

Green Facades

Analog and Digital Lesson Unit

Combating Urban Heat with Urban Greenery

Lower Secondary Level (all school types)

Middle school

Biology, Geography, Physics, Technology, and Art

Project day, 4-5 class periods

Classroom

Includes student experiments

Designed for middle school students, this project day explores the topic of the thermal benefits of green facades and demonstrates how research findings from academic and pedagogical fields can be successfully integrated into the classroom to teach Education for Sustainable Development (ESD) as a cross-curricular theme.

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Content

Cities actively contribute to global climate change and, at the same time—unlike other forms of land use—are particularly affected by the impacts of climate change. In addition to air pollution and extreme weather events such as heavy rain, city dwellers suffer in particular from summer heat waves, which will continue to intensify as a result of global warming. Urban green spaces, as a measure designed to protect the climate and adapt to climate change, offer an effective way to counteract the so-called "heat island effect."

Through a series of stations, students learn about various green facade systems as well as climbing plant species and use experiments to investigate the properties of plants using sensors (the greenhouse gas carbon dioxide, photosynthesis, the shading effect, transpiration, and evaporative cooling). They also have the opportunity to build their own green facade models with the help of detailed digital instructions.

Prerequisites

None; basic knowledge of photosynthesis and thermodynamics is beneficial

Notes

The learning module is designed as a project day and lasts 4-5 hours, depending on the learning group, excluding the construction of green facade models. The development phase takes place through group work. We recommend 4 students per group. A separate project day should be scheduled for building the green facade models. The experiments can also be integrated individually into lessons, for example, to address the content area "Ecosystems and Nature Conservation" (NRW) in biology class.



Materials

- Introductory presentation (PowerPoint)
- Worksheets
- iPads, projector
- Sensors (CO_2, humidity), kitchen thermometer
- See the lesson plan for additional materials (e.g., funnel, salt, small plastic bottles)



Apps

- Plant identification app (e.g., PlantNet)



Student Experiments

- Measurement of various parameters (CO_2, temperature, humidity)

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Learning Objectives

Main Objective

The goal is, on the one hand, to show students how cities contribute to climate change due to their essential functions and spatial characteristics (urban densification) and, on the other hand, to highlight the impacts of climate change on urban areas and their residents, as well as to convey the positive effects—and thus the potential—of urban green spaces, using green facades as an example of a measure designed to protect against and adapt to climate change. Since the negative effects of climate change—such as the increase in hot days and the associated rise in heat-related deaths—cause significant anxiety among children and adolescents, it is particularly important to us that this project day helps students understand the significance of urban green spaces as a solution strategy and highlights practical, real-world options for action (greening the school grounds).

Competency Areas

Handling Specialized Knowledge

Students will be able to...

» Identify the advantages and disadvantages of urban life and explain how they relate to the phenomenon of urban densification.

» Describe the characteristics of various green facade systems and climbing plant species.

» Explain the role of the greenhouse gas CO_2 in the natural and anthropogenic greenhouse effects.

» Explain the basic principles of photosynthesis.

» Explain the phenomenon of transpiration as well as the mechanism of shading and their significance for the cooling effect of plants in urban areas.

» Describe the characteristics of the scientific method.

Communication

Students can...

» identify relevant information in texts with scientific content and use the findings to justify self-formulated hypotheses and evaluate experiments.

» Document observations and results from various experiments on the topic of green facades in a structured manner.

» take responsibility for work processes and products when conducting scientific work in a team and negotiate tasks and work results in a fact-based manner.

Gaining Insights

Students can...

» Formulate hypotheses regarding scientific questions and support them with information from the source material.

» Conduct experiments on the topic of green facades using various measurement sensors largely independently, in a goal-oriented and appropriate manner, while identifying potential sources of error.

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Areas of Competence

Continuation: Knowledge Acquisition

Students can...

» Interpret records of observations and measurement data related to a specific question and use them to deduce how urban green spaces can contribute to heat reduction.

Assessment Students recognize...

» explain the relevance of raw data for decision-making in scientific and technical contexts.

» weigh the arguments for and against green facades, take a stance, and defend it against other positions with sound reasoning.

Fact Analysis

The All-Around Solution: Green Building Facades–Many Positive Effects of Green Facades

Cities, in particular, contribute to climate change and are themselves severely affected by its consequences. Prolonged periods of high temperatures, with an increasing number of tropical nights, are transforming densely built-up and heavily impervious urban neighborhoods into heat islands, with negative effects on urban green spaces, biodiversity, and the health of city residents. Global warming, increasing soil sealing, and waste heat from air conditioning systems, industry, and traffic are causing the urban climate to heat up more and more. The temperature differences between inner-city heat islands and suburban areas can easily reach 10 °C in the summer (Bundesverband Garten-, Landschafts- und Spielplatzbau e.V., 2020).

And cities continue to grow: In 1950, not even one-third of the world's population lived in cities; since 2007, that figure has been more than half. According to UN projections, by 2025 more than two-thirds of all people will live in urban areas (UN, 2019). In line with this urbanization, the degree of land sealing is increasing, which places greater strain on the urban population and eliminates habitats for flora and fauna. Climate protection and adaptation to climate change are therefore complementary strategies that cities must urgently address.

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Therefore, greening roof and facade surfaces represents an ideal measure—within the scope of architectural possibilities—for converting existing areas into vegetated spaces, with anticipated positive effects on many levels:

Positive effects of green facades on the urban climate, building energy efficiency, well-being, and biodiversity.

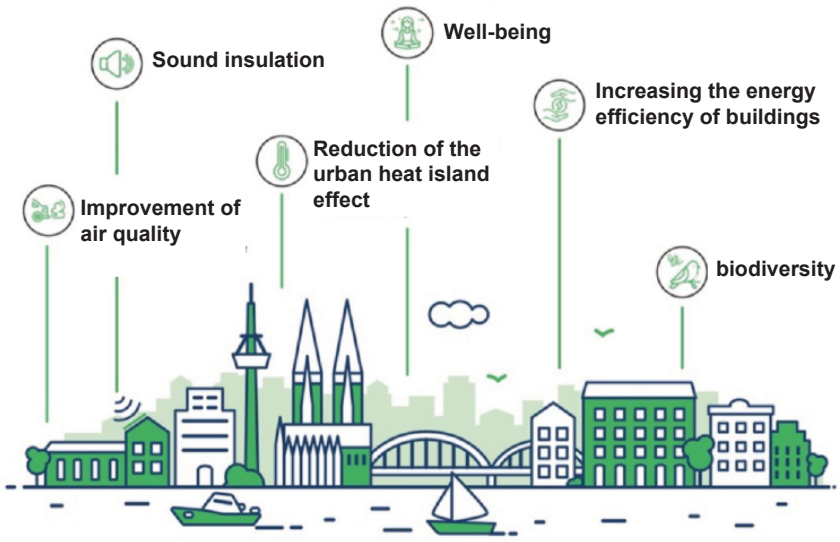

Figure 1: Positive effects of green facades, Institute of Biology Education, 2022

Reduction of the heat island effect

Green roofs and facades act as natural air conditioners and can alleviate overheated hot spots locally. By cooling and humidifying the dry, hot air, they create a more pleasant climate. When properly implemented and distributed, green roofs and facades can influence not only the immediate vicinity of a building but also the climate of the entire city. Depending on the building structure and the proportion of the building's surface area covered by greenery, temperature reductions of up to 2 °C can be achieved (Federal Association of Garden, Landscape, and Playground Construction, 2020).

Increasing the Energy Efficiency of Buildings

Cities account for over 75 percent of global greenhouse gas emissions and 66 percent of global energy consumption (UN, 2019). About one-third of this final energy is consumed by buildings (construction and operation, including heating and cooling). Since green roofs have positive energy effects on the heating and cooling balance of buildings, they can help reduce urban energy consumption in the building sector: In summer, the cooling and shading effects of green facades keep the interior of the building from heating up as much. In winter, (evergreen) climbing plants, especially on north- and east-facing facades, reduce heat loss through the building envelope (Pfoser, 2023; see the GrüneFassadeKöln research project, 2023).

Improvement of Air Quality

Plants have a positive impact on urban air quality and help reduce particulate matter pollution: Depending on the surface structure of their leaves, plants can trap dust particles (Pfoser, 2023). Due to the large surface area of plants, respirable fine particulate matter can be deposited and adsorbed from the air (Gorbachevskaya et al., 2012). Thus, plants along heavily trafficked roads can help reduce PM10 particulate matter pollution. The particles settle on the leaves of the plants and remain there until they are washed away by rain (Schmauck, 2019).

Biodiversity

Green roofs and green facades provide natural refuges for insects and birds. Evergreen plants, in particular, serve as effective year-round refuges. Furthermore, green roofs and

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facades serve as building blocks of a biotope network–especially in urban areas that do not allow for other forms of greening. As "stepping-stone biotopes," they ensure the survival of species and, by expanding food and habitat resources for plants and animals, help prevent species extinction (Pfoser, 2023; Federal Association of Garden, Landscape, and Playground Construction e.V., 2020).

Additional Benefits: Building Preservation & Value Appreciation

An unprotected flat roof typically lasts only 15–25 years because it is exposed to severe stresses such as extreme temperature fluctuations, UV radiation, ozone, hail, and wind. This leads to material fatigue, cracks, and leaks. Green roofs, on the other hand, protect the roof membrane from heat, cold, and mechanical damage. This significantly reduces temperature stress, and the service life can–as examples from the 1970s show–roughly double (Federal Association of Garden, Landscape, and Playground Construction, 2020). In addition, green facades protect materials from UV radiation, extreme temperatures, storms, rain, and hail. Furthermore, green facades offer another advantage: deciduous and evergreen climbing plants provide protection against graffiti (Pfoser, 2023). Roof gardens, as well as green roofs and green facades, contribute to improving the living and working environment, create opportunities for experiencing nature and provide nearby recreational spaces, and increase the value of both the property and the entire residential neighborhood (Federal Association of Garden, Landscape, and Playground Construction, 2020).

References

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Didactic Justification

The topic of "green facades"through its action-oriented approach and the demonstration of a solution strategy that can be implemented–even on a small scale–offers the opportunity to address and, where possible, alleviate climate-related fears about the future. This is just one of the many social, technical, and pedagogical reasons to integrate this topic into school curricula.

The topic of green facades is a current, socially relevant issue in urban planning that, when considered in the context of "urban heat," connects to the everyday lives of many young people. The topic also highlights the link between human actions and ecological consequences and, in the spirit of ESD, can help raise awareness of the need for sustainable approaches. Furthermore, engaging with such a topic has the potential to foster learners' emotional connection to their surroundings and to nature, and to create positive associations with urban green spaces. Overall, the topic can thus help raise young people's awareness of sustainable development and the relevance of nature to our society, thereby helping them develop a sense of responsibility toward the environment.

Middle school students learn important curriculum-based content through this topic. Examples include biological concepts such as photosynthesis, the importance of green spaces for the ecosystem, and the role of plants in air purification and CO_2 sequestration, all of which align with the North Rhine-Westphalia (NRW) state curriculum. By situating the topic within the field of urban planning, connections to geography lessons are also possible. In this way, for example, ideas are introduced that can be revisited in upper-level classes when addressing urbanization and urban development (NRW). In the field of physics, the material can also be linked to the content area "Temperature and Heat" in the first progression level (pilot phase) (NRW), which could be utilized in the context of a spiral curriculum.

These curricular connections already highlight another characteristic of the topic: its interdisciplinary nature. In our time, when global challenges cannot be solved with the expertise of a single discipline, such approaches are becoming increasingly important in general education. Thanks to the module's action-oriented approach, students not only engage with subject-specific content but also put related ideas for greening facades into practice, thereby establishing connections to the subjects of technology and art. Engaging with practical applications also fosters problem-solving skills and creative thinking. Particularly in the context of Education for Sustainable Development (ESD), it is important that students link theoretical foundations with practical examples and expand their knowledge through their own ideas in order to take action themselves. This action-oriented approach as a pedagogical principle is evident not only in the implementation of green facade measures but also in the conduct of preparatory experiments as part of guided inquiry-based learning.

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Schedule of the Project Day

Introduction



The teacher begins the project day with the presentation and first asks the students to estimate what percentage of the world's population lives in cities. The students then discuss the advantages of city life.

Media: Projector

Materials: HidS_Introduction file

Problem Statement



As the presentation continues, the issue of urban heat is introduced (explanatory video "Urban Densification"). Using the example of Lisa, who lives in a densely built-up neighborhood, the problem is illustrated and the reasons behind it are discussed.

Solution-oriented -> Lisa has already researched ways to reduce the heat problem in the city. Based on this, the class will work together to formulate the research question for the project day and derive the corresponding hypothesis.

Media: Slide or projector

Materials: HidS_Introduction file

Development



The development phase takes place in groups and consists of five different stations, which are described on the following pages (9–13). We recommend 4 students per group.

Media and materials: see notes for the following stations

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Station: Green Facades

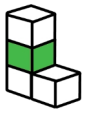
Goal



Using a digital learning environment, students explore various green facade systems and plant species.

For this station, plant identification apps or existing green facade models can be used.

Procedure



A) Students use plant identification apps to identify the plants in the photos within the digital learning environment.

or

B) As part of a workshop, students build small green facade models. Digital building instructions with a materials list are available for the students and to help the teacher prepare for the course.

Media: iPads,

Files: Learning Environment, Worksheet: WS_facade_greening

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Experiment Station – Carbon Dioxide, a Greenhouse Gas

Goal



At this station, the greenhouse effect is first explained. In the subsequent experiment, students discover the effect carbon dioxide has on air temperature.

Materials



Media: iPad

Materials per group:

- 2 kitchen thermometers
- 1 small plastic bottle: still water
- 1 small plastic bottle: sparkling water
- 1 teaspoon
- Salt
- Funnel
- Lamp (heat)
- Ruler
- Clock (cell phone or iPad)

Files: Worksheet: WS_facade_greening (Experiment Station – Carbon Dioxide, a Greenhouse Gas)

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Experiment Station – Photosynthesis

Goal



In this experiment, students learn how plant photosynthesis affects the composition of the air.

Materials



Equipment: 2 iPads

Materials per group:

- Ivy
- Scissors
- Sample containers
- CO_2sensor
- Lamp (light)
- Clock (cell phone or iPad)

Files: Worksheet: WS_facade_greening (Experiment Station – Photosynthesis)

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Experiment Station – The Shadow Effect

Goal



In this experiment, students measure the effect of "green facades" on the heating of surfaces.

Materials



Materials per group:

- Kitchen thermometer
- Wooden box or cardboard house
- Ivy
- Lamp (heat)
- Ruler
- Glass of water
- Clock (cell phone or iPad)

Files: Worksheet: WS_facade_greening (Experiment Station – The Shadow Effect)

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Experiment Station – Transpiration and Evaporative Cooling

Goal

Through two different experimental approaches, students learn about the phenomenon of transpiration in plants. In addition, the evaporative cooling resulting from transpiration is explored through text-based activities.

Materials

Media: iPad

Materials per group for Experiment 1:

- 1 plant (cut flower; white tulips work best)
- Glass of water
- Ink
- Knife
- Cutting board
- spoon

Materials per group for Experiment 2:

- Humidity sensor
- Ivy
- Scissors
- Lamp (light)
- Sample container
- Clock (cell phone or iPad)

Files: Worksheet: WS_facade_greening (Experiment Station – Transpiration and Evaporative Cooling)

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Schedule for the Project Day (Continued)

Backup



The students record their results on the designated worksheets.

Media: Worksheets

Transfer



During the closing plenary session, the results from the individual stations are compiled, the initial hypothesis is tested, and the research question is answered. Additionally, students can discuss possible ways to implement green facades at their own school. For more information and greening options, visit: https://greencoolschools.eu/

Additional



Project Day: Building Your Own Green Facade Models

With the help of digital building instructions, students can build and plant their own green facade models.

Media: iPads

Materials: See the click-through tutorial on building a green facade model

Files: Click-through tutorial: BuildingInstruction_Modell_ScaffholdingSystem.pdf

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Notes & Tips

» The project phase is conducted in groups. We recommend 4 students per group.

» After the "Green Facades" station, we recommend practicing with the students how to use the sensors for the "Photosynthesis" and "Transpiration & Evaporative Cooling" in a whole-class setting.

» Preparation for the "Carbon Dioxide as a Greenhouse Gas" experiment station: Drill holes in the lids of the small plastic bottles large enough to fit the kitchen thermometers. On the day of the experiment, fill each plastic bottle with still water and sparkling water at room temperature. Instruct the students to maintain the exact distance between the heat lamp and the plastic bottles. The kitchen thermometers must not be submerged in the water but should measure "in the atmosphere."



Photo: Institute for Biology Education

» Preparation for the "Shading" experiment station: To shade the boxes or houses, it's a good idea to tie together bundles of ivy or fern leaves.





Photos: Institute for Biology Education

Imprint

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https://www.greencoolschools.eu

Authors: Wibke Niels und Marlin Penzenstadler, Institut für Biologiedidaktik, Universität zu Köln

Contributors: Nils Kampen, Layout, Institut für Biologiedidaktik, Universität zu Köln

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