

Large Prefabricated Concrete Panels Collective Dwellings from the 1970s: Context and Improvements

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Abstract. The period between 1960s and 1970s had a significant impact in Romania on the urban development of major cities. Because the vast expansion of the industry, the urban population has massively increased, due the large number of workers coming from the rural areas. This intense process has led to a shortage of homes on the housing market. In order to rapidly build new homes, standard residential project types were erected using large prefabricated concrete panels. By using repetitive patterns, such buildings were built in a short amount of time through the entire country. Nowadays, these buildings represent 1.8% of the built environment and accommodate more than half of a city's population. Even though these units have reached only half their intended life span, they fail to satisfy present living standards and consume huge amounts of energy for heating, cooling, ventilation and lighting. Due to the fact that these building are based on standardised projects and were built in such a large scale, the creation of a system that brings them to current standards will not only benefit the building but also it will significantly improve the quality of life within. With the transition of the existing power grids to a "smart grid" such units can become micro power plants in future electricity networks thus contributing to micro-generation and energy storage. If one is to consider the EU 20-20-20 commitments, to find ideas for alternative and innovative strategies for further improving these building through locally adapted measures can be seen as one of the most addressed issues of today. This research offers a possible retrofitting scenario of these buildings towards a sustainable future. The building envelope is upgraded using a modular insulation system with integrated solar cells. Renewable energy systems for cooling and ventilation are integrated in order to provide flexibility of the indoor climate. Due to their small floor area, the space within the apartments is redesigned for a more efficient use of space and an improved natural lighting. Active core modules are placed on top of the unused attics and a solar panel array is introduced. Furthermore accessibility issues are addressed by facilitating access for disabled people and implementing an elevator system that currently these building do not have.

1. Introduction

The industrialization period had a major impact on the existing urban environment. The urban population has significantly increased. New homes had to be created in a short time in order to



accommodate the workers coming from the rural areas in hope of a better life. Architecture project-types using Reinforced-Concrete Large Prefabricated Panels (RCLPP) were implemented in order to reduce construction time and rapidly meet the increased housing demands. A repetitive pattern has resulted that could be applied in multiple ways according to the urban limits [1]. These so called “match boxes”, because of their small dimensions, have been built extensively throughout the Eastern bloc. The technology of building using RCLPP has been applied in the northern European countries as well. Although the technology was similar, these buildings have managed to be optimized towards sustainability [2].

Today, the topic of existing building retrofitting, especially applied on those from the east-European areas has become a concern as well as a necessity world-wide for ensuring optimal parameters towards sustainable development. Because these buildings were used on such a wide scale and sheer numbers, upgrading them to the current standards, instead of demolishing them is the best economical solution [3]. The papers present a possible retrofit scenario of these buildings, while considering social, economic and ecological aspects.

2. The collective housing stock in Romania. Target and background.

In Romania, the buildings out of RCLPP represent 1.8% of the entire building stock and house more than half of the country's urban population (see figure 1) [4]. Although similar with the dwelling typologies from the Western Europe, these blocks of flats have different characteristics and background. Design for disadvantaged people was not a considered factor. They were simply seen as the only new housing option. Compared to the rest of Europe, between 1961 and 1990 Romania had one of the highest percentage of RCLPP units being built (60%), with Ireland (32%) and Estonia (80%) at both ends of the list. However, if the number of apartments being occupied by owners, Romania leads with 96%, with 4% tenants compared to Switzerland with 65% tenants. More so, the ratio between square meter available to each person, Romanian collective housing allocate 20 m²/person while South and North Western Europe providing 31 m²/person and 36 m²/person respectively [5].



Figure 1. RCLPP unit distributions in one of the major cities of Romania

One of the most common RCLPP building typology is the 770 one as figures 2-3 show. This 5-storey residential unit was built extensively all over the country during the 70s and offered the lowest building comfort conditions. The model was designed from 68 prefabricated components that would be brought on site and put together in the shortest time possible in different configurations in order to obtain diversity in the planning of new neighbourhoods. However the repetitive pattern is still present and creates a sense of confusion. The particularity of the 770 model is represented by 5 possible bay dimensions: 2.40, 3.00, 3.30 and 5.40 meters. The model can be configured on three subtypes, i.e. Pa, Pb and Pc.

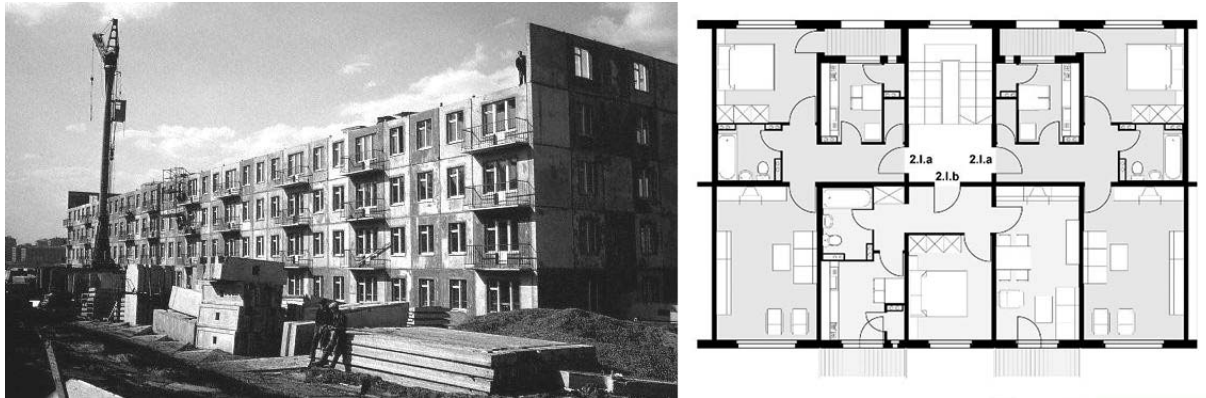


Figure 2. Model T770



Figure 3. Examples of project type 770

The infrastructure consists of a strip foundation under the structural walls made out of concrete B75 (C4/5). The width of the foundation varies depending on the block typology, because the conventional pressure is different in all zones. Foundation elevations (basement) are made of 20 cm thick cast-in-place reinforced concrete B150 (C8/10) [6]. Concerning the superstructure, made entirely of precast panels, the 14 cm bearing reinforced concrete B200 (C12/15) panels used in the interior upper floors respect a maximum weight of 5.1 tones because, a lifting restraint of the used crane model MT110 at that time. The exterior wall panels are made of 2 layers of concrete B250 (C16/20) and a thermal insulation layer of CBA, all within a total width of 27 cm (see figure 4). The slabs are made of reinforced concrete panels and have a width of 13 cm.

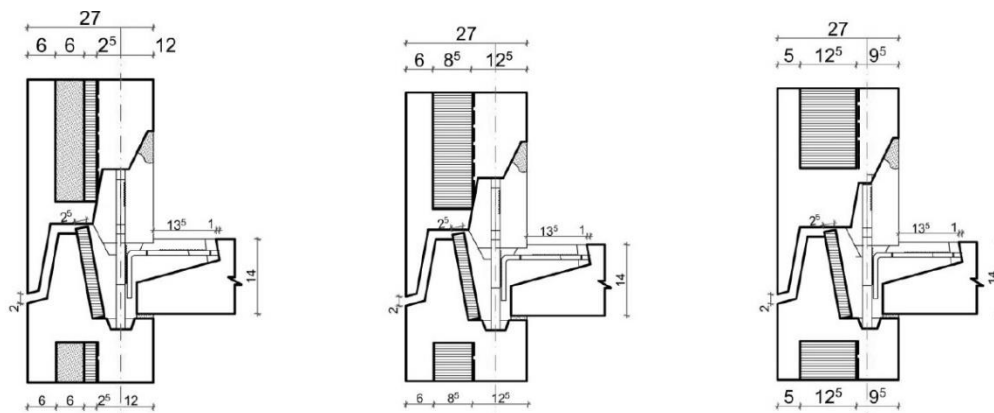


Figure 4. RCLPP connection details

The wall reinforcement consists of PC52 type (S355 grade) for 10 mm longitudinal 97 bars and for 14 mm vertical continuity bars and STPB type (S490) for 4 mm welded wire mesh. The ultimate cubic compressive strength of concrete for the tested and modelled wall panel is 17.5 MPa [7]. Joints between the panels were assured by welding the concrete steel reinforcements and B300 (C18/22.5) quality concrete in-place casting.

3. Sustainable development strategy

It is not only about creating something new, but also taking something existing and using it in a new and improved way, extending the lifespan of existing buildings. From the social perspective, a solution that could fit the inhabitant's exact needs can be developed. The design intends to improve the overall quality of life not only at the apartment level, but also on a larger scale, on the district level.

3.1 Social approach

According to the study, shown in figure 5, most of the families (36.8%) have roughly monthly income at around 1.000-2.000 RON (250-450 euro), families having two (34.4%) or three (36.2%) members. When it comes down to daily outdoor activities, these involve either relaxing (27.1%), interacting with their neighbours (16.9%), sitting/ reading on a bench (16.2%) or playing together with their children (15%). If one would consider with whom they usually spend their free time with, most (37.4%) preferred their own families, with the neighbours (15.4%) and with their friends (14.8%). Most of them are talking with their neighbours on a daily basis regardless of topic (22.7%) or at least once a day (12.9%) [8].

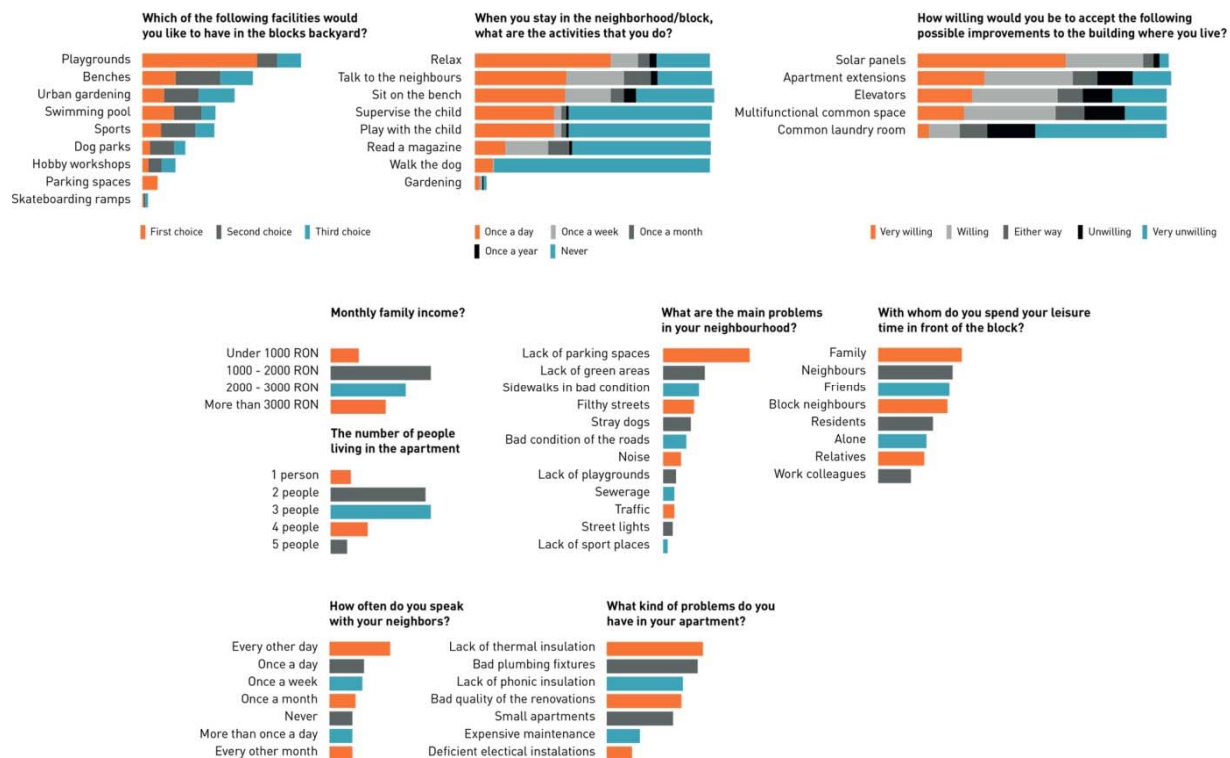


Figure 5. Result of the social analysis

At the apartment level the main problems usually are the lack (or insufficient) thermal insulation (15.5%), the current state of the plumbing fixtures (14.6%), soundproofing (12.2%), poorly executed thermal rehabilitation (12%) and the small and cramped interior space within the apartments.

Within the neighbourhood, the main problems consist in the insufficient parking spaces (31.3%), bad and/ or lacking infrastructure - roads and streets - (22.7%), the inexistent green spaces (14.7%), noise or the lack of playgrounds. Most of them pointed out that if they were to assume the position of mayor, they would create more parking spaces (21.8%), green spaces (14.5%), or playgrounds (12.8%).

Another important aspect to be considered is accessibility for disabled people. Initially, these buildings were designed without taking this factor into account. The ground floor was not built at the same level as the entrance while no ramps were provided within the design process. Also the building norms of that time did not require introducing an elevator. Due to modern accessibility codes a new staircase system was introduced. By extending the intermediary landing towards the outside, a metallic structure with lightweight enclosures is introduced that will house the new elevator for the building.

The space of the apartments has been reorganized. The '60s and '70s society was less stressed as people had few expectations. As stated above, most the residents were from the rural areas where they had no access to electricity or running water. Thus the apartments met their needs and even exceeded them in some cases, despite their overall minimum dimensions. With all of these, the society has changed a lot over the last couple of decades and the initial '70s socialist apartment now fails to satisfy the residents' more modern and sophisticated standard of living (see figure 6).

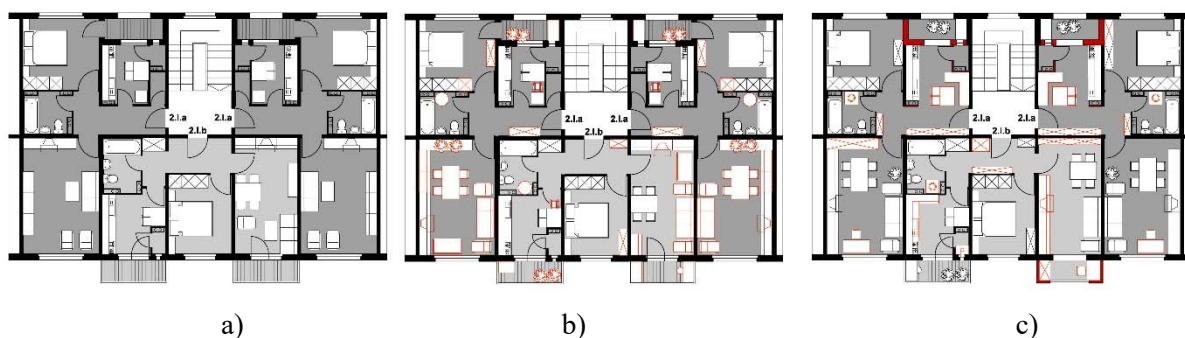


Figure 6. Evolution of the apartment throughout the years: (a) 1970s, (b) 1990s- early 2000, (c) 2014

The floor area is extended by redesigning the existing balconies of the apartments that increase the floor area and can possibly create a multifunctional space that further increases indoor comfort conditions. Users tend on a large scale to extend their apartments either by creating new balconies (the ground floor usually did not have balconies) or by extending the ones existing to convert them into storage area or by simply tearing down the walls between the room and the old balconies. Usually this happened due to the small size of the available balcony and the need to extend the living area in order to use a space that is otherwise felt as inefficient. Furthermore, having an intermediate space as buffer area can be used as a thermal regulator that can further help in improving indoor comfort conditions. This idea has been used repeatedly in traditional Romanian architecture [8].

3.2. Economic and ecological approach

Due to the significant changes in energy efficiency standards since the 1960's, these housing units are now being technically and morally out-dated. They consume large amounts of energy every day for lighting, cooling, heating and ventilation. Because they were build trough-out the entire country and in such numbers, the development of a strategy that improves their overall energy efficiency parameters would have a significant impact on the energy consumption values in the residential sector. In order to improve these parameters, the last five years marked the beginning of a governmental program which finances the thermal rehabilitation of apartment buildings using polystyrene, thus reducing the energy consumption for heating and cooling with approximately 40%. This intervention is usually done without changing the entire plumbing which, in most cases, is 30-40 years old.

Currently in Romania there are very few building rehabilitation programs for the social dwellings. Most of them are also inefficient because they only solve very few issues. The most common approach is to simply add a layer of polystyrene on the facades. This is efficient only in terms of thermal insulation and it overlooks other important aspects such social, architectural and ecological. Coating the buildings leads to stopping the airflow and causes mould and health problems for people living there. In order to get fresh air, the residents open their windows. This leads to heat loss and also negates what energy economy advantage that building might have after the interventions.

In most cities of Romania, residents are offered to accept the option of attic block of flats in exchange for benefits for thermal insulation of the building. Some people accept this offer because they can't use the upper part of the building and they are not informed, that this space could be put to better use; more than this, in Romania they don't have many information about green roofs or roof gardens. The problem with these newly-added attics is the fact that other apartments are built on top of the building. This increases the population density, it extends the existing building facilities (heating, cooling and plumbing fixtures) furthermore extra parking spaces are needed [9]. The density grows more than the existing functions and infrastructure can cover and already the existing problems are amplified. If all this is to be considered, one can say that despite having norms and technical guidelines for interventions such as over roofing as well as codes for reinforcing the buildings to withstand seismic loads, they are less strict than they should be. This tends to lead to a low quality of the end result.

Starting from the definition and concept of sustainable development, that refer to the evolution of society on all aspects, without irreversibly affecting the surrounding environment, it is ideal to balance the social, economic and ecological factors. Also one can state that today, the building sector is one of the most intensive energy consumers and buildings are one of the main economic factors that contributes to the negative impact on the environment. According to The Chartered Institute of Buildings, United Kingdom, roughly 45% of the energy used worldwide is for maintaining these buildings with 5% representing the impact of the built process. Also the electricity that is used for lighting, for HVAC systems and other technical additions that the buildings have can be seen as an indirect source of GHG and CO₂ emissions [10].

Sustainable development is an important part of the design. It needs to be considered early from the first stages and through the entire design process. Life Cycle Assessment (LCA) represents the most exact method of determining the effects of the products and processes on the environment. Furthermore, LCA is an extremely important element in retrofitting existing residential buildings, in order to ensure an improved quality of life for the inhabitants as well as energy efficiency of the building [11].

3.2.1. Building envelope

The prefabricated panels of the targeted building have a standard thickness of 27 cm and are designed from two reinforced concrete boards with an insulation layer (usually autoclaved aerated concrete) in-between as shown in figure 6. Due to the major seismic activities that can occur, safety measures had to be considered. These have led to the design and execution of connections between the panels where thermal bridges are formed. These connections between different panels as well as the concrete layers of the panel have generated solutions that meant interrupting the insulation layer. The resulting gaps within the insulation, creates areas prone to forming thermal bridges that significantly affect the behaviour of the building envelope and reduce the thermal resistance in some cases even by up to 40%. Using the online thermal simulation platform U-wert [12] the behaviour of the existing building envelope has been studied (see figure 7a). In order to run the simulations, the indoor and outdoor temperature has been considered 20°C and -5°C.

An alternative building envelope is designed to meet the passive retrofitting standards EnerPHit [13]. It is based on a ventilated façade system (see figure 7b). The idea focuses on two different types of

insulation layers. One layer is the existing insulation of the prefabricated concrete panel. The other, is wrapped around the outer shell, using a case system supported by a lightweight steel structure connected to the building through chemical anchors (see figure 7b).

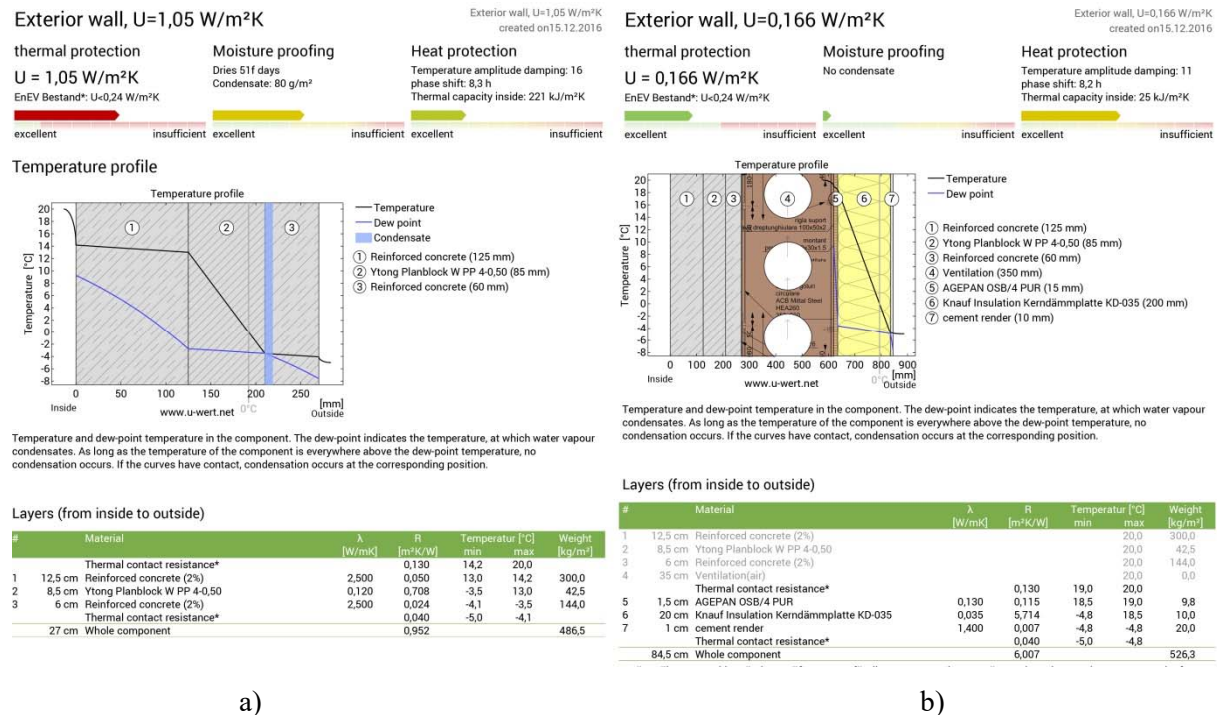


Figure 7. Existing and new building envelope

3.2.2. Upgrading the existing systems for heating, ventilation and cooling

Initially the ventilation systems were design to operate via multiple chamber extraction tubing, so that the extracted foul air from the lower floor would not contaminated the apartments from the upper levels. However this system did not work as intended. Bad building process and disregard of technical specifications have led to a single tube that due to its inefficiency was soon demolished by the apartment owners. This created the need of a new type of system and ducting channels.

The heating operation system is improved by reusing the existing District Heating System together with solar heating for domestic water. Radiant floors are responsible for the comfort conditions inside the apartments as well as a reduction in operating price and fuel consumption. Concrete blocks have high thermal inertia that can be exploited during the year. A hybrid ventilation system that mechanically provides fresh air in the apartments also ensures free cooling during intermediate seasons by activating the thermal inertia of the building walls. A new feature that currently these buildings do not have is introduced, passive adiabatic cooling. Also, by treating and reusing the rainwater as domestic water will reduce the overall water consumption. The top extensions modules are a support for a hybrid thermal and photovoltaic panel network and represent the active core of the integrated renewable energy distribution network. The modules also function as micro power plants that generate electrical energy and cover the common facilities energy yield, while the surplus is being either stored or injected into the local electricity grid (figure 8).

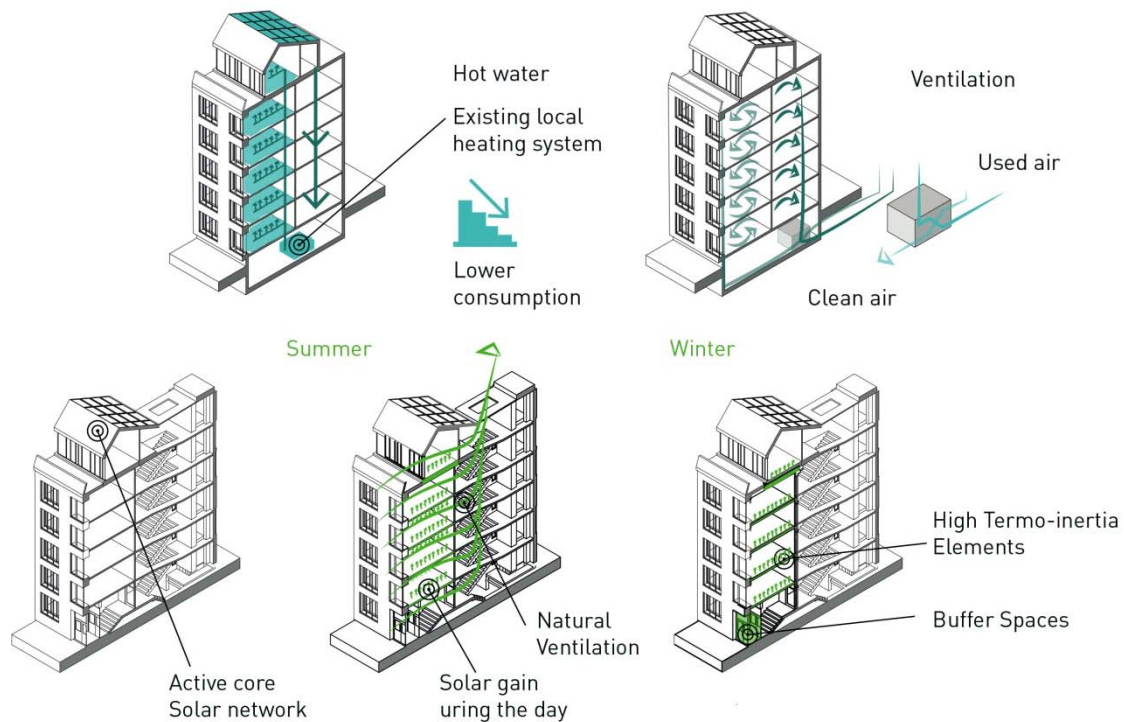
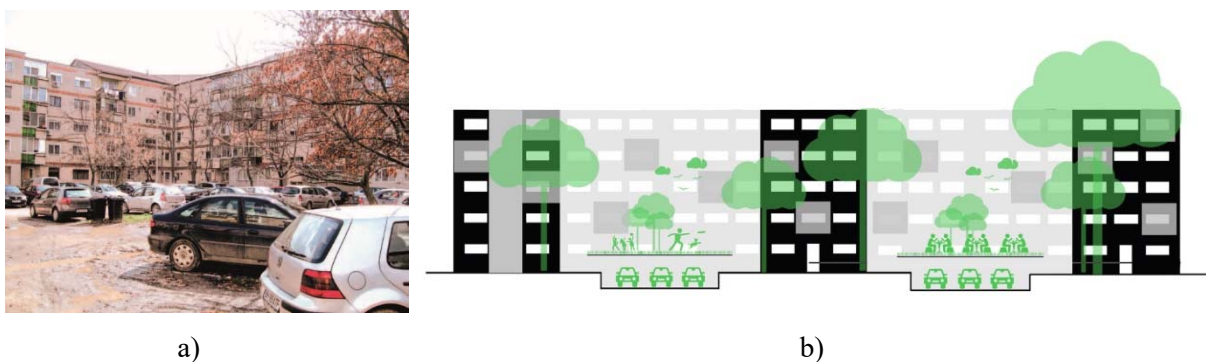


Figure 8. Building new operation system diagrams

3.2.3 Accessible green

Initially, most of these housing units were designed and arranged that an inner courtyard was formed. With the evolution of technology and ease of access, this space is now being mostly occupied by cars and concrete with little of the green areas are left (figure 9a). The project aims to increase the number of green space allocated to a person by partially place the parking lots in the underground while creating green spaces on top. Thus the once grey and negative space is transformed into a positive and healthy space.



a) b)
Figure 9. The existing inner courtyard (a) and the alternative version (b)

3.2.4. Smart grid integration

Today governments around the world recognize that the current power grids are out-dated, and must be upgraded or replaced with a more efficient, intelligent and flexible system. The existing national power grids will not disappear. They will operate more like the Internet a part of a complex web through which people will supply electricity, by uploading, as well as downloading it in so call “smart grids” (smart integration of energy production, storage and consumers) (see figure 10) [14].

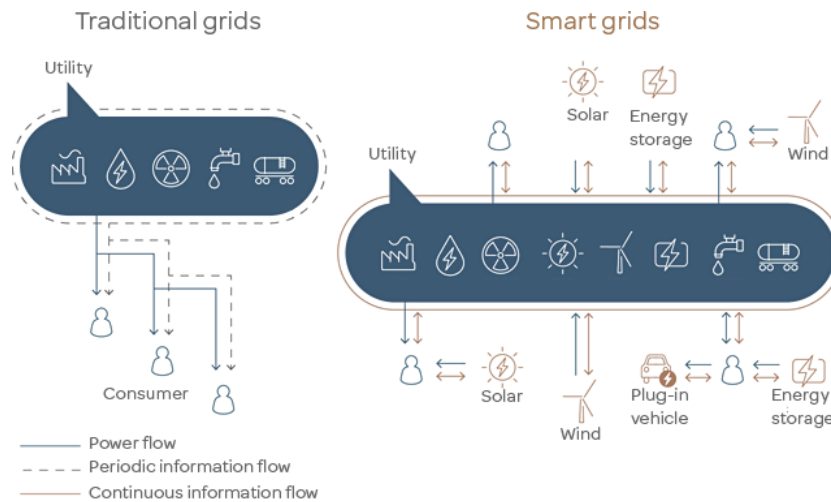


Figure 10. Smart grid operation diagram

These are digitally controlled and monitored, self-healing energy systems that can deliver electricity or gas from generation points (distributed renewable sources included), to the consumers. By optimizing power delivery and a two-way communication facilitated on the grid, the introduction of these networks enables end-user energy management. The power disruptions are minimized and only the required amount of power is transported. It results a lower cost to both the utility and the customer, more reliable power, and reduced carbon emissions [14].

Smart grid technologies can help ease the transition to sustainable electricity systems. These technologies, however, are continually evolving and improving. A flexible and thoughtful smart grid implementation strategy that balances risk and reward, coupled with openness to private sector direct investment in the electricity system, is the most promising approach [15].

4. Conclusions

Most of the collective housing stock was built in the 1970s. Even though these buildings have not yet reached their intended lifespan, they are in most aspects out-dated and do not meet the current living standards. These buildings had a major impact on the current urban space development.

One of the most important aspects on retrofitting residential buildings is the social aspect, related to the building inhabitants. They need to be well informed of the benefits that these upgrades provide as well as the downsides. Otherwise, it can lead to poorly executed and inefficient interventions that offer only temporary solutions.

Due to the fact that upgrading these housing units has become a world-wide topic for date, defining a standard and coherent adaptive design strategy will have a significant impact in improving the overall quality of life around the building and within. Life Cycle Analysis and Life Cycle Cost simulations can determine the sustainability factor of a future adaptive design strategy. Also Green Building programs can contribute in further improvement of these units.

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