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Teaching unit:
From waste to clean resources: a virtuous bio-cycle for the creation of an eco-habitat

DiFC - University of Palermo

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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Contents

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General topic of the learning path	From waste to clean resources: a virtuous bio-cycle for the creation of an eco-habitat
Specific name of the learning unit	Bio-innovations in Designing Eco-cities
Age of the target users	17-19 years old
Requirements for the learner	Basic knowledge of Physics, Chemistry, Biology, Civics and Citizenry
Description of the learning unit	It will guide teachers and students through an inquiry-based teaching/learning multidisciplinary path on sustainability
Subject: Parties involved	Physics, Chemistry, Biology, Civic and Citizenry
Keywords	Renewable energy; Urban waste management; circular economy; life cycle thinking; sustainability and sustainable development; Biodiversity
Key qualifications, skills and knowledge that can be acquired	• Problem solving • Design thinking • Reasoning • Conceptual and practical knowledge of Physics, Chemistry, Engineering, Scientific economy and green-business administration.
Resources and didactic aids used	Web-based resources, remote and virtual laboratories, research papers, scientific database.
Assessment criteria and evaluation	Different levels of concept knowledge, abilities and skills achieved

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1. From waste to clean resources: a virtuous bio-cycle for the creation of an eco-habitat

Bio-innovations in Designing Eco-cities

There are several benefits of developing Eco-cities which among other things, are largely green and eco-friendly. These include efficient land-use, habitat preservation and restoration, effective transport management and energy efficiency, efficient use of resources, emissions and pollution control and enhanced quality of life for the occupants.

An eco-city is a city built off the principles of living within the means of the environment.
The ultimate goal of an eco-city is to eliminate all carbon waste, to produce energy entirely through renewable sources, and to incorporate the environment into the city; however, eco-cities also should stimulate economic growth, reducing poverty, organizing cities to have higher population densities, and therefore higher efficiency, and improving health.

The Smart Recycling Lab - Assemblr EDU Implementation
This AR experience guides students through decision-based scenarios that demonstrate circular economy principles in action. Beginning with four waste objects placed on a classroom desk (plastic bottle, aluminum can, paper, apple), students interact with each item to access dedicated decision scenes. Using Assemblr EDU's library, the experience employs realistic 3D waste models and result objects including

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post-it notes for recycled paper, cardboard boxes for reuse, farm environments for organic composting, and desert landscapes for improper disposal effects. Students navigate through three-option choice scenarios (recycle, reuse, improper disposal) leading to specific outcome scenes with educational content about decomposition times, environmental impact, and sustainability benefits.

Educational Benefits of AR in Environmental Science

Augmented Reality transforms abstract environmental concepts into concrete, interactive experiences. In waste management education, AR allows students to visualize the consequences of disposal choices through step-by-step decision making rather than theoretical study. The scene-based navigation approach enables students to explore cause-and-effect relationships between individual actions and environmental outcomes, supporting critical thinking about personal responsibility and circular economy principles while maintaining engagement through interactive 3D visualization.

2. Explore Module

Engagement phase

1) micro-MOOC: Renewable sources of Energy
We have a problem!
Growing Appetites, Limited Resources
Energy definition
A never-ending supply of energy. Is it possible?

2) Official Trailer of Wall-E
https://www.youtube.com/watch?v=alIq_wG9FNk
https://www.youtube.com/watch?v=TW1Y4HDBLB4 (In Italian language)

3) Introduction to Biomes and Need of biodiversity
https://www.youtube.com/watch?v=hIy0ZlyPPDg
https://www.youtube.com/watch?v=Kx3n0FFgpT4

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Brainstorming activities in the classroom

Driving sentence: The most challenging problem facing our cities today is to meet the ever-rising demand for renewable energy, water supply and waste management

Basic Level

Physics and Renewable energies

Advancements in physics and related fields of scientific research have led to many breakthroughs in renewable energy technologies that, in turn, have given us the products that are today beginning to make a difference in the lives of people all around the world.

What does a scientist do in the laboratory, from getting an idea to developing a new solar cell or design for a wind turbine blade? How do scientists use physics, including quantum and solid-state physics, materials science, biophysics, polymer science, aerodynamics, thermodynamics, superconductivity and optics?

Although windmills have been around for centuries and the sun has warmed buildings in many parts of the world for generations, these technologies took a quantum leap beginning with scientific advances in the 1950s and 1960s. Photovoltaics - turning sunlight into electricity - got its first boost from early satellites and the space program. With the help of physics and advanced materials, the cost of solar electricity has been cut 100 fold in the past two decades. Solar panels will provide clean and reliable power in many parts of the world in the coming century, as will wind power.
The understanding of aerodynamics, sped along by the aerospace industry, has given us air foil designs that make electricity from modern wind turbines almost cost competitive with power from fossil fuels.

We must take physics out of the laboratory and into our home. What are the renewable energy products that today are in use by industry and consumers?

PV-roofing; thin-film solar cells and panels with record-setting efficiencies; solar walls (transpired solar collectors); stand-alone solar energy systems for the home and business; utility-scale PV applications that provide power to thousands of customers; small, single-building wind turbines and massive, utility-scale wind machines deployed in wind farms around the country.

What research in the lab today will give us the next generation of renewable energy products and systems?
Hydrogen generation and storage; fuel cells; thermophotovoltaics—using heat instead of sunlight to generate electricity and advanced wind turbines.

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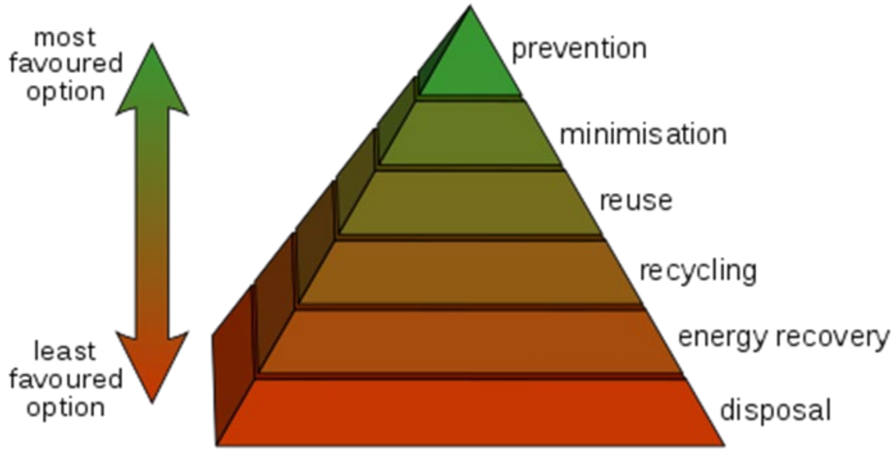
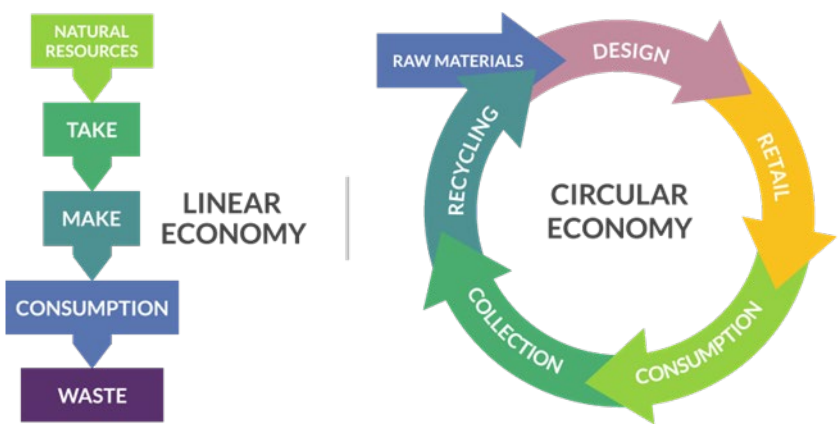
What role can physic and other scientific disciplines play in the development of clean energy technologies that will help solve serious environmental problems, such as global climate change and air pollution?



Linear economy is a wasteful system: many valuable materials are “lost” to landfills, and the products that are manufactured are consistently under-utilized.
Waste management (WM) represents a challenge for public authorities due to increased waste generation following urban population growth, economic burdens imposed on the municipal budget, and nuisances inevitably caused to the environment and local inhabitants.
In contrast to a linear economy, a circular economy aims to decouple growth from finite resource consumption and is restorative and regenerative by design.



The transition towards a circular economy is challenging as only 9 percent of the goods and product of the global economy loop in one or the other way. Such a multi-disciplinary and multi-facets process inherently

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needs evidence-based and scientific sound information on the potential consequences of the decisions made.

Simultaneously with industrial growth, increasing population, rapid urbanization and improved community living standards, enormous quantities of materials are being wasted in the European Union (EU) in the last decades. EU statistics illustrate that up to 2.6 billion tons of waste (specified by Directive 2008/98/EC) was generated in 2014, of which most originates from economic activities such as construction (34.7%), mining (28.2%) and manufacturing (10.2%), while households contributed for 8.3%. Consumption patterns, economic wealth in combination with the projected population growth will likely lead to an increased amount of municipal solid waste in the near future. Overall, waste generation indicates the limited ability to use primary resources efficiently. The linear economy is a basic structured model that relies on the extraction of raw materials and their processing into products and potential by-products which, after usage, are treated as waste and mainly disposed of into landfills or dumpsites. In the past, this model has been considered as a successful and effective approach, able to manufacture products at competitive prices, boosting the economies of developing and industrialized countries, and encouraging human consumption.

However, concerns about the depletion of natural biotic and abiotic resources (coal, minerals, metals, wood, etc.), with consequent challenges in supply, have brought increased attention to the way we should manage the available resources. In this respect, waste disposal not only results in significant losses of materials but also incurs significant impacts on the environment finally reducing the quality of life. Ultimately, this may lead to exceed certain environmental thresholds or tipping points, affecting the current ecosystem irreversibly. Therefore, waste should be managed so that it does not poses risks to air, water, soil, plant and animals e.g., by the release of methane or leachate, eventually leading to impacts on human health and well-being which is absolutely to be avoided. Therefore, changing this linearity of material flows is high on the agenda as it is one of the profound challenges the EU is facing today. The linear “take-make-dispose” model of economic growth we relied on in the past is no longer suited for the needs of today’s socio-economic European system. A shift towards a circular economy as an industrial system that is restorative or regenerative will increase resource efficiency and reduce waste significantly. Furthermore, the circular economy model aims to create secure jobs in Europe, to boost innovations giving competitive advantages to EU industry and to provide increased level of protection to humans and the environment. It should also provide consumers with more durable and innovative products that provide monetary savings in a life cycle perspective and a better quality of life.

Consumables in the circular economy should be largely made of biological ingredients or “nutrients” that are at least non-toxic and possibly even beneficial, and can safely be returned to the biosphere, either directly or in a cascade of consecutive uses. This could contribute greatly to reduction of waste, when done in a safe and smart manner. Reconceptualization and re-design of products and processes is paramount, enabling materials to be used and reused at their highest utility for the intended performance, while either circulating through manmade systems as long as possible or through natural systems in pure, shorter and longer cycles.

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Let's reflect together

Although multiple waste policies and targets have been established since the 1990s, in practice the status of the EU economy remains far from being circular or sustainable. Clearly, optimizing waste management alone does not solve the linear economy problem—to "close the loop" and achieve a circular economy, it is equally important for example to examine product designs, production systems, and consumption habits.

Chemistry, bioenergy and biomaterials

Once the matter around us is well-known, scientists should be able to develop technologies to take advantage of and improve citizens' lifestyles.

Chemistry is considered the "central science", being involved in studying the composition of matter and of its interactions.

For several years, though, chemistry industries were considered the most damaging place of the planet; nowadays, thanks to environmental sensitivity and law restriction, every chemical company is moving in "a green direction" as a consequence of the fact that guarantee the planet's health is a common aim.

In this contest bio-energy and biomaterials are becoming common words that play a key role in sustainability and are related to the essential global need to keep living reducing the impact on the planet in terms of carbon emissions and environmental pollution.

The IEA (International Energy Agency) defines bioenergy as the most important source of renewable energy today, made from biomass and biofuel. Biomass is any organic material that has absorbed sunlight and stored it in terms of chemical energy through the photosynthesis process. Since biomass technically can be used as a fuel source directly, it denotes the raw material of which biofuel is made of. IEA also argues that the current rate of bioenergy deployment is well below the levels required in low carbon scenarios, and that accelerated deployment is urgently needed.

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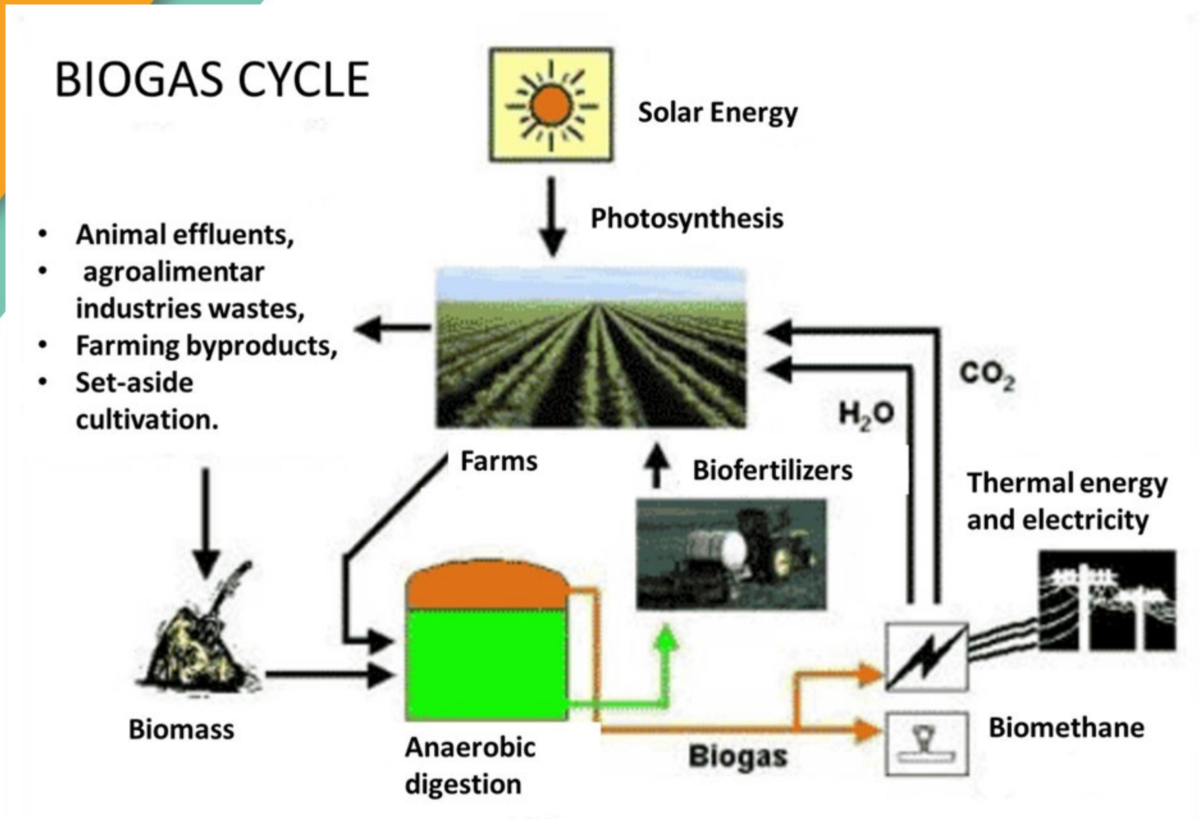

Scheme of a Biogas Cycle process

Anaerobic digestion is a complex biological process that allows the conversion of organic compounds into biogas, a blend of methane (CH4) and carbon dioxide (CO2), without requiring the use of oxygen that, even is quite common in the environment, its use is not generally convenient in the industries. The process stems from all the things included in a farm. The most important initial issue when considering the application of anaerobic digestion systems is the feedstock to the process. Almost any organic material can be processed with anaerobic digestion. Poultry's effluents are considered the most efficient one thanks to their moisture content and nitrogen high content. However, chicken manure contains inert substances that tend to sediment and cause operative problems and force the use of small-volume reactors. Other feedstock could be depuration's mud, included what is accumulated downstream urban and industrial solid wastes. During this process, a lot of microorganisms are involved in converting the organic compound into an intermediate compound, like acetic acid, and finally, convert the latter one into methane. Anaerobic microorganisms present a low growth rate and low kinetics reaction rate, so they require the most optimized operative conditions, consequently, the timing of the process is longer than other biological processes.

The edge of this process is that the green feedstock allows the production of biofuel with a significantly high heat of combustion. Thus, the only environmental impact is caused by process machinery employed or energy (and costs) required for transportation and compression of biomethane for commercial use. So, this green concept of energy is optimized when fermenters or reactors (and all the others treatment

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processes related to them) are energetically fed with renewable energy, such as hydropower, solar collector, photovoltaic system, wind power, and so on.

The biogas-biomethane chain provides a double advantage as it simultaneously produces energy and recovers residues, reducing the amount of material destined for the landfill. Thus, is totally in line with sustainability and circular economy concept.

Sustainability and sustainable development: a new paradigm

In 1987 the World Commission on Environment and Development sought to address the problem of conflicts between environment and development goals by formulating a definition of sustainable development:
Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs.

In particular, an environmentally sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions, and depleting nonrenewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources.

The conservation of ecosystems and natural resources is essential for sustainable economic production and intergenerational equity. From an ecological perspective, both human population and total resource demand must be limited in scale, and the integrity of ecosystems and diversity of species must be maintained.

Sustainability, however, is more than limits on population or restraint in consumption - though these are important. It means that the choice of goods and technologies must be oriented to the requirements of ecosystem integrity and species diversity as well as to social goals. Elements of all three perspectives – economic, ecological, and social – are essential to an understanding of the requirements for sustainability.

Both supply limits and environmental impacts, in particular the accumulation of greenhouse gases, mean that it will be necessary to accomplish a transition away from fossil fuels well before 2050. A non-fossil energy system would be significantly more decentralized, adapted to local conditions and taking advantage of opportunities for wind, biomass, and off-grid solar power systems. This is unlikely to occur without a major mobilization of capital resources for renewable energy development in countries now rapidly expanding their energy systems.
As the scale of global industrial production increases several-fold over current levels, which themselves represent a quadrupling over 1950 levels, it is apparent that ‘end-of-pipe’ pollution control not be adequate. The concept of ‘industrial ecology’ implies the restructuring of whole industrial sectors based on a goal of reducing emissions and reusing the materials at all stages of the production cycle.

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Flipped Learning:

Reading of the paper https://journals.openedition.org/sapiens/1684

SAPIENS

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Ecosystem Services Analysis in Response to Biodiversity Loss Caused by the Built Environment

Maibritt Pedersen Zari

Gaëll Mainguy (ed.)

Like climate change, global biodiversity loss is an issue of great significance that should be addressed urgently. Human survival is dependent on the diverse range of organisms inhabiting the planet because they affect ecosystem processes and functions. There is growing evidence that biodiversity loss has at least as significant an impact on ecosystem processes and functions as climate change does or will. As biodiversity is lost and ecosystems are degraded, the bio-capacity of the planet to support living organisms reduces. As bio-capacity decreases there are diminishing resources available to support a growing human population and increasing collective ecological footprint.

Let's comment the results of the paper:

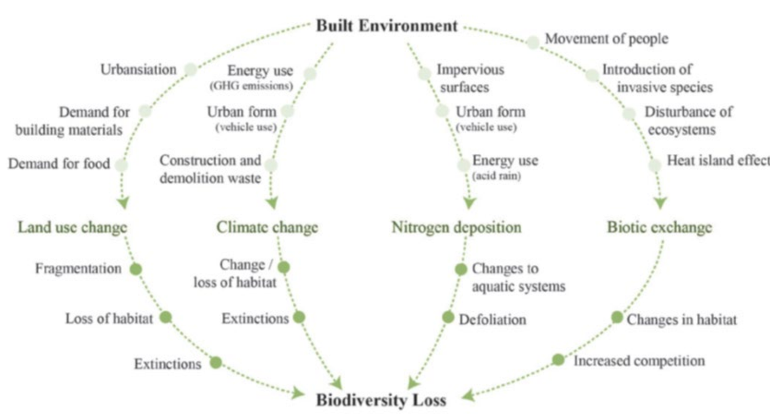

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Table 1: Impacts of Changing Biodiversity on the Built Environment

Potential indirect biodiversity loss/alteration impacts:	Potential consequences for the built environment:	Possible scale of the impact:
More rapid climate change due to biophysical feedbacks of ecosystems and loss of carbon sequestration.	Climate change impacts on the built environment are both direct and indirect.	High
Reduction in resilience of ecosystems to environmental change.	Increased damage to buildings and infrastructure from storm events, floods, landslides and wildfire.	High
	Increased cost of disaster relief.	Medium
	Increased repair/maintenance/insurance costs.	Medium
Increased disease/pest risk to crops, animals and humans. Changes in productivity/timing of crops. Loss of available protein and vitamins from food sources. Loss of soil nitrogen and carbon. Changes in soil fertility.	The built environment may be expected to allow for food growing more effectively.	High (potentially positive)
	Human work force and inhabitants may be negatively affected and impact indirectly on the viability of the built environment.	High
	Building materials such as timber may be affected.	Medium
Changes to precipitation patterns and water availability and quality. Warmer, drier climates. This can occur through increasing replacement of many land types with pasture for example.	Increased cooling loads.	High
	Reduction of water availability.	High
	Increased cost of water.	Medium
	Increased requirement for buildings to harvest rainwater.	Medium (potentially positive)
Loss of provision of ecosystem services (such as fuel, structural materials, etc.).	Changes in the viability of some urban environments to support human life.	High
	More expensive construction costs.	Medium
	Changes in availability and costs of materials.	Medium
Negative impacts on animal, plant and human physical health.	Changes in capabilities to design, construct, and maintain the built environment.	High
	User capabilities and expectations of the built environment may change.	Medium
Increased social dislocation, poverty and loss of income particularly of indigenous and poor communities.	Increased urban populations through rural migration.	Medium
	Poorer quality of building stock.	Medium
Increased local and international emigration and immigration.	Changes in expectations of the built environment to accommodate different and possibly increased numbers of users.	Medium
	Changes in population and activity patterns will affect expectations of and viability of parts of the built environment.	Medium
Changes in global and regional economies.	Shifts in money and resources available for construction.	Medium
	Changes in costs to run/build the built environment	Low
Increase in regulations to protect biodiversity.	Changes in construction methods.	Medium
	Changes in materials available, suitable and desirable for construction.	Medium
	Changes in development zones.	Medium (potentially positive)
	Greater skill and knowledge required to design.	Low (potentially positive)
	More vegetation in urban areas.	Potentially positive
	Increased multidisciplinary collaboration.	Potentially positive
	Increased use of the precautionary principle.	Potentially positive
Reduction in air quality, increase in acid rain.	Damage to building materials and infrastructure.	Medium
Decline in human mental health.	Changes to workforce available to build and maintain the built environment.	Medium
	Desire to have more vegetation in urban areas.	Low (potentially positive)
Loss of 'option value', through increased extinctions or biodiversity loss.[1]	Less ability to develop responses to future changes that could affect the built environment.	Medium

[1] Option value is 'the value of attaining more knowledge about species and their contribution to human wellbeing in order to make informed decisions in the future' Chapin *et al.* (2000: 240).

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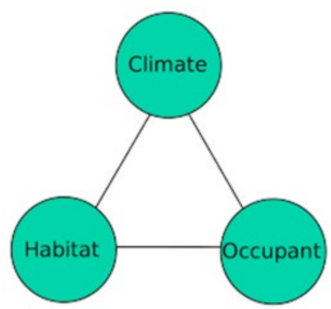
Let's comment the proposed solutions:

Bioarchitecture: Architecture discipline whose goal is to exploit the conditions of a site and its environment.



UN17 Village to be built in Copenhagen with recycled materials (https://www.dezeen.com/2018/12/10/un17-village-eco-housing-copenhagen-lendager-group-arstiderne-arkitekter/)

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3. Operation Module

Physics and Chemistry activities

Basic Level

By replacing fossil fuels with renewable energy nations could achieve their emissions commitments without encroaching on vital natural land. Low-emission energy sources like wind and solar can have a larger geographical footprint than fossil-fuel plants of equivalent capacity. Even so, the renewable-energy potential of already developed land is more than enough to fulfill pledges made as part of the Paris Agreement and could satisfy the total energy demand projected for 2050. At the 21st Conference of the Parties (COP21) in Paris in 2015, 196 countries agreed to aim to limit warming to less than 2 °C above pre-industrial levels. The rapid cuts in greenhouse-gas emissions imply a large-scale shift away from fossil fuels.

Renewable-energy schemes are not without environmental impact themselves, however, so it’s important to choose locations and generation techniques that cause the least possible harm. Similar to conventional energy sources, we need to think beyond just the direct footprint of the wind turbine or solar panel and consider the associated structures and roads that renewable energy development brings with it.

The first step is the mapping of each country’s potential for wind and solar energy generation. We also should include the potential output from retrofitting existing hydroelectric plants – assuming their efficiency could be slightly improved – and repurposing non-hydroelectric dams to become power-generating.

To achieve this task, we can exploit the potentialities of the

Lab on Renewable Energy powered by Teach Engineering, University of Colorado, Boulder
https://www.teachengineering.org/livinglabs/renewableenergy912

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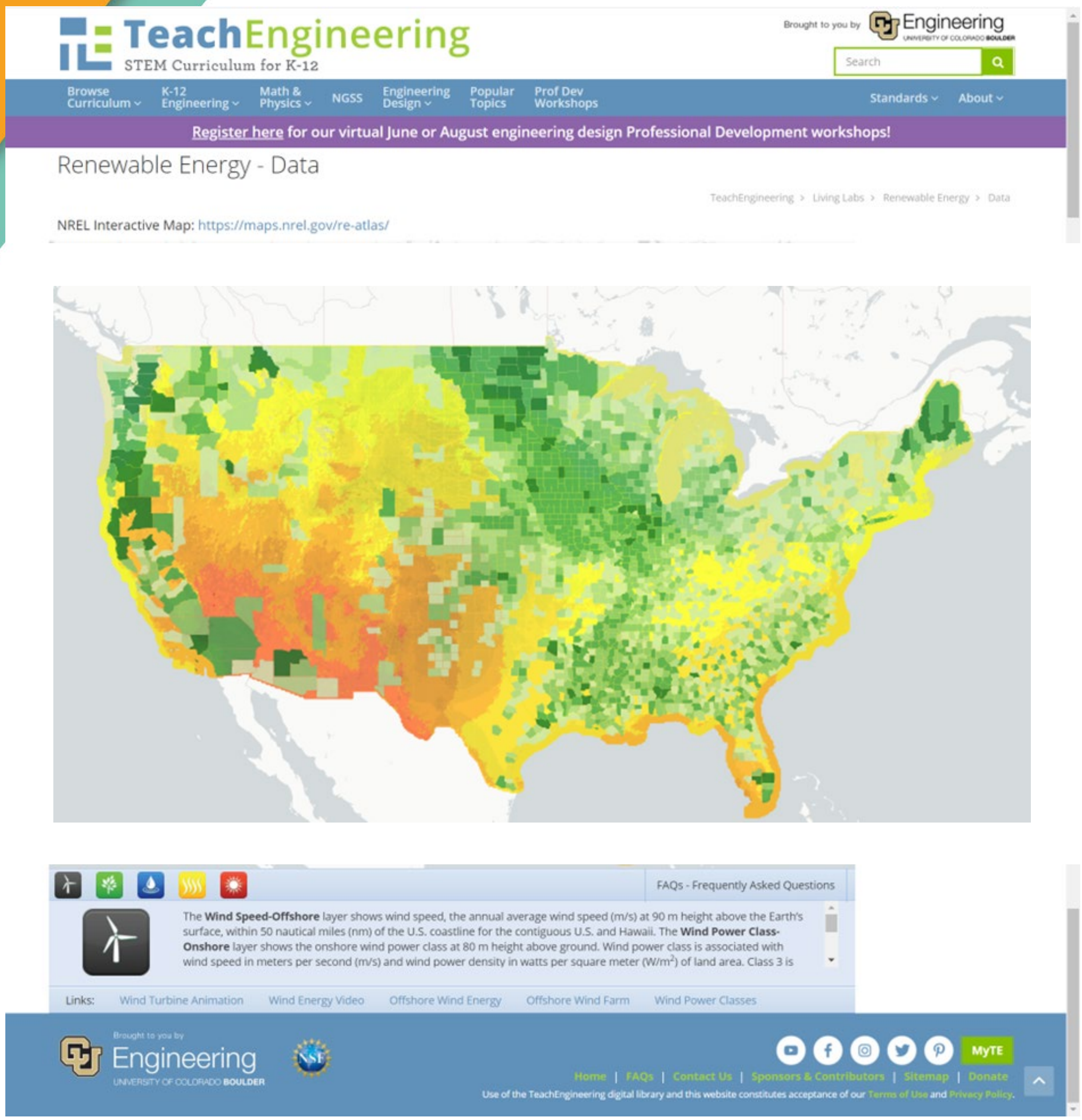

Or exploiting the

CLEAN Collection of Climate and Energy Educational Resources, a collection of 700+ free, ready-to-use learning resources rigorously reviewed by educators and scientists suitable for secondary through higher education classrooms.
https://cleanet.org/index.html

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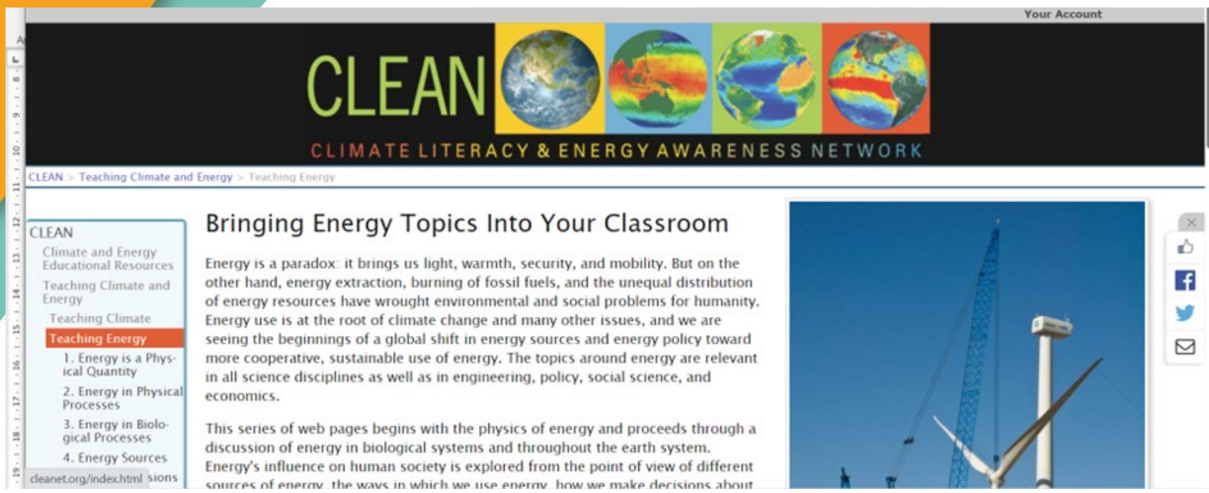

Resources of the National Renewable Energy Laboratory (NREL)
https://www.nrel.gov/index.html
Data and tools: Find NREL-developed data sets, maps, models, and tools used for the analysis of energy and energy efficiency technologies.
Energy basics: Learn about the basics of research areas—bioenergy, geothermal, hydrogen, solar, transportation, wind, and water.

NREL Transforming ENERGY

Design your own eco-city

An eco-city is an ecologically healthy city. In the future, the cities in which we live must enable people to thrive in harmony with nature and achieve sustainable development. People oriented, eco-city development requires the comprehensive understanding of complex interactions between environmental, economic, political, and socio-cultural factors based on ecological principles. Cities, towns and villages should be designed to enhance the health and quality of life of their inhabitants and maintain the ecosystems on which they depend. Eco-city development integrates vision, citizen initiative, public administration, ecologically efficient industry, people's needs and aspirations, harmonious culture, and landscapes where nature, agriculture, and the built environment are functionally integrated in a healthy way.
EU Prototype Model of Smart Eco-Polis adopted the Smart Eco Polis Strategy and Implementation Plan where Eco-town and local communities are envisioned as smart and green, livable and creative, vibrant and attractive, climate-resilient places of the future and unique destination of excellence.

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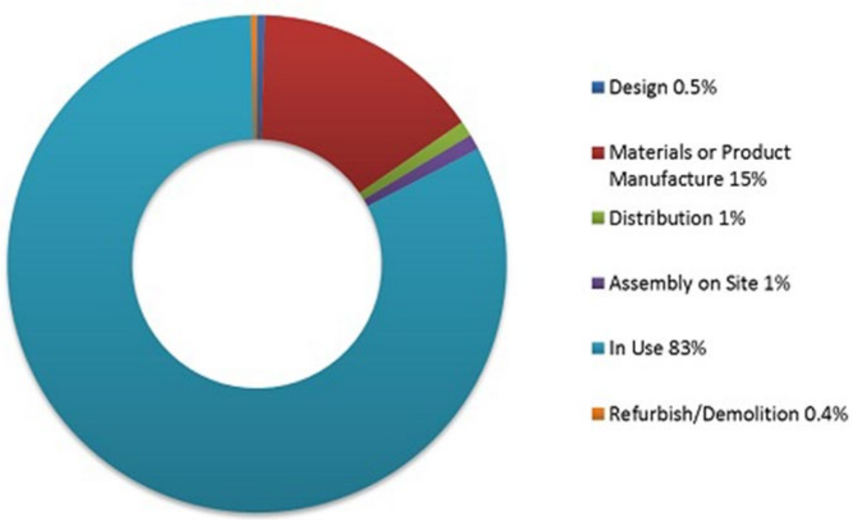
Web-based resources:
https://medium.com/climate-conscious/how-to-design-a-sustainable-city-367b481d2039
https://www.sustainablelearning.com/resource/my-green-city
https://www.southampton.ac.uk/news/2017/07/how-to-build-a-sustainable-city.page

Advanced Level

A big debate to reduce human's environmental impact concerns the chose materials for buildings constructions. As shown in Figure, the building is a process that requires energy during the whole lifetime. Steve Howard, the corporate innovator of IKEA, resumes the compelling needs of sustainability considering that: "we're building cities like never before, bringing people out of poverty like never before and changing the climate like never before. Sustainability has gone from a nice-to-do to a must- to do"



Current energy required for building constructions

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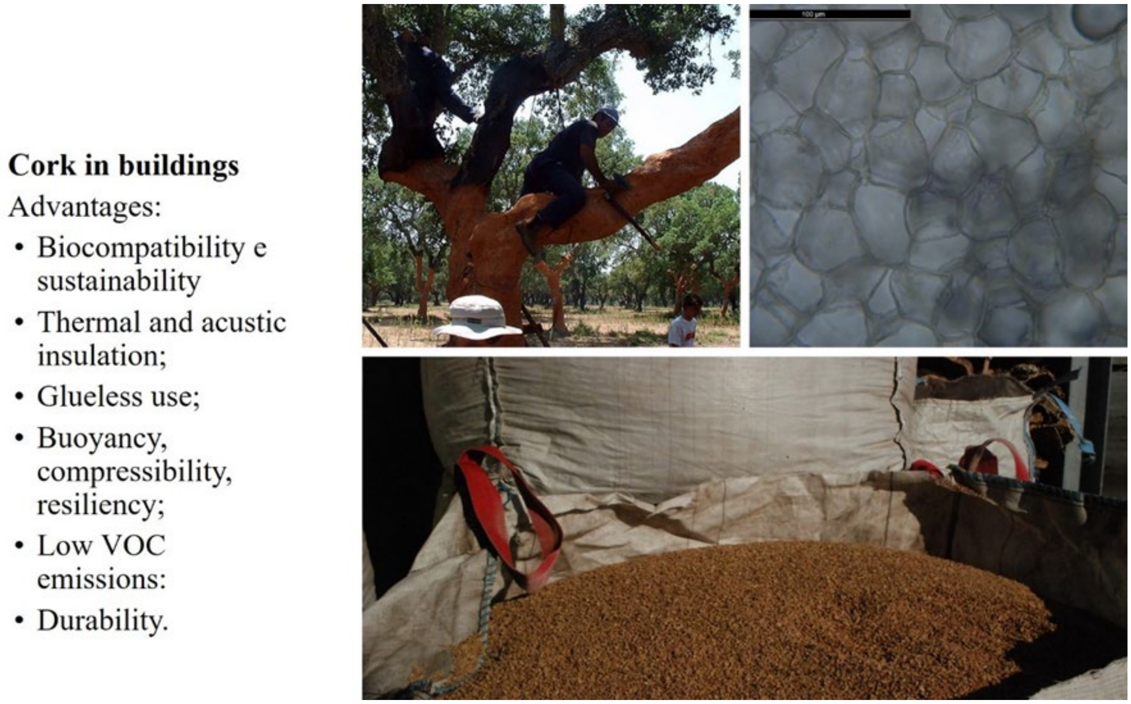
In buildings, it is possible to save energy both in the used materials and in the improvement of the life cycle of the buildings.
Recalling the concept of circular economy, building materials that required less energy and come from recycled materials already exist. For example, the use of sedimentary rock or recycled glass particularly appreciated for their high mechanical resistance. But the new frontier of eco-building seems to be the cork.



Due to the fact that more than 50% of the cell volume of a cork piece consists of air, cork is one of the lightest solid substances. Because heavy pressure does not break down or destroy the tiny air cells but compresses the air within the cells, the cork begins to spring back when the pressure is removed. A roll or sheet of composition cork can be compressed in one direction without losing its dimensions in the other direction. This is of great importance for many applications of composition cork. Moreover, cork is a highly frictional material, both in its natural form as well as in cork composition. Even when wet or coated with oil or grease, cork retains this quality which surpasses that of leather, rubber, and many other products used for frictional or non-skid purposes. The high degree of stability under varying conditions is paramount to the continuing success and use of cork in the world today.

Cork thermal insulation is primarily made from cork oak and can be produced as both a filler material or as boards. Typical thermal conductivity values for cork are between 40 and 50 mW/mK. Cork insulation products may be perforated and also cut and adjusted at the building site, without any loss of thermal resistance.

Some disadvantages in the use of cork are related to aesthetic issues as the limited color availability and the possibility to punctuate or damage if employed as a flooring surface.

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In conclusion, biomaterials is a science about fifty years old. IUPAC's definition of this word is "a material exploited in contact with living tissues, organisms or microorganisms". So, this term includes even the substances that, combined with a suitable polymeric substrate, are able to interact with biological systems and for that reason are employed also for a medical purpose.

From fashion to design, from building to constructions, biomaterials and their application are multiplying, changing the future of our life.

[Advantages & Disadvantages Of Cork Flooring | The Flooring Group]

Activities:

- Propose sustainability Frameworks in the Context of Waste Management: methods, indicators and eventual tools used.
- Propose solutions for an eco-sustainable home

- Flipped learning: discover the Lifecab European project https://www.lifecab.eu/pages/home.aspx

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

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