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Home automation, bio-sustainability and energy saving

BIOS4YOU AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS THANKS TO THE USE OF AUGMENTED REALITY

Project Number: KA220-BW-23-30-126516

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General topic of the learning path	Smart Technologies for a Sustainable Future
Specific name of the learning unit	Home Automation, Bio-sustainability and Energy Saving
Age of the target users	14-18 years
Requirements for the learner	Basic knowledge of technology and natural sciences. Basic digital skills (browsing, use of educational apps). Interest in the environment, sustainability and innovative technologies. Experience with augmented reality tools (not mandatory).
Description of the learning unit	Students will explore how home automation and the principles of bio-sustainability can contribute to reducing energy consumption and CO_2 emissions. The unit integrates **augmented reality (AR)** tools to simulate smart home environments, compare energy classes and design innovative solutions inspired by nature (biomimicry). Through a workshop-based and interdisciplinary approach, participants will design smart homes that optimise consumption through sustainable technologies and AR control and simulation systems.
Subject: Parties involved	Science, Technology, Civic Education, Computer Science
Keywords	Home automation, bio-sustainability, energy saving, smart homes, smart sensors, biomimicry, environmental automation, augmented reality,

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	SDG 7 (Affordable and clean energy), SDG 11 (Sustainable cities and communities)
Key qualifications, skills and knowledge that can be acquired	• Understanding of how home automation systems work and sources of energy consumption in the home • Ability to design sustainable solutions inspired by natural models (biomimicry) • Critical use of AR technologies for the exploration, simulation and presentation of energy data • Transversal skills: teamwork, problem solving, systemic thinking, effective communication • Basic knowledge of the **Sustainable Development Goals (SDGs)**, with a focus on energy and sustainable living.
Resources and didactic aids used	• **Augmented reality** apps and platforms (e.g. CoSpaces Edu, Merge EDU, Assemblr) • Technical data sheets on home automation systems, renewable sources, insulating materials • Online energy simulations (consumption calculators, energy classes) • Creative workshops (for digital and physical prototyping) • Informative videos, case studies (e.g. passive houses, smart cities, bioclimatic architecture)
Assessment criteria and evaluation	• Knowledge of scientific concepts Accurate understanding of home automation, energy saving, sustainability and their environmental impact • Use of AR technologies Ability to use augmented reality tools to explore and simulate smart home systems • Sustainable design Creativity and consistency in the design of an efficient and bio-inspired housing solution • Link to SDGs Reflection on the contribution of technologies to the achievement of the UN Goals • Collaborative work Active and constructive participation in the team, sharing of tasks • Project presentation Clarity, effective communication and appropriate use of multimedia and AR

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	• Continuous assessment Formative feedback during group work and interim assessments through interactive AR quizzes

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1. Evidence of Climate Change

Explaining what is meant by a smart city is a rather complex operation, as there is currently no clear definition of the concept. An attempt to outline the characteristics of a smart city was made by the United Nations, which provided this definition in 2016:

> "[smart city] makes use of opportunities from digitalization, clean energy and technologies, as well as innovative transport technologies, thus providing options for inhabitants to make more environmentally friendly choices and boost sustainable economic growth and enabling cities to improve their service delivery"[1]

The use of technologies in urban contexts could, therefore, be a resource to deal with the climate emergency as well. According to the data collected by the United Nations in the World's Cities in 2018 report, by 2050 two-thirds of the world's population will live in cities: this will determine a sustainability problem on several fronts, especially in the environmental sphere.

One of the most interesting topics to investigate to better understand what opportunities the transition towards smart urban and housing forms can offer us may be that related to electricity and, more specifically, to electricity consumption.

In 2015, as many as 130 countries belonging to the UN signed the 2030 Agenda for Sustainable Development in which an action programme for people, planet and prosperity is adopted; the programme consists of 17 Sustainable Development Goals, i.e. seventeen targets through which sustainable development policies can be implemented.

Figure 1 - The seventeen sustainability goals

These include ensuring access for all to cheap, reliable, sustainable and modern energy systems (Goal 7): electricity has become essential for many of our daily activities, and the transition to clean forms of electricity represents a major social, economic and environmental opportunity; moreover, around 60 per cent of greenhouse gas emissions are due to energy, which represents a huge threat to our planet and its survival.

Reaching the seventh objective means:

- Ensuring access to modern, reliable and, above all, affordable energy services;
- Increase the share of renewable energy in total energy consumption;
- Doubling the global rate of energy efficiency improvement by 2030

[1] United Nations (2016), UN-Habitat & New Urban Agenda
http://nua.unhabitat.org/pillars.asp?PillarId=7&ln=1

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- Improve international cooperation to facilitate access to clean energy research and technologies, as well as promote investment in energy infrastructure and clean energy-related technologies;
- Support least developed countries in the adoption of energy from non-polluting sources.

Figura 2 - Objective 7/30

The European Union also adopts policies aimed at combating climate change, so much so that it has even set itself a particularly ambitious goal: to be the first climate-neutral continent by 2050. Regarding the energy issue, the European Union promotes energy efficiency and renewable energy sources.

2. Where does the energy we use come from?

The first distinction on electricity sources must be made between non-renewable and renewable. Non-renewable energy sources are so called because they constitute a limited pool that is exhausted through use: these are sources such as fossil and nuclear fuels, whose impact on the environment is negative. Currently, fossil fuels are the most widely used source of electricity: according to ISPRA in Italy until 2008, around two thirds of all electricity produced came from fossil fuels. However, in recent decades there has been a greater push for a gradual transition towards renewable energy sources: these are called renewables because they are inexhaustible and whose renewal - unlike non-renewable sources - takes a very short time.

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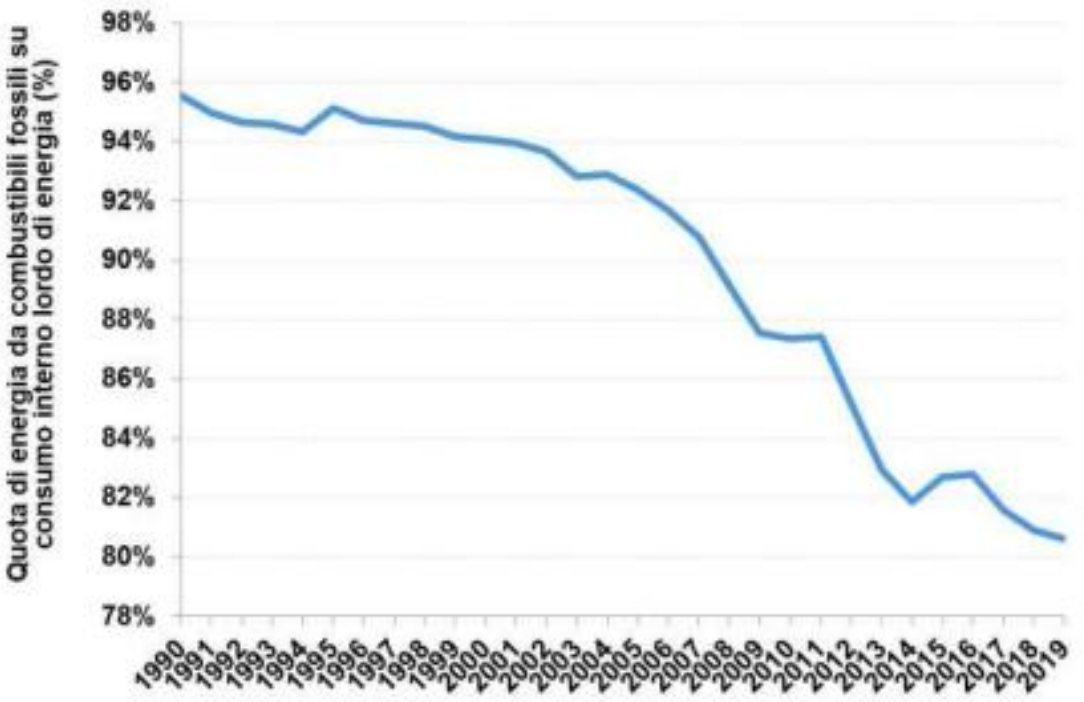

Figure 3 - The percentage of fossil fuel energy used in Italy, ISPRA (2019)

It should be remembered that the combustion of fossil fuels contributes to the increase in the concentration of CO2, a component that contributes to climate change and thus to the rise in global temperatures. According to data released by the European Union, the average daily electrical energy demand for a European citizen is 27 megawatt hours (MwH) per year, and if we consider that approximately 77% of this consumption is from fossil fuels, it is possible to understand how much of an impact the expenditure of electrical energy can have on the planet.
The main renewable sources are:

- **Solar energy**. It is obtained by capturing the energy radiated by the sun's rays, and the devices capable of this process are photovoltaic panels that, by absorbing and processing the heat from the sun's rays, transform it into electrical energy useful for everyday activities. Although this source is particularly strategic as it allows energy to be produced continuously, the costs to be incurred for the purchase and maintenance of the appropriate panels are not affordable by everyone, especially households;
- **Eolic energy**. It is obtained from the wind and is a particularly clean source, as the entire process does not produce air pollution. The devices capable of producing
- energy from the wind are wind turbines, which, however, need to be installed far from population centres and in particularly windy areas: this increases the costs of transporting and distributing the energy they can produce, as well as having high maintenance costs;
- **Hydropower**. It is obtained from water flows by harnessing kinetic energy. In fact, hydropower is produced by building dams and penstocks that convey water to devices capable of transforming its potential energy into electrical energy, are capable of storing for the times when demand is greatest. Hydropower is not only produced in freshwater basins,

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but can also be obtained by exploiting sea waves, currents and tides: in this case, the energy is called tidal power. Although hydropower is a sector that can bring benefits in terms of energy sustainability, it requires the construction of large, complex plants whose environmental impact can be particularly harmful to the ecosystems that host them;

- **Geothermal energy**. It is obtained from the heat radiated from the deepest layers of the Earth, in which are found radioactive elements whose decay process naturally produces heat that can be converted into electricity. This type of source, however, is not particularly exploited and is a marginal energy resource;
- **Hydrogen energy**. This energy is quite complex to obtain and for which technologies are still being developed to optimize the entire process;
- **Energy from biomass**. It is obtained from so-called biomass, i.e. organic materials from, for example, waste products from agricultural activities.

According to ISPRA, renewable energy sources in Italy enjoyed slow growth between 1990 and 2007, constituting only shares between 4.4% and 9%. The acceleration occurred from 2007 to 2019 when, on the other hand, 19% of gross domestic consumption from renewable sources was reached.

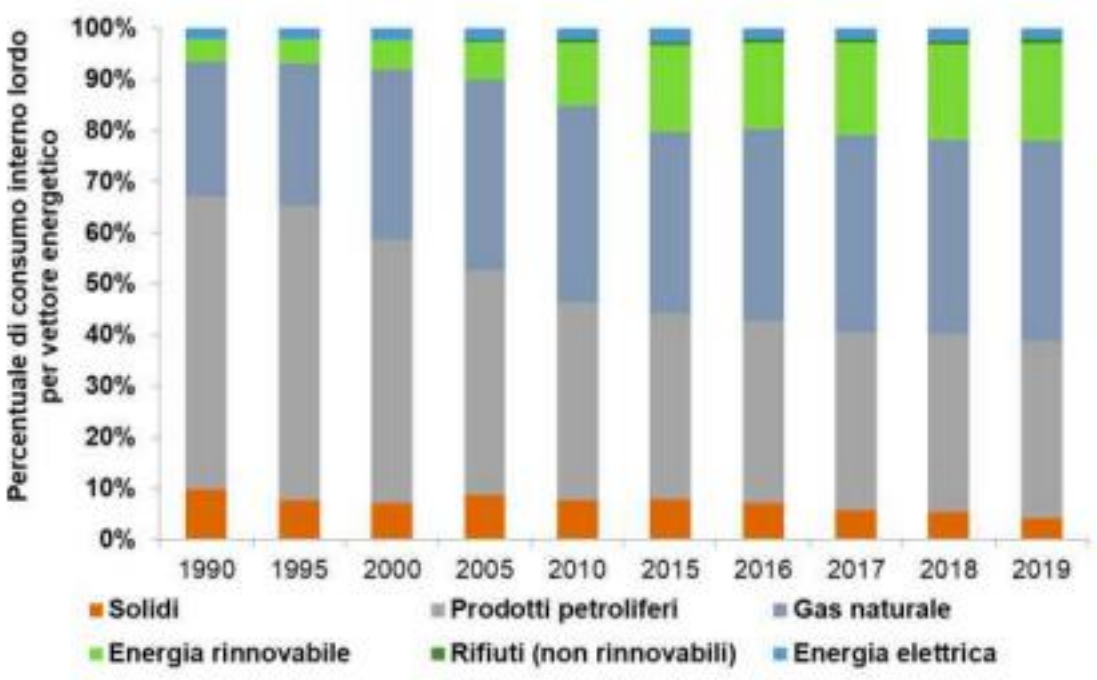

Figure 4 - Classification of sources used for electricity production in Italy, ISPRA (2019)

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3. Heating & Cooling

Global warming brings with it many implications, one of which is the increased consumption of electricity for cooling and heating of rooms, whether domestic or not. According to a survey produced in 2020 by EUROSTAT, electricity consumption for the year 2018 in Europe is stable and, unfortunately, although it has decreased, the efficiency target of an overall 20% reduction in consumption has not yet been reached. The European Commission has pointed out that about a quarter of CO2 emissions in Europe are attributable to household electricity consumption and that about three quarters of the energy used in European homes is for heating and cooling . The extensive use of electricity for these activities also results from the rise in temperatures caused by global warming but, at the same time, contributes to worsening the environmental situation. Some comforting news is that, according to data from the International Energy Agency, world demand for electricity from renewable sources is gradually increasing.
This graph produced by IEA, the International Energy Agency, clearly demonstrates how much of an impact energy consumption for space heating activities has on the planet.

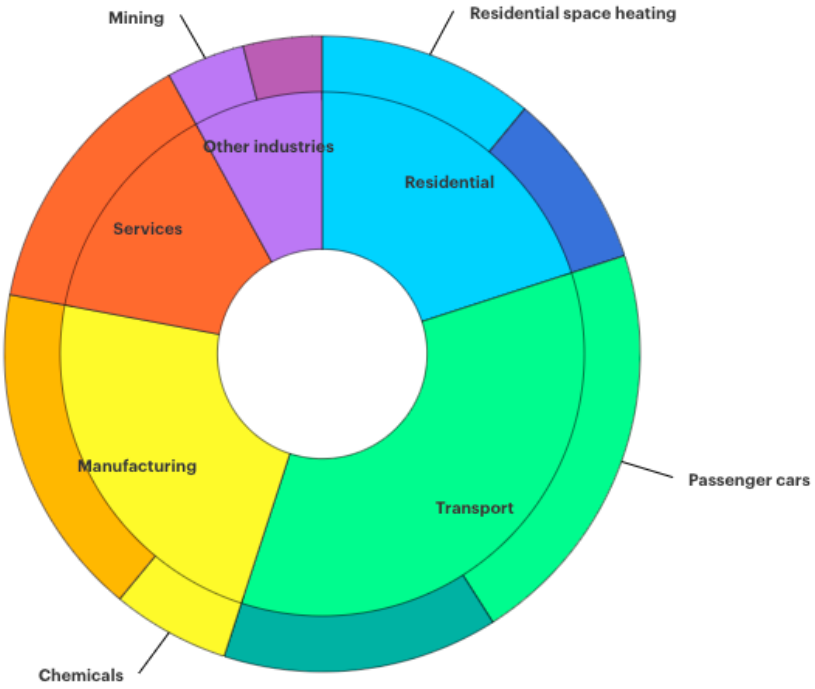

Figura 5 - Consumo di energia elettrica nei paesi selezionati da IEA

In addition to tricks such as switching off devices when they are not in use, or rationalizing the load on the washing machine by not giving in to the temptation to turn it on only for a few items, tips are given on how to make our behavior related to the search for the perfect temperature in the home more efficient.

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A block of suggestions regarding domestic efficiency consists of promoting building actions aimed at thermal insulation: this type of action falls into a category called bio-architecture.

4. Energy classes

Within the European Union, many everyday products such as household appliances or light bulbs have a label stating their energy efficiency.
Devices that require more electricity contribute further to direct CO2 emissions and have labels tending towards red, as well as being marked with letters of the alphabet increasingly closer to zeta. Devices that, on the other hand, manage to optimize electricity consumption have labels that are increasingly green, based on their ability to prove efficient, and have the letter A; in turn, devices marked A may be accompanied by the sign '+' and the greater these signs are, the better the energy efficiency. The European Commission's advice, for example, states that a class D dishwasher consumes twice as much energy as an A++ class one.

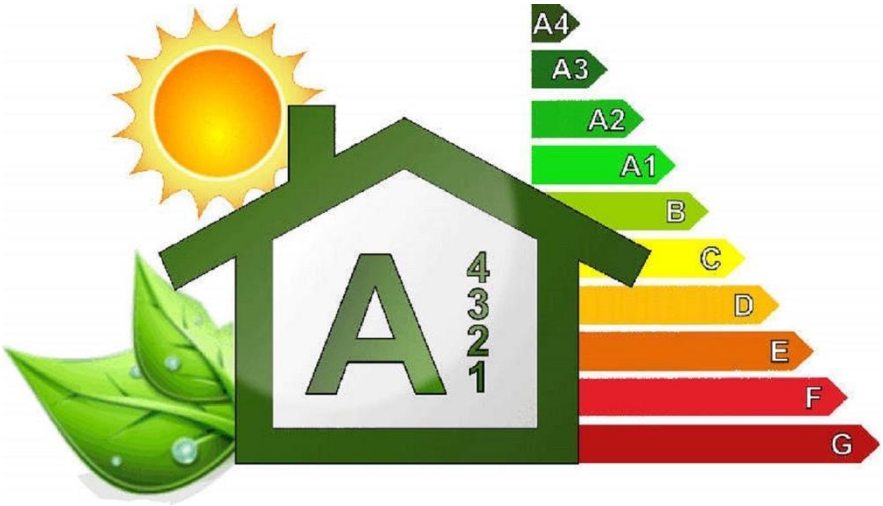

Figure 6 - Classification by energy efficiency

5. Bio architecture

Bio-architecture is a branch of architectural disciplines that focuses on respect for ecosystems and the ability to realize building solutions that are environmentally friendly. Its fundamental principles include, for example, respect for the context within which the building will be constructed, the design of buildings that can be easily adapted, the limitation of polluting gas emissions and the use of sustainable yet high-performance materials. Buildings designed according to the methods of bio-architecture, therefore, must integrate perfectly within the reality that surrounds them and must be an example of how innovation can help us live in harmony with nature and not worsen climate change.

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However, bio-architecture is not exactly a new invention. Our ancestors, in fact, had already designed solutions capable of combining comfort, functionality and respect for the surrounding territory: these buildings today constitute, among other things, an important testimony of how man has settled in the territory. In Italy you can visit some of these structures that constitute an embryonic form of bio-architecture.

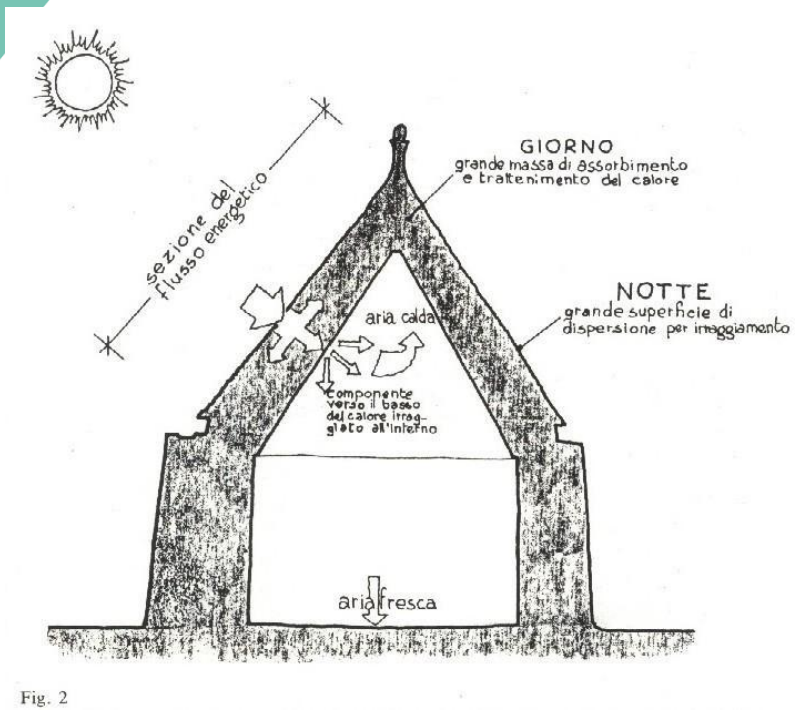

Fig. 2

The Trullo is a typical piece of architecture in the Apulian region and is an excellent example of a bioclimatic building. In fact, it is built from materials readily available in nature but capable of thermally insulating the interior of the structure. The trullo was built by the same farmer who would inhabit it and this means that there is no waste; furthermore, the need to build a residential building in a country context determined the need to use zero kilometer and low cost materials. In this case, the trullo was built from the stone the farmer collected by tilling the land on which his dwelling was to be built.
Two other elements are worthy of note: firstly, the fact that the interior of the trullo was thermally insulated by building very thick walls and reducing the openings to the minimum necessary to ensure the entry of light and the exchange of air; secondly, the trullo is a building which, by its very construction technique, is reusable. When a trullo was permeable to damp, the farmer could pull it down and reuse the same materials recovered from demolition to build his new dwelling.

Another example of architecture perfectly grafted into the surrounding territory is the Palmento, a typical structure in Pietragalla in the province of Potenza. Like trulli, palmenti are buildings made of stone: the locality of Pietragalla owes its name to the fact that there is availability of stones whose

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colour tends to yellow. The palmenti were dug into the sandstone rock that characterizes the area and were used for operations related to wine production. Because of their ability to keep the temperature constant and never too hot or too cold, these structures ensured that farmers could work without being affected by outside temperatures; moreover, ventilation was ensured by only two openings, the door and a window, thus avoiding a weakening of the thermal insulation system.

A more contemporary example is the work of architect Frank Lloyd Wright, considered one of the founding fathers of bio-architecture. Wright's work tends towards harmony between the built element and the surrounding landscape and enhances this union through the choice of predominantly natural building materials. Kaufmann House - also known as Falling Water, because it is built on a waterfall - has been included in the UNESCO World Heritage list. Its splendid architecture fits effectively into the context within which it was conceived and the choice of materials was made favoring the use of stone for the external cladding and wood for the interior finishes.
In Italy, one of the most recent and iconic experiments in bio-architecture can be found in the so-called Vertical Forest in Milan. Designed by studio Boeri, the building aims to emphasise biodiversity and become ‘a house for trees that also houses humans and birds’ . The vegetation in the Bosco Verticale is watered, for the most part, with water

coming from a filtration system of grey condominium water. Residential solutions of this kind could prove invaluable in the near future, when even larger segments of the population will migrate to the cities and more pollution will be at risk.

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Figure 8 - The vertical forest in Milan

To learn more about vertical forests and the positive impact they can have on air quality in urban settings, a short video produced by the BBC is available in the additional materials section.

6. The bioclimatic branch

Construction is a sector whose impact on pollution is by no means negligible. Among the branches pertaining to bio-architecture is bioclimatic architecture, the objective of which is to design solutions that can guarantee good building insulation, while also exploiting the natural elements present in the area concerned such as, for example, the sun, water, soil and flora. There are many bioclimatic structures that make it possible to avoid heat loss and exploit the sun's rays to one's advantage, favoring a pleasant indoor microclimate and avoiding the excessive use of heating or cooling systems that, clearly, presuppose the use of raw materials such as methane gas or electricity, which, moreover, does not always come from renewable sources. According to a study produced by the University of California, the use of air-conditioning systems will become increasingly widespread in the future for two main reasons: on the one hand, the rise in temperatures already triggered by global warming, and on the other, the fact that many more people will be able to afford them and, therefore, use them in their homes.
An article in The Guardian even talks about a real trap: global warming causes temperatures to rise, making people more inclined to use air conditioning; the use and abuse of air conditioning at the same time contributes to global warming[2].

[2] https://www.theguardian.com/environment/2019/aug/29/the-air-conditioning-trap-how-cold-air-is-heating-the-world

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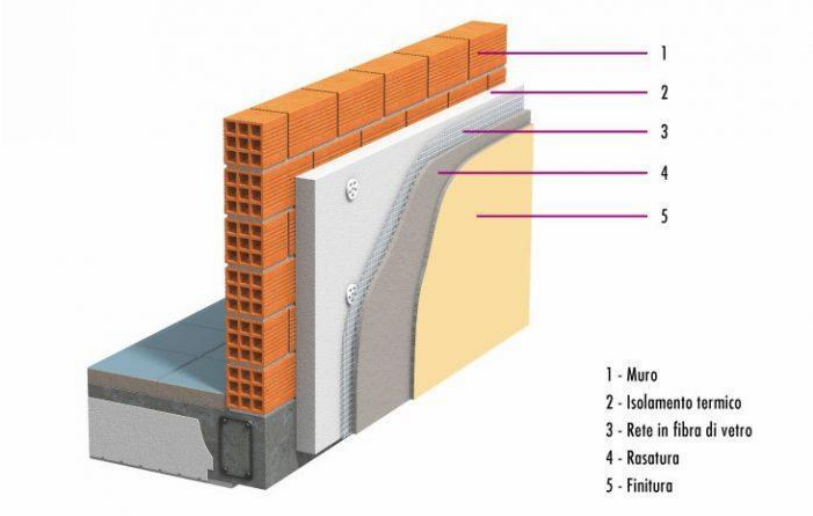
The bioclimatic branch, therefore, thanks to its techniques in the building sector, can come to the aid of citizens, limiting the use of devices that modify the domestic microclimate.



7. Technology in the reduction of energy consumption

Quoting Treccani , domotics consists of the study and application of a complex of technologies based on computer and electronic engineering, with the aim of creating a series of integrated devices to automate and facilitate the performance of various operations usually carried out in a building. These technologies use information obtained from a computer network to which the building must be connected.

Automation applied to the domestic context facilitates the inhabitant, allowing him to carry out an enormity of actions even remotely: thanks to domotics, it is possible to scan the perimeter of one's home, control one's household appliances or activate an irrigation system. One of the functions that are most likely to have a positive impact on reducing energy consumption is the ability of some devices to control the temperature inside buildings or homes and to adopt intelligent heating or cooling methods: indeed, a second aspect that is more related to awareness of one's consumption behavior would seem to be relevant. As home automation devices can collect data and make it available to the user, some research has revealed that as soon as consumers have statistics on their domestic consumption and their consumption habits, the consumer seeks to intervene by modifying behavior that he or she deems unpleasant or to be improved[3]. What are, then, these functions thanks to which home automation generally saves on electricity consumption? First of all, for example, a home automation system allows the lighting system to be activated only when it detects the presence of someone in the room; it is also possible to set different

[3] Mukendi H.K., Adonis M. (2018). *Smart homes and sustainable cities: the design of a low-cost solution for comprehensive home automation*, https://www.intechopen.com/chapters/61771

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temperature profiles for each season and activate them only when the rooms are actually lived in; again with regard to the domestic microclimate, it is significant in terms of reducing consumption that the temperature of each room can be set according to its function and use; adjusting the internal temperature according to the external temperature by means of sensors on the windows. One of the advantages of having a smart home lies in the fact that the system prioritises the various actions and devices connected, thus deactivating the less useful ones if there is a risk that an electrical overload could lead to a blackout.

"Home automation offers users the opportunity to actively participate in accessing and controlling their environment. This is achieved by providing users with tangible means for energy saving, perimeter security, data access and control of household appliances. As an energy management tool, home automation synchronises the technology platform with practical benefits, such as the ability to reduce home electricity bills by controlling household electrical loads. The capability is further enhanced by the provision of remote access and resource management. This is possible if the user's desired features include access via a web application and mobile software application.[4]."

Home automation systems have been improved in recent years, and progress in this area is mainly attributable to the explosion of interest in the Internet of Things (IoT). The IoT - which literally translates as the Internet of Things - can be defined as the network of objects that physically exist within which there are devices capable of connecting and sharing data with other objects or systems on the Internet, such as sensors, software or other technologies. One of the main advantages of the IoT is that these smart objects do not require any expertise on the part of the consumer, in fact they are able to collect and exchange data autonomously and without the need for human intervention.
Despite the potential benefits of installing a home automation system, the costs that the consumer incurs are still quite exorbitant. However, new methods are being advanced that can reduce the price: this is the case, for example, of home automation systems for which no proprietary software is provided.
Low-cost home automation can be achieved by programming an algorithm on an Arduino and basing the whole system on GSM, Ethernet, etc. networks. Although programming requires special skills, it does, in its own way, conceal an advantage: the user-programmer can modify the code of his own

[4] https://www.intechopen.com/chapters/61771

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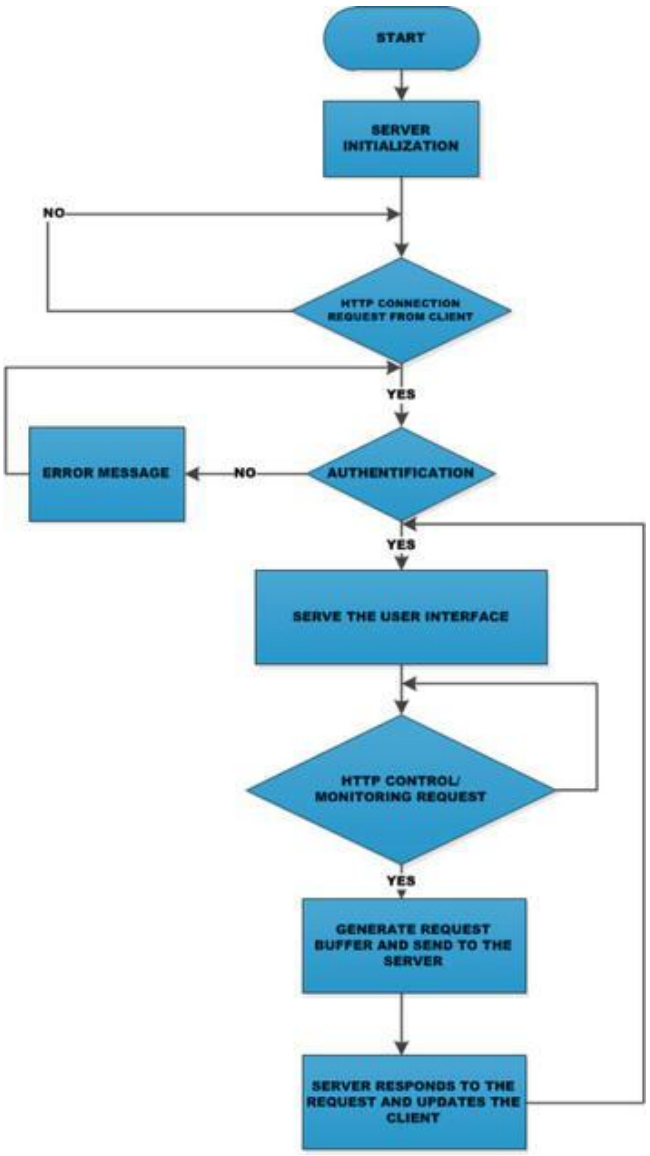
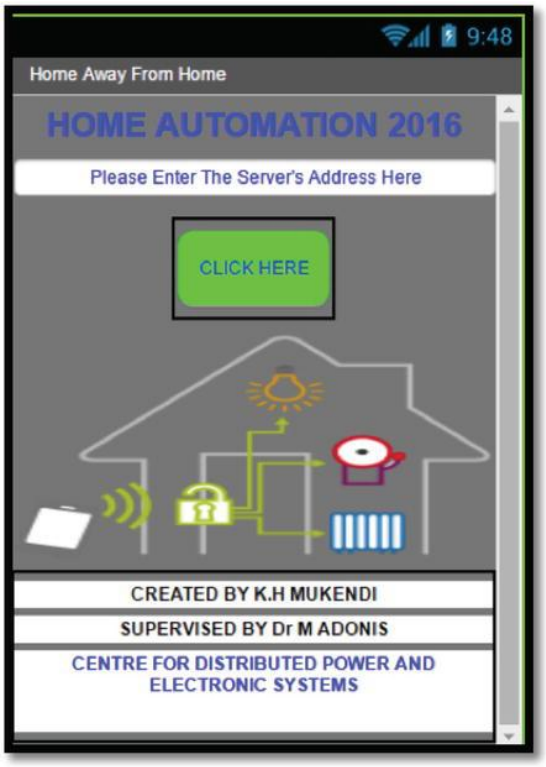
system and thus vary its behaviour and capabilities. As far as the graphical interface is concerned, these low-budget systems can be modelled graphically using HTML or by programming in Android. At this link you can read how you can make a small home automation system that can detect indoor and outdoor temperatures, whether windows are open or closed, and whether it is raining outside, producing the sound of an alarm.

https://www.instructables.com/Smart-home-with-arduino/

Ultimately, smart homes and smart cities can be an additional resource in the fight against climate change, as they can be efficient in many functions, including smart energy saving: in this case, not only do they help reduce emissions harmful to the planet, but they also increase the quality of life of those living in automated homes.





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7. Augmented Reality (AR) Integration

Augmented reality in the home automation, bio-sustainability and energy saving sectors is being incorporated into school curricula, offering students the opportunity to explore augmented domestic environments. Project 3D models of smart homes onto desks or floors, where each room contains sustainable technologies (solar panels, motion sensors, smart HVAC systems). Activate environmental simulations with the ability to modify sunlight, temperature or human presence to observe in real time the activation of heating, cooling or automatic light switching systems. Analyse energy flows by observing energy consumption and savings through coloured flows representing the energy consumed or saved by each device. Customise and design AR environments to build a model home by choosing insulation materials, efficient appliances, natural ventilation systems and monitoring their environmental impact.

- **Advanced digital skills** (AR interaction, 3D modelling, simulated data manipulation);
- **Critical thinking and problem solving**, through the comparison of different energy solutions;
- **Design and collaborative skills**, in co-design activities for sustainable homes;
- **Environmental awareness and active citizenship**, exploring the role of technology in the fight against climate change.

Augmented Reality (AR) offers a unique opportunity to transform abstract and often technical concepts such as those related to **home automation**, **bio-sustainability** and **energy saving** into **interactive**, **visual** and **engaging** experiences. In particular, for students aged between 14 and 18, the opportunity to **see and interact with sustainable environments and technologies in 3D**, directly within their own space (classroom or home), promotes active, interdisciplinary and design-oriented learning.

8. Conclusion: The Future of AR in Vision Science

Integrating Augmented Reality (AR) into bio-inspired vision research transforms how students learn, experiment, and innovate. Through immersive 3D simulations, interactive visual mapping, and AI-powered analytics, AR bridges the gap between biological vision science and engineered optical systems.

By experiencing hands-on AR-enhanced learning, the next generation of scientists and engineers will be better equipped to develop advanced bionic vision technologies, AI-driven robotic sensors, and augmented optical interfaces, shaping the future of bio-inspired innovation.

Phase	Description

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Explore	They visualise the greenhouse effect in 3D, compare greenhouse gas levels over time and overlay historical data and future projections directly onto the real environment to visually understand the impact of climate change at a global and local level. They use AR to map energy sources (fossil and renewable) in their region and observe how these affect the environment. They can follow simulated energy flows (e.g. from the sun to solar panels to the home). They observe traditional and sustainable heating and cooling systems projected in AR within domestic or school environments to analyse their efficiency and energy impact.
Execute	They design virtual buildings with different energy classes and analyse their environmental performance through AR simulations (e.g., use of insulation, smart windows, reflective materials). They create digital prototypes of bioclimatic architecture (e.g., green roofs, ventilated facades), inspired by the behaviour of plants and ecosystems. In AR, they can test the effect of light, wind and shading. They explore energy-saving technologies (home automation, sensors, passive energy systems) and create simplified versions in AR to integrate into their designs. They can evaluate costs, avoided emissions and energy savings in real time.
Enhance	They enter interactive virtual environments (e.g. forests, coastal cities, power plants) to understand complex climate and energy systems. They can modify energy parameters in their AR models (e.g. change energy sources or building materials) and visualise the effects on emissions or thermal comfort in real time. They accumulate points by solving interactive quizzes on the causes, effects and solutions of climate change and complete group design challenges, advancing to higher levels in the design of sustainable energy systems. They present their 3D models with enhanced AR, answer dynamic quizzes and reflect on the future role of augmented reality in scientific, environmental and engineering understanding.

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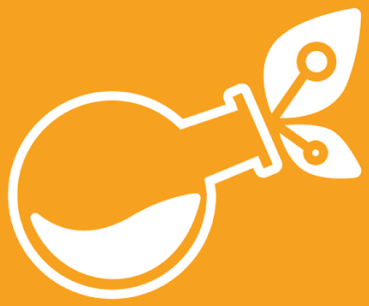

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