ACTIVITY 9	The Hydrogen Revolution
The aim of the activity	Reflect on pollution and climate change with particular reference to possible technological solutions to this problem, such as the transition to hydrogen as an energy source
Places where the event can be held	Hydroelectric energy museum
Age group for the activity	9-11

B. IN THE OUT-OF-SCHOOL LEARNING ENVIRONMENT	
Educational tools	PPT presentation, hydrogen-fuel cell, hydrogen mini car. Kit for electrolysis experiment (a basin of tap water, a 9V battery, two electrodes (possibly platinum, but common pencil leads can also work), two small plastic tubes, alligator clips, modelling clay, two small balloons)
Method, technique and strategies	Participatory lesson, storytelling, practical activity
PRACTICE	
Introduction of the activity	**Ecology, renewable resources and sustainable development** The experience begins with an introductory section, much in dialogue, in which students are accompanied to understand why the advent of hydrogen as a new energy source is so important. The starting point will therefore be a general overview of the resources used by man to produce energy. What are the most used resources? How has resource consumption changed over the years? By asking this question, students' opinions are awaited, leading them to list what according to them are the most used sources of energy today and, in particular, which is the most used. Together you can make a small description of the energy sources, to understand what we are referring to (for example, not all students understand what is meant by "biomass" or "geothermal"). The main sources of energy are then outlined, distinguishing (but always making the students think) about which ones are renewable and which are not, thus introducing the concept of renewable resource and sustainability. The speech can be accompanied by the vision of some explanatory images. At the end of this overview of the main sources of energy and the difference between renewable and non-renewable, students are shown

	a graph which illustrates, in percentage terms, where the energy used in the present era comes from (see appendix). It then explores how oil represents a fundamental resource not only for energy and transport, but for the production of bitumen, dyes, plastics, materials that we see and use every day. We think about how our society and our economy are deeply based, to the point of being dependent on it, on a non-renewable resource and which, consequently, will one day run out. To show the importance and complexity of the situation, and to historically contextualize the discourse, we briefly talk about the energy crisis of 1973, perhaps the moment in which for the first time the environmental issue is imposed in society in such an incisive way. Keep in mind that according to some estimates, oil could be depleted between 2050 and the end of the century. In support of this story, and to deepen the question of oil, it is possible to read and comment on some excerpts from the writings of Giorgio Nebbia, an Italian product specialist and popularizer of whom the Micheletti Foundation has a well-stocked archive and who has done his utmost to inform regarding the environmental crisis and the need to move towards sustainable development (see appendix). We can also talk about Earth Overshoot Day and how this is brought forward year after year, a figure with a strong impact on the issue of sustainability and which highlights the seriousness of the situation. In support of this story, and to deepen the question of oil, it is possible to read and comment on some excerpts from the writings of Giorgio Nebbia, an Italian product specialist and popularizer of whom the Micheletti Foundation has a well-stocked archive and who has done his utmost to inform regarding the environmental crisis and the need to move towards sustainable development (see appendix). A quick overview of the international agreements made over the years is then shown, showing some of the proposed objectives, especially in the energy field: • Kyto protocol; • Paris agreement; • European Green Deal.
Development of the activity	**Producing energy with hydrogen** <u>Experiment: electrolysis</u> To understand the phenomenon of electrolysis, a classic experiment can be carried out which requires few and simple materials, but whose effects are easily visible and verifiable. The class is divided into groups. Each group is provided with the material necessary to carry out the experiment: • A basin of tap water; • A 9V battery;

- Two electrodes (possibly platinum, but common pencil leads can also work);
- Two small plastic tubes
- Alligator clips
- Pongo
- Two small balloons

The experimental apparatus is easy to prepare: first of all, the electrodes are connected to the two connectors and clay is used to protect the connections, making them waterproof. Plug one end of the tubes with the balloons and immerse them until they are completely filled with water, making sure that the water does not enter the balloons. The electrodes are inserted into the tubes through the free end. Now connect the free ends of the connectors to the battery poles. Soon, thanks to the water that acts as a conductor, electricity circulates. Around the two electrodes you can see the formation of bubbles, which will gradually fill the balloons with gas.
It is explained that the formation of bubbles is the consequence of the splitting of water molecules into its two components: hydrogen and oxygen, the first at the anode and the second at the cathode. How to prove this difference? First of all, the chemical reaction can be shown (, highlighting the fact that the quantity produced by the two gases is different (the hydrogen will be twice as much as oxygen), therefore after a certain time it will be seen that one of the gases is produced in a greater quantity Secondly, the nature of the gases can be verified using a simple match: take the balloons, taking care not to disperse the accumulated gas, and leave them to deflate near the flame. feeds the combustion) will rekindle the flame, on the contrary the hydrogen will generate crackling noises.
If time permits, the experiment can be repeated using distilled water to explore the phenomenon of electrolysis. It will be noted that in this case the phenomenon does not exist: water, contrary to popular belief, is not a good conductor, it does not allow the passage of current. What makes water conductive are the mineral salts dissolved in it: by dissolving common table salt in water. by dissolving common table salt in distilled water and retrying the experiment it can be seen how now, effectively, electrolysis occurs.

<u>Experiment: reverse electrolysis and the fuel cell</u>
At this point, a fuel cell is shown (see figure in the appendix) and before explaining its operation to the students, it is shown in action. First of all, the cell is used "in reverse": water is injected and it is seen how the cell, if powered by a battery, produces electrolysis (filling the special ampoules with gas). Then the battery is disconnected and the electrodes are connected to a LED, or a small light bulb. This time the cell is used to produce electricity from the two gases: the light bulb turns on!
<u>The hydrogen cell</u>

	At this point, once you have clarified and seen with your own eyes what is meant by electrolysis and reverse electrolysis, you can explain how a hydrogen cell works in a simple and intuitive way. At this point, once you have clarified and seen with your own eyes what is meant by electrolysis and reverse electrolysis, you can explain how a hydrogen cell works in a simple and intuitive way. Here we highlight the focal point of the workshop (at least from a technological-industrial point of view): we have seen that to separate the molecules of water into hydrogen and oxygen it is necessary to supply electricity (these two gases are not found "ready-made" in nature). Subsequently, the two gases are recombined to generate electricity again. But then, if electricity is consumed to generate electricity, why is this done? Can't you just use the starting electricity? After having collected some opinions from the students, it is anticipated that the answer will be given in the third phase of the laboratory, inserting it within the discussion of a specific project, under construction, regarding the use of hydrogen as a fuel: the H2iseO project. **The H2iseO project** Having acquired the necessary tools to understand the importance of this new source of energy, the case of the Brescia-Iseo-Edolo railway, which almost entirely crosses the Valcamonica, is explored. The project, which intends to replace the line currently in use (diesel-powered) with one powered exclusively by hydrogen, will create the first hydrogen valley in Italy, further enhancing a territory that boasts a thousand-year history, as well as the first Italian site registered in the list of the UNESCO World Heritage Site. How long will it take to make it? How and where will hydrogen be produced? Where will the storage take place? The explanation will be accompanied by images of the current railway line, the sites in question (Trenord headquarters of Iseo and the Edolo hydroelectric plant) and examples of hydrogen trains and fuel cells. Experiment: the hydrogen car The experience concludes by showing the "magic" of hydrogen transport. For this purpose, a model of a car is used that moves thanks to the same fuel cell seen previously (see attached image). Possibly the production of hydrogen by electrolysis is started at the end of the previous experiment (therefore at the end of the second phase of the experiment). During the third phase, a sufficient quantity of hydrogen will be produced to ensure prolonged operation of the model for a few minutes.
Evaluation of the activity	Collective discussion about the importance of renewable energy sources and sustainability, with a questionnaire with open-ended question.

APPENDIX 1:

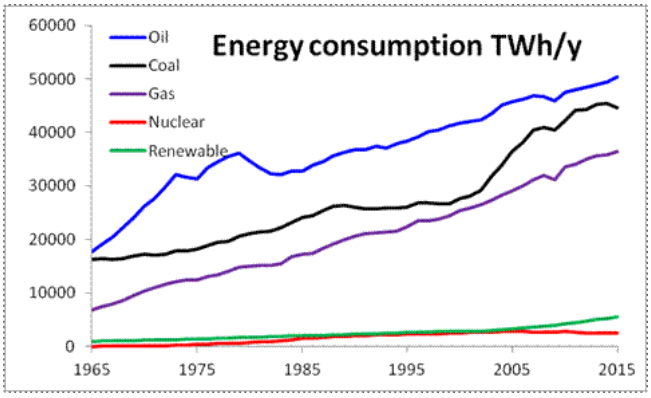
This workshop was born on the basis of two themes of a very different nature, but in this case intrinsically related: on the one hand, it highlights the environmental crisis which becomes more and more serious every year and which, consequently, increasingly needs to be treated, known and clarified; on the other it wants to focus on the Valcamonica area, of whose history the Cedegolo Museum is an excellent example of dissemination and information. The meeting point between these two areas lies in a recent project that will completely restructure the Brescia public transport system: the **H2iseO project**. This initiative aims to completely replace the *Brescia-Iseo-Edolo* railway line - currently fueled by diesel - with trains powered by hydrogen, an extremely current and cutting-edge technology in the field of transport and the production of renewable energy. Valcamonica will become the first Hydrogen Vally in Italy by totally decarbonising the emissions of the current railway line and following the lines of a European initiative that aims to bring the continent to zero the impact of polluting gas emissions by 2050. This topic is very topical and is transversal to many school disciplines, favoring interdisciplinarity and giving a large number of ideas for further study in view of a path that does not end with the workshop in the museum, but which can also be carried out in school environment.

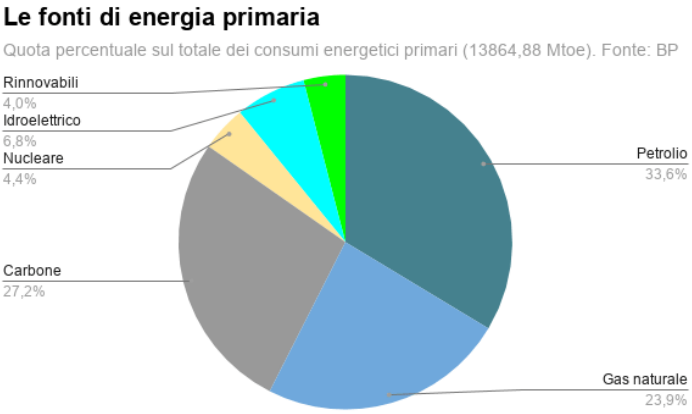
The initial and final phases of the workshop can be accompanied by the reading of some excerpts from the writings of the commodity specialist and popularizer Giorgio Nebbia (of which the Micheletti Foundation has a well-stocked archive), an Italian scholar perhaps too little known for the extent of his work and who has made a large effort to warn Italy about the climate crisis.

> *"[...] Yet it is precisely oil that is indispensable, in the form of its derivatives, petrol and diesel, to keep in motion the 50 million cars and motorbikes that crowd Italian streets and cities. But oil also enters our lives in so many other forms that we can speak of an "oil cost" for all goods and services. Oil enters the life of every "Mr. Rossi" from the moment he gets up in the morning. He has just sat down to breakfast and the milk his wife bought yesterday was also obtained from a cow which fed on fodder and cereals and feed which was "manufactured" by agriculture using tractors and manure and which were transported by ship and truck, all of which required petroleum products. Coffee also required a little oil, which was needed to move the ships that brought it from Africa or South America, and to operate the roasting machines. And there is also oil "inside" the jacket and trousers and shoes worn by Mr. Rossi because the synthetic textile fibers required oil; the cultivation of cotton and the raising of sheep and the weaving and making of shoes, have all been made possible by energy derived from petroleum.*

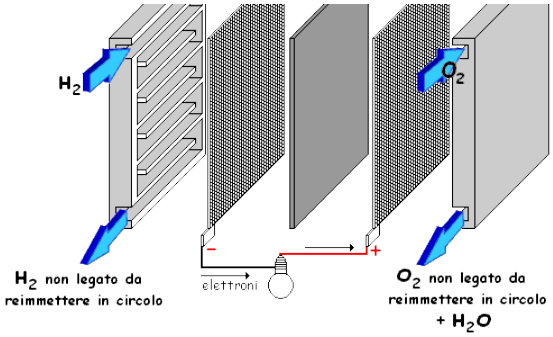
Not even in the office, Mr. Rossi will be able to free himself from the invisible slavery of oil: his office is equipped with all the electronic equipment that allows you to abandon the dusty paper archives and access information at the speed of light. Unfortunately an old proverb says that you can't have anything for free: in fact even his machines contain plastics, electronic circuits, gold and rare metals and lithium salts and graphite which all required minerals and processes which consumed petroleum. To have peace of mind, Mr. Rossi would do well to print the results of his work on paper, the production of which required oil when the trees were sawn, then transported from the distant northern woods to the paper mills, and when the cellulose was transformed into paper and then cut into well-squared sheets."

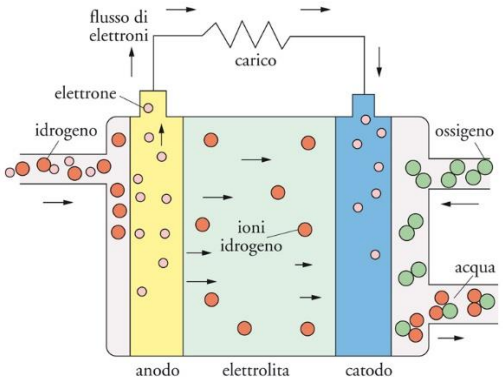
Giorgio Nebbia, "Remembering oil", 2015 October, 20





Graphs on consumption from different energy sources

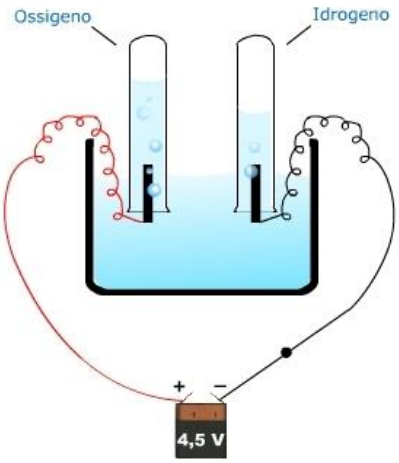




Explanatory images on the structure of an electrolytic cell

Fuel cell for educational activity

Hydrogen model car



Schematic example of the experimental apparatus for visualizing the electrolysis of water