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# Heat flow calculations through a Cubus and Identification of at Least 10 Best Practice Examples of Building Shading

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Solar Village Project – Heat flow calculations and Identification of Examples of Shading

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## **Abstract**

This document presents the calculation of heat flow through a cubus without shading and the identification of best practice examples of building shading. The study combines theoretical analysis, student-based calculations, and real-world observations collected in several European countries.

The results confirm that glazing is the dominant pathway of heat transfer and that shading systems, particularly external ones, play a crucial role in reducing heat gain during summer. The analysis of best practice examples further demonstrates that effective shading significantly improves indoor comfort and reduces energy consumption.

# 1 Introduction

Improving energy efficiency in buildings is one of the key challenges of modern sustainable construction. Buildings account for a significant share of global energy consumption, particularly due to heating and cooling demands. As a result, reducing unwanted heat gains in summer and minimizing heat losses in winter are essential for achieving energy-efficient and climate-responsive buildings.

One of the most critical elements influencing thermal performance is the building envelope, especially glazed surfaces. While walls can be effectively insulated, windows allow a substantial amount of solar radiation to enter the interior. This can lead to overheating during summer months and increased cooling demand. Conversely, during winter, windows can also become a major source of heat loss, increasing the need for heating.

Shading systems play a crucial role in controlling these thermal processes. By limiting the amount of solar radiation entering a building, shading systems directly influence indoor temperature, thermal comfort, and energy consumption. Among different types of shading, external systems are particularly effective because they block solar radiation before it reaches the glazing, preventing the greenhouse effect inside the building. Internal shading systems, while still useful, are generally less efficient because solar radiation has already passed through the glass.

In addition to shading systems, building orientation significantly affects the amount of solar exposure. South- and west-facing façades typically receive the highest solar radiation, especially during summer. Therefore, the design of shading must be adapted to orientation and local climate conditions. The effectiveness of shading solutions is also influenced by factors such as solar angle, surrounding environment, and material properties.

The analytical part of this study is based on heat flow calculations through a cubus without shading, using measured geometrical and material properties. The results clearly indicate that heat transfer through the glazed surface is significantly higher than through insulated walls. Calculations show that the vast majority of total heat flow passes through the window, while the contribution of insulated wall elements remains minimal. This confirms that glazing represents the dominant pathway for heat exchange and therefore requires targeted protection through shading strategies.

The document combines two complementary approaches to better understand these phenomena. The first part focuses on the calculation of heat flow through a cubus without shading, providing a clear understanding of how heat is transferred through building elements. The second part focuses on the identification and analysis of best practice shading solutions based on real-world examples collected by students in different countries.

The study is based on an interdisciplinary and project-based learning approach, involving students from technical and vocational schools. Through a combination of theoretical learning, digital calculations, field observation, and collaborative analysis, students were able to connect abstract physical principles with practical architectural solutions. This approach not only enhances understanding of building physics but also promotes critical thinking, problem-solving skills, and awareness of sustainable design.

The main objective of this document is to demonstrate how relatively simple architectural strategies, such as appropriate shading, can significantly improve building performance. By combining analytical calculations with real-life examples, the study provides both a scientific and practical perspective on reducing energy consumption and improving indoor environmental quality.

## 2 Educational and Experimental Context

The activities presented in this document were carried out within the framework of an interdisciplinary educational project involving several European partner schools. The project combined elements of physics, engineering, architecture, information technology, and environmental education, with the aim of providing students with a comprehensive understanding of energy-efficient building design.

The central experimental concept was based on the use of a simplified physical model – the *cubus*. This small-scale structure represents a reduced version of a real building, allowing students to study heat transfer processes in a controlled and understandable way. Each cubus consists of insulated walls and a glazed surface, which together form a basic building envelope. Despite its simplicity, the model effectively demonstrates the key thermal phenomena that occur in real buildings.

The project followed a project-based learning approach, where students actively participated in all phases of the work. These phases included: understanding theoretical concepts of heat transfer, collecting and defining input data, performing calculations using digital tools, analyzing real-world examples of shading systems, presenting and discussing results.

This approach encouraged active learning and enabled students to connect abstract scientific concepts with practical applications.

## 2.1 Interdisciplinary Learning Approach

The project was intentionally designed as an interdisciplinary activity. Students applied knowledge from multiple subject areas:

**Physics:** understanding heat transfer mechanisms (conduction, convection, radiation)

**Engineering:** analyzing material properties and thermal performance

**Information Technology:** using Excel and digital tools for calculations and data organization

**Architecture:** evaluating shading systems and building design

**Environmental studies:** understanding sustainability and energy efficiency

By combining these disciplines, students developed a holistic understanding of how buildings function as thermal systems.

## 2.2 Role of the Cubus Model

The cubus model played a central role in the experimental part of the project. It allowed students to:

simplify complex building physics into a manageable system

isolate key variables such as material properties and surface areas

compare heat flow through different elements (walls vs. window)

understand the impact of missing shading

The cubus was designed with:

insulated walls (typically expanded polystyrene)

one transparent surface representing a window

defined dimensions for accurate calculation

This simplified geometry enabled students to perform precise calculations while maintaining a clear conceptual understanding of the processes involved.

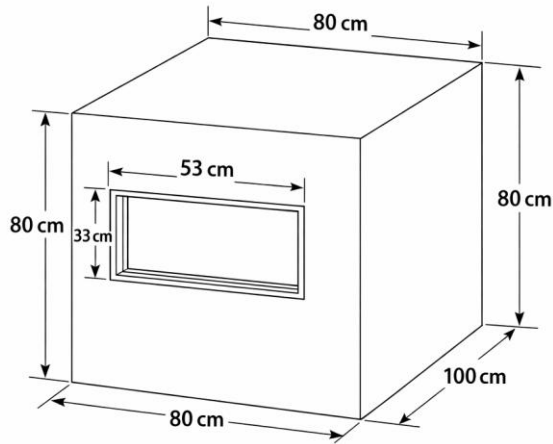


Figure 1 Illustration of the cubus with a polycarbonate window

### 3 Methodology and Results of Heat Flow Calculation

This section presents both the methodology and the results of the heat flow calculations through the cubus. The calculations are based on measured geometrical properties and material characteristics of the model. The results provide a quantitative comparison of heat transfer through insulated walls and glazing, highlighting the dominant role of the window in overall heat flow.

#### 3.1 Calculation Principles

The calculation of heat flow through the cubus is based on fundamental principles of heat transfer and thermal resistance. The methodology follows a step-by-step approach, allowing clear understanding of how different materials influence overall heat flow.

To calculate the thermal flow through the cube, we must calculate heat flow through cube’s window separately and through the rest of the cube (styrofoam) separately.

$$P = P_{win} + P_{styro}$$

The heat flow will be calculated using thermal resistance:

$$P = \frac{\Delta T}{R}$$

where thermal resistance is

$$R = \frac{d}{\lambda \cdot A}$$

### 3.2 Thermal Resistance of Styrofoam Walls

The total area of the styrofoam consists of:

- 1 surface with area of 80 cm x 80 cm. The calculation for area of this surface is:  $A = 0,8 \cdot 0,8 = 0,64 \text{ m}^2$
- 4 surfaces with area 80 cm x 100 cm. The calculation for area of this surfaces is  $A = 4 \cdot 0,8 \cdot 1 = 3,2 \text{ m}^2$
- 1 surface with area 80 cm x 80 cm with window of the area 53 cm x 33 cm. The area of this surface is:  $A = 0,8 \cdot 0,8 - 0,53 \cdot 0,33 = 0,4651 \text{ m}^2$

The whole area of the styrofoam is:  $A = 0,64 + 3,2 + 0,4651 = 4,3051 \text{ m}^2$ .

The thickness of the styrofoam is 10 cm and the thermal conductivity is  $0,031 \frac{W}{mK}$ .

Thermal resistance for the styrofoam is:

$$R_{styro} = \frac{0,1 \text{ m}}{0,031 \frac{W}{mK} \cdot 4,3051 \text{ m}^2} = \frac{0,1 \text{ m}}{0,13345 \frac{Wm}{K}} = 0,749 \frac{K}{W}$$

### 3.3 Thermal Resistance of the Window

The area of the window is  $A = 0,53 \cdot 0,33 = 0,1749 \text{ m}^2$ .

The thickness of the window is 2 cm and the thermal conductivity is  $1,7 \frac{W}{mK}$ .

Thermal resistance for the styrofoam is:

$$R = \frac{0,02 \text{ m}}{1,7 \frac{\text{W}}{\text{mK}} \cdot 0,1749 \text{ m}^2} = \frac{0,02 \text{ m}}{0,2973 \frac{\text{Wm}}{\text{K}}} = 0,0672 \frac{\text{K}}{\text{W}}$$

### 3.4 Heat Flow Results

The heat flow through the cube can now be calculated for a given temperature difference. For example: for a temperature difference  $\Delta T = 20 \text{ }^\circ\text{C} = 20 \text{ K}$ , the heat flow is:

$$P_{\text{styro}} = \frac{\Delta T}{R_{\text{styro}}} = \frac{20 \text{ K}}{0,749 \frac{\text{K}}{\text{W}}} = 26,7 \text{ W}$$

$$P_{\text{win}} = \frac{\Delta T}{R_{\text{win}}} = \frac{20 \text{ K}}{0,06722 \frac{\text{K}}{\text{W}}} = 297,5 \text{ W}$$

$$P = P_{\text{win}} + P_{\text{styro}} = 26,7 + 297,5 = 324,2 \text{ W}.$$

As shown in Figure 2, the heat flow through the window is significantly higher than through the insulated walls.

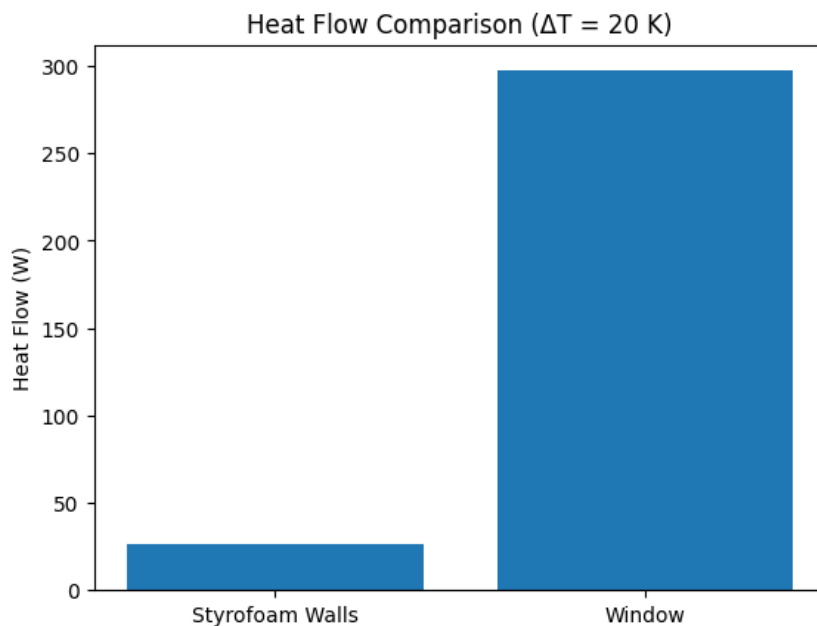


Figure 2 Comparison of the heat flow through the styrofoam walls and window

### **3.5 Comparison and Interpretation**

The results clearly demonstrate that heat flow through the window is more than ten times greater than through the insulated walls. Despite its relatively small surface area, the window dominates the overall heat transfer due to its low thermal resistance.

This confirms that glazing represents the weakest element of the building envelope. It also shows that improving wall insulation alone is not sufficient to achieve optimal thermal performance if glazing is not properly addressed.

### **3.6 Connection to Real Buildings and Experimental Measurements**

Although the cubus represents a simplified physical model, the calculated results reflect fundamental principles that are directly applicable to real buildings. The comparison between the thermal resistance of insulated walls and glazing clearly demonstrates that windows are the dominant pathway for heat transfer.

The results show that even a relatively small glazed area can significantly influence the total heat flow. This explains why buildings with large, unshaded glazing surfaces are highly susceptible to overheating during summer and increased heat losses during winter.

The cubus model therefore provides a reliable basis for understanding how different building elements contribute to overall thermal performance. In particular, it highlights the necessity of controlling heat flow through glazing by means of appropriate design strategies, such as external shading.

In the next phase of the project, this theoretical understanding will be complemented by experimental measurements. Temperature data collected from the Solar Village cubes will be used to analyse the influence of building orientation, presence or absence of shading and type of shading systems.

By comparing cubes with different orientations and shading conditions, it will be possible to directly observe how solar exposure affects internal temperature and heat flow. This will allow validation of the theoretical calculations and provide deeper insight into the relationship between design decisions and thermal performance.

The combination of analytical calculations and experimental data provides a comprehensive approach to studying building physics and demonstrates how relatively simple architectural

interventions, such as shading, can significantly improve indoor comfort and reduce energy demand.

## **4 Identification of Best Practice Shading Systems**

This section describes the methodology used to identify and evaluate best practice examples of building shading systems. The analysis is based on student research, field observations, and real-world case studies collected across multiple partner countries. The objective is to understand how different shading strategies influence heat gain, indoor comfort, and overall energy efficiency.

### **4.1 Methodology of Data Collection**

The identification of shading systems was carried out through a structured, multi-step process that combined theoretical learning with practical investigation.

Students first gained basic knowledge of heat transfer and the role of shading in building performance. This theoretical foundation enabled them to understand why certain shading solutions are more effective than others.

The data collection process included:

#### **Field observation**

Students explored their local environment and identified buildings with different shading solutions. They documented both effective and ineffective examples by taking photographs and recording key characteristics.

#### **Online research**

Additional examples were identified through online sources, allowing students to explore a wider range of architectural solutions and climate conditions.

#### **Expert input**

In some cases, teachers with professional experience in building design and energy efficiency presented real-life projects and explained practical shading strategies.

#### **Group work and discussion**

Students worked individually or in small groups to analyse their findings. The results were then presented and discussed in class, allowing comparison of different approaches and collective evaluation of the most relevant examples.

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This methodology ensured a strong connection between theoretical knowledge and real-world applications, while also promoting critical thinking and collaborative learning.

## **4.2 Types of Shading Systems Identified**

The collected examples revealed a wide range of shading strategies used in contemporary and traditional architecture. These systems can be broadly classified into the following categories:

### **External shading systems**

These include elements such as brise-soleil, external blinds, shutters, overhangs, and pergolas. They are installed outside the building envelope and block solar radiation before it reaches the glazing.

### **Internal shading systems**

Examples include curtains and internal blinds. These systems are placed inside the building and primarily reduce glare and light intensity, but are less effective in preventing heat gain.

### **Façade-integrated systems**

These include double-skin façades, ventilated façades, and shading elements integrated into the building design. They often combine aesthetic and functional roles.

### **Dynamic and automated systems**

Adjustable or automated shading devices that respond to solar position and environmental conditions, allowing optimized performance throughout the day.

### **Nature-based shading solutions**

Vegetation such as trees, green façades, and pergolas with climbing plants. These systems provide seasonal shading and contribute to environmental sustainability.

This classification provides a framework for analysing and comparing different shading approaches.

## **4.3 Evaluation Criteria**

Students approached the identification of effective and ineffective shading examples based on prior knowledge and guided preparation. Their understanding of basic physical principles, such as

heat transfer, solar radiation, and the impact of materials on thermal behaviour, had already been developed through subjects like natural sciences and physics in earlier stages of their education.

In addition to theoretical knowledge, students relied on experiential learning gained from everyday observations of buildings and their surroundings. This combination of formal education and real-life experience provided an initial framework for recognising shading performance.

Before starting the research activity, these concepts were revisited and reinforced with the support of a mentor. Together, they defined key evaluation guidelines, which helped students systematically observe, analyse, and classify shading solutions as effective or ineffective.

To identify best practice examples, shading systems were evaluated using several key criteria:

#### **Effectiveness in reducing heat gain**

The primary criterion was the ability of the system to reduce solar radiation entering the building and to prevent overheating.

#### **Position relative to glazing**

External shading systems were considered more effective than internal ones, as they block solar radiation before it passes through the window.

#### **Adaptability and control**

Systems that can be adjusted according to solar angle, time of day, or season were evaluated as more efficient.

#### **Integration with building design**

The degree to which shading is incorporated into the architectural concept, contributing both to performance and aesthetics.

#### **Suitability for local climate and orientation**

The effectiveness of shading depends on solar exposure, which varies with orientation and geographic location.

#### **Sustainability and environmental impact**

Preference was given to solutions that reduce energy consumption and, where possible, incorporate natural elements.

These criteria allowed a consistent and structured comparison of different shading systems across all partner countries.

#### **4.4 Transition to Case Study Analysis**

Based on the methodology and evaluation criteria described above, a selection of representative examples was identified in each participating country. These examples illustrate both effective and ineffective shading solutions and provide insight into how design decisions influence building performance.

The following section presents a detailed analysis of these case studies, highlighting the most successful strategies and common design shortcomings.

#### **4.5 Implementation Across Partner Countries**

Although all partner schools followed a common methodological framework, the implementation of the activity varied according to local educational context, available resources, and teaching approaches. This provided valuable diversity in methods while maintaining comparable results.

##### **Italy**

In Italy, the activity was carried out in a structured sequence combining theoretical instruction, expert input, and fieldwork.

Students were first introduced to the principles of heat transfer and shading systems through an interdisciplinary lesson. This was followed by a presentation from a teacher with professional experience in building renovation, who introduced real-life shading solutions from practice.

Students then conducted online research to identify different shading systems and participated in a guided field trip, where they observed and photographed shading solutions in the urban environment. This approach ensured a strong link between theoretical knowledge and real-world application.

##### **Portugal**

In Portugal, the activity was organised as a project-based learning process involving a larger group of students.

Students were divided into smaller groups, each responsible for researching shading solutions in their local environment. The work included online research, analysis of regional buildings, and preparation of presentations.

Each group presented its findings to the class, followed by discussion and collective evaluation. The most relevant examples were selected collaboratively. The activity was also integrated into broader educational initiatives related to sustainability and environmental awareness.

### **Slovenia**

In Slovenia, the activity focused strongly on individual observation and critical evaluation.

Each student was assigned to identify one effective and one ineffective example of building shading in their surroundings. They documented these examples with photographs and analysed their performance.

The findings were presented in class, where students explained their reasoning and discussed the results with their peers and teacher. Based on this process, the most representative examples were selected and included in the final report.

This approach encouraged independent thinking, critical analysis, and active participation.

### **Türkiye**

In Türkiye, the activity combined fieldwork, digital tools, and collaborative analysis.

Students identified real-life examples of shading systems in their local environment, documented them through photographs, and analysed their effectiveness. The results were presented and discussed within the group.

In addition to field observation, students used digital tools such as Excel, CAD software, and AI-based simulations to support their analysis. This added a strong technical and digital dimension to the activity.

### **Serbia**

In Serbia, the activity was organised as a combination of individual fieldwork, collaborative analysis, and interdisciplinary teaching.

Students were assigned to identify examples of effective and ineffective shading in their local environment. Each student documented one effective and one ineffective solution using photographs and provided a brief explanation. This ensured a variety of examples from both urban and residential areas.

The collected examples were then presented and discussed in class. Through group discussion and comparison, students evaluated the effectiveness of different shading strategies and reflected on their impact on indoor comfort.

In parallel, the activity included the calculation of thermal resistance of an unshaded cubus. An interdisciplinary approach was used, where concepts from electrical engineering, such as series

and parallel connections, were applied to explain thermal resistance. With support from teachers from different technical fields, students developed a clearer understanding of heat transfer and material properties.

The activity was completed over a two-week period and contributed to improved understanding of both theoretical concepts and their practical application.

### **Latvia**

In Latvia, the activity was carried out at Valmieras tehnikums with the involvement of students from mechatronics and renewable energy programmes.

Students were assigned to identify examples of effective shading solutions in their local environment. Each student was responsible for selecting and documenting two different examples, ensuring that no cases were repeated. The task was completed independently, with students collecting and describing examples within a one-week period. This approach resulted in a diverse set of real-world case studies.

The collected examples were analysed and discussed, allowing students to better understand how shading systems reduce overheating, improve indoor comfort, and decrease energy consumption. In particular, students recognised that external shading systems are the most effective, as they prevent solar radiation from entering the building.

The second part of the activity focused on calculating heat flow through an unshaded cubus. This task required a deeper understanding of thermal conductivity, heat transfer, and thermal resistance. Students first revisited the theoretical background and then applied it to a more complex system that included both homogeneous (styrofoam) and heterogeneous (styrofoam and window) elements.

To support the calculations, students developed a digital model using Excel. They defined input parameters such as dimensions, material properties, and surface areas, and calculated thermal resistance and total heat flow. The presence of the window required the use of a parallel resistance approach, which added complexity to the task.

Although the calculations were challenging, students demonstrated strong analytical skills, teamwork, and perseverance. Through iterative work, discussion, and teacher support, they successfully completed the task and developed a functional calculation model.

The activity contributed to a deeper understanding of both theoretical concepts and their practical application, and provided a solid basis for further analysis in the next stages of the project.

## Common Outcomes

Despite differences in implementation, all partner countries achieved similar learning outcomes:

- improved understanding of heat transfer and shading
- ability to evaluate real buildings
- awareness of the importance of shading for energy efficiency
- development of analytical and collaborative skills

The diversity of approaches enriched the overall project and provided a broader perspective on shading strategies in different climatic and architectural contexts.

## 5 Analysis of Best Practice Examples of Building Shading

This section presents a detailed analysis of selected best practice examples of building shading identified across partner countries (see Appendix). The examples include both effective and ineffective solutions, allowing a comprehensive understanding of how different design approaches influence heat gain, indoor comfort, and energy efficiency.

The analysis is organised by country, reflecting different climatic conditions, architectural traditions, and design strategies.

### 5.1 Italy

The examples identified in Italy demonstrate a strong focus on **external shading systems** and practical architectural solutions.

Effective examples include:

- **Pergolas and roof overhangs**  
These elements provide shading for south-facing windows by blocking direct solar radiation before it reaches the glazing. This significantly reduces indoor overheating.
- **Adjustable brise-soleil systems**  
External shading panels with adjustable slats allow dynamic control of solar radiation depending on the sun's position, making them highly effective throughout the day.

- **Integrated shading within glazing systems**

Some buildings use Venetian blinds inside double glazing combined with solar-control coatings. While these systems reduce solar gain, they are less effective than external shading.

Ineffective examples include:

- **Large glazed façades without external shading**

Buildings with extensive glass surfaces and no external protection experience significant heat gain.

- **Short or insufficient roof overhangs**

These fail to block direct sunlight during peak hours.

**Conclusion:**

External shading systems that intercept solar radiation before it reaches the glazing are the most effective solutions.

## 5.2 Portugal

Portuguese examples highlight **integrated and technologically advanced shading solutions**.

Effective examples include:

- **Brise-soleil on façades (e.g. cultural buildings in Lisbon)**

These systems reduce direct solar radiation while maintaining daylight and visual comfort.

- **Green roofs and vegetation-based solutions**

These provide thermal insulation and surface shading, reducing cooling demand.

- **Automated shading systems**

Adjustable blinds controlled according to solar position optimize indoor conditions and energy efficiency.

Ineffective examples include:

- **Large glass surfaces without shading**

Common in office buildings, leading to excessive cooling demand.

- **Fixed awnings without adaptability**

These do not respond to seasonal changes and may reduce efficiency.

- **Lack of shading in dense urban environments**

Leads to overheating and increased reliance on air conditioning.

**Conclusion:**

The most effective solutions combine architecture, technology, and environmental design.

**5.3 Latvia**

Latvian examples illustrate a combination of **modern engineering solutions and traditional passive design**.

Effective examples include:

- **Wooden façade panels and external shading elements**  
These reduce solar radiation while allowing natural light.
- **Double glazing with improved insulation (argon-filled units)**  
Enhances thermal performance and reduces heat transfer.
- **Traditional architectural solutions (deep eaves and porches)**  
Provide seasonal shading and passive thermal regulation.
- **Vegetation-based shading (deciduous trees)**  
Offer shading in summer and allow sunlight in winter.

Ineffective examples include:

- **Fully glazed buildings without external shading**  
These rely heavily on air conditioning due to high solar heat gain.
- **Buildings with only internal shading systems**  
These do not prevent heat from entering the building envelope.

**Conclusion:**

A combination of traditional and modern strategies provides effective and sustainable shading.

**5.4 Serbia**

Examples from Serbia demonstrate that **simple and well-positioned shading solutions** can be highly effective.

Effective examples include:

- **Awnings above windows and shopfronts**  
These act as a physical barrier that prevents direct solar radiation from entering the interior.
- **Optimized building orientation combined with shading**  
Reduces solar exposure and improves thermal comfort.
- **Use of protective façade materials**  
Limits solar penetration and helps maintain cooler indoor temperatures.

Ineffective examples include:

- **Unshaded windows exposed to direct sunlight**  
Lead to overheating and increased cooling demand.
- **Large glass surfaces without shading systems**  
Result in poor energy performance.
- **Lack of any shading strategy**  
Causes discomfort and reliance on mechanical cooling.

#### **Conclusion:**

Even simple shading solutions can be highly effective when properly designed and positioned.

## **5.5 Slovenia**

Slovenian examples demonstrate a strong integration of **architectural design and environmental strategies**.

Effective examples include:

- **Perforated façades and external shading panels**  
These reduce direct solar radiation while allowing diffused light.
- **Balconies and overhangs**  
Provide shading during peak solar hours and reduce cooling demand.
- **Combination of natural and built shading**  
Trees and architectural elements together create a cooler microclimate.

Ineffective examples include:

- **Buildings with large unshaded windows**  
Lead to excessive heat gain.
- **Inconsistent shading across façades**  
Results in uneven thermal performance.

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**Conclusion:**

Integrated solutions combining architecture and natural elements are particularly effective.

**5.6 Türkiye**

Examples from Türkiye focus on **modern buildings with integrated façade systems**.

Effective examples include:

- **Shaded glass façades (e.g. Bursagaz building)**  
External shading structures reduce solar exposure and improve energy efficiency.
- **Reflective glazing combined with shading panels (e.g. hotels)**  
Helps control solar gain while maintaining daylight.
- **Integrated shading in high-rise buildings**  
Provides balanced indoor conditions and enhances user comfort.

Ineffective examples include:

- **Large glazed buildings without sufficient shading**  
Lead to overheating and high energy consumption.
- **Design focused on aesthetics rather than performance**  
Results in poor thermal efficiency.

**Conclusion:**

Effective shading must be integrated into the architectural design from the early stages.

**5.7 Key Findings Across All Countries**

Across all analysed examples, several consistent conclusions emerge:

- External shading systems are the most effective in reducing heat gain
- Glazing is the most critical element requiring protection
- Adjustable and dynamic systems provide optimal performance
- Combining multiple strategies (architecture, technology, vegetation) yields the best results
- Poor shading design leads directly to increased energy consumption and reduced comfort

## 6 Discussion

The results of the heat flow calculations and the analysis of best practice shading examples provide a coherent understanding of the relationship between building design, material properties, and thermal performance.

The analytical results clearly demonstrate that the window is the dominant pathway for heat transfer in the cubus model. Despite its relatively small surface area, the low thermal resistance of the glazing leads to a significantly higher heat flow compared to the insulated walls. This confirms that improving wall insulation alone is not sufficient to achieve optimal thermal performance if glazing is not properly addressed.

The analysis of real-world examples across different countries further supports this conclusion. In all observed cases, buildings with effective external shading systems showed better thermal performance and reduced overheating. Conversely, buildings with large, unshaded glazing surfaces consistently exhibited higher indoor temperatures and increased reliance on mechanical cooling.

A key finding of this study is the importance of the position of shading systems. External shading proves to be significantly more effective than internal shading, as it prevents solar radiation from entering the building in the first place. Internal shading, while useful for controlling light and glare, does not significantly reduce heat gain because the solar energy has already passed through the glazing.

Another important aspect is the adaptability of shading systems. Fixed shading elements, such as overhangs, can be effective when properly designed according to solar angles, but adjustable or dynamic systems provide greater flexibility. These systems can respond to changing environmental conditions, such as time of day or season, and therefore offer improved performance.

The comparison across partner countries highlights that the effectiveness of shading strategies also depends on local climatic conditions and building orientation. While the general principles remain the same, the optimal design of shading systems must consider factors such as solar path, latitude, and surrounding environment. This reinforces the idea that there is no universal solution, but rather a need for context-sensitive design.

The educational dimension of the project also plays an important role. By combining theoretical calculations with real-world observations, students were able to develop a deeper understanding of building physics. The use of a simplified model, such as the cubus, proved to be an effective tool for illustrating complex concepts in a clear and accessible way. At the same time, fieldwork and case study analysis allowed students to connect these concepts with practical applications.

Finally, the integration of analytical and experimental approaches strengthens the reliability of the results. While the calculations provide a theoretical understanding of heat flow, the experimental

measurements from the Solar Village cubes will allow validation under real environmental conditions. This combination of methods represents a comprehensive approach to studying energy efficiency in buildings.

The discussion confirms that effective shading strategies are essential for improving thermal comfort and reducing energy consumption. The findings highlight the need for an integrated design approach that considers materials, geometry, orientation, and shading as interconnected elements of building performance.

### **6.1. Summary Matrix Evaluation**

To provide a structured overview of the educational outcomes and implementation approaches across partner countries, a summary matrix was developed. The matrix consolidates key aspects of the activity, including teaching methods, subjects involved, student engagement, challenges encountered, and recommendations for future implementation.

The evaluation was carried out after the completion of the activity at each partner school and was based on inputs from teachers implementing the activity, the project coordinator, and the students involved. The collected data were synthesised into a summary matrix prepared by the project coordinator, enabling a systematic comparison of practices and outcomes across all participating countries.

The purpose of this evaluation was to identify common strengths, challenges, and transferable practices that can support the further development and scaling of the activity within different educational contexts.

The evaluation highlights several important findings. All partner schools successfully combined theoretical knowledge with practical activities, such as field observations and digital modelling. Students showed higher motivation when working with real-life examples and when using digital tools such as Excel, CAD software, and AI-based simulations.

One of the main challenges identified was the understanding of thermal physics concepts, particularly for students without prior technical background. This challenge was effectively addressed through additional explanations, interdisciplinary teaching approaches, and the use of practical examples.

The results also confirm that project-based and interdisciplinary learning approaches significantly enhance student engagement, critical thinking, and the ability to apply theoretical knowledge in real-world contexts.

Partner school	Key practices identified	Subjects involved	Students & teachers involved	Student feedback summary	Teacher reflection key points	Recommended for scaling
CFP Cebano Monregales e (IT)	Field trip to identify real-life shading systems; Excel spreadsheet for heat flow calculations; research on advanced shading (brise-soleil, vegetation, solar films)	Physics, IT, Natural Sciences, Architecture	5 core students, 3 teachers	Students appreciated real-life examples and hands-on learning; theory was challenging but became clearer with practical application	Needed more time for technical concepts; fieldwork motivated students	YES – interdisciplinary approach highly effective
Amar Terra Verde (PT)	Group research on local shading examples; integration into PAP (Professional Aptitude Projects); AI-assisted calculations	Technical subjects (Electrotechnics, Physics)	20 students, 2 teachers	Collaborative work increased engagement; PAP students wanted more data from control panels	Project-Based Learning worked well; required extra teacher support for complex calculations	YES – strong integration with school projects
ŠC Ptuj (SI)	Students photographed and analyzed good/poor shading practices; two students did heat flow Excel model	Energy Efficiency module, Mechanical Engineering Technician	18 students + 2 selected students, 1 teacher	Class was engaged by practical shading examples; two students deepened understanding through advanced task	Advanced physics required extra self-study; visualizing results in Excel improved understanding	YES – mix of simple + advanced tasks fits diverse levels
Çavit Çağlar MTAL (TR)	Class identified local shading examples; two students did heat flow modeling with Excel & AutoCAD; AI simulations	IT, Physics, Technical Design	~12 students, 2 teachers	Students motivated by digital tools and real-life applications; struggled initially with thermal physics theory	Combining AutoCAD & AI made concepts clearer; time-intensive but rewarding	YES – digital modeling enriched learning outcomes

Solar Village Project – Heat flow calculations and Identification of Examples of Shading

Valmieras Tehnikums (LV)	Students evaluated effective and ineffective techniques of shading practices locally, used excel spreadsheet for heat flow calculations, researched innovative and modern shading practices	Physics, IT, Renewable energy	5 core students + 1 teacher	Students appreciated real-life examples and hands-on learning practice, the task helped them to better understand the theory	To devote more time to completing the task, visualizations helped to perceive the results of the task	YES – strong integration with school projects
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## 7 Practical Recommendations

Based on the results of the heat flow calculations and the analysis of best practice examples, several practical recommendations can be formulated for improving building energy performance and indoor thermal comfort.

### 7.1 Prioritise External Shading Systems

The most important recommendation is the use of external shading systems. As demonstrated in the calculations and case studies, external shading is significantly more effective than internal shading because it blocks solar radiation before it reaches the glazing.

Recommended solutions include:

- brise-soleil systems
- external blinds and shutters
- pergolas and overhangs

These systems should be considered as a primary strategy for reducing summer heat gains.



## 7.2 Protect Glazed Surfaces

Glazing has been identified as the weakest element of the building envelope in terms of heat transfer. Therefore, special attention must be given to the design and protection of windows.

Recommendations include:

- limiting excessive glazing areas where possible
- using high-performance glazing materials
- always combining glazing with appropriate shading systems

Unprotected glazing should be avoided, especially on façades exposed to strong solar radiation.

## Protect Glazed Surfaces

**⊘ Avoid Excessive Glazing Areas**

- Limit large unprotected glass surfaces

**🏠 Use High-Performance Glazing**

- Triple glazing
- Solar control coating
- Heat-reflective materials

**🌿 Combine Glazing with Shading**

- Always pair windows with external shading

⊘ **Avoid Excessive Glazing Areas**

• Limit large unprotected glass surfaces

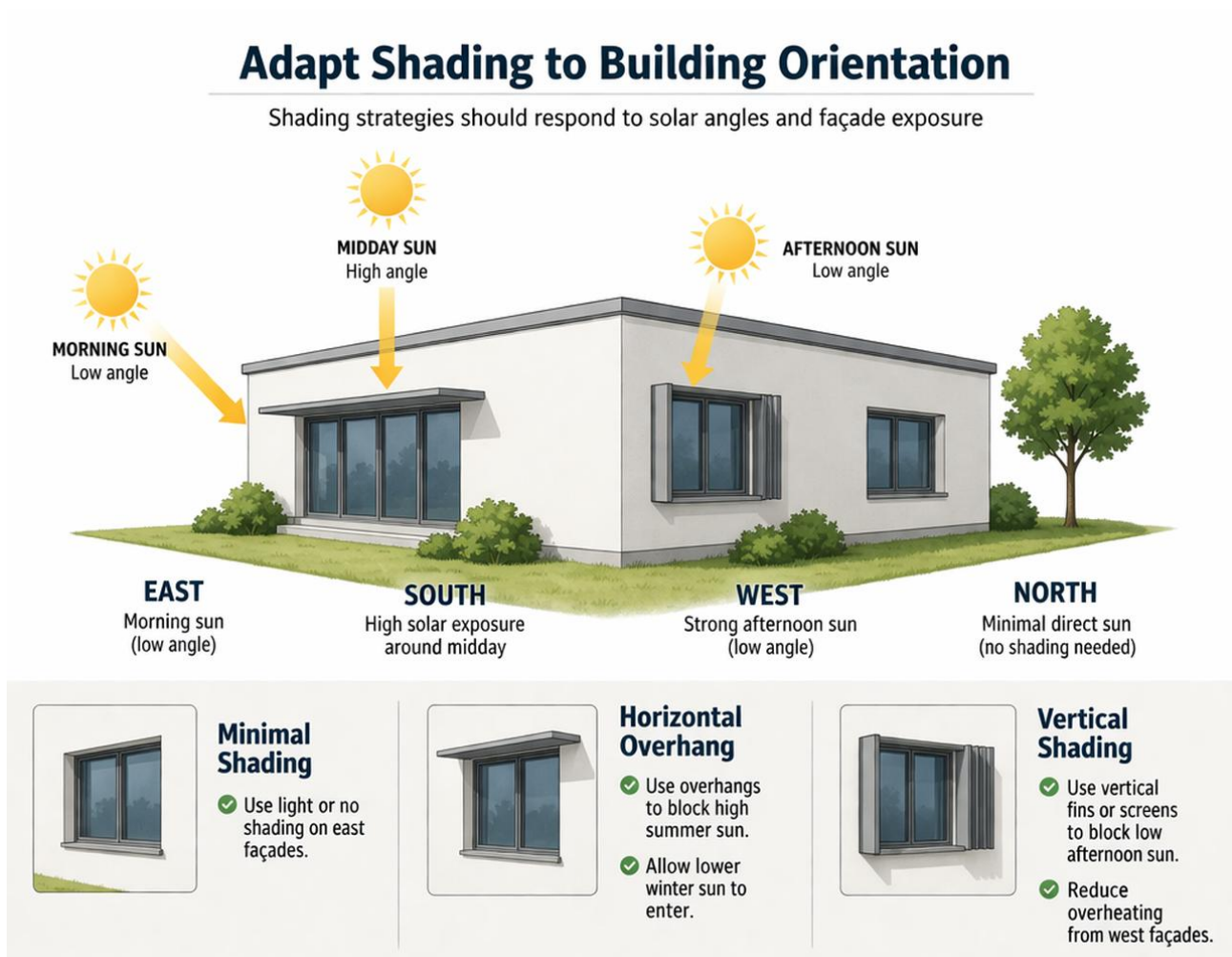
### 7.3 Adapt Shading to Building Orientation

The effectiveness of shading systems depends strongly on building orientation. South- and west-facing façades typically receive the highest solar radiation and require the most effective shading solutions.

Design strategies should therefore:

- consider solar angles throughout the day,
- apply stronger shading on highly exposed façades,
- use different shading approaches depending on orientation.

This ensures optimal performance under varying conditions.



## 7.4 Use Adjustable and Dynamic Shading Systems

Whenever possible, shading systems should be adjustable or automated. Dynamic systems can adapt to changing environmental conditions, such as time of day, season and weather conditions.

This allows for maximum solar protection in summer and beneficial solar gains in winter.

Such systems significantly improve overall energy efficiency.

## 7.5 Combine Architectural and Natural Solutions

The most effective shading strategies often combine multiple approaches, including:

- architectural elements (overhangs, façades),
- mechanical systems (blinds, shutters),
- natural solutions (trees, vegetation).

Vegetation-based shading is particularly beneficial because it provides seasonal adaptability, improves microclimate conditions and contributes to environmental sustainability.

### Combine Architectural and Natural Solutions



Architectural Elements



Mechanical Systems



Natural Solutions

Using **vegetation for shading** can be **seasonally adaptive** and **environmentally beneficial**.

## 7.6 Integrate Shading into Early Design Phases

Shading should not be treated as an additional element but as an integral part of the architectural design process.

Early integration allows:

- better optimisation of building form and orientation,
- improved aesthetic integration,
- higher overall efficiency .

Design decisions made in early stages have the greatest impact on building performance.

## 8 Conclusion

This activity has demonstrated the fundamental relationship between building design, material properties, and heat transfer. Through analytical calculations using the cubus model, it was shown that glazing represents the dominant pathway for heat flow due to its significantly lower thermal resistance compared to insulated walls.

The results highlight that even a relatively small window area can have a disproportionate impact on overall thermal performance. This confirms that addressing heat transfer through glazing is essential for improving energy efficiency and indoor comfort.

The analysis of real-world examples across multiple countries further reinforced these findings. Effective shading systems, particularly external and adjustable solutions, were consistently identified as key elements in reducing heat gain and preventing overheating. In contrast, buildings lacking adequate shading demonstrated poor thermal performance and increased reliance on mechanical cooling.



An important outcome of the activity is the recognition that no single solution is sufficient on its own. The most effective strategies combine architectural design, technological systems, and natural elements. This integrated approach allows for adaptable, climate-responsive solutions that improve both performance and sustainability.

In addition to technical insights, the activity also demonstrated the value of combining theoretical calculations with experimental measurements and real-world observations. This approach

enhances understanding of building physics and supports the development of practical problem-solving skills.

Overall, the findings emphasise the importance of considering shading as a fundamental component of building design rather than an optional addition. By integrating appropriate shading strategies from the early design stages, it is possible to significantly improve thermal comfort, reduce energy consumption, and contribute to more sustainable built environments.

## Appendix: Compilation of Effective and Ineffective Building Shading Examples by Country

<b>PARTNER SCHOOL: CFP CEMON</b>	
<b>COUNTRY: ITALY (Ceva)</b>	
<b>Effective building shading</b>	
<i>Photo</i>	<i>Reasons why you think shading is effective</i>
	<p>The pergola shades the south window and intercepts solar radiation before it can be transmitted into the building</p>
	<p>The roof overhangs are long and shade the windows below. The windows have screens with adjustable slats to control radiation</p>



Sunshade panels, also called brise-soleil, shield the wall of a building before the window. Sunshade panels can be fixed or adjustable, manual or automatic, to manage the level of protection from radiation, based on the position of the sun.





The windows have white Venetian blinds inside the double glazing and the glass has a solar radiation selective coating



The windows have screens with adjustable and reflective slats to control radiation and prevent it from entering in the buiding  
The windows on the first floors are partly shaded by roof overhangs

## Ineffective building shading

Photo	<i>Reasons why you think shading is ineffective</i>
 A photograph of a modern, multi-story building with a prominent glass facade. The building features a large, cantilevered roof structure. The windows are large and unobscured by external shading devices. The building is situated on a grassy area with a paved parking lot in the foreground.	<p>The pool has large windows to the south and east without external screens and curtains and the roof overhang is short</p>
 A photograph of a two-story white house with blue shutters on the windows. The house has a tiled roof with a small overhang. The windows are not shaded by the roof overhang. The house is surrounded by greenery and a paved driveway.	<p>The house has only open shutters and the roof overhang does not shade them</p>



The building hasn't fixed screens or overhangs and the windows on the first floor are old, large and single glazed and they haven't external shading



The windows on the first and second floors are partly shaded by overhangs but they only have internal curtains, that are less effective. The windows on the ground floor haven't screens.





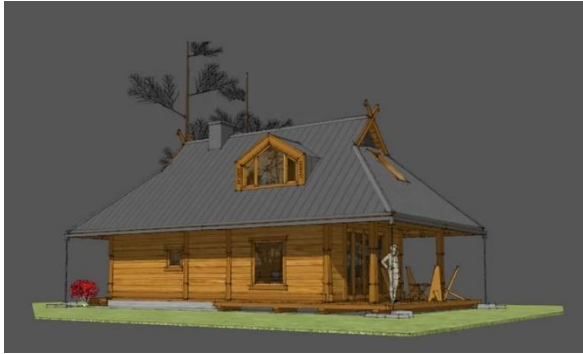
The building hasn't fixed screens or overhangs and the windows haven't external shading, but only Venetian blinds inside.

**PARTNER SCHOOL: Valmieras tehnikums**

**COUNTRY: Latvia (Valmiera)**

**Effective building shading**

<i>Photo</i>	<i>Reasons why you think shading is effective</i>
	<p>The newly constructed Children's Clinical University Hospital in Riga, Latvia, showcases a striking blend of concrete and wood. Large <b>windows, partially screened by stylish wooden panels</b>, offer natural light while reducing solar heat gain and <b>effective shading</b>. <b>Interior blinds</b> provide further shading options. This innovative design not only enhances the building's aesthetics but also contributes to its sustainability.</p>
	<p>Zunda Towers is the tallest building in Riga and Latvia. The Zunda Towers multifunctional complex consists of two round-section towers with bases of different areas, each tower is 30 floors high. The facade of the building provides high sound insulation and <b>protection against ultraviolet radiation</b>. The uniqueness of the Z-Towers facades lies in the fact that it consists of <b>glass units filled with argon</b> and installed one behind the other. Glass units filled with argon <b>provide thermal insulation</b> (argon is a better thermal insulator than air, so glass units with argon help reduce heat loss through windows), <b>sound insulation</b> and <b>UV protection</b> (argon helps protect against ultraviolet rays that can damage furniture and other indoor objects).</p>



Latvia, with its four distinct seasons and varying solar angles throughout the year, presents unique challenges and opportunities for effective building shading. In traditional Latvian Architecture wooden houses often incorporated **deep eaves, overhanging roofs, and strategically placed windows** to minimize solar gain during summer and maximize natural light during winter. Many rural Latvian houses feature wide eaves that extend significantly beyond the walls, providing shade for the windows and walls during the summer months. Also in techniques like using **thick walls, small windows, and deep porches** were employed to regulate internal temperatures.





Flower shop in Riga, Latvia with outdoor exterior **wooden sliding shutters**. These adjustable shading devices offer **precise control over sunlight** and can be easily integrated into the building's facade. They are used to regulate solar heat gain and enhance the building's aesthetic appeal. While summers in our region can be warm, winters are cold. Shading solutions must be carefully considered to avoid excessive heat loss during the colder months. Also shading devices should be aesthetically pleasing and complement the building's architectural style.



The main building of the Latvian State Forests in the country's capital, Riga, located among the trees. The building is well equipped from an engineering point of view. A common **centralized ventilation and cooling system** has been created throughout the building, which is controlled by the building management system, ensuring the most efficient use of resources in terms of energy consumption. The building is **equipped with external blinds**, which reduce the impact of the sun in the summer. Planting **deciduous trees** strategically around the building can provide shade during summer and allow sunlight to reach the building during winter. Also **proper building orientation** can significantly minimize solar heat gain.

## Ineffective building shading

Photo	Reasons why you think shading is ineffective
	<p>Saules akmens (Swedbank Central Building) is an office tower in Riga, Latvia. The building has 27 floors. The building was commissioned on November 17, 2004, and this tower marked the beginning of modern high-rise construction in Riga. The glazed facade solution is designed so that the building is completely transparent in some angles. The building's glass is tinted, which probably protects and reduces the penetration of sunlight into the room and thus reduces the heating of the room. The building also uses internal blinds, which allow you to adjust the lighting according to specific needs and additionally protect against sunlight and heating of the room.</p> <p>However, since the building was built in 2004 and its main goals were to demonstrate the abilities of the architects, not energy efficiency, the technical solutions of the building <b>is ineffective</b> and should currently be improved so that air conditioners do not have to be constantly used to regulate the temperature in the rooms.</p>
	<p>This is the Valmiera Tourist Information Center. This building is located in Valmiera city, Latvia. This building has a very interesting design and this building is all made of glass which is without shading. Tinted glass was chosen for the information center, which reduces the intensity of sunlight (as well as creating a greater sense of privacy for those inside the rooms and reducing glare), thus reducing the penetration of sunlight and heat into the room. However, in sunny and warm seasons, this is not enough to ensure a comfortable stay in the room without the continuous use of air conditioners.</p>



In Riga, on the left bank of the Daugava River, the Latvian National Library (LNB) building, or the Palace of Light, rises. This is one of the most ambitious cultural buildings in the history of renewed Latvia. The new library building was opened in August 2014. This project was created at a time when the concept of "energy efficiency" was not at all on the agenda and its maintenance costs ranged from 2.5 to 4 million euros per year. Glass area: 13,910 m<sup>2</sup>. The building's windows have no external shading, and the windows in the interior are mostly without blinds. The windows are tinted in a greenish color, which is more of a design solution than to protect against the strong effects of sunlight.



Many buildings feature shallow overhangs that fail to provide adequate shade during the peak sun hours. This results in direct sunlight penetrating deep into the building, increasing cooling loads. Large floor-to-ceiling windows certainly look beautiful, but if they are not properly shaded with roof overhangs, outdoor blinds, or panels, too much sunlight can enter the building, heating up the room temperature and making it uncomfortable to stay in. It also requires a lot more energy to prevent this.





This apartment building is located in the Valmiera region and has not undergone any energy efficiency improvements since the Soviet era, when it was built. The windows of the building face south and the only protection from the heat of the sun during the hot summer season is only from the interior of the apartments - curtains or blinds that can cover the window. There are no trees in the yard of the building that would provide shade on sunny days.

**PARTNER SCHOOL: Escola Profissional Amar Terra Verde**

**COUNTRY: Portugal (Villa Verde)**

**Effective building shading**

<i>Photo</i>	<i>Reasons why you think shading is effective</i>
<p><b>Non-structural beams to control solar incidence (Braga)</b></p> 	<p><b>Description:</b> The rehabilitation project of the Braga Municipal Market included the implementation of wooden shading beams on the roof. These non-structural beams were designed to control solar incidence and improve thermal comfort inside the market.</p> <p><b>Effectiveness:</b> The shading beams help reduce the entry of direct solar radiation, maintaining a more comfortable indoor temperature and decreasing the need for artificial climate control systems.</p>
<p><b>Brise-soleil at the Belém Cultural Center (Lisbon)</b></p> 	<p><b>Description:</b> The Belém Cultural Center (CCB) uses brise-soleil on its facades, which are horizontal or vertical solar protection devices installed along the external walls.</p> <p><b>Effectiveness:</b> The brise-soleil reduces the entry of direct solar radiation during the summer months, maintaining a comfortable indoor temperature without compromising natural light. The solution is adapted to the building's solar orientation.</p>

**Green roofs at the EDP Foundation Building (Lisbon)**



**Description:** The EDP Foundation building features green roofs that help regulate the building's temperature.

**Effectiveness:** The plants on the roofs act as thermal insulators, providing surface shading and helping retain moisture, which reduces the need for air conditioning in summer. Additionally, they contribute to CO2 absorption and increased biodiversity.

**Ventilated facade with automated blinds**



**Description:** EPATV school building uses a ventilated facade with automated blinds that control solar incidence throughout the day.

**Effectiveness:** The blinds adjust automatically according to the sun's position, allowing precise control of the amount of solar radiation entering the building, optimizing energy efficiency and providing thermal comfort.

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## Ineffective building shading

*Photo*

**Large glass windows without solar protection in office buildings**



*Reasons why you think shading is ineffective*

**Description:** Many commercial buildings like this in downtown Lisbon, including some office towers, have large glass windows without external solar protection, allowing excessive heat entry.

**Ineffectiveness:** These large glass surfaces increase heat gain inside the building during summer, resulting in the need for intensive air conditioning systems, which raises energy consumption and reduces thermal comfort.

**Fixed and inadequate awnings in old buildings**



**Description:** Some old buildings, especially in historic neighborhoods, use fixed awnings as their primary shading solution for balconies or windows.

**Ineffectiveness:** Fixed awnings do not adjust to seasonal variations or the sun's angle, meaning that in winter they block sunlight and heat, while in summer they may not always provide efficient protection against intense heat.

**Facades without adequate solar protection**



**Description:** Many old buildings like these in downtown Porto lack adapted shading solutions, with glass facades and traditional tiles exposed to direct sunlight.

**Ineffectiveness:** The lack of solar protection (such as blinds or brise-soleil) results in significant heat gain during summer, forcing the use of air conditioning systems to maintain a comfortable indoor temperature, increasing energy consumption.

**Panoramic windows without shading in modern apartments**



**Description:** In some newly built apartments, especially those with panoramic views, the large windows lack effective shading systems such as external blinds or brise-soleil.

**Ineffectiveness:** These windows allow excessive heat entry in summer, causing thermal discomfort and increasing air conditioning costs due to insufficient external solar protection.

**Lack of natural ventilation and shading in apartment buildings in urban areas**




**Description:** Some apartment buildings in urban areas (like Lisbon or Porto) have facades with little space for natural ventilation and suffer from a lack of adequate shading, especially in areas with high solar exposure.

**Ineffectiveness:** The lack of effective ventilation and shading makes residential units very hot in summer, resulting in thermal discomfort and increased air conditioning use, leading to higher energy costs.

**PARTNER SCHOOL: Technical school “Ivan Sarić”**

**COUNTRY: Serbia (Subotica)**

**Effective building shading**

<i>Photo</i>	<i>Reasons why you think shading is effective</i>
	<p>This image is an example of good building shading. The awning in this case serves as a physical barrier between the glass of the shop window and the sun. This prevents direct sun influence and the heating of the room.</p>



The building is excellently positioned relative to the sun's path, providing effective protection against excessive sunlight exposure. It is also equipped with curtains that allow for additional regulation of sunlight entering the space. Thanks to these features, air conditioning is not necessary.



This building has good shading because the windows are covered with a protective material that reduces sunlight penetration and heat. This feature helps maintain a cooler indoor environment and minimizes glare.





This building doesn't have too many windows, just enough to let the light in. All of the windows have curtains on the inside, so it's not the best but it's an improvement.



The shading on this house is good because the windows don't have a lot of exposure to sunlight during its peak. During the mid-day the sun isn't that strong and the windows let in the sunlight. This house is a good representation of shading

## Ineffective building shading

Photo	<i>Reasons why you think shading is ineffective</i>
	<p>This image is an example of bad building shading. This case shows the upper window of a building that is exposed to the sun without any barrier. Thus the sun can warm the interior of the room directly through the window.</p>
	<p>The building has inadequate sun protection due to its unfavorable position relative to the sun's path. The lack of curtains or other systems for controlling sunlight further contributes to the overheating of the rooms. As a result, air conditioning is essential to maintain an optimal indoor temperature.</p>



This building has poor shading because the large glass surfaces are fully exposed to direct sunlight without adequate overhangs or shading devices. This design can lead to excessive heat gain and glare, making the interior less energy-efficient and less comfortable.



This building has an excessive amount of windows on a single tall wall and none of them have any kind of curtains.






During the summer, this part of the building is extremely hot and stuffy, as sunlight predominantly enters the rooms. Especially during summer, it becomes so hot that it is hard to breathe during the day, and the nights are also warm. Even open windows do not help, as no air flows in. However, during winter, it becomes pleasant and suitable for living.

**PARTNER SCHOOL: School Center Ptuj**

**COUNTRY: Slovenia (Ptuj)**

**Effective building shading**





<i>Photo</i>	<i>Reasons why you think shading is effective</i>
	<p>The shading structure visible on this building demonstrates a well-designed solution for reducing heat gain and optimizing energy efficiency. The metal panels provide partial shading, which minimizes direct sunlight entering the interior spaces. This not only reduces cooling costs but also helps maintain a comfortable indoor environment. The pattern of the panels may additionally create an aesthetically pleasing façade, contributing to the architectural value of the building. Overall, this approach balances functionality and design, making it an excellent example of effective shading.</p>
	<p>This circular building incorporates an external perforated façade that acts as a shading layer. The design reduces the intensity of direct sunlight while allowing diffused natural light to enter, thereby reducing the reliance on artificial lighting. This method also minimizes solar heat gain, especially in warmer months, improving energy efficiency. The uniform coverage around the building ensures consistent shading and contributes to the structure's modern and innovative appearance, highlighting both energy-saving and aesthetic benefits.</p>
	<p>The building in this image benefits from shading elements provided by surrounding trees and architectural overhangs. Trees act as natural shading solutions, reducing heat buildup and creating a cooler microclimate. Additionally, the structure itself seems to integrate shading devices on its windows, limiting exposure to direct sunlight. This combination of natural and built shading strategies ensures a sustainable approach to managing energy use while creating a visually appealing and environmentally friendly setting.</p>



This residential building features shading elements such as balconies and overhangs, which prevent excessive sunlight from penetrating the windows during peak hours. These elements are particularly beneficial during summer, as they keep indoor spaces cooler and reduce the need for air conditioning. The integration of solar panels on the roof complements the shading system, demonstrating a holistic approach to energy efficiency. This setup not only improves the building's sustainability but also increases its value for occupants.



The multi-story residential complex showcases a well-thought-out shading system with horizontal and vertical elements on balconies. These features block direct sunlight while maintaining adequate ventilation and natural light. The use of consistent materials and designs across the façade enhances the building's visual coherence. Such shading solutions are particularly effective for large structures, as they provide thermal comfort for residents and contribute to the overall energy efficiency of the complex. This demonstrates a practical and scalable approach to shading in urban environments.

<b>Ineffective building shading</b>	
<i>Photo</i>	<i>Reasons why you think shading is ineffective</i>
	The shading design on this building appears insufficient for preventing solar heat gain. The large windows are fully exposed to direct sunlight, which likely increases the interior temperature, leading to higher cooling costs during warmer months. The lack of overhangs or external shading structures highlights a missed opportunity to improve energy efficiency and occupant comfort. This example demonstrates the importance of integrating shading solutions during the design phase to mitigate these issues.
	This commercial building's glass façade lacks adequate shading features, such as overhangs or louver systems, to block direct sunlight. The extensive glass surface increases solar heat gain, making the interior heavily reliant on air conditioning. Additionally, the absence of shading results in potential glare issues, which could affect visibility and comfort for occupants. This scenario underscores the need for thoughtful shading solutions in buildings with large glass façades.
	The building design does not incorporate external shading elements, leaving the large windows exposed to direct sunlight. This exposure can lead to significant heat buildup inside, reducing thermal comfort and increasing energy consumption for cooling. Furthermore, the flat roof design lacks features that could contribute to passive cooling, making the structure less sustainable. This highlights the importance of incorporating shading strategies to optimize energy performance.
	The residential building in this image has large, unshaded windows that are vulnerable to direct sunlight. Without overhangs or shading devices, the interior spaces are likely to experience excessive heat during the summer months, leading to higher cooling demands. This case demonstrates how insufficient shading can negatively impact both energy efficiency and indoor comfort, particularly in residential buildings.


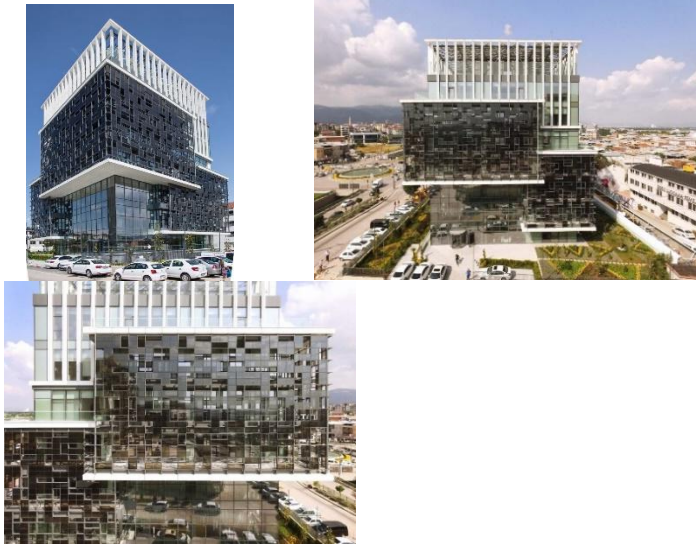


This multi-story residential complex exhibits a lack of uniform shading solutions, leaving many windows exposed to direct sunlight. While some balconies may provide minimal shading, the overall design does not prioritize solar protection. This results in uneven energy performance and comfort levels for residents. Implementing consistent shading elements, such as adjustable louvers or deeper overhangs, could significantly improve the building's sustainability and functionality.

**PARTNER SCHOOL:** Cavit Çağlar Mesleki ve Teknik Anadolu Lisesi

**COUNTRY:** Turkey (Bursa)

**Effective building shading**

<i>Photo</i>	<i>Reasons why you think shading is effective</i>
	<p><b>BURSAGAZ BUILDING</b> City: Bursa</p> <p>The Bursagaz building's Shading Systems help maintain the temperature balance inside the building, reducing the use of air conditioning and heating systems. This decreases energy consumption and ensures cost savings. The building features a glass façade that shades and surrounds the offices. This cube-shaped shading system also adds a modern and innovative look to the architectural design of the building.</p> 



## TOWN SQUARE

City: Bursa

The most of glass in the Town Square allows a lot of Sunlight to enter.

The glass in Town Square is thick, and the sunlight coming from the sun takes in only the warm air without disturbing the people and coming from the very little amount sunlight.

In winter, sunlight comes in, and the glass absorbs the sunlight, letting only the warm air in. In summer, however, because there is much more sunlight, the glass absorbs the incoming rays and prevents people from being disturbed by the heat.





## **MATLI PLAZA**

City: Bursa

The shading system of **Matlı Plaza** is designed in harmony with the building's circular and modern architecture. This system balances sunlight in the office spaces, enhancing energy efficiency and improving indoor comfort. It also provides a healthier working environment for employees and offers an aesthetically pleasing appearance throughout the building. With its eco-friendly features, it contributes to sustainability goals.





## SKY TOWER

City: Bursa

The shading system of **Sky Tower** is designed in harmony with its modern architecture. This system balances the sunlight entering the office spaces, keeping the indoor temperature under control and increasing energy efficiency. Additionally, it provides a comfortable working environment for employees and enhances the aesthetic value of the building.








## HILTON BURSA

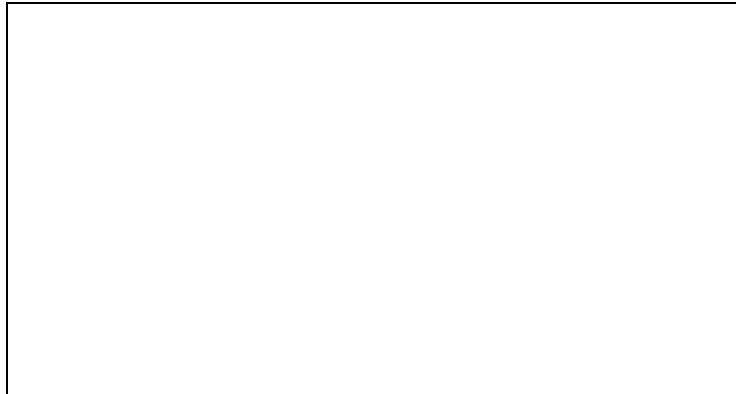
City: Bursa

The Bursa Hilton is a prime example of modern hotel design, where energy efficiency and aesthetics are of paramount importance. The façade design incorporates sunlight-reflecting glass and solar shading panels. This innovative design helps to prevent overheating in the rooms during the summer months, which in turn reduces cooling costs and provides a comfortable and aesthetically pleasing environment for hotel guests. The use of LED lighting ensures a well-balanced natural light environment.



## Ineffective building shading

Photo	Reasons why you think shading is ineffective
	<p><b>BURSA AOS ONCOLOGY HOSPITAL</b></p> <p>Despite the large glass surfaces and modern design, the shading system of <b>Bursa AOS Oncology Hospital</b> may lead to excessive overheating indoors during the summer. This can increase the usage of air conditioning, thereby raising energy consumption. Additionally, if adequate shading is not provided on the building's facade and outdoor areas, it may become challenging to create a comfortable environment for visitors in outdoor spaces. These deficiencies could have negative impacts on both energy efficiency and user comfort.</p> 
	<p>The shading system of <b>Bursa Courthouse</b> may lead to excessive overheating indoors during the summer due to the large glass surfaces. This can increase the use of air conditioning, raising energy consumption. Additionally, the lack of sufficient shading measures on the building's facade could allow direct sunlight to enter, causing glare issues indoors. These deficiencies can negatively affect</p>



both comfort and energy efficiency.



### BURSA ATATÜRK HIGHSCHOOL

Although the Old Bursa Atatürk High School is a historic building, it lacks modern shading systems. The large windows allow excessive sunlight during the summer, while significant heat loss occurs in the winter. During the restoration processes, no improvements were made for energy efficiency, and the focus was solely on aesthetic priorities.



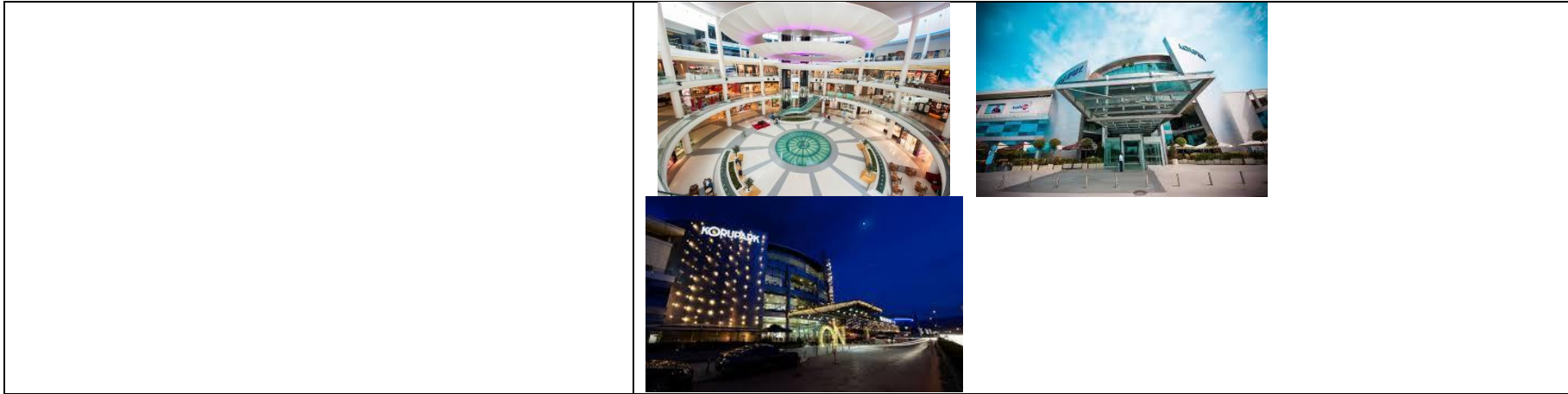


The glass facades of the Istanbul Beyoğlu Business Center allow sunlight to enter directly, causing excessive heat during the summer and heat loss in the winter. There is a lack of shading elements or designs focused on energy efficiency, and modern climate control solutions are not implemented on the exterior.



The shading system of **Bursa Korupark** Shopping Mall may not effectively block sunlight due to the abundance of large glass surfaces and open spaces. This can lead to overheating indoors, especially during the summer, increasing the need for air conditioning and reducing energy efficiency. Additionally, the lack of sufficient shading in outdoor areas could make it difficult for visitors to spend long periods of time outdoors. These shortcomings can negatively affect both comfort and environmental sustainability.





Solar Village Project – Heat flow calculations and Identification of Examples of Shading

**COUNTRY: GLOBAL**

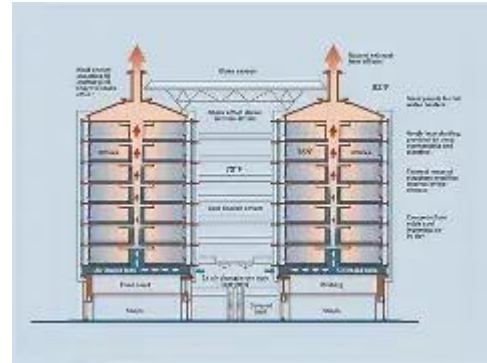
**Effective building shading**

*Photo* *Reasons why you think shading is effective*

**Eastgate Centre – Harare, Zimbabwe**



The Eastgate Centre uses passive cooling and natural ventilation, drawing inspiration from termite mounds. It integrates deep overhangs, shading devices, and ventilation chimneys to reduce the need for mechanical air conditioning. **Why it's effective:** Combines natural shading with thermal mass and airflow to drastically cut energy use.



**Arizona Biomedical Campus – Phoenix, USA**



This building employs horizontal brise-soleil systems optimized for solar orientation. The aluminum fins block harsh desert sun while maintaining daylight and visibility. **Why it's effective:** Custom-designed shading systems adapted to the region's intense solar gain and heat.



**Pearl River Tower – Guangzhou, China**




This skyscraper includes an intelligent façade with sunshades and double-skin glazing. Shading and wind turbines are integrated into the building skin.  
**Why it's effective:** Reduces heat gain while producing energy and maintaining aesthetics.

**Solar Umbrella House – Los Angeles, USA**



A private residence with a large solar array that acts as a sunshade over the building, providing energy while blocking direct sun.  
**Why it's effective:** Synergistic design – shading and energy production in one elegant architectural solution.

Ineffective building shading	
Photo	Reasons why you think shading is ineffective
<p><b>Glass Box Homes – Australia / USA suburbs</b></p> 	<p>Many new suburban homes feature large, unshaded glass facades, often oriented west.</p> <p><b>Why it's ineffective:</b> Leads to excessive heat gain, glare, and high air conditioning loads.</p>

**20 Fenchurch Street (“Walkie Talkie”), London, UK**



This building famously acted like a concave mirror in sunlight, focusing intense reflected light onto streets below. Temperatures on impacted surfaces reportedly reached up to **91 °C** and even damaged parked vehicles and outdoor furniture. In effect, instead of shading, it magnified solar heat into small areas. Improper façade curvature combined with reflective materials leads to unintended solar concentration; no counter-shading or matte surfaces to mitigate glare.

**Over-shading with static vertical louvers**



In some designs, vertical louvers are applied uniformly around building façades, without adapting to orientation or sun paths. These louvers can block desired daylight on north-facing walls or cause deep shadows inside. One-size-fits-all louver systems don't distinguish east/west vs. north/south façades, resulting in over- or under-shading. Some studies indicate that mismatch of shading geometry leads to poor daylight.

### Perforated mesh shading panels



Perforated mesh can reduce light too much if the aperture is too small, or be insufficient if the mesh is too open. It may lead to **uneven shading**, glare through holes, or poor heat control if not optimally designed.

### Buildings with horizontal overhangs



Overhangs alone may not shield low sun angles in winter or low afternoon sun on west façades. This results in **insufficient shading** at critical times, especially late afternoons or mornings.

