> Видети енергију
> Seeing Energy

Милица Јовановић Поповић, Душан Игњатовић
Milica Jovanović Popović, Dušan Ignjatović
Monograph “Seeing Energy” is the right way to point out the issue of energy that is consumed in the buildings in which we live and work. Concept of a comparative presentation of a photograph of a building and its thermal image has shown to be an ideal and obvious tool in pointing out the fact that our buildings are significant consumers of energy, and at the same time, it has revealed many fallacies and mistakes that experts often, unconsciously, make in building design and construction. Through comparative presentations of characteristic buildings in large Serbian urban centers, like Belgrade, Novi Sad and Niš, it communicates in a straightforward manner to its readers, who after reading it, will certainly have a very different view of the world constructed around them.

Ph.D. Prof. Ana Radivojević
Faculty of Architecture, University of Belgrade

Establishment of a methodology is crucial for planning, design, production, consumption and management of energy and can be seen as a prerequisite for its rationalisation. Seen from the standpoint of consumption, design and construction of buildings and settlements, and a reconstruction for existing one is a first step towards the sustainable development of urban and rural areas. In their research, the authors developed the method how to improve the awareness for inefficient consumption of energy, answering questions regarding the adjustment of approaches and concepts in design. Now you hold the Monograph in your hand. Although, there are neither spectacular findings nor provocative proclamations, together with competent and substantial contents, we face the chance to make understandable the complexity and effect of the conditions of our buildings regarding the efficient use of energy.

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Project Manager, “Energy Efficiency”
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Seeing energy

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This monograph has only two authors; however, it would have never have come into existence had it not been for its numerous participants and contributors.

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Изложбата енергијата има само два аутора, но не може да се направи без великиот број учесници и соработници.

Оваа монографија ние ја даде велика благодарност на Наташа Џуковиќ Игњатовиќ за нејзината активна участво во создавањето на овој дел од нашата работа. Без нејзиното општество и помагање, целата работа би требало да се направи многу по-сложено.

Анита Мраовиќ и Санја Апориќ останаа непобедливи соработници, ги освојуваа изведбата на изложбата Свиђети енергија и во низа случаи вклучуваа Јасна Јовановиќ, Петар Ѓуђеѓиќ и Душан Трифуновиќ. Веќе во изработка на овој дел од монографијата, тоа ги добиваа граѓанска и материјална поддршка од Дедан Ковач, директорот на Агенцијата за енергија на градот Нови Сад.

Детален преглед на техничките карактеристики на секој од изложбите би била немислима без целиот архиварски фонд на историскиот архив на градот Ниш и Београд.

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Претходник

Већ више деценија, архитекти, па самим тим и архитектура, суочени су са потребом да се у процесу пројектовања размишља и брине и о енергији. Након интернационализације стила, након опште прихваћене идеје „мање је више“, енергетске кри- зе и екологиjsких покрета вратиле су у архитектон- ske парадигме поштовање климатских параметара, локације, транспоновање традиционалних принципа пројектовања и грађења у модерне технологије- грађења уз примену савремених материјала. Тако настала архитектура, менаћа се током времена и у зависности од доминантних опредења, среће се у литератури под називима: соларна архитектура, биоклиматска архитектура, зелена архитектура, одрживе архитектура, енергетски ефикасна архи- тектура. Завршни иновација свих ових приступа- ћа је архитектонски одговор на императив да се у објектима постигне што већа енергетска ефикасност, што подразумева смањење потребе енергије уз очување или побољшање комфора.

Колико је велика одговорност архитеката – архитекту- ре, просцењена из чињенице да се у изграђеним зградама троши око 45-50% укупно произведене енергије. Како би се смањила потреба енергије у зградама, током протеклих деценија, у развијеним европским земљама, прописи о термичкој заштити су стално поштравани, а временом је промењено и тежиште ових прописа: са утврђивања и ограничавања вредности појединачних термичких карактеристика елемената зграде прешло се на дозвољену потрошњу енергије у целој згради, а затим и на ограничавање емисије гасова стаклене баште, барање да је емисија гасова ста- клене баште директно корелација са потребом за потребом горива. Доношењем Кјото протокола Европска унија се обавезала на смањење углекислита за 8% у односу на ниво из 1990. године у периоду од 2008. до 2012. године. Како би се овај циљ остварио, предузете су бројне мере и акције у борби против углекислате емисије и енергетског ефикасног изграђивања и грађења.

Foreword

For the past several decades, architects and, consequent- ly, architecture itself, have been faced with the need to include energy considerations into the design process. After the internationalization of styles and the widely ac- cepted notion that “less is more”, energy crises and en- vironmental movements have brought back the recog- nition of climatic parameters of location to architecture, transposing traditional principles of design and building into modern building technologies with the application of contemporary materials. The resulting architecture has changed over time and has been differently named, de- pending on its primary considerations: solar architecture, bioclimatic architecture, green architecture, sustainable ar- chitecture, or energy efficient architecture. Nevertheless, all these approaches share the architectural response to the imperative of attaining the greatest possible energy ef- ficiency, which assumes reducing energy consumption while preserving or improving comfortable conditions in buildings.

The great extent of responsibility bestowed upon architects and architecture is manifested in the fact that buildings account for the consumption of roughly 45- 50% of the total energy generated. In order to reduce energy consumption in buildings, the developed European countries have tightened the regulations on thermal insulation in the past decades; besides, the focus of these regulations has shifted in time, from determining and limiting the individual thermal characteristics of particular elements in a building to restricting energy consumption allowed for the entire building so as to further limit greenhouse gas emission due to its direct correlation to fossil fuel consumption. By ratifying the Kyoto Protocol, the European Union committed itself to reducing carbon emissions by 8% as compared to 1990 levels in the period between 2008 and 2012. In order to achieve this, numerous measures and activities have been taken to reduce energy consumption in buildings. The Energy Performance of Buildings Directive came...
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Energy and its more rational use in buildings. Furthermore, there still remain issues that concern energy loss in complex systems such as buildings, structures and interrelated connections, these are invisible and abstract and therefore mostly difficult to comprehend, especially to the non-expert.

The method of thermal imaging allows for energy to be "seen" by the naked eye.

In spite of the fact, that the laws and by-laws have tended explicitly to regulate the methods for achieving energy efficiency in buildings, there still remain issues that concern energy loss in complex systems such as buildings, structures and interrelated connections, these are invisible and abstract and therefore mostly difficult to comprehend, especially to the non-expert.

The method of thermal imaging allows for energy to be "seen" by the naked eye.
The preparation and writing of this monograph, as well as the attendant exhibitions, were enabled by GTZ (Deutsche Gezellschaft für Technische Zusammenarbeit).

показује рефлексије, и обратно, што је већа емисивчаности ε се приближава нули и термограм углавном практично значи да за објекте високог степена углаизводимо да је ε= ά, односно ε+ ρ=1 или ρ=1 – ε. Ово, енергију је једнака способности да је прими, из чега ма Кирховој закону способност тела да емитује

У грађевинарству, најчешће, објекти нису провидни, а обично се чине из разних материјалних састојака, који имају разне енергије мора бити константна, тј. да је:

\[ \varepsilon + \rho + t = 1. \]

отама тела, 3-атмосфера, 4-камера

Слика 1. Шематски приказ типичног мерења: 1-окружење, 2-објекат, 3-атмосфера, 4-камера

Термовизија се базира на мерењу зрачења у оквиру температурског спектра између 8-14 μm са корисним опсегом од 2-5 μm односно 8-14 μm. Термограм шоје температуре на површини грађевинског објекта, углавном на основу апсорбције енергије и рефлексије окружења и енергије емитоване од објекта. Овај процес се илуструје на слици 1, која посебно је точна за структуре са високим температурама.

Термограм познат је као „намаца температуре“ на којој се види разлика у температури различитих делова грађевинског објекта.

**Термограм шоје температуре на површини грађевинског објекта, углавном на основу апсорбције енергије и рефлексије окружења и енергије емитоване од објекта.**
енергија се не преноси само у овим таласним дужинама, што значи, сунчева енергија се највише преноси у видимој дијапазону спектра. Према топлоти почиње у зони ултраљубичастог зрачења и простире се кроз целокупан видими и инфрачрвени спектар.

Однос кoličine zračeња у зависности од таласне дужине изказан је Планковим законом

\[ W_\lambda = \frac{2 h \nu^2}{c^2} \times \frac{e^{h \nu / k T} - 1}{\nu^5} \]

где је:
- \( W_\lambda \) = зрачење црног тела на одређену таласну дужину (W/m² µm),
- \( c \) = брзина светлости (3x108 m/s),
- \( h \) = Планков константа (6.6x10⁻34 Js),
- \( k \) = Болцманова константа (1.38x10⁻23 J/K),
- \( T \) = апсолутна температура црног тела (°K),
- \( \lambda \) = таласна дужина [µm]

Графичка илустрација ове законитости се види на слици 3 и можемо уочити да се за више температуре максимум помера ка мањим таласним дужинама. На графикону се може видети и да је за температуре које су предмет наше интересовања, максимална вредност у зони инфрачрвеног зрачења, а црвеном бојом је приказан спектрални опсег коришћене камере.

The basics of thermal imaging

Similarly to ordinary digital photography, thermal imaging is done by converting infrared radiation, which is focused on a detector through the lens and then turned into an electric intensity-dependent signal whereby a thermal image is formed.

Compared to photography, there are two basic differences:
- here imaging is done of the radiation which originates from both the building and the reflections, unlike photography, where reflections are mainly recorded (with the exception of extremely heated objects);
- the visual spectrum refers to both the color and the intensity, while infrared imaging refers to intensity only.
What does a thermal image represent? Contrary to common belief, it does not show temperature distribution but the intensity of radiation, which can have different sources as mentioned above. In buildings with higher emissivity, the image shows temperatures more realistically (there is a small percentage of reflection) and vice versa. For example, a window that is transparent in visual photography represents a reflective surface in a thermogram (like that of a mirror). That is why the so-called apparent temperature is recorded in fact, which must be compensated in the process since the image remains visually unchanged although the registered numeric parameters will differ.

To achieve adequate measurements (since thermal imaging is in fact measuring, a minimum 10°C difference in temperature must be achieved between the surfaces (internal - external) under analysis, while at the same time a stable internal temperature, i.e., negative pressure of 10-50Pa must be maintained in case infiltration is measured.

The thermal images of buildings presented in this monography were made by Thermacam B20 camera, manufactured by Flir Systems, which is a nanosized diaphragm for the measurement in a panoramic range of 7.5-13 μm and on temperatures between -15 and +50°C. It is standardised and optimised for the analysis of objects through the focal plane (focal plane array) microbolometer with a digital output of 320x240 pixels. In practice it is able to achieve at least 7680 in a single image, which is a remarkable result. Thermacam B20 camera is equipped with a digital output of 320x240 pixels. Thus subsequent software analysis (by Thermacam Reporter) yields information on each of the 7680 output pixels regarding the obtained values and enables the use of special analytical tools (marked points, regions, isotherms etc.) for their comparison.
Seeing Energy – Architecture and Thermo-vision

Missing insulation seen from inside, significantly warmer part of the wall severe energy loss.

Missing insulation seen from inside, significantly colder part of the wall severe energy loss.

Definition of structural elements of façade walls and inspection for damages. Building with wooden construction.

Definition of structural elements of façade walls and inspection for damages. Building with panel façade.

Air leakage through façade due to the low quality of wall construction.

Air leakage through balcony door, losses for almost 50% of energy needed for heating.

Leakage of flat roof construction. Clearly visible zone of wet insulation enables efficient and fast repair.

Localizing and visualizing of the floor heating pipes.

Leaking from the heating system and water entering the wall, clearly visible wet zones and position of leakage.

Moisture intrusion due to the lack of adequate hydro-insulation.

Detection of loose contacts within home electrical network resulting in temperature increase usually causing fire.

Detection of blockages as well as leakages of pipes hidden within the construction.

Leakage of water entering the wall, clearly visible wet zones and position of leakage.

Defining structural elements of façade walls and inspection for damages. Building with wooden construction.
Belgrade

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Републичка скупштина

Трг Николе Пашића 13, Јован Илкић, 1906-1936.

Зграда Републичке скупштине, грађена више деценија, према првобитном пројекту архитекте Јована Илкића, својим монументалном изгледу у духу стила касне ренесансе, као да представља официјалну функцију у време у коме је грађена. Објекат је комплетан приликом склопа, архитектонским стилом и значајем своје друштвене функције, као што се види из неколико приказа и анимација на овој страни.

The House of the National Assembly

13 Nikole Pašića Square, Jovan Ilkić, 1906-1936.

The building of the National Assembly, which was under construction for several decades, was originally designed by the architect Jovan Ilkić. Its Late Renaissance monumentality and the importance of its social function, seems to symbolize the prevailing spirit of the age in which it was built. The building was envisioned as a free-standing structure immersed in greenery, featuring complex plan with a basement, ground level and two floors. Its central part is emphasized by approach ramps, a dominant staircase and a portico with a triangular tympanum and four smaller decorative domes, among which the great central dome rises. Two wings reach out from the central corps, each with an overhang, an emphasized roof cornice, and an attic under a smaller dome.

This building stands out as one of the most important architectural monuments in Belgrade.
The building was constructed with load bearing masonry walls. The facade has no thermal insulation and is finished with cast stone layer. The Neo Renaissance and Neo Baroque forms with their corresponding decorative elements have a special place in the elaborately embelished frontispiece.

The thermographic image of the building reveals different types of thermal loses that vary depending on the material, wall thickness and construction detailing. The most noticeable are the loses at the windows, showing that, at the time when the old casings were replaced, the opportunity was missed to improve the thermal characteristics of the building significantly by using high-quality tightly fitting window systems.
- Детаљнији снимак показује разлике стењашке температуре зида. Температуре су приметно ниже на деловима где се налазе пиластри и други елементи пластике, где је дебљина зида двоструко већа од основе. Наставак томе, јасно се види и разлика у температура зида на деловима где се налазе парапети и друге поља где је дебљина зида (испуне) мања.

- Губици око прозора су посебно изражени на попу- кружним сегментима, где је очигледно већа разлика између температура око прозора и температура зида.

- Детаљ фасаде са прозорима јасно показује разлику у температуре у зависности од режима коришћења просторија (нпр. прозор горе десно), као и колико је значајно искључивање свих уређаја када нису у функцији. На истом примеру види се и да недовољна утврђења може имати за последицу директну губитак топлоте - спољашња температура зида на „критичном” месту у темену лука је 17.3°C, што је једва неколико степени мање од температуре унутрашњег простора.

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- The more detailed image shows different outdoor temper- atures of the walls; they are notably lower in the parts where there are pilasters and other decorative elements and the walls are twice as thick as the main wall. By contrast, the parapets and the other areas where the wall is not as thick are clearly defined in thermographic image.

- The losses around the windows are especially evident at the semicircular segments, where there is obviously a greater discrepancy between the geometry of the window casings and the wall openings.

- The detail of the façade with windows clearly shows the difference in thermal performances, depending on how the space is used (e.g., the top right window), as well as how important it is that all electric devices are disconnected when not used. The same example indicates that inadequate installation can cause direct heat loss – the outdoor temperature of the wall in the critical place in the arch vertex is 17.3°C, which is only several degrees lower than the temperature inside the room itself.

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The building was constructed with load bearing masonry walls, with the façade walls made of 38 cm thick brick and mortar cladding, with no thermal insulation. The double windows are wooden (in wide casing) with the division characteristic of the 1930s residential buildings; they have not been replaced since their original installation. The effect of the recessing ground floor was achieved by a slight cantilevered overhanging of the residential floors and by minimizing the massive appearance of the ground level with large glass surfaces.

The thermographic image reveals the structure of the façade, equally visible in parts where the original renderings were preserved, as well as in parts that have “bared” in time. The concrete elements - lintels and spandrel beams - have poorer thermal performance compared to the brick segments. The corner shop on the ground level was not used during the audit, which is evident in both the daytime image and in the thermogram, where the camera detected a significantly less heat loses than at the neighboring shops.
- A histogram from the thermal image shows that temperatures between 2 and 8°C were detected on the facade; the highest values were at the concrete lintels and the lowest at the loggias, where there was actually no direct transmission from the heated interior.

- The installation of windows into the openings, fitted with window reveals, reduces heat waste per window perimeter, while the brick columns on the corner windows help better adjustment between the geometry of the casing with the curve of the facade wall. Significant heat loss results from the non-insulated facade wall.

- The Albanija Palace
  4-6 Knez Mihailova Street, Branko Bon, Miladin Prljević, 1938-1939.
  Located on the crest of Terazije, it represents the starting point of the main city axis. The building was named after a tavern (kafana) that used to be in its place. With the height of 53 m and its 13 above-ground and 4 below-ground levels, it was once the tallest building in the Balkans. It was designed in the international style of Modernism of the 1930s, with facades in marble cladding.
With respect to construction and technology, it represents a significant achievement of contemporary Serbian architecture. With its gentle convex shape, a free ground level with shops and the first floor with a border which visually underlines the base of the building, combined with its prominent tall vertical volume rising from the lower side wings, this building accentuates Terazije spatially and is one of Belgrade's signature landmarks.

As a whole, the building displays greatest heat losses at the windows and glazed surfaces. There was a noticeable difference between the ground floor shops with strong lighting and the spaces on the floors above, which were not used at the time when the thermal images were taken.
- The windows, that were not closed properly, are emphasized, and there is an obvious, systemic, problem in the upper zone of the window openings. In fact, the camera registered room temperature (25°C) at an open window; the windows with lowered blinds show fairly realistic temperatures; while a reflection of the night sky was registered at certain windows so that the thermogram shows them as cold (completely dark).

- Due to the skeleton design, the pilasters (border columns) show better thermal properties than the parapets, which logically ensues from greater thickness and thermal mass in those parts of the façade. Poor sealing in some windows causes notable heat losses.

- Originally housing the Presidency of the FPR Yugoslavia and from 1961 the Federal Executive Council (Savezno izvršno veće – SIV), the building was opened to host the First Non-Aligned Movement Summit in 1961.

The Srbija (former SIV) Palace

Originally designed as a monumental, free-standing composition, based on a clean modern neoclassical architectural arrangement. The H-shaped ground floor plan of the palace is symmetrical with the central corps and two side wings, and takes up an area of 5000 square meters. In front of the central wing, there is a lower glass-domed section housing a grand conference hall that accommodates 2000 guests. The building has six reception rooms and around 1000 administrative offices.
Зграда СИВ-а је рађена као армиранобетонска ске- летна конструкција, са испуном од опеке. Фасада је обложена белом брачком мермером, а употребом алюминијумских прозора, са профилима бојеним у бело постигнут је савремени архитектонски израз фа- садног платна.

The SIV Palace is a skeleton construction built in rein- forced concrete with brick walls. Brač white marble cladin- ding and the white aluminium windows lend them- selves to creating a modern architectonic expression of the façade.

Термовизијски снимак палате „Србија“ открива нави- ке од оштега слабих енергетских особина, карак- теристичних за објекте модернизма: велики део фаса- де је, заправо, у стаклу, и ту се исказују велики губици, нед су у питању технологије коришћене средином прошлог века. Атрактивно архитектонско решење има, нажалост, веома велику површину фасаде у от- носу на волумен који затвара, што додатно увећава топлотне губитке на нивоу читавог објекта и умањује комфор у његовој унутрашњости.

The thermal image of the Serbia Palace reveals some of the aspects of poor energy performances typical of Mod- ernist architecture: a large section of the façade is glazed, and this is where great thermal losses are detected re- garding the technologies used in the middle of the last century. However attractive, the architectural solution has a much larger façade surface relative to the volume it covers, which additionally increases heat loss of the entire building and thereby compromises the thermal comfort in its interior.
На термовизијском снимку калкана јасно се уочава структура зида (стубови и греде) која се, иначе, не може видети голим оком због униформне камене облоге. Бетон је бољи проводник топлоте од зидане испуне, па се, самим тим, бетонски елементи издвајају нешто вишим регистрованим температурама.

Снимак убедљиво илуструје и разлику у топлотним губицима између пуног платна (лево) и фасадног платна са великим бројем отвора (десно).

Велики линијски губици око густо постављених прозора указују нам на значај правилног избора профила и застакљења, као и добро промишљених и уградених детаља столарије, тј. браварије у оваквим ситуацијама кад се највећи део енергије “губи” кроз прозорске отворе.

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Стамбена зграда у Блоку 7а - „Павиљони”

Снимак на термовизијском снимку уочава структуру зида (стубови и греде) која се, иначе, не може видети голим оком због униформне камене облоге. Бетон је бољи проводник топлоте од зидане испуне, па се, самим тим, бетонски елементи издвајају нешто вишим регистрованим температурама.

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The building was constructed as a masonry structure with 25 and 38cm brick walls; technologically, it was based on pre-war building practice (master builders provided on-site training to a multitude of unqualified workers). There is no thermal insulation in the structure of the plastered brick façade since in those days there were no regulations regarding such issues. The double wooden windows were built as individual openings in standardized sizes.

In such structures, where loggias were formed by projecting the slabs, there is significant thermal loss in the zones where reinforced concrete slab penetrate the façade wall, so that the heat is transmitted from the interior part to the exterior. In a sense, the open loggia is partially heated together with the room, however inadvertently. Like in all other non-insulated buildings, the concrete sections are easily recognizable in the thermo-gram – they are warmer than the brick.

Код објеката попут овог, где су лође формиране препуштањем таванице, јављају се значајни термички губици у зонама где армирано-бетонске таванице плоче «пробијају» фасадни зид, те се топлота прено-си са унутрашњег, загрејаног дела таванице на њен спољашњи део, па се може рећи да, када грејемо собу, једном делом, непољне грејамо и терасу. Као и код осталих неизолованих зиданих зграда, на термовизијском снимку се јасно препознају бетонски делови - топлији од зидавка.
- The façade detail shows how much energy is wasted in the slab projections (loggias), around the openings and through the corresponding woodwork with poor thermal efficiency. Compared to concrete elements, the masonary walls display better thermal properties even without thermal insulation.

- The dark area represents a segment of the façade which has been additionally insulated from the outside by a tenant on his or her own accord. The thermal image reveals the obvious effect of the thermal insulation on the amount of energy thus preserved.

- Тамни део представља сегмент фасаде који је ста- нар, самопроизвођачки изоловао са спољашње стране. На овом термовизијском снимку очигледан је ефекат термоизолације на количину енергије која остала сачувана у стану.

A Residential building
19 Gospodar Jovanova Street

A residential four-storey building on the corner of the streets of Gospodar Jovanova and Cara Uroša is representative of post-war downtown construction, whose purpose was to fill out the urban matrix and to consolidate the urban tissue damaged in the war. Even though it was built with modest means, this building carries some elements of modern city architecture, with its recessed ground floor, the central volume projecting over the corner, and the corpus destressed by opening loggias.
The building was constructed as a masonry structure, with a cantilevered overhanging towards Gospodar Jovanova St and two bays leaning on the free columns at the ground level towards Cara Uroša St. The façade walls were made of plastered brick. The wooden standard-sized triple-pane casement windows have wooden roller shutters – like in most Belgrade residential buildings from this period. The loggias were formed by the façade recessing into the plane of the basic volume.

The thermogram reveals very poor thermal performance of the thin masonry parapets. As it is in the parapet zone that the radiators are placed, the effect of heating the façade is even more significant. The weathered original woodwork and non insulated rolling shutter boxes result in excessive heat loss in the upper window zones. At the loggias, the temperature of the concrete slabs is practically the same as at the concrete lintels, so it is obvious how much energy is lost to the surroundings through these elements.
More detailed images show clearer distinctions between the thermal performances of the various materials used on the same façade: the thinner parapets below the windows release much more energy than thick solid walls; the reinforced concrete elements are distinct for surface temperatures, which are on average 5-6°C higher than the brickwork.

At the windows, the greatest losses appear at the contact between the window reveal and the shutter, where temperatures higher than 15°C were registered, which is an indication of a weak spot; weathered woodwork combined with dry roller shutter boxes provide no sealing in the upper zone of the window opening.

The six residential towers, popularly known as the “Six Corporals”, have been listed as important works of the post-war architecture in New Belgrade, their design congruous with, at the time, ideologically prominent principles of functionalism. According to the planning solution for Block 21, a group of towers (GF+16Fs+L) was rotated at a 45° angle to the street matrix. Following the investor demands, the towers numbered 2, 4 and 6 were designed to accommodate only four-room apartments. The ground levels provided dedicated space for maintenance and repair services, and smaller retail premises. Each tower contains a janitor’s apartment, a laundry room, and 64 four-room apartments.
The building’s structures of reinforced concrete frame, founded on a 1m reinforced-concrete mat, with prefabricated load-bearing ceilings. The façade walls were made of grouted brick or clay blocks with no thermal insulation, and were cladded in 2x2cm ceramic mosaic tiles, while the loggia walls were rendered in Terranova plaster.

Window ribbons, which stretch through five bays, show the greatest heat loss in the thermal image of this residential tower. In the apartments, especially in the rooms where the windows stretch along the entire wall, heat efficiency mostly depends on the quality of the woodwork and its proper installation. The solid wall surfaces unmistakably display the reinforced concrete elements: the ceiling slabs, the ring beams, the columns etc. The advertising canvases have no effect on the thermal performance of the walls and were not detected by the thermographic camera while it did register the heat from the neon signs on the roof.
- The details from a building with smaller apartments and individual windows also reveal extensive thermal loss at the visible concrete elements, and the temperatures are by approximately 5°C higher than at solid walls. The thinner façade walls could no longer accommodate window reveals so that linear losses are noticeable around the window openings; there are considerable temperature differences between the zones next to the openings (5-7°C) and the lower parts of the parapet (0.4°C, in the bottom image).

Культурни центар „Дом Омладине”
Македонска 22-24, 
Зоран Тасић, Драган Филиповић, 1964.

Зграда Дома омладине налази се на углу Улица Дечанске и Македонске, у непосредној близини Трга Републике. Оквирно се састоји од пословне куле, повукануте у односу на уличне регулације, и анекса са двораном, галеријским и угоститељским просторима. Модерна израз објекта наглашен је, осим урбанистички, и материјализацијом – једном од првих примена фасадног система типа „зид завеса” код нас. Оригинална фасада задржана је на кули док је анекс реконструисан.

The building of the Youth Culture Center is located at the corner of Dečanska and Makedonska Streets, in the vicinity of Republic Square. It houses an office tower, which is withdrawn further from the street zone, and an annex accommodating an auditorium, galleries and cafe. Its modern expression is highlighted by both its urban and material solutions – one of our country’s first applications of the curtain wall façade system was used here. The original façade has been retained in the tower while the annex has been reconstructed.
Својим једноставним конструктивним решењем, армираним бетонским скелетним системом, и стакленом фасадом, издваја се из непосредног окружења.

Реконструкцијом објекта 2007. године на делу анекса, уведен је нови фасадни систем, који чини комбинација алукобонд плоча и „зид завесе“.

With its simple solution of a reinforced concrete skeleton system and a glass façade, the building stands out in its immediate surroundings. The reconstruction of 2007 introduced a new façade system to a part of the annex, featuring a combination of alucobond panels and the curtain wall.

На објектима, попут Дома омладине, није једноставно добити реалистичан термовизијски снимак, пошто је велики утицај рефлексија, што је нарочито уочљиво на вишим етажама. Тако, прозори нереално приказују далеку низку температуру од парапета као последица рефлектовања температуре окружења (атмосфере). На парапетима степен рефлексије је знатно мањи, а сами прозори чине вредности температуре много реалније. На анексу, уочавају се мања топлотна зрачења, што показује да су реконструкцијом побољшане и термичке перформансе овог објекта.

For the buildings such as the Youth Culture Center, it is not easy to obtain a realistic thermogram due to a high impact of reflections, which is particularly evident on the higher floors. Thus, as a consequence of the temperature reflection from the environment (the atmosphere), the windows show a much lower temperature than the parapets, which is unrealistic. However, the degree of reflection is much lower at the parapets and thereby the detected values are much more feasible. The annex had lower heat emissions, which shows that the reconstruction has improved the thermal performance of the structure.
A detailed inspection of the tower façade gives away not only the parapets with poorer insulation, but also the position of the opened or improperly closed windows and the heat loss at the façade surrounding them.

The materialization of the reconstructed annex with the entrance hall meets the current requirements of thermal regulation; however, heat losses are still noticeable on the large glazed surfaces. The thermogram of the main hall shows how the interior lighting heats the surrounding surfaces.
Both buildings have a reinforced concrete skeleton structure. The unique foundation system of the office tower made it possible to straighten the building after it had been repeatedly struck in the air raids. The curtain wall façade had to be completely replaced during the reconstruction, when also a multifunctional area was added on the roof. By contrast, the façade of the shopping mall was made of clay block, with thermal insulation and a finishing in multicolored alucobond panels on a metal substructure.

Thermal imaging at a greater distance recorded only the contours of the office tower and the shopping mall, with a few thermal accents revealing the positions of neon advertisements and decorative lighting. Such an image was obtained by the superimposition of several significant factors: at greater distances the camera, purposely designed for capturing architectural structures, has difficulty compensating for the reflections from low-emissive surfaces such as the curtain wall of the office tower; moreover, the shopping mall cladding is offset from the main wall (in some places more than 50cm) and heat radiation has been significantly reduced considering the fact that contemporary technical solutions were applied in the materialization of the thermal envelope.
The thermogram of the tower top end reveals the position of the uninhabited service space (the “cold” ring above the 23rd floor), and shows a different system of the curtain wall applied to the 24th and 25th floors, which has better performances compared to the standard floors owing to advanced technical solutions. Although the graphic representation is contrasting, the detected temperatures range from around 0°C, which points to efficient thermal insulation.

On the mall façade, as explained above, the shopping mall façade cannot render a successful analysis of its thermal properties; however, a range of temperatures from different sources of lighting can be distinctly observed: the neon signs (topmost), a lit billboard (top left), vertical neon lights (middle left), etc. The only position related to the architectural solution in which heat radiation can be observed is the skirting towards the unheated underground garage (bottom).

The Beograd Palace – Beograđanka

Located in the old city matrix, the Beograd Palace was the first high-rise building erected in the historic downtown. Its position, height and materialization render it a unique Belgrade’s landmark, whose dark silhouette dominates the cityscape. The structure is composed of two basic volumes: the lower base and the upper tower. The former blends in the surrounding elevations, while the latter creates a strong vertical accent with its 24 floors. Half of the total area of 40,000 m² is dedicated to commercial purposes and holds a number of retail premises, a department store with accompanying facilities, restaurants, open terraces and the observation deck; the remaining half is occupied by offices.
The structure system is 9m span skeleton reinforced concrete with beams in both directions. The curtain wall façade features dark anodized aluminium construction elements, double smoky grey thermopane glass panels and a glass and honeycomb Porophene parapet sandwich. The external Venetian shutters are electrically operated.

„Зид-завеса“ се на термограмском снимку види као рит- намно низање међуправних таваница и етажа, али на њим овај графички приказ открива и низ других аспеката битисања једног од најпрепознатљивијих београдских објеката. Топлотно зрачење у зони таване на четвртом спрату је резултат недовољно изоловане кровне терасе, а просторије “Студија B” на последњим етажама су топлије због природе активности радио станице и ТВ студија који се ту налазе. Према Масариковој улици, тераса видиковца на последњем спрату, као и тераса на петом спрату, у термичком смислу се понашају на исти начин.

The curtain wall is displayed as a rhythmic series of floors in the thermogram, which also gives insight into a number of other aspects of existence of one of the most recognizable Belgrade’s buildings. The heat radiation in the ceiling zone above the fourth floor results from an inadequately insulated roof terrace, while the premises of the radio and TV broadcaster “Studio B” that occupy the top floors are warmer due to the nature of their activities. Similar thermal behavior was observed at the top floor observation deck at the section overlooking Masarikova St.
More detailed images indicate the positions with the poorest thermal performance. A spacious roof terrace over the entire base was formed on the fifth floor where the tower joins its base, there is a recessed terrace in the section overlooking Masarikova St. In an attempt to achieve absolute continuity of the curtain wall (the design incorporated the terrace fence into the façade cladding), a problematic detail appeared at the contact with the ceiling. Thus very high temperatures – as high as 19°C – were registered at the façade (bottom). Heat distribution is such that the roof terrace fence emits an even higher value than the parapets on the lower floors.

- Детаљнији снимци указују на позиције са најслабијим термичким карактеристикама. На делу где се кула спаја са својим постаментом, на петом спрату, формирана је велика кровна тераса изнад целог постамента и, повучена тераса, на делу према Масариковој улици. У тежњи да се оствари потпуни континуитет “зид-завесе” (ограда терасе је формирана као интегрални део фасадне облоге) остварен је проблематичан детаљ на споју са таваницом, па се на фасади очитавају веома високе температуре, чак до 19°C (доле). Дистрибуција топлоте је таква да ограда кровне терасе показује чак и већу вредност од парапета на нижим спратовима.

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A residential building in Block 28 – The Televizorka
96-118 Milutina Milankovica Street, Ilija Arnautović, 1971.

The two linear 10-storey structures 270m in length are popularly known as the Televizorke (TV Buildings) named after the characteristic window trims reminiscent of the TV screen. The structure housing over 500 apartments of diverse structures, is characterized by a playful façade formed by a combination of only a few panel types.
The construction was built as a prefabricated skeleton reinforced concrete 4.20 x 4.20 m span system. The façade walls consist of prefabricated façade panels with a washed pebble washing and the recognizable concrete window trimming.

The iconic structure of New Belgrade residential architecture from the beginning of the 1970s scintillates with life in infrared light as well. A motley of the tenants' ingenious interventions in the form of glazed loggias, self-mounted roller shutters, extensions on the flat roof, etc. has had a considerable impact on both the exterior appearance and the thermal performances of the building.
- У уоквиреном пољу детектују се температуре од 0 до 8°C, док су око прозора измерене температуре веће од 15°C, као последица лошег стања прозора и неадекватне уградње.

- In the framed section, temperatures between 0 and 8°C were detected, whereas they were above 15°C around the windows as a result of their poor condition and mounting.

- Снимак типичног фасадног панела показује уравнену структуру фасадног зида, са губицама који се опажају на спојницима између панела, али су релативно мали за префабриковану градњу тог времена. На овом детаљу може се видети како емитована топлота загрева и карактеристичне "рамове" око прозора.

- The thermogram of a typical façade panel shows an evenly structured façade wall with evident losses at the panel connections, which are still relatively small for the 70’s prefabricated construction. This detail shows how the thermal leaks heat the characteristic window trims.

Стамбена зграда у Блоку 28
Булевар уметности 37, Илија Арнаутовић, 1971.
Објекат у блоку 28 налази се у непосредној близини "Телевизорке". Карактеристика ове седамнаесто-спратнице је ликовна једноставност фасаде објекта релативно разуђене основе. Фасада је изведена коришћењем малог броја типова фасадних панела са карактеристичним детаљем сакривених прозорских оквира.

A residential building in Block 28
The building is located in Block 28, in the vicinity to the TV tower. This seventeen-storey building is characterized by minimalistic detailing on the façade, which was formed by a combination of a few panel types, and features the characteristic motive of hidden window cases.
Конструкција објекта изведена је као префабрикован- ни панелни армиранобетонски систем. Фасадни зидови се састоје од префабрикованих бетонских фасадних панела са завршном обрадом у натур бетону или ломљеном кулију.

The building construction was carried out as a prefabricated panel reinforced concrete system. The façade panels were done in exposed concrete or crushed pebble finishing.

Термовизијски снимак показује знатно веће топлотне губитке на фасадним платнима са прозорима и вертикалним логијама са пољама, него на пуном бочном зиду. На пуним платнима показују се мани префабрикованог система у којем је изграђен овај солитер спојем између фасадних панела, посебно хоризонталне спојнице у нивоу са межуспратном конструкцијом, нису изоловане и емитују у окружење велике количине топлотне енергије.

The thermal image detects considerably higher heat losses at the façades with windows and loggias than at the solid side walls. On the other hand, these display the drawbacks of the prefabricated system used in this tower block: the connections between the façade panels, especially those that are in level with the floor, were not insulated and therefore release vast amounts of thermal energy into the environment.

Seeing Energy – Belgrade
A more detailed presentation of the building reveals the structure of the concrete façade panels whose thermal performance is in places almost as poor as that of the windows. Excessive radiation renders almost impossible identification of the windows as distinct from the solid wall surfaces.

Although the standard façade panels contain a thermo-insulating layer, it is not continuous due to the manufacturing and mounting technology. There is almost no thermal insulation at the interior corner connection between the panels. The lower window is ajar, while the window above it cannot close properly so considerable thermal energy is lost to the environment.

The Genex Tower (The Western City Gate) rises next to the highway which cuts through New Belgrade. The building complex is one of the most original pieces of Serbian architecture and it is the best known design by the architect Mihailo Mitrović. The Gate comprises two concrete towers, an apartment and an office block; they are of uneven height and connected by a two-storey bridge, which lends a striking note to the whole composition. The taller tower is residential, while the other is owned by the Genex Group. There is a round revolving restaurant/observation deck at the top of the business tower.
With its form as well as the qualities of its structure and construction, the Genex Tower is a recognizable architectonic symbol – a gate at the Western entrance to Belgrade. The bold and attractive construction with a unique reinforced concrete skeleton is resolved by an arched motive in the ground contact zone; it is a solution that clears the ground floor by reducing the façade columns to two massive supporting pillars.

Taken at a relatively large distance for this type of measurement, the thermal image yields a general view of the Western City Gate; the rendition of the reinforced concrete elements is more correct, while the window panes reflect the temperature of the sky. The thermogram gives a more realistic image of the relations between the glass and concrete components positioned behind the large advertisement since canvas is fairly successful at eliminating the reflection effect in low-emission materials such as glass.
- At a closer distance, this building shows equally problematic thermal behavior as other skeleton structures with prefabricated concrete façade components: heat is lost through horizontal and vertical panel connections, thermal insulation deteriorates along the panel edges, the roller shutter boxes were not adequately insulated etc. The exposed horizontal construction surfaces are poorly insulated and cause losses, which may be negligible with respect to the whole building but they significantly reduce the thermal comfort in the residential and office units.

- Свица најчешће из веће близине, показују да и овој објект испукава, у попрсности термичких перформанси, сличне проблеме као и остале скелетне зграде са префабрикованим бетонским фасадним компонентама. Топлота се губи кроз хоризонталне и вертикалне спојне чиниле, термоизолација пропада по ободу панела, кутија за ролету није адекватно изолована и сл. Хоризонталне површине конструкције у контакту са спољашњом средином, слабо су изоловане и узрокују губитке, који су могуће значајно умањити термички комфорт у припадајућим стамбеним и пословним единицама.
The construction of the building is a reinforced concrete skeletal system with brick paneling. The buildings are characterized by clay block façades with horizontal concrete ring beams visible at the floor zones, and by horizontal ribbons formed by alternating window assemblies and prefabricated concrete parapets clad in white mosaic tiles.

Even at a greater distance, the thermal image of the building reveals almost the entire structure of the façade envelope, which indicates poor thermal insulation. Different types of materialization lead to different temperature values, thus forming a specific image of this New Belgrade high rise.
Vast gaps between the window frames and the parapets cause linear losses; besides, permanent deterioration of the thermal insulation in the parapets adds to thermal loss. In the thermogram, the parapet ribbons on the right seem ‘cold’; however, there are unheated glazed loggias behind them so that there is no heat transmission to detect.

The clay block mortar joints are clearly outlined on the wall face, which results from the differences in heat conductivity of the blocks and the joining mortar. The horizontal concrete ring beams show the highest temperature since concrete is the best heat conductor of all the materials in the recorded detail. Therefore, some heat accumulated in the concrete floor construction is radiated onto the façade.

A residential building in Block 29
115 Bulevar AVNOJ-a,

The recognizable two wing buildings of the GF+6+L floor structure were built in the IMS 3.60 x 4.20m span prefabricated skeleton system. Joining the two wings, the staircase is connected to four apartments at each floor, with access via a common vestibule serving two by two apartments. Owing to the design, all apartments feature two-sided orientation, or three-sided at the corners, which provides optimal conditions for ventilation and insulation. The ground floor is also residential, with central intermissions that enable transverse connectivity within the entire project. The basement area of the whole building holds garages and storage rooms.
All elements on the longer façades are clad in ceramic and glass mosaic in ivory color. External side façades are built of prefabricated concrete elements with ribbed vertical outer surface. The ground floors, the lofts and the parapets on the side façades were done in facing brick.

One of the characteristics of the constructive system applied here is that the bearing elements – columns and beams – remain hidden behind the façade panels so that the thermogram reveals the connections and the geometry of the façade cladding, while the main construction practically has no influence on the thermal image of the building. The double lines of heat permeation at the floors indicate that the façade panels end with a horizontal slot so that one line accounts for the external connection and the other indicates where the panels are connected on the inside.
- Despite the building showing all thermal problems of its prefabrication type, the surface temperature values registered on the façade are still lower than at similar structures of only several years older. Namely, the implementation of the first regulations covering thermal protection started in 1967 and 1970, thereby affecting thermal insulation in the period buildings.

- A more detailed image of the façade segment shows the internal structure of the façade panel, similarly to the tower block in Block 28 (p. 63). Since the panel is borne by the primary construction, the sealing of the horizontal connection is minimal due to the specific technological solution therefore, excessive linear losses are detected.

- The building of the health care center was designed as a complex consisting of the ground floor base and a four-storey wing. It accommodates units for general medical care, infant and schoolchildren care, women medical care, and a series of specialist medical services. The organization of the complex and the access to the building as well as the motor and pedestrian traffic network were all carefully designed so as to avoid various user groups intersecting. With the surface area of 7,100m², the center was planned to provide primary health care to approximately 80-90 thousand citizens at the time of construction.
The construction of this building was carried out as a prefabricated skeleton reinforced concrete system. The façade walls consist of prefabricated façade panels with the horizontal sliding windows with thermally insulated panes and external Venetian blinds as shading devices.

Seen as a whole, the building displays clearly different thermal behavior at the glazed surfaces and the solid façade panels. The application of the advanced technological solutions has resulted in thermal performances that surpass the standards and the common practice of the 1970s.
- The façade panels show relatively good thermo-insulating properties, with low surface temperatures similar to that of the air. Higher heat radiation can be noticed at a basement segment, especially in contact with the ground.

- Placing thermal insulation on the interior of the façade wall reduced an amount of heat loss characteristic of prefabricated façade cladding. However, reduced thickness in the zones of connection between horizontal and vertical construction elements are evident in this image. In the basement, there are no panels; instead, there are fillings between the columns and the linear losses are noticeably higher than at the ground floor zone.

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A residential building in Block 30

The four storey residential buildings in Block 30 are placed in a staggered formation on a common plateau above the garage. The building features prefabricated façade panels in exposed concrete molding, with ground floor clad in facing brick. The loft is recessed, forming vast roof terraces, with a prefabricated panel fence-cornice.

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The construction is a 5.80x6.00m span reinforced concrete skeleton system with the core around the vertical communication node. The facade walls are made of prefabricated concrete elements in exposed concrete molding while the parapets have smooth white surfaces. The window assemblies are wooden with Esslinger roller shutters.

The thermal image of the building shows the entire facade panel structure and geometry, revealing thermal bridges at the horizontal and vertical, external and internal connections. The applied facade panel system reveals a particularly weak point at the internal corner, where the registered temperatures indicate excessively poor joints detailing.
Linear losses deriving from the flaws in the applied façade system also can be identified through the temperatures measured at different positions: -0.7°C at the solid wall (the central section of the façade panel); +3.6°C at the panel in the connection zone between the column and the beam, and +10.8°C along the panel edge at the internal corner.

The side panel of the overhang is of somewhat different structure compared to the larger panels that cover the entire construction grid, and thus has relatively poorer thermal performances.

The Inex Office Tower
3 Kraljice Marije Street, Uroš Martinović, 1985.

The Inex-Interexport building, designed as an office tower, is a part of the Municipality of Pakluka Center complex, which consists of a number of multi-purpose buildings organized in a single architectonic ensemble. The specific layout of the complex is separated into two blocks by Starine Novaka Street. The office tower, the annex with the Postal Savings Bank and the city administration centre are connected by a system of underground passages. The thoughtful design of the ground area with de-levelled piazzetas is unique in Belgrade.

Пословна зграда „Инекс”

Зграда „Инекс - интерекспорта”, пројектована као по-словна кула, представља део комплекса центра општине Палилула који се састоји од већег броја објеката различитих намена организованих у јединствену архитектонско-урбанистичку целину. Специфичност комплекса је његова диспозиција која се простире на два блока, раздвојена улицом Starine Nouaka. Високи пословни објекат, анекс салоштанком штедионаком и објекат градске управе, повезани су подземним путевима, а партерно уређење је пажљиво пројектовано са де-левелираним грацетима и јединствено је у Београду.
The façade of the complex was clad in white profiled aluminium parapets and continuous window assemblies. The external façade features a grid of vertical aluminium profiles and horizontal brise-soleils. The thermo-technical installation system was used as an element of resolving the appearance of the façade by forming strong angular motives.

The building displays excessive heat losses, primarily through the glazed surfaces. The system of parapet cladding leaves ample space for thermal bridges, and reflection and indirect heating around the window assemblies visually expand the “warm” zones in the thermogram, and make the parapets seem thinner than they really are.
Among other features, the architecture of the 1970s and 1980s office blocks is characterized by an utter absence of considerations about heat energy consumption/preservation; the thermal image in which the building seems to radiate heat illustrates the energy issues arising from such an approach.

A more detailed image of the angular section of the annex reveals a very poor condition of the façade structure. Over time, water and impurities passing through the connections build up in the thermal insulation, causing decay and deterioration. This is particularly evident at the angle installation pipes with recorded temperatures as high as 16°C.

This residential building, built at the beginning of the 1980s, is one of the first attempts of Postmodern approaches to the exterior visual expression in prefabricated building. The building segments are positioned so as to emulate a traditional city block, an enclosure with a pedestrian access to the inner yard, towards which all bedroom, service and maintenance rooms are oriented, while the living and dining rooms open toward the outer perimeter.
The floor structure of the building is GF+6+L with a slanted roof and apartments in the loft. The façade is in prefabricated panels with visible connections and colored concrete finishing. Multi-coloring is applied in attempt to diminish uniformity that characterizes prefabrication. The windows feature low parapets and external blinds, uncommon to the standard practice of the period.

The thermal image of the building illustrates linear losses, characteristic of prefabricated concrete panels. In the staircase zone, the losses are less pronounced: the staircase is colder than the residential units (it is not heated), and the landings are not in level with the connections on the façade panels so that there is no distinct linear waste.

Термовизијски снимак објекта показује линијске губитке карактеристичне за префабриковане бетонске панеле. У зони степеништа се то манифестује у мањој мери: степенишни простор је хладнији од стамбених јединица (не греје се), а подесне плоче нису у равни спојница на фасадним панелима, па нема ни упадљивих линијских губитака.
- The façade thermal insulation is in poor condition, just as is the quality of the wood- and metalwork. The loggia windows gave realistic values, while the façade window panes showed reflection of the heat radiation from the environment/atmosphere.

- The image of the characteristic façade segment confirms that the thermal insulation inside the façade panels has deteriorated; there is practically no sealing in the upper zone of the loggias, the loft floors that extend from the interior of the building into the loggias without any thermal interruption have the same temperature as the walls of the heated rooms.

A residential building in Block 70
27a-d Jurja Gagarina Street, 1992.

The residential building, constructed at the beginning of the 1990s, represents a characteristic example of residential architecture that developed at the suburban periphery in the early years of transition. The construction industry was slumping so that large construction companies, such as "Energoproject", were turning towards smaller scale developments (the building in the photo was built by "Enjüb") and moving away from industrialized technologies. At the same time, this was an attempt to break away from Modernism and search for the forms and architectural elements inspired by the traditional models of a house.

The audited building in Block 70 has a horseshoe shape, 6 entrances, GF+3+L floor structure, and commercial premises on the ground floor.
The building was built in a skeleton construction system with reinforced concrete floor slabs. The slanted roof has roof windows and a functional loft. The three-layered sandwich façade walls were built on site. The finishing was done in sand-lime brick with some fields in façade mortar. The windows are assembled as single standard-sized openings, with Thermopane glass and Esslinger roller shutters.

Although the façade finishing treated relatively large surfaces uniformly, the thermal image reveals the rhythm of horizontal ring beams which were not properly insulated. Significant linear losses are detected on the dilatations (the building comprises 3 segments with 2 entrances each). The heat radiation is also noticeable in the upper window zone near the roller shutter box.
Seeing Energy – Belgrade

Стамбена зграда

Стамбени блок у Булевару краља Александра представља комплекс нових зграда, пројектованих од стране различитих архитеката у складу са јединственим урбанистичким решењем. Зграда на угулу се издваја својим положајем и јединственим концептом обликовања: карактерише је скулптурална цилиндрична форма која се постепено "ослобађа" из бочних кубуса, креирајући динамични и савремени углојни мотив.

A residential building

Traditional city block has been reinterpreted through complex of residential buildings designed by various, prominent Belgrade architects. The corner building stands out by its location and unique identity: it is characterized by sculptural cylindrical form which gradually "disengages" itself from the side-volumes, creating a dynamic and modern corner motive.
The façade constructed in sandwich walls system is clad in ceramic tiles. The steady rhythm of the balanced openings in characteristic purple and burgundy color and the detailing of the windows with an emphasized frame are the well studied elements that lend authenticity and picturesqueness to this building.

On the whole, this building shows relatively sound thermal properties. The regulations covering thermal protection, which, although obsolete in many respects, have been in force almost unchanged since they were formulated in the late 1980s and early 1990s, were equivalent to the German regulations at the time this block was designed. The results are the buildings with significantly better thermal performances compared to the practices of the 1970s and 1980s.
- More detailed thermal images show a fairly adequate insulation of the main façade wall, with surface temperatures of up to 2°C. In the zone of the horizontal ring beams and the edge beams, higher values were detected, but there were no significant linear losses as it was the case in the previous examples. The moldings around the openings were more carefully treated, the sealing is good and there is continuity of thermal insulation throughout the various positions and materials, so that heat loss is significantly reduced.
The construction of the building is a combination of skeleton reinforced concrete and a masonary system, with clay block walls. The façade is in cast stone, coloured in a simple combination of white and blue. The aluminium and wood windows of the residential units have panes with thermal insulation and low-emissive foil. The ground level façade is clad in Alucobond panels.

The residential building from 2008 illustrates the benefits of architectural solutions that improve thermal performance – when compared to a somewhat older example from Block 70 (p. 95), the difference is obvious. Lower heat radiation is detected, with the registered façade temperatures of approximately 0°C. However, there are still linear losses in the zone of the horizontal ring beams primarily due to the contractors’ negligence.
Although thermal images of characteristic façade segments show adequate insulation of the main wall, they also detect some flaws. In both images, the framed segments show how the same position – the horizontal ring beams and the lintel beams – yields different thermal characteristics on different floors. In the bottom image, heat losses are registered above the lowest window, as if there was no thermal insulation or it was thinner than specified by the design; by contrast, the losses at the floor above were marked only in particular spots where thermal insulation had to be interrupted for construction reasons. In the top image, the situation is similar: the lower ring beam was built differently than in the ceiling above. This example illustrates how thermal imaging can reveal construction flaws, and if necessary, distinguish between the responsibilities of the designer and the contractor when this is no longer possible by visual inspection only.
1. Novi Sad Town Hall, 2 Žarka Zrenjanina St
2. The Agrovojvodina Office Tower, 127 Bulevar oslobođenja
3. The EPS – Elektrovojvodina Building, 100 Bulevar oslobođenja
4. The Bazar Retail Center, 1 Mihajla Pupina Blvd
5. The NIS – Naftagas Head Office Building, 12 Narodnog fronta St
6. The Development Bank of Vojvodina, 2 Stražilovska St
Novi Sad Town Hall

The building of the Town Hall is located opposite the Banovina Building in downtown Novi Sad. Constructed in the 1950s, its design is consistent to the logic of Modernism of that period. The minimalist prismatic volumes resolve the composition of the form materialized in white stone with rhythmic alternations of horizontal window ribbons and parapets. The building has three entrances, more than a hundred offices, five conference halls, a library, a printing office and a restaurant.
The construction of the building is reinforced concrete skeleton with bracing plates. The façade is in cast and natural stone, with dark cladding at the window ribbons. Visually, the first floor stands out by the size of its window openings and the emphasized horizontal brise-soleil. On the left side of the building, the different functions were consistently stressed on the façade by the introduction of an additional motive of a framed rectangle filled with a row of vertical brise-soleils.

Termodinamički sнимак содржава објекат мате-ријализован коришћењем техничких решења ка-рактеристичних за половину двадесетог века, без коришћења термоизолације и са системима фасад-не браварије који не задовољавају данашње стан-дарде. Губици кроз отворе су приметни, а велики броj отворених прозора указује да интензивно грење објекта компенсуje недостатке начинита примењене материјализациjе.
A facade detail shows the poor quality of window frames and ensuing significant losses around them. The parapet zone also has no insulation — it is almost possible to identify the position of the radiators behind them.

A side wall detail which easily identifies the positions of reinforced concrete elements due to the absence of insulation and imminent heat radiation. Particular openings on the façade are in poor condition with excessive heat losses.
Зграда је материјализована у препознатљивом духу, сменом хоризонталних прозорских трака и пуних, профабрикованих, парапета. Вертикални акценти композиције изведени су наглашавањем пуног платна у зони лифтове вертикале, односно „слободним“ (застакљеним) углом, где је локално степенште. Прозорске траке су, у великој мери, замењене различитим системима застакљења, углавном коришћењем ПВЦ столарије.

The building was rendered in the recognizable style of alternating the horizontal window ribbons and solid prefabricated parapets. The composition is accented by emphasizing of the elevator vertical and the “free” (glazed) corner which holds the staircase. Most window assemblies have been replaced by different glazing systems, mainly PVC.

Термовизијски снимак указује на акумулациони потенцијал неколико армиранобетонских елемента парапета. Северна страна зграде приказује реално очигледавање температурних вредности, на коме је уочљива чињеница да су прозори замењени, да су парапети без изолације, док западна страна приказује значајно више температуре парапета, које су овде последица загревања од стране сунца током дана.

The thermographic image shows the accumulating potential of non-insulated reinforced concrete parapet elements. The north side of the building showed realistic temperature readings, which confirm that the windows have been replaced and that the parapets are without insulation, while the west side displayed considerably higher temperatures that were caused by the heat from the sun during the day.
On the north façade, there are problems due to the use of prefabricated elements, which cause significant losses at the connections between the panels and the structure.

Replaced windows are of good thermal quality; the parapets display noticeable higher temperature readings as a consequence of sun radiation. Although the thermographic image was taken six hours after the sunset, the impact of the external heat gains is still evident.

The replaced windows are of good thermal quality; the parapets display noticeable higher temperature readings as a consequence of sun radiation. Although the thermographic image was taken six hours after the sunset, the impact of the external heat gains is still evident.

The EPS – Elektrovojvodina Building

The EPS – Elektrovojvodina Building is one of the most significant architectural achievements in the wider center of Novi Sad. The massive building was designed under the influence of the British Brutalist movement and pursues the constructive and aesthetic values of reinforced concrete. Functional segregation was implemented not only through the form by combining different, mainly prismatic volumes, but also through the material by varying the color range and textual potentials of concrete and glass. In 1989, the extension to a dispatch centre was added, whose attractive architectural solution introduced a new quality to the existing composition.

The EPS – Elektrovojvodina Building
Објекат је изведен у скелетном конструктивном систemu са платним и језгром у коме се налазе вертикалне комуникације. Карактеристична за ову пословну зграду је материјализација. Она се огледа у комбинацијама различитих типова фасаде: коришћена су платна од пуног армираног бетона, „зид-завеса“ и хоризонталне смене прозорских и паралептичких трaka. Оваква, ефективна комбинација стакла и нагрева бетона, кулминира у наосној доградњи из 1989. године, у коме је нови објекат потпуно застаклен.

The building was built in the skeleton construction system with bracing plates and the core with vertical communication facilities. What is characteristic of this office block is its materialization reflected in the combination of different façade types: from solid reinforced concrete to the curtain wall to horizontal alternations of window ribbons and parapets. Such an effective combination of glass and exposed concrete culminates again in the subsequent extension in 1989, when the added part was completely clad in glass.

Термовизијски снимак одсликава типичне термичке карактеристике коришћене сендвич зидове од армираног бетона с термоизолацијом у свом саставу, а које се огледају у немогућности избегавања хладних мостова на местима спојева са конструкцијом објекта. Спојеви појединих форми објекта такође приказују значајне линијске губитке. Системи застакљења су разноврсни, а термички губици су најизразитији у приземљу објекта и на старим системима „зид-завеса“.

The thermal image illustrates typical thermal performance achieved by using reinforced concrete sandwich walls with incorporated thermal insulation, which are reflected in the impossibility to avoid thermal bridges at the connections with the construction. Moreover, the connections between particular volumes show significant linear losses. The glazing systems are diverse, but the thermal loss is most evident at the ground floor and at the older curtain wall systems.
На детаљу фасаде видни су проблеми који прате армиранобетонске фасадне зидове, где се највећи губици јављају код спојева бетонских делова надограђеног дела са комуникационим вертикалима. Код бочних зидова је, такође, могуће уочити хоризонталне констуктивне елементе, што илуструје недовољну термоизолацију на овом месту.

The facade detail displays the problems that accompany reinforced concrete face walls, where the greatest losses occur at the connections between the concrete segments of the extension and the vertical communication facilities. Besides, the lateral walls reveal the positions of horizontal construction elements, which is an indication of inadequate thermal insulation.

Застакљење приземља је неодговарајућег квалитета и термичких перформанси.

The ground floor glazing is of inadequate quality and thermal performance.

Комерцијални центар „Базар”
Булевар Михајла Пупина 1, Милан Михелић, 1972.

Зграда робне куће „Базар” налази се на крају пешачке зоне и представља једну од најекспресивнијих грађевина Новог Сада. Слободних, непреграђених основа, са потребним вертикалним комуникацијама и техничким просторима, у потпуности је наменена трговини. Обликовање је изведено „разигравањем” фасадног платна, креирањем непрекидне игре покретних волумена и наглашених пауза у вертикалном и хоризонталном правцу.

The Bazar Retail Center
1 Mihajla Pupina Boulevard, Milan Mihelić, 1972.

The Bazar Building is located at the end of the pedestrian zone and represents one of the most expressive buildings in Novi Sad. Featuring free, open-plan with the necessary vertical communications and technical facilities, it is perfectly convenient for commerce. Its shape was formed by “animating” the building envelope, by creating continuous play between the volumes in motion and the accentuated caesuras both vertically and horizontally.
The building has a skeleton construction. The façade walls were built as a sandwich construction with interior thermal insulation and colored exposed concrete or, in some segments, stone finishing. The transparent surfaces were materialized by the use of glass panes with visible connections and "patched" support fittings.

The thermogram shows the building with adequate thermal insulation, resulting in the absence of linear losses, which would be quite distinct in such a complex façade structure. Even though the thermal insulation positioning excludes the thermal capacity of massive concrete walls, the program of the building results in significant thermal gains and consequently obliterates the weaknesses and justifies the concept applied.
- A façade detail indicates significant loss at the glazing and at the connections with the concrete face walls. The glazed areas, with panes punctually fixed lose heat at the joints.

- More heat is lost at the glazing than at the solid façade. Higher temperature readings at the slanted segments result from geometric characteristics and the reflection from the glazing.

The NIS – Naftagas Head Office Building

The NIS Head Office Building was conceived as a domin­nant structure, the town’s new landmark, which engages and coordinates the vast space that surrounds it. The ad­ministrative program is situated in an architectural com­position of four 8- to 12-storey parallelepipeds. The prima­ry forms are positioned so that they form two recipro­cally staggered letters T, connected by a vast hallway ending in a semi-circular glazed vault. The opulently arranged and equipped offices and common areas are distinguished by the high quality of the materials used, the inventiveness of detailing and the recognizable appearance.
The façade is formed upon the contrast between the solid (wall) and the void (glass), so that the general impression takes in the perforated wall and the continuous play of planes. The hall, the central motive of the building, stretches transparently in the form of a vast atrium throughout all levels, thus uniting the interior of the building.

At first sight, the thermogram of the building seems as if it had captured a “local fire” that started on the sixth and the eighth floors. Naturally, there was no fire, but the thermal loss at the non-insulated passages between the protruding and the recessing façade planes is so excessive that it created a very descriptive thermographic image. Apart from this obvious negligence, the building is generally well-insulated and constructed according to the standards that provide satisfactory thermal performances.
In the image of a façade detail there are distinct losses, due to the discontinuity in the insulation, in places where the façade planes change. The amount of energy that is radiated off these zones is significant (registered temperature of 12°C) and can be followed through several levels due to the heating of the ceramic tile cladding.

As in the first detail, there is also a very noticeable difference between the characteristic, poorly insulated segments and the rest of the façade which is adequate. In the glazed hall, there is heat reflection from the poorly insulated segment of the façade resulting in unrealistically high temperature readings.

The primary volume of the bank was shaped by the curved street regulations of a Y-crossroad. The functional nucleus of the building was developed in the middle of the sharp angle formed by the streets. The architectural structure consists of two "wings" of four and five floors, respectively. By their shape, the "wings" encompass the central motive of the building, a five-storey vestibule with water surfaces on the ground level and a glazed roof surface. The composition ends in a "floating" roof that connects the segments of different heights. The lounge with the counters takes up the largest area of the ground floor and the mezzanine, while the rest of the building contains offices and the accompanying facilities. The roof of the building features a restaurant for the employees.
У циљу креирања веће флексибилности и отворености простора, као и употребе неких неуобичајених елемената изказаног у виду провидних таваница, за конструктивни систем изабран је армиранобетонски скелет, са потребним додатним ојачањем у виду армиранобетонских зидова. Завршно обраде површина фасаде, све до појединачних детаља, посвећена је велика пажња, од осмишљавања до израде. Највећим делом коришћена је облога од камених плоча монтирана у систему “ветрене фасаде”, а у зони приземља и вестибила примењена је транспарентна “зид-завеса”.

The requirement for greater flexibility and openness of space, and the application of certain uncommon elements, such as transparent ceilings, prompted the choice of the reinforced concrete skeleton structure, with the necessary support of reinforced concrete walls. Careful and detailed consideration, from design to fabrication, was given to the façade finishing. The stone slab cladding was mainly used, mounted on the principle of the “ventilated façade”, while a transparent curtain wall was used in the ground level zone and the vestibule.

Темровизијски снимак објекта илуструје квалитетно изведену „ветрену фасаду” са облогом од камених плоча, где се готово уопште не виде никакви губици, као и транспарентну фасаду типа „зид-завеса”, која и поред коришћења савремених технологијских решења, показује одређене губитке углавном на местима спајања са другим елеменатима облоге.

The thermal image illustrates an adequately built “ventilated façade” with the stone slab cladding, where almost no losses are found, as well as the transparent curtain wall façade, which shows certain losses despite the modern technological solutions, mainly in places of the connections with other cladding elements.
More detailed images of the façade show that even though there are obvious differences in the thermal performances of the various materials used for the façade envelope, the temperature readings show good thermal insulation, with remarkably low values on the curtain wall. The only evident loss occurs at the connections between the vestibule façade and the roof. The ventilated stone-clad façade is not suitable for thermographic analysis because there is a ventilated cavity in the structure of the façade so that there is no continuous heat conduction to the final layer. Extremely low values result from the effect of reflection and do not represent relevant data for a thermal image of the building. In this segment of the façade, the only visible losses occur in places of the joints between the window frames and the façade cladding.
1. The National Theater, bb Sinđelićev Sq
2. The Appellate Court, bb Vojvode Putnika St
3. The Ambassador Hotel, 4 Kralja Milana Sq
4. The OTP Bank, 28 Nikole Pašića St
5. The Radon Hotel, Niška Banja, 2 Srpskih junaka St
6. The Primary Health Care Center, 15 Vojvode Tankosića St
7. Residential buildings, 58-62 Vojvode Mišića St
Narodno pozorište
Синђелићев трг 66, Всеволод Татаринов, 1938.

Народно позориште се налази на Синђелићевом тргу, у најужем градском језгру Ниша. Објекат препознатљивог, монументалног, архитектонског израза, одликује се речником модерних карактеристика тридесете године двадесетог века, када је изграђен. Јасно дефинисани кубични облици трећане су без декоративних елемента, а исецањем сегмената из цилиндричне форме прилагођени дела креирају упечатљив ликовни израз.

The National Theater
bb Sindeljevic Square, Vsevolod Tatarinov, 1938.

The National Theatre is located in Sindeljevic Square, in downtown Niš. Its recognizable monumental architectural expression is characterized by the Modernist features of the 1930s, when it was built. The clearly defined cubic forms are treated without any decorative elements and the cutting out of the segments of the cylindrical form of the access to the building creates a strong visual impression.
Massive brick walls are forming the basic structure of the building. As for the final finishing, the base of the building is rendered in cast stone, whilst the greatest part of the façade envelope has a plaster finishing. The building was reconstructed twice, in 1967 and 2002, and the original appearance and materialization were preserved.
A more detailed image indicates the different external wall temperatures, which are higher at the ring beams and other reinforced concrete elements. In the zone of the access portico, the façade wall is thinner therefore higher temperatures occur.

The connections between the assemblies and the façade reflect the flaws of the obsolete types of woodwork and the mounting techniques.

The vertical window assemblies on the staircase cubes demonstrate inadequate thermal performances. Heat losses are visible at the window panes and molding.

Originally the building of the gendarmerie quarters, it is located in the wider center of Niš, and was designed as a distinct, pure cubic form. With its simplicity of expression, the subdued ornamentation and the materials used, it dominates its immediate surroundings. A classic structure features a three-partite division of the façade, an accentuated ground level, the main corpus, and a high attic without a decorative cornice; it all reflects the austerity of its original purpose. After the reconstruction of 2009/2010, the purpose of the building changed into the Appellate Court.
The building structure is traditional with load-bearing brick walls. The cladding is cast stone for the base and granite slabs for the pilasters in the central part of the main façade; during the reconstruction, the dominant part of the façade envelope was clad in thermal insulation and façade mortar.

The infrared image of the building reflects the thermal performance discrepancies between the insulated main corpus and the poorly or non-insulated ground floor. The heat losses at the window assemblies are also noticeable.

The building structure is traditional with load-bearing brick walls. The cladding is cast stone for the base and granite slabs for the pilasters in the central part of the main façade; during the reconstruction, the dominant part of the façade envelope was clad in thermal insulation and façade mortar.

The infrared image of the building reflects the thermal performance discrepancies between the insulated main corpus and the poorly or non-insulated ground floor. The heat losses at the window assemblies are also noticeable.
- A more detailed image displays the different outdoor wall temperatures resulting from different geometry and insulation quality. The visible horizontal reinforced concrete ring beams suggest that insulation could have been better. Besides, the window frames are of poor quality with noticeable heat losses.

- The discrepancy of 8°C noticeable at the façade detail occurred due to the presence of insulation in the upper segment and its absence in the lower segment, also the position of the reinforced concrete elements (the ring beams and the lintels) is clearly distinct from the brickwork.
Seeing Energy – Niš

The construction system of the building is reinforced concrete skeleton with concrete bracing plates. Visually most dominant longitudinal façade plane, overlooking the Square, was done in a curtain wall (semi-structural façade). The lateral face walls are clad in mosaic ceramic tiles. The façade of the low-rise is fully clad in stone slabs.

The thermogram of the complex showed a clear distinction between the low-rise office block and the hotel. At the time of the survey, the hotel, despite its considerable occupant capacity and business potential, was not operational (it was not heated) and this is visible in the thermal image. On the other hand, the low-rise structure displayed the typical performances of the 1960s buildings with no thermal insulation.
The unheated hotel tower (there was minimal technical temperature maintenance) showed the obvious flaws of the first-generation curtain wall façades without adequate thermal characteristics. Temperature fluctuations depend on the positions they show on the façade: the load-bearing walls, the parapets and the window assemblies. The right side of the building is clad in highly reflective mosaic tiles, rendering it even colder.

The heated part of the complex had significant heat losses in all elements of the building envelope: the stone façade, the window frames and panes. The most distinct were losses in the display window zone and at the entrances.
Despite its corner position, the original building was designed without particular corner treatment; it is rather a synthesis of two prismatic volumes with a recessed ground floor. The construction system is reinforced concrete skeleton. The façade is clad in a combination of white and grey marble slabs. The extension has taken over the role of the “main” building and, in spite of its less pronounced location, it owes its dominant presence to the cascading curtain wall façade topped with an emphasized cornice.

The thermal image of the building shows a noticeable difference between the original non-insulated segment with aluminum metalwork, and the extension with the curtain wall façade. The latter’s concrete walls, which stretch beyond the building volume, on the ground floor, are not adequately insulated. The stone cladding was also done with no insulation.
- Old building of the complex with the non-insulated façade and the inadequate metalwork shows significant heat losses.

- Significantly higher heat losses were recorded in the parapet zone due to the thinner wall in comparison with the rest of the façade. In the extension, whose façade is of better quality, losses are comparatively lower.

**The Radon Hotel**

**Niška Banja, 2 Srpskih Junaka Street, Aleksandar Buđevac, Borislav Spasić, 1975.**

The Radon Hotel belongs to the Institute of Niška Banja, and it is located at the very end of the pedestrian zone and the park. Its south side faces the park, while on the north it opens to the Nišava valley. Set on a natural cascade, it has two entrances on the ground level, accessed from the parking lot, and on the fifth floor, directly from the park. A natural stream of warm spa water was de-regulated to the centre of the building as a cascading waterfall, creating an extraordinary ambient effect.
The building was designed in the skeleton system, founded on a reinforced concrete mat with precast floor slabs. The façade walls are a combination of prefabricated reinforced concrete panels and red face brick. The “terraces” are visually connected, built as glazed cubes ending in a cornice of roof terraces. The horizontal aspect is emphasized by prefabricated concrete ribbons which frame the entire building at the floor level.

The thermographic presentation of the building shows high levels of quality design and construction, which surpass the standard practice of the time. Thermal losses are quite evident at the connections between the reinforced concrete elements of the roof terraces, the horizontal ribbon frames, and between the metal assemblies and the façade wall. The boiler room chimney, which penetrates the roof extension, is clearly outlined in the thermogram.
Видети енергију – Ниш

Сегмент омотача објекта, на термовизијском сним-ку, поседује изражене губитке топлоте на спојевима застакљених "тераса" и фасаде, односно на местима повученог спрата. Надограђено поткровље, обложен металним профилисаним лимом, услед великих степена рефлексије, приказује очитавања нереално ниских температурних вредности.

The segment of the envelope displays significant heat losses at the connection between the glazed "terraces" and the façade, and at the recessed floor. The roof extension in profiled metal cladding with a high degree of reflection shows unrealistically low heat values.

Армирано бетонске декоративне хоризонтале узрокују губитке топлоте на месту њиховог споја са међуспратном конструкцијом. На профилима фасадне браварије, такође су приметни губици топлоте док рефлексија стакла резултира очитавањем нерелално ниских температурних вредности.

The decorative reinforced concrete horizontals cause heat losses at the connection with the floor slabs. Besides, losses are visible at the façade metal assemblies, while glass reflection caused unrealistically low readings.

Дом здравља
Војводе Танкосића 15,

Објекат Дома здравља, највећи објекат примарне здравствене заштите у Србији, налази се у ширем центру Ниша. Способност ову зграду, мањих габарит, са препознатљивим материјализацијом од профабрикованих фасадних панела, доминира својим окружењем и представља један од најкарактеристичнијих модерних објеката Ниша.

The Primary Health Care Center
15 Vojvode Tankosića Street,

The Centre, the largest primary health care center in Serbia, is located in the wider center of Niš. The massive free-standing building recognizably materialized in pre-fabricated façade panels dominates its surroundings and represents a modern architectonic landmark of Niš.
The building was built of prefabricated façade elements with variable thickness in two forms only: as solid panels and window panels. The entrances to the building are in the form of independent cubes, which, besides the vertical technical facility segments, are the singular accents to the composition. The construction was done in a prefabricated reinforced concrete skeleton system.

The thermal image of the building indicates the particularities of the chosen type of prefabricated façade and the problems arising from inconsistent insulation. The entire vertical facilities: hallways, storages and staircases, are with no thermal insulation and thus show significant losses. In addition, the basement of the building, visible as a skirting, in the thermogram, also has no insulation.

The detail shows a segment on the façade with the most distinct temperature variation, i.e. the greatest heat loss. There are also problems due to the prefab- ricated façade panel mounting, seen through losses at connections and vertical covering profiles. Some panels reveal visible damage (absence) of the insulation in the panel structure.

A detail of the connection between the façade panels with variations as high as 8°C, depending on the mounting quality. Furthermore, the panel zones where damage or soaking occurred display poorer thermal performance.
Both buildings were built as reinforced concrete skeleton constructions with bracing plates. The older building has the prefabricated concrete façade with thermal insulation in the paneling and with accentuated connections. The façade wall of the more modern building is in brick panels clad in thermal insulation and mortar with discrete decorative elements.

The thermographic image of the complex illustrates all problems related to prefabricated reinforced concrete façade panels with respect to thermal performance; excessive heat loss occurs at interconnections between and within panels. The more recent building displayed significant heat loss at the loggias and cornices, and partly at the horizontal ring beams, due to decay or poor quality of the insulation.
Видети енергију – Ниш

Код детаља фасаде новије зграде, на термовизијском снимку је могуће јасно уочити неадекватно изо-ловане хоризонталне серклаже и лође. Такође, профилације венаца и декорације на фасади нису адекватно изоловане и узрокују топлотне губитке.

The thermogram showing façade details of the more recent building reveals inadequate insulation in the horizontal ring beams and the loggias. Moreover, the molding of cornices and façade decorations were not adequately insulated, thereby causing heat waste.

Детаљ фасаде старјег објекта од префабрикованих армиранобетонских панела указује да је термоизолација у саставу панела неадекватних карактеристика. Такође, приметни су и лоши спојеви који за последицу имају значајне топлотне губитке. Застакљене терасе, услед рефлексије стакла, на термограму имају несразмерно ниске температурне вредности.

A façade detail of the older building shows inadequate insulation performance of the prefabricated concrete panels. Again, the connections are poor and result in heat losses. The glazed loggias cause reflections so that the temperature values in the thermogram are disproportionately low.

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