Renewable energies – the future is sunny!

This guideline will provide an overview of the content and didactic context of the media in the media package entitled “Renewable energies – the future is sunny!”

1 Introduction to teaching this topic

The topic of renewable energies has been in schools for a long time. Educational standards and, to some extent, curricula require this topic to be covered in various grades and within various subjects.
The present media package offers a wide range of interfaces for teaching geography, physics, and chemistry. It supports teachers in introducing this highly topical subject in class and provides an initial overview of renewable energy sources.
To provide more in-depth information about the topic in class, there are two more media packages on the media portal of the Siemens Stiftung that deal with renewable energy sources in detail:

- “Solar thermal energy and photovoltaics – energy forms with a future”
- “Water and wind – traditional energy sources rediscovered”

Teachers can use the guideline on “Renewable energies,” which summarizes the entire topic thoroughly yet compactly in 21 pages, as both an introduction and a quick reference.
The media files in the package can be used individually and completely independently of each other strictly by subject. However, the lesson will certainly be livelier when the media are used in context. The direct applicability of the material to the lives of the students creates an opportunity to spark students’ interest in technical details. To that end, we recommend working through the topic in the following steps:

- Introduction: What are renewable energies?
- Why do we need renewable energies?
  (Shortage of fossil energies, climate change, energy shortages as a problem of humankind)
- What renewable energy sources are there?
  (Biomass, hydropower, wind power, solar thermal energy, photovoltaics, geothermal energy)
- The sun as an inexhaustible energy reservoir for our future!
- Follow-up

On the basis of this introduction, students can make the connection with topics in the areas of the basic physics, chemistry, and biology of the various energy sources.

2 Introduction: What are renewable energies?

To renew literally means “to make like new.” This doesn’t exist yet, strictly speaking, because energy can neither be created nor destroyed, nor renewed, but only converted.
Nevertheless, the custom of referring to particular energy sources as “renewable” is correct.
A renewable energy source is a source which “regenerates itself” on its own, so to speak. This gives rise to the term “renewable energies.” The basic principle behind the use of renewable energies is the fact that energy is tapped from processes that take place continuously in our environ-

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ment, such as solar radiation, and is then used in technology. In this process, resources are not used to a greater extent than energy continues to flow and “renew” them.
It must be clear to the students that the term “renewable energies” is not a contradiction to the conservation of energy. Although the energy in a closed system remains constant, solar energy flows constantly into the open system that is Earth; because of the long life of the sun, this solar energy is inexhaustible by human standards.
The term “renewable energy sources” was coined in contrast to fossil and nuclear energy sources which will be used up by people in a foreseeable period of time.
The media files from the media package that could be used in developing this chapter are as follows.

To set the stage:

Medium: Overview graphic “Renewable energy sources”

An initial introduction to illustrate the term “renewable energy sources” to students based both on the example of renewable biomass and on the years of use remaining for fossil and renewable energy sources in comparison with the life of humans:

Medium: Graphic and chart “What are renewable energy sources?”

Preparation for teachers:

Medium: Guideline “Renewable energies”

Sources of information for teachers and students (for example, for presentations):

Media: Information sheet “Overview of energy sources”
Link list “Renewable energies”

3 Why do we need renewable energies?

The call to use renewable energies was first heard back in the late 1970s, after the report from the Club of Rome (1972) and the first oil crisis (1974). However, it was ridiculed by many politicians and members of the business community as “ecological craziness.” But now things have changed as a result of climate change, the constant growth in the world’s population, the global increase in industrialization, the related rise in energy requirements, and the fact that stores of fossil energy sources are dwindling and becoming more expensive. Today, everyone agrees that the increased use of and ultimately the total changeover to renewable energies will become a matter of survival for humankind in just a few decades.

3.1 The shortage of fossil and nuclear energy sources

An optimistic estimate from the year 2005 indicates that stores are set to last between 40 and 190 years, depending on the energy source. However, these calculations did not take into account the dramatic increase in use in developing countries such as China and India. In addition, these estimates are based on the assumption that rising energy prices will also make mining deposits that are not currently worth mining more economically viable. However, the estimates also assume a steadily rising demand and the means to pay for these energy sources. This assumption now

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seems improbable – just think of the “steel and coal crisis” in 2007, followed by the global financial crisis of 2008/2009. Considerable shortages could therefore start to occur in just 15 to 20 years. First, the percentage share of various primary energy sources in the worldwide energy supply is considered. The consumption distribution of the fossil energy sources shows the dependency on coal, oil, and natural gas.

Medium: Chart “Worldwide consumption of fossil energy sources”

The students will then be confronted with the problem of the energy shortage based on today’s nearly exponentially growing energy requirement:

Medium: Chart “Future worldwide primary energy requirement”

This can then be compared with the years of use left for fossil and renewable energy sources:

Medium: Chart: “How long will our energy sources last?”

The following information sheet may be useful in providing more in-depth information for teachers and students (for example, for presentations):

Medium: Information sheet “An overview of energy sources”

3.2 Renewable energy sources in the battle against the greenhouse effect and climate change

The emission of greenhouse gases – like carbon dioxide from the combustion of fossil energy sources – must be reduced as fast as possible because with each increase in temperature, the need for energy for cooling (air-conditioning and refrigerators for food) increases. The rapid development of renewable energies and thus the replacement of fossil energy sources can play a crucial role in this.

An interactive information module can be used, for example, in geography classes to explain the difference between the “natural” and the anthropogenic greenhouse effect. Physics classes can deal with the topics of energy conservation and radiative equilibrium, and chemistry classes can cover the energy absorption of various molecules:

Media: Information module with animation “Is the greenhouse effect caused by people?”
Information sheet: “Greenhouse effect and climate change”
Graphic: “Waste and emissions from power plant operations”
Information sheet: “Waste and emissions from power plant operations”
Information sheet: “Where do greenhouse gases come from?”

A comparison of the carbon dioxide emissions of power plants using fossil or renewable energy sources (construction, fuel supply, and operation) will clearly illustrate the advantage of renewable energies. However, with nuclear power, the problem of disposing of radioactive waste is not taken into account!

Medium: Chart “Carbon dioxide emissions from power plants”

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If the students now look at the targets set for carbon dioxide emissions by 2012 in the Kyoto Protocol and the values reached in 2008, they will realize what massive efforts are still required.

Medium: Information module “Development of greenhouse gas emissions”

The information sheet on the greenhouse effect will provide teachers and students with more in-depth geographical, physical, and chemical information about this phenomenon.

Medium: Information sheet “Greenhouse effect and climate change”

In chemistry class, a simple experiment could be carried out to show how much carbon dioxide humans produce with every breath:

Media: Experimentation instructions “Carbon dioxide in the breath and in the classroom”
Teaching methods “Carbon dioxide in the breath and in the classroom (teacher information)”
Answer sheet “Carbon dioxide in the breath and in the classroom (answer sheet)”

3.3 The energy shortage as a cause of global poverty

The production of food involves a massive consumption of energy. A chart shows the enormous amount of energy wasted in food production due to the standard of living in the rich industrialized countries of the world. But what is the situation in the world’s less developed countries?

Media: Interactive graphic “Food production – energy hog” (image)
Information sheet “Food and animal feed from renewable energy, air, and water”

In many regions of developing countries, large portions of the population still live as small, self-sufficient farmers. A vicious circle of poverty arises: All the heating material used for cooking comes from biomass, of which more is used than grows back. The resulting steppization and desertification is lowering yields from agriculture and cattle breeding. Freshwater is needed for reforestation and/or to stabilize agricultural production, but there is no energy to transport and treat this water. In the rich industrialized countries, saving energy, for example, by using A+ energy-saving stoves, can achieve a considerable amount. But it does no good to preach energy saving to people in Haiti or in the Sahel suffering from hunger who are heating up their last remnants of vegetation. Here, solar power and photovoltaics must be used instead of the already overstretched renewable energy source biomass.

Students can realize that traditional biomass such as wood or dung leads to a vicious circle of poverty in many parts of the world if it is the sole source of energy. The use of new renewable energies could make a valuable contribution there to improving the energy supply and thus to escaping from poverty.

Medium: Schematic diagram “Energy poverty”

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4 What renewable energy sources are there?

The energy sources are covered in order, based on their significance in the history of culture and technology, starting with the oldest energy source, biomass, and ending with modern photovoltaics.

4.1 Biomass

The oldest of any of the energy sources used by humans is biomass. Traditionally, ever since the discovery of fire, humans initially used only renewable biomass in the form of wood; later, in the plains where wood was scarce, they also used the dung of their domestic animals as fuel.
With biomass, plants are used to convert solar radiation to organic matter via the process of photosynthesis. Biomass thus represents solar energy stored in plants. Biomass currently covers around 10 percent of the primary energy requirement worldwide. However, this percentage can be increased only to a limited extent.

Detailed information on biomass is available here:

Medium: Guideline “Renewable energies”

Biomass is used, for example, in the form of wood chips, wood pellets, biodiesel, and biogas.

Medium: Chart “Biomass as an energy source”

Detailed information on biomass is available here:

Media: Guideline “Renewable energies”
Information sheet: “Is biomass climate neutral and sustainable?”
Information sheet: “Climate and environmental pollution caused by the most important energy crops”

A film can be used to prompt discussion about the advantages and disadvantages of biofuels:

Medium: Video “On our plates or in our tanks – energy from biomass”

4.2 Hydropower

Hydropower, also referred to as hydroelectric power, is the term used to describe the energy of flowing water, which is then converted to mechanical or electrical energy via turbines and the generators connected to them. Over 4,300 years ago, people in Mesopotamia (present-day Iraq) and other places were already using hydropower in the form of scoop wheels for irrigation. Hydropower is also a form of solar energy stored in nature. After all, it ultimately comes from the cycle of evaporation and precipitation brought about by the sun. Here, we are just considering the mechanical “hydropower” used directly as an energy source. Water is also used to store heat (district heating, geothermal energy). In contrast, when electrical energy is stored in the form of hydrogen through the electrolysis of water, it is hydrogen rather than water that is the energy source.

Detailed information on hydropower is available here:

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Medium: Guideline “Renewable energies”

A graphic summarizes the significance of water as an energy source; only waves, tidal flow, and flowing water are classified as “hydropower.” Thermal water is a form of geothermal energy.

Medium: Overview graphic “Water as an energy source”

4.3 Wind power

People have been using wind energy to drive windmills for around 2,000 years.
When Earth’s surface is heated by radiation, the layers of air above it are heated, which lifts the air and causes it to flow upward. At the same time, air flows back in horizontally from less heated areas; this cross flow is described as wind. The kinetic energy of the linear air movement of the wind can now be converted to rotational movement via wind turbines. Wind turbines in Europe alone already have a capacity of around 35,000 MW, which is the equivalent of 35 large coal-fired power plants.

Detailed information on wind power is available here:

Medium: Guideline “Renewable energies”

This offshore plant is an excellent example of the massive potential of wind power:

Medium: Photo “Offshore wind farm”

A teaching idea that takes this topic further, or an interesting topic for a presentation: Wind turbines are often rejected because of the noise they make, the shadows they cast, or the blight they are on the landscape. So why do critics of wind turbines accept traffic noise, roads, logistics centers, industrial parks, cell towers, and high-voltage power lines?

4.4 Solar heat – solar thermal energy

Way back in the Stone Age, before fire was discovered, cavemen used the heat of the sun stored in rocks to protect against the cold in the night or during cold weather.
In physics and biophysics, light is defined as the visible portion of the electromagnetic spectrum. However, with solar thermal energy and photovoltaics, the invisible portions of solar radiation are also partly used. In addition, a distinction is made between heat and light in physics, chemistry, and energy conversion technology. The potential of solar thermal energy is great: If all heating of rooms and water in all households in a country in a temperate zone, like Germany, were converted to solar thermal energy, the total CO_2 emissions there could be cut by up to 20 percent and the energy consumption of each household could be cut by up to 70 percent!
Detailed information on solar thermal energy is available here:

Medium: Guideline “Renewable energies” (PDF)

The use of solar thermal power for generating electric power would also be worthwhile in all southern countries where solar radiation is stronger and the sun shines longer:

Medium: Labeled graphic “Solar thermal power plants” (image)

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4.5 Photovoltaics

Photovoltaics refers to the direct conversion of sunlight to electrical energy using solar cells. Direction conversion is a fascinating possibility, at first glance, since photovoltaics could theoretically achieve efficiency of almost 100 percent. In Germany, for example, with the current level of efficiency of solar cells (around 24 percent), approximately 1 percent of the land surface would suffice to supply the entire demand for electrical energy for industry and all private households. Ten percent of the surface would suffice for Germany's total energy requirement. That means that photovoltaic electric power could then also meet the entire demand for thermal energy (process heat in industry, heating, cooking, and hot water in households) and the entire transport energy requirement (electric cars!). However, this is only a theoretical calculation that aims to show the massive potential of photovoltaics even in countries with a temperate climate. But the idea is not as utopian as it may sound, if we bear in mind what huge surfaces are available just in the form of roofs, building facades, and windows. Technically, solutions that could be implemented immediately today are available for all three applications. (For chemistry teachers: Fuels for aircraft would be produced from CO_2 and H_2 in the event of a changeover to photovoltaics.)

Detailed information on photovoltaics is available here:

Medium: Guideline "Renewable energies"

Not only in sunny Africa but also in Central Europe and the United States, solar power is the renewable energy source with the greatest potential for the future:

Media: Photo "Solar cells on the roof of a house"
Photo "Solar electric power plant on open space ("solar field," "solar park")"

4.6 Deep geothermal energy

Literally, geothermal energy is "heat obtained from the ground." Because the heat of Earth's strata exists to a depth of approximately 30 m, primarily as a result of solar radiation and counter-radiation from the atmosphere, this type of heat is classified as solar thermal energy. The term "geothermal energy" or, more accurately, "deep geothermal energy" means obtaining heat from Earth's interior, which has to be extracted by drilling holes several thousand meters deep. The heat stored in the upper 3,000 m of Earth's crust could theoretically meet the current energy requirement worldwide for the next 100,000 years or more. But at present, this geothermal energy could be extracted economically only at a very few points on Earth's crust containing "hotspots" at a depth of a few hundred to a few thousand meters.

Detailed information on deep geothermal energy is available here:

Medium: Guideline "Renewable energies"

For heating purposes, in the temperate zones such as North America, Central Europe, and thus Germany, near-surface and deep geothermal energy is a good substitute for natural gas and oil:

Medium: Overview graphic "Geothermal energy as an energy source"

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5 The sun as an inexhaustible energy reservoir for our future

Apart from deep geothermal energy, the sun, or its radiation, is the origin of all renewable energy sources on Earth. The energy radiated by the sun is by far the greatest source of renewable energy. In the ranking of renewable energies, solar energy is followed by geothermal energy (deep geothermal energy) and tidal energy (effects of the moon and the rotation of Earth).
Each year, the sun radiates an average energy volume worldwide of approximately $1.56 \cdot 10^{18}$ kWh ($5.6 \cdot 10^{24}$ J) onto Earth's surface. This is more than 10,000 times the world demand for primary energy.

Media: Labeled graphic "The sun – our main source of energy"
Overview graphic "Facts on solar energy"

The energy-providing process of nuclear fusion will continue on the sun for another five billion years or so. This could be covered in greater depth in physics or chemistry classes.

Medium: Information sheet "Nuclear fusion in the sun"

6 Follow-up

Finally, the teacher and the class could go through an interactive worksheet on the advantages and disadvantages of the various energy sources.

Medium: Interactive worksheet "Advantages and disadvantages of energy sources"

The topic could also be followed up in the form of an inquiry task or group work using a teaching idea that asks the question "Can we meet our future energy requirement with green electricity?"

Medium: Teaching idea "Renewable energies – energy of the future"

The topic can also be covered in greater depth through experiments in physics or chemistry classes.

Media: Experimentation instructions "B5 We build a thermal solar plant (student instructions)" with teacher instructions and answer sheet
Experimentation instructions "B6 Renewable energies (student instructions)" with teacher instructions and answer sheet

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