



#**Solar**4Future+



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SOLAR ENERGY CURRICULUM

2026

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Introduction.....	4
Recommendations gathered from the testing phase of the Solar Energy Curriculum.....	5
Chapter 1: Solar energy curriculum, pedagogical strategies and role play units.....	6
Chapter 1.1: Solar Energy and the Science of Light.....	6
1.1.1: Solar Energy.....	6
1.1.2: Science of Light.....	11
1.1.3: How can we capture solar energy?.....	12
1.1.4: The job market in renewable energy.....	15
1.1.5: Pedagogical Strategies Developed for This Chapter.....	16
Solar Energy and the Science of Light - Role Play Units.....	16
Chapter 1.2: Designing and Building a Solar-Powered Device.....	22
1.2.1: Introduction to Solar Energy and Photovoltaic Principles.....	22
1.2.2: Understanding Efficiency Through Digital Simulations.....	23
1.2.3: Designing, Building, and Testing a Solar-Powered Device.....	23
1.2.4: Real-World Applications and Environmental Reflection.....	25
Role Play Unit: Solar Crossroads - What should our town do?.....	27
Chapter 1.3: Artistic Expression through Solar Energy.....	30
1.3.1: The Sun as a Medium for Artistic Expression.....	30
1.3.2: The Technology Behind Solar Art.....	35
1.3.3: Solar Art and Social Impact.....	37
Artistic Expression through Solar Energy - Role Play Unit.....	41
Chapter 1.4: Exploring Solar Energy Through Mathematics.....	43
1.4.1: Solar Energy - A Brief Scientific Overview of the Concepts.....	43
1.4.1.1: What do you know about the Sun?.....	43
1.4.1.2: What do you know about the Solar System?.....	44
1.4.1.3: What do you know about the planet Earth?.....	45
1.4.2: The Impact of Solar Energy Use on the Economy (Industry, Agriculture, Forestry).....	46
1.4.2.1: Theoretical Framework:.....	47
1.4.2.2: Sector-Specific Impacts:.....	51
1.4.2.3: Cross-Cutting Themes:.....	54
1.4.2.4: Challenges and Opportunities:.....	57
1.4.3: Practical Application Through Mathematics of Solar Energy.....	58
Powering Our Lives: Solar Energy in the Modern Family Pedagogical strategy - Role Play Activity...	64
Chapter 1.5: The Engineering of Solar Energy Systems.....	68
1.5.1: Understanding Solar Energy Engineering.....	68
1.5.2: Engineering Design and Prototyping in Solar Systems.....	72
"The Engineering of Solar Energy Systems" – Role Play Unit.....	78
Chapter 1.6: Renewable Energy and Sustainability in Technology and Society.....	80
1.6.1: Understanding Renewable Energy.....	80
1.6.2: Renewable Energy Technologies.....	83
1.6.3: Benefits of Renewable Energy.....	84
1.6.4: Challenges and the Future of Renewable Energy.....	87
"Renewable Energy Solutions: Community Challenge" - Role Play Unit.....	92



Chapter 2: Solar energy lesson plans.....	95
Chapter 2.1: Lesson Plans - Solar Energy and the Science of Light.....	95
Chapter 2.2: Lesson Plans - Designing and Building a Solar-Powered Device.....	100
Chapter 2.3: Lesson Plans - Artistic Expression Through Solar Energy.....	108
Chapter 2.4: Lesson Plans - Exploring Solar Energy through Mathematics.....	112
Chapter 2.5: Lesson Plans - Engineering a Solar-Powered Device.....	123
Chapter 2.6: Lesson Plans - Renewable Energy and Sustainability in Technology and Society.....	130
Summary.....	143

Introduction

The project “**Solar Energy for Future Generations: Be bright, turn to solar power**” or #Solar4Future+ aims to incorporate STEAM (Science, Technology, Engineering, Arts and Mathematics) to fight against climate change effectively, inclusively, and cooperatively already at school level. For this purpose the six project partner institutions have jointly developed a solar energy curriculum. Each partner was tasked to lead the development of a different STEAM related chapter with role play units and at least three pedagogical strategies for the Solar Energy Curriculum:

- Chapter 1. “**Solar Energy and the Science of Light**” - led by *Rīgas Tehniskā universitāte* (Latvia).
- Chapter 2. “**Designing and Building a Solar-Powered Device**” - led by *Srednja skola Metkovic* (Croatia).
- Chapter 3. “**Artistic Expression through Solar Energy**” - led by *I.I.S.S. Federico II Stupor Mundi* (Italy).
- Chapter 4. “**Exploring Solar Energy through Mathematics**” - led by *Colegiul National Pedagogic Stefan cel Mare* (Romania).
- Chapter 5. “**The Engineering of Solar Energy Systems**” - led by *İnovasyon ve Dijital Gelişim Derneği* (Turkey).
- Chapter 6. “**Renewable Energy and Sustainability in Technology and Society**” - led by *CEIP SAN ISIDRO LABRADOR* (Spain).

While the development of each chapter, role play units and pedagogical strategies was led by a different partner institution, all partners were involved in the quality assurance process of each chapter by providing feedback and suggestions. The chapters, role play units and pedagogical strategies were further used to develop detailed lesson plans to cover all six topics of the solar energy curriculum.

In total, 18 lesson plans were developed, with three lesson plans created for each of the six themes. The development of the curriculum chapters, role-play units, pedagogical strategies, and lesson plans has been completed. With the testing phase of the Solar Energy Curriculum now

concluded, feedback has been collected and analyzed, resulting in a set of recommendations for further improvement and implementation.

Recommendations gathered from the testing phase of the Solar Energy Curriculum.

Overall, the feedback gathered from the testing phase of the Solar Energy Curriculum confirms that the lesson plans are strong and suitable for wider implementation, while also indicating that they would benefit from some adjustments. Some recommendations were highly specific, such as the addition of two worksheets, extra experiments, revisions to certain content and visual materials, and the development of new visual resources, as outlined in the test report. However, the evaluation also identified several broader recommendations that teachers should consider when delivering the lessons:

- Lesson plans benefit when delivered by teachers whose subject expertise is closely aligned with the lesson content.
- In international settings, teachers should actively encourage interaction and collaboration between different groups.
- Teachers should be prepared to adapt the lesson plans to different classroom contexts as needed.
- Teachers can incorporate more audiovisual materials during lessons to foster understanding among students.

Chapter 1: Solar energy curriculum, pedagogical strategies and role play units.

The developed chapters of the solar energy curriculum, pedagogical strategies and role play units are mainly meant as a foundation for the lesson plans. They function as instructional tools to deliver content across the curriculum's six thematic areas and to enhance student comprehension of the various concepts related to solar energy. However, these resources are not limited to this specific purpose. Educators and institutions are encouraged to adapt and use any part of the Solar Energy Curriculum for broader educational purposes related to combating climate change, even outside the specific theme of solar energy.

Chapter 1.1: Solar Energy and the Science of Light

Overview

This chapter explores Solar energy and examines the science of light more thoroughly, as well as provides insight into how the different aspects of solar energy are used with different types of solar power technologies to generate power. Additionally, this chapter explores the job market in the Solar energy industry.

1.1.1: Solar Energy

Solar energy is the energy we can harness from sunlight and heat. The Sun produces energy through a process called nuclear fusion, where tiny particles called atoms are fused together to create energy. This energy travels through space in the form of light and heat, reaching the Earth.

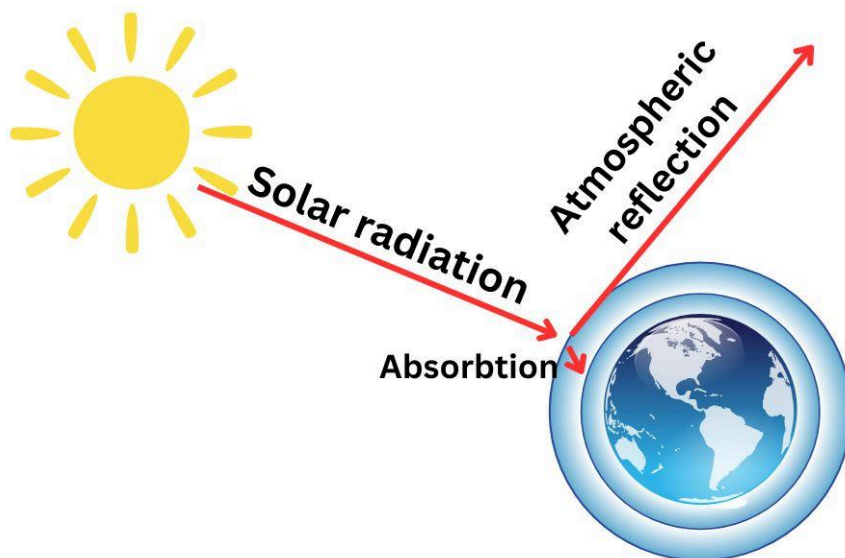
Averaged over an entire year, approximately 171 watts of solar energy fall upon every square meter of Earth. This is a tremendous amount of energy. 22 quadrillion (2.2×10^{16}) watts of power to be exact. As a comparison, a large electric power plant produces about 1 billion ($1 \times$

109) watts of power. It would take 22 million such power plants to equal the energy coming from the Sun. This amount of energy begs the question: Why doesn't Earth just get hotter and hotter?

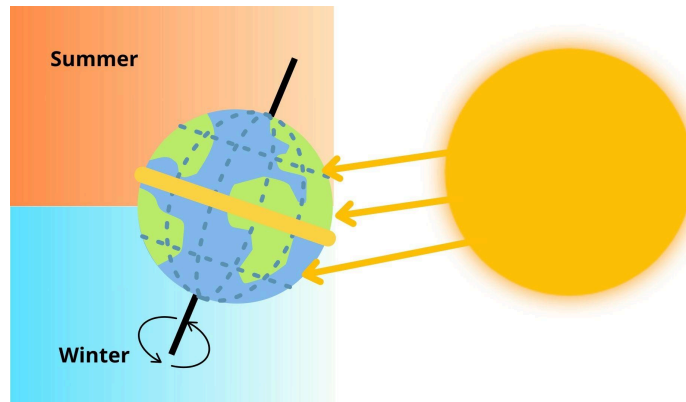
The reason why this doesn't happen is that at the same time the Sun's energy heats Earth, the planet radiates energy that we can't see with our eyes (*longwave radiation or heat*) back to space. As an object heats up, it starts to dramatically increase the amount of heat energy it gives off. So the more Earth heats up, the more rapidly it will lose energy to space. If we measure the total amount of energy Earth receives from the Sun and then subtract the total amount of energy Earth reflects and emits back to space, we are able to get a number called an *energy budget*.

Although it is even more complicated. There are many factors that influence the amount of Sun's energy that gets to the surface of Earth as well as the *energy budget*.

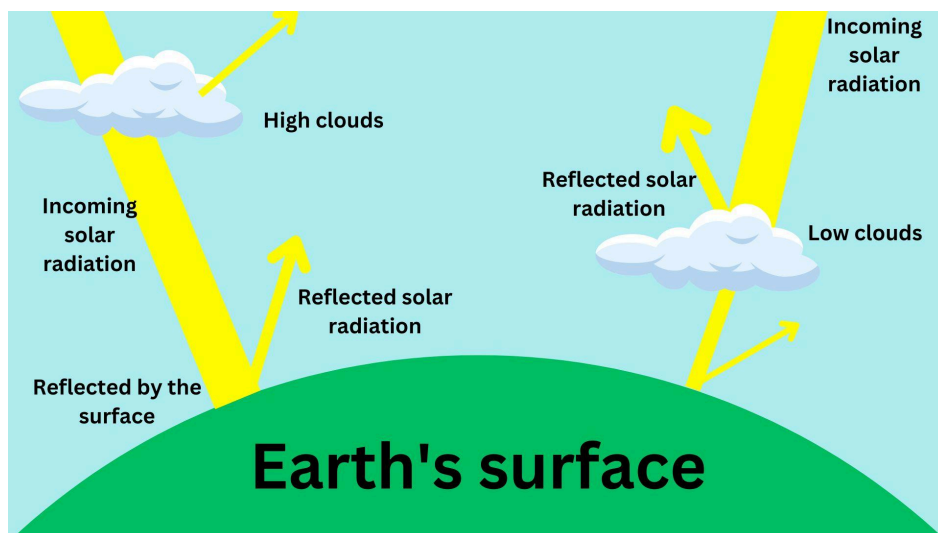
- The atmosphere reflects some of the incoming solar energy back to space immediately and absorbs some of the energy before it can reach the surface;



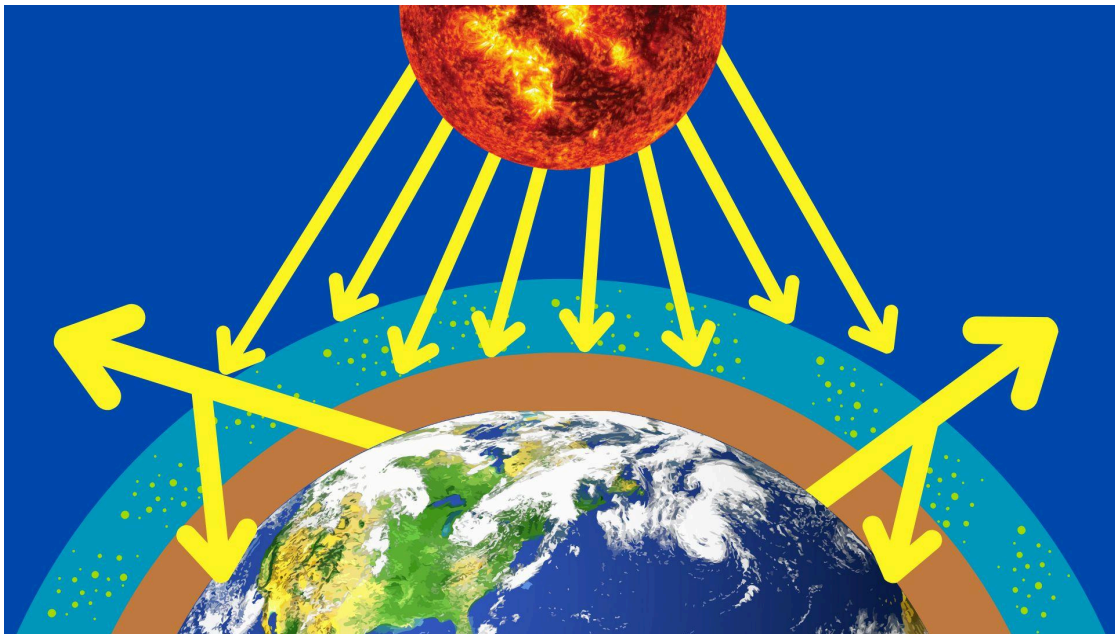
- The Earth maintains an elliptical orbit around the Sun and is tilted relative to the Sun's plane of orbit. At the same time, Earth itself spins on its axis each day. It is this tilt of the Earth's axis that causes the position of the Earth's Poles to change relative to the Sun over the course of a year and explains why we have seasons.



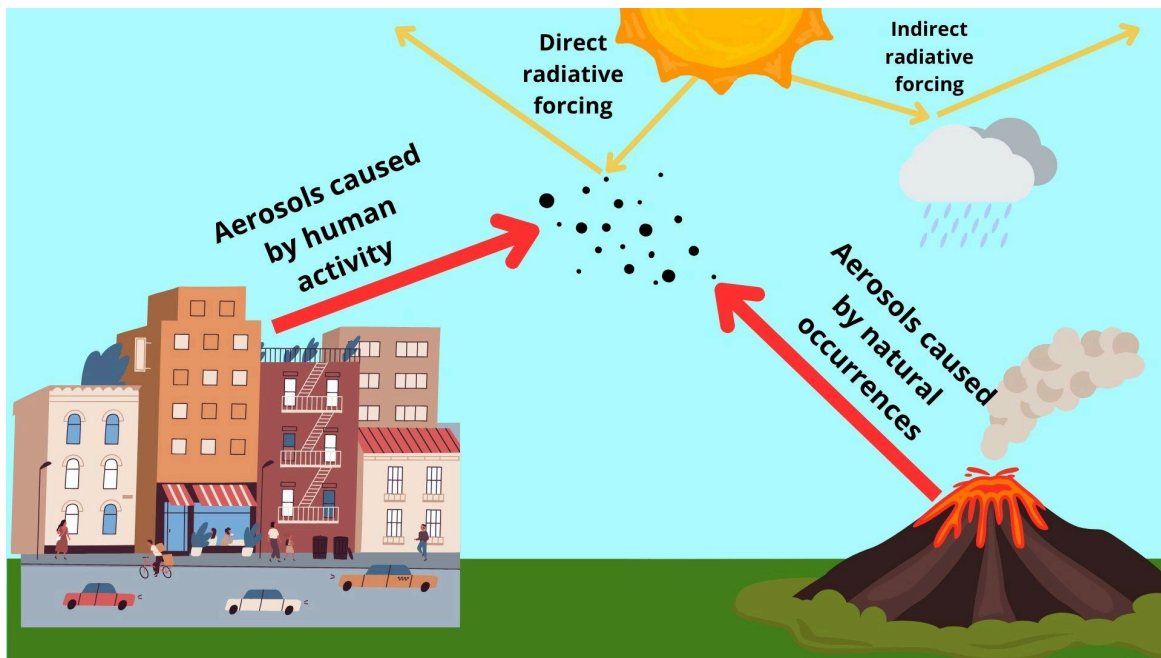
- The amount of change from season to season varies depending on where you are on the planet's surface. Around the Equator, the energy received stays fairly constant throughout the year.
 - In the Poles, there are significant differences between summer and winter.
- Clouds can block a significant portion of the Sun's incoming radiation from reaching Earth's surface.



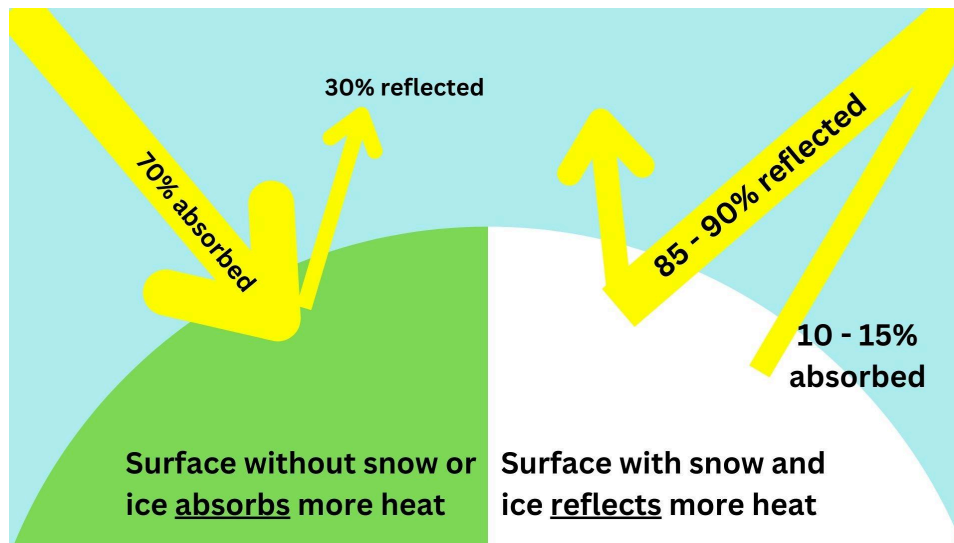
- Only some heat radiated directly from the surface makes it back into space; atmospheric gases, such as water vapor and carbon dioxide, absorb the rest. The gases, in turn, re-radiate some of the heat they absorb. Because these atmospheric gases radiate energy in all directions, some of the energy escapes to space, and some remains in the Earth system, which continues warming the atmosphere and Earth's surface. This trapping of heat by gases like carbon dioxide and water vapor is referred to as the *greenhouse effect*, and the gases that produce this effect are called *greenhouse gases*.



- The presence of aerosols, which are tiny particles (liquids or solids), in the atmosphere can also have a significant impact on Earth's energy budget. Some occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels and the alteration of natural surface cover, also generate aerosols. Averaged over the globe, aerosols made by human activities currently account for about half of the total mass of aerosols in our atmosphere. It's hard to understand the net impact of the aerosols on Earth's energy budget. The answer seems to depend critically on the physical and chemical makeup of the aerosols, the concentration of aerosols present, how effective the aerosols are at absorbing incoming solar radiation, how large the aerosols are, and how high the aerosols are in the atmosphere. Aerosols can also impact the characteristics of clouds, which themselves impact Earth's energy budget.



- Earth's surface is highly variable, and the amount reflected (referred to as albedo) constantly changes. Scientists have to consider the albedo of the surface when they attempt to make energy budget calculations. For example, a snowy and icy surface reflects more sunlight back to space.



1.1.2: Science of Light

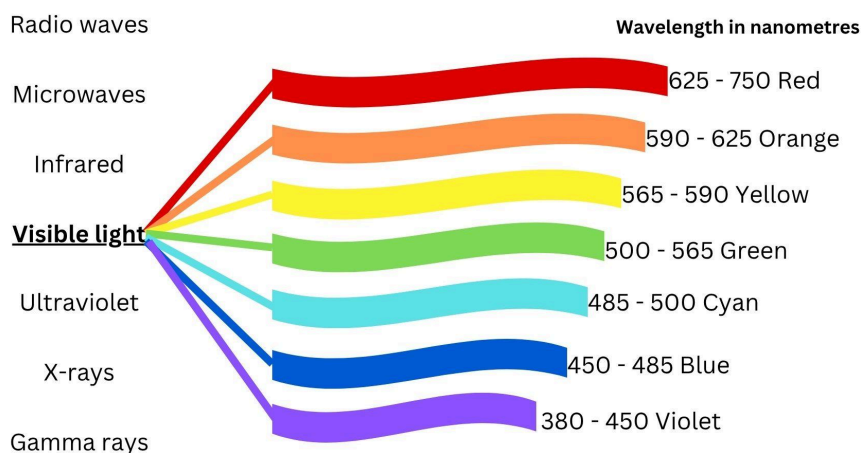
Light is a form of energy. It travels in waves, much like the ripples on a pond. These waves are called electromagnetic waves. These waves don't need a medium (like air or water) to travel through, so light can travel through the vacuum of space. Light travels incredibly fast, about 300,000 kilometers per second. That means the Sun's light reaches Earth in just over 8 minutes.

These waves are what allow us to see things around us. When light hits an object, some of it bounces back into our eyes, which is why we can see it. Although the human eye can see only a very narrow range of wavelengths from about 700 nanometres (nm; billionths of a metre) for red light down to about 400 nanometres for violet light. In physics, the term "light" may refer more broadly to electromagnetic radiation of any wavelength, whether visible or not. In this sense, *gamma rays*, *X-rays*, *microwaves*, and *radio waves* are also light.

Sunlight is made up of many different colors. When light passes through a prism, it splits into a spectrum of colors (red, orange, yellow, green, blue, indigo, violet). This is because different colors of light have different wavelengths.

Wavelengths of Visible Light:

- Violet: 380–450 nm (688–789 THz frequency)
- Blue: 450–495 nm.
- Green: 495–570 nm.
- Yellow: 570–590 nm.
- Orange: 590–620 nm.
- Red: 620–750 nm (400–484 THz frequency)



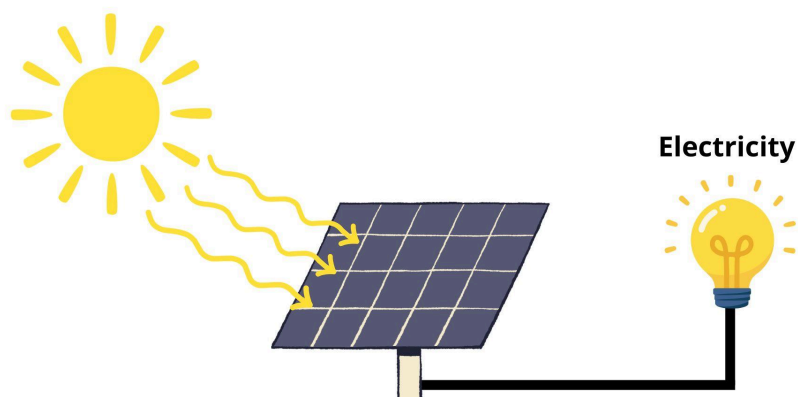
1.1.3: How can we capture solar energy?

Photovoltaic Cells - A *photovoltaic cell* absorbs light and converts it directly into electricity. A group of photovoltaic cells is known as a solar panel. There is confusion over the impact of heat and light in solar power. There is sometimes confusion about the roles of light and heat in solar energy generation because different solar technologies operate in different ways.

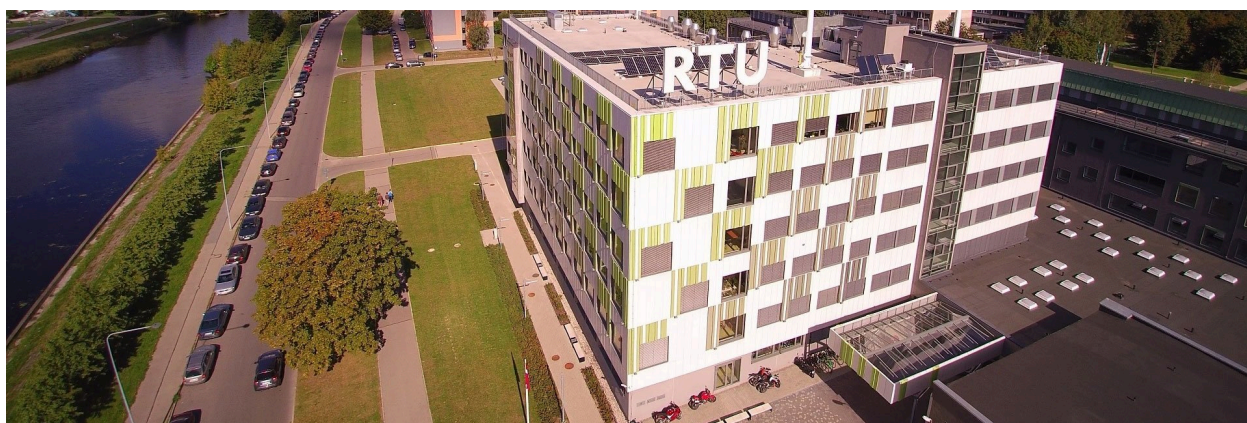
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However, *photovoltaic cells* strictly use light, not heat, to generate electricity. *Photovoltaic cells* are designed to absorb light across a broad spectrum of wavelengths, but they are most efficient at absorbing light in the visible portions of the electromagnetic spectrum (400 - 700 nm). But it can also absorb some ultraviolet light (100 nm to 400 nm) and infrared light (700 - 1100 nm).

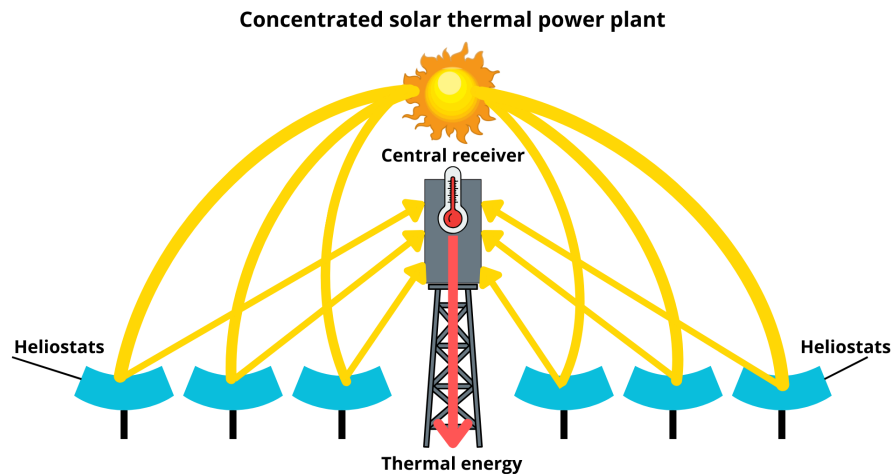


In Latvia, more and more buildings are equipped with *Photovoltaic cells*. That also goes for the RTU campus. Some of the buildings are equipped with solar cells in an effort to reach a climate-neutral university campus.



RTU Campus

Solar Thermal Technology - *Solar thermal power plants or concentrating solar-thermal power (CSP)* use mirrors or lenses to focus a large area of sunlight onto a small area, usually a receiver that absorbs the concentrated solar energy. This concentrated heat is then used to generate steam, which drives a turbine connected to a generator to produce electricity.



One such example in real life is the Ivanpah Solar Power Facility, located in the Mojave Desert, USA. Unfortunately, it is planned to be shut down in 2026. It utilizes 173,500 heliostats, each with two mirrors that focus solar energy on boilers located on three 140-meter-tall solar power towers.



Ivanpah Solar Power Facility

On a smaller scale, solar panels that harness thermal energy can be used for heating water in homes, other buildings, and swimming pools.

Below you can see a picture of how Solar Thermal Technology can be used for home use to heat water.



Solar Thermal Technology for home use

1.1.4: The job market in renewable energy

It is estimated that in 2023, the renewable energy industry was employing approximately 13.7 million people. From which 4.9 million people worked specifically in the Solar photovoltaic (PV) industry. It is a growing industry that offers many well-paid jobs, such as:

- **Manufacturing technician** - works in the solar industry, uses various computer, pneumatic, hydraulic, mechanical, and electrical technologies to set up and modify plant equipment and machinery.
- **Solar technician** - monitors solar photovoltaic (PV) hardware systems to keep them working at their peak performance levels. They provide quality assurance to customers at equipment sites by diagnosing problems, optimizing equipment, and repairing underperforming systems
- **Solar fleet manager** - Oversees the operations of solar equipment installations. They may contact and manage third-party vendors to help with the transport and installation processes and interact with clients to make sure the team meets all service-level agreements.
- **Engineering technician** - Assists civil, mechanical, and environmental engineers and scientists in testing and applying theories to help improve the performance of solar energy-related facilities, processes, or equipment.



- **Solar PV installer** - Design the system layouts using site characteristics and get the proper permits to complete the relevant projects. Solar PV installers also work on the construction characteristics like cutting, bolting, assembling the structural framework, connecting wires, and attaching panels to roofs or ground mounts.
- **Solar site supervisor** - They create and share site drawings and reports, and analyze shade properties and weather patterns at the locations to determine the best type, size, and layout of solar equipment.

These are just some of the professions in the solar power energy field. There are many more interesting career paths that could be found in this field. Some solar energy companies found in Europe are *Enpal*, *NexWafe*, *AMPYR Solar Europe*, Etc.

1.1.5: Pedagogical Strategies Developed for This Chapter

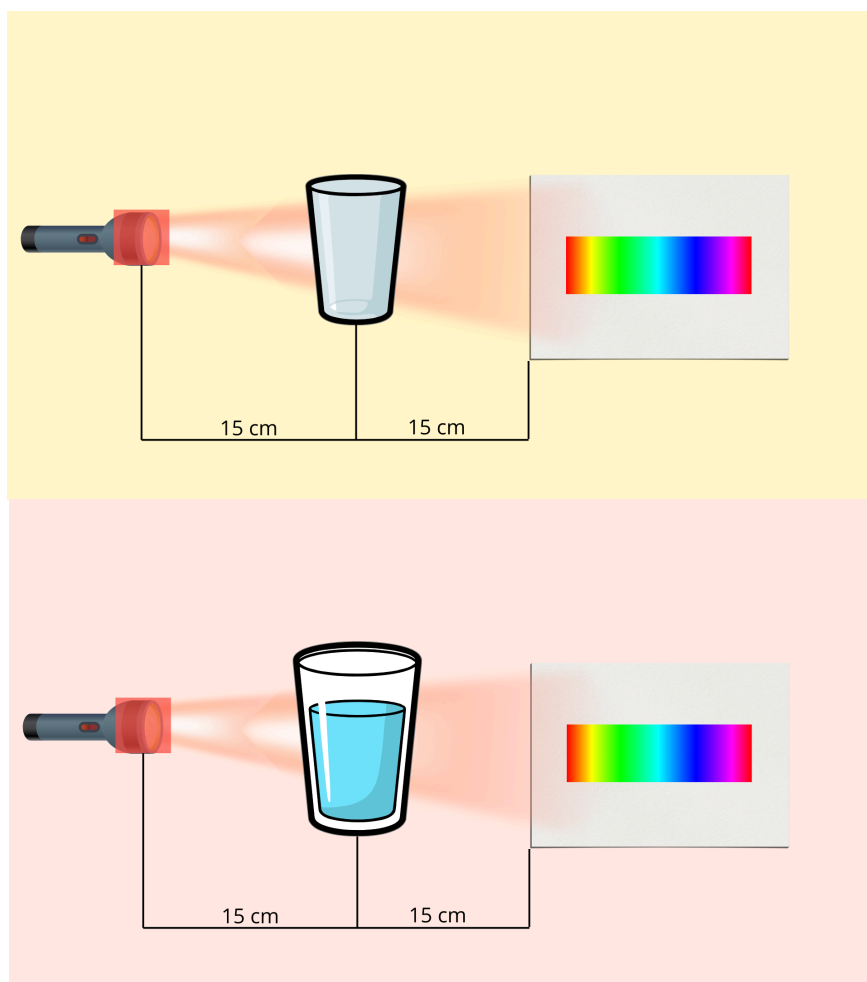
1. **Small Group Discussions** - This strategy requires active participation on the part of the learners to work together in a small group to explore, investigate, make connections, engage in discussion, and reach conclusions.
2. **Questioning and Discussion** - Asking questions that lead to a productive discussion among class members is a way to involve students and keep them engaged with the lesson material.
3. **Inquiry-based learning** - It is an approach to learning that encourages students to engage in problem-solving and experiential learning.

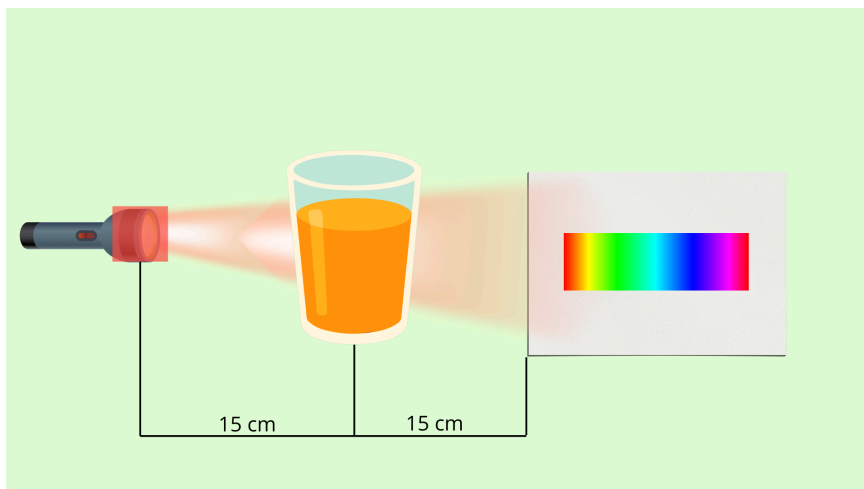
Solar Energy and the Science of Light - Role Play Units

1. The Light Waves in Praxis.

- **Objective:** See which colours pass through a glass and which get absorbed more.
- **Materials:** A glass, water, and some liquid in a different color like orange juice, flashlight, white paper, sheets of coloured cellophane or some other transparent colored plastic material (red, green, blue, yellow)
- **Instructions:**
 1. Place a white paper sheet on a wall or table.
 2. Make a coloured filter: tape one sheet of coloured cellophane over the flashlight (so the light shining on the paper is that colour).

3. Place the flashlight about 30 cm from the white sheet and shine the light on the sheet. Notice the brightness of the colour.
4. Now place the glass between the flashlight and the paper sheet (same distance from the flashlight and the paper). Observe the colour and brightness of the paper.
5. Repeat for each available coloured cellophane (red, green, blue, yellow).
6. Then pour water into the glass and repeat the process.
7. Then pour the third liquid (Orange juice) into the glass and repeat the process.





- **Register** the changes in colour and brightness for each colored light shone through each different liquid.
- **Discuss** the results with the class.
- **Expected results:**
 - Some colours will pass through the glass with little change, but some may appear less bright. Ordinary glass transmits visible light fairly well, but coloured filters can reveal differences. For example, blue light might dim more.
 - In clear water, there also should be very little change; however, red light might be very slightly dimmer than blue colour.
 - If you choose orange juice as your third liquid, then blue and green light would be absorbed the most, but red and yellow light would pass through the liquid very well. You can also choose different liquids, but the results would vary depending on the chosen liquid.



2. Classroom Experiment - Solar panel optimization lab

- **Objective:** Measure and maximize the electrical power produced by a solar cell/panel under different lighting conditions.
- **Explanation:** Solar panels convert light into electricity. Output depends on light intensity, angle, and spectrum. You will act like engineers: change one variable at a time, measure V and I, then compute power $P = V I$.
- **Materials:** Solar cell, multimeter, load (resistor or small motor/LED), lamp/flashlight, colored filters (cello-phane / sunglasses / tinted plastic), tape.
- **Setup:** Connect the panel to the load. Measure:
 - **Voltage V (volts):** measure across the load
 - **Current I (amps):** measure in series with the load (your teacher will show the correct multi- meter mode)

Control conditions (keep constant):

Lamp distance:

Load:

Test at least 3 filters (example: none, red, blue/green, sunglasses).

Data table

Compute: $P = V \times I$ (watts). If I is in mA, convert to A: 1000 mA = 1 A.

Filter	V (V)	I (A)	P (W)
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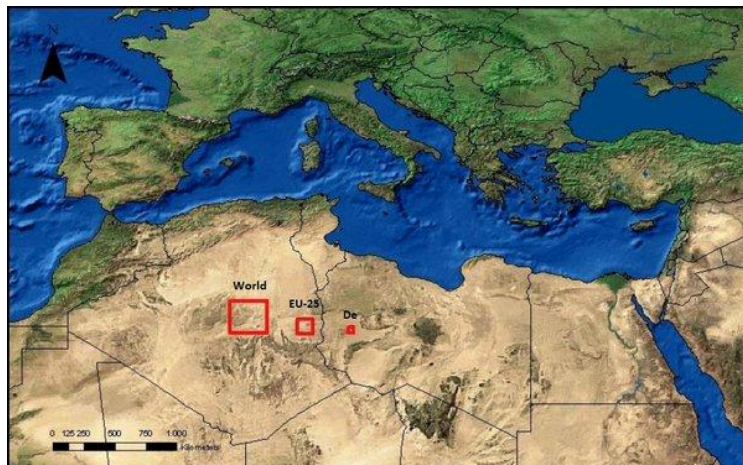
Results

Highest power you achieved: _____ **W**

What filter gave that result?

3. Implementation of Solar panels discussion (ANNEX 2: Solar Energy Park – Decision Matrix)

- **Objective:** A Better understanding of Photovoltaic Cells.
- **Instructions:** 1. Discussion about solar energy parks. Split the class in groups of five.
(Context - There is a theory that if you were to cover 1.2% of the Sahara desert in photovoltaic cells, it would be enough to provide energy for the whole world).



1.1. Ask a question to the groups if you were to build a solar park, which specific spot on Earth would you choose?

Possible answers: Places with a lot of sunlight and located closer to the equator, such as the Sahara Desert, the Arabian Peninsula, Arizona, Nevada, the Australian outback, Atacama Desert...

1.2. Ask a follow-up question - Why would you choose this place? Do you foresee any problems or challenges in building solar cells in the chosen place?

Possible answers: Students should choose a place with a lot of sunlight, low cloud cover, having large open spaces.

Possible challenges: Harsh environment (sandstorms, extreme heat), lack of infrastructure, located too far away from major cities, lack of water for maintenance and workers.

1.3. Engage the other groups to share their opinions regarding the specific group's choice of where to place a solar park.



4. Solar Power courtroom (ANNEX 1: Solar Power Courtroom)

- **Objective:** Students will engage in a debate about the benefits and challenges of solar energy.
- **Instructions:**
 - Split the class into two teams of “lawyers”.
 - One team will argue that solar energy is the future of power generation, while the other will argue that it has limitations.
 - After both sides present their arguments, hold a class discussion where students can share their thoughts and come up with solutions to challenges posed by solar energy.

Chapter 1.2: Designing and Building a Solar-Powered Device

Overview

This chapter is designed to introduce students aged 14 to the concepts, applications, and societal importance of solar energy through an immersive STEAM-based (Science, Technology, Engineering, Arts, Mathematics) approach. By combining theoretical instruction, digital simulations, and hands-on prototyping, students gain a well-rounded understanding of how solar energy works, how it can be harnessed, and how it is applied in the real world to tackle environmental and engineering challenges. The cornerstone of this chapter is the process of designing and constructing a functional solar-powered device that will not only reinforce technical concepts but also encourage innovation, collaboration, and critical thinking.

1.2.1: Introduction to Solar Energy and Photovoltaic Principles

Solar energy is a renewable and sustainable source of power that comes from the Sun. It is one of the most important alternatives to fossil fuels because it is clean, widely available, and does not produce greenhouse gases during use. As the world looks for ways to fight climate change and reduce pollution, solar energy plays a key role in creating a greener future.

A key way solar energy is used is through **photovoltaic (PV) technology**. This is the process of turning sunlight directly into electricity. PV systems are made up of solar panels, which contain special materials called **photovoltaic cells**. When sunlight hits these cells, it creates an electric current — a process known as the **photovoltaic effect**.

The photovoltaic effect is a physical and chemical reaction that happens when light energy causes electrons to move within a material, producing electricity. This principle is used in many everyday devices, such as **solar-powered calculators, garden lights, and traffic signs**. These simple examples show how solar energy can be used in small, practical ways.

Solar energy also has many larger benefits. It can help reduce our use of fossil fuels, lower air pollution, and provide electricity in areas that are far from power plants. As technology improves, solar panels are becoming more affordable and easier to install, making solar energy a growing part of the world's energy mix.

Understanding how solar energy works helps us see how science and technology can support a more sustainable future. This chapter gives the basic principles and ideas behind solar power and photovoltaic systems, preparing students to explore the topic further in future lessons.

1.2.2: Understanding Efficiency Through Digital Simulations

Before transitioning to physical construction, students engage in a digital exploration of solar panel efficiency. Using platforms such as PhET Interactive Simulations and Tinkercad Circuits, students explore how various factors, such as sunlight angle, panel surface area, light intensity, temperature, and weather conditions, affect a solar panel's energy output. These simulations are crucial in providing a safe, scalable, and customizable learning environment where students can manipulate variables and immediately observe results.

Students work in pairs or small groups to test different configurations, documenting the energy outputs from each scenario and noting any patterns. Educators should encourage students to analyze the data and extract conclusions about optimal panel orientation and placement. Through guided questions and reflection, students begin to apply scientific reasoning, bridging the gap between theoretical knowledge and practical application. These insights will later inform their physical prototype designs.

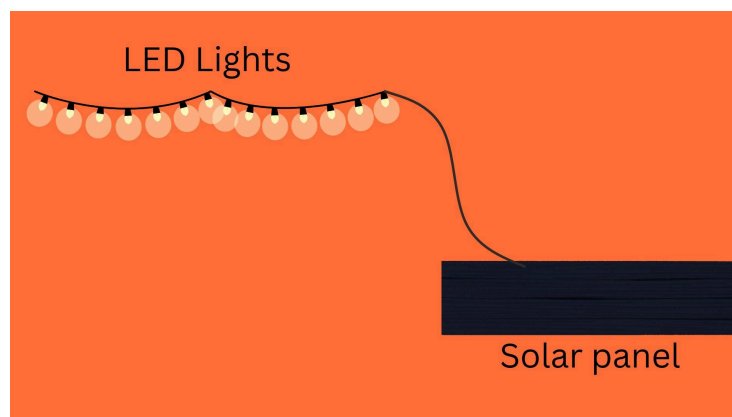
1.2.3: Designing, Building, and Testing a Solar-Powered Device

At the heart of the chapter is the hands-on project: designing and building a solar-powered device. Students are divided into small groups and tasked with creating a device that performs a simple function using solar energy. Possible project ideas include solar-powered fans, LED lights, model vehicles, water pumps, or rotating displays. Educators provide each

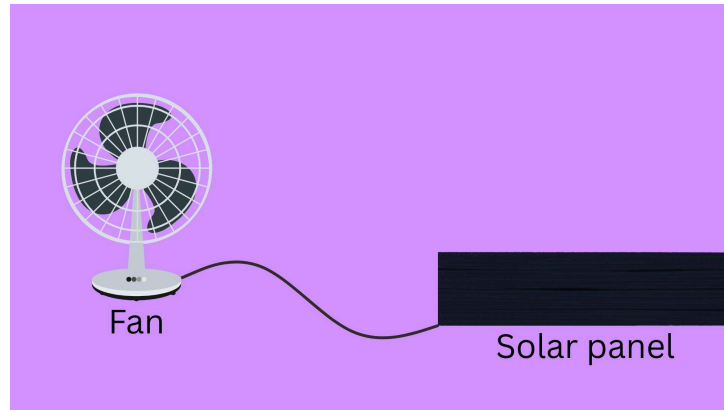
group with a kit that includes small solar panels, motors or LEDs, wires, connectors, building materials (such as cardboard, straws, and wheels), and tools like scissors, glue guns, and multimeters.

The project process begins with brainstorming and sketching design ideas. Students are guided to think critically about how the solar panel will be positioned, how energy will flow through the circuit, and how they can optimize performance. Safety protocols are emphasized, particularly when working with electrical components and tools.

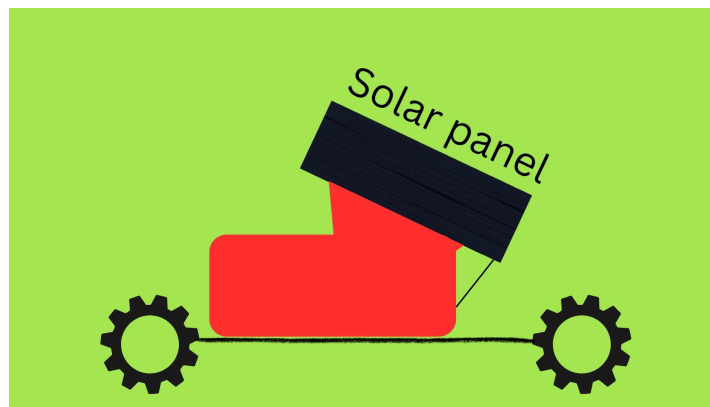
Once construction begins, students test their devices in various lighting conditions, natural sunlight, shaded areas, and artificial light. Using multimeters, they measure voltage and current to evaluate how changes in lighting, angle, and construction affect performance. This encourages scientific inquiry and real-time problem-solving. Students should record their observations, reflect on what worked and what didn't, and modify their designs accordingly. Teachers monitor progress and provide formative feedback throughout the process.



Solar-powered LED lights



Solar-powered fan



Solar-powered module vehicle

1.2.4: Real-World Applications and Environmental Reflection

After building and testing their prototypes, students are encouraged to expand their thinking by exploring real-world applications of solar energy. Each group is assigned or selects a case study, such as solar-powered vehicles, solar farms, solar cookers, or disaster-relief energy kits. They research these systems and analyze their environmental, technical, and societal impacts. A structured worksheet guides their exploration, prompting students to consider the device's purpose, target user, cost efficiency, scalability, and environmental benefit.

Groups then present their findings to the class through a short multimedia presentation. This segment of the chapter fosters public speaking skills, encourages creativity in presentation, and cultivates a deeper awareness of the practical implications of renewable energy technologies.

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Educators facilitate a whole-class discussion that connects these case studies to broader themes such as climate change, sustainable development goals, and energy justice.

Assessment and Evaluation

The chapter employs both formative and summative assessment strategies to ensure a robust understanding of concepts and engagement in activities. Formative assessments include teacher observations during group discussions, simulation activities, and construction sessions, where educators assess understanding, collaboration, and initiative. Teachers also listen for students' ability to reason scientifically, articulate their design choices, and troubleshoot problems effectively.

Summative assessments focus on three main outputs: the functionality and creativity of the final solar device, the clarity and relevance of the group presentations, and a reflection report or learning journal in which students document their process, findings, and what they would improve in the future. A rubric can be used to ensure consistency and transparency in grading.

Resources for Teachers

To successfully deliver this chapter, teachers should prepare a combination of physical materials, digital tools, and educational content:

Digital & Online Tools:

- PhET Solar Panel Efficiency Simulation – <https://phet.colorado.edu>
- Tinkercad Circuits – <https://www.tinkercad.com>
- YouTube Explainer Videos:
 - How Solar Power Works: <https://www.youtube.com/watch?v=dHVZ6jEf8To>
 - Advanced Solar Cell Physics: <https://youtu.be/8RjGHmlOu58>
- Solar Schools Knowledge Bank – <https://solarschools.net/knowledge-bank/energy>
- SEI Renewable Energy Courses – <https://www.solarenergy.org>

Skills Developed

This chapter is designed to build a wide range of student competencies:

- Scientific Literacy – Understanding energy conversion and electrical circuits.
- Engineering and Design Thinking – Applying iterative design and optimization strategies.
- Problem-Solving – Troubleshooting design and technical issues in real-time.
- Collaboration – Working effectively in groups with shared responsibilities.
- Environmental Awareness – Understanding sustainability and energy systems.
- Digital Literacy – Navigating simulations and virtual design tools.
- Communication – Presenting findings clearly and confidently.

Feedback and Reflection

At the end of the project, students complete a reflection form detailing their learning journey, challenges faced, and insights gained. Teachers also collect feedback through direct conversation and anonymous surveys to assess the effectiveness of the lesson and guide future improvements. A post-project debrief provides space for both celebration and constructive discussion, helping students internalize their experience and recognize its value.

Role Play Unit: Solar Crossroads - What should our town do?

Objective

This activity helps students understand how different people feel about using solar energy. Students will think about the environment, jobs, money, and fairness. By acting as different people in a town, they will learn how decisions about energy can be difficult and involve many points of view.

Learning Goals

By the end of the activity, students will:

- Understand what different people want or worry about when it comes to solar power.
- Speak clearly and try to explain their role's opinions.
- Work together to make a fair decision.

- Think about how we can use clean energy fairly and smartly.

Scenario

The small town of **Metković** has just won money from the government to start a clean energy project. They must choose between:

1. A **small town-owned solar system** (microgrid) for local use.
2. A **big solar power plant** was built by a company nearby.

The mayor has asked a **Citizens' Assembly** to meet and give advice on what to do. Students will act as members of this assembly.

Roles

Each student will play one of these people:

1. **Retired Coal Miner** – worried about losing jobs and town traditions.
2. **Indigenous Land Representative** – wants to protect cultural land.
3. **Tech Business Owner** – excited about new solar technology.
4. **Low-Income Resident** – wants cheaper energy for families.
5. **Local School Teacher** – cares about students' future and learning.
6. **Energy Expert** – knows about costs and rules for solar.
7. **Religious Leader** – thinks about what's right and fair.
8. **NGO Moderator** – runs the meeting and keeps things fair.

Preparation

1. Give each student a **Role Card** with facts and ideas.
2. Students read their cards and plan what to say.
3. Optional: Students can dress up or bring a simple prop to match their role.

Activity Time

1. Set up the classroom like a meeting circle.
2. The Moderator welcomes everyone and explains the issue.
3. Each role gives a short 2-minute talk.



4. Students talk and respectfully respond to each other.
5. In the end, the group tries to vote or agree on what to recommend.

Debrief and Reflection

After the role play, have a class talk or writing task:

- What arguments were the strongest?
- Did anyone change their mind? Why?
- What made it hard to agree?
- How can solar power be used fairly?
- Students can write a short reflection or opinion from their role's view.

Materials Needed

- Role Cards
- Name tags or signs
- Internet or reading info
- Grading checklist or rubric
- (Optional) Props or costumes



Chapter 1.3: Artistic Expression through Solar Energy

Overview

In this chapter, we will explore how solar energy is not just a source of sustainable electricity but also a creative tool that artists and engineers use to create innovative and interactive artworks. By combining science, technology, and art, solar energy becomes a medium to express ideas, illuminate public spaces, and raise awareness about the importance of renewable energy.

1.3.1: The Sun as a Medium for Artistic Expression

Key Concepts Covered:

- Solar kinetic art: sculptures and installations that move thanks to sunlight.
- Interactive artworks powered by solar energy.
- Solar light art and solar painting.

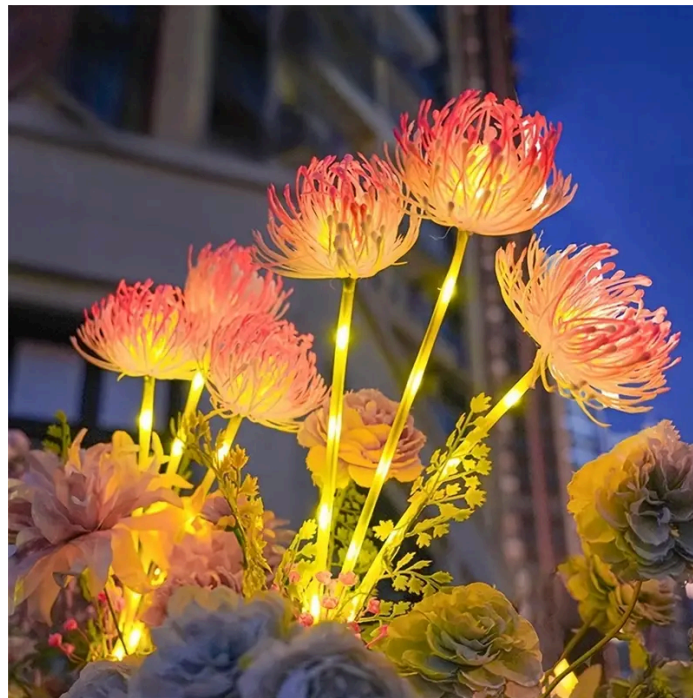
Solar Kinetic Art and Installations:

Kinetic art is a form of art that incorporates movement as an essential element. When solar energy is used to power these movements, sculptures come to life with sunlight. An iconic example is "**Sunflowers**" by **Anthony Howe**, a stainless-steel sculpture that gently rotates thanks to small solar-powered motors.



"Sunflowers" by Anthony Howe

Another example is the **Innovative sculptural solar flower** with advanced photovoltaic solar panels that open and close to cleaning itself for maximum efficiency.



Purchasable sculptural solar flowers

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“An artwork is never just the object; it is also the experience and its contextual impact, how it is used and enjoyed, and how it raises questions and changes ways of thinking and living. The Solar Panel Art Series does exactly that, and it is a great example of how to open up the discussion about renewable energy and the unequal distribution of energy today. In addition, they not only make us think, but also act. The Solar Panel Art Series decided to donate a part of their proceeds to the Little Sun Foundation, in order to bring light and study time to children in rural Rwanda, and we are very grateful for this. Collectively, we can work towards global togetherness and a better future, including energy access for all.”

<https://www.youtube.com/watch?v=VTqzruNcrGs>



"Artist Olafur Eliasson's "Little Sun"

Interactive Artworks Powered by Solar Energy

Solar art can be interactive, engaging the audience through light and movement. An example is "**Mécaniques Discursives**" by **Fred Penelle and Yannick Jacquet**, where solar energy powers dynamic projections that change depending on the intensity of sunlight.



Fred Penelle and Yannick Jacquet's "Mécaniques Discursives"

Artists also use photovoltaic panels to power their artworks. **"Solar Tree"** by **Ross Lovegrove**, for instance, is a structure that resembles a tree with solar panel "leaves," which illuminate the surrounding space at night.



"Solar Tree" by Ross Lovegrove

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Solar Light Art and Solar Painting

Some artists experiment with **photo-reactive paints** that glow under the sun, creating images that are only visible under certain light conditions. Solar energy is also used to illuminate murals at night or project temporary images that fade away as the sun sets.

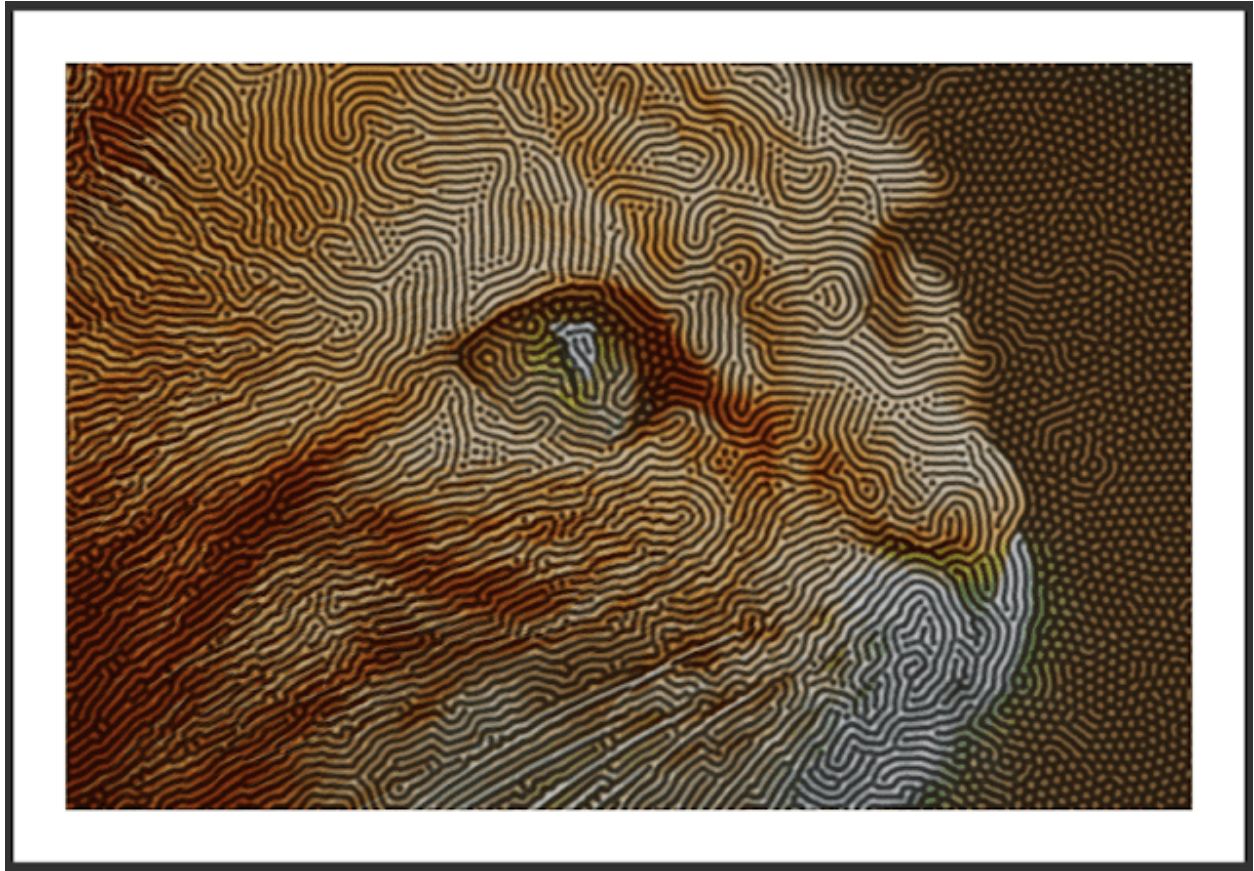


Image processing with a Reaction-Diffusion using the Gray-Scott model



Comparison of Different Types of Solar Art

Type of Solar Art	Description	Example	Energy Usage & Efficiency
Solar Kinetic Sculptures	Moving sculptures powered by solar energy, often using small solar panels to drive mechanical parts.	"Sunflowers" by Anthony Howe	Uses small motors powered by solar panels; efficiency depends on sunlight availability.
Solar-Powered Murals	Wall art that integrates solar panels to store energy and illuminate designs at night.	"The Solar Mural Project" (Los Angeles)	Solar panels charge batteries during the day, providing light at night with high efficiency.
Interactive Solar Installations	Public art installations that react to sunlight by changing colors or movement.	"Mécaniques Discursives"	Solar energy powers LEDs or mechanical components, requiring efficient battery storage.
Solar Light Art	Artworks using solar-powered lights to create glowing effects at night.	"Solar Trees" by Ross Lovegrove	Uses photovoltaic panels to charge LEDs; highly efficient with minimal energy waste.
Photo-Reactive Paintings	Paintings using special solar-reactive materials that change appearance in sunlight.	Experimental solar paintings	No electricity needed; relies on chemical reactions with sunlight.

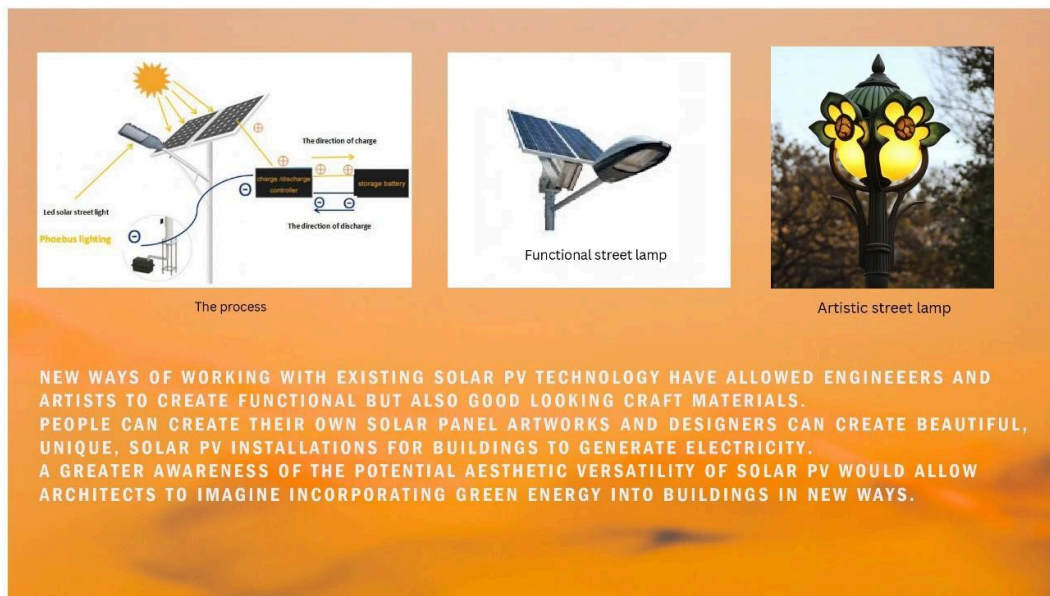
1.3.2: The Technology Behind Solar Art

Key Concepts Covered:

- The use of photovoltaic cells in art.
- Innovative and sustainable materials.
- The role of engineering in artistic design.

How Do Photovoltaic Cells Work in Art?

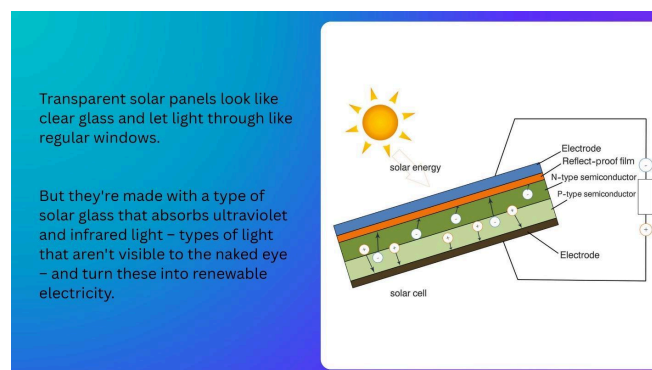
Artists use solar cells to generate energy that powers their installations. These cells can be integrated into artworks either visibly or discreetly, creating a unique aesthetic effect. Some installations use transparent panels that allow light to pass through without compromising the artwork's beauty.



Here's a graphic illustrating the use of photovoltaic (solar) cells in art. It shows how solar-powered sculptures, interactive installations, and architectural designs can integrate solar panels creatively.

Innovative and Sustainable Materials

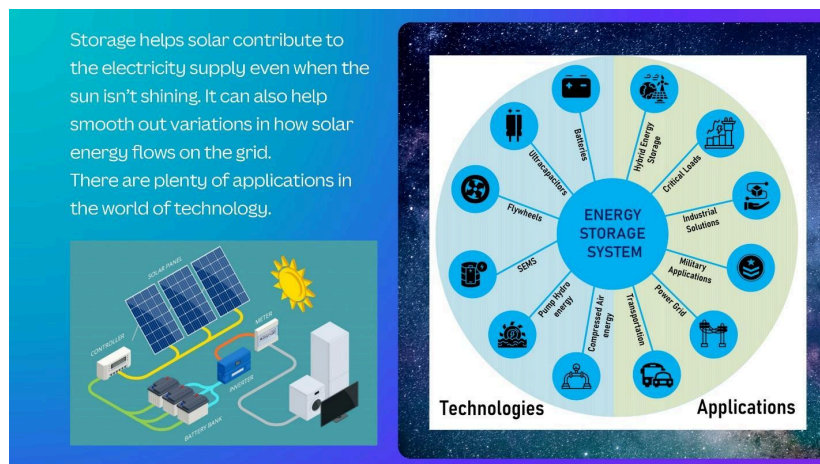
Beyond traditional photovoltaic panels, artists explore new materials such as **graphene**, which allows for ultra-thin and flexible solar cells, and **transparent solar films**, which can be applied to glass and plastic surfaces.



Here's a graphic representing, for instance, how transparent solar films work.

The Role of Engineering in Artistic Design

Engineering plays a key role in turning an artistic idea into a functional reality. Engineers collaborate with artists to develop energy storage systems and automation that allow artworks to react to sunlight in surprising ways.



Here is a graphic illustrating the technological applications of the energy storage system.

1.3.3: Solar Art and Social Impact

Key Concepts Covered:

- Solar art as an educational tool.
- Artistic installations for urban sustainability.
- Solar art and climate change awareness.

Solar Art as an Educational Tool

Many solar art projects are designed to raise public awareness about renewable energy.

Installations in public spaces, such as **"The Solar Mural Project" in Los Angeles**, combine art and technology to educate visitors on the importance of solar energy.



“Choose Earth”, a Land Art Generator Solar Mural by artist Peggy Flavin

Artistic Installations for Urban Sustainability

Solar-powered artworks are often integrated into urban landscapes to enhance city aesthetics and provide sustainable lighting. A great example is "**The Sunflower Project**," where sunflower-shaped street lamps autonomously power themselves with solar energy, reducing environmental impact.



Solar energy flower street lamp

Solar Art and Climate Change Awareness

Solar art is not just decorative; it is also a means of protest and reflection on climate change. Some artists create works that highlight the need to reduce fossil fuel consumption, such as murals that glow at night only thanks to the solar energy collected during the day.



Andreea Dumez

In a world where the clock is ticking on climate change, artists are stepping up in a big way. Through a vivid and impactful medium, they're shining a spotlight on the environmental challenges we face, and they're doing it with style.

Educational Strategies:

- **Project-Based Learning (PBL):** students design their own solar artwork;
 - **Interactive Labs:** experiments with photovoltaic cells to create small solar sculptures;
 - **Role-Playing & Gamification:** simulations where students take on the roles of solar artists and engineers;
 - **The Solar Mural Project (Los Angeles)** – A real-world example of solar-powered murals used for educational purposes;
 - **The Solar Panel Art Series** – A project where artists use solar panels as canvases, raising awareness about renewable energy.
-

Artistic Expression through Solar Energy - Role Play Unit

Overview:

This activity, "Artistic Expression through Solar Energy," engages students in exploring the intersection of solar energy and the arts. Students will take on roles representing different stakeholders to develop creative projects that use solar energy as a medium for artistic expression. Through this experience, students will gain a deeper understanding of sustainable energy while fostering innovation in the arts.

Objective:

To provide hands-on experience in integrating solar energy with artistic creativity. Students will learn about sun powered technologies, explore the environmental and social impacts of solar energy, and develop artistic projects that harness the power of the sun.

Step-by-Step Guide:

Step	Description	Roles Involved
1. Introduction to the Activity	Introduce the concept of "Artistic Expression through Solar Energy." Explain how solar energy can be used creatively in visual arts, such as Photography. Define the roles: Experimental Photographers, Experts of Science/Biology, Artists.	All roles (Experimental Photographers, Experts of Science/Biology, Artists)
2. Divide Students into Groups & Assign Project Themes	Split students into groups and assign each a specific artistic project theme (e.g., solar-powered cyanotypes, anthotypes, chlorophyll photography). Assign roles within each group: Experimental Photographer, Experts of Science/Biology, Community manager.	Experimental Photographer, Experts of Science/Biology, Community manager.
3. Research and Preparation	Each group member researches their assigned role. Experts of Science/Biology explore sun powered chemical reactions (emulsions created by flowers, fruits and vegetables). Experimental Photographers produce negatives for the sun-powered prints. Community managers organize the final exhibition.	Experimental Photographer, Experts of Science/Biology, Community manager
4. Group Discussion & Project Development	Groups discuss the results of the artistic products, assess feasibility, and brainstorm artistic solar projects. Scientists and biologists propose the chemical solutions and the best procedures to create	Experimental Photographer, Experts of Science/Biology, Community manager



	emulsions. Experimental Photographers present their botanical photos. Community managers address logistics for the exhibition and community involvement.	
5. Prototype Design & Storytelling	Groups sketch, design, or create small-scale prototypes of their sun-powered photography. They prepare a story or a Moodboard behind their project to present to the class.	Experimental Photographer, Experts of Science/Biology, Community manager
6. Presentations & Community Feedback Simulation	Each group presents their artistic solar project, highlighting innovation, sustainability, and community impact. The class simulates a community meeting, providing feedback and asking questions.	Experimental Photographer, Experts of Science/Biology (presenters) and Community managers (community feedback)
7. Evaluation & Refinement	Groups reflect on feedback and evaluate the effectiveness of their projects. They refine their designs based on critiques from peers and the simulated community discussion.	All roles (evaluators and refiners)
8. Final Exhibition & Action Plan	Each group showcases their refined solar artworks. The class votes on the most engaging and impactful project, and groups develop an action plan for real-world implementation.	All roles (as voters and decision-makers)

This role-play unit provides a unique and engaging way for students to understand the potential of solar energy while fostering artistic expression. Through collaboration and creativity, students will gain insight into how science and art can work together to promote sustainability.

Conclusion

Art and solar energy come together to create unique experiences, transforming sunlight into movement, colour, and powerful messages. Beyond being a source of inspiration, solar art demonstrates how technology can be used in innovative and sustainable ways, promoting a greener and more conscious future.

Chapter 1.4: Exploring Solar Energy Through Mathematics

Overview

Mathematics provides the essential framework for understanding, designing, and optimizing solar energy technologies and systems. This, in turn, fuels the growth of the solar industry, leading to significant positive economic impacts through job creation, investment, and reduced energy costs. The economic viability of solar energy projects is also heavily reliant on mathematical modeling for financial forecasting, risk assessment, and return on investment calculations.

In conclusion, mathematics acts as the bedrock for the advancement and deployment of solar energy, which, as a clean and sustainable energy source, yields substantial economic benefits, contributing to a more prosperous and environmentally responsible future.

By exploring the mathematical concepts, the chapter would provide a comprehensive understanding of how mathematics plays a crucial role in the development and implementation of solar energy solutions.

1.4.1: Solar Energy - A Brief Scientific Overview of the Concepts

Key Concepts:

- *Solar System*
- *Solar Energy*
- *Solar Radiation - The Sun as the Source*

1.4.1.1: What do you know about the Sun?

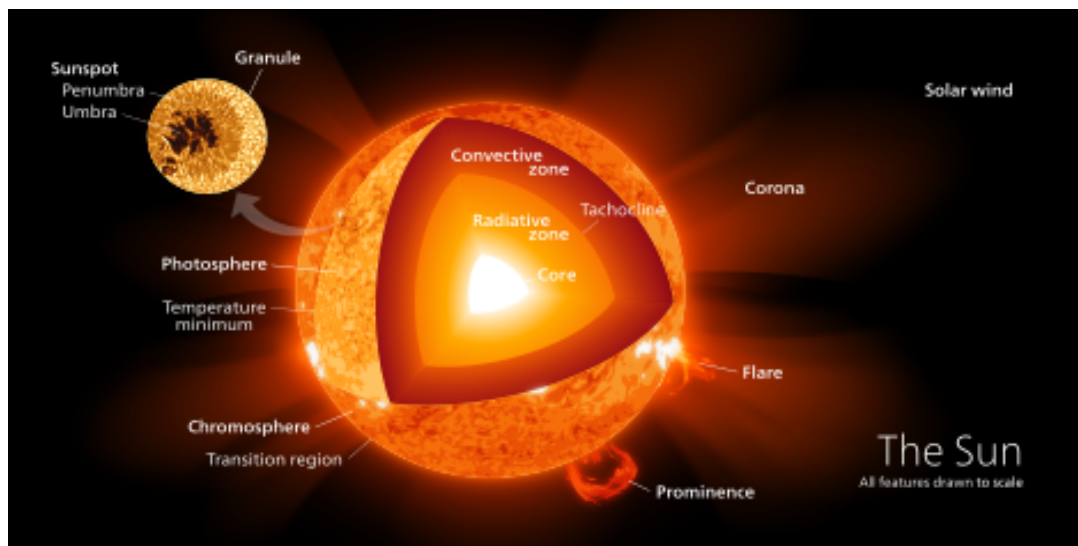
The Sun is the star at the center of the Solar System. It is a nearly perfect sphere of hot plasma, held together by gravity and shaped by a magnetic field. It is by far the most important source of energy for life on Earth.

Its diameter is approximately 1.39 million kilometers (or 109 times that of Earth), and its mass is approximately 330,000 times that of Earth. It represents approximately 99.86% of the total mass of the Solar System. Approximately three-quarters of the Sun's mass is made up of hydrogen (73%), and the rest is mostly helium (25%), with much smaller amounts of heavier elements, including oxygen, carbon, neon, and iron.¹

¹ <https://norwegianhydrogen.com/green-hydrogen/facts-about-hydrogen>

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Currently, the Sun fuses approximately 600 million tons of hydrogen into helium every second, converting 4 million tons of matter into energy.¹ This energy, which can take between 10,000 and 170,000 years to escape its core, is the source of the Sun's light and heat.²



The Sun emits approximately 3.8×10^{26} W of energy, which corresponds to roughly 9×10^{10} megatons of TNT per second.

1.4.1.2: What do you know about the Solar System?

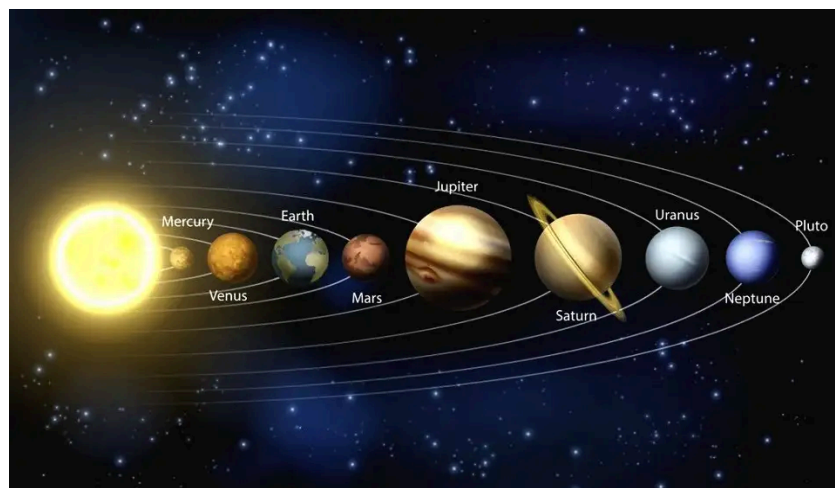
The Solar System consists of the Sun together with its planetary system (which includes eight planets along with their natural satellites) and other non-stellar objects.¹ It formed 4.6 billion years ago due to the gravitational collapse of a giant molecular cloud. The most massive object is the central star – the Sun, with the second most massive object being the planet Jupiter. The four small inner planets, Mercury, Venus, Earth, and Mars, called terrestrial planets, are composed mainly of rock and metal

The four outer planets, called gas giants, are much more massive than the terrestrial ones. The two largest planets, Jupiter and Saturn, are¹ composed mainly of hydrogen and helium; the two more distant planets, Uranus and Neptune, are composed largely of substances with a relatively high melting point (compared to hydrogen and helium), called ices, such as water,

² <https://www2.nau.edu/~gaud/bio301/content/sun/sun.htm>

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ammonia, and methane. They are referred to as "ice giants" (a term distinct from "gas giant"). All the planets have nearly circular orbits arranged in a nearly flat disc called the ecliptic plane³.



1.4.1.3: What do you know about the planet Earth?

Earth is the third planet from the Sun and the largest of the Solar System's terrestrial planets in both mass and diameter.⁴ It is the only celestial body known to harbor life. Approximately 29.2% of Earth's surface is land, consisting of continents and islands.⁵ The remaining 70.8% is covered with water, mostly by oceans, seas, gulfs, and other saltwater bodies, but also by lakes, rivers, and other freshwater, which together constitute the hydrosphere.⁶

A large portion of Earth's polar regions is covered in ice. Earth's outer layer is divided into several rigid tectonic plates that migrate across the surface over many millions of years.⁷ The Earth's interior remains active with a solid iron inner core, a liquid outer core that generates Earth's magnetic field, and a convecting mantle that drives plate tectonics.⁸

Average radius	6.371 km
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³ <http://www.flyhighineurope.co.uk/category/romania+space/>

⁴ <https://www.ucl.ac.uk/culture-online/case-studies/2022/apr/why-earth-third-planet-shouldnt-it-be-first>

⁵ <https://en.wikipedia.org/wiki/Earth>

⁶ <https://eduindex.org/2021/07/03/the-third-planet-and-its-facts/>

⁷ <https://www.earth.com/image/an-astronauts-view-of-the-earth/>

⁸ <https://www.earth.com/image/an-astronauts-view-of-the-earth/>

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Mass	6×10^{24} kg
Medium Density	5,5 g/cm ³
Gravity	9,8 m/s ²
Circumference	40075 km
Rotation period	23h 56m 4s
Aphelion (maximum distance from the Sun)	152100000 km
Perihelion (minimum distance from the Sun)	147095000 km
Semi-major axis (average distance from the Sun)	149600000 km
Orbital period	365,25 zile

1.4.2. The Impact of Solar Energy Use on the Economy (Industry, Agriculture, Forestry)

Key Concepts:

- *Solar Energy*
- *Sustainability*
- *Macroeconomic impact of Solar energy*
- *Environmental Economics*

The imperative for a global transition towards sustainable development has placed renewable energy sources at the forefront of policy and technological innovation. Among these, solar energy has emerged as a particularly promising and rapidly expanding resource. Its inherent abundance and declining costs position it as a crucial element in mitigating the adverse effects of climate change, primarily driven by the combustion of fossil fuels. This chapter delves into the theoretical underpinnings of the economic impacts associated with the widespread adoption of solar energy. We will explore the potential ramifications across diverse sectors, including industry, agriculture, and forestry, highlighting both the opportunities for economic growth and the challenges that may arise during this energy transition. By examining the theoretical linkages between solar energy deployment and economic activity, this chapter aims to provide a foundational understanding for subsequent empirical analyses and policy considerations.

1.4.2.1: Theoretical Framework:

- **Resource Economics:**

Solar energy, as a virtually inexhaustible resource, fundamentally challenges traditional economic models built upon the finite nature of fossil fuels. Conventional resource economics grapples with concepts like resource depletion and the resulting scarcity rents – the increasing economic value derived from a dwindling supply. The shift towards solar power necessitates a rethinking of these paradigms, focusing instead on the efficient utilization of a continuous energy flow. This transition to a renewable resource-based economy has implications for investment strategies, infrastructure development, and long-term economic sustainability, moving away from the inherent limitations and price volatility associated with exhaustible resources.



Solar Power versus Traditional Energy Sources

- ☐ Solar energy is widely accessible worldwide. In the meantime, the traditional energy sources are concentrated in some particular areas. That means these resources need to be extracted from those areas and transported there to be used in other places, including additional costs.
- ☐ Solar power is a renewable energy source that comes from the sun, a limitless resource. On the other hand, coal, oil, and natural gas - traditional energy sources- are non-renewable and finite, meaning these will run out of resources.



- ☐ Solar power generation doesn't produce any greenhouse gases or air pollutants while it is used, in comparison to conventional sources, which contribute to climate change by polluting the environment (air, water, and atmosphere).
- ☐ Solar energy becomes less expensive due to ongoing price reductions, but the price of conventional energy sources, particularly fossil fuels, is influenced by many factors, such as geopolitical evolutions, extraction costs, and transportation costs.
- ☐ Solar panels have a long lifespan with little maintenance (approx. 25 to 30 years). Power plants and other traditional energy infrastructure, such as extraction facilities, frequently need ongoing maintenance, repairs, and replacement.

<https://intersolarsystems.com/solar-power-vs-traditional-energy-sources-a-comparison>

● Environmental Economics:

Traditional energy sources often generate significant negative externalities, such as air and water pollution, and greenhouse gas emissions, which are not fully reflected in their market prices. Environmental economics provides a framework for analyzing these external costs and designing mechanisms to internalize them. Solar energy offers a pathway to significantly reduce these externalities. Policies like carbon pricing (e.g., carbon taxes, cap-and-trade systems) can make polluting energy sources more expensive, thereby enhancing the economic competitiveness of cleaner alternatives like solar. Green subsidies and incentives can further accelerate the adoption of solar energy, reflecting its environmental benefits. The economic advantages of reduced pollution include lower healthcare costs, improved agricultural yields, and a healthier environment overall.

● Innovation and Technological Change:

The increasing adoption of solar energy acts as a powerful catalyst for innovation across various sectors. It drives research and development in areas such as photovoltaic technology, energy storage solutions (batteries, thermal storage), smart grids, and energy management systems. This innovation leads to new technologies, improved efficiency, and lower costs for solar energy deployment. The concept of learning curves suggests that as production and deployment volumes increase, costs tend to decrease due to technological advancements and economies of scale. Furthermore, the growth of the solar industry fosters the emergence of new



business models, such as solar leasing, power purchase agreements, and decentralized energy systems, creating new opportunities for entrepreneurship and job creation in manufacturing, installation, maintenance, and related services. The diffusion of these technologies and business models can have widespread economic benefits.



Solar collectors for domestic hot water preparation at a hotel in Mallorca.



Solar collectors for heating swimming pool water.

A photovoltaic solar panel, unlike a solar thermal panel, transforms the light energy from solar rays directly into electrical energy. The main components of a photovoltaic solar panel are solar cells.



There are a variety of **applications** that use the electricity produced by solar cells, ranging from common household appliances to space technology. Watches produced by the Japanese company Citizen are equipped with a solar cell integrated into the dial that charges a lithium-ion battery with an autonomy of 150-240 days and which, after 20 years of operation, shows a maximum capacity decrease of 20%.



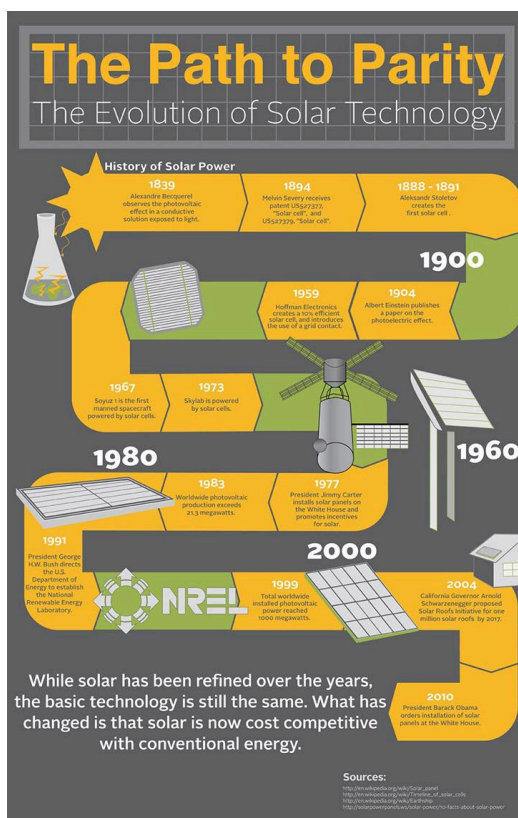
Pocket calculators can have dual power supply from a battery and a solar cell, or a simple power supply only from solar cells, in which case relatively strong illumination is required for operation.



Automatic parking payment machines belong to self-powered systems, having a module with solar cells and a battery to ensure a continuous supply of electricity

● Macroeconomic Impacts:

The transition to a solar-powered economy has significantly broader macroeconomic implications. Increased investment in solar energy infrastructure and manufacturing can contribute to GDP growth. Strategic government policies, such as tax incentives, feed-in tariffs, and renewable energy mandates, play a crucial role in stimulating this investment. The impact on inflation can be complex, with initial investments potentially leading to price pressures, but long-term, stable solar energy costs can provide energy price stability. For countries reliant on fossil fuel imports, domestic solar energy production can improve trade balances and enhance energy security, reducing vulnerability to international price fluctuations and geopolitical risks. Furthermore, the development of a strong domestic solar industry can create export opportunities, further boosting economic growth.



1.4.2.2: Sector-Specific Impacts:

- Industry:

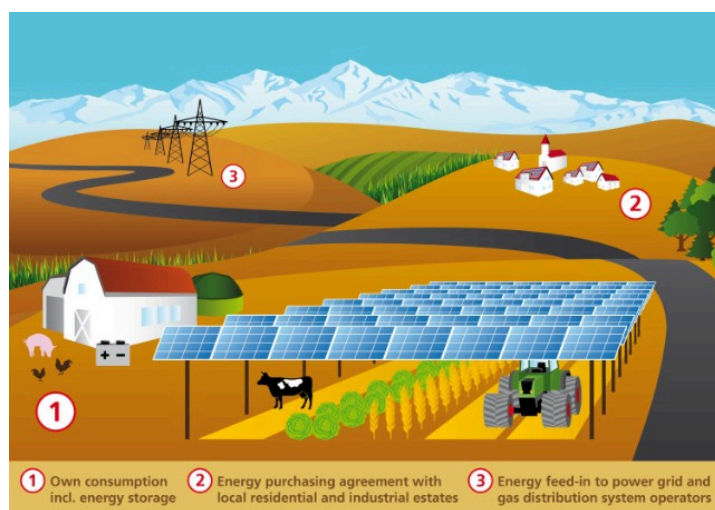
Solar energy offers significant potential to reshape the industrial sector. By directly powering industrial processes or feeding into on-site grids, solar installations can substantially reduce energy costs, a major operational expense for many industries. This cost reduction can enhance the competitiveness of businesses, both domestically and internationally. Furthermore, the growth of the solar industry itself drives the development of new "green" industries, such as the manufacturing of solar panels, inverters, batteries, and other energy storage solutions, creating new value chains and economic opportunities. Decentralized energy generation through on-site solar can also impact industrial location decisions, potentially reducing reliance on centralized power infrastructure and influencing supply chain logistics.

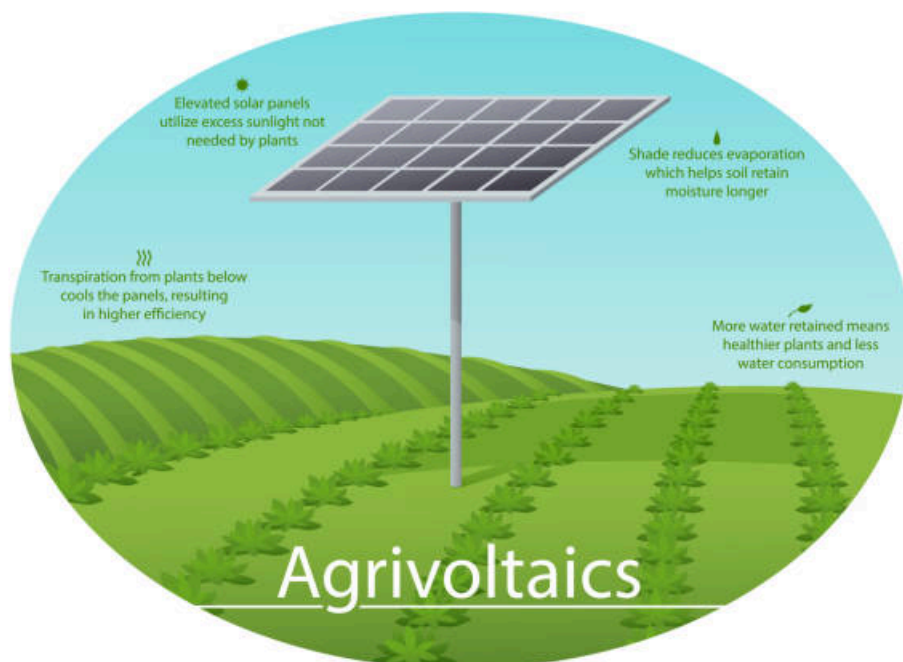


The solar power plant in Quierschied, a suburb of Göttingen, Germany, built on an area of 165,000 square meters in 2004/2005, produces 7.4 MW of electricity using solar panels.

- Agriculture:

Solar energy presents numerous applications for modern agriculture. It can power irrigation systems, reducing reliance on diesel-powered pumps and lowering operational costs. Solar energy is also ideal for powering climate control systems in greenhouses, extending growing seasons and improving yields. Additionally, solar can be used to run various farm equipment and provide electricity for on-farm processing and storage. By decreasing dependence on fossil fuels, solar energy contributes to more sustainable agricultural practices, reduces carbon emissions, and can enhance food security, particularly in regions with limited access to reliable grid electricity. Moreover, it can stimulate economic development in rural areas by creating new opportunities and reducing energy expenses for farmers.





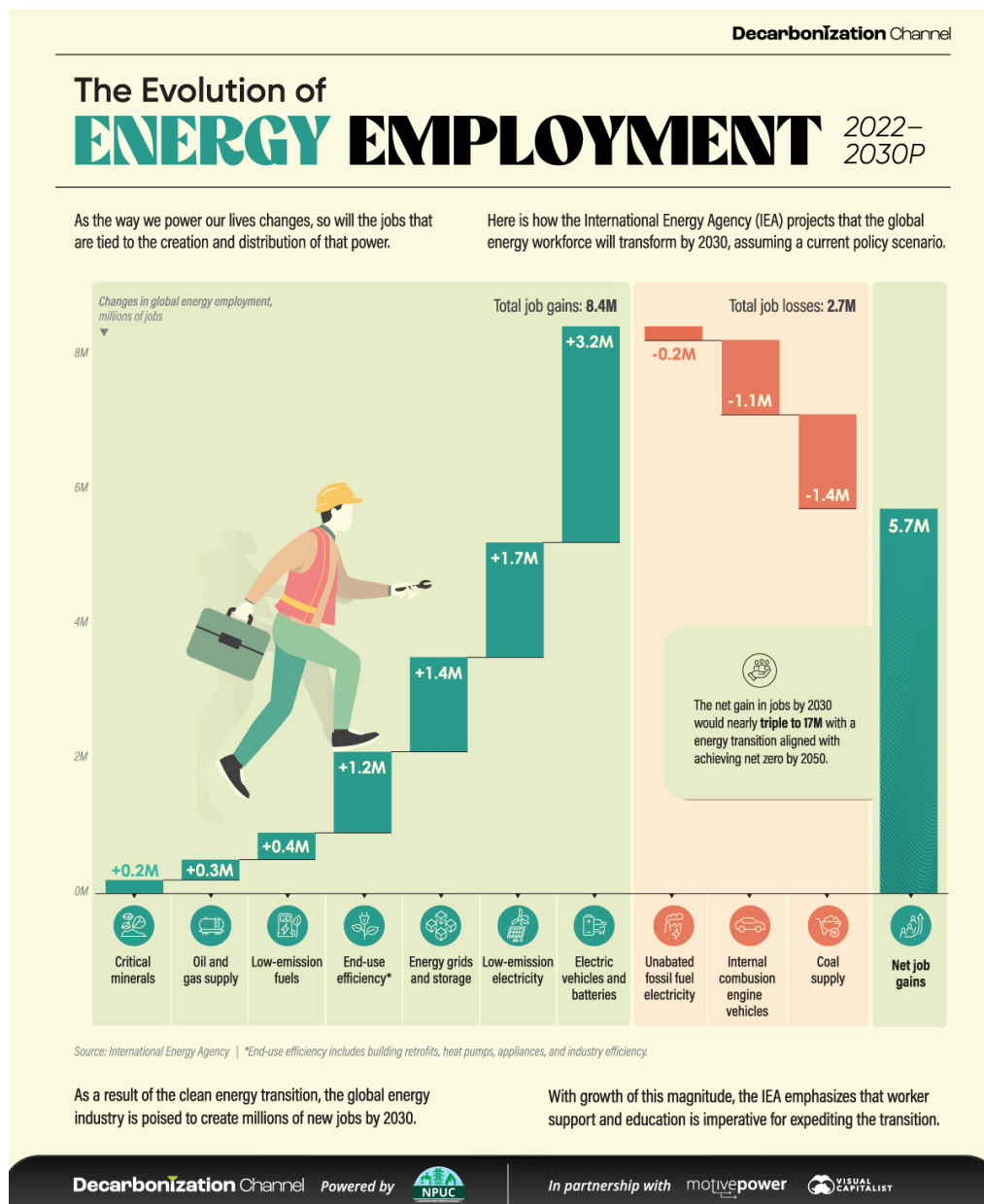
- Forestry:

The forestry sector can also benefit from the adoption of solar energy. Solar power can be used to operate machinery for harvesting and processing timber, especially in remote or off-grid locations, reducing the need for diesel fuel and its associated costs and emissions. Furthermore, solar-powered sensors and communication systems can facilitate remote monitoring and management of forests, improving efficiency and sustainability efforts. By reducing the carbon footprint of forestry operations and promoting sustainable forest management practices, solar energy can contribute to a more environmentally responsible and economically viable forestry sector.

1.4.2.3: Cross-Cutting Themes:

- **Job Creation and Labor Markets:**

The expansion of the solar energy sector has significant implications for job creation and labor markets. New jobs are emerging across the value chain, including manufacturing solar components, system installation, maintenance and repair, project development, and research. However, this transition may also lead to job displacement in traditional fossil fuel industries. To ensure a smooth and equitable transition, it is crucial to invest in education and training programs that equip workers with the skills needed for the solar energy sector and related green industries. This includes technical skills, engineering expertise, and knowledge of renewable energy technologies.



<https://decarbonization.visualcapitalist.com/visualized-the-evolution-of-energy-employment-2022-2030p/>

- Investment and Financing:

Large-scale deployment of solar energy requires substantial investment in manufacturing facilities, infrastructure, and research and development. Both public and private financing mechanisms play a critical role in mobilizing these investments. Government incentives, such as tax credits, rebates, and feed-in tariffs (guaranteed payments for solar electricity fed into the grid), can reduce the financial risk and improve the economic viability of solar projects, attracting private capital. Carbon markets, by placing a price on carbon emissions, can further incentivize investment in low-carbon technologies like solar. The availability and cost of financing are key determinants of the pace and scale of solar energy adoption.



Photovoltaic power plants on the new logistics center and Dedeman stores in Bacău, Romania

- Energy Access and Equity:

Solar energy offers a unique opportunity to improve energy access in remote and underserved areas that are not connected to traditional electricity grids. Stand-alone solar systems and mini-grids can provide clean and reliable electricity for households, businesses, and essential services like healthcare and education, promoting economic development and reducing energy poverty. Ensuring equitable access to solar energy technologies and the associated benefits is crucial for fostering social inclusion and a just energy transition. This includes

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addressing affordability barriers and tailoring solutions to the specific needs of different communities.



Electric vehicle charging station powered by solar panels

1.4.2.4: Challenges and Opportunities:

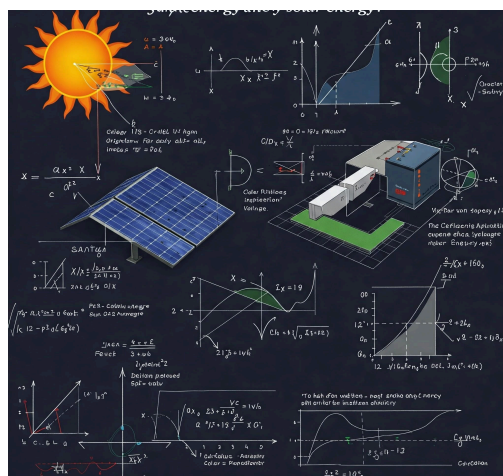
While solar energy offers numerous benefits, its large-scale adoption also presents certain challenges. Intermittency, the variability of solar energy due to weather conditions and the day-night cycle, requires solutions such as energy storage (batteries, pumped hydro) and smart grid technologies to ensure a reliable power supply. Land use considerations for large solar farms need careful planning to minimize environmental and social impacts. Integrating distributed solar generation into existing electricity grids can also pose technical and regulatory challenges. However, these challenges also present significant opportunities for technological advancements in energy storage, grid management, and forecasting. Policy innovation, including supportive regulations, grid modernization efforts, and streamlined permitting processes, is crucial for overcoming these hurdles. International cooperation can facilitate the sharing of best practices, technology transfer, and financial support for global solar energy deployment.

In conclusion, this theoretical exploration underscores the profound and multifaceted impact of solar energy adoption on the economy. From the fundamental reshaping of resource economics away from finite fuels to the internalization of environmental costs and the stimulation of technological innovation, solar energy presents a compelling pathway towards a more sustainable economic paradigm. Its sector-specific benefits, ranging from reduced

industrial costs and enhanced agricultural sustainability to a greener forestry sector, highlight its versatility. Furthermore, the potential for job creation, the dynamics of investment and financing, and the crucial role in expanding energy access and promoting equity solidify solar energy as a key driver of positive economic change.

However, realizing the full potential of a solar-powered economy requires continued effort and research. Future investigations could delve deeper into the intricacies of grid integration at high penetrations of variable renewable energy, the long-term economic viability of various energy storage solutions, and the macroeconomic modeling of a fully decarbonized energy system. Further research is also needed to understand the social and economic impacts of the energy transition on different communities and to develop effective strategies for ensuring a just and equitable transition. Exploring optimal policy mixes, including carbon pricing mechanisms, targeted subsidies, and regulatory frameworks, will be crucial for accelerating solar energy deployment and maximizing its economic benefits. Ultimately, the theoretical insights presented here, coupled with ongoing research and strategic implementation, affirm the significant potential of solar energy to contribute to a future that is both environmentally sustainable and economically prosperous.

1.4.3: Practical Application Through Mathematics of Solar Energy





The approach to the topic "Exploring Solar Energy Through Mathematics" allows teachers to creatively combine *methods and pedagogical strategies* that stimulate critical thinking, creativity, and student collaboration:

1. Project-Based Learning (PBL):

● Practical Projects:

- They can analyze weather data to determine the efficiency of solar panels in different periods of the year.
- They can perform calculations to determine the costs and benefits of installing solar panels at a home or school.

● Investigations:

- Students can investigate how the sun's angle varies throughout the day and year, using trigonometry.
- They can explore the relationship between the surface area of solar panels and the amount of energy produced, using proportions.

2. Collaborative Learning:

● Teamwork:

- Students can work in groups to solve complex problems related to solar energy and mathematics.
- They can collaborate to create presentations or reports about their projects.

● Discussions and Debates:

- Students can discuss the advantages and disadvantages of solar energy, using mathematical and scientific arguments.
- They can debate energy policies and their impact on the environment.

3. Discovery Learning:

● Experiments:

- Students can conduct simple experiments to demonstrate how solar energy works, such as heating water with sunlight.
- They can use sensors and measurement tools to collect data on solar energy.

● Simulations:

- Students can use simulation software to model solar energy systems and analyze their performance.
- They can explore different scenarios and see how the results change.

4. Technology Integration:

● Applications and Software:

- Using mobile apps or educational software to visualize solar energy data and perform mathematical calculations.



- Using online tools to access weather data and information about solar panels.
- Augmented Reality (AR) and Virtual Reality (VR):
- Using AR/VR applications to visualize 3D models of solar energy systems and explore their operation.

5. Evaluation:

●Formative Assessment:

- Observing students during group activities and experiments.
- Evaluating student reports and presentations.

●Summative Assessment:

- Tests and quizzes to assess understanding of mathematical and scientific concepts.
- Final projects that demonstrate students' ability to apply acquired knowledge.

Suggestions of concrete examples of activities:

- Calculating the angle of incidence of solar rays on a solar panel, depending on location and time.
- Determining the efficiency of a solar panel by measuring the electrical energy produced and the solar energy received.
- Calculating cost savings achieved by installing solar panels.
- Creating mathematical models to predict solar energy production in different weather conditions.

By using these strategies, the teachers can create an engaging and relevant learning experience for students, which will develop their mathematical and scientific skills, as well as awareness of the importance of solar energy.

Role play units

❖ Pedagogical strategy 1: Project-Based Learning (PBL) and Technology Integration:

● Practical Projects as teamwork using Applications and Software

Aim: To use collaborative learning to create team project as an e-book on topics related solar energy applications

Objectives:

- To develop the ability to search for information and scientific data about solar panels, the electricity produced by solar cells, and their various applications, and the advantages and disadvantages of their use.
- To create an e-book integrating technology.
- To exercise teamwork abilities



Tasks: Students will create three e-books using one of specific applications like Book Creator, Google Docs, Canva, FlipBuilder, etc. as team projects. Students are divided in three groups and will carry out projects about solar energy.

The project themes are:

- 1. Solar panels
- 2. Applications that use electricity produced by solar cells
- 3. Advantages and disadvantages of using solar panels

Each team will present their e-books project and will evaluate their own project (autoevaluation) and the other teams projects.

Expected outcomes:

- to select relevant information and scientific data
- to integrate digital technology and internet resources
- to realise innovative and creative e-books on requested topics
- to exercise public speaking, the ability in communication and oral presentation

❖ **Pedagogical strategy 2: Solving Maths Problems (for students 10-14 years old)**

Problem no.1: How many photovoltaic panels does a household that uses 2700 kWh annually need, if the power of each panel is 300 W, and the production ratio is 1.5?

Solution: Number of panels = system size / production ratio / panel power = $2700 / 1.5 / 300 = 6$ panels of 300 W.

Problem no.2: What is the power of the panels in a dwelling with 10 solar panels and the following appliances: a central heating system (800 kWh/year), an electric stove (450 kWh/year), a refrigerator (350 kWh/year), an air conditioner (1000 kWh/year), a clothes dryer (300 kWh/year), a dishwasher (250 kWh/year), and a washing machine (350 kWh/year)?

Solution: Panel power = Total energy consumption / number of panels = $(800 + 450 + 350 + 1000 + 300 + 250 + 350) / 10 = 3500 / 10 = 350$ W.

Annual electricity consumption is the amount of energy you consume at home over the course of an entire year.

Panel power is the electricity production under ideal conditions.

The production ratio of a solar panel system is the ratio between the estimated energy production of a system over time (in kWh) and the actual size of the system (in watts).

❖ **Pedagogical strategy 3: Solar Energy- Vital Resource for Agriculture: "Agrivoltaics in relation to alfalfa" - Study Case and Mathematical Applications**

Alfalfa is cultivated in numerous countries, highlighting its significance in agriculture.

In essence, alfalfa is a vital plant that plays a significant role in agriculture, particularly in providing nutritious feed for livestock.

So, this is a plant of major importance in the feeding of ruminant animals (cattle, sheep, goats), occupies 45% of the area dedicated to forage crops sown on arable land in our country. With an average annual production of 18 tons/hectare of green mass, alfalfa provides 20% of the total requirement of fibrous fodder for the approximately 2.2 million Livestock Units (LU).

The Livestock Unit (LU) represents the stocking rate or the number of animals per hectare of pasture.

Agrivoltaics, also known as agro photovoltaics, agrisolar, or dual-use solar, is essentially the practice of using the same area of land for both solar photovoltaic (PV) power generation and agriculture. This innovative approach aims to create a synergistic relationship between renewable energy production and food production.

When examining agri voltaics in relation to alfalfa⁹ research indicates a promising synergy. A concise overview of a case study could highlight key concepts:

Key concepts:

- **Increased Biomass:**
 - Studies have shown that alfalfa biomass can actually increase under the shade of agrivoltaic systems. In some cases, there has been an average increase of around 10% in biomass. This is counterintuitive, but it is thought to be due to the reduction of evapotranspiration.
- **Water-Use Efficiency:**
 - A major benefit observed is the improved water-use efficiency of alfalfa. The solar panels create a microclimate that reduces water loss through evaporation, particularly important for alfalfa, which is sensitive to water deficits.
- **Land-Use Efficiency:**
 - The combined production of solar energy and alfalfa results in a significant increase in overall land-use efficiency. This means that more value is being produced from the same area of land.
- **Optimization:**
 - Research is ongoing to optimize the design of agrivoltaic systems for alfalfa. This includes determining the ideal height, spacing, and orientation of solar panels to maximize both energy production and alfalfa yield.

In essence:

⁹https://www.researchgate.net/publication/365291926_Increasing_land_productivity_with_agriphotovoltaics_Application_to_an_alfalfa_field



- Agrivoltaic systems can provide a beneficial microclimate for alfalfa, leading to increased biomass and improved water-use efficiency.
- This approach offers a sustainable way to produce both renewable energy and valuable forage.

This type of case study is very important because it shows that agrivoltaics is not just a theoretical concept, but can be a very practical application in the agricultural sector.

Problem no. 3: A wheat crop produces, under optimal conditions (light intensity of 10000-20000 lux), a total biomass (roots, stems, leaves, grains) of 10 tons per hectare, a grain yield of 4 tons per hectare, and the straw represents 50% of the aerial biomass of 8 tons. Determine the total biomass, grain production, and the amount of straw obtained from 10 hectares.

Solution: Total biomass is $10 \times 10 = 100$ tons Grain yield is $4 \times 10 = 40$ tons Amount of straw is $50\% \times 8 \times 10 = 40$ tons.

Problem no.4: A one-hectare orchard, planted on a hill with exposure to solar energy, produces 50 tons of fruit under optimal conditions. Knowing that due to environmental conditions, the production is lower by two-fifths, find the quantity of fruit obtained.

Solution: $2/5$ of 50 tons is $2 \times 50 / 5 = 20$ tons. $50 - 20 = 30$ tons is the quantity obtained.

❖ **Pedagogical Strategy 4: Discovery Learning Using the Experimental Method**

● **Experiment 1: *Conversion of solar energy into thermal energy - the influence of surface color on the absorption of solar energy and the heating of water***

Aim: to demonstrate how surface color influences the absorption of solar energy and the heating of water

Required materials: 2 identical transparent glasses, tap water, 1 sheet of white paper, 1 sheet of black paper, 1 thermometer, solar energy source, a stopwatch;

Procedure:

- Fill both glasses with the same amount of water and measure the initial temperature.
- Wrap one glass with black paper and the other with white paper, cover them with a circle of black paper and white paper, respectively;
- Place both glasses in the sun for 30-60 minutes;
- Measure the water temperature at regular intervals (for example, every 10 minutes);
- Record and compare the results for the two glasses.

● **Experiment 2: *Change in the state of aggregation of some products in the "solar oven" under the action of light energy***

Aim: to observe and highlight the influence of solar energy on the state of aggregation of some products (melting of ice, butter, and chocolate)

Required materials: a cardboard box (e.g., a shoebox), aluminum foil (to reflect light), a sheet of black paper (for heat absorption), transparent plastic wrap (for the greenhouse effect), adhesive tape, scissors, thermometer, scale, 3 small plastic plates with a previously weighed ice cube, butter, and chocolate.

Procedure:

- Line the inside of the box with aluminum foil to reflect sunlight towards the center of the box.
- Place the black paper on the bottom of the box to better absorb heat.
- Place the 3 small plates with ice, butter, and chocolate in the solar oven.
- Cover the opening of the box with transparent plastic wrap and insert a thermometer.
- Measure the temperature inside the oven before placing it in the sun and note the time.
- Place the oven in the sun and observe at what temperature and how long it takes for the ice, butter, and chocolate to melt.

In conclusion, exploring solar energy through the lens of mathematics reveals the profound interconnectivity between abstract concepts and real-world applications.

From calculating solar irradiance and optimizing panel placement to modeling energy conversion efficiencies and predicting long-term performance, mathematics provides the essential tools for understanding and advancing solar technology. By harnessing the power of equations, algorithms, and statistical analyses, we can refine solar energy systems, enhance their efficiency, and ultimately accelerate the transition towards a sustainable, solar-powered future.

This mathematical foundation not only deepens our understanding of solar energy but also empowers us to innovate and create more effective solutions for a cleaner, more energy-secure world.

Powering Our Lives: Solar Energy in the Modern Family

Pedagogical strategy - Role Play Activity

Grade Level: 7th Grade

Time Allotment: 2 activities (50 minute class periods)

Unit Objectives:

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- Students will be able to identify how a modern family uses energy in their daily lives.
- Students will be able to explain the benefits and challenges of incorporating solar energy into a household.
- Students will be able to analyze different family members' perspectives on adopting solar energy.
- Students will be able to propose solutions to overcome barriers to solar energy adoption.
- Students will be able to develop persuasive arguments and communicate effectively in a role-play setting.

Materials:

- Informational texts about residential solar energy (articles, websites, brochures)
- Visual aids (diagrams of home solar systems, charts of energy consumption, examples of solar-powered devices)
- Role cards (see below)
- Props (optional: poster board, markers, sample utility bills)
- "Family Meeting" area in the classroom

1. Role-Play Introduction

- Activity: Introduce the role-play scenario:
 - A family is considering installing a solar energy system on their home. Each family member has a different perspective and set of priorities.
 - Explain that students will take on the roles of these family members and participate in a "family meeting" to discuss the pros and cons of going solar.
- Role Assignment: Divide students into groups (representing different families) and assign each student a role within the family. (See role card examples below).
- Role Card Distribution: Give each student a role card with a description of their character's personality, concerns, and financial situation.
- Preparation Time: Students read their role cards and begin to develop their arguments and talking points. Encourage them to consider their character's values and how solar energy might affect their daily life.

2. The Family Meeting

- Activity: Conduct the "family meeting" role-play.
 - Arrange the classroom to simulate a family living room or dining room.



- o Facilitate the meeting, ensuring that each family member has a chance to express their views.
 - o Encourage students to use persuasive language and support their arguments with evidence from the informational texts and their own research.
 - o Promote respectful dialogue and active listening.
- Meeting Structure: You can structure the meeting in several ways:
 - o Open Discussion: Allow family members to discuss the issue freely.
 - o Agenda Items: Provide a list of questions or topics to guide the discussion (e.g., cost, environmental impact, aesthetics, reliability).
 - o Decision-Making Process: Guide the family towards a decision-making process (e.g., weighing pros and cons, considering compromises).

3. Family Decision and Reflection

- Activity: Each family group attempts to reach a decision about whether or not to install a solar energy system.
 - o Compromise and Consensus: Encourage students to find solutions that address the concerns of all family members.
 - o Decision Justification: Each group presents their decision and explains the reasoning behind it.
- Reflection: Conclude the unit with a class discussion about the role-play experience.
 - o What did students learn about the challenges and opportunities of adopting solar energy in a family setting?
 - o How did it feel to consider different perspectives and make a group decision?
 - o What are some real-world examples of families using solar energy?
 - o How can they apply what they learned to their own lives and communities?
- Extension Activity: Students write a reflection paper or create a presentation summarizing their family's decision-making process and their personal views on home solar energy.

Example Role Cards:

Here are some example role cards for a family considering solar energy. Teacher could modify them to fit our students' interests and the specific aspects of home solar energy teacher wants to emphasize.

- Role Card 1: Mom - Sarah (40s, Accountant)

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- o You are the primary financial planner for the family. You are very budget-conscious and want to make sure any major purchase is a good investment. You are interested in the long-term cost savings of solar energy but are concerned about the upfront expenses and how long it will take to recoup the investment. You want to see a detailed cost-benefit analysis.
 - o Concerns: Initial cost, return on investment, financing options, impact on the family budget.
 - o Priorities: Financial responsibility, long-term savings, value for money.
- Role Card 2: Dad - Michael (40s, Engineer)
 - o You are an engineer and are fascinated by technology. You are excited about the idea of using solar energy and reducing the family's carbon footprint. You are eager to learn about the technical aspects of solar systems and are interested in the latest innovations. You also like the idea of increasing the home's value.
 - o Concerns: System reliability, maintenance requirements, the efficiency of solar panels.
 - o Priorities: Environmental impact, technological advancement, home improvement.
- Role Card 3: Teenager - Emily (16 years old)
 - o You are a high school student and are very concerned about climate change and environmental issues. You are a strong advocate for renewable energy and believe that it is important for the family to do their part to protect the planet. You are less concerned about the cost and more focused on the ethical implications.
 - o Concerns: Climate change, environmental impact, social responsibility.
 - o Priorities: Sustainability, environmental activism, making a difference.
- Role Card 4: Younger Child - Ben (10 years old)
 - o You are a curious and energetic kid. You like the idea of having cool, new technology like solar panels on the roof. You are interested in how it works and whether it can power your video games! You don't have strong opinions about the costs, but you are excited about the idea of being more environmentally friendly.
 - o Concerns: How the system works, will it look cool, can it power my stuff.
 - o Priorities: Curiosity, technology, helping the environment.

Chapter 1.5: The Engineering of Solar Energy Systems

Overview

This chapter introduces students (ages 10-14) to the principles of engineering applied to solar energy systems. It integrates STEAM (Science, Technology, Engineering, Arts, and Mathematics) to engage students in interactive, hands-on learning experiences that develop their understanding of solar power, photovoltaic systems, and the engineering challenges of designing sustainable energy solutions.

1.5.1: Understanding Solar Energy Engineering

Key Concepts Covered:

- **Photovoltaic Cell Design:** *How photovoltaic (PV) cells are designed to convert sunlight into electricity, focusing on the material science and electrical engineering behind solar panels.*

Photovoltaic (PV) cells are a key technology in solar energy systems, designed to convert sunlight into electricity. The process begins when sunlight, which consists of tiny particles of energy called **photons**, strikes the surface of the PV cell. The PV cell itself is made primarily of **silicon**, a material that is chosen because of its ability to conduct electricity when treated properly. A typical PV cell is made up of two layers of silicon: the **n-type layer** and the **p-type layer**. The **n-type layer** is treated to have extra electrons, which are negatively charged particles, while the **p-type layer** has fewer electrons and therefore has positive spaces called **holes** where electrons can move into.

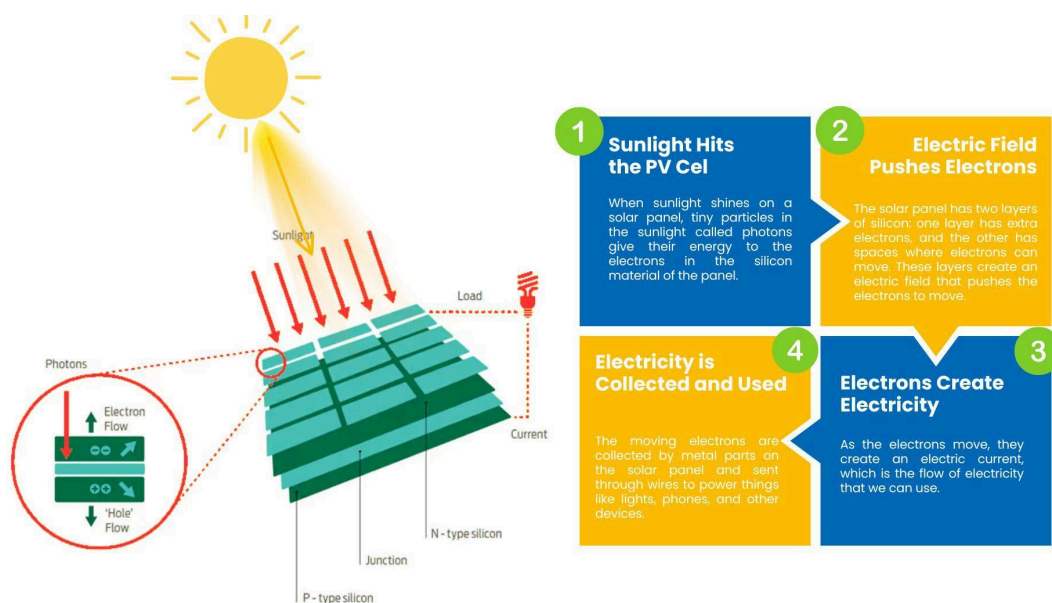
When sunlight hits the PV cell, the **photons** in the sunlight transfer their energy to the electrons in the silicon atoms. This energy is strong enough to knock the electrons loose from their positions in the silicon atoms. Once the electrons are freed, they are pushed by the **electric field** created at the junction between the **n-type** and **p-type** layers. This electric field forces the electrons to move toward the **n-type layer**, which has extra electrons ready to accept them.

As these free electrons move through the material, they create an **electric current**. This flow of electrons is what we use as electricity. The current travels through metal contacts at the surface of the PV cell, and from there, it can be sent through wires to power electrical devices such as lights, fans, or even a home. To put it simply, the PV cell acts like a little engine, turning sunlight into usable electricity by causing electrons to move through the material.

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The reason silicon is used in PV cells is because it is a **semiconductor**. This means it has special properties that allow it to conduct electricity under certain conditions — in this case, when it absorbs the energy from sunlight. Silicon is perfect for this job because it can be treated (or **doped**) to either have extra electrons (n-type) or fewer electrons (p-type), creating the conditions necessary for electrons to move when the sun shines on them.

In summary, the process of how PV cells work starts with sunlight striking the silicon in the cell, knocking electrons loose from their atoms. These freed electrons are then pushed into motion by the electric field between the two layers of silicon, creating an electric current. This current is what powers electrical devices, and this process is how solar panels convert sunlight into electricity.

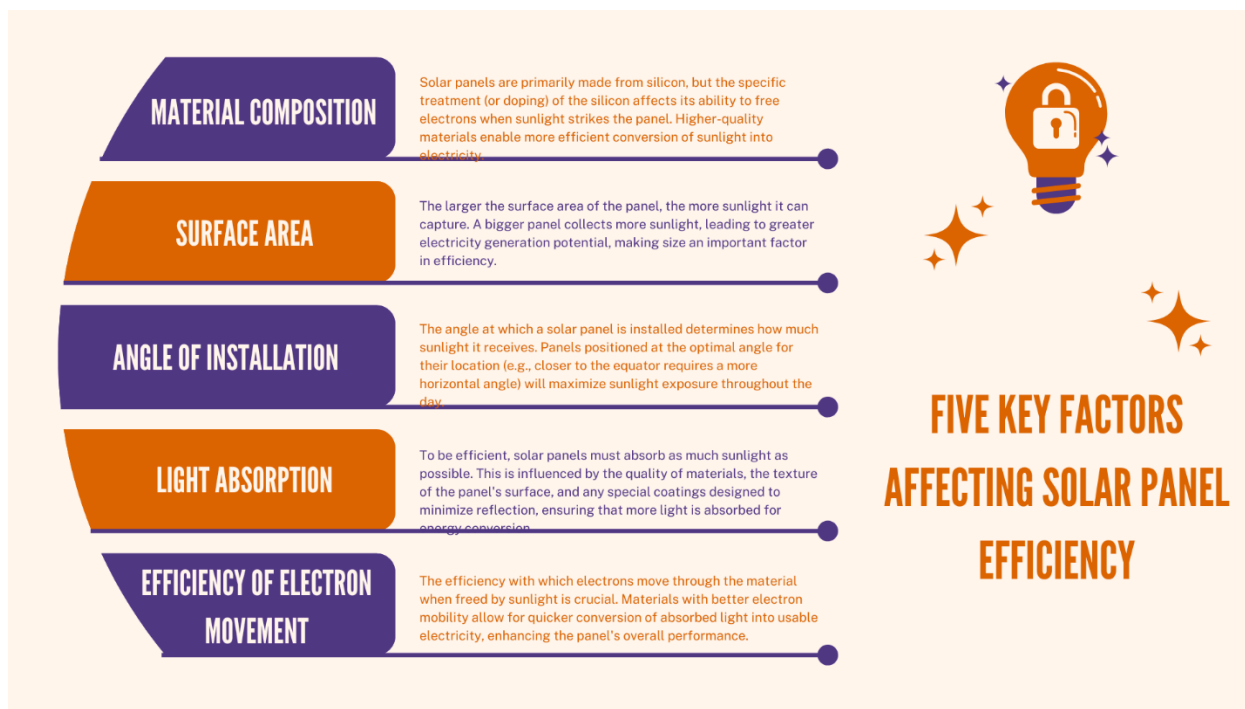


For a detailed video explanation, you can access the Student Energy YouTube video here: [LINK](#).

- **Solar Panel Efficiency Engineering:** *Factors that affect the efficiency of solar panels, such as material composition, surface area, angle of installation, and light absorption.*

The efficiency of a solar panel refers to how well it can convert sunlight into usable electricity. Several factors influence how efficiently a solar panel works. One important factor is the **material composition** of the solar cells. Most solar panels are made from **silicon**, but the way the silicon is treated (or **doped**) affects how many electrons can be freed when sunlight hits the panel. The better the material, the more sunlight it can absorb and convert into electricity. Another key factor is the **surface area** of the panel. The larger the surface area, the more

sunlight the panel can collect. So, if a solar panel has a bigger surface, it can capture more sunlight and generate more electricity. The **angle of installation** is also very important. Solar panels work best when they are positioned at an angle that allows them to receive the most sunlight throughout the day. The angle depends on where the solar panels are located—closer to the equator, they may be tilted more horizontally, while at higher latitudes, a steeper angle might work better. **Light absorption** is another factor that affects efficiency. Solar panels need to absorb as much sunlight as possible to produce electricity. The quality of the materials, the surface texture, and the presence of coatings that reduce reflection all help improve how much light the panel can absorb. If a panel reflects too much sunlight away, it won't absorb enough energy to generate electricity efficiently. In summary, the efficiency of a solar panel is influenced by the materials used, the size of the panel, the angle it's positioned at, and how well it absorbs sunlight. By improving these factors, engineers can make solar panels that work better and produce more electricity from the same amount of sunlight.

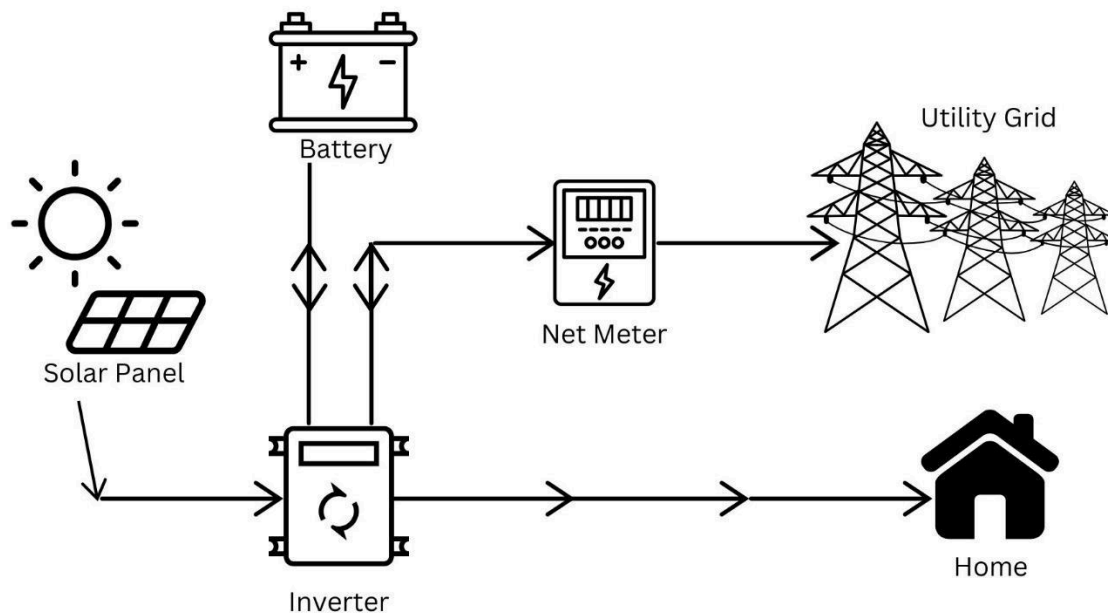


- **Electrical Wiring and Systems Integration:** *The engineering behind connecting solar panels to the electrical grid, including inverters, battery storage, and circuit protection.*

When solar panels generate electricity, it's in the form of **direct current (DC)**, which is different from the **alternating current (AC)** that we use in our homes. To make the electricity from the solar panels usable, it needs to be converted from DC to AC. This is where **inverters** come in. Inverters are devices that take the DC electricity produced by the solar panels and change it into AC electricity, which is what powers most of the devices in our homes. Once the electricity is converted to AC, it can flow into the **electrical grid**, which is the network of wires that delivers electricity to homes, schools, and businesses.

In addition to inverters, many solar energy systems include **battery storage**. Batteries store extra electricity that the solar panels generate during the day, so it can be used at night or on cloudy days when the panels aren't producing electricity. This helps ensure a constant supply of power even when the sun isn't shining. The battery is connected to the system through special wiring, which allows electricity to flow into the battery when there is more energy than needed and out of the battery when extra power is required.

Another important part of the system is **circuit protection**. Just like the electrical system in your home, the solar energy system needs safety features to prevent overloading or short circuits. These features include **fuses** or **breakers**, which act like safety switches. If the system detects something wrong, like too much electricity flowing through the wires, these devices automatically shut off the power to protect the solar panels, batteries, and wiring from damage. In summary, solar panels generate electricity in DC, which is converted to AC using an inverter. Extra energy can be stored in batteries for later use, and the entire system is protected with circuit breakers or fuses. Together, these parts work to make sure that the electricity produced by the solar panels can be safely used in our homes and connected to the electrical grid.



Teaching Resources & Materials

1. **Interactive Simulation:** "[How Solar Panels Work](#)" – Online simulation that allows students to experiment with solar panel angles and efficiency (Source: *PhET Interactive Simulations, University of Colorado Boulder*)
2. **Experiment Guide:** "[Solar Oven Challenge](#)" – A guide for students to construct a simple solar oven to explore heat absorption and reflection (Source: *NASA Climate Kids - Solar Oven*)
3. **Case Study Analysis:** "[Comparing Solar Technologies Around the World](#)" – A worksheet analyzing how different countries use solar power (Source: *International Energy Agency (IEA) Solar Reports*)
4. <https://scratch.mit.edu/search/projects?q=solar%20energy>

1.5.2: Engineering Design and Prototyping in Solar Systems

Key Concepts Covered:

- *The engineering design process (problem identification, design, prototyping, testing, iteration)*

The **engineering design process** is a step-by-step way to solve problems and create solutions, like designing a solar panel system. It starts with **problem identification**, which means figuring out what the problem is that needs solving. For example, engineers might notice



that we need more clean energy, so they decide to design solar panels that can generate electricity from sunlight. The next step is **design**, where engineers plan how the solution will work. They draw pictures, make models, and think about how the solar panels will be made, what materials will be used, and how they will be set up. After the design is ready, engineers move on to **prototyping**, which is when they build a working model of the solution. For solar panels, this could mean making a small version of the panel to test how well it works. Once the prototype is built, the engineers begin **testing** it to see if it does what they want. They might check how much electricity it can produce, how well it handles bad weather, or how long it lasts. After testing, they move to **iteration**, which means making changes and improvements based on the test results. They might find that the solar panel needs to be more efficient, so they redesign it and test it again. This process of designing, testing, and improving is repeated over and over until they create a final product that works well. In short, the engineering design process helps engineers figure out problems, create ideas, build and test solutions, and keep improving them until they work perfectly.



<https://sunroof.withgoogle.com/>

- *Environmental and economic considerations of solar technology*

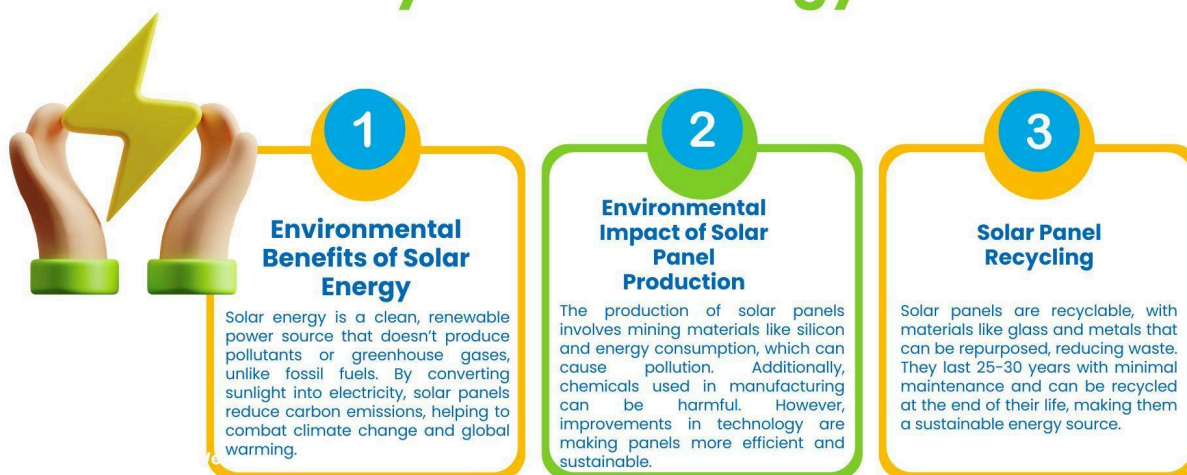
When we think about using solar technology, it's important to consider both its **environmental impact** and its **economic impact**.

Solar technology is often seen as a **clean energy source** because it uses the sun, a renewable and natural resource, to generate electricity. The biggest advantage of solar energy is that it doesn't produce **pollution** or **greenhouse gases** like other traditional sources of energy, such as coal or oil. These gases, like carbon dioxide, contribute to **climate change** by trapping heat in the Earth's atmosphere. By using solar panels to capture sunlight and turn it into electricity, we can [reduce our carbon footprint](#) and help slow down global warming.

However, the production of solar panels does have some environmental impacts. Making the panels requires materials like **silicon**, and the process can involve mining and manufacturing, which consumes energy and can create waste and pollution. Additionally, some of the chemicals used to create solar cells can be harmful if not properly handled. But the good news is that solar panels are becoming more efficient and sustainable, and the environmental benefits of generating clean energy far outweigh these impacts.

Another positive environmental aspect of solar power is that **solar panels are recyclable** at the end of their life. Many of the materials in the panels, such as glass and metals, can be recycled and reused in other products, which helps reduce waste. Also, once installed, solar panels can work for 25-30 years with little maintenance, providing a long-term, reliable source of clean energy.

Environmental Impact and Sustainability of Solar Energy

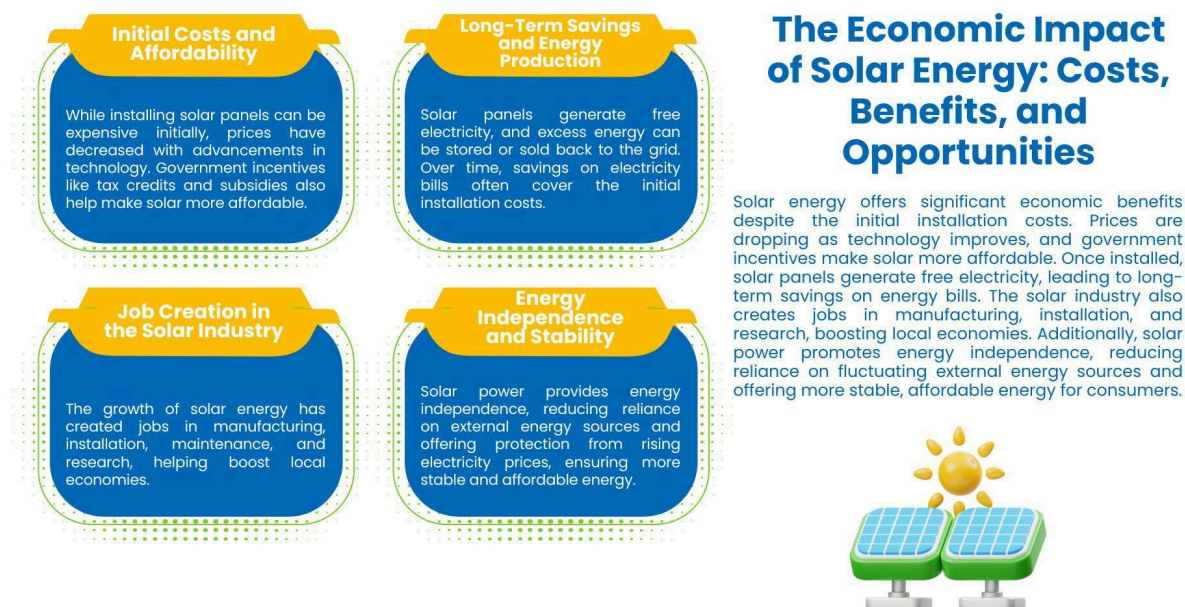


When we think about the **economic impact** of solar technology, it's important to look at both the costs and the benefits. Initially, installing solar panels can be expensive. The **upfront cost** includes purchasing the panels, installing them, and connecting them to the electrical system. However, this cost is becoming more affordable as technology improves and production increases, which has led to lower prices. Many governments around the world also offer **incentives**, such as tax credits or subsidies, to help people and businesses afford solar panels. These incentives make solar energy more accessible to a wider group of people.

Once the solar panels are installed, they can provide **free energy** by capturing sunlight. Solar panels generate electricity during the day, and in some cases, extra energy can be stored in **batteries** or sold back to the electrical grid. This means that after the initial investment, solar panels can save homeowners and businesses a lot of money on electricity bills. Over time, the savings can make up for the initial cost of installation, and in many cases, people end up saving money in the long run.

Another economic benefit of solar energy is the **job creation** it brings. The growth of the solar industry has created many new jobs in areas like manufacturing, installation, maintenance, and research. As more people turn to solar energy, the demand for skilled workers in these fields increases, helping boost the economy.

Additionally, solar power can provide **energy independence**. By generating their own electricity, people and businesses are less dependent on energy from other sources, which can fluctuate in price. This can protect consumers from rising electricity costs and make energy more stable and affordable.



In summary, solar technology has a positive environmental impact because it produces clean energy without contributing to pollution or climate change. Although there are some environmental costs in making solar panels, these are much smaller compared to the long-term benefits of using clean energy. Economically, while solar panels can be expensive to install at first, they save money over time through lower electricity bills and create new jobs in the energy industry. With more incentives, falling prices, and the growing demand for clean energy, solar technology is becoming an increasingly affordable and beneficial option for both the environment and the economy.

Pedagogical Strategies Developed for This Chapter:

1. **Problem-Based Learning (PBL):** Students are given a real-world challenge (e.g., designing a solar-powered school) and work in teams to develop solutions.
2. **Inquiry-Based Learning (IBL):** Students investigate how different materials affect solar panel efficiency through hands-on experiments.
3. **Role-Playing & Gamification:** Students take on roles as engineers, policymakers, and environmentalists in a simulated "Solar Energy Summit" to debate and design the best solar solutions for their community.

Expected Outcome:

Students will engage with interactive and role-play activities that deepen their understanding of solar energy engineering. By the end of the chapter, they will have designed their own small-scale solar energy systems and participated in discussions about real-world solar implementation.

“The Engineering of Solar Energy Systems” – Role Play Unit

Overview:

The "Solar Energy Summit" is an engaging and immersive educational activity designed to introduce students to the complex world of solar energy solutions, sustainability, and the collaborative decision-making process required to implement them effectively. The activity is structured as a simulated summit where students take on the roles of engineers, policymakers, and environmentalists. Together, they work to develop, debate, and present solar energy solutions that can benefit a community.

Objective:

The main objective of the "Solar Energy Summit" is to provide students with a hands-on experience in addressing real-world environmental and energy challenges. Through role-play, research, and teamwork, students will gain a deeper understanding of solar energy systems, the policy and regulatory environment surrounding energy solutions, and the environmental considerations that influence sustainable energy decisions.

Step	Description	Roles Involved
1. Introduction to the Activity	Introduce the purpose of the "Solar Energy Summit" simulation, where students will debate and design solar energy solutions for a community. Explain the different roles: engineers, policymakers, and environmentalists.	All roles (engineers, policymakers, environmentalists)
2. Divide Students into Groups	Split the students into small groups, each assigned a community (real or fictional) to focus on. Assign roles within each group: engineer, policymaker, and environmentalist.	Engineers, Policymakers, Environmentalists
3. Research and Preparation	Each group member conducts research based on their role. Engineers study solar technology and systems, policymakers research energy policies and regulations, and environmentalists investigate sustainability and environmental impacts.	Engineers, Policymakers, Environmentalists



Step	Description	Roles Involved
4. Group Discussion	Groups discuss their findings and collaborate to identify the best solar energy solutions for their community. Engineers provide technical insights, policymakers discuss funding and regulations, and environmentalists ensure environmental sustainability.	Engineers, Policymakers, Environmentalists
5. Design the Solar Solution	Based on the research and group discussions, each group designs a comprehensive solar energy solution for their community. Engineers outline the technical specifications, policymakers define the supporting policies and regulations, and environmentalists confirm the environmental impact of the solution.	Engineers, Policymakers, Environmentalists
6. Debate and Presentations	Each group presents their solar solution, discussing the benefits, challenges, and feasibility of their design. The class engages in a debate, discussing the strengths and weaknesses of each solution.	Engineers, Policymakers, Environmentalists
7. Final Decision	After the debate, students vote on the most effective solar energy solution for their community. They assess the solutions in terms of energy efficiency, sustainability, and overall feasibility.	All roles (as voters and decision-makers)



Chapter 1.6: Renewable Energy and Sustainability in Technology and Society

Overview

"Renewable Energy and Sustainability in Technology and Society" lesson, keeping in mind our 10-14-year-old audience and the context of the solar energy chapter.

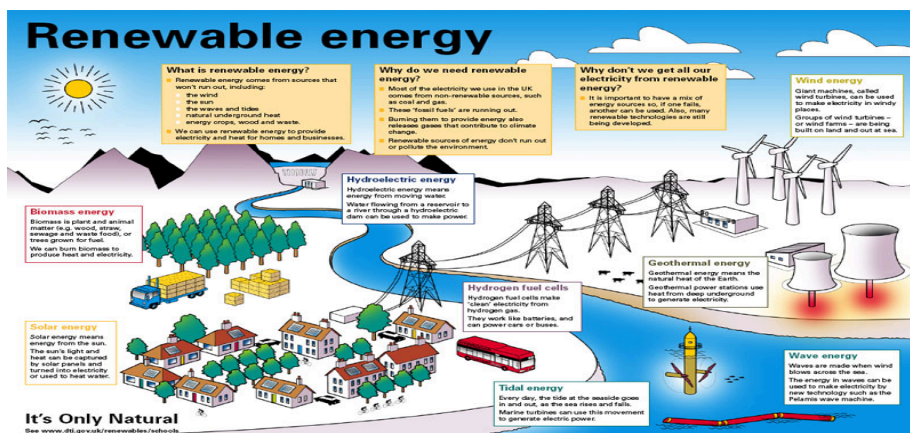
1.6.1. Understanding Renewable Energy

Renewable energy comes from natural sources that are constantly replenished. This means they won't run out, unlike fossil fuels. Some of the main types of renewable energy include:

- **Solar Energy:** Exploiting energy from the Sun's light and heat.
- **Wind Energy:** Using wind turbines to convert the kinetic energy of wind into electricity.
- **Hydropower:** Generating electricity from the movement of water, such as in rivers or dams.
- **Geothermal Energy:** Utilizing heat from within the Earth to produce electricity or for heating.
- **Biomass Energy:** Burning organic materials like wood, crops, or waste to generate heat or electricity.

Key Concepts:

- **Renewable Resources:** Resources that are naturally replenished on a human timescale.
- **Sustainability:** Meeting the needs of the present without compromising the ability of future generations to meet their own needs.



Teaching Resources & Materials

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youtube: [Renewable Energy 101](#)

This video provides an overview of renewable energy. Here are some key points:

- **Definition:** Renewable energy comes from sources that don't run out or can be replenished in a person's lifetime [[00:08](#)].
- **Common types:**
 - Solar [[00:11](#)]
 - Wind [[00:17](#)]
 - Hydropower [[00:21](#)]
 - Biomass [[00:26](#)]
 - Tidal [[00:33](#)]
 - Geothermal [[00:42](#)]
- **Nuclear energy:** Not considered a renewable energy source, but an alternative energy source [[00:42](#)].
- **Growth:** Renewable energy is the fastest growing energy source on the planet [[00:57](#)].
- **Benefits:** It's a clean energy source, meaning it doesn't directly produce greenhouse gas emissions or air pollutants [[01:03](#)].
- **Challenges:** Low efficiency, high capital costs, and intermittency [[01:11](#)].

Youtube: [Climate Change Series – 7. Renewable Energy and Climate Change](#)

This video focuses on the crucial role renewable energy plays in combating climate change. Here's a breakdown of the key points:

- **The Problem:**
 - The video emphasizes that burning fossil fuels is the primary driver of climate change due to the release of greenhouse gases, particularly carbon dioxide.
 - It highlights the urgent need to transition away from fossil fuels to mitigate the impacts of global warming.
- **Renewable Energy as a Solution:**
 - Renewable energy sources, such as solar, wind, and hydropower, offer clean alternatives that produce significantly fewer greenhouse gas emissions.
 - The video explains how these technologies work and their potential to replace fossil fuel-based energy generation.
- **Benefits of Renewable Energy:**
 - Reduced greenhouse gas emissions, leading to a decrease in the rate of climate change.
 - Improved air quality and public health.
 - Increased energy security and independence.
 - Creation of new jobs and economic opportunities.
- **Challenges and Opportunities:**

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- The video acknowledges the challenges associated with transitioning to renewable energy, such as intermittency (the variability of solar and wind power) and the need for grid modernization.
- It also highlights the rapid advancements in renewable energy technologies and the decreasing costs, making them increasingly competitive with fossil fuels.
- **The Importance of Action:**
 - The video stresses the importance of taking immediate action to accelerate the adoption of renewable energy and reduce our reliance on fossil fuels.
 - It implies that a global effort is needed, from governments, businesses, and individuals, to make the change.
- **Connection to climate change:**
 - The video makes a very clear connection between the use of renewable energy, and the reduction of the effects of climate change.
- "Solar Energy Kits: Educational kits exist that allow students to build small models of solar panels, solar cars, or even solar weather stations. These kits are excellent for hands-on experimentation.

Example: LittleBits kits, or Snap Circuits."

- "Interactive Simulations: In addition to PhET, there are other online simulations that explore different aspects of renewable energy, such as the efficiency of wind turbines or the operation of hydroelectric power plants.

Resources: Exploratorium, Energy3D."

Bibliography for Section 1:

- *"The Energy Challenge"* by Valeriano Ruiz: A reference book on renewable energy and its impact on future society.
- *"Renewable Energy: What You Need to Know"* by José Roldán Vilora: Explains renewable energy sources and their technologies.
- *"Innovation and Energy Sustainability"* by M^a Soledad Ramírez-Montoya and Alberto Mendoza-Domínguez: Focuses on energy sustainability education through MOOCs.
- *"Natural Capitalism: Creating the Next Industrial Revolution"* by Paul Hawken, Amory Lovins, and Hunter Lovins: Explores how businesses can adopt sustainable strategies.
- *"Green to Gold"* by Daniel Esty and Andrew Winston: Showcases how companies can innovate and create value through environmental strategies.

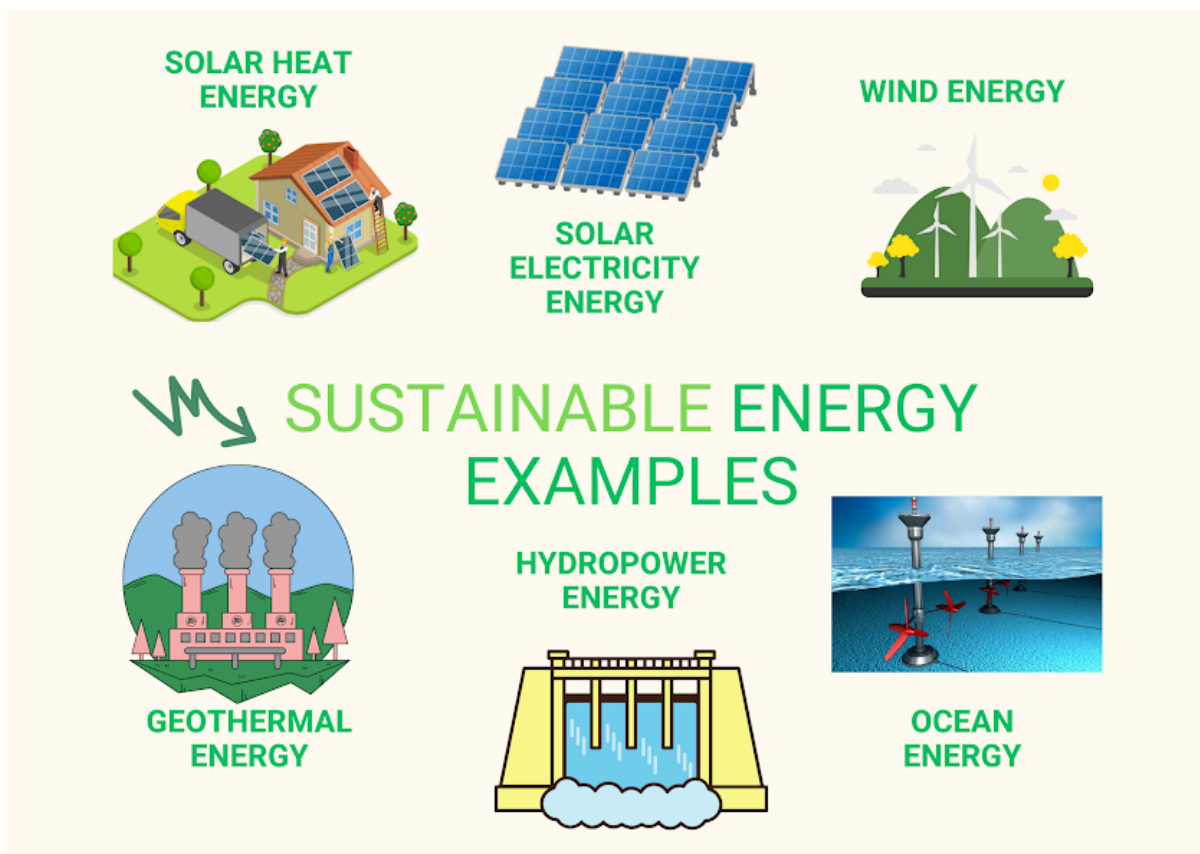
Recommended Publishers:

- **Planeta de Libros:** Offers a wide selection of books on climate change and sustainability.
- **Feníe Energía:** Publishes books related to energy and sustainability.
- **Greening Solutions:** Specializes in books on sustainability and renewable energy.

1.6.2: Renewable Energy Technologies

Technology plays a vital role in harnessing renewable energy sources and making them usable for society. Here are some examples:

- **Solar Panels:** These devices convert sunlight into electricity through the photovoltaic effect.
- **Wind Turbines:** Tall structures with blades that rotate in the wind, powering a generator to produce electricity.
- **Hydroelectric Dams:** Structures that hold back water to create reservoirs, with controlled release of water to spin turbines and generate electricity.
- **Geothermal Power Plants:** Facilities that drill into the Earth to access hot water or steam, which is used to drive turbines and produce electricity.
- **Biomass Power Plants:** Similar to traditional power plants, but they burn biomass instead of fossil fuels to generate electricity.





Educational Websites & Simulations:

- **PhET Interactive Simulations (University of Colorado Boulder):**
 - Excellent for visualizing the photovoltaic effect. Search for "photovoltaic" or "solar cell" to find relevant simulations.
 - Provides a hands-on learning experience by allowing users to manipulate variables.

Bibliography for Section 2:

- *"The Energy Challenge"* by Valeriano Ruiz: A reference book on renewable energy and its impact on future society.
- *"Renewable Energy: What You Need to Know"* by José Roldán Vilora: Explains renewable energy sources and their technologies.
- *"Innovation and Energy Sustainability"* by M^a Soledad Ramírez-Montoya and Alberto Mendoza-Domínguez: Focuses on energy sustainability education through MOOCs.
- *"Natural Capitalism: Creating the Next Industrial Revolution"* by Paul Hawken, Amory Lovins, and Hunter Lovins: Explores how businesses can adopt sustainable strategies.
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- **Planeta de Libros:** Offers a wide selection of books on climate change and sustainability.
- **Feníe Energía:** Publishes books related to energy and sustainability.
- **Greening Solutions:** Specializes in books on sustainability and renewable energy.

1.6.3: Benefits of Renewable Energy

Renewable energy offers numerous advantages for both the environment and society:

- **Environmental Benefits:**
 - Reduced greenhouse gas emissions, helping to combat climate change.
 - Less air and water pollution, leading to improved public health.
 - Conservation of natural resources.
- **Social and Economic Benefits:**
 - Increased energy security by reducing dependence on fossil fuel imports.
 - Job creation in the renewable energy sector.
 - Cost savings in the long term, as renewable energy sources have low operating costs.
 - Improved access to energy in remote or developing areas

BENEFITS OF RENEWABLE ENERGY

Renewable energy offers numerous advantages for both the environment and society:

1 ENVIRONMENTAL BENEFITS:

- Reduced greenhouse gas emissions, helping to combat climate change.
- Less air and water pollution, leading to improved public health.
- Conservation of natural resources.



2 SOCIAL AND ECONOMIC BENEFITS:

- Increased energy security by reducing dependence on fossil fuel imports.
- Job creation in the renewable energy sector
- Cost savings in the long term, as renewable energy sources have low operating costs.
- Improved access to energy in remote or developing areas.



3 GENERAL RESOURCES:

EDUCATIONAL VIDEOS:

- https://youtu.be/Giek094C_l4?feature=shared - YouTube: This video offers a basic introduction to renewable energies, ideal for young students. You can find it on YouTube by searching for that title.
- <https://youtu.be/UVf2Yw7uFoE> - YouTube: A deeper documentary that explores various renewable technologies and their impact, useful for older students.
- Many YouTube channels, such as those of National Geographic or Student Energy, offer clear explanations and animations about how different renewable technologies work.



General Resources:

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- **Educational Videos:**

- "Renewable energies - Types of energy for children - YouTube": This video offers a basic introduction to renewable energies, ideal for young students. You can find it on YouTube by searching for that title.
- "DOCUMENTARY | Renewable energies, the clean alternative - YouTube": A deeper documentary that explores various renewable technologies and their impact, useful for older students.
- Many YouTube channels, such as those of National Geographic or Student Energy, offer clear explanations and animations about how different renewable technologies work.

Bibliography for Section 3:

Books and Academic Articles

- Hawken, P., Lovins, A., & Lovins, H. (1999). *Natural Capitalism: Creating the Next Industrial Revolution*. Little, Brown and Company. An in-depth exploration of sustainable business strategies, including renewable energy innovations.
- Esty, D., & Winston, A. (2009). *Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value, and Build Competitive Advantage*. Wiley. Focuses on the social and economic impacts of renewable energy initiatives.
- Roldán Vilora, J. (2015). *Energías renovables: Lo que hay que saber*. Editorial Almuzara. A practical guide to renewable energy technologies, emphasizing their environmental benefits.

Websites and Online Resources

- National Renewable Energy Laboratory (NREL). *Renewable Energy Basics*. Comprehensive information on the benefits and applications of renewable energy. Available at <https://www.nrel.gov>.
- NASA Climate Kids. *Solar Energy Explained for Students*. Engaging and interactive educational tools for young audiences. Available at <https://climatekids.nasa.gov>.

Educational Videos

- *Renewable energies - Types of energy for children*: A YouTube video providing a simple introduction to renewable energy concepts for young learners. Search on YouTube by title.
- *DOCUMENTARY | Renewable energies, the clean alternative*: Explores various renewable energy technologies and their societal impacts. Accessible on YouTube.
- *Climate Change Series – Renewable Energy and Climate Change*: Highlights the role of renewable energy in combating climate change, focusing on both challenges and benefits.

1.6.4: Challenges and the Future of Renewable Energy

While renewable energy has many benefits, there are also challenges to overcome:

- **Intermittency:** Some renewable sources, like solar and wind, are intermittent, meaning they are not available all the time.
- **Storage:** Developing efficient and cost-effective ways to store renewable energy for use when it is not being produced is crucial.
- **Infrastructure:** Building new infrastructure, such as transmission lines, to connect renewable energy sources to consumers is necessary.
- **Cost:** Although the cost of renewable energy technologies has been decreasing, it can still be a barrier to adoption.
- However, the future of renewable energy is promising. Ongoing research and development are leading to:
- **More efficient and cost-effective technologies.**
- **Improved energy storage solutions.**
- **Smarter grids that can better integrate renewable energy sources.**



Renewable energy is essential for creating a sustainable future. By transitioning to cleaner energy sources, we can protect our planet, improve our lives, and ensure a better future for generations to come.

Our Role in a Sustainable Society

We all have a part to play in creating a sustainable future.

- **Conserve Energy:** Turn off lights when you leave a room, unplug devices when you're not using them, and walk or bike instead of driving whenever possible.
- **Support Renewable Energy:** Encourage your family and community to adopt renewable energy solutions.
- **Learn and Educate:** Continue to learn about renewable energy and share your knowledge with others.
- **Innovate and Create:** Explore your own ideas for sustainable solutions!

Let's build a brighter, cleaner future powered by the amazing potential of renewable energy!

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- **Interactive Discussion:** Ask students about their ideas for using renewable energy in their daily lives.
- **Real-World Examples:** Share stories of communities and companies that are successfully using renewable energy.
- **Creative Projects:** Have students design their own renewable energy systems or create artwork that illustrates a sustainable future.
- **Connect to Current Events:** Discuss recent news about renewable energy and climate change.
- **Scratch projects:** Have students use the scratch projects you linked as a way to engage with the lesson.

Bibliography for Section 4: Challenges and the Future of Renewable Energy

Books and Academic Articles

- Lovins, A., & Hawken, P. (1999). *Natural Capitalism: Creating the Next Industrial Revolution*. Little, Brown and Company. Explores the future of renewable energy and its challenges, including technological advancements.
- Esty, D., & Winston, A. (2009). *Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value, and Build Competitive Advantage*. Wiley. Focuses on the economic and strategic importance of renewable energy.
- Ramirez-Montoya, M. S., & Mendoza-Domínguez, A. (2020). *Innovación y sustentabilidad energética*. Editorial ITESO. Discusses the challenges of integrating sustainable energy into modern education systems.

Websites and Online Resources

- International Renewable Energy Agency (IRENA). *Renewable Energy Solutions for Climate Change*. Provides research on overcoming intermittency and storage challenges. Available at <https://www.irena.org>.
- National Renewable Energy Laboratory (NREL). *Energy Storage and Integration of Renewable Energy*. Offers insights into infrastructure development for renewable energy. Available at <https://www.nrel.gov>.

Educational Videos

- *Challenges in Renewable Energy* (YouTube). Offers a breakdown of the intermittency issues and solutions for energy storage technologies. Search by title on YouTube.



- *Future of Renewable Energy Technologies* (National Geographic). Examines ongoing advancements and the promising outlook for renewable energy. Available on the National Geographic YouTube channel.
- *Climate Change Series: Renewable Energy and Sustainability*. Focuses on building smarter grids and integrating renewable sources. Accessible on YouTube.

Interactive Learning Resources

- NASA Climate Kids. Features simulations and tools for students to explore solar energy technologies and sustainability. Available at <https://climatekids.nasa.gov>.
- PhET Interactive Simulations. Provides virtual labs to explore renewable energy efficiency and energy grid models. Available at <https://phet.colorado.edu>.

Pedagogical strategies for the chapter on "Renewable Energy and Sustainability in Technology and Society," especially for students aged 10-14. We want to make it engaging, hands-on, and promote deep understanding.

1. Inquiry-Based Learning:

- **Strategy:** Pose open-ended questions that encourage students to explore and discover.
 - Example: "How can we capture more energy from the sun?" or "What are the advantages and disadvantages of different renewable energy sources?"
- **Implementation:**
 - Start with a question or problem.
 - Guide students to investigate, research, and experiment.
 - Encourage them to draw their own conclusions.

2. Creative Design and Model Building:

- **Strategy:** Provide opportunities for students to creatively design and build non-functional models or representations of solar-powered solutions using accessible materials.
- **Examples:**
 - Designing and building a model of a solar-powered water pump for a remote village using cardboard, plastic bottles, and other recycled materials.
 - Designing and sketching plans for a solar-powered charging station for phones in a public park.
 - Building simple models illustrating how solar panels capture sunlight (e.g., using reflective surfaces).
- **Implementation:**
 - Provide a variety of simple, accessible materials (cardboard, paper, craft supplies, recycled items, etc.).
 - Encourage imaginative design and representation over functional engineering.
 - Facilitate brainstorming and collaborative design within teams.
 - Guide students to explain how their design is intended to work, even if the model isn't functional.



3. Problem-Solving Design Projects:

- **Strategy:** Engage students in projects where they apply their understanding of solar energy principles to design creative solutions for real-world problems, focusing on the design process and representation.
- **Examples:**
 - Designing a solar-powered solution to a specific problem faced by their local community (e.g., lighting a dark path, providing power for an outdoor event).
 - Creating a presentation, poster, or short video showcasing their designed solar solution and explaining its benefits.
 - Developing a concept and visual representation for a new product that uses solar energy.
- **Implementation:**
 - Present clear problem scenarios that can realistically be addressed with solar energy.
 - Guide students through a design thinking process (understand, ideate, design, present).
 - Focus on the creativity and feasibility of the design concept, as well as the clarity of their presentation.
 - Encourage teams to articulate their design choices and the potential impact of their solution.

4. Visual Learning and Multimedia:

- **Strategy:** Utilize visuals, videos, and interactive simulations to enhance understanding.
 - Examples:
 - Showing videos of solar panel installations or wind turbine farms.
 - Using simulations to demonstrate the photovoltaic effect.
 - Using infographics to explain energy statistics.
- **Implementation:**
 - Select high-quality visuals and multimedia resources.
 - Facilitate discussion and analysis of the visuals.
 - Use online resources like PhET and YouTube.

5. Collaborative Learning:

- **Strategy:** Promote teamwork and peer learning.
 - Examples:
 - Group projects and presentations.
 - Peer review and feedback.
 - Class discussions and debates.
- **Implementation:**
 - Assign roles and responsibilities to group members.
 - Provide clear guidelines for collaboration.
 - Facilitate constructive feedback and discussion.

6. Real-World Connections:

- **Strategy:** Connect the concepts to real-world applications and current events.
 - Examples:
 - Discussing the impact of climate change.
 - Exploring local renewable energy initiatives.
 - Inviting guest speakers from the renewable energy industry.
- **Implementation:**
 - Use case studies and examples from the news.
 - Encourage students to research and share real-world examples.
 - Organize field trips.

7. Differentiated Instruction:

- **Strategy:** Adapt instruction to meet the diverse needs of learners.
 - Examples:
 - Providing multiple options for assignments.
 - Using varied teaching methods.
 - Offering extra support or enrichment activities.
- **Implementation:**
 - Assess students' prior knowledge and learning styles.
 - Provide flexible grouping and individualized support.
 - Offer a range of resources and activities.

8. Critical Thinking and Problem-Solving:

- **Strategy:** Encourage students to analyze information, evaluate evidence, and solve problems.
 - Examples:
 - Analyzing the pros and cons of different renewable energy sources.
 - Designing solutions to energy storage challenges.
 - Debating the ethics of large scale renewable energy projects.
- **Implementation:**
 - Pose challenging questions and problems.
 - Provide opportunities for students to justify their reasoning.
 - Encourage students to consider multiple perspectives.

Expected Student Outcomes:

- **Deep Understanding:**
 - Students will explain renewable energy technologies and sustainability concepts.
 - They will grasp the role of renewables in combating climate change.
- **Critical Thinking:**
 - Students will analyze renewable energy information and solve related problems.
- **Increased Engagement:**
 - Hands-on activities will boost interest in science and engineering.



- Students will feel empowered to support sustainability.
- **Collaboration & Communication:**
 - Group projects will enhance teamwork and communication skills.
- **Real-World Awareness:**
 - Students will connect renewable energy concepts to daily life.
 - They will understand their role as environmentally responsible citizens.
- **Practical Skills:**
 - They will develop hands-on skills by participating in the construction of different projects.

Expected Classroom Outcomes:

- **Dynamic Learning:**
 - The classroom will become a space for active learning and collaboration.
- **Increased Participation:**
 - Students will be more engaged and show greater interest in class activities.
- **Community Building:**
 - Working in groups will help build a sense of community.

Evaluation:

- Continuous assessment through observation, participation, projects, and presentations.
- Use of rubrics to measure progress.

"Renewable Energy Solutions: Community Challenge" - Role Play Unit

Overview:

This activity, "Renewable Energy Solutions: Community Challenge," is designed to engage students in understanding the complexities of transitioning to a sustainable energy future. Students will take on roles representing various stakeholders and collaborate to develop comprehensive renewable energy solutions for a specific community.

Objective:

To provide a hands-on experience in exploring renewable energy technologies, understanding their benefits and challenges, and developing sustainable energy plans for a community. Students will learn about the interconnectedness of technology, policy, environment, and society in achieving a sustainable energy future.

Step	Description	Roles Involved
------	-------------	----------------



1. Introduction to the Activity	Introduce the "Renewable Energy Solutions: Community Challenge." Explain the need for sustainable energy and the various renewable energy sources. Define the roles: Renewable Energy Engineers, Community Planners, Environmental Advocates, and Policy Advisors.	All roles (Engineers, Planners, Advocates, Advisors)
2. Divide Students into Groups & Assign Communities	Split students into groups and assign each a specific community (real or fictional) with unique energy needs and resources. Assign roles within each group: Renewable Energy Engineer, Community Planner, Environmental Advocate, Policy Advisor.	Engineers, Planners, Advocates, Advisors
3. Research and Preparation	Each group member researches their assigned role. Engineers focus on various renewable energy technologies (solar, wind, hydro, geothermal, biomass). Planners study community energy needs and infrastructure. Advocates research environmental impacts and sustainability. Advisors investigate relevant policies and incentives.	Engineers, Planners, Advocates, Advisors
4. Group Discussion & Resource Assessment	Groups discuss their findings, assess the community's resources, and identify potential renewable energy solutions. Engineers present technology options. Planners discuss infrastructure and feasibility. Advocates highlight environmental considerations. Advisors discuss policy frameworks.	Engineers, Planners, Advocates, Advisors
5. Develop the Community Energy Plan	Groups collaborate to create a detailed renewable energy plan for their community. Engineers design integrated systems. Planners outline implementation strategies. Advocates ensure environmental sustainability. Advisors propose policy recommendations.	Engineers, Planners, Advocates, Advisors
6. Presentations & Community Feedback Simulation	Each group presents their energy plan, highlighting benefits, challenges, and feasibility. The class simulates a community meeting, asking questions and providing feedback.	Engineers, Planners, Advocates, Advisors (presenters) and All roles (community feedback)



7. Evaluation & Refinement	Groups reflect on the feedback and evaluate the effectiveness of their plans. They refine their solutions based on the simulated community feedback and the critiques of their peers.	All roles (evaluators and refiners)
8. Final Recommendations & Action Plan	Each group presents their refined renewable energy solution and creates a final action plan that includes the steps needed to implement their solution. The class then votes on the best plan for each community.	All roles (as voters and decision-makers)

Chapter 2: Solar energy lesson plans.

The six developed lesson plans are thematically aligned with the educational tools presented in the previous chapter. Each lesson plan is designed to be used alongside its corresponding educational tools during preparation, enabling educators to deliver content in a cohesive and engaging manner. While the primary target audience for these lesson plans is students aged 10 to 14, the content is mature and intellectually stimulating enough to be of interest to older students as well. Although the lesson plans are designed to complement each other, educators are free to use a single lesson plan, select specific sections, or mix and match elements from multiple lesson plans. They are designed to be flexible, clear and easy to use.

Chapter 2.1: Lesson Plans - Solar Energy and the Science of Light.

Title

Solar Energy and the Science of Light

Date	
Teaching Staff	Mr/Mss/Ms
Term	
Year Level	10-14 years
Time/Length	2 hours
Key Learning Area	Science, Technology, Engineering, Arts, Mathematics (STEAM)

Summary

The Lesson plan developed on the topic of “Solar Energy and the Science of Light” is a part of the Erasmus+ funded project #Solar4Future+. The aim of the project is to incorporate STEAM into climate change and to promote a virtual cooperation culture amongst teachers, students, and schools to fight against climate change.

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The project takes a specific look at Solar energy. In this course, the students will be educated on solar energy and the science of light in general.

Aims of the lesson

The main goal of this lesson is to increase the knowledge, understanding, and skills of students on the topics of solar energy and the science of light, while at the same time trying to popularize the topic of solar energy, sustainable energy and STEAM at large among pupils across many different countries in Europe.

Age of students

10 - 14

Teaching resources (material & online tools)

- Glasses
- Water
- Orange Juice
- Coloured filters
- Flashlight
- A white sheet of paper
- Chapter 1 - Solar Energy and the Science of Light of the Solar energy curriculum
- Information on Solar energy technology:
<https://archive.epa.gov/climatechange/kids/solutions/technologies/solar.html>
- Information on Science of light:
<https://www.britannica.com/science/light>
- Information on Energy budget:
<https://scied.ucar.edu/learning-zone/how-climate-works/energy-budget>
- Information on Solar energy:
<https://www.britannica.com/science/solar-energy>



Lesson plans

One Period = 40 minutes

1. Understanding the Science of Light. Pedagogical strategy - Inquiry-based learning/Questioning and Discussion				
Name of the activity	Process	Aim	Skills gained	Time 1 period
Theory of light	Explaining basics on the topic of science of light in an understandable and engaging manner by providing examples and situations to the students, which would help them more easily understand the theory. (Use information from 1.1.2. Science of Light pp. 10 - 11)	Providing information and knowledge on the topic - science of light.	Basic understanding of how light works in nature and how it relates to solar energy.	Approx 15 minutes
The Wavelengths in praxis	Students will use the flashlight with different coloured filters to shine light through an empty glass, a glass with water, and a glass with the third coloured liquid, and observe which colours are absorbed the most in each different liquid on the white paper. (The Light Waves in Praxis pp. 14 - 15). The teacher should engage all students in the exercise and asks them to write down observations (The Light Waves in Praxis pp. 14 - 15).	Deliver a visible example of how wavelengths work.	Understanding what visible light is and how it is absorbed	Approx 10 minutes



Questioning and Discussion on the topic of electromagnetic waves	The teacher will engage the class in a discussion through asking questions on the topic of electromagnetic waves, wavelengths and experiments in which the class participated in. (The Light Waves in Praxis pp. 14 - 15). The teacher can engage the class also during the experiment. Not necessarily after.	Provide an in-depth understanding of electromagnetic waves and wavelengths and how they relate to solar energy.	Understanding of what is electromagnetic waves and wavelengths and how they work in relation to Photovoltaic Cells	Approx 15 minutes
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2. Understanding of Solar Power. Pedagogical strategy - Questioning and discussion

Name of the activity	Process	Aim	Skills gained	Time
Theory of Solar Energy	Explaining basics on the topic of solar energy in an understandable and engaging manner by providing examples and situations to the students which would help them more easily understand the theory. (1.1.1: Solar Energy pp. 5 - 9)	Providing information and knowledge on the topic - Solar Energy.	Basic understanding of Solar Energy, what affects the solar energy and energy budget.	Approx 10 minutes
Solar Power Courtroom	The teacher will split the classroom in two camps and engage them in a debate about the benefits and challenges of solar energy. (Solar Power courtroom pp. 16)	To understand both the pros and cons of Solar Energy.	Developing students' critical thinking and argumentative capabilities. Gaining a deeper understanding of Solar energy.	Approx 20 minutes



Solar Power discussion	After the debate the teacher will engage both groups in a discussion, so to come together to a conclusion on this topic. (Solar Power courtroom pp. 16)	In-depth understanding of Solar energy	Development of critical thinking. A deeper understanding of the Solar Energy	Approx 10 minutes
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3. Capturing Solar Energy and opportunities. Pedagogical strategy - Questioning and Discussion/Small Group Discussions				
Name of the activity	Process	Aim	Skills gained	Time
Insight on how to capture Solar Energy.	Explaining how Photovoltaic cell and Solar Thermal Technology works and differ from each other. (1.1.3: How can we capture solar energy? Pp. 11 - 13).	Educating students on different Solar Energy devices	Basic Understanding of Photovoltaic cell and Solar Thermal Technology	Approx 10 minutes
Insight in the career opportunities offered by the Solar energy industry	Providing information on the renewable energy job market. 1.1.4: The job market in renewable energy. Pp 13 - 14).	Educating students on the many career paths one may be able to take in the Solar energy industry	Understanding of Solar energy job roles and their responsibilities	Approx 5 minutes
Discussing solar energy parks	Splitting the classroom into groups of five. Give them a task to decide where to put a Solar Energy Park . Ask them follow-up questions from the role play unit. (Implementation of Solar panels discussion. Pp 15 - 16). Engage other groups to provide their opinion on the matter. As written in the roll play unit. (Implementation of Solar panels discussion. Pp 15 - 16).	Giving a deeper understanding of Photovoltaic Cells and what may prevent them from working efficiently	Deeper understanding of Photovoltaic Cells . More developed critical thinking, argumentative capabilities, and analytical thinking, because students have to take into consideration all of the information provided previously to successfully do the task.	Approx 25 minutes



Feedback and evaluation

Evaluation

Evaluation Method	Details
Observation & Participation	Teachers observe the student engagement in the class and the activities.
Observation & results	Teachers observe student understanding of the topic

Feedback

Method of collecting feedback	Details
Asking	The teacher directly asks for the feedback from the students after the class ends
Survey - 1	Anonym survey for the students, to gain an understanding how engaging was the class for the students and if they have gained more understanding of the topic
Survey - 2	Anonym survey for the teachers to gain their thoughts on the solar curriculum

1. [Survey for students.](#)
2. [Survey for teachers.](#)

Chapter 2.2: Lesson Plans - Designing and Building a Solar-Powered Device.

Title and key information of the lesson plan

Designing and Building a Solar-Powered Device

Date	
Teaching Staff	Mr/Mss/Ms
Term	
Year Level	14-years old
Time/Length	
Key Learning Area	Science, Technology, Engineering, Arts, Mathematics (STEAM)



Aims of the Lesson

- Understand how solar panels convert sunlight into electricity.
- Design and build a functional solar-powered device.
- Develop teamwork and engineering skills through collaborative prototyping.
- Reflect on the role of solar energy in addressing environmental challenges.

Summary

Students will explore solar energy and its applications by designing and building a solar-powered device. Through hands-on activities, they will learn how photovoltaic cells generate electricity and experiment with optimizing their device's performance. The lesson emphasizes teamwork, creativity, and technical problem-solving.

Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Hands-On Solar Device	Engage students in designing and building a solar-powered device to understand the principles of solar energy and its practical applications.	Discuss real-world examples of solar-powered devices. Demonstrate how a small solar panel powers an LED light or fan. Explain factors affecting solar energy efficiency (e.g., sunlight angle, intensity). Divide students into small groups to brainstorm device ideas (e.g., solar-powered fan or light). Provide materials for prototyping, ensuring proper connections between components like solar panels, wires, and motors. Encourage experimentation with panel angles to optimize performance. Test devices under various light conditions (e.g., sunlight, shade). Record observations and adjust designs for improved efficiency.	Understand how photovoltaic cells convert sunlight into electricity. Apply engineering concepts to create functional prototypes. Develop teamwork and problem-solving skills through collaborative design and testing	Formative: evaluate the functionality of prototypes and students' understanding of solar energy principles during group discussions. Summative: Assess creativity in design, teamwork effectiveness, and clarity in presenting results during reflection sessions.
Exploring Solar Efficiency Through Simulations	Introduce students to the concept of solar panel efficiency using digital simulations before transitioning to hands-on prototyping.	Use PhET Solar Panel Efficiency Simulations or Tinkercad Circuits to explore how sunlight angle, intensity, and weather conditions affect energy output. In groups, discuss findings from simulations and decide on a device design based on	Analyze factors influencing solar panel efficiency using simulations. Apply theoretical knowledge to improve physical prototypes. Enhance critical thinking by	Formative: Observe student engagement during simulations and their ability to connect theoretical concepts with practical designs. Summative: Assess prototypes for functionality and

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Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
		efficiency insights (e.g., optimal panel angles). Build physical prototypes using provided materials while applying knowledge gained from simulations. Test devices under different conditions and compare results with simulation predictions.	comparing digital models with real-world results.	efficiency improvements based on simulation insights.

Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Solar Energy in Real-World Applications	Encourage students to reflect on the environmental impact of solar energy and explore its potential applications in addressing global challenges.	- Discuss the importance of renewable energy sources like solar power in reducing carbon footprints and combating climate change. - Build solar-powered devices in groups while considering how they could be scaled for real-world applications (e.g., powering homes or outdoor lighting). - Groups present their devices, explaining design choices and potential uses in real-world scenarios. - Facilitate a class discussion on the broader implications of solar energy adoption.	Understand the environmental benefits of renewable energy sources like solar power. Develop innovative solutions for real-world challenges using engineering principles. Improve communication skills through presentations and discussions.	Monitor group discussions on environmental impact and creativity during prototyping sessions. Evaluate presentations for clarity, relevance, and depth of understanding regarding solar energy applications.

Aims of the lesson



1. Introduce solar energy principles

Ensure students understand how solar energy is harnessed and converted into electricity through photovoltaic cells. Students will learn the science behind solar panels, including how sunlight interacts with photovoltaic cells to generate electrical energy. This foundational knowledge will prepare them for hands-on activities and real-world applications.

2. Develop problem-solving skills

Encourage students to identify challenges and devise solutions during the design and prototyping process. Through group work, students will face technical and creative challenges, such as optimizing solar panel angles or troubleshooting circuit connections. This fosters critical thinking and resilience.

3. Foster collaboration and teamwork

Promote effective teamwork by having students collaborate in small groups to design, build, and test their solar-powered devices. Working in teams allows students to share ideas, divide responsibilities, and learn from one another, cultivating interpersonal skills essential for future academic and professional environments.

4. Apply theoretical knowledge practically

Enable students to apply theoretical concepts of solar energy efficiency in a hands-on activity. By designing and building solar-powered devices, students bridge the gap between theory and practice, reinforcing their understanding of scientific principles through experimentation.

5. Enhance creativity and innovation

Inspire students to think creatively while designing unique solar-powered devices. Students will brainstorm ideas for their prototypes, encouraging them to innovate solutions that could have real-world applications, such as sustainable energy systems or eco-friendly gadgets.

6. Cultivate environmental awareness

Highlight the importance of renewable energy sources like solar power in addressing environmental challenges.

Through discussions and reflections, students will understand how solar energy contributes to reducing carbon footprints and mitigating climate change, fostering a sense of responsibility toward sustainability.

7. Strengthen analytical skills

Teach students to analyze the performance of their prototypes under varying conditions (e.g., light intensity or angle). Using tools like multimeters and recording observations, students will learn to assess efficiency, troubleshoot issues, and make data-driven adjustments to optimize their devices.

8. Develop communication skills

Encourage clear communication through group presentations and class discussions about their prototypes and findings.

Students will present their designs, explain their choices, and share results with peers, improving their ability to articulate ideas effectively in both technical and non-technical contexts.

Age of students

The lesson is designed for students aged **14**.



Teaching resources (material & online tools)

1. Solar Energy Components:

- Small solar panels
- LED lights, small motors, or fans (depending on the project)
- Wires, connectors, and alligator clips
- Multimeters for measuring voltage and current
- Miscellaneous building materials (e.g., cardboard, plastic cups, wooden sticks)
- Basic tools (scissors, tape, wire strippers, glue guns)

2. Prototyping Supplies:

- Cardboard or other materials for device casings
- Small model wheels and axles (for solar-powered cars)
- 3D printers and CAD software (optional for advanced projects)

3. Safety Equipment:

- Safety goggles for hands-on activities

4. Demonstration Tools:

- A pre-assembled solar-powered device to showcase functionality
- Access to strong artificial light sources for testing in controlled conditions

Online Tools

1. Simulation Platforms:

- PhET Solar Panel Efficiency Simulations: An interactive tool to explore solar panel efficiency under different conditions
- Tinkercad Circuits: For designing and testing virtual solar circuits before physical prototyping[1].

2. Educational Games:

- Solar Simulator: A gamified platform where students design solar systems and tackle real-world challenges related to solar energy.

3. Video Resources:

- YouTube videos explaining how solar panels work:
 - How Solar Power Works (basic overview) <https://www.youtube.com/watch?v=dHVZ6jEf8To>
 - How Do Solar Panels Work? (advanced physics of solar cells) <https://youtu.be/8RjGHmlOu58?si=MRTLmrKVAtUaF3GI>

4. Free Online Courses:

- Introduction to Renewable Energy by Solar Energy International (SEI): Covers basic renewable energy concepts. <https://www.solarenergy.org/courses/introduction-to-renewable-energy/>
- Webinar Library by SEI: Offers recorded webinars on various solar topics. <https://www.solarenergy.org/webinars/>

5. Knowledge Banks and Toolkits:

- Solar Schools' Knowledge Bank: A self-directed learning resource for students to explore energy topics. <https://solarschools.net/knowledge-bank/energy>



Interactive Classroom Activities

1. Projects

- Build a solar-powered device such as a fan or a small car using provided materials
- Disassemble and analyze a solar-powered calculator to understand its components and suggest design improvements.

2. Design Challenges:

- Use CAD software to design a 3D-printed solar-powered car and test its performance
- Plan a solar power system for a mobile classroom or disaster-relief setting.

3. Testing & Optimization:

- Experiment with different angles and light intensities to optimize solar panel performance.
- Record observations using multimeters to measure voltage and current changes under varying conditions

Suggested Kits and Materials:

- **Solar Education Kits (affordable and beginner-friendly):**
 - *Elenco Snap Circuits Green – Alternative Energy Kit*
A hands-on kit that includes a small solar panel, fan, and light components. Easy to use, with snap-on parts—great for beginners.
 - *OWI Solar Science Kit*
Offers several mini solar-powered models (car, boat, windmill). Ideal for showing how sunlight powers small machines.
 - *SunWind Solar Panel Kit for Kids*
Includes small panels, motors, wires, and fans. Affordable and reusable for multiple projects.

Basic Materials for DIY Projects:

- Small solar panels (2V–6V, often included in kits or available on platforms like Amazon or AliExpress)
- LED lights, small DC motors, or mini fans
- Wires, alligator clips, and connectors
- Multimeters (affordable digital models, e.g., AstroAI or TekPower)
- Cardboard, plastic cups, wooden sticks, recycled materials
- Basic tools: scissors, glue guns, wire strippers, tape

Online Tools & Resources:

- **PV Education** – Clear simulations and explanations of how photovoltaic systems work
- **NASA Climate Kids – Solar Energy** – Simple explanations and visuals for younger learners
- **PhET Interactive Simulations (Solar Cell Simulation)** – Great for exploring how light, panel material, and angle affect energy production
- **Instructables.com** – Step-by-step solar project tutorials for classrooms and hobbyists

Lesson plans

1 Period = 45 minutes

Pedagogical Strategy 1: Hands-On Solar Device				
Name of the activity	Process	Aim	Skills gained	Time (period)



Build & Test a Solar Device	Divide students into small groups. Each group receives materials (solar panel, wires, LED/fan, etc.). They built a basic solar-powered device. Test performance in different lighting conditions and experiment with the angle of the solar panel.	Understand how photovoltaic cells work and how design impacts performance.	Engineering basics, teamwork, experimentation, observation	25 minutes
Reflect & Improve	Groups discuss what worked and what didn't. Each team presents their findings and suggests improvements. Discuss factors affecting efficiency (e.g., light intensity, angle, shade).	Deepen understanding of solar energy principles and design thinking.	Communication, critical thinking, self-evaluation, presentation skills	20 minutes

Pedagogical Strategy 2: Exploring Solar Efficiency Through Simulations				
Name of the activity	Process	Aim	Skills gained	Time
Simulate Solar Panel Efficiency	Students use an online simulation (e.g., PhET Solar Panel Simulation or similar). They adjust variables: sunlight angle, panel surface area, temperature, and light intensity. Record how each affects energy output.	Understand how environmental and technical factors impact solar panel efficiency.	Data interpretation, digital literacy, scientific reasoning, inquiry skills	25 minutes
Analyze & Discuss Findings	In pairs or small groups, students compare their simulation results. As a class, discuss key trends and real-world implications (e.g., best panel placement in homes).	Reflect on key concepts and connect simulations to practical solar energy applications.	Collaboration, communication, critical thinking, synthesis of scientific data	20 minutes

Pedagogical Strategy 3: Solar Energy in Real-World Applications

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Name of the activity	Process	Aim	Skills gained	Time
Role-Play – Citizens’ Assembly on Solar Energy	Students receive role cards and prepare short statements. Acting as community members, they discuss and debate two solar energy project options, aiming to reach a group recommendation.	To understand multiple perspectives in energy decision-making and explore fairness, sustainability, and community impact.	Critical thinking, perspective-taking, public speaking, collaboration, decision-making.	30 minutes
Group Presentations & Discussion	Each group briefly presents their findings. Lead a whole-class discussion on how solar energy is changing the world and what might improve its adoption.	Encourage reflection on sustainability and energy solutions for the future.	Public speaking, synthesis, communication, environmental awareness	15 minutes

Feedback and evaluation

Evaluation

Evaluation Method	Details
Observation & Participation	Teachers observe the students' engagement in the class and the activities.
Observation & results	Teachers observe students' understanding of the topic

Feedback

Method of collecting feedback	Details
Asking	The teacher directly asks for feedback from the students after the class ends
Survey - 1	An anonymous survey for the students, to gain an understanding of how engaging the class was for the students, and if they have gained more understanding of the topic
Survey - 2	An anonymous survey for the teachers to gain their thoughts on the solar curriculum

1. [Survey for students.](#)



2. [Survey for teachers.](#)

Chapter 2.3: Lesson Plans - Artistic Expression Through Solar Energy.

Title and key information of the lesson plan

ARTISTIC EXPRESSION THROUGH SOLAR ENERGY

Date	
Teaching Staff	Mr/Mss/Ms
Term	
Year Level	13-16 years
Time/Length	
Key Learning Area	Science, Technology, Engineering, Arts, Mathematics (STEAM)

Summary

Botanical Photography - Basics of chemical components and solutions for cyanotypes, anthotypes and chlorophyll printing.

Students will discover different techniques of solar printing and their impact on the environment, designing sustainable artistic solutions for their photos.

Aims of the lesson

- Creating photographic images using sun-powered printmaking on botanic elements, paper & natural fabrics
- Understand how natural and organic materials can contribute to sustainability
- Develop teamwork, research, and presentation skills.

Age of students

13 - 16 years



Teaching resources (material & online tools)

- Recycled materials (paper, natural fabrics, glass, ceramic)
- Prints of photographic negatives
- Online tutorials:
 - https://alternative-processes-s-school1.teachable.com/p/alternative-processes-academy-spring-equinox?coupon_code=SPRINGEQUINOX
 - <https://www.alternativephotography.com/processes/>

Materials: paper, natural fabrics, botanic elements, photo negatives, inkjet printer.

Bibliography:

- “Back to Basics – A guide to Ecological Photo Chemistry. Vol. 1”, the Sustainable Darkroom, 2024.

Lesson plans

Pedagogical Strategy 1: Warm Up exercises for Botanical Photography				
Name of the activity	Process	Aim	Skills gained	Time (period)
Build & Test a Botanical Photo	Basics of chemical components and solutions for cyanotypes and anthotypes. Divide students into small groups. Each group receives materials (paper, emulsions, etc.) They build different shapes of cyanotypes and anthotypes from negatives or leaves. Test sunprints in different lighting conditions and time exposure	Understand how sunprint photography work. Creating photographic images using sun-powered printmaking on botanic elements, paper & natural fabrics.	Analog Photography, Experimental Photography, teamwork, Theoretical and practical skills for the improvement of processes and behaviors for the role of a future Ecological Photographer who work in a Sustainability Darkroom	45 minutes
Reflect & improve	Groups discuss what worked and what didn't. Each team	Experimental understanding of solar printing principles.	Communication, critical thinking, self-evaluation, presentation skills	45 minutes

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	presents their findings and suggests improvements. Show results (e.g., darkness of sunprints, shadows, color shades).			
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Pedagogical Strategy 2: Anthotype Photography				
Name of the activity	Process	Aim	Skills gained	Time
Workshop: Anthotype process (printing photographs using juice extracted from the petals of flowers, the peel from fruits and pigment from plants)	Discuss the anthotype process and how it was used in the 19th century by artists like Anna Atkins. Show examples of anthotypes and explain how plant materials are used as light-sensitive substances. Explain the science behind how anthotypes work (e.g., light sensitivity of plant pigments).	Making photography prints using plants Teach students about the process and history of anthotype photography	Practical skills for the improvement processes of botanical photography (avoiding using chemical pollutants) Analogue Photography: Students will learn how to photograph plant life with attention to lighting, composition, and detail.	45 minutes
Analyze & Discuss Findings	In pairs or small groups, students compare their anthotype results.	Reflect on key concepts and connect experiments to practical solar energy applications in the Art field.	Collaboration, communication, critical thinking, synthesis of scientific data applied to Photography field.	45 minutes

Pedagogical Strategy 3: Chlorophyll printing.				
Name of the activity	Process	Aim	Skills gained	Time
Workshop: Chlorophyll	Printing with Sunlight, Water and Leaves.	Making photography using	Practical use of nature, leaves and flowers to	45 minutes



printing.	Using the pigments of the life-giving photosynthesis process to develop images. The chlorophyll process is an organic alternative photography process akin to the anotype process. However, instead of printing on the crushed extract of fruit or plant matter, the prints are bleached by sunlight directly onto the surface of leaves using a positive.	chlorophyll printings on leaves. Introduce students to the concept of chlorophyll printing and its significance in art and photography.	create crafts and artistic photos without using chemical solvents. Printmaking Techniques: Students will gain skills in creating unique, one-of-a-kind prints using the chlorophyll printing technique. Scientific Understanding: Students will gain a deeper understanding of the relationship between plant biology (chlorophyll) and light-sensitive materials. Artistic Expression: Students will have the opportunity to express their creativity through different compositions, materials, and exposure times. Eco-Friendly Art Practices: Students will develop an appreciation for sustainable and environmentally conscious artistic processes.	
Group Presentations & Discussion	Each group briefly presents their results. Lead a whole-class discussion on how solar printing could change the Photography world and what might improve its adoption.	Encourage reflection on sustainability and sun printing solutions for the future.	Public speaking, synthesis, communication, environmental awareness	45 minutes

Feedback and evaluation

Evaluation

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Evaluation Method	Details
Observation & Participation	Teachers observe the student engagement in the class and the activities.
Observation & results	Teachers observe student understanding of the topic

Feedback

Method of collecting feedback	Details
Asking	The teacher directly asks for feedback from the students after the class ends
Survey - 1	Anonym survey for the students, to gain an understanding of how engaging the class was for the students and if they have gained more understanding of the topic
Survey - 2	Anonym survey for the teachers to gain their thoughts on the solar curriculum

1. [Survey for students.](#)
2. [Survey for teachers.](#)

Chapter 2.4: Lesson Plans - Exploring Solar Energy through Mathematics.

Title and key information of the lesson plan

Exploring Solar Energy through Mathematics

Date	
Teaching Staff	Mr/Mrs/Ms
Term	
Year Level	10-14 years
Time/Length	4 hours
Key Learning Area	Science, Technology, Engineering, Arts, Mathematics (STEAM)

Summary

- **The activity is structured in four sequences (4 hours):**

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- Solar energy presented through e-book projects (first hour)
- Solving problems/practical applications related to solar panels (second hour)
- The relation between Solar energy -agrivoltaics and agriculture- Study case and solving problems related to biomass (third hour)
- Solar energy through experiments (fourth hour)

Key information:

Exploring solar energy through the lens of mathematics reveals the profound interconnectivity between abstract concepts and real-world applications. From calculating solar irradiance and optimizing panel placement to modeling energy conversion efficiencies and predicting long-term performance, mathematics provides the essential tools for understanding and advancing solar technology.

Aims of the lesson

1. **Applying mathematical concepts in the context of solar energy:** Students will be able to use mathematical operations (addition, subtraction, multiplication, division, percentages) to solve practical problems related to solar energy.
2. **Understanding the relationship between mathematics and science:** Students will observe how mathematics is an essential tool in analyzing and understanding scientific phenomena, especially solar energy.
3. **Developing data analysis and interpretation skills:** Students will learn to interpret graphs, tables, and other graphical representations of data related to solar energy.

Age of students

10-14 years old

Teaching resources (material & online tools)

- Google Presentations
- Book Creator, Google Docs, Canva
- Materials: Flipchart, flipchart paper, markers, glass beakers, thermometer, black paper, cardboard boxes, aluminum foil, solid foods (butter, chocolate).
- Links:
 - https://ro.wikipedia.org/wiki/Sistemul_solar
 - <https://ro.wikipedia.org/wiki/Soare>
 - <https://ro.wikipedia.org/wiki/Pamant>



- https://ro.wikipedia.org/wiki/Energie_solara
- <https://www.e-acumulatori.ro/blog/cate-panouri-fotovoltaice-sunt-necesare-pentru-o-casa.html>
- <https://revista-ferma.ro/si-lucerna-cere-tehnologie/>

Lesson plans

One Period = 50 minutes

Pedagogical strategy – 1 Project-Based Learning (PBL) and Technology Integration				
Name of the activity	Process	Aim	Skills gained	Time (Period)
Solar energy through e-book projects	Tasks: Students will create three e-books using one of specific applications like Book Creator, Google Docs, Canva, FlipBuilder, etc. as team projects. Students are divided in three groups and will carry out projects about solar energy. The project themes are: 1. Solar panels 2. Applications that use electricity produced by solar cells 3. Advantages and disadvantages of using solar panels	1. To use collaborative learning to create team project as an ebook on topics related solar energy applications 2. To integrate digital technology in their research, and design of the projects 3. To collaborate for a productive and efficiency teamwork	To search informations and scientific data about solar panels, the electricity produced by solar cells and their various applications, and the advantages and disadvantages of their use. To create an ebook integrating technology. teamwork abilities collaborative learning critical thinking regarding the advantages and disadvantages of solar energy applications.	50 min



	Each team will presents their e-books project and will evaluate their own project (auto evaluation) and the other teams projects.			
Expected outcomes:	to select relevant informations and scientific data to integrate digital technology and internet resources to realise innovative and creative e-books on requested topics to exercise public speaking the abilities on communication and oral presentation			
Assessment	The students will present their e-books and will evaluate their own presentation and (auto evaluation) and the other teams projects Formative Assessment: - Observing students during group activities			



	- Evaluating student reports and presentations. Summative Assessment: - Final projects that demonstrate students' ability to apply acquired knowledge.			
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Pedagogical strategy – 2 Maths Problem Solving				
Name of the activity	Process	Aim	Skills gained	Time
Problem 1	A family that uses photovoltaic panels consumes 300 kWh/month, produces 275 kWh/month from the panels, and the price of electricity from the supplier is 0.7 lei/kWh. How much more does the family have to pay the supplier? What if their consumption increases to 350 kWh/month? What if their production increases to 300 kWh? What if the price of electricity in the area increases to 1 leu/kWh? Solution: The family would have paid 210 lei (300×0.7) to the	1. Calculating the efficiency of solar panels: Students will be able to calculate the efficiency of solar panels based on data regarding received solar energy and produced electrical energy. Cost-benefit analysis: Students will be able to	Analyzing data and information to find solutions. Identifying relevant information and discarding irrelevant information. Constructing and evaluating arguments.	50 min



	supplier for the electricity bill, but with the help of solar panels, they saved 192.5 lei (275×0.7), so they will only pay the supplier 17.5 lei. If their consumption increases to 350 kWh/month, then they would have to pay 245 lei (350×0.7) to the supplier. The solar panels still help them save 192.5 lei, but they have to pay 52.5 lei instead of 17.5 lei. On the other hand, if their production increases to 300 kWh, then they no longer have anything to pay. Practically, they are powered by the panels, so the electricity bill is 0, and the solar panels reduce the bill by 210 lei. Or, if the price of electricity in the area increases to 1 leu/kWh, then the family would have to pay 300 lei, but the panels reduce the bill by 275 lei, and they only pay 25 lei to the supplier.	calculate the costs of installing a solar panel system and the long-term economic benefits, including savings on energy bills.	Understanding the relationships between mathematical concepts.	
Problem 2	How many photovoltaic panels does a household that uses 2700 kWh annually need, if the power of each	Solving practical problems: Students will be able to solve practical	Analyzing data and information to find solutions.	



	panel is 300 W, and the production rate is 1.5? Solution: Number of panels = system size / production ratio / panel power = $2700 / 1.5 / 300 = 6$ panels of 300 W.	problems related to sizing a solar panel system to meet the energy needs of a home.	Developing fluency with mathematical operations. Applying formulas and algorithms.	
Problem 3	3. What is the power of the panels in a house with 10 solar panels and the following appliances: a central heating system (800 kWh/year), an electric stove (450 kWh/year), a refrigerator (350 kWh/year), an air conditioner (1000 kWh/year), a clothes dryer (300 kWh/year), a dishwasher (250 kWh/year), and a washing machine (350 kWh/year)? Solution: Panel power = Total energy consumption / number of panels = $(800 + 450 + 350 + 1000 + 300 + 250 + 350) / 10 = 3500 / 10 = 350$ W	Estimating solar energy production: Students will be able to estimate the amount of solar energy that a system can produce, taking into account factors such as panel size, orientation, and location.	Analyzing data and information to find solutions. Developing fluency with mathematical operations. Applying formulas and algorithms. Understanding the relationships between mathematical concepts	
Assesement	Formative - Observing students during activities. - Evaluating student individual activity and results.			



Pedagogical strategy – 3 Discovery Learning using the experimental method				
Name of the activity	Process	Aim	Skills gained	Time
Solar Energy Through Experiments Experiment 1: <i>Conversion of solar energy into thermal energy - the influence of surface color on the absorption of solar energy and the heating of water</i>	Required materials: 2 identical transparent glasses, tap water, 1 sheet of white paper, 1 sheet of black paper, 1 thermometer, solar energy source, a stopwatch; Procedure: -Fill both glasses with the same amount of water and measure the initial temperature; -Wrap one glass with black paper and the other with white paper, cover them with a circle of black paper and white paper, respectively; -Place both glasses in the sun for 30-60 minutes; -Measure the water temperature at regular intervals (for example, every 10 minutes); -Record and compare the results for the two glasses. Expected Results: By comparing the water	To demonstrate how surface color influences the absorption of solar energy and the heating of water To develop the ability to observe, to be receptive, to collaborate in carrying out tasks, and to synthesize.	Students will be able to measure the variation in water temperature depending on sun exposure, using a thermometer and a container. Students will be able to observe and record how different materials (e.g., black paper, white paper, aluminum foil) absorb heat from the sun. Students will be able to demonstrate the effect of lenses concentrating sunlight, observing how it can ignite flammable material (with safety precautions). Students will be able to build a simple solar oven from recycled materials and will be able to cook food (e.g., a marshmallow). Students will be able to assemble a small solar irrigation system, using a solar pump and a water container. Students will be able to build a model of a solar house, demonstrating how orientation and materials can	50 min



	temperatures in the two glasses, obtained at 10-minute intervals, it is observed that the water in the glass wrapped in black paper will have a higher temperature than the one in the glass wrapped in white paper. Black paper absorbs more solar energy and transforms it into heat, heating the water faster. White paper reflects more light, heating the water less. Conclusion: The color of the surface influences the absorption of solar energy and its transformation into thermal energy. Dark surfaces absorb more light and heat up more and faster compared to light surfaces that reflect light radiation and heat up less and more slowly.		influence the interior temperature.	
Experiment 2:	Required materials: a cardboard box (e.g., a shoebox), aluminum	To observe and highlight the influence of	• Analysis and interpretation of experimental data:	



<i>Change in the state of aggregation of some products in the "solar oven" under the action of light energy</i>	foil (to reflect light), a sheet of black paper (for heat absorption), transparent plastic wrap (for the greenhouse effect), adhesive tape, scissors, thermometer, scale, 3 small plastic plates with a previously weighed ice cube, butter, and chocolate; Procedure: -Line the inside of the box with aluminum foil to reflect sunlight towards the center of the box. -Place the black paper on the bottom of the box to better absorb heat. -Place the 3 small plates with ice, butter, and chocolate in the solar oven. -Cover the opening of the box with transparent plastic wrap and insert a thermometer. -Measure the temperature inside the oven before placing it in the sun and note the time. -Place the oven in the sun and observe at what temperature and	solar energy on the state of aggregation of some products (melting of ice, butter, and chocolate)	Students will be able to create graphs to illustrate the data collected during the experiments (e.g., temperature variation over time). Students will be able to compare the results obtained with different materials or experimental setups and draw conclusions. Students will be able to identify the factors that influence the efficiency of solar energy conversion into other forms of energy.	
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	how long it takes for the ice, butter, and chocolate to melt. Expected Results: The temperature inside the oven will be significantly higher than the air temperature due to the greenhouse effect. The ice, butter, and chocolate will melt in turn, thus transitioning from a solid to a liquid state. Upon subsequent weighing, it will be observed that the products, regardless of their state of aggregation, maintain the same weight. Conclusion: The solar oven demonstrates the efficiency of absorbing and retaining solar heat, which changes the state of aggregation of some products but not their mass.			
Assesement	Formative Assessment: - Observing students during group activities and experiments.			



	- Evaluating student reports and presentations			
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Feedback and evaluation

Evaluation

Evaluation Method	Details
Observation & Participation	Teachers observe the student engagement in the class and the activities.
Observation & results	Teachers observe student understanding of the topic

Feedback

Method of collecting feedback	Details
Asking	The teacher directly asks for feedback from the students after the class ends
Survey - 1	Anonym survey for the students, to gain an understanding of how engaging the class was for the students and if they have gained more understanding of the topic
Survey - 2	Anonym survey for the teachers to gain their thoughts on the solar curriculum

1. [Survey for students.](#)
2. [Survey for teachers.](#)

Chapter 2.5: Lesson Plans - Engineering a Solar-Powered Device.

Title and key information of the lesson plan

Engineering a Solar-Powered Device

Date	
Teaching Staff	Mr/Mss/Ms
Term	



Date	
Year Level	10-14 years
Time/Length	
Key Learning Area	Science, Technology, Engineering, Arts, Mathematics (STEAM)

Summary

These lesson plans are designed to engage students in an **interactive, hands-on, and inquiry-based learning experience** about **solar energy** and its applications. The activities incorporate **scientific investigation, engineering design, problem-solving, and role-playing**, fostering a deep understanding of renewable energy concepts while developing essential **21st-century skills** such as **critical thinking, collaboration, communication, and innovation**. Each pedagogical strategy includes a series of well-structured activities, ensuring a comprehensive approach to teaching solar energy from multiple perspectives, including **scientific exploration, practical engineering applications, policy-making, and sustainability solutions**. Below is a summary of the lesson plans categorized by pedagogical strategies:

Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Inquiry-Based Learning	Encouraging students to explore solar energy concepts through hands-on experimentation and data analysis.	- Hands-on Experimentation: Groups conduct controlled experiments, collecting and analyzing quantitative data on solar panel efficiency in different conditions.	- Developing data analysis and critical thinking skills through real-world problem-solving. - Enhancing students' ability to interpret scientific graphs and tables.	- Lab reports - Quizzes - Peer review - Teacher observations - Self-assessment reflections

Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Project-Based Learning	Designing and implementing real-world solar energy solutions through collaborative teamwork.	- Community Solar Proposal: Groups research, plan, and present a solar energy project to address real-world community needs, including feasibility studies.	- Strengthening teamwork and project management skills.	- Presentations - Written reports - Rubric-based evaluation - Expert panel feedback



Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Role-Playing & Gamification	Exploring solar energy from multiple perspectives through simulation, debate, and interactive challenges.	- Solar Power Challenge Game: A strategy-based educational game where students make decisions about solar energy use, grid integration, and efficiency optimization.	- Developing negotiation, communication, and decision-making skills. - Applying scientific concepts in a realistic, problem-solving context.	-Performance-based assessment - Classroom discussions - Peer reviews - Game score analysis

Aims of the lesson

The aim of the lesson on "The Engineering of Solar Energy Systems" is to engage students in the exploration of solar energy from both a theoretical and practical standpoint. This lesson encourages students to understand the significance of renewable energy in addressing global energy challenges while fostering essential skills in science, technology, engineering, arts, and mathematics (STEAM).

By the end of the lesson, students should be able to:

1. **Understand the fundamentals of solar energy** – Gain a strong conceptual understanding of solar power, how solar energy is harnessed, and its relevance to sustainable energy solutions. This includes understanding the technology behind solar panels and the factors that influence their efficiency.
2. **Develop problem-solving and critical thinking skills** – Engage in hands-on experiments and data analysis to explore solar panel efficiency. Students will apply their scientific knowledge to solve real-world problems associated with renewable energy and energy conservation.
3. **Engage in creative and collaborative engineering design** – Participate in group projects that involve designing solar energy solutions. This includes designing a sustainable city powered by solar energy, fostering teamwork, creativity, and the application of mathematical, physics, and engineering principles.
4. **Explore solar energy through role-playing and gamification** – Through simulations, students will assume various roles such as engineers, policymakers, and environmentalists to debate solar energy solutions, enhancing their negotiation, communication, and decision-making skills.
5. **Learn to analyze and present data** – Students will collect and analyze data on solar panel efficiency, interpret the results, and present their findings to the class, encouraging data-driven decision-making.
6. **Build awareness of sustainability and environmental impact** – Develop a deeper appreciation for the role of solar energy in reducing carbon footprints and promoting sustainable development, linking theoretical knowledge with real-world application in urban planning and energy systems.
7. **Enhance collaboration and communication skills** – The lesson encourages teamwork, group discussions, and peer reviews, promoting collaboration and effective communication among students while engaging in inquiry, research, and debates on solar energy solutions.
8. **Cultivate strategic thinking and adaptability** – Through the "Solar Power Challenge Game," students will face various challenges that require strategic thinking and the ability to adapt to



changing conditions, providing an engaging and interactive approach to learning about solar energy systems.

Age of students

The lesson is designed for students aged **10-14 years old**.

Teaching resources (material & online tools)

1. **Interactive Simulation: "How Solar Panels Work"** – This online tool allows students to experiment with solar panel angles and efficiency, helping them understand how various factors impact the performance of solar energy systems.
 - **Source:** PhET Interactive Simulations, University of Colorado Boulder
 - **Link:** [PhET Interactive Simulations](#)
2. **Experiment Guide: "Solar Oven Challenge"** – A practical guide that encourages students to build a simple solar oven, offering hands-on experience with the principles of heat absorption and reflection, essential in understanding solar power.
 - **Source:** NASA Climate Kids - Solar Oven
 - **Link:** [NASA Climate Kids - Solar Oven](#)
3. **Case Study Analysis: "Comparing Solar Technologies Around the World"** – A worksheet designed to help students analyze how different countries implement solar power technologies and how these solutions vary globally.
 - **Source:** International Energy Agency (IEA) Solar Reports
 - **Link:** [IEA Solar Reports](#)
4. **Solar Energy Projects on Scratch** – A collection of student-led projects related to solar energy. This platform lets students explore coding and simulations related to solar technology.
 - **Source:** Scratch MIT
 - **Link:** [Scratch Solar Energy Projects](#)
5. **Prototyping Tools for Engineering Design** – Students will have access to tools that support the creation of prototypes for solar technology systems, enhancing their understanding of engineering concepts.
 - **Source:** Tinkercad
 - **Link:** [Tinkercad Prototyping](#)
6. **Interactive Online Tool: "Sunroof by Google"** – A tool that helps students understand how solar panels could be used on buildings by analyzing roof space and sunlight exposure, directly tying to engineering decisions in solar system design.
 - **Source:** Google
 - **Link:** [Google Sunroof](#)

Chapter 5: The Engineering of Solar Energy Systems



This chapter introduces students to the engineering principles behind solar energy systems. It covers topics in photovoltaic (PV) cell design, solar panel efficiency, electrical wiring systems, and integration with energy grids, emphasizing hands-on learning through STEAM.

Key Sections:

1. Understanding Solar Energy Engineering:

- Focus on the design of photovoltaic cells and how they convert sunlight into electricity.
- Exploration of materials used (e.g., silicon) and the role of the n-type and p-type silicon layers.
- Efficiency factors, including material composition, surface area, angle of installation, and light absorption.

2. Solar Panel Efficiency Engineering:

- Introduction to factors influencing solar panel efficiency.
- Detailed exploration of how surface area, angle, and material quality can impact energy production.
- Explanation of methods to improve efficiency and solar technology performance.

3. Electrical Wiring and Systems Integration:

- Overview of electrical systems, including inverters, battery storage, and circuit protection.
- Explanation of how DC power from solar panels is converted to usable AC electricity.
- Introduction to energy storage and grid connection.

4. Engineering Design and Prototyping in Solar Systems:

- Examination of the engineering design process, including problem identification, design, prototyping, testing, and iteration.
- Discussion on environmental and economic considerations of solar technology, including lifecycle impacts and cost-benefit analysis.

Expected Outcome:

- Students will develop a comprehensive understanding of solar energy engineering, enhance their critical thinking and problem-solving skills, and be able to articulate how solar energy can be used sustainably and efficiently in real-world scenarios.

Lesson plans

1 period = 40 minutes

Pedagogical Strategy 1: Inquiry-Based Learning				
Name of the activity	Process	Aim	Skills gained	Time (period)



Investigating the Urban Heat Island Effect	Students split into groups of 4–5 and use an online temperature mapping tool to compare urban and rural temperature differences. - Each group selects a city and a nearby rural area, then records temperatures for different times of the day. - Students analyze the data to identify temperature variations and factors affecting them. - Groups research how green spaces, reflective surfaces, and city design impact urban heating. - They create infographics or short presentations suggesting solutions for reducing the Urban Heat Island effect.	- To help students understand the causes and impacts of urban heat islands. - To explore sustainable urban design solutions for mitigating extreme temperatures. - To encourage students to think critically about city planning and climate resilience.	Data Collection & Analysis: Extracting and interpreting environmental data. Research Skills: Investigating solutions for urban heat issues. Creativity & Communication: Designing infographics and presenting findings. Collaboration: Working as a team to propose actionable solutions.	1 period
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Pedagogical Strategy 2: Project-Based Learning				
Name of the activity	Process	Aim	Skills gained	Time
Community Energy Audit	Students are divided into small teams (3–4 members) to assess energy usage in their school or local community. - They survey energy consumption in lighting, heating, and electronic devices and identify inefficiencies. - Teams propose energy-saving solutions, such as switching to LED lights, using solar panels, or improving insulation. - Each team prepares a report and action plan with practical recommendations. - Students present their findings to the school administration or a local sustainability organization.	- To provide students with real-world problem-solving experience. - To encourage awareness of energy efficiency and its impact on climate change. - To promote student-driven action in sustainability initiatives.	Environmental Awareness: Understanding energy consumption and conservation. Data Collection & Analysis: Conducting real-world audits. Public Speaking & Advocacy: Presenting findings to decision-makers. Leadership & Initiative: Proposing actionable changes in their community.	1 period

Pedagogical Strategy 3: Role-Playing & Gamification				
Name of the activity	Process	Aim	Skills gained	Time



Solar Energy Summit Simulation	Students are divided into three groups: Engineers: Research and propose the best solar technologies for the community. Policymakers: Assess the feasibility of implementing solar solutions based on regulations and funding. Environmentalists: Advocate for sustainable and community-friendly solar energy solutions. Each group prepares arguments and data to support their perspectives. The class holds a "Solar Energy Summit" debate, where groups negotiate the best approach for implementing solar power in their community. At the end, students vote on the most effective solar plan and reflect on the decision-making process	☑ To help students understand the real-world complexities of implementing solar energy solutions. ☑ To develop critical thinking and decision-making skills. ☑ To encourage collaboration and negotiation between different stakeholders.	☑ Public Speaking & Persuasion: Presenting and defending viewpoints. ☑ Negotiation & Problem-Solving: Reaching a compromise between different interests. ☑ Research & Critical Thinking: Evaluating solar energy feasibility and impact. ☑ Teamwork: Collaborating in role-based discussions.	1 period
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Feedback and evaluation

Evaluation

Evaluation Method	Details
Observation & Participation	Teachers observe the student engagement in the class and the activities.
Observation & results	Teachers observe student understanding of the topic

Feedback

Method of collecting feedback	Details
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Asking	The teacher directly asks for feedback from the students after the class ends
Survey - 1	Anonym survey for the students, to gain an understanding of how engaging the class was for the students and if they have gained more understanding of the topic
Survey - 2	Anonym survey for the teachers to gain their thoughts on the solar curriculum

1. [Survey for students.](#)
2. [Survey for teachers.](#)

Chapter 2.6: Lesson Plans - Renewable Energy and Sustainability in Technology and Society.

Title and key information of the lesson plan

Renewable Energy and Sustainability in Technology and Society

Date	
Teaching Staff	Mr/Mss/Ms
Term	
Year Level	10-14 years
Time/Length	
Key Learning Area	Science, Technology, Engineering, Arts, Mathematics (STEAM)

Summary

"Renewable Energy Solutions: Community Challenge" is designed to engage students in understanding the complexities of transitioning to a sustainable energy future. Students will take on roles representing various stakeholders and collaborate to develop comprehensive renewable energy solutions for a specific community.

Aims of the lesson

- Explore Renewable Energy Technologies: Provide students with a practical understanding of renewable energy solutions like solar, wind, and hydro, highlighting their applications and impact.
- Analyze Benefits and Challenges: Enable students to critically assess the environmental, social, and economic aspects of renewable energy, including issues such as cost, efficiency, and infrastructure development.

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- Develop Sustainable Energy Plans: Foster collaboration by having students design renewable energy strategies tailored to the needs of a specific community.
- Understand Interconnected Systems: Demonstrate the interplay between technology, policy, environment, and societal factors in transitioning to a sustainable energy future.
- Encourage Stakeholder Perspectives: Engage students in role-play to understand diverse stakeholder viewpoints and the complexities of decision-making in energy transitions.
- Promote 21st Century Skills: Cultivate problem-solving, critical thinking, teamwork, and communication skills through hands-on, collaborative activities.

Age of students

Based on the context of the activity, "Renewable Energy Solutions: Community Challenge," we can present the lesson to students aged 10 to 14 years old. This age range aligns well with the objectives of engaging learners in hands-on exploration, critical thinking, and collaborative problem-solving. It's also a fantastic stage for introducing concepts like renewable energy, as students in this group are typically curious, eager to experiment, and capable of understanding the interconnectedness of technology, environment, and society.

Teaching resources (material & online tools)

Materials for Model Building (Focus on Representation and Design):

1. Designing Solar-Powered Solutions

Provide readily available and inexpensive materials for students to construct non-functional models and representations of solar-powered devices or installations.

Materials: cardboard, paper, glue, tape, scissors, rulers, markers, colored pencils, recycled materials (plastic bottles, containers, packaging), aluminum foil, and clear plastic wrap.

The focus is on creative design and illustrating the concept of how a solar-powered device would look and work in principle, rather than building a fully functional one.

2. Books:

- *"The Energy Challenge"* by Valeriano Ruiz: A comprehensive guide to renewable energy.
- *"Green to Gold"* by Daniel Esty and Andrew Winston: Focuses on sustainable strategies for businesses.



3. Posters and Infographics:
 - Visual aids explaining the types of renewable energy and their benefits.
 - Diagrams of solar panels and wind turbines.
4. Worksheets and Activities:
 - Sorting activities for renewable vs. non-renewable energy.
 - Energy-saving calculation exercises.
 -
5. Video-shorts: [Solar energy model](#) [MAQUETA CON PANELES SOLARES](#)

[Solar House working model making](#) | [Eco friendly house school project](#) | [Solar powered house project](#)

Online Tools

1. Interactive Simulations:
 - *PhET Interactive Simulations*: Explore solar panel efficiency and energy conversion.
 - *Energy3D*: Simulate renewable energy systems like wind turbines and solar farms.
2. Educational Websites:
 - *NASA Climate Kids*: Offers interactive games and resources on solar energy.
 - *National Renewable Energy Laboratory (NREL)*: Provides detailed guides and tools for teaching renewable energy.
3. Videos:
 - *"Renewable energies - Types of energy for children"* (YouTube): A simple introduction to renewable energy.
 - *"Climate Change Series – Renewable Energy and Climate Change"* (YouTube): Explains the role of renewable energy in combating climate change.

Lesson plans

1 session = 50 minutes

Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Inquiry-Based Learning	Developing students' understanding of renewable energy concepts, fostering collaborative problem-solving, and	Use multimedia resources (e.g., videos, infographics) to explain	Grasp key renewable energy technologies and their environmental, social, and economic benefits.	Observe group collaboration and provide guidance

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Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
	connecting theoretical knowledge to real-world applications.	renewable energy types and sustainability concepts. Facilitate a class discussion on the importance of renewable energy in combating climate change.		during planning and design phases.

Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Role-Based Group Work:	Developing students' understanding of renewable energy concepts, fostering collaborative problem-solving, and connecting theoretical knowledge to real-world applications.	Assign students to roles (e.g., Engineers, Planners, Advocates, Advisors) and divide them into groups. Each role focuses on a specific aspect (technology, community needs, environmental impacts, policy).	Develop teamwork and communication skills through collaborative activities. Apply critical thinking and problem-solving to real-world challenges.	Assess individual contributions through role-specific research summaries.

Pedagogical Strategy	Focus	Key Activities	Learning Outcomes	Assessment & Feedback
Presentations & Feedback Simulation:	Facilitating peer-to-peer feedback during presentations.	Groups present their plans during a simulated community meeting, highlighting benefits, challenges, and feasibility. The class participates as stakeholders, providing feedback and posing questions. Reflection & Refinement: Groups refine their plans based on feedback and develop final action steps for implementation.	Recognize the interconnectedness of technology, policy, and sustainability.	Facilitate peer-to-peer feedback during presentations. Provide constructive feedback after presentations and reflections, focusing on strengths and areas for improvement.



Pedagogical strategy - 1				
Name of the activity	Process	Aim	Skills gained	Time
"Renewable Energy Solutions: Community Challenge"	-Introduction: Present the concept of renewable energy and sustainability using engaging videos or interactive slides. Explain the importance of transitioning to renewable energy sources to combat climate change. Define the roles for the activity: Renewable Energy Engineers, Community Planners, Environmental Advocates, and Policy Advisors. Role Assignment and Community Selection: Divide students into small groups. Assign each group a fictional or real community (e.g., rural village, urban neighborhood). Each student within the group takes on a specific role.	To engage students in real-world problem-solving, emphasizing the interconnectedness of technology, policy, environment, and society in developing renewable energy solutions.	Communication and understanding	Session 1: Introduction and Role Assignment



	Each role investigates their specific focus area: Engineers explore renewable energy technologies like solar or wind. Planners assess community infrastructure needs. Advocates analyze environmental and sustainability aspects. Advisors look into policies and incentives for renewable energy adoption.			Session 2: Research and Collaboration
	Group Collaboration: Students share their findings and collaborate to create a renewable energy plan tailored to their assigned community. Use tools like online simulations (PhET) or mapping platforms (Google Earth) for practical insights. Presentations and Community Feedback			Session 3: Presentations and Feedback



	Simulation: Groups present their plans to the class, simulating a community meeting. Other students act as community members, asking questions and giving feedback.			
	Reflection and Refinement: Groups refine their energy solutions based on the feedback received. Develop final action plans with clear steps for implementation. Final Recommendations and Voting: Each group presents their improved proposal. The class votes on the most impactful energy plan for each community.			Session 4: Refinement and Final Voting

Detailed Activities

1. "Renewable Energy Solutions: Community Challenge"

- **Aim:** Real-world problem-solving; connect technology, policy, and environment.

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- **Sessions:**
 - Session 1: Introduction to roles, assignment of fictional communities.
 - Session 2: Group research and collaboration to create tailored energy plans.
 - Session 3: Present plans in a simulated meeting, receive peer feedback.
 - Session 4: Refine solutions, develop action plans, and vote on impactful ideas.
- **Skills Gained:** Problem-solving, teamwork, and critical thinking.

Pedagogical strategy - 2				
Name of the activity	Process	Aim	Skills gained	Time
"Designing Solar-Powered Solutions: A Creative Approach"	Kick-Off with Context: Begin with a brief discussion about renewable energy and its significance in combating climate change. Show a short video (e.g., Renewable energies - Types of energy for children) to engage students and introduce key concepts. Interactive Demonstration: Conduct a demonstration of a small solar-powered device (if available) or show a video/simulation to inspire curiosity about how they work. Problem Identification: Present students with real-world challenges (e.g., energy access in remote areas or reducing energy	To engage students in designing and representing solar energy solutions to real-world problems, fostering problem solving and teamwork skills using accessible materials. To encourage creative thinking and understanding of basic solar energy principles through building non-functional models or representations	Design thinking and creative problem-solving, Research and critical analysis, Teamwork and collaboration, Communication and presentation, Understanding of solar energy principles and design.	Session 1: Introduction, Context Setting, and Problem Identification



	consumption). Encourage groups to brainstorm possible solutions using solar energy.			
Collaborative Project Work:	Students work in teams to design and build their own <i>imitation</i> solar-powered models or representations (e.g., a model of a solar fan or solar charger) using readily available and inexpensive materials (cardboard, paper, recycled items, etc.). Assign roles within the group: Designer, Researcher, Builder (focus on representation), and Presenter.		Research and critical analysis, Teamwork and collaboration	Session 2: Design and Initial Construction (Focus on Representation)
Review & Refinement:	Teams review and refine their designs and models based on the problem they are addressing and the materials used, focusing on how well their model represents the intended solution and demonstrates understanding of basic solar principles.		Teamwork and collaboration	Session 3: Review, Iteration, and Refinement



Presentation & Reflection:	Each team presents their design and model, explaining the problem it addresses, the design process, and how a real functional device based on their model would work. Facilitate a class discussion on the potential benefits and challenges of implementing similar solar-powered solutions in the real world.		Communication and presentation	Session 4: Presentations and Reflections
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2. "Designing Solar-Powered Solutions: A Hands-On Approach"

- **Aim: Designing and representing solutions, understanding principles through building representations, and using accessible materials.**
- **Sessions:**
 - **Session 1: Set the context, identify challenges to solve.**
 - **Session 2: Design and Initial Construction (Focus on Representation)**
 - **Session 3: Review, Iteration, and Refinement**
 - **Session 4: Presentations and Reflections**
 -
- **Skills Gained: Design thinking, technical knowledge, communication.**

Pedagogical strategy - 3				
Name of the activity	Process	Aim	Skills gained	Time
"Community Energy Mapping: A Real-World Renewable Energy	Kick-Off Session: Begin by introducing the concept of energy mapping and how renewable energy	To provide students with a hands-on experience in applying renewable	Data analysis and critical thinking Project management and teamwork	Session 1: Introduction and Community Selection

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Exploration"	sources can be integrated into real-world community settings. Present a brief overview of tools such as Google Earth and Energy3D for mapping renewable energy projects. Community Selection: Assign students to specific communities (real or fictional) with varied energy needs, such as urban areas, remote villages, or industrial zones.	energy concepts to real-world community challenges while promoting environmental awareness and innovative thinking.		
	Data Collection: Students gather information about their assigned communities, including current energy use, local renewable energy resources, and environmental challenges. Encourage teamwork as students explore technologies like solar, wind, and hydropower. Designing Solutions:		Creative problem-solving and design thinking	Session 2: Data Collection and Solution Design



	Students collaborate to design energy systems tailored to their communities. They use simulations (e.g., PhET or Energy3D) to test efficiency and feasibility. Incorporate fieldwork opportunities if possible, like local solar panel site visits.			
	Presentation and Feedback: Each group presents their energy mapping solutions to the class. Facilitate peer feedback focusing on creativity, feasibility, and environmental impact.		Communication and presentation skills	Session 3: Presentations and Feedback
	Reflection and Finalization: Groups refine their proposals based on feedback and prepare an action plan for implementation, considering potential challenges and benefits.		Technical understanding of renewable energy systems	Session 4: Reflection and Finalization



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"Community Energy Mapping: A Real-World Renewable Energy Exploration"

- **Aim: Apply renewable energy concepts to real-world challenges.**
- **Sessions:**
 - **Session 1: Intro to energy mapping and tools like Google Earth.**
 - **Session 2: Gather data on community needs and design solutions.**
 - **Session 3: Present energy plans, receive peer feedback.**
 - **Session 4: Refine proposals and prepare implementation plans.**
- **Skills Gained: Data analysis, teamwork, environmental awareness**

Feedback and evaluation

Evaluation

Evaluation Method	Details
Observation & Participation	Teachers observe the students' engagement in the class and the activities.
Observation & results	Teachers observe students understanding of the topic

Feedback

Method of collecting feedback	Details
Asking	The teacher directly asks for feedback from the students after the class ends
Survey - 1	An anonymous survey for the students, to gain an understanding of how engaging the class was for the students, and if they have gained more understanding of the topic
Survey - 2	An anonymous survey for the teachers to gain their thoughts on the solar curriculum

1. [Survey for students.](#)
2. [Survey for teachers.](#)

Summary

The chapters of the Solar Energy Curriculum along with their accompanying pedagogical strategies, role-play units, visual tools and detailed lesson plans were developed using the principles of STEAM education. Building on the foundation of STEM (Science, Technology, Engineering, and Mathematics), STEAM also integrates the **Arts**, promoting creativity and innovation in the learning process. By encouraging students to explore and apply knowledge through interdisciplinary and hands-on approaches, STEAM fosters deeper conceptual understanding and critical thinking.

Through the integration of STEAM principles, the Solar Energy Curriculum and its educational tools offer a comprehensive and engaging learning experience. This approach helps ensure that students develop a well-rounded understanding of solar energy and its vital role in addressing climate change.

A significant portion of the project consortium is made up of school teachers from various countries. This ensures that the developed educational tools are practical and relevant, supporting teachers in effectively preparing for and delivering the Solar Energy Curriculum lessons.

The Solar energy curriculum was developed by a consortium of six institutions from six different countries across Europe. From the outset, one of the project's key challenges was ensuring that the curriculum would be accessible and aligned with the national curricula of all participating countries. This was taken into account during the development of the Solar energy curriculum. The curriculum does not conflict with the national standards of any of the partner countries. Although the lesson plans include suggested durations for each session and may not always align with the standard class structure in some of the participating countries. However, the lesson plans are designed with built-in flexibility, allowing educators to adapt the content to their local context. Thanks to this adaptability, the Solar Energy Curriculum can also be effectively implemented beyond the six countries involved in the #Solar4Future+ project, offering the potential for broader impact and reach.



The development of the Solar Energy Curriculum and its educational tools has been completed. The testing phase provided valuable feedback, which has been used to refine and improve the curriculum.

Solar energy discussion worksheets

Worksheet 1: Solar Power Courtroom

Group role (circle your role): Pro-Solar Lawyers / Skeptical Lawyers

My main claim in this debate (one sentence):

Together with your group, research four data-based arguments for your claim! Rank the arguments from 1 (weakest) to 4 (strongest) based on how convincing they are.

Argument (with justification):

Rank:

Argument (with justification):

Rank:

Argument (with justification):

Rank:

Argument (with justification):

Rank:

Prepare to present your arguments to the class!

Reflection:

Which argument from the opposing side was the strongest? Why?

What was your own opinion on this matter before the debate?

Did any evidence that you encountered in this lesson change or weaken your original position? Explain.

Worksheet 2: Solar Energy Park – Decision Matrix

In your group, choose a location where you, as a large investor, would like to place a solar plant (give your initial idea!)

Our chosen location: _____

Now it is time for research!

Each member of the group should research one of the following about your chosen location:

Fill in the table (1 = low, 5 = high)

Sunlight intensity: _____ Team member to research this was _____

Cloud cover: _____ Team member to research this was _____

Infrastructure access: _____ Team member to research this was _____

Environmental factors: _____ Team member to research this was _____

Social / political factors: _____ Team member to research this was _____

Explain the marks you gave the location for your chosen factor!

The sum of all marks for this location: _____

Present your location to the rest of the class! Together with the class, decide which location was the best of your offered ones!