(3) PIR insulation (125 mm)
(4) External steel sheet (6 mm)
(5) Shingle with fastening clips (15 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,022 W/mK.



Inside air :	20,0°C / 40%		Thickness:	27,6 cm
Outside air:	-5,0°C / 60%	sd-value: 2051,6 m	Weight:	92 kg/m²
Surface temperature.:	19,9°C / -4,8°C		Heat capacity:	46 kJ/m²K

*Comparison to the maximum U-value according to the german EnEV 2014/2016 for first-time installation or renewal of Außenwänden (Anlage 3, Tabelle 1, Zeile 1).

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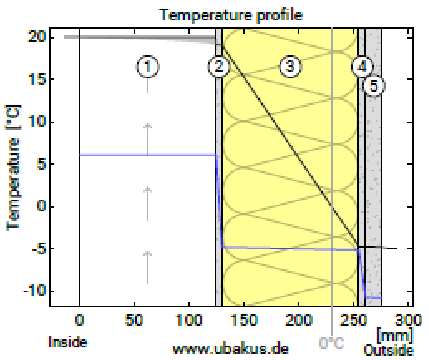
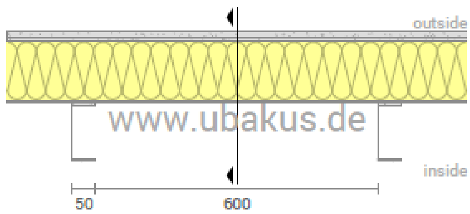
PIR 1, U=0,17 W/(m²K)

Temperature profile





① Inside air (125 mm)
② Internal steel sheet (5 mm)
③ PIR insulation (125 mm)
④ External steel sheet (6 mm)
⑤ Shingle with fastening clips (15 mm)

Left: Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	19,9	20,0	
1	12,5 cm	Inside air			19,1	20,0	
	12,5 cm	Steel (0,092%)	50,000	0,003	19,2	19,9	0,9
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	20,0	20,0	0,0
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	19,2	19,2	0,0
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,2	19,2	0,4
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,9	20,0	0,4
2	0,5 cm	Internal steel sheet	50,000	0,000	19,1	19,2	38,5
3	12,5 cm	PIR insulation	0,022	5,682	-4,8	19,2	3,8
4	0,6 cm	External steel sheet	50,000	0,000	-4,8	-4,8	46,2
5	1,5 cm	Shingle with fastening clips	1,200	0,013	-4,8	-4,8	1,8
		Thermal contact resistance*		0,040	-5,0	-4,8	
	27,6 cm	Whole component		5,850			92,1

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max):	19,9°C	20,0°C	20,0°C
Surface temperature outside (min / average / max):	-4,8°C	-4,8°C	-4,8°C

ubakus All statements without guarantee

PIR 1, U=0,17 W/(m²K)

Moisture proofing

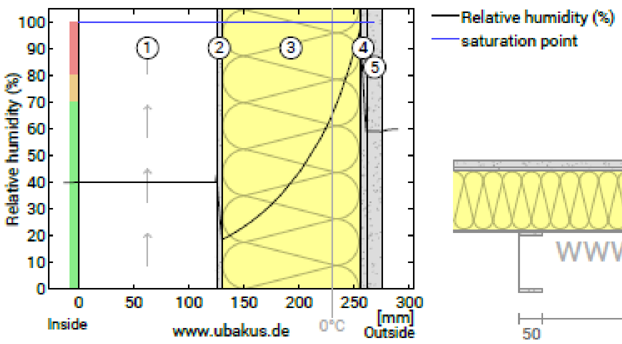
For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 40% Humidity; outside: -5°C und 60% Humidity (Climate according to user input).

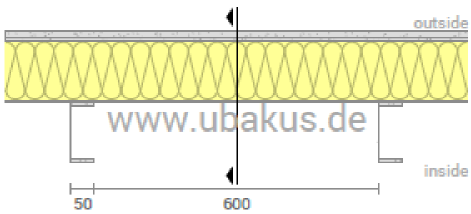
This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	12,5 cm	Inside air		-		
	12,5 cm	Steel (0,092%)	7,20	-		0,9
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
2	0,5 cm	Internal steel sheet	1500	-		38,5
3	12,5 cm	PIR insulation	30,00	-		3,8
4	0,6 cm	External steel sheet	450,00	-		46,2
5	1,5 cm	Shingle with fastening clips	4,50	-		1,8
	27,6 cm	Whole component	2.051,63			92,1

Humidity

The temperature of the inside surface is 19,9 °C leading to a relative humidity on the surface of 40%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.





① Inside air (125 mm) ③ PIR insulation (125 mm) ⑤ Shingle with fastening clips (15 mm)
② Internal steel sheet (5 mm) ④ External steel sheet (6 mm)

Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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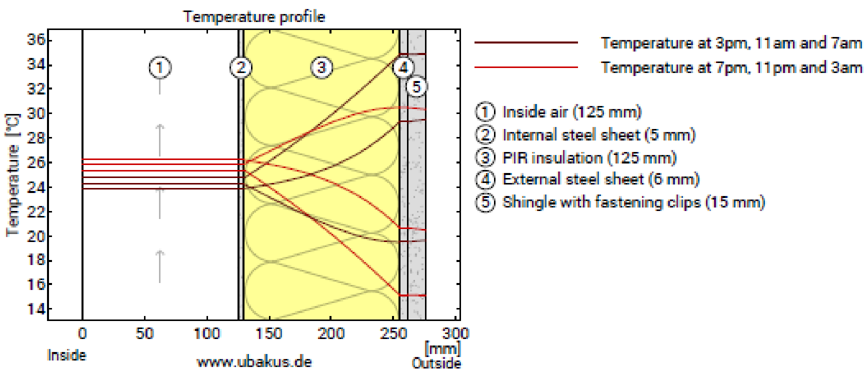
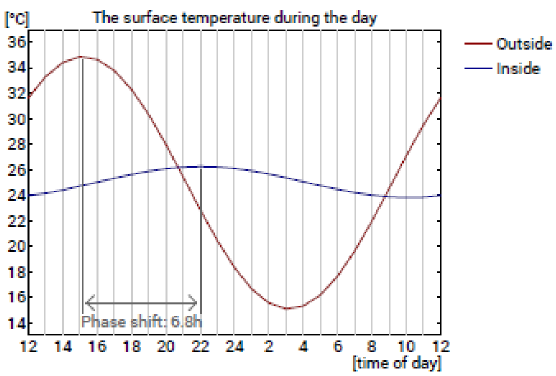
All statements without guarantee

PIR 1, U=0,17 W/(m²K)

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	6,8 h	Heat storage capacity (whole component):	46 kJ/m²K
Amplitude attenuation **	8,2	Thermal capacity of inner layers:	21 kJ/m²K
TAV ***	0,122		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
***The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

The calculations presented above have been created for a 1-dimensional cross-section of the component.

ubakus

All statements without guarantee

PIR 2

Exterior wall
created on 24.2.2019

Thermal protection

U = 0,17 W/(m²K)b

EnEV Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

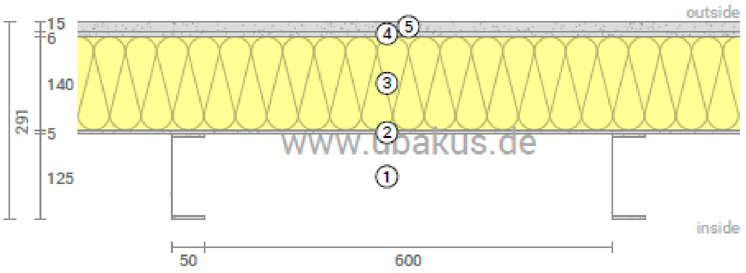
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: 8,5
phase shift: 7,2 h
Thermal capacity inside: 21 kJ/m²K

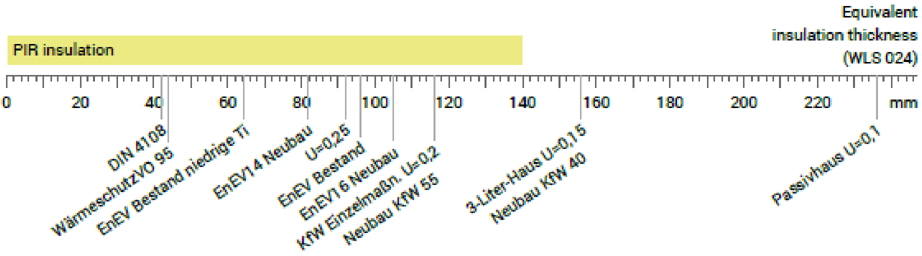
excellent insufficient



1. Steel (125x0.6)
2. Internal steel sheet (5 mm)
3. PIR insulation (140 mm)
4. External steel sheet (6 mm)
5. Shingle with fastening clips (15 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,024 W/mK.



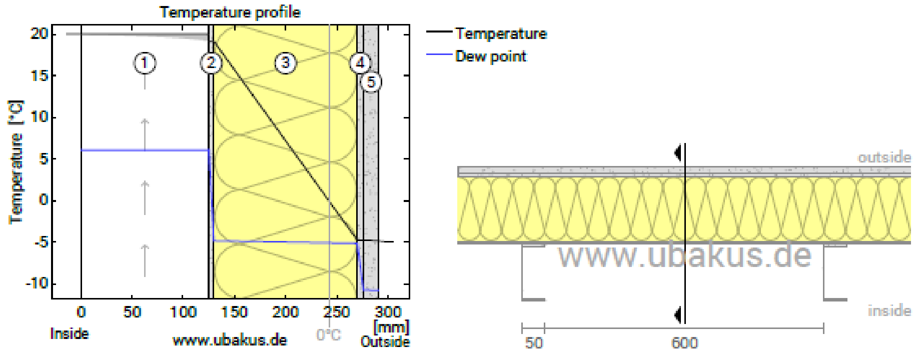
Inside air :	20,0°C / 40%		Thickness:	29,1 cm
Outside air:	-5,0°C / 60%	sd-value: 2051,6 m	Weight:	93 kg/m²
Surface temperature.:	19,9°C / -4,8°C		Heat capacity:	46 kJ/m²K

*Comparison to the maximum U-value according to the german EnEV 2014/2016 for first-time installation or renewal of Außenwänden (Anlage 3, Tabelle 1, Zeile 1).

ubakus All statements without guarantee

PIR 2, U=0,17 W/(m²K)

Temperature profile



(1) Inside air (125 mm)
(2) Internal steel sheet (5 mm)
(3) PIR insulation (140 mm)
(4) External steel sheet (6 mm)
(5) Shingle with fastening clips (15 mm)

Left:Temperature and dew-point temperature at the place marked in the right figure. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew point, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.
Right: The component, drawn to scale.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	19,9	20,0	
1	12,5 cm	Inside air			19,1	20,0	
	12,5 cm	Steel (0,092%)	50,000	0,003	19,2	19,9	0,9
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	20,0	20,0	0,0
	0,5 cm	Steel (Width: 0,06 cm)	50,000	0,000	19,2	19,2	0,0
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,2	19,2	0,4
	0,06 cm	Steel (Width: 5 cm)	50,000	0,000	19,9	20,0	0,4
2	0,5 cm	Internal steel sheet	50,000	0,000	19,1	19,2	38,5
3	14 cm	PIR insulation	0,024	5,833	-4,8	19,2	4,2
4	0,6 cm	External steel sheet	50,000	0,000	-4,8	-4,8	46,2
5	1,5 cm	Shingle with fastening clips	1,200	0,013	-4,8	-4,8	1,8
		Thermal contact resistance*		0,040	-5,0	-4,8	
	29,1 cm	Whole component		6,001			92,5

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max):	19,9°C	20,0°C	20,0°C
Surface temperature outside (min / average / max):	-4,8°C	-4,8°C	-4,8°C

ubakus All statements without guarantee

PIR 2, U=0,17W/(m²K)

Moisturebproofing

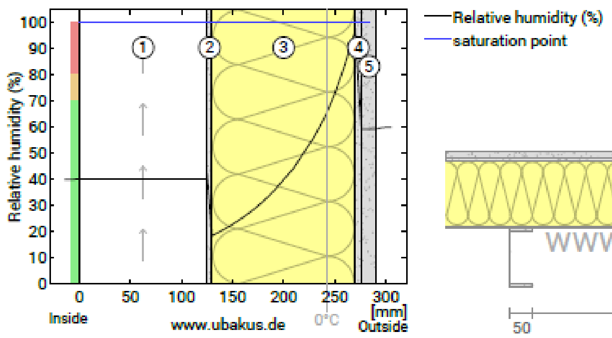
Forbthebcalculationbofbthebamountbofbcondensationbwater,bthebcomponentbwasbexposedbtobthebfollowingbconstantbclimatebfc 90bdays:binside:b20°Cbundb40%bHumidity;boutside:b-5°Cbundb60%bHumidityb(Climatebaccordingbtobuserbinput).

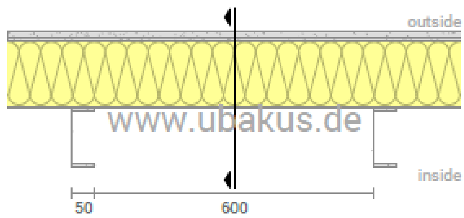
Thisbcomponentbisbfreebofbcondensatebunderbthebgivenbclimatebconditions.

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	12,5 cm	Inside air		-		
	12,5 cm	Steel (0,092%)	7,20	-		0,9
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,5 cm	Steel (Width: 0,06 cm)	180,00	-		0,0
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
	0,06 cm	Steel (Width: 5 cm)	1500	-		0,4
2	0,5 cm	Internal steel sheet	1500	-		38,5
3	14 cm	PIR insulation	30,00	-		4,2
4	0,6 cm	External steel sheet	450,00	-		46,2
5	1,5 cm	Shingle with fastening clips	4,50	-		1,8
	29,1 cm	Whole component	2.051,63			92,5

Humidity

The temperature of the inside surface is 19,9 °C leading to a relative humidity on the surface of 40%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.





① Inside air (125 mm) ② Internal steel sheet (5 mm) ③ PIR insulation (140 mm) ④ External steel sheet (6 mm) ⑤ Shingle with fastening clips (15 mm)

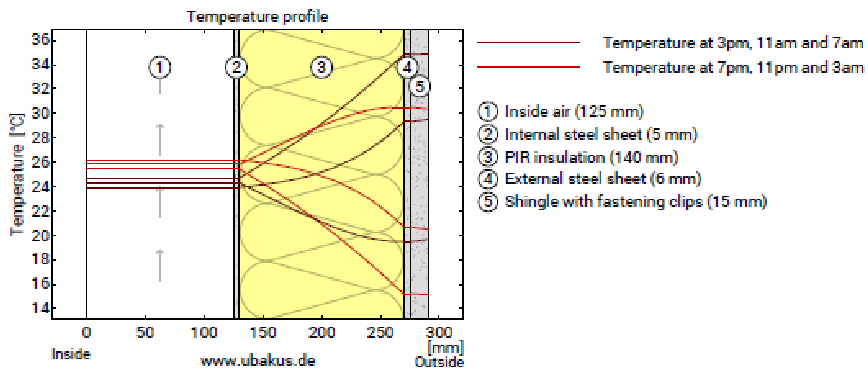
Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

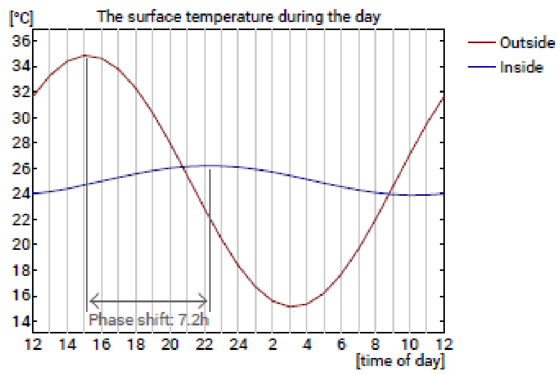
All statements without guarantee

PIR 2,U=0,17W/(m²K)

Heatbprotection

Thebfollowingbresultsbarebpropertiesbofbthebtestedbcomponentbalonebandbdobnotbmakebanybstatementbaboutbthebheatbprotec ofbthebentirebroom:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	7,2 h	Heat storage capacity (whole component):	46 kJ/m²K
Amplitude attenuation **	8,5	Thermal capacity of inner layers:	21 kJ/m²K
TAV ***	0,117		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

The calculations presented above have been created for a 1-dimensional cross-section of the component.

RUUKI LIBERTA 500

xx/2017 ROtemplate

Key Values

General Project Data		
Project Name:	ROtemplate	
City Location:	Timisoara	
Latitude:	45° 45' 0" N	
Longitude:	21° 14' 0" E	
Altitude:	650.00	m
Climate Data Source:	Strusoft server	
Evaluation Date:	17-Feb-19 6:15:48 PM	

Building Geometry Data		
Gross Floor Area:	32.06	m²
Treated Floor Area:	24.60	m²
External Envelope Area:	120.93	m²
Ventilated Volume:	124.44	m³
Glazing Ratio:	6	%

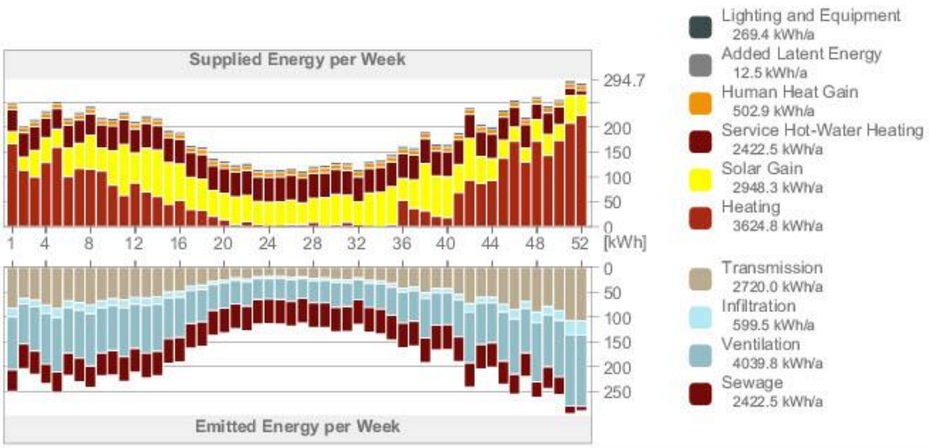
Building Shell Performance Data		
Infiltration at 50Pa:	3.84	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	0.24	
Floors:	--	
External:	0.13 - 0.13	
Underground:	--	
Openings:	0.99 - 2.84	

Specific Annual Values		
Net Heating Energy:	147.34	kWh/m²a
Net Cooling Energy:	0.00	kWh/m²a
Total Net Energy:	147.34	kWh/m²a
Energy Consumption:	256.76	kWh/m²a
Fuel Consumption:	210.35	kWh/m²a
Primary Energy:	770.27	kWh/m²a
Fuel Cost:	--	GBP/m²a
CO_2 Emission:	0.00	kg/m²a

Degree Days	
Heating (HDD):	2911.11
Cooling (CDD):	2125.18

Project Energy Balance



Thermal Blocks

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 SIMULATION	1	Rezidential	32.06	124.44
Total:	1		32.06	124.44

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001 SIMULATION - Key Values

Geometry Data		
Gross Floor Area:	32.06	m²
Treated Floor Area:	24.60	m²
Building Shell Area:	120.93	m²
Ventilated Volume:	124.44	m³
Glazing Ratio:	6	%

Internal Temperature		
Min. (01:00 Dec. 23):	5.69	°C
Annual Mean:	24.87	°C
Max. (14:00 Aug. 24):	60.34	°C

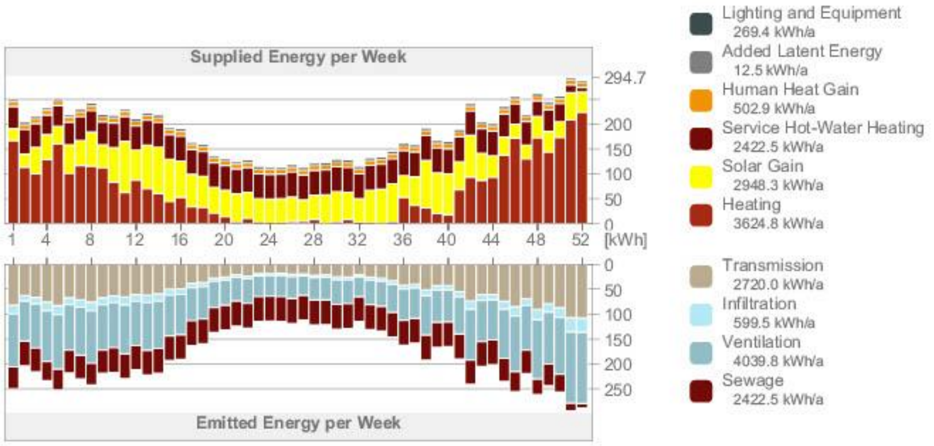
Unmet Load Hours		
Heating:	524	hrs/a
Cooling:	2587	hrs/a

Heat Transfer Coefficients	U value	[W/m²K]
Floors:	-	
External:	0.13 - 0.13	
Underground:	-	
Openings:	0.99 - 2.84	

Annual Supplies		
Heating:	3624.77	kWh
Cooling:	0.00	kWh

Peak Loads		
Heating (01:00 Jan. 26):	1.50	kW
Cooling (01:00 Jan. 01):	0.00	kW

001 SIMULATION Energy Balance



Daily Temperature Profile

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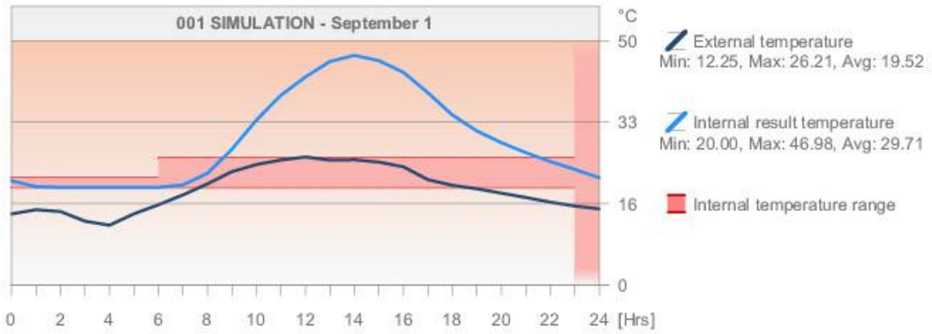

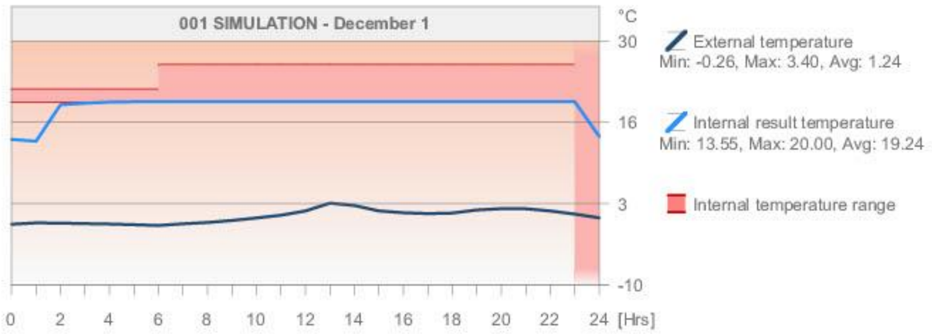

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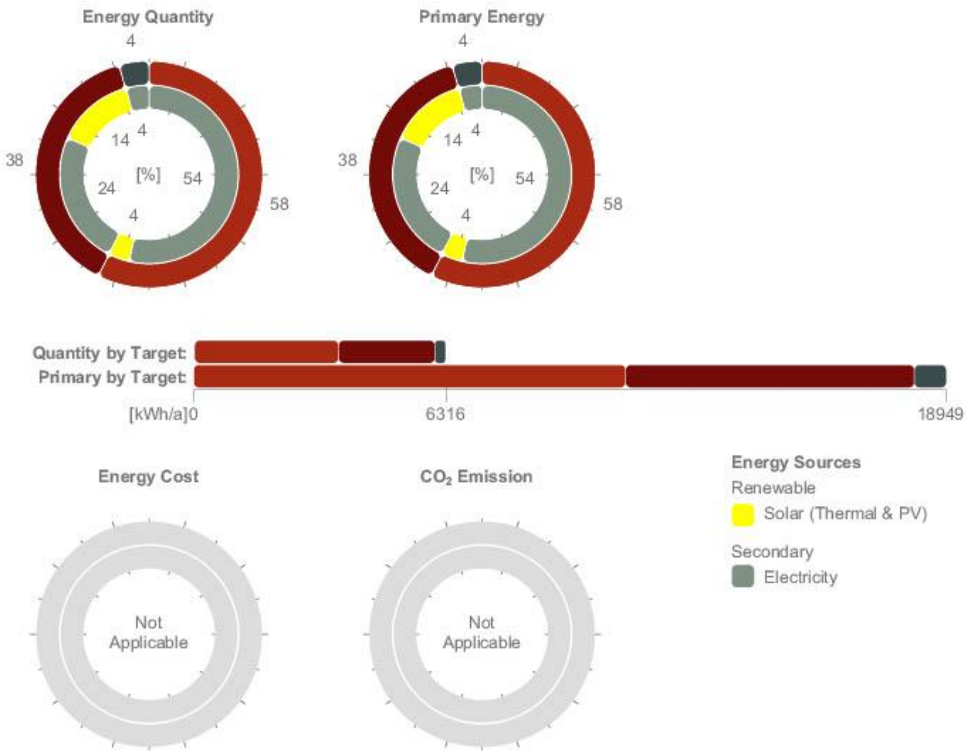
Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Heating	3624	10874	0	0
Cooling	0	0	0	0
Service Hot-Water	2422	7267	0	0
Ventilation Fans	0	0	0	0
Lighting & Appliances	269	808	0	0
Total:	**6316**	**18949**	**NA**	**0**



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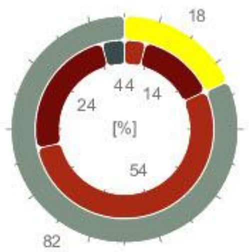
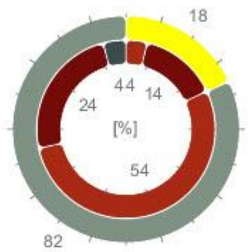
Energy Consumption by Sources

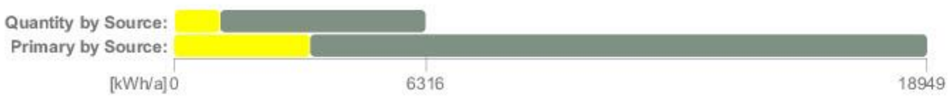
Source Type		Source Name	Energy Quantity kWh/a	Primary kWh/a	Cost GBP/a	CO_2 Emission kg/a
Renewable		Solar (Thermal & PV)	1141	3425	NA	0
Secondary		Electricity	5174	15524	--	0
		Total:	**6316**	**18949**	Not Applicable	**0**

Energy Quantity

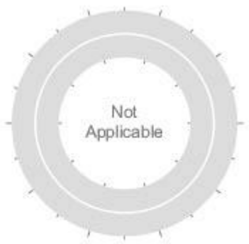


Primary Energy

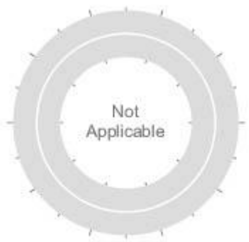




Energy Cost



CO_2 Emission



Energy Targets

- Heating
- Service Hot-Water Heating
- Cooling
- Ventilation Fans
- Lighting
- Equipment

Environmental Impact

Source Type		Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable		Solar (Thermal & PV)	3425	0
Secondary		Electricity	15524	0
		Total:	**18949**	**0**

QBISS ONE

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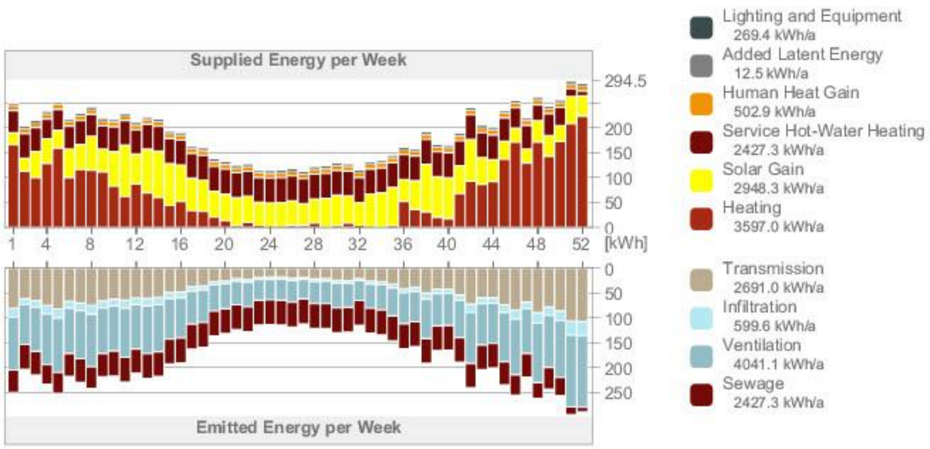
Key Values

General Project Data		
Project Name:	ROtemplate	
City Location:	Timisoara	
Latitude:	45° 45' 0" N	
Longitude:	21° 14' 0" E	
Altitude:	650.00	m
Climate Data Source:	Strusoft server	
Evaluation Date:	17-Feb-19 6:22:51 PM	
Building Geometry Data		
Gross Floor Area:	**32.25**	m²
Treated Floor Area:	**24.60**	m²
External Envelope Area:	**120.93**	m²
Ventilated Volume:	**124.44**	m³
Glazing Ratio:	**6**	%
Building Shell Performance Data		
Infiltration at 50Pa:	**3.84**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**0.24**	
Floors:	--	
External:	**0.13 - 0.13**	
Underground:	--	
Openings:	**0.99 - 2.84**	
Specific Annual Values		
Net Heating Energy:	**146.21**	kWh/m²a
Net Cooling Energy:	**0.00**	kWh/m²a
Total Net Energy:	**146.21**	kWh/m²a
Energy Consumption:	**255.83**	kWh/m²a
Fuel Consumption:	**209.44**	kWh/m²a
Primary Energy:	**767.48**	kWh/m²a
Fuel Cost:	--	GBP/m²a
CO_2 Emission:	**0.00**	kg/m²a
Degree Days		
Heating (HDD):	**2911.11**	
Cooling (CDD):	**2125.18**	

Project Energy Balance



Thermal Blocks

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 SIMULATION	1	Rezidential	32.25	124.44
Total:	**1**		**32.25**	**124.44**

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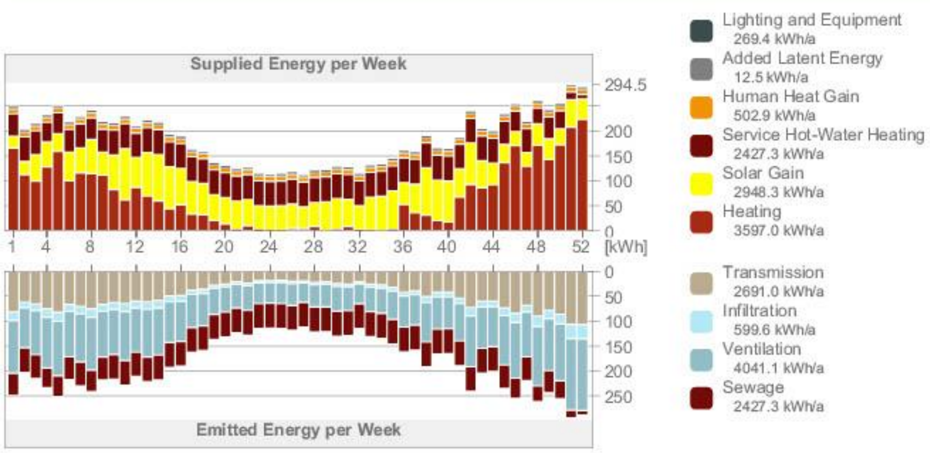
001 SIMULATION - Key Values

Geometry Data		
Gross Floor Area:	32.25	m²
Treated Floor Area:	24.60	m²
Building Shell Area:	120.93	m²
Ventilated Volume:	124.44	m³
Glazing Ratio:	6	%
Internal Temperature		
Min. (01:00 Dec. 23):	5.82	°C
Annual Mean:	24.88	°C
Max. (14:00 Aug. 24):	60.25	°C
Unmet Load Hours		
Heating:	520	hrs/a
Cooling:	2593	hrs/a

Heat Transfer Coefficients	U value	[W/m²K]
Floors:	-	
External:	0.13 - 0.13	
Underground:	-	
Openings:	0.99 - 2.84	
Annual Supplies		
Heating:	3597.05	kWh
Cooling:	0.00	kWh
Peak Loads		
Heating (01:00 Jan. 26):	1.50	kW
Cooling (01:00 Jan. 01):	0.00	kW

001 SIMULATION Energy Balance



Daily Temperature Profile

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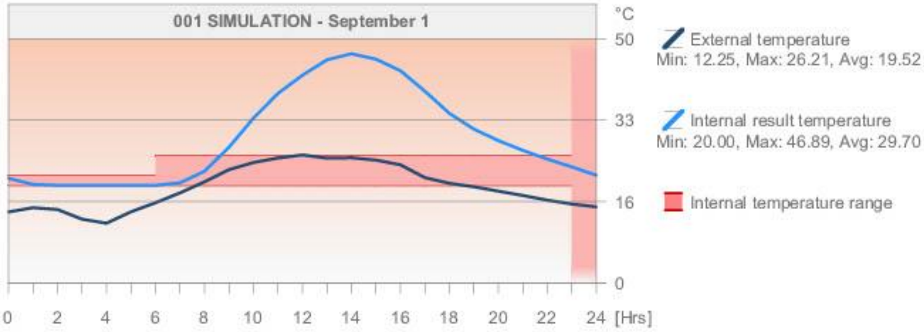

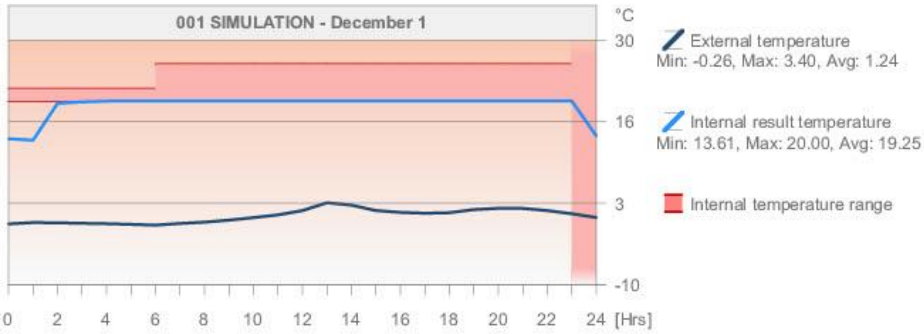

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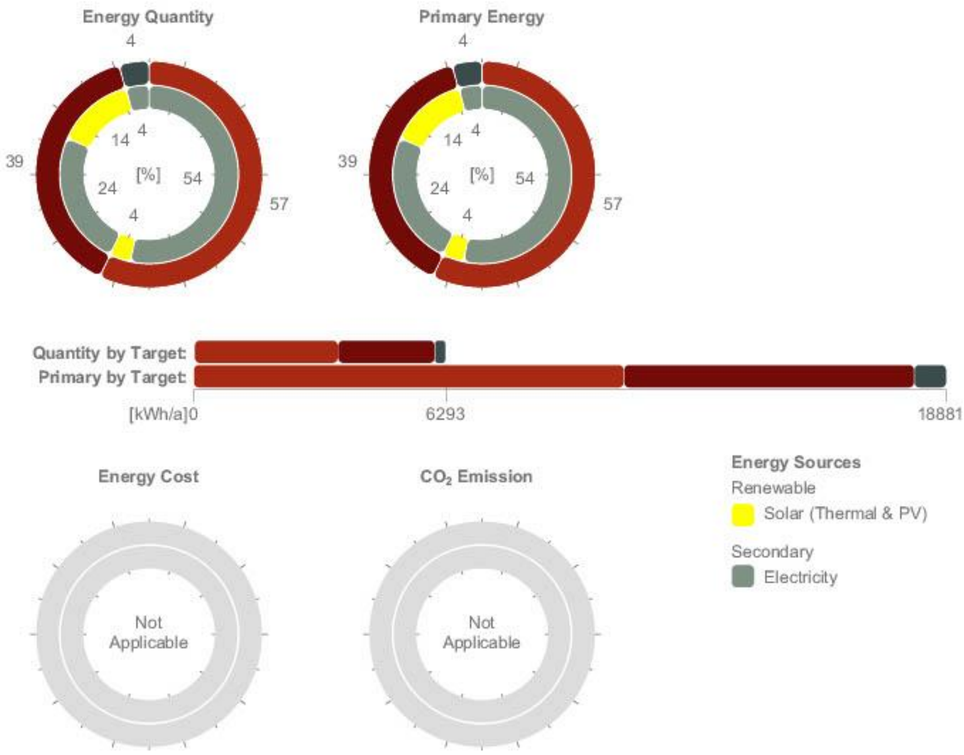
Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Heating	3597	10791	0	0
Cooling	0	0	0	0
Service Hot-Water	2427	7281	0	0
Ventilation Fans	0	0	0	0
Lighting & Appliances	269	808	0	0
Total:	**6293**	**18881**	**NA**	**0**



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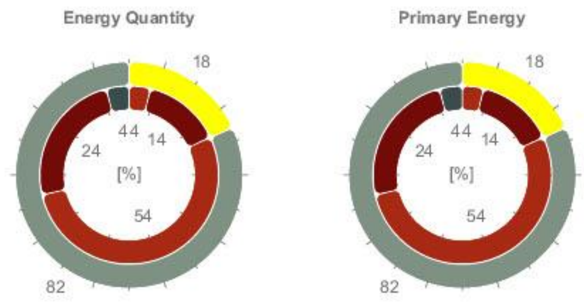
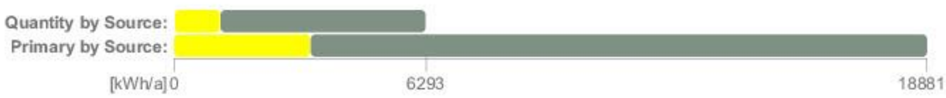
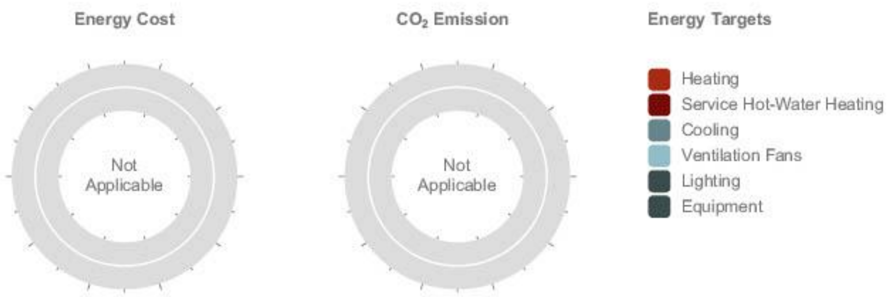
Energy Consumption by Sources

Source Type	Source Name	Energy Quantity kWh/a	Primary kWh/a	Cost GBP/a	CO_2 Emission kg/a
Renewable	Solar (Thermal & PV)	1141	3423	NA	0
Secondary	Electricity	5152	15457	--	0
	Total:	**6293**	**18881**	Not Applicable	**0**







Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	Solar (Thermal & PV)	3423	0
Secondary	Electricity	15457	0
	Total:	**18880**	**0**

KINGSPAN BENCHMARK KARRIER

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Key Values

General Project Data

Project Name:	ROtemplate	
City Location:	Timisoara	
Latitude:	45° 45' 0" N	
Longitude:	21° 14' 0" E	
Altitude:	650.00	m
Climate Data Source:	Strusoft server	
Evaluation Date:	17-Feb-19 6:19:08 PM	

Building Geometry Data

Gross Floor Area:	**30.09**	m²
Treated Floor Area:	**24.60**	m²
External Envelope Area:	**120.93**	m²
Ventilated Volume:	**124.44**	m³
Glazing Ratio:	**6**	%

Building Shell Performance Data

Infiltration at 50Pa:	**3.84**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**0.25**	
Floors:	--	
External:	**0.13 - 0.13**	
Underground:	--	
Openings:	**0.99 - 2.84**	

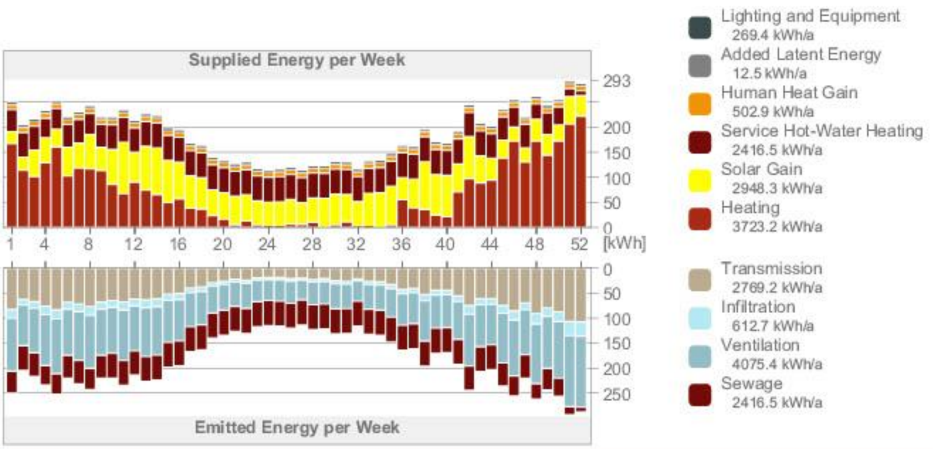
Specific Annual Values

Net Heating Energy:	**151.34**	kWh/m²a
Net Cooling Energy:	**0.00**	kWh/m²a
Total Net Energy:	**151.34**	kWh/m²a
Energy Consumption:	**260.52**	kWh/m²a
Fuel Consumption:	**214.26**	kWh/m²a
Primary Energy:	**781.55**	kWh/m²a
Fuel Cost:	--	GBP/m²a
CO_2 Emission:	**0.00**	kg/m²a

Degree Days

Heating (HDD):	**2911.11**
Cooling (CDD):	**2125.18**

Project Energy Balance



Thermal Blocks

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 SIMULATION	1	Rezidential	30.09	124.44
Total:	**1**		**30.09**	**124.44**

KINGSPAN BENCHMARK KARRIER

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001 SIMULATION - Key Values

Geometry Data		
Gross Floor Area:	30.09	m²
Treated Floor Area:	24.60	m²
Building Shell Area:	120.93	m²
Ventilated Volume:	124.44	m³
Glazing Ratio:	6	%

Internal Temperature		
Min. (01:00 Dec. 23):	4.69	°C
Annual Mean:	25.00	°C
Max. (14:00 Aug. 23):	62.86	°C

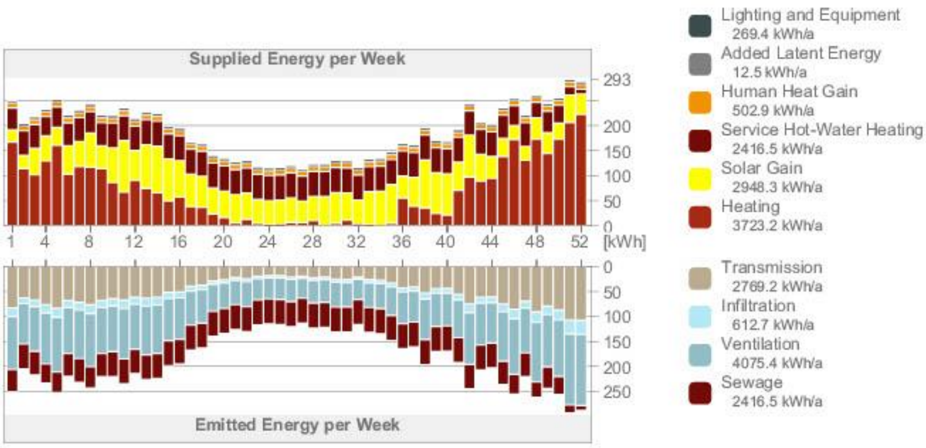
Unmet Load Hours		
Heating:	539	hrs/a
Cooling:	2533	hrs/a

Heat Transfer Coefficients	U value	[W/m²K]
Floors:	-	
External:	0.13 - 0.13	
Underground:	-	
Openings:	0.99 - 2.84	

Annual Supplies		
Heating:	3723.24	kWh
Cooling:	0.00	kWh

Peak Loads		
Heating (23:00 Jan. 25):	1.50	kW
Cooling (01:00 Jan. 01):	0.00	kW

001 SIMULATION Energy Balance



Daily Temperature Profile

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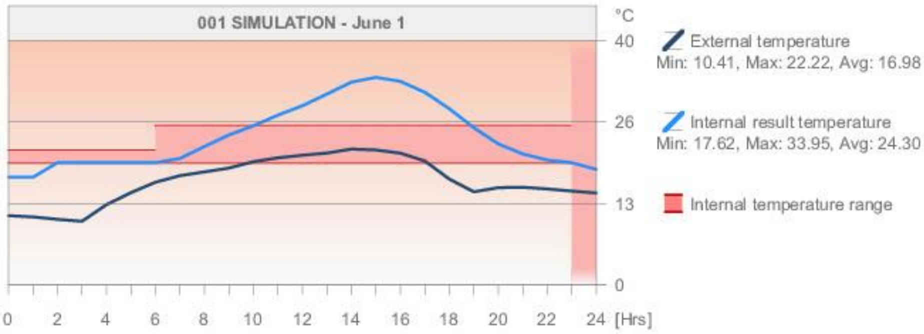

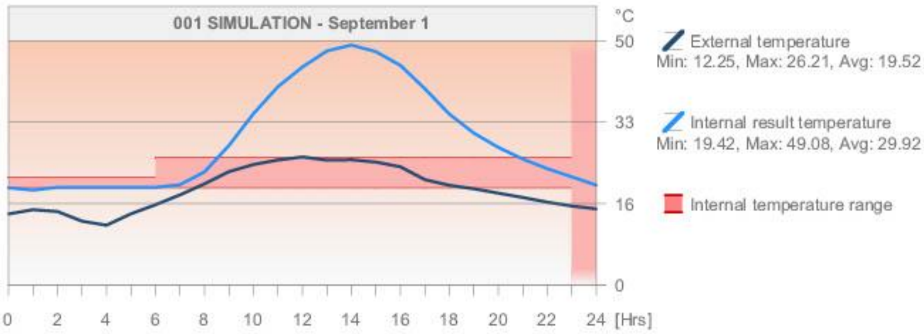

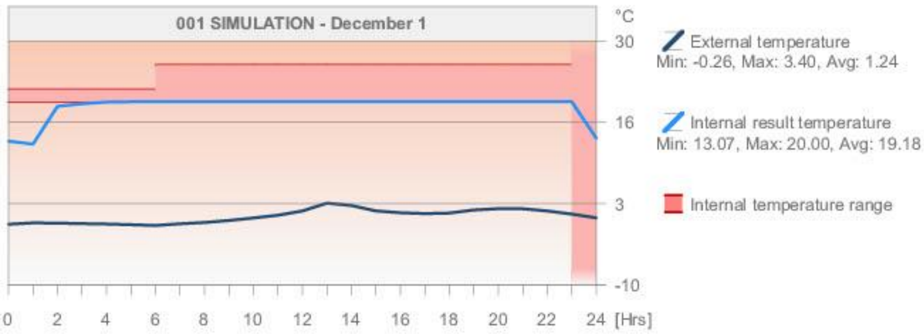

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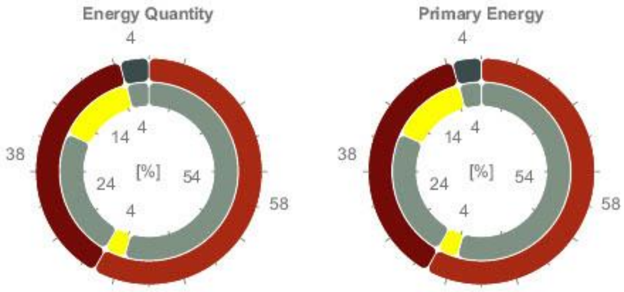
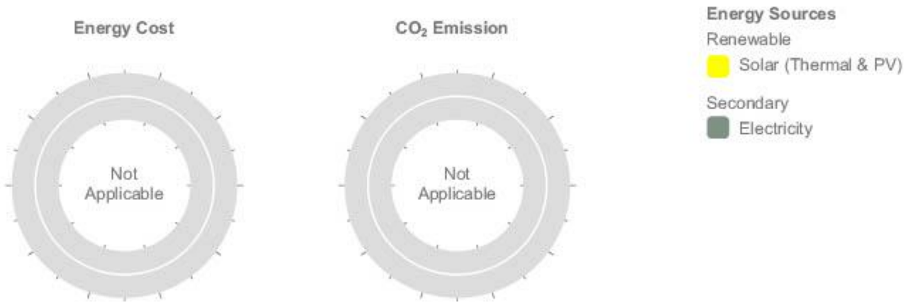
Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Heating	3723	11169	0	0
Cooling	0	0	0	0
Service Hot-Water	2416	7249	0	0
Ventilation Fans	0	0	0	0
Lighting & Appliances	269	808	0	0
Total:	**6409**	**19227**	**NA**	**0**





BUPT

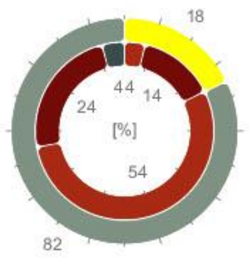
KINGSPAN BENCHMARK KARRIER

xx/2017 ROtemplate

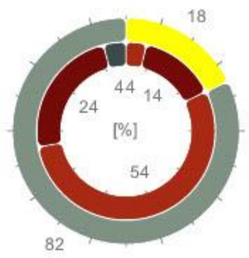
Energy Consumption by Sources

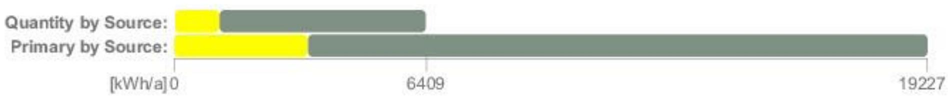
Source Type	Energy Source Name	Quantity kWh/a	Primary kWh/a	Cost GBP/a	CO_2 Emission kg/a
Renewable	Solar (Thermal & PV)	1138	3414	NA	0
Secondary	Electricity	5271	15813	--	0
	Total:	**6409**	**19227**	Not Applicable	**0**

Energy Quantity

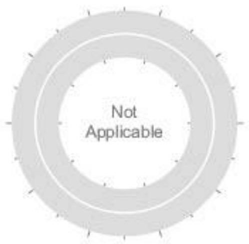


Primary Energy

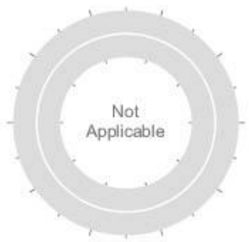




Energy Cost



CO_2 Emission



Energy Targets

- Heating
- Service Hot-Water Heating
- Cooling
- Ventilation Fans
- Lighting
- Equipment

Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	Solar (Thermal & PV)	3414	0
Secondary	Electricity	15813	0
	Total:	**19227**	**0**

KINGSPAN BENCHMARK KARRIER

xx/2017 ROtemplate

Key Values

General Project Data		
Project Name:	ROtemplate	
City Location:	Timisoara	
Latitude:	45° 45' 0" N	
Longitude:	21° 14' 0" E	
Altitude:	650.00	m
Climate Data Source:	Strusoft server	
Evaluation Date:	17-Feb-19 6:21:03 PM	

Building Geometry Data		
Gross Floor Area:	**30.37**	m²
Treated Floor Area:	**24.60**	m²
External Envelope Area:	**120.93**	m²
Ventilated Volume:	**124.44**	m³
Glazing Ratio:	**6**	%

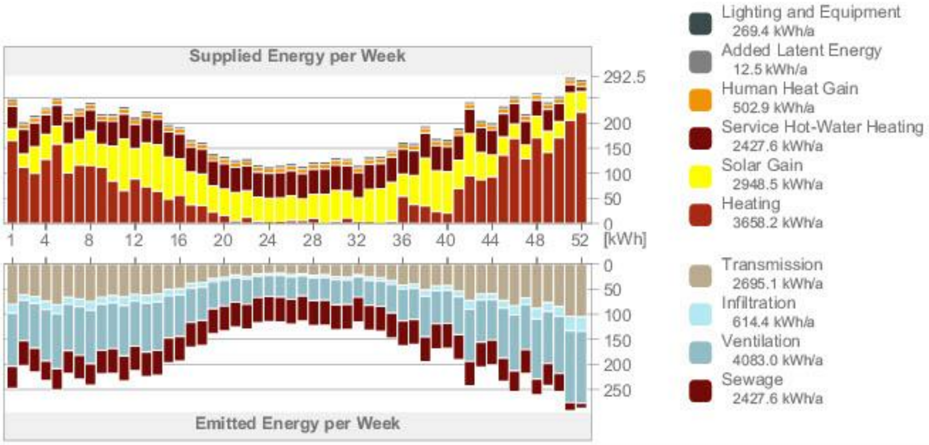
Building Shell Performance Data		
Infiltration at 50Pa:	**3.84**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**0.24**	
Floors:	--	
External:	**0.12 - 0.13**	
Underground:	--	
Openings:	**0.99 - 2.84**	

Specific Annual Values		
Net Heating Energy:	**148.70**	kWh/m²a
Net Cooling Energy:	**0.00**	kWh/m²a
Total Net Energy:	**148.70**	kWh/m²a
Energy Consumption:	**258.32**	kWh/m²a
Fuel Consumption:	**212.14**	kWh/m²a
Primary Energy:	**774.97**	kWh/m²a
Fuel Cost:	--	GBP/m²a
CO_2 Emission:	**0.00**	kg/m²a

Degree Days	
Heating (HDD):	**2911.11**
Cooling (CDD):	**2125.18**

Project Energy Balance



Thermal Blocks

Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 SIMULATION	1	Rezidential	30.37	124.44
Total:	1		30.37	124.44

KINGSPAN BENCHMARK KARRIER

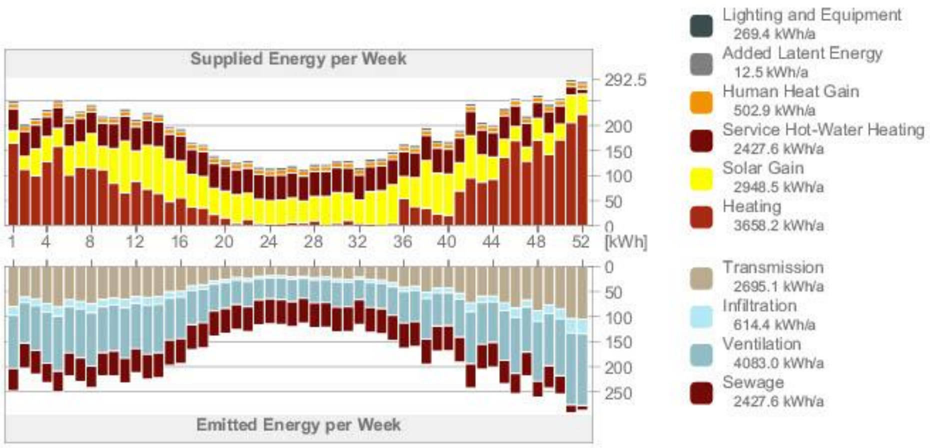
xx/2017 ROtemplate

001 SIMULATION - Key Values

Geometry Data		
Gross Floor Area:	30.37	m²
Treated Floor Area:	24.60	m²
Building Shell Area:	120.93	m²
Ventilated Volume:	124.44	m³
Glazing Ratio:	6	%
Internal Temperature		
Min. (01:00 Dec. 23):	5.06	°C
Annual Mean:	25.02	°C
Max. (14:00 Aug. 23):	62.63	°C
Unmet Load Hours		
Heating:	526	hrs/a
Cooling:	2553	hrs/a

Heat Transfer Coefficients	U value	[W/m²K]
Floors:	-	
External:	0.12 - 0.13	
Underground:	-	
Openings:	0.99 - 2.84	
Annual Supplies		
Heating:	3658.17	kWh
Cooling:	0.00	kWh
Peak Loads		
Heating (01:00 Jan. 26):	1.50	kW
Cooling (01:00 Jan. 01):	0.00	kW

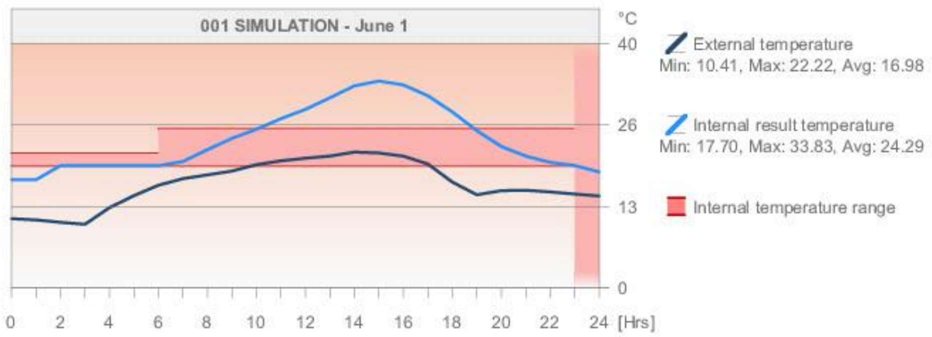
001 SIMULATION Energy Balance

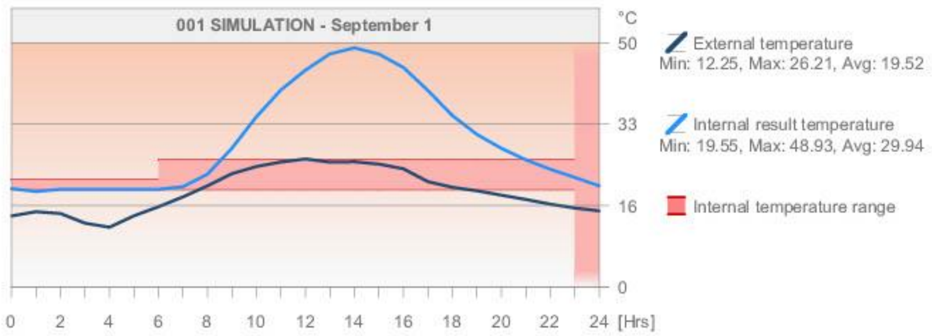


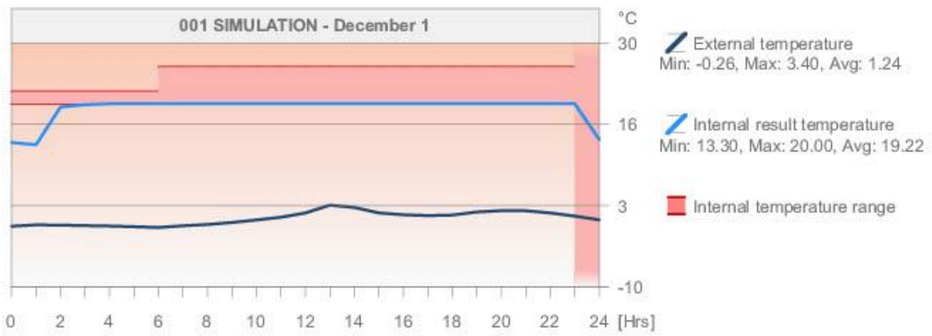
Daily Temperature Profile

KINGSPAN BENCHMARK KARRIER

xx/2017 ROtemplate







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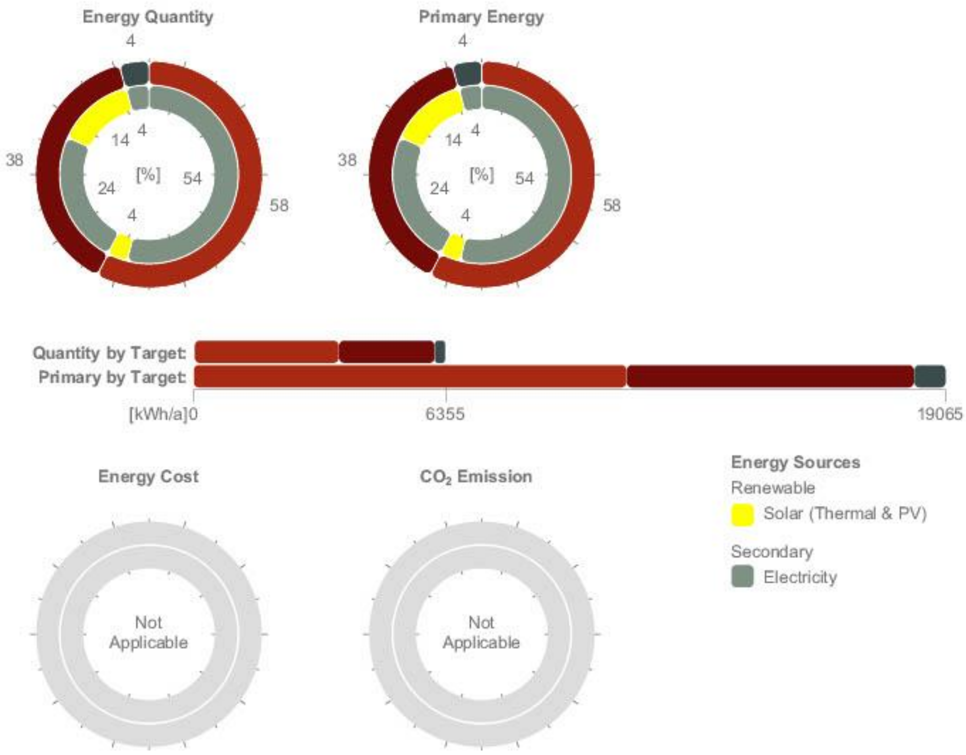
KINGSPAN BENCHMARK KARRIER

xx/2017 ROtemplate

Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Heating	3658	10974	0	0
Cooling	0	0	0	0
Service Hot-Water	2427	7282	0	0
Ventilation Fans	0	0	0	0
Lighting & Appliances	269	808	0	0
Total:	**6355**	**19065**	**NA**	**0**

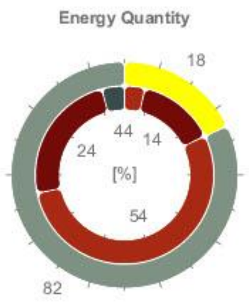


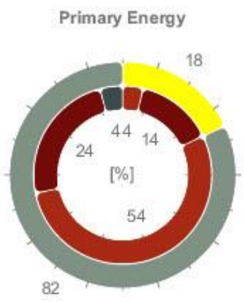
KINGSPAN BENCHMARK KARRIER

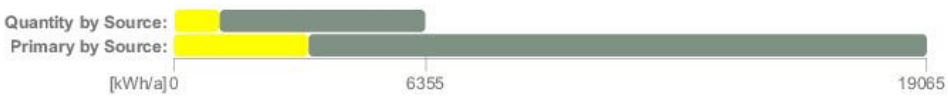
xx/2017 ROtemplate

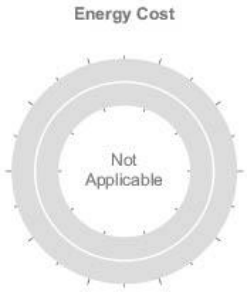
Energy Consumption by Sources

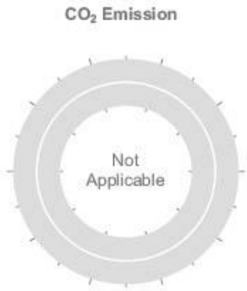
Source Type	Source Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Renewable	Solar (Thermal & PV)	1136	3408	NA	0
Secondary	Electricity	5219	15657	--	0
	Total:	**6355**	**19065**	Not Applicable	**0**











Energy Targets

- Heating
- Service Hot-Water Heating
- Cooling
- Ventilation Fans
- Lighting
- Equipment

Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	Solar (Thermal & PV)	3408	0
Secondary	Electricity	15657	0
	Total:	**19065**	**0**

ANNEX 3 – TEST MODEL DESIGN THERMAL SIMULATION

ubakus

Alle Angaben ohne Gewähr

ICER - Exterior wall

Außenwand
erstellt am 29.1.2023

Wärmeschutz

R_{tot} = 3,43 m²K/W

EnEV Bestand*: U<0,24 W/(m²K)

sehr gut mangelhaft

Feuchteschutz

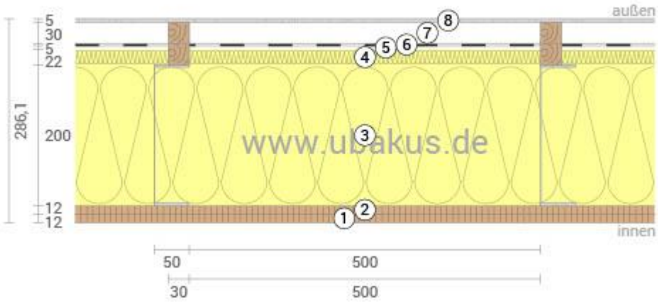
Kein Tauwasser

sehr gut mangelhaft

Hitzeschutz

Temperaturamplitudendämpfung: 9,5
Phasenverschiebung: 8,0 h
Wärmekapazität innen: 28 kJ/m²K

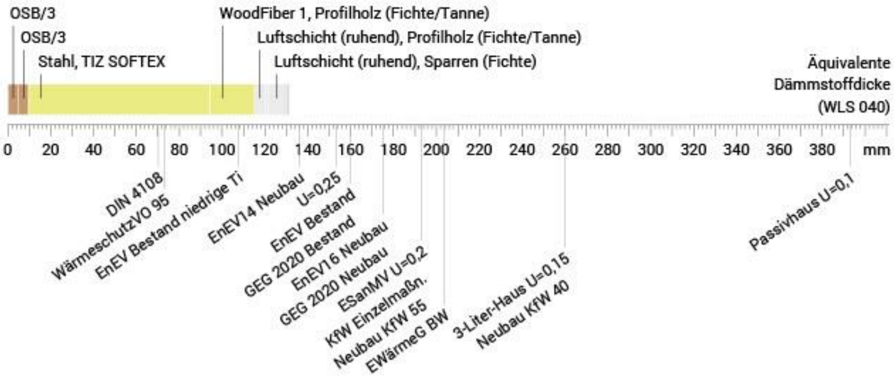
sehr gut mangelhaft



1. OSB/3 (12 mm)
2. OSB/3 (12 mm)
3. TIZ SOFTEX (200 mm)
4. WoodFiber 1 (22 mm)
5. Luftschicht (5 mm)
6. Windbarrier
7. Luftschicht (30 mm)
8. Eternit Eterplan (5 mm)

Dämmwirkung einzelner Schichten und Vergleich mit Richtwerten

Für die folgende Abbildung wurden die Wärmedurchgangswiderstände (d.h. die Dämmwirkung) der einzelnen Schichten in Millimeter Dämmstoff umgerechnet. Die Skala bezieht sich auf einen Dämmstoff der Wärmeleitfähigkeit 0,040 W/mK.



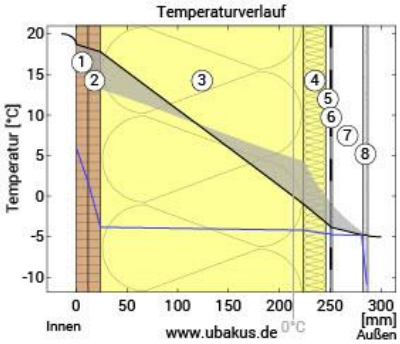
Raumluft:	20,0°C / 40%		Dicke:	28,6 cm
Außenluft:	-5,0°C / 60%	sd-Wert: 5,5 m	Gewicht:	37 kg/m²
Oberflächentemp.:	16,5°C / -4,7°C		Wärmekapazität:	52 kJ/m²K

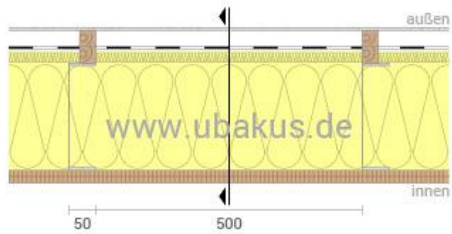
*Vergleich mit dem Höchstwert gemäß EnEV 2014/2016 für erstmaligen Einbau, Ersatz oder Erneuerung von Außenwänden (Anlage 3, Tabelle 1, Zeile 1).

ubakus Alle Angaben ohne Gewähr

ICER - Exterior wall, R_{tot}=3,43 m²K/W

Temperaturverlauf





① OSB/3 (12 mm)
② OSB/3 (12 mm)
③ TIZ SOFTEX (200 mm)
④ WoodFiber 1 (22 mm)
⑤ Luftschicht (5 mm)
⑥ Windbarrier
⑦ Luftschicht (30 mm)
⑧ Eternit Eterplan (5 mm)

Links: Verlauf von Temperatur und Taupunkt an der in der rechten Abbildung markierten Stelle. Der Taupunkt kennzeichnet die Temperatur, bei der Wasserdampf kondensieren und Tauwasser entstehen würde. Solange die Temperatur des Bauteils an jeder Stelle über der Taupunkttemperatur liegt, entsteht kein Tauwasser. Falls sich die beiden Kurven berühren, fällt an den Berührungspunkten Tauwasser aus.
Rechts: Maßstäbliche Zeichnung des Bauteils.

Schichten (von innen nach außen)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Gewicht [kg/m²]
		Wärmeübergangswiderstand*		0,130	16,5	20,0	
1	1,2 cm	OSB/3	0,130	0,092	15,1	18,7	7,4
2	1,2 cm	OSB/3	0,130	0,092	13,2	18,3	7,4
3	20 cm	TIZ SOFTEX	0,054	3,704	-1,0	17,8	4,0
	20 cm	Stahl (0,11%)	50,000	0,004	4,3	13,2	2,2
	0,06 cm	Stahl (Breite: 5 cm)	50,000	0,000	3,3	4,3	0,6
	0,06 cm	Stahl (Breite: 5 cm)	50,000	0,000	13,2	14,1	0,6
4	2,2 cm	WoodFiber 1	0,050	0,440	-3,2	4,3	5,1
	3 cm	Profilholz (Fichte/Tanne) (Breite: 3 cm)	0,140	0,214	-1,6	3,8	0,9
5	0,5 cm	Luftschicht (ruhend)	0,045	0,110	-3,8	-0,4	0,0
6	0,01 cm	Windbarrier	0,040	0,003	-3,8	-1,4	0,0
7	3 cm	Luftschicht (ruhend)	0,167	0,180	-4,7	-1,4	0,0
	3 cm	Sparren (Fichte) (5,7%)	0,130	0,231	-4,4	-1,0	1,0
8	0,5 cm	Eternit Eterplan	0,580	0,009	-4,8	-4,4	8,3
		Wärmeübergangswiderstand*		0,040	-5,0	-4,5	
	28,61 cm	Gesamtes Bauteil		3,433			37,4

*Wärmeübergangswiderstände gemäß DIN 6946 für die U-Wert-Berechnung. Für Feuchteschutz und Temperaturverlauf wurden Rsi=0,25 und Rse=0,04 gemäß DIN 4108-3 verwendet.

Oberflächentemperatur innen (min / mittel / max):	16,5°C	18,2°C	18,7°C
Oberflächentemperatur außen (min / mittel / max):	-4,8°C	-4,7°C	-4,5°C

ubakus

Alle Angaben ohne Gewähr

ICER - Exterior wall, R_{tot}=3,43 m²K/W

Feuchteschutz

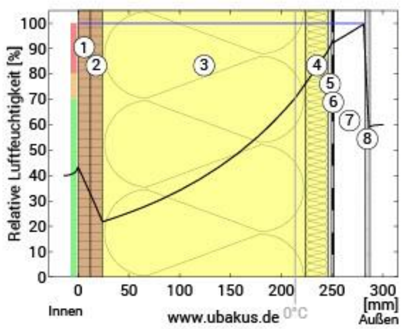
Für die Berechnung der Tauwassermenge wurde das Bauteil 90 Tage lang dem folgenden konstanten Klima ausgesetzt: innen: 20°C und 40% Luftfeuchtigkeit; außen: -5°C und 60% Luftfeuchtigkeit (Klima gemäß Benutzereingabe).

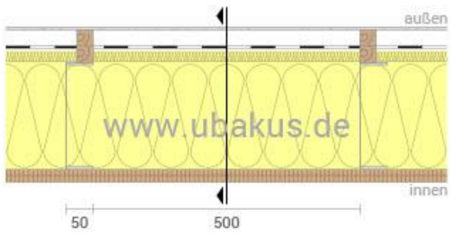
Unter den angenommenen Bedingungen bildet sich kein Tauwasser.

#		Material	sd-Wert [m]	Tauwasser [kg/m²]	[Gew.-%]	Gewicht [kg/m²]
1	1,2 cm	OSB/3	1,80	-	-	7,4
2	1,2 cm	OSB/3	1,80	-	-	7,4
3	20 cm	TIZ SOFTEX	0,10	-		4,0
	20 cm	Stahl (0,11%)	4,50	-		2,2
	0,06 cm	Stahl (Breite: 5 cm)	1500	-		0,6
	0,06 cm	Stahl (Breite: 5 cm)	1500	-		0,6
4	2,2 cm	WoodFiber 1	0,11	-		5,1
	3 cm	Profilholz (Fichte/Tanne) (Breite: 3 cm)	1,50	-	-	0,9
5	0,5 cm	Luftschicht (ruhend)	0,01	-		0,0
6	0,01 cm	Windbarrier	0,03	-		0,0
7	3 cm	Luftschicht (ruhend)	0,01	0,0048		0,0
	3 cm	Sparren (Fichte) (5,7%)	1,50	-	-	1,0
8	0,5 cm	Eternit Eterplan	1,20	-		8,3
	28,61 cm	Gesamtes Bauteil	5,55	0		37,4

Luftfeuchtigkeit

Die Oberflächentemperatur auf der Raumseite beträgt 16,5 °C was zu einer relativen Luftfeuchtigkeit an der Oberfläche von 50% führt. Unter diesen Bedingungen sollte nicht mit Schimmelbildung zu rechnen sein.
Das folgende Diagramm zeigt die relative Luftfeuchtigkeit innerhalb des Bauteils.





① OSB/3 (12 mm)
② OSB/3 (12 mm)
③ TIZ SOFTEX (200 mm)
④ WoodFiber 1 (22 mm)
⑤ Luftschicht (5 mm)
⑥ Windbarrier
⑦ Luftschicht (30 mm)
⑧ Eternit Eterplan (5 mm)

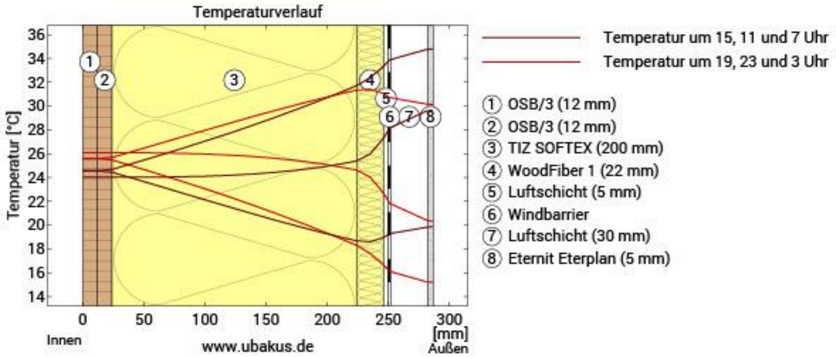
Hinweise: Berechnung mittels Ubakus 2D-FE Verfahren. Konvektion und die Kapillarität der Baustoffe wurden nicht berücksichtigt. Die Trocknungsdauer kann unter ungünstigen Bedingungen (Beschattung, feuchte/kühle Sommer) länger dauern als hier berechnet.

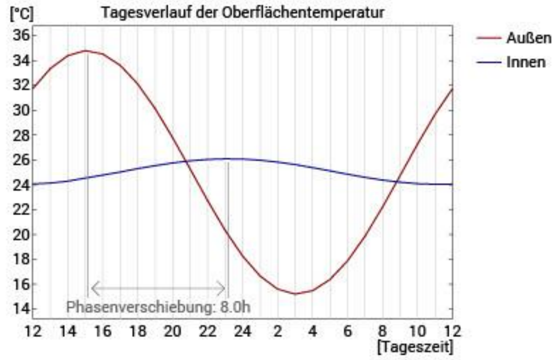
ubakus Alle Angaben ohne Gewähr

ICER - Exterior wall, R_{tot}=3,43 m²K/W

Hitzeschutz

Die folgenden Ergebnisse sind Eigenschaften des untersuchten Bauteils allein und machen keine Aussage über den Hitzeschutz des gesamten Raums:





Obere Abbildung: Temperaturverlauf innerhalb des Bauteils zu verschiedenen Zeitpunkten. Jeweils von oben nach unten, braune Linien: um 15, 11 und 7 Uhr und rote Linien um 19, 23 und 3 Uhr morgens.
Untere Abbildung: Temperatur auf der äußeren (rot) und inneren (blau) Oberfläche im Verlauf eines Tages. Die schwarzen Pfeile kennzeichnen die Lage der Temperaturhöchstwerte. Das Maximum der inneren Oberflächentemperatur sollte möglichst während der zweiten Nachthälfte auftreten.

Phasenverschiebung*	8,0 h	Wärmespeicherfähigkeit (gesamtes Bauteil):	52 kJ/m²K
Amplitudendämpfung**	9,5	Wärmespeicherfähigkeit der inneren Schichten:	28 kJ/m²K
TAV***	0,105		

* Die Phasenverschiebung gibt die Zeitdauer in Stunden an, nach der das nachmittägliche Hitzemaximum die Bauteilinnenseite erreicht.
** Die Amplitudendämpfung beschreibt die Abschwächung der Temperaturwelle beim Durchgang durch das Bauteil. Ein Wert von 10 bedeutet, dass die Temperatur auf der Außenseite 10x stärker variiert, als auf der Innenseite, z.B. außen 15-35°C, innen 24-26°C.
*** Das Temperaturamplitudenverhältnis TAV ist der Kehrwert der Dämpfung: TAV = 1/Amplitudendämpfung

Hinweis: Der Hitzeschutz eines Raumes wird von mehreren Faktoren beeinflusst, im Wesentlichen aber von der direkten Sonneneinstrahlung durch Fenster und der Gesamtmenge an Speichermasse (darunter auch Fußboden, Innenwände und Einbauten/Möbel). Ein einzelnes Bauteil hat auf den Hitzeschutz des Raumes in der Regel nur einen sehr geringen Einfluss.

Die oben dargestellten Berechnungen wurden für einen 1-dimensionalen Querschnitt des Bauteils erstellt.

ubakus

Alle Angaben ohne Gewähr

ICER - Ground floor slab

Fußboden
erstellt am 29.1.2023

Wärmeschutz

R_{tot} = 4,66 m²K/W

EnEV Bestand*: U<0,3 W/(m²K)

sehr gut — mangelhaft

Feuchteschutz

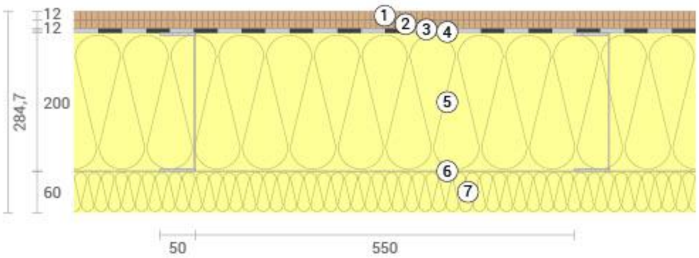
Kein Tauwasser

sehr gut — mangelhaft

Hitzeschutz

Temperaturamplitudendämpfung: 11
Phasenverschiebung: 7,7 h
Wärmekapazität innen: 28 kJ/m²K

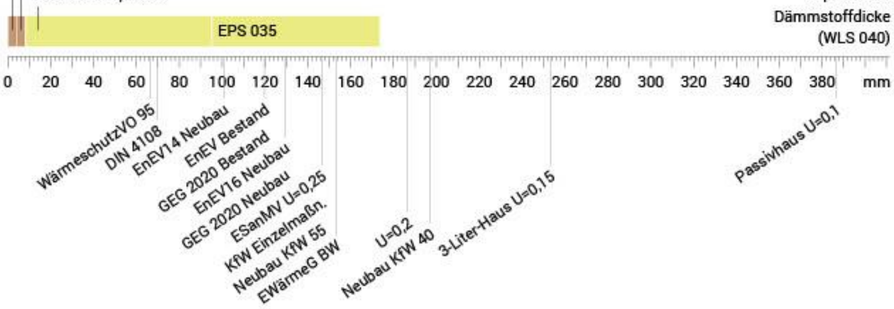
sehr gut — mangelhaft



1. OSB/3 (12 mm)
2. OSB/3 (12 mm)
3. BauderVAP DB
4. BauderVAP DB
5. TIZ SOFTEX (200 mm)
6. Stahl (0,2 mm)
7. EPS 035 (60 mm)

Dämmwirkung einzelner Schichten und Vergleich mit Richtwerten

Für die folgende Abbildung wurden die Wärmedurchgangswiderstände (d.h. die Dämmwirkung) der einzelnen Schichten in Millimeter Dämmstoff umgerechnet. Die Skala bezieht sich auf einen Dämmstoff der Wärmeleitfähigkeit 0,040 W/mK.



Raumluft:	20,0°C / 40%		Dicke:	28,5 cm
Unbeheizter Raum:	-5,0°C / 60%	sd-Wert: 1845,7 m	Gewicht:	25 kg/m²
Oberflächentemp.:	17,2°C / -4,8°C		Wärmekapazität:	34 kJ/m²K

*Vergleich mit dem Höchstwert gemäß EnEV 2014/2016 für erstmaligen Einbau, Ersatz oder Erneuerung von Decken nach unten gegen Erdreich oder unbeheizte Räume (Anlage 3, Tabelle 1, Zeile 5a).

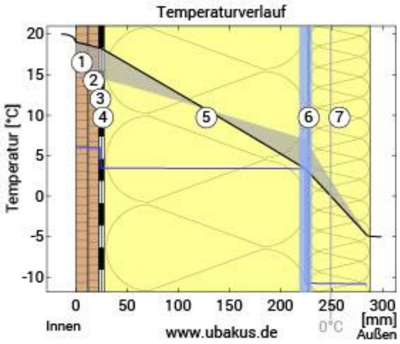
Seite 1

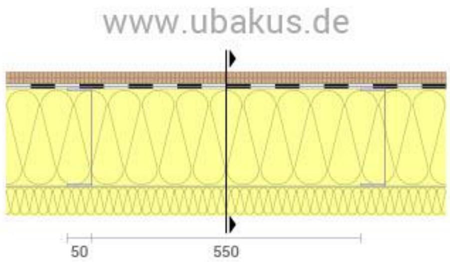
ubakus

Alle Angaben ohne Gewähr

ICER - Ground floor slab, R_{tot}=4,66 m²K/W

Temperaturverlauf





① OSB/3 (12 mm)
② OSB/3 (12 mm)
③ BauderVAP DB
④ BauderVAP DB
⑤ TIZ SOFTEX (200 mm)
⑥ Stahl (0,2 mm)
⑦ EPS 035 (60 mm)

Links: Verlauf von Temperatur und Taupunkt an der in der rechten Abbildung markierten Stelle. Der Taupunkt kennzeichnet die Temperatur, bei der Wasserdampf kondensieren und Tauwasser entstehen würde. Solange die Temperatur des Bauteils an jeder Stelle über der Taupunkttemperatur liegt, entsteht kein Tauwasser. Falls sich die beiden Kurven berühren, fällt an den Berührungspunkten Tauwasser aus.
Rechts: Maßstäbliche Zeichnung des Bauteils.

Schichten (von innen nach außen)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Gewicht [kg/m²]
		Wärmeübergangswiderstand*		0,170	17,2	20,0	
1	1,2 cm	OSB/3	0,130	0,092	16,1	19,0	7,4
2	1,2 cm	OSB/3	0,130	0,092	14,6	18,6	7,4
3	0,025 cm	BauderVAP DB	0,170	0,001	14,6	18,3	0,3
4	0,025 cm	BauderVAP DB	0,170	0,001	14,5	18,3	0,3
5	20 cm	TIZ SOFTEX	0,054	3,704	3,4	18,3	4,0
	20 cm	Stahl (0,10%)	50,000	0,004	7,1	14,5	1,6
	0,06 cm	Stahl (Breite: 5 cm)	50,000	0,000	6,5	6,7	0,4
	0,06 cm	Stahl (Breite: 5 cm)	50,000	0,000	15,0	15,2	0,4
6	0,02 cm	Stahl	50,000	0,000	3,4	7,1	1,6
7	6 cm	EPS 035	0,035	1,714	-4,8	7,1	1,8
		Wärmeübergangswiderstand*		0,170	-5,0	-4,7	
	28,47 cm	Gesamtes Bauteil		4,663			25,1

*Wärmeübergangswiderstände gemäß DIN 6946 für die U-Wert-Berechnung. Für Feuchteschutz und Temperaturverlauf wurden Rsi=0,25 und Rse=0,04 gemäß DIN 4108-3 verwendet.

Oberflächentemperatur innen (min / mittel / max):	17,2°C	18,6°C	19,0°C
Oberflächentemperatur außen (min / mittel / max):	-4,8°C	-4,8°C	-4,7°C

ubakus

Alle Angaben ohne Gewähr

ICER - Ground floor slab, R_{tot}=4,66 m²K/W

Feuchteschutz

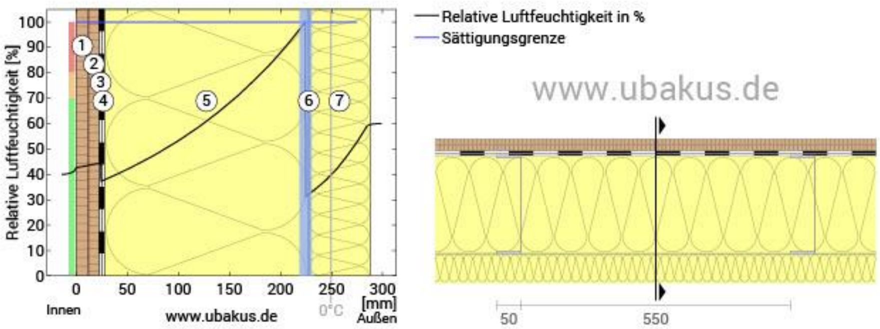
Für die Berechnung der Tauwassermenge wurde das Bauteil 90 Tage lang dem folgenden konstanten Klima ausgesetzt: innen: 20°C und 40% Luftfeuchtigkeit; außen: -5°C und 60% Luftfeuchtigkeit (Klima gemäß Benutzereingabe).

Unter den angenommenen Bedingungen bildet sich kein Tauwasser.

#		Material	sd-Wert [m]	Tauwasser [kg/m²]	Tauwasser [Gew.-%]	Gewicht [kg/m²]
1	1,2 cm	OSB/3	1,80	-	-	7,4
2	1,2 cm	OSB/3	1,80	-	-	7,4
3	0,025 cm	BauderVAP DB	120,00	-		0,3
4	0,025 cm	BauderVAP DB	120,00	-		0,3
5	20 cm	TIZ SOFTEX	0,10	-		4,0
	20 cm	Stahl (0,10%)	4,50	-		1,6
	0,06 cm	Stahl (Breite: 5 cm)	1500	-		0,4
	0,06 cm	Stahl (Breite: 5 cm)	1500	-		0,4
6	0,02 cm	Stahl	1500	-		1,6
7	6 cm	EPS 035	6,00	-		1,8
	28,47 cm	Gesamtes Bauteil	1.845,72	~0		25,1

Luftfeuchtigkeit

Die Oberflächentemperatur auf der Raumseite beträgt 17,2 °C was zu einer relativen Luftfeuchtigkeit an der Oberfläche von 48% führt. Unter diesen Bedingungen sollte nicht mit Schimmelbildung zu rechnen sein.
Das folgende Diagramm zeigt die relative Luftfeuchtigkeit innerhalb des Bauteils.



(1) OSB/3 (12 mm)
(2) OSB/3 (12 mm)
(3) BauderVAP DB
(4) BauderVAP DB
(5) TIZ SOFTEX (200 mm)
(6) Stahl (0,2 mm)
(7) EPS 035 (60 mm)

Hinweise: Berechnung mittels Ubakus 2D-FE Verfahren. Konvektion und die Kapillarität der Baustoffe wurden nicht berücksichtigt. Die Trocknungsdauer kann unter ungünstigen Bedingungen (Beschattung, feuchte/kühle Sommer) länger dauern als hier berechnet.

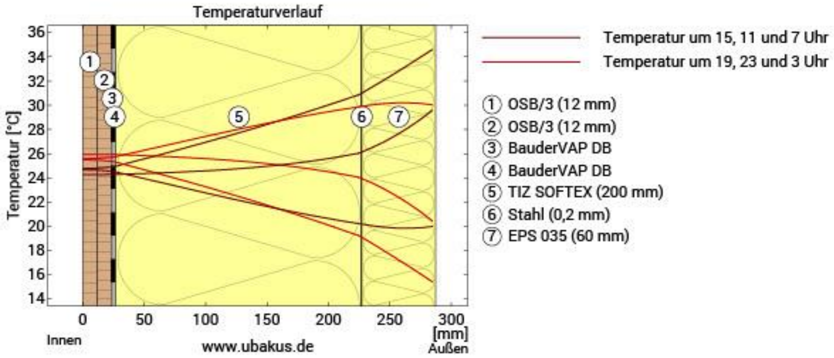
ubakus

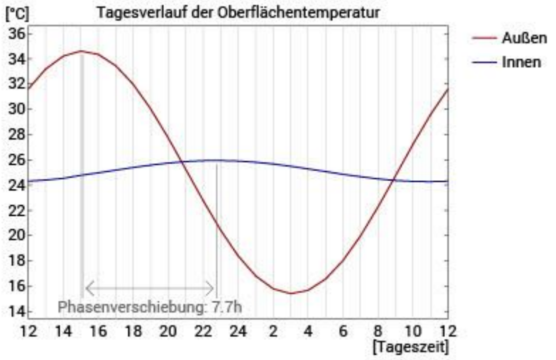
Alle Angaben ohne Gewähr

ICER - Ground floor slab, R_{tot}=4,66 m²K/W

Hitzeschutz

Die folgenden Ergebnisse sind Eigenschaften des untersuchten Bauteils allein und machen keine Aussage über den Hitzeschutz des gesamten Raums:





Obere Abbildung: Temperaturverlauf innerhalb des Bauteils zu verschiedenen Zeitpunkten. Jeweils von oben nach unten, braune Linien: um 15, 11 und 7 Uhr und rote Linien um 19, 23 und 3 Uhr morgens.
Untere Abbildung: Temperatur auf der äußeren (rot) und inneren (blau) Oberfläche im Verlauf eines Tages. Die schwarzen Pfeile kennzeichnen die Lage der Temperaturhöchstwerte. Das Maximum der inneren Oberflächentemperatur sollte möglichst während der zweiten Nachthälfte auftreten.

Phasenverschiebung*	7,7 h	Wärmespeicherfähigkeit (gesamtes Bauteil):	34 kJ/m²K
Amplitudendämpfung**	11,5	Wärmespeicherfähigkeit der inneren Schichten:	28 kJ/m²K
TAV***	0,087		

* Die Phasenverschiebung gibt die Zeitdauer in Stunden an, nach der das nachmittägliche Hitzemaximum die Bauteilinnenseite erreicht.
** Die Amplitudendämpfung beschreibt die Abschwächung der Temperaturwelle beim Durchgang durch das Bauteil. Ein Wert von 10 bedeutet, dass die Temperatur auf der Außenseite 10x stärker variiert, als auf der Innenseite, z.B. außen 15-35°C, innen 24-26°C.
*** Das Temperaturamplitudenverhältnis TAV ist der Kehrwert der Dämpfung: TAV = 1/Amplitudendämpfung

Hinweis: Der Hitzeschutz eines Raumes wird von mehreren Faktoren beeinflusst, im Wesentlichen aber von der direkten Sonneneinstrahlung durch Fenster und der Gesamtmenge an Speichermasse (darunter auch Fußboden, Innenwände und Einbauten/Möbel). Ein einzelnes Bauteil hat auf den Hitzeschutz des Raumes in der Regel nur einen sehr geringen Einfluss.

Die oben dargestellten Berechnungen wurden für einen 1-dimensionalen Querschnitt des Bauteils erstellt.

ubakus

Alle Angaben ohne Gewähr

ICER - Roof

Außenwand
erstellt am 29.1.2023

Wärmeschutz

R_{tot} = 5,45 m²K/W

EnEV Bestand*: U<0,24 W/(m²K)

sehr gut mangelhaft

Feuchteschutz

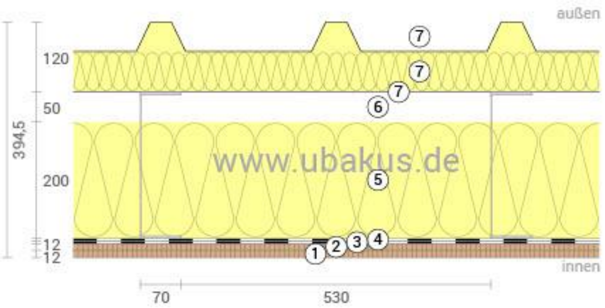
Kein Tauwasser

sehr gut mangelhaft

Hitzeschutz

Temperaturamplitudendämpfung: 18
Phasenverschiebung: 10,0 h
Wärmekapazität innen: 33 kJ/m²K

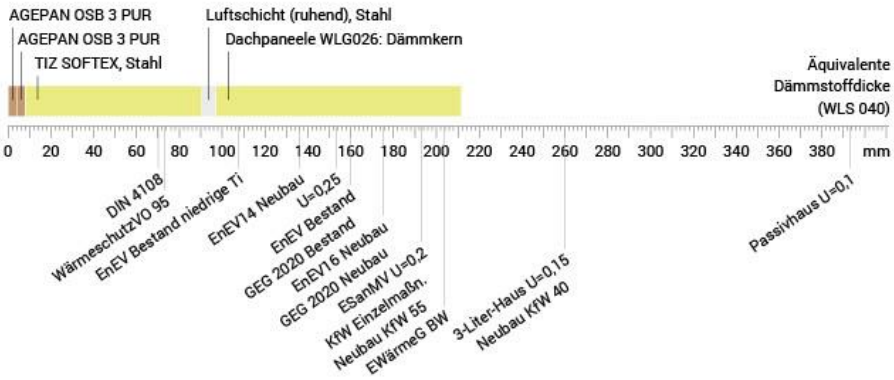
sehr gut mangelhaft



1. AGEPAN OSB 3 PUR (12 mm)
2. AGEPAN OSB 3 PUR (12 mm)
3. BauderVAP DB
4. BauderVAP DB
5. TIZ SOFTEX (200 mm)
6. Luftschicht (50 mm)
7. Dachpaneele WLG026 (120 mm)

Dämmwirkung einzelner Schichten und Vergleich mit Richtwerten

Für die folgende Abbildung wurden die Wärmedurchgangswiderstände (d.h. die Dämmwirkung) der einzelnen Schichten in Millimeter Dämmstoff umgerechnet. Die Skala bezieht sich auf einen Dämmstoff der Wärmeleitfähigkeit 0,040 W/mK.



Raumluft:	20,0°C / 50%		Dicke:	39,5 cm
Außenluft:	-5,0°C / 80%	sd-Wert: 3441,6 m	Gewicht:	41 kg/m²
Oberflächentemp.:	17,7°C / -4,8°C		Wärmekapazität:	46 kJ/m²K

*Vergleich mit dem Höchstwert gemäß EnEV 2014/2016 für erstmaligen Einbau, Ersatz oder Erneuerung von Außenwänden (Anlage 3, Tabelle 1, Zeile 1).

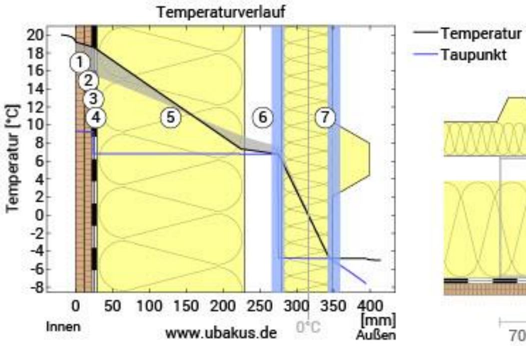
Seite 1

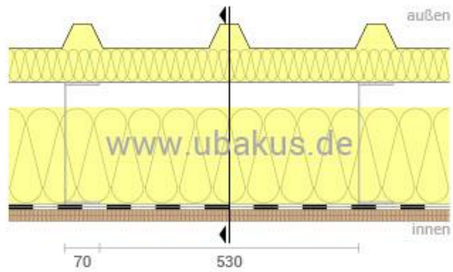
ubakus

Alle Angaben ohne Gewähr

ICER - Roof, R_{tot}=5,45 m²K/W

Temperaturverlauf





① AGEPAN OSB 3 PUR (12 mm)
② AGEPAN OSB 3 PUR (12 mm)
③ BauderVAP DB
④ BauderVAP DB
⑤ TIZ SOFTEX (200 mm)
⑥ Luftschicht (50 mm)
⑦ Dachpaneele WLG026 (120 mm)

Links: Verlauf von Temperatur und Taupunkt an der in der rechten Abbildung markierten Stelle. Der Taupunkt kennzeichnet die Temperatur, bei der Wasserdampf kondensieren und Tauwasser entstehen würde. Solange die Temperatur des Bauteils an jeder Stelle über der Taupunkttemperatur liegt, entsteht kein Tauwasser. Falls sich die beiden Kurven berühren, fällt an den Berührungspunkten Tauwasser aus.
Rechts: Maßstäbliche Zeichnung des Bauteils.

Schichten (von innen nach außen)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Gewicht [kg/m²]
		Wärmeübergangswiderstand*		0,130	17,7	20,0	
1	1,2 cm	AGEPAN OSB 3 PUR	0,130	0,092	16,8	19,2	7,2
2	1,2 cm	AGEPAN OSB 3 PUR	0,130	0,092	15,6	18,9	7,2
3	0,025 cm	BauderVAP DB	0,170	0,001	15,6	18,7	0,3
4	0,025 cm	BauderVAP DB	0,170	0,001	15,5	18,6	0,3
5	20 cm	TIZ SOFTEX	0,054	3,704	7,3	18,6	8,0
	25 cm	Stahl (Breite: 0,06 cm)	50,000	0,005	7,7	15,5	1,9
	0,06 cm	Stahl (Breite: 7 cm)	50,000	0,000	7,4	7,5	0,5
	0,06 cm	Stahl (Breite: 7 cm)	50,000	0,000	16,1	16,4	0,5
6	5 cm	Luftschicht (ruhend)	0,278	0,180	6,8	8,8	0,1
7	0,1 cm	Dachpaneele WLG026: Innenseite	50,000	0,000	6,8	7,7	7,8
	6,9 cm	Dachpaneele WLG026: Dämmkern	0,026	2,654	-4,8	7,7	2,1
	5 cm	Dachpaneele WLG026: Trapezblech	10,000	0,005	-4,8	-4,8	5,0
		Wärmeübergangswiderstand*		0,040	-5,0	-4,8	
	39,45 cm	Gesamtes Bauteil		5,446			40,9

*Wärmeübergangswiderstände gemäß DIN 6946 für die U-Wert-Berechnung. Für Feuchteschutz und Temperaturverlauf wurden Rsi=0,25 und Rse=0,04 gemäß DIN 4108-3 verwendet.

Oberflächentemperatur innen (min / mittel / max):	17,7°C	18,9°C	19,2°C
Oberflächentemperatur außen (min / mittel / max):	-4,8°C	-4,8°C	-4,8°C

ubakus

Alle Angaben ohne Gewähr

ICER - Roof, R_{tot}=5,45 m²K/W

Feuchteschutz

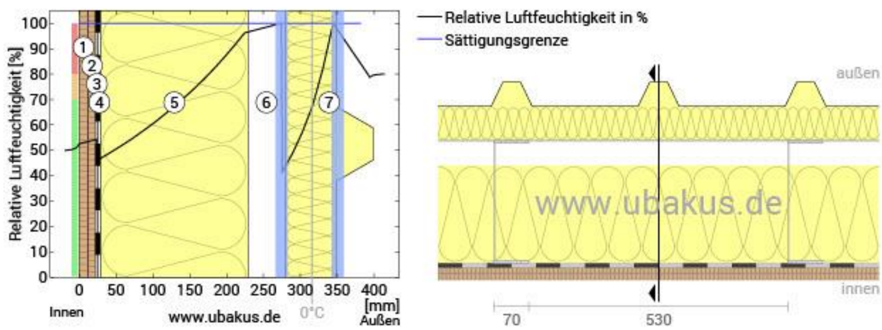
Für die Berechnung der Tauwassermenge wurde das Bauteil 90 Tage lang dem folgenden konstanten Klima ausgesetzt: innen: 20°C und 50% Luftfeuchtigkeit; außen: -5°C und 80% Luftfeuchtigkeit. Dieses Klima entspricht DIN 4108-3.

Unter den angenommenen Bedingungen bildet sich kein Tauwasser.

#		Material	sd-Wert [m]	Tauwasser [kg/m²]	Tauwasser [Gew.-%]	Gewicht [kg/m²]
1	1,2 cm	AGEPAN OSB 3 PUR	1,80	-	-	7,2
2	1,2 cm	AGEPAN OSB 3 PUR	1,80	-	-	7,2
3	0,025 cm	BauderVAP DB	120,00	-		0,3
4	0,025 cm	BauderVAP DB	120,00	-		0,3
5	20 cm	TIZ SOFTEX	3,11	-		8,0
	25 cm	Stahl (Breite: 0,06 cm)	3,60	-		1,9
	0,06 cm	Stahl (Breite: 7 cm)	1500	-		0,5
	0,06 cm	Stahl (Breite: 7 cm)	1500	-		0,5
6	5 cm	Luftschicht (ruhend)	0,01	~0		0,1
7	0,1 cm	Dachpaneele WLG026: Innenseite	1500	-		7,8
	6,9 cm	Dachpaneele WLG026: Dämmkern	2,76	~0		2,1
	5 cm	Dachpaneele WLG026: Trapezblech	1500	-		5,0
	39,45 cm	Gesamtes Bauteil	3.441,56	~0		40,9

Luftfeuchtigkeit

Die Oberflächentemperatur auf der Raumseite beträgt 17,7 °C was zu einer relativen Luftfeuchtigkeit an der Oberfläche von 58% führt. Unter diesen Bedingungen sollte nicht mit Schimmelbildung zu rechnen sein.
Das folgende Diagramm zeigt die relative Luftfeuchtigkeit innerhalb des Bauteils.



① AGEPAN OSB 3 PUR (12 mm)
② AGEPAN OSB 3 PUR (12 mm)
③ BauderVAP DB
④ BauderVAP DB
⑤ TIZ SOFTEX (200 mm)
⑥ Luftschicht (50 mm)
⑦ Dachpaneele WLG026 (120 mm)

Hinweise: Berechnung mittels Ubakus 2D-FE Verfahren. Konvektion und die Kapillarität der Baustoffe wurden nicht berücksichtigt. Die Trocknungsdauer kann unter ungünstigen Bedingungen (Beschattung, feuchte/kühle Sommer) länger dauern als hier berechnet.

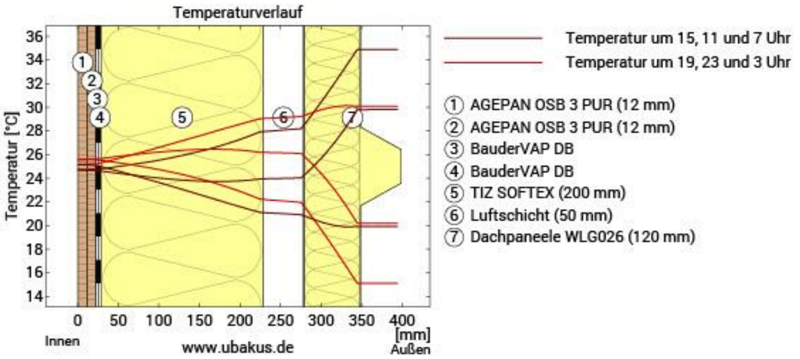
ubakus

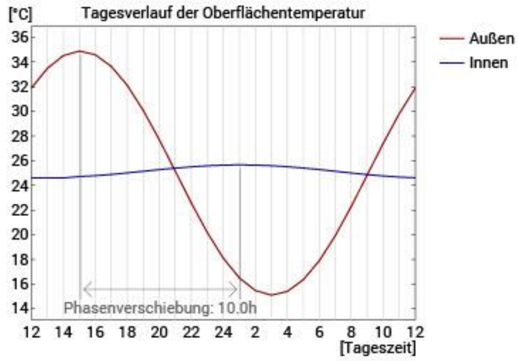
Alle Angaben ohne Gewähr

ICER - Roof, R_{tot}=5,45 m²K/W

Hitzeschutz

Die folgenden Ergebnisse sind Eigenschaften des untersuchten Bauteils allein und machen keine Aussage über den Hitzeschutz des gesamten Raums:





Obere Abbildung: Temperaturverlauf innerhalb des Bauteils zu verschiedenen Zeitpunkten. Jeweils von oben nach unten, braune Linien: um 15, 11 und 7 Uhr und rote Linien um 19, 23 und 3 Uhr morgens.
Untere Abbildung: Temperatur auf der äußeren (rot) und inneren (blau) Oberfläche im Verlauf eines Tages. Die schwarzen Pfeile kennzeichnen die Lage der Temperaturhöchstwerte. Das Maximum der inneren Oberflächentemperatur sollte möglichst während der zweiten Nachthälfte auftreten.

Phasenverschiebung*	10,0 h	Wärmespeicherfähigkeit (gesamtes Bauteil):	46 kJ/m²K
Amplitudendämpfung**	18,5	Wärmespeicherfähigkeit der inneren Schichten:	33 kJ/m²K
TAV***	0,054		

* Die Phasenverschiebung gibt die Zeitdauer in Stunden an, nach der das nachmittägliche Hitzemaximum die Bauteilinnenseite erreicht.
** Die Amplitudendämpfung beschreibt die Abschwächung der Temperaturwelle beim Durchgang durch das Bauteil. Ein Wert von 10 bedeutet, dass die Temperatur auf der Außenseite 10x stärker variiert, als auf der Innenseite, z.B. außen 15-35°C, innen 24-26°C.
*** Das Temperaturamplitudenverhältnis TAV ist der Kehrwert der Dämpfung: TAV = 1/Amplitudendämpfung

Hinweis: Der Hitzeschutz eines Raumes wird von mehreren Faktoren beeinflusst, im Wesentlichen aber von der direkten Sonneneinstrahlung durch Fenster und der Gesamtmenge an Speichermasse (darunter auch Fußboden, Innenwände und Einbauten/Möbel). Ein einzelnes Bauteil hat auf den Hitzeschutz des Raumes in der Regel nur einen sehr geringen Einfluss.

Die oben dargestellten Berechnungen wurden für einen 1-dimensionalen Querschnitt des Bauteils erstellt.

ANNEX 4 – APARTMENT MODEL THERMAL AND ENERGY SIMULATIONS BASED ON DIFFERENT ENVELOPE SYSTEMS

All statements without guarantee

770 Existing outer wall

Exterior wall
created on 29.1.2023

Thermal protection

R = 1,35 m²K/W

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

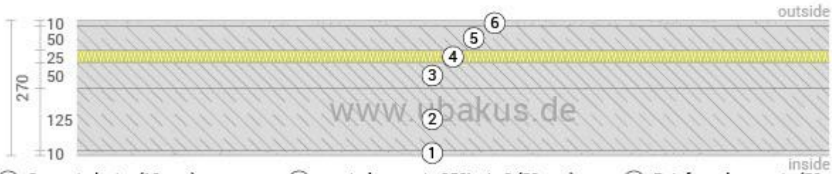
Dries 39 days
Condensate: 82 g/m²

excellent insufficient

Heat protection

Temperature amplitude damping: 28
phase shift: 8,0 h
Thermal capacity inside: 252 kJ/m²K

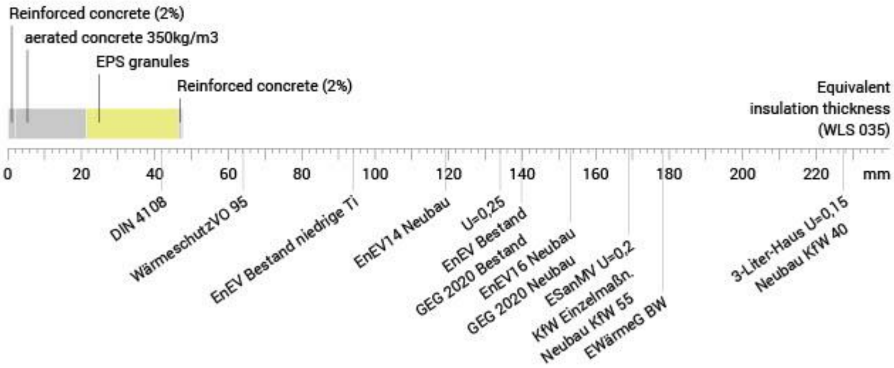
excellent insufficient



(1) Cement plaster (10 mm)
(2) Reinforced concrete (125 mm)
(3) aerated concrete 350kg/m3 (50 mm)
(4) EPS granules (25 mm)
(5) Reinforced concrete (50 mm)
(6) Cement plaster (10 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,035 W/mK.



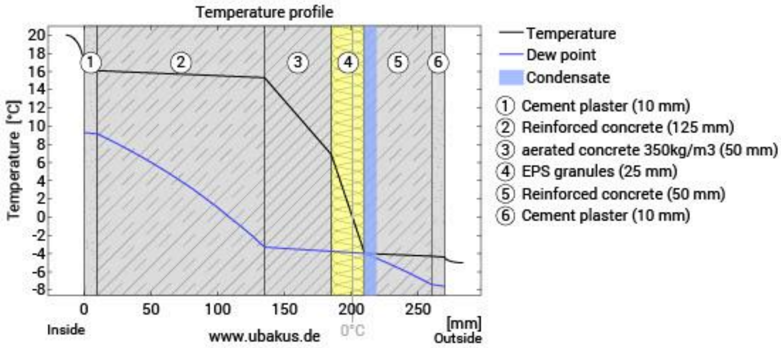
Inside air :	20,0°C / 50%		Thickness:	27,0 cm
Outside air:	-5,0°C / 80%	sd-value: 17,4 m	Weight:	478 kg/m²
Surface temperature.:	16,2°C / -4,4°C		Heat capacity:	428 kJ/m²K

*Vergleich mit dem Höchstwert gemäß GEG 2020 für erstmaligen Einbau, Ersatz oder Erneuerung von Außenwänden (Anlage 7, Zeile 1a,1b).

ubakus All statements without guarantee

770 Existing outer wall, R=1,35 m²K/W

Temperature profile



Temperature and dew-point temperature in the component. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew-point temperature, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	16,2	20,0	
1	1 cm	Cement plaster	1,400	0,007	16,1	16,2	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	15,3	16,1	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	6,9	15,3	17,5
4	2,5 cm	EPS granules	0,035	0,714	-4,0	6,9	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	-4,3	-4,0	120,0
6	1 cm	Cement plaster	1,400	0,007	-4,4	-4,3	20,0
		Thermal contact resistance*		0,040	-5,0	-4,4	
	27 cm	Whole component		1,524			478,0

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max):	16,2°C	16,2°C	16,2°C
Surface temperature outside (min / average / max):	-4,4°C	-4,4°C	-4,4°C

ubakus

All statements without guarantee

770 Existing outer wall, R=1,35 m²K/W

Moisture proofing

For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 50% Humidity; outside: -5°C und 80% Humidity. This climate complies with DIN 4108-3.

Under these conditions, a total of 0,082 kg of condensation water per square meter is accumulated.This quantity dries in summer in 39 days (Drying season according to DIN 4108-3:2018-10).

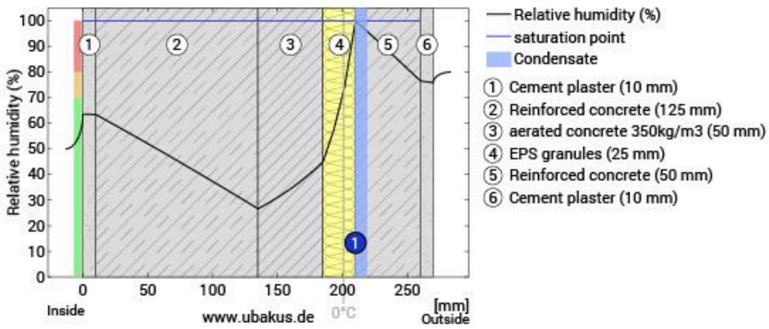
#		Material	sd-value [m]	Condensate [kg/m²]	Condensate [Gew.-%]	Weight [kg/m²]
1	1 cm	Cement plaster	0,15	-		20,0
2	12,5 cm	Reinforced concrete (2%)	10,00	-		300,0
3	5 cm	aerated concrete 350kg/m3	0,25	-		17,5
4	2,5 cm	EPS granules	0,13	0,082		0,5
5	5 cm	Reinforced concrete (2%)	6,50	0,082		120,0
6	1 cm	Cement plaster	0,35	-		20,0
	27 cm	Whole component	17,38	0,082		478,0

Condensation areas

1 Condensate: 0,082 kg/m² Affected layers: Reinforced concrete (2%), EPS granules

Humidity

The temperature of the inside surface is 16,2 °C leading to a relative humidity on the surface of 63%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

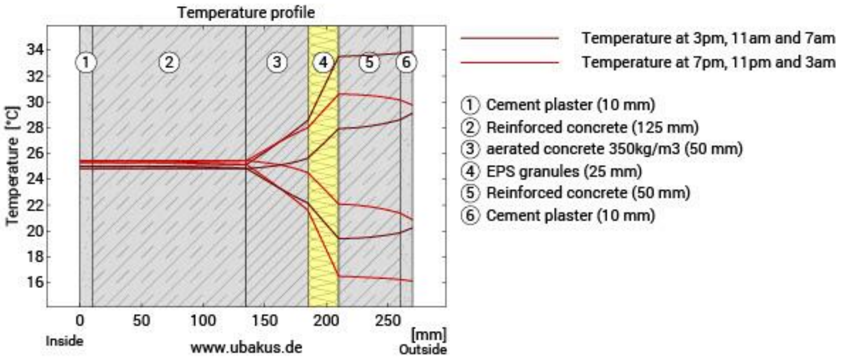
ubakus

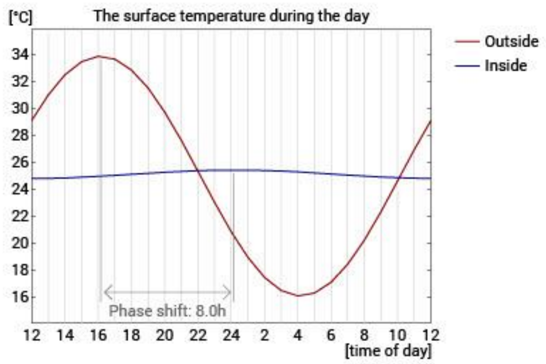
All statements without guarantee

770 Existing outer wall, R=1,35 m²K/W

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	8,0 h	Heat storage capacity (whole component):	428 kJ/m²K
Amplitude attenuation **	28,5	Thermal capacity of inner layers:	252 kJ/m²K
TAV ***	0,035		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

EXISTING BUILDING

[Project Number] ENERGY EVALUATION

Key Values

General Project Data		
Project Name:	ENERGY EVALUATION	
City Location:	Timisoara	
Latitude:	46° 21' 45" N	
Longitude:	25° 48' 22" E	
Altitude:	662.00	m
Climate Data Source:	ROU_Timiso...0_IWEC.epw	
Evaluation Date:	1/30/2023 4:43 AM	

Building Geometry Data		
Gross Floor Area:	**51.6**	m²
Treated Floor Area:	**46.4**	m²
External Envelope Area:	**124.5**	m²
Ventilated Volume:	**133.12**	m³
Glazing Ratio:	**3**	%

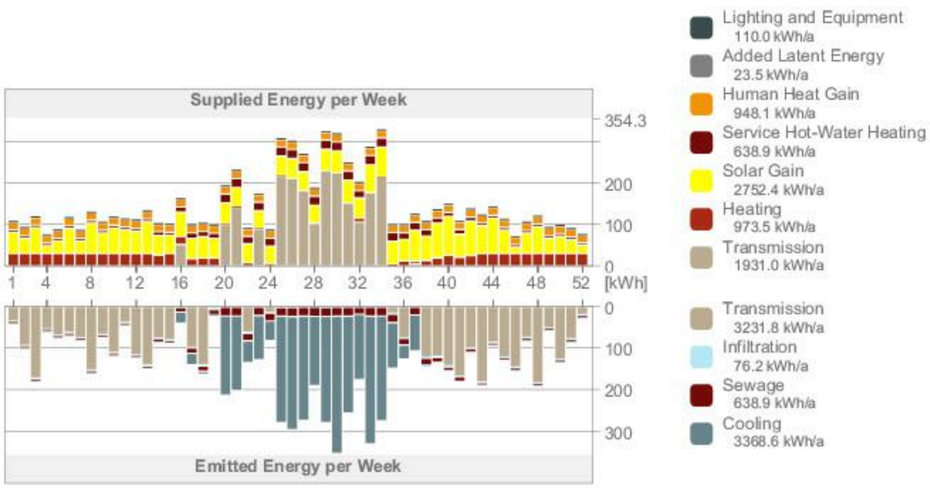
Building Shell Performance Data		
Infiltration at 50Pa:	**4.31**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**3.12**	
Floors:	**2.31 - 2.31**	
External:	**0.78 - 4.35**	
Underground:	**0.80 - 5.11**	
Openings:	**4.93 - 4.93**	

Specific Annual Values		
Net Heating Energy:	**20.99**	kWh/m²a
Net Cooling Energy:	**72.62**	kWh/m²a
Total Net Energy:	**93.61**	kWh/m²a
Energy Consumption:	**109.76**	kWh/m²a
Fuel Consumption:	**60.49**	kWh/m²a
Primary Energy:	**277.45**	kWh/m²a
Fuel Cost:	--	GBP/m²a
CO_2 Emission:	**5.75**	kg/m²a

Degree Days	
Heating (HDD):	**4316.20**
Cooling (CDD):	**1298.53**

Project Energy Balance



Thermal Blocks

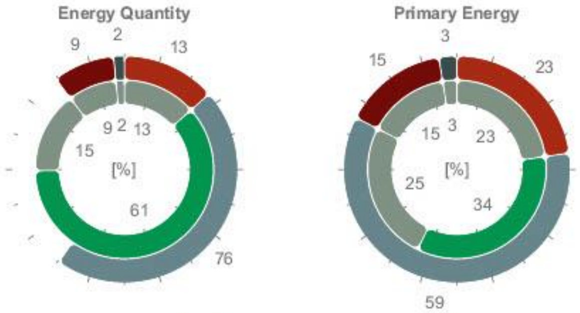
Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 Sample Thermal Block	1	Rezidential	51.6	133.12
Total:	**1**		**51.6**	**133.12**

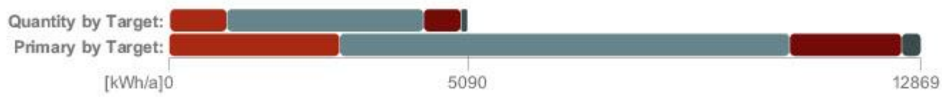
EXISTING BUILDING

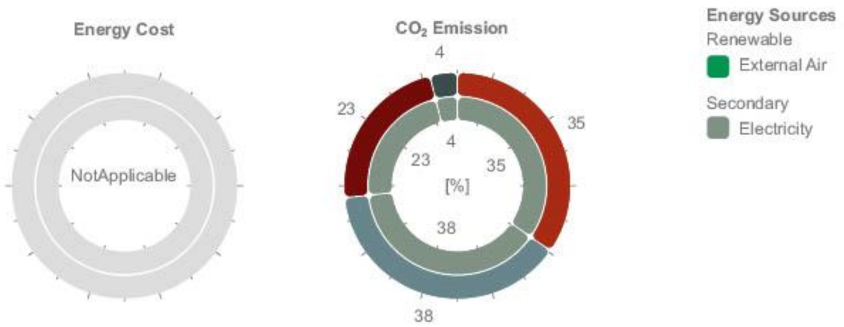
[Project Number] ENERGY EVALUATION

Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Primary kWh/a	Cost GBP/a	CO_2 Emission kg/a
Heating	973	2920	0	92
Cooling	3368	7702	0	102
Service Hot-Water	638	1916	0	60
Ventilation Fans	0	0	0	0
Lighting & Appliances	110	330	0	10
Total:	**5090**	**12869**	**NA**	**266**







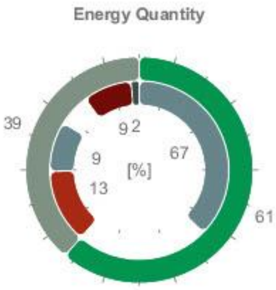
BUPT

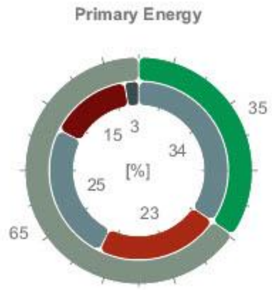
EXISTING BUILDING

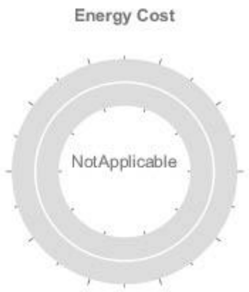
[Project Number] ENERGY EVALUATION

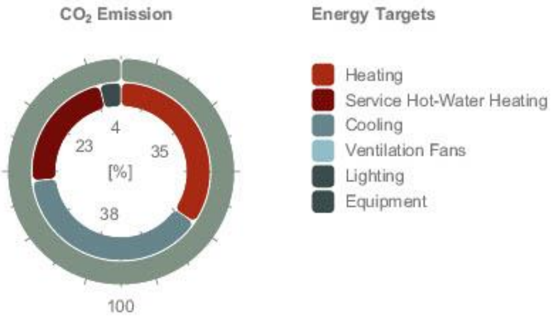
Energy Consumption by Sources

Source Type	Energy Source Name	Quantity kWh/a	Primary kWh/a	Cost GBP/a	CO_2 Emission kg/a
Renewable	External Air	4452	4452	NA	0
Secondary	Electricity	2805	8417	--	266
	Total:	**7257**	**12869**	Not Applicable	**266**









Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	External Air	4452	0
Secondary	Electricity	8417	266
	Total:	**12869**	**266**

All statements without guarantee

770 Existing outer wall - Classic thermal rehabilitation

Exterior wall
created on 29.1.2023

Thermal protection

R = 3,64 m²K/W

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

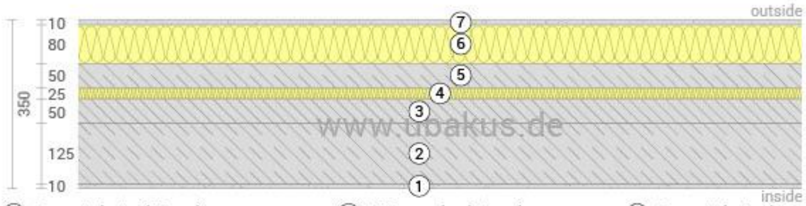
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 344 kJ/m²K

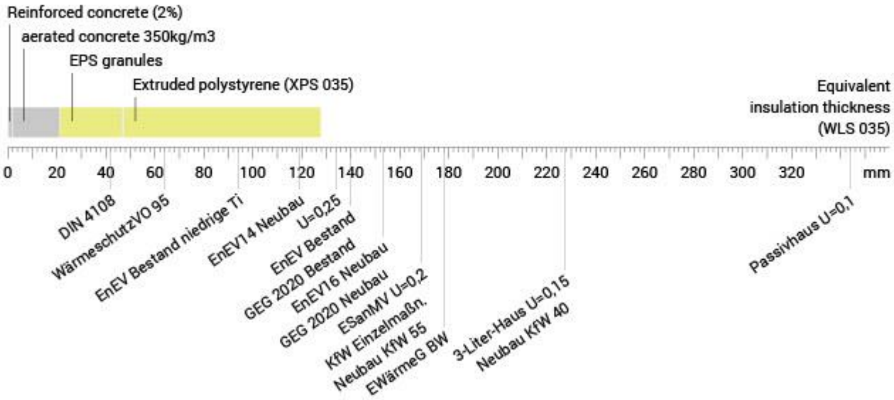
excellent insufficient



1. Cement plaster (10 mm)
2. Reinforced concrete (125 mm)
3. aerated concrete 350kg/m3 (50 mm)
4. EPS granules (25 mm)
5. Reinforced concrete (50 mm)
6. Extruded polystyrene (80 mm)
7. Cement plaster (10 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,035 W/mK.



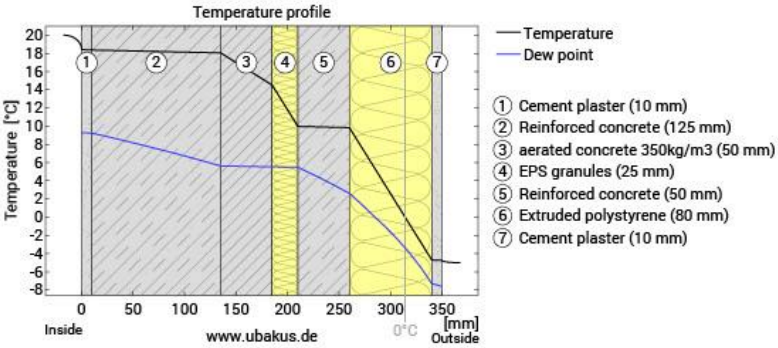
Inside air :	20,0°C / 50%		Thickness:	35,0 cm
Outside air:	-5,0°C / 80%	sd-value: 33,4 m	Weight:	481 kg/m²
Surface temperature.:	18,4°C / -4,7°C		Heat capacity:	432 kJ/m²K

*Vergleich mit dem Höchstwert gemäß GEG 2020 für erstmaligen Einbau, Ersatz oder Erneuerung von Außenwänden (Anlage 7, Zeile 1a,1b).

Page 1

770 Existing outer wall - Classic thermal rehabilitation, R=3,64 m²K/W

Temperature profile



Temperature and dew-point temperature in the component. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew-point temperature, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	max	Weight [kg/m²]
		Thermal contact resistance*		0,130	18,4	20,0	
1	1 cm	Cement plaster	1,400	0,007	18,4	18,4	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	18,0	18,4	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	14,5	18,0	17,5
4	2,5 cm	EPS granules	0,035	0,714	10,0	14,5	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	9,8	10,0	120,0
6	8 cm	Extruded polystyrene (XPS 035)	0,035	2,286	-4,7	9,8	2,8
7	1 cm	Cement plaster	1,400	0,007	-4,7	-4,7	20,0
		Thermal contact resistance*		0,040	-5,0	-4,7	
	35 cm	Whole component		3,810			480,8

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max):	18,4°C	18,4°C	18,4°C
Surface temperature outside (min / average / max):	-4,7°C	-4,7°C	-4,7°C

ubakus All statements without guarantee

770 Existing outer wall - Classic thermal rehabilitation, R=3,64 m²K/W

Moisture proofing

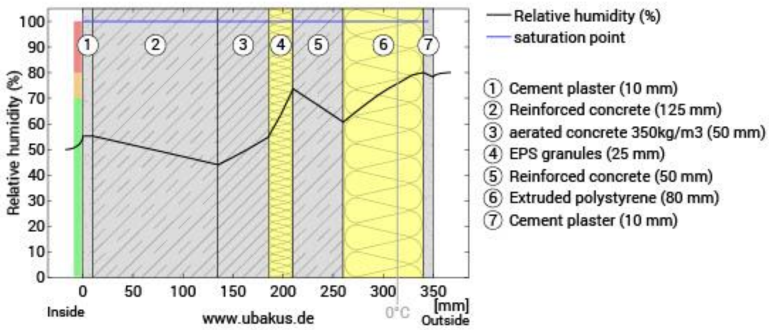
For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 50% Humidity; outside: -5°C und 80% Humidity. This climate complies with DIN 4108-3.

This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	1 cm	Cement plaster	0,15	-		20,0
2	12,5 cm	Reinforced concrete (2%)	10,00	-		300,0
3	5 cm	aerated concrete 350kg/m3	0,25	-		17,5
4	2,5 cm	EPS granules	0,13	-		0,5
5	5 cm	Reinforced concrete (2%)	6,50	-		120,0
6	8 cm	Extruded polystyrene (XPS 035)	16,00	-		2,8
7	1 cm	Cement plaster	0,35	-		20,0
	35 cm	Whole component	33,38	0		480,8

Humidity

The temperature of the inside surface is 18,4 °C leading to a relative humidity on the surface of 55%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

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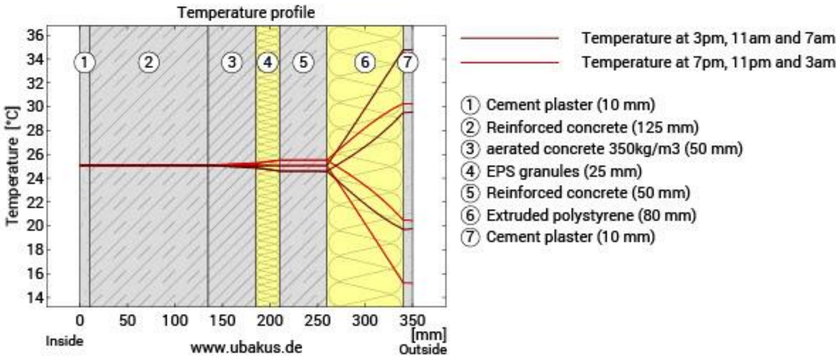
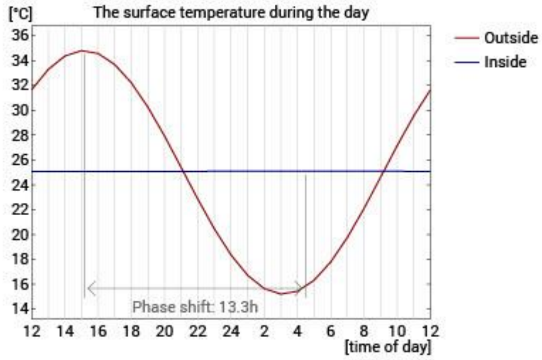
All statements without guarantee

770 Existing outer wall - Classic thermal rehabilitation, R=3,64 m²K/W

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	non relevant	Heat storage capacity (whole component):	432 kJ/m²K
Amplitude attenuation **	>100	Thermal capacity of inner layers:	344 kJ/m²K
TAV ***	0,002		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

EXISTING BUILDING - PET

[Project Number] ENERGY EVALUATION

Key Values

General Project Data		
Project Name:	ENERGY EVALUATION	
City Location:	Timisoara	
Latitude:	46° 21' 45" N	
Longitude:	25° 48' 22" E	
Altitude:	662.00	m
Climate Data Source:	ROU_Timiso...0_IWEC.epw	
Evaluation Date:	1/30/2023 4:55 AM	

Building Geometry Data		
Gross Floor Area:	**52.3**	m²
Treated Floor Area:	**46.4**	m²
External Envelope Area:	**124.5**	m²
Ventilated Volume:	**133.12**	m³
Glazing Ratio:	**3**	%

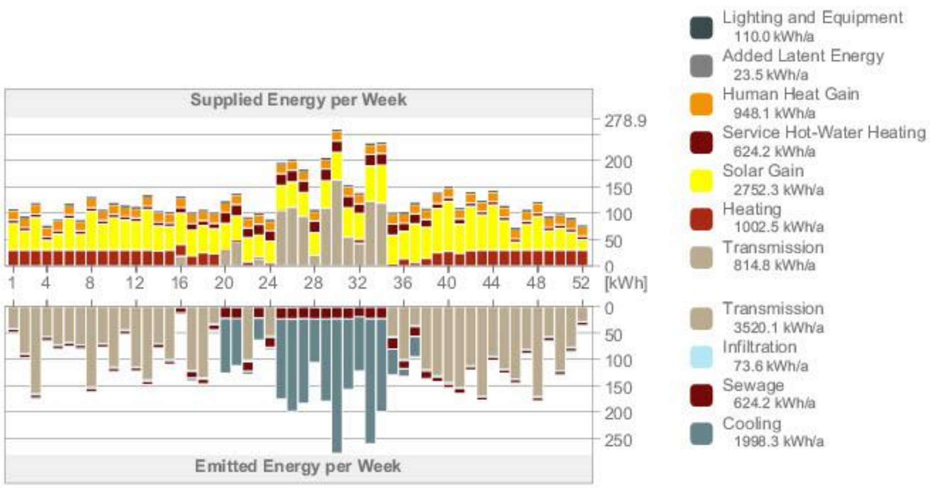
Building Shell Performance Data		
Infiltration at 50Pa:	**4.31**	ACH

Thermal Resistances	R value	[m²K/W]
Building Shell Average:	**0.46**	
Floors:	**0.43 - 0.43**	
External:	**5.90 - 0.23**	
Underground:	**3.75 - 0.20**	
Openings:	**0.20 - 0.20**	

Specific Annual Values		
Net Heating Energy:	**21.61**	kWh/m²a
Net Cooling Energy:	**43.08**	kWh/m²a
Total Net Energy:	**64.69**	kWh/m²a
Energy Consumption:	**80.52**	kWh/m²a
Fuel Consumption:	**51.46**	kWh/m²a
Primary Energy:	**211.49**	kWh/m²a
Fuel Cost:	**--**	GBP/m²a
CO_2 Emission:	**4.89**	kg/m²a

Degree Days	
Heating (HDD):	**4316.20**
Cooling (CDD):	**1298.53**

Project Energy Balance



Thermal Blocks

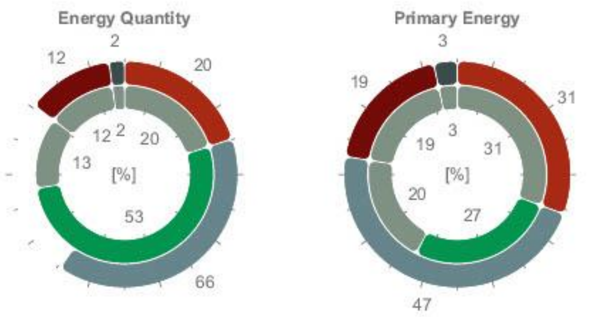
Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 Sample Thermal Block	1	Rezidential	52.3	133.12
Total:	**1**		**52.3**	**133.12**

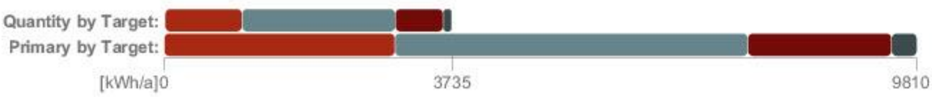
EXISTING BUILDING - PET

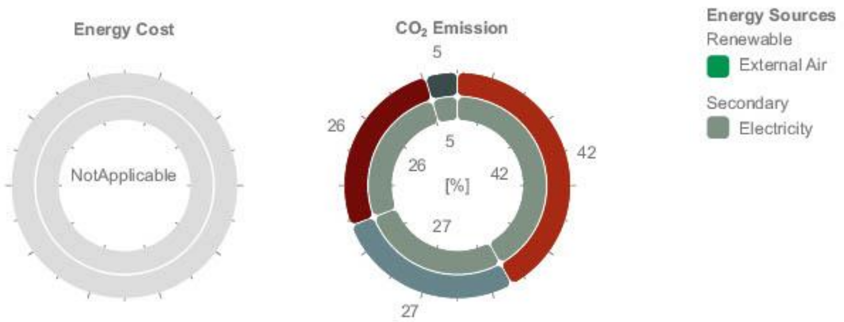
[Project Number] ENERGY EVALUATION

Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Heating	1002	3007	0	95
Cooling	1998	4599	0	61
Service Hot-Water	624	1872	0	59
Ventilation Fans	0	0	0	0
Lighting & Appliances	110	330	0	10
Total:	3735	9810	NA	226





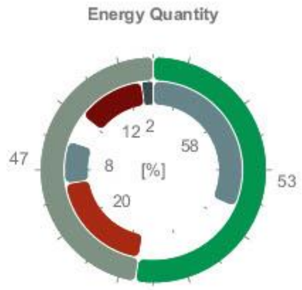


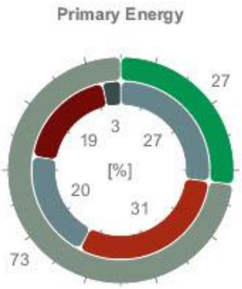
EXISTING BUILDING - PET

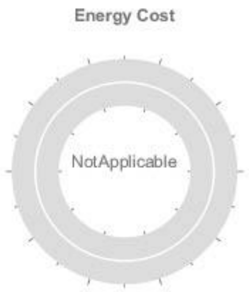
[Project Number] ENERGY EVALUATION

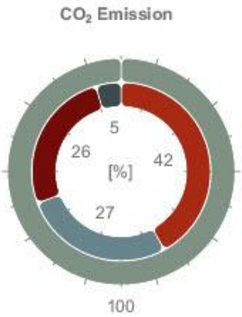
Energy Consumption by Sources

Source Type	Energy Source Name	Quantity kWh/a	Primary kWh/a	Cost GBP/a	CO_2 Emission kg/a
Renewable	External Air	2648	2648	NA	0
Secondary	Electricity	2387	7161	--	226
	Total:	5035	9810	Not Applicable	226









Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	External Air	2648	0
Secondary	Electricity	7161	226
	Total:	9809	226

ubakus

All statements without guarantee

770 Existing outer wall - Proposed rehabiliation v1

Exterior wall
created on 29.1.2023

Thermal protection

R = 4,21 m²K/W

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

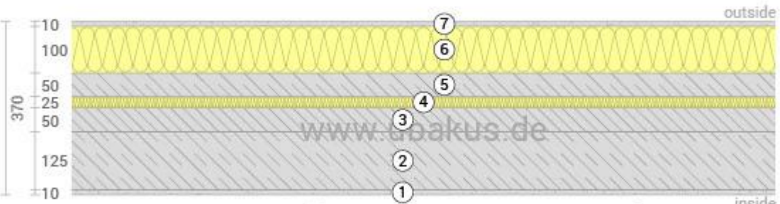
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 352 kJ/m²K

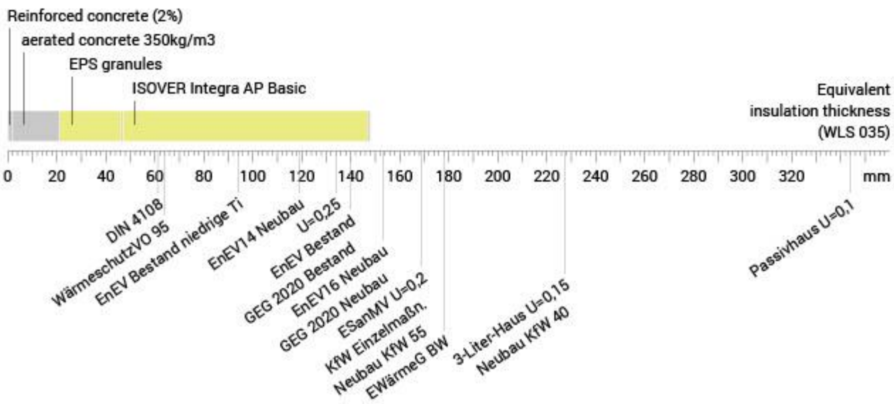
excellent insufficient



1. Cement plaster (10 mm)
2. Reinforced concrete (125 mm)
3. aerated concrete 350kg/m3 (50 mm)
4. EPS granules (25 mm)
5. Reinforced concrete (50 mm)
6. ISOVER Integra AP Basic (100 mm)
7. Cement plaster (10 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,035 W/mK.



Inside air :	20,0°C / 50%		Thickness:	37,0 cm
Outside air:	-5,0°C / 80%	sd-value: 17,5 m	Weight:	0 kg/m²
Surface temperature.:	18,6°C / -4,8°C		Heat capacity:	430 kJ/m²K

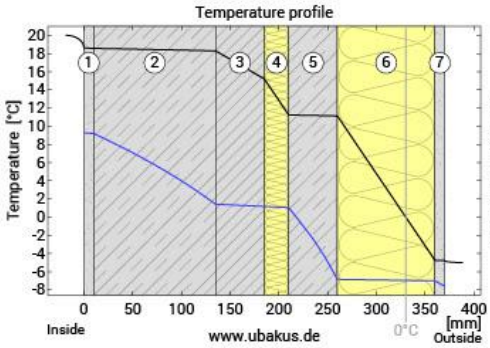
*Vergleich mit dem Höchstwert gemäß GEG 2020 für erstmaligen Einbau, Ersatz oder Erneuerung von Außenwänden (Anlage 7, Zeile 1a,1b).

Page 1

ubakus All statements without guarantee

770 Existing outer wall - Proposed rehabiliation v1, R=4,21 m²K/W

Temperature profile



Temperature and dew-point temperature in the component. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew-point temperature, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,130	18,6	20,0	
1	1 cm	Cement plaster	1,400	0,007	18,6	18,6	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	18,3	18,6	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	15,2	18,3	17,5
4	2,5 cm	EPS granules	0,035	0,714	11,2	15,2	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	11,1	11,2	120,0
6	10 cm	ISOVER Integra AP Basic	0,035	2,857	-4,7	11,1	no inform ation
7	1 cm	Cement plaster	1,400	0,007	-4,8	-4,7	20,0
		Thermal contact resistance*		0,040	-5,0	-4,8	
	37 cm	Whole component		4,381			>478

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max):	18,6°C	18,6°C	18,6°C
Surface temperature outside (min / average / max):	-4,8°C	-4,8°C	-4,8°C

ubakus All statements without guarantee

770 Existing outer wall - Proposed rehabiliation v1, R=4,21 m²K/W

Moisture proofing

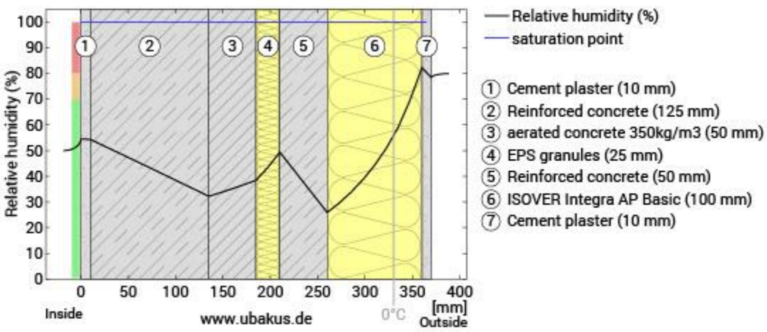
For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 50% Humidity; outside: -5°C und 80% Humidity. This climate complies with DIN 4108-3.

This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	[Gew.-%]	Weight [kg/m²]
1	1 cm	Cement plaster	0,15	-		20,0
2	12,5 cm	Reinforced concrete (2%)	10,00	-		300,0
3	5 cm	aerated concrete 350kg/m3	0,25	-		17,5
4	2,5 cm	EPS granules	0,13	-		0,5
5	5 cm	Reinforced concrete (2%)	6,50	-		120,0
6	10 cm	ISOVER Integra AP Basic	0,10	-		no information
7	1 cm	Cement plaster	0,35	-		20,0
	37 cm	Whole component	17,48	0		>478

Humidity

The temperature of the inside surface is 18,6 °C leading to a relative humidity on the surface of 55%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

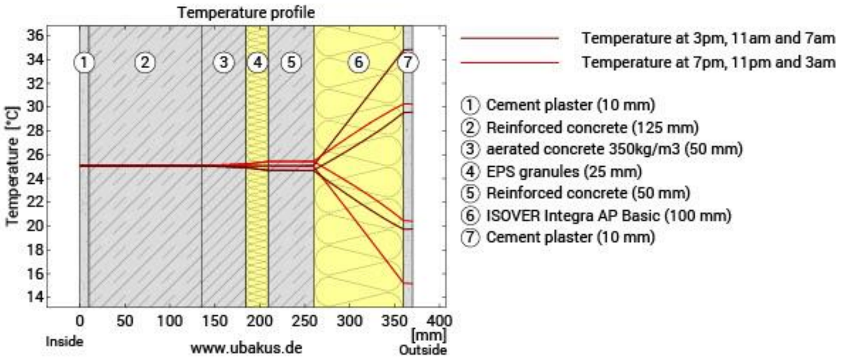
ubakus

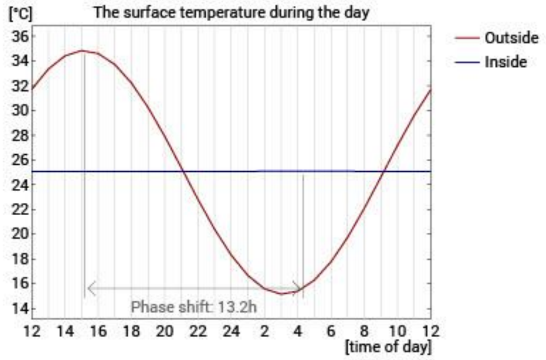
All statements without guarantee

770 Existing outer wall - Proposed rehabiliation v1, R=4,21 m²K/W

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	non relevant	Heat storage capacity (whole component):	430 kJ/m²K
Amplitude attenuation **	>100	Thermal capacity of inner layers:	352 kJ/m²K
TAV ***	0,002		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

EXISTING BUILDING - isulation option 1

[Project Number] ENERGY EVALUATION

Key Values

General Project Data

Project Name:	ENERGY EVALUATION	
City Location:	Timisoara	
Latitude:	46° 21' 45" N	
Longitude:	25° 48' 22" E	
Altitude:	662.00	m
Climate Data Source:	ROU_Timiso...0_IWEC.epw	
Evaluation Date:	1/30/2023 4:46 AM	

Building Geometry Data

Gross Floor Area:	**52.5**	m²
Treated Floor Area:	**46.4**	m²
External Envelope Area:	**124.5**	m²
Ventilated Volume:	**133.12**	m³
Glazing Ratio:	**3**	%

Building Shell Performance Data

Infiltration at 50Pa:	**4.31**	ACH

Heat Transfer Coefficients	U value	[W/m²K]
Building Shell Average:	**2.19**	
Floors:	**2.31 - 2.31**	
External:	**0.17 - 4.35**	
Underground:	**0.25 - 5.11**	
Openings:	**4.93 - 4.93**	

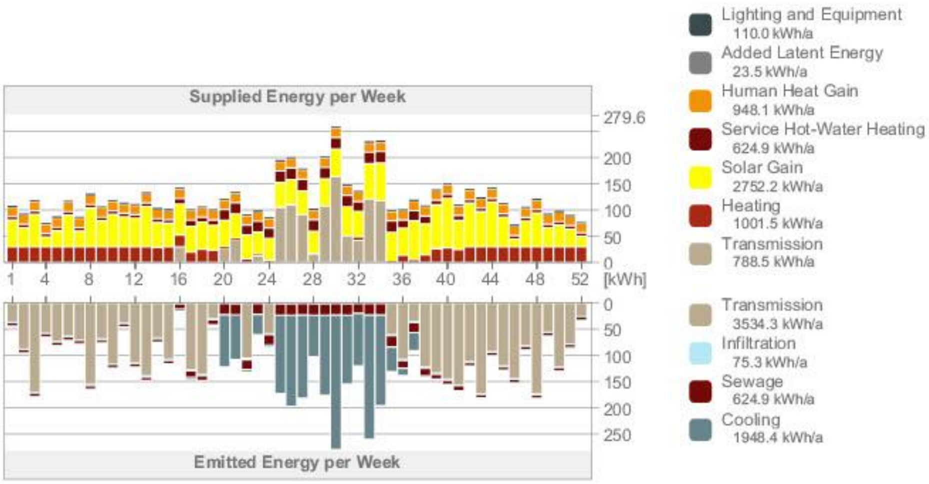
Specific Annual Values

Net Heating Energy:	**21.59**	kWh/m²a
Net Cooling Energy:	**42.01**	kWh/m²a
Total Net Energy:	**63.60**	kWh/m²a
Energy Consumption:	**79.44**	kWh/m²a
Fuel Consumption:	**51.10**	kWh/m²a
Primary Energy:	**208.96**	kWh/m²a
Fuel Cost:	**--**	GBP/m²a
CO_2 Emission:	**4.85**	kg/m²a

Degree Days

Heating (HDD):	**4316.20**
Cooling (CDD):	**1298.53**

Project Energy Balance



Thermal Blocks

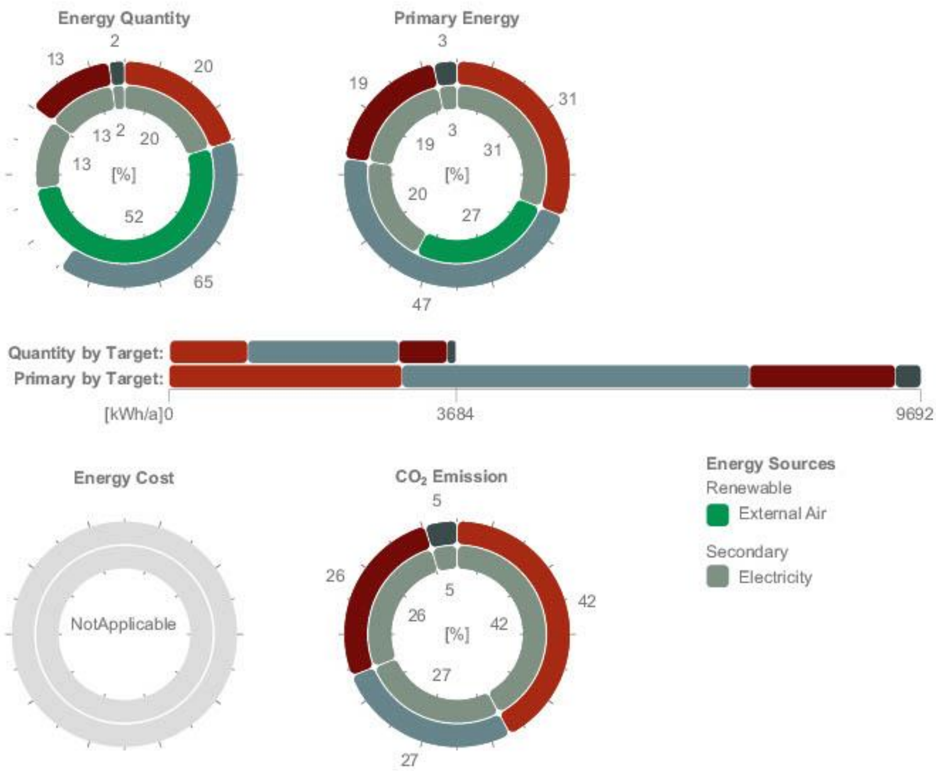
Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 Sample Thermal Block	1	Rezidential	52.5	133.12
Total:	**1**		**52.5**	**133.12**

EXISTING BUILDING - isulation option 1

[Project Number] ENERGY EVALUATION

Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Heating	1001	3004	0	95
Cooling	1948	4483	0	60
Service Hot-Water	624	1874	0	59
Ventilation Fans	0	0	0	0
Lighting & Appliances	110	330	0	10
Total:	3684	9692	NA	225



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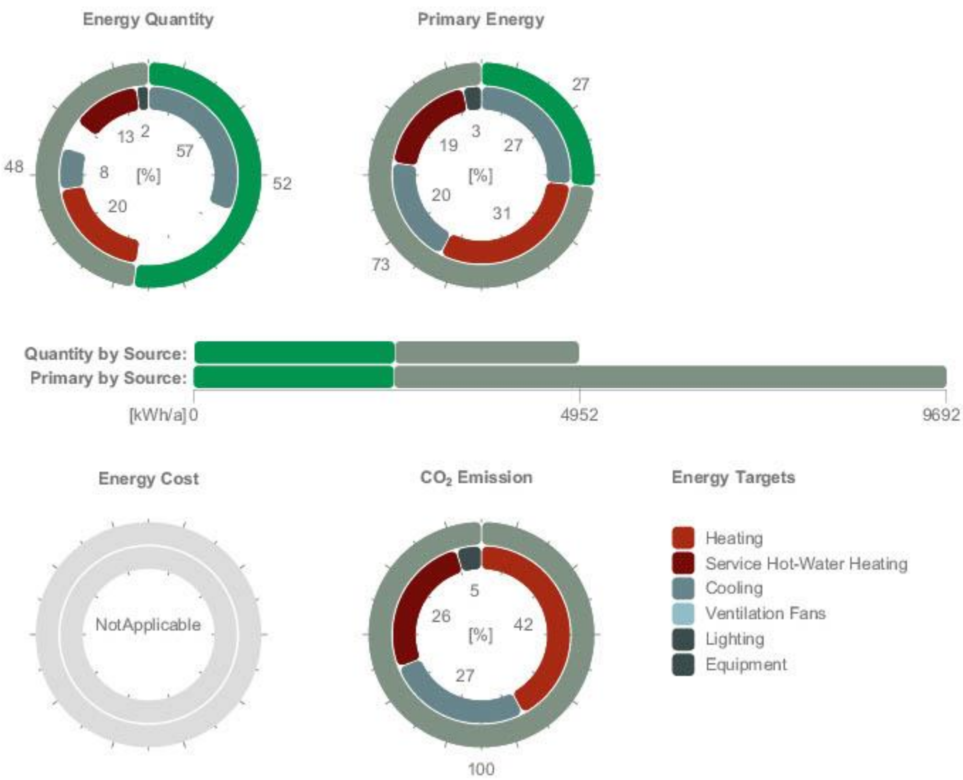
EXISTING BUILDING - isulation option 1

[Project Number] ENERGY EVALUATION

Energy Consumption by Sources

Source Type	Source Name	Energy Quantity kWh/a	Primary kWh/a	Cost GBP/a	CO_2 Emission kg/a
Renewable	External Air	2582	2582	NA	0
Secondary	Electricity	2370	7110	--	225
	Total:	**4952**	**9692**	Not Applicable	**225**



Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	External Air	2582	0
Secondary	Electricity	7110	225
	Total:	**9692**	**225**

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770 Existing outer wall - Propose rehabilitation v2

Exterior wall
created on 29.1.2023

Thermal protection

R = 4,13 m²K/W

GEG 2020 Bestand*: U<0,24 W/(m²K)

excellent insufficient

Moisture proofing

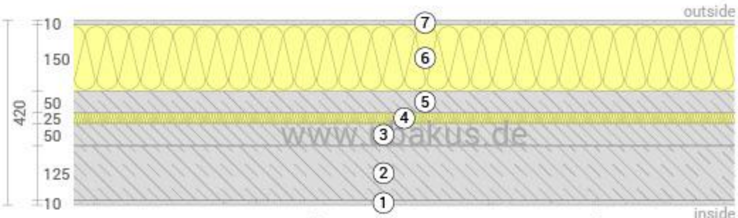
No condensate

excellent insufficient

Heat protection

Temperature amplitude damping: >100
phase shift: non relevant
Thermal capacity inside: 351 kJ/m²K

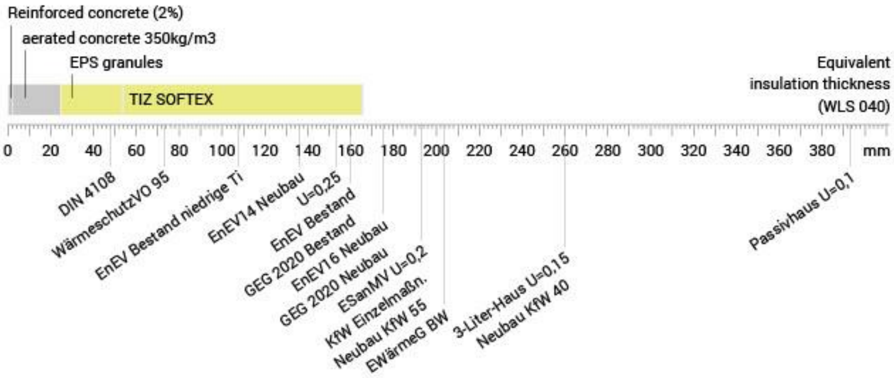
excellent insufficient



1. Cement plaster (10 mm)
2. Reinforced concrete (125 mm)
3. aerated concrete 350kg/m3 (50 mm)
4. EPS granules (25 mm)
5. Reinforced concrete (50 mm)
6. TIZ SOFTEX (150 mm)
7. Cement plaster (10 mm)

Impact of each layer and comparison to reference values

For the following figure, the thermal resistances of the individual layers were converted in millimeters insulation. The scale refers to an insulation of thermal conductivity 0,040 W/mK.



Inside air :	20,0°C / 50%		Thickness:	42,0 cm
Outside air:	-5,0°C / 80%	sd-value: 32,4 m	Weight:	481 kg/m²
Surface temperature.:	18,6°C / -4,8°C		Heat capacity:	431 kJ/m²K

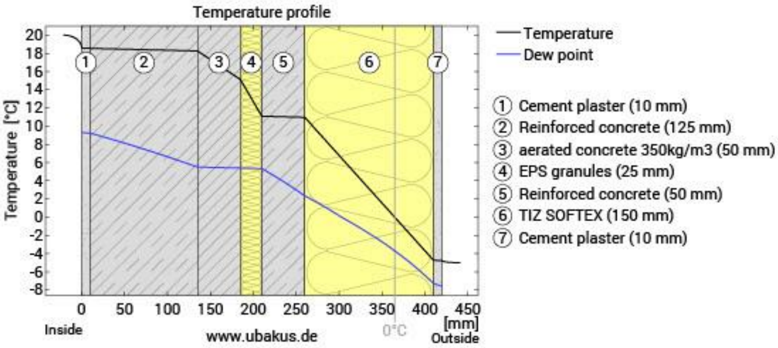
*Vergleich mit dem Höchstwert gemäß GEG 2020 für erstmaligen Einbau, Ersatz oder Erneuerung von Außenwänden (Anlage 7, Zeile 1a,1b).

Page 1

ubakus All statements without guarantee

770 Existing outer wall - Propose rehabilitation v2, R=4,13 m²K/W

Temperature profile



Temperature and dew-point temperature in the component. The dew-point indicates the temperature, at which water vapour condensates. As long as the temperature of the component is everywhere above the dew-point temperature, no condensation occurs. If the curves have contact, condensation occurs at the corresponding position.

Layers (from inside to outside)

#		Material	λ [W/mK]	R [m²K/W]	Temperatur [°C] min	Temperatur [°C] max	Weight [kg/m²]
		Thermal contact resistance*		0,130	18,6	20,0	
1	1 cm	Cement plaster	1,400	0,007	18,5	18,6	20,0
2	12,5 cm	Reinforced concrete (2%)	2,500	0,050	18,3	18,5	300,0
3	5 cm	aerated concrete 350kg/m3	0,090	0,556	15,1	18,3	17,5
4	2,5 cm	EPS granules	0,035	0,714	11,1	15,1	0,5
5	5 cm	Reinforced concrete (2%)	2,500	0,020	11,0	11,1	120,0
6	15 cm	TIZ SOFTEX	0,054	2,778	-4,7	11,0	3,0
7	1 cm	Cement plaster	1,400	0,007	-4,8	-4,7	20,0
		Thermal contact resistance*		0,040	-5,0	-4,8	
	42 cm	Whole component		4,302			481,0

*Thermal contact resistances according to DIN 6946 for the U-value calculation. Rsi=0,25 and Rse=0,04 according to DIN 4108-3 were used for moisture proofing and temperature profile.

Surface temperature inside (min / average / max):	18,6°C	18,6°C	18,6°C
Surface temperature outside (min / average / max):	-4,8°C	-4,8°C	-4,8°C

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All statements without guarantee

770 Existing outer wall - Propose rehabilitation v2, R=4,13 m²K/W

Moisture proofing

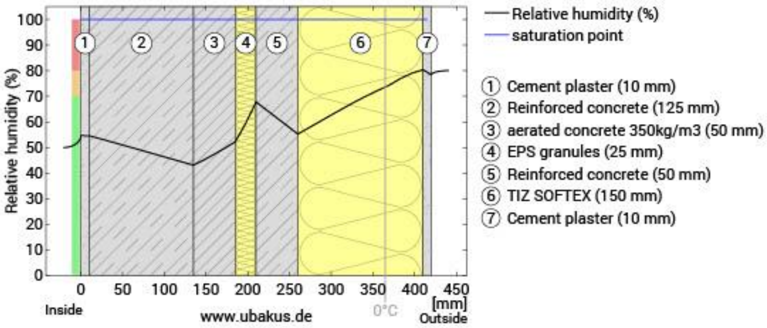
For the calculation of the amount of condensation water, the component was exposed to the following constant climate for 90 days: inside: 20°C und 50% Humidity; outside: -5°C und 80% Humidity. This climate complies with DIN 4108-3.

This component is free of condensate under the given climate conditions.

#		Material	sd-value [m]	Condensate [kg/m²]	Condensate [Gew.-%]	Weight [kg/m²]
1	1 cm	Cement plaster	0,15	-		20,0
2	12,5 cm	Reinforced concrete (2%)	10,00	-		300,0
3	5 cm	aerated concrete 350kg/m3	0,25	-		17,5
4	2,5 cm	EPS granules	0,13	-		0,5
5	5 cm	Reinforced concrete (2%)	6,50	-		120,0
6	15 cm	TIZ SOFTEX	15,00	-		3,0
7	1 cm	Cement plaster	0,35	-		20,0
	42 cm	Whole component	32,38	0		481,0

Humidity

The temperature of the inside surface is 18,6 °C leading to a relative humidity on the surface of 55%.Mould formation is not expected under these conditions.
The following figure shows the relative humidity inside the component.



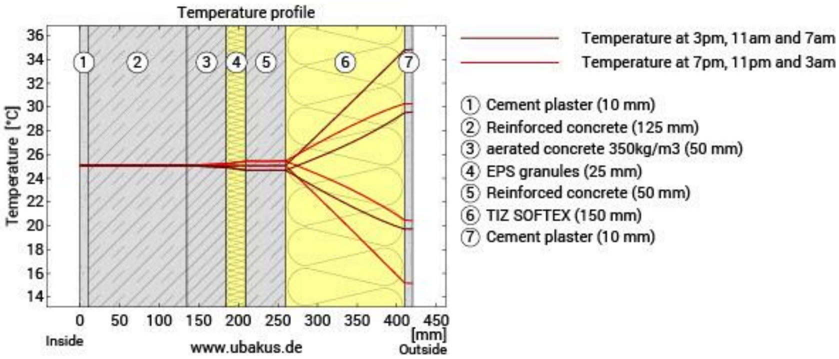
Notes: Calculation using the Ubakus 2D-FE method. Convection and the capillarity of the building materials were not considered. The drying time may take longer under unfavorable conditions (shading, damp / cool summers) than calculated here.

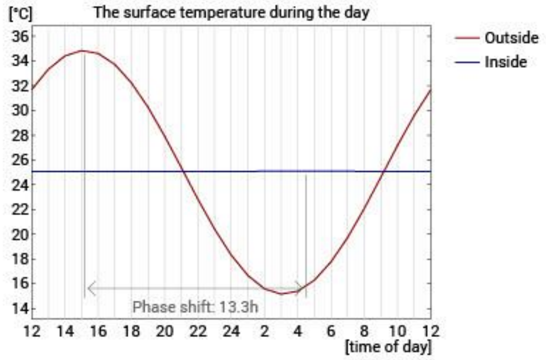
All statements without guarantee

770 Existing outer wall - Propose rehabilitation v2, R=4,13 m²K/W

Heat protection

The following results are properties of the tested component alone and do not make any statement about the heat protection of the entire room:





Top: Temperature profile within the component at different times. From top to bottom, brown lines: at 3 pm, 11 am and 7 am and red lines at 7 pm , 11 pm and 3 am.
Bottom: Temperature on the outer (red) and inner (blue) surface in the course of a day. The arrows indicate the location of the temperature maximum values . The maximum of the inner surface temperature should preferably occur during the second half of the night.

Phase shift*	non relevant	Heat storage capacity (whole component):	431 kJ/m²K
Amplitude attenuation **	>100	Thermal capacity of inner layers:	351 kJ/m²K
TAV ***	0,002		

* The phase shift is the time in hours after which the temperature peak of the afternoon reaches the component interior.
** The amplitude attenuation describes the attenuation of the temperature wave when passing through the component. A value of 10 means that the temperature on the outside varies 10x stronger than on the inside, e.g. outside 15-35 °C, inside 24-26 °C.
*** The temperature amplitude ratio TAV is the reciprocal of the attenuation: TAV = 1 / amplitude attenuation

Note: The heat protection of a room is influenced by several factors, but essentially by the direct solar radiation through windows and the total amount of heat storage capacity (including floor, interior walls and furniture). A single component usually has only a very small influence on the heat protection of the room.

EXISTING BUILDING - PET

[Project Number] ENERGY EVALUATION

Key Values

General Project Data		
Project Name:	ENERGY EVALUATION	
City Location:	Timisoara	
Latitude:	46° 21' 45" N	
Longitude:	25° 48' 22" E	
Altitude:	662.00	m
Climate Data Source:	ROU_Timiso...0_IWEC.epw	
Evaluation Date:	1/30/2023 4:53 AM	

Building Geometry Data		
Gross Floor Area:	**52.9**	m²
Treated Floor Area:	**46.4**	m²
External Envelope Area:	**124.5**	m²
Ventilated Volume:	**133.12**	m³
Glazing Ratio:	**3**	%

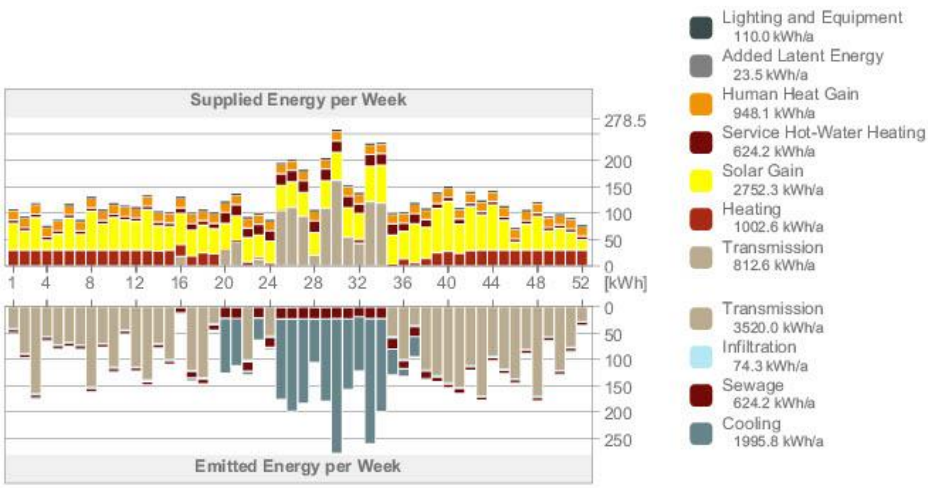
Building Shell Performance Data		
Infiltration at 50Pa:	**4.31**	ACH

Thermal Resistances	R value	[m²K/W]
Building Shell Average:	**0.46**	
Floors:	**0.43 - 0.43**	
External:	**5.90 - 0.23**	
Underground:	**4.13 - 0.20**	
Openings:	**0.20 - 0.20**	

Specific Annual Values		
Net Heating Energy:	**21.61**	kWh/m²a
Net Cooling Energy:	**43.03**	kWh/m²a
Total Net Energy:	**64.64**	kWh/m²a
Energy Consumption:	**80.47**	kWh/m²a
Fuel Consumption:	**51.45**	kWh/m²a
Primary Energy:	**211.37**	kWh/m²a
Fuel Cost:	**--**	GBP/m²a
CO_2 Emission:	**4.89**	kg/m²a

Degree Days	
Heating (HDD):	**4316.20**
Cooling (CDD):	**1298.53**

Project Energy Balance



Thermal Blocks

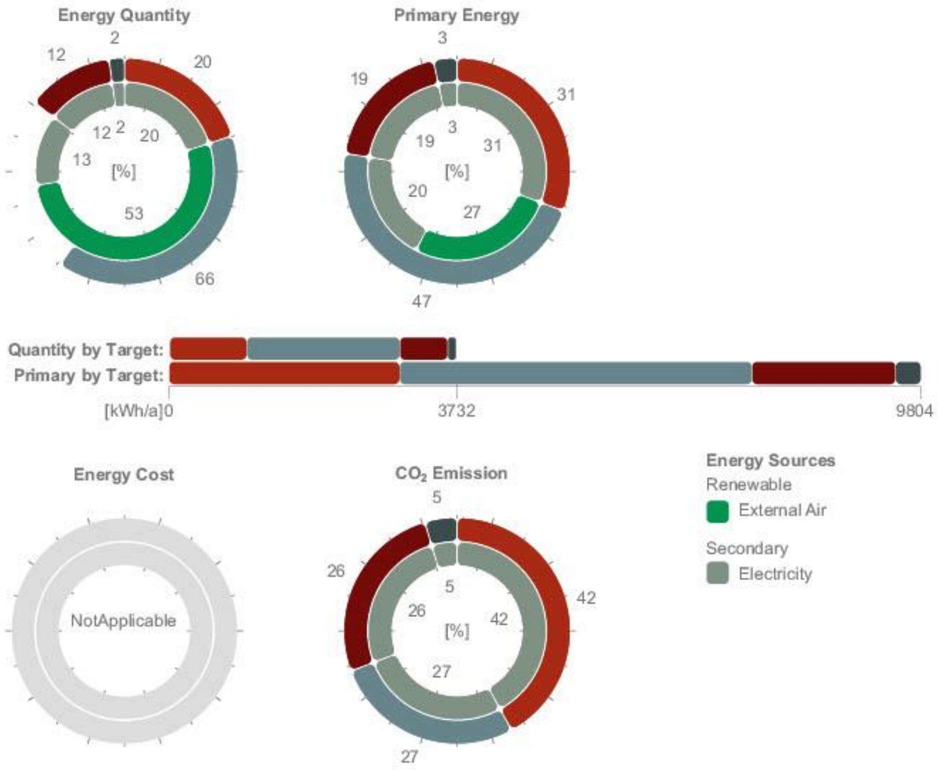
Thermal Block	Zones Assigned	Operation Profile	Gross Floor Area m²	Volume m³
001 Sample Thermal Block	1	Rezidential	52.9	133.12
Total:	**1**		**52.9**	**133.12**

EXISTING BUILDING - PET

[Project Number] ENERGY EVALUATION

Energy Consumption by Targets

Target Name	Energy Quantity kWh/a	Energy Primary kWh/a	Energy Cost GBP/a	CO_2 Emission kg/a
Heating	1002	3007	0	95
Cooling	1995	4594	0	61
Service Hot-Water	624	1872	0	59
Ventilation Fans	0	0	0	0
Lighting & Appliances	110	330	0	10
Total:	**3732**	**9804**	**NA**	**226**

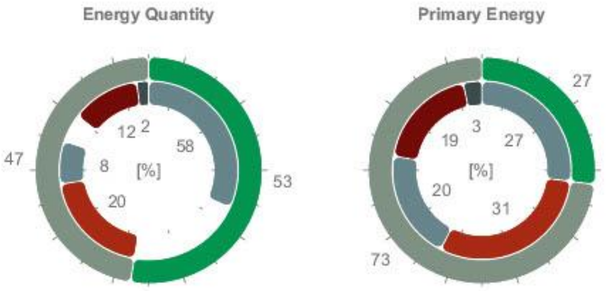


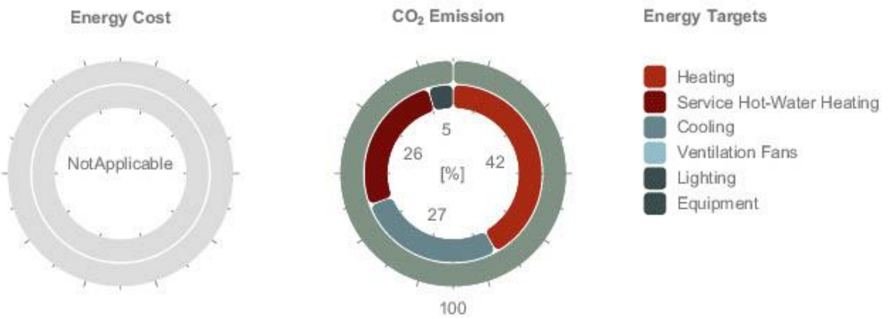
EXISTING BUILDING - PET

[Project Number] ENERGY EVALUATION

Energy Consumption by Sources

Source Type	Source Name	Energy			CO_2 Emission
		Quantity	Primary	Cost	
		kWh/a	kWh/a	GBP/a	kg/a
Renewable	External Air	2645	2645	NA	0
Secondary	Electricity	2386	7159	--	226
	Total:	**5031**	**9804**	Not Applicable	**226**





Environmental Impact

Source Type	Source Name	Primary Energy kWh/a	CO_2 emission kg/a
Renewable	External Air	2645	0
Secondary	Electricity	7159	226
	Total:	**9804**	**226**