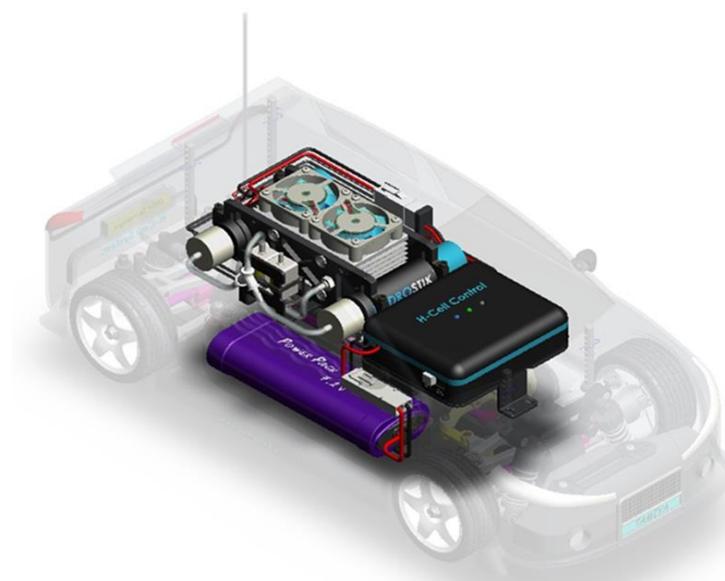


2 - The Role of Hydrogen

What are the pros and cons of using a hydrogen fuel cell, in terms of sustainability, compared with modern batteries?

2.1 Understanding the hydrogen fuel cell..... pg. 2

2.2 Understanding modern batteries..... pg. 10



2 - The Role of Hydrogen

What are the pros and cons of using a hydrogen fuel cell, in terms of sustainability, compared with modern batteries?

2.1
Understanding the
hydrogen fuel cell

Time required: 1h

Study direction

Necessary equipment and resources:

Horizon Equipment:

- Fuel cell



Objectives:

In this activity, we will reading documents mainly sourced from internet sites in order to identify possible factors of environmental hazards associated with the fuel cell system, as well as its safe disposal and recycling.

Zero pollution: a utopian idea?

It is impossible to try to invent a system that poses no threat to our environment.

Pollution is an omnipresent part of a product's life cycle. As early as during the design phase we have to deal with materials and processes that are more or less damaging to our environment. During the production phase, we have to extract raw materials from the Earth, transform and transport them, make and assemble the components, distribute the product, maintain and repair it, and possibly get it back at the end of its working life to recycle it.

Furthermore, any system needs power to work. During its working life it will necessarily release all sorts of pollution, more or less harmful to our environment. These come in the form of overheating, air pollution, leaks, etc.

A rigorous report of all the forms of pollution created would be too complex to complete, due to the vast number of variables that need to be considered. In this case, we must first examine what seems to us to be the most urgent and have the highest priority, in order to best protect our environment.

This analysis tends to be rather global and simply qualitative, but for this activity it will be used to establish a preliminary comparison between two modern technologies (fuel cell vs. battery), which will enable us to focus on the main pros and cons of each solution.

Zero pollution may be a utopia, but it remains a goal that we must do everything to achieve.

Technologies...

PEM fuel cells and metal hydride cartridges

The PEM fuel cell

It is primarily made of:

- Electrode plates
- Proton membranes (or proton exchange membranes)

As is the case for research into electric batteries, fuel cell technology is still evolving today, for example in the use of cheaper and more efficient materials.

The metal hydride cartridge

It contains a metal alloy that captures, by the process of adsorption, hydrogen atoms inside the gaps in its crystal structure.

This represents significant progress in the field of hydrogen storage, improving reliability and safety of stored hydrogen.

Documentary research

Resources to use for further information: See the recommended internet sites in the "Additional Resources" document. If necessary, make other searches using suitable keywords that you can list below, writing the names of the sites and documents that you use.

Examples of keywords for internet research:

Graphite

Nafion, polymers

Lanthanum, rare earth elements

Nickel

Time required: 15 min

2.1.1

0:05

The fuel cell's internal structure

Question:

Given all the materials used in the general internal structure of the fuel cell in its current version, explain whether these materials risk being harmful to our environment in the mid- and long-term.

Internal structure	Main risk factors for the environment and health
Graphite, used for electrode plates	Example opinion on the subject: Graphite is a mineral that would not present any particular risk in terms of health and could be recovered at the end of its lifespan for recycling
Nafion, a polymer made by Dupont, used for the proton-exchanging membranes	Example opinion on the subject: Nafion would not present any particular risk in terms of health except that, being a polymer, we must use oil to manufacture it, which eventually may cause slight problems for the environment, but the thickness of the membranes is very small.

2.1.2

Time required: 5 min

0: 20

Internal structure of Hydrostik cartridges

Question:

Given all the materials used in the internal general structure of Hydrostik cartridges, explain whether these materials risk being harmful to our environment in the mid- and long-term.

Internal structure	Main risk factors for the environment and health
Lanthanum and nickel, used for storing hydrogen	Example opinion on the subject: The lanthanum oxide is non-radioactive and fairly widespread in the earth's crust. Occupational hazards include lung disease (through breathing vapors and dust) as a risk for the user. It's a recyclable material, presenting no danger to the environment. Nickel, also used for the production of coins, can be recycled and poses no health risk.

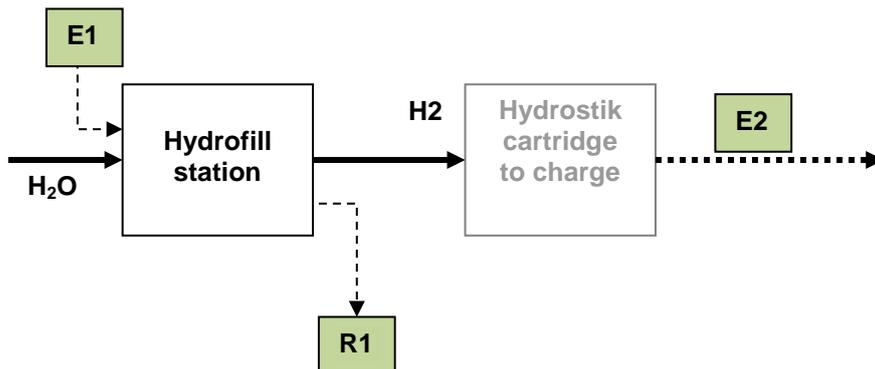
2.1.3

Time required: 5 min

0:25

Question:

Having examined the charging station for hydrogen cartridges and read its information sheets, complete the following description of its operation in terms of energy consumption and, if such data is available, in terms of emissions.



Form of energy consumption for operation	E1: Electric energy
Form of emissions during operation	R1 Heat and Oxygen (O₂)
Form of energy available	E2: Hydrogen (H₂)

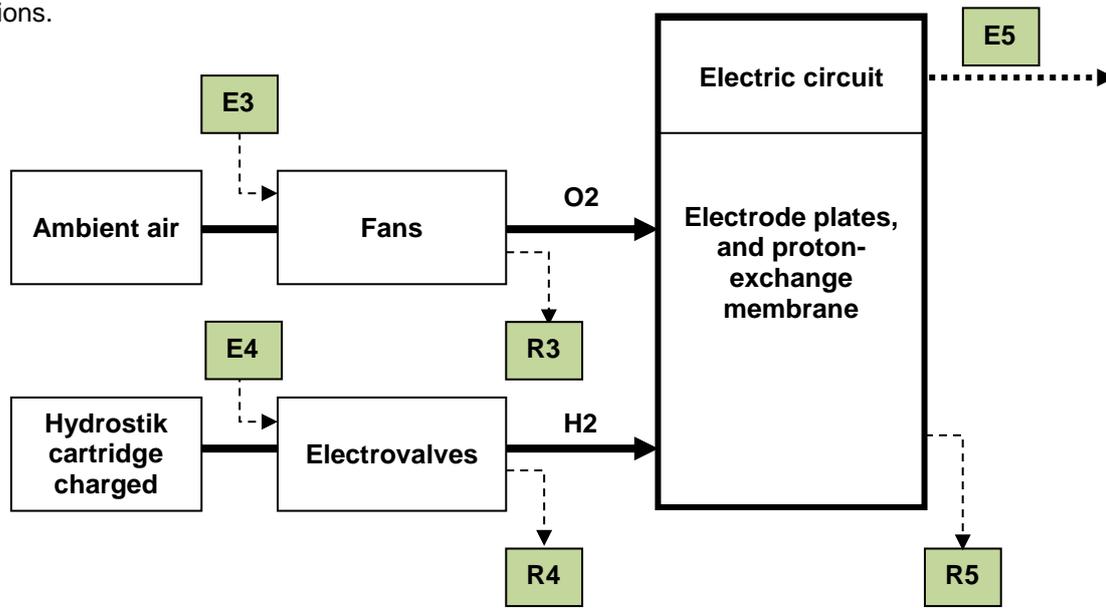
2.1.4

Time required: 10 min

0:30

Question:

Having examined the hydrogen fuel cell installed in the FCAT H-Cell car and studied its information sheets, complete the diagram below of its operation in terms of energy consumption and in terms of emissions.



Form of energy consumption for operation	E3: Electrical energy
	E4: Electrical energy
Form of emissions during operation	R3: Heat and moving air
	R4: Heat and exhaust
	R5: Heat and water
Form of energy available	E5: Electrical energy

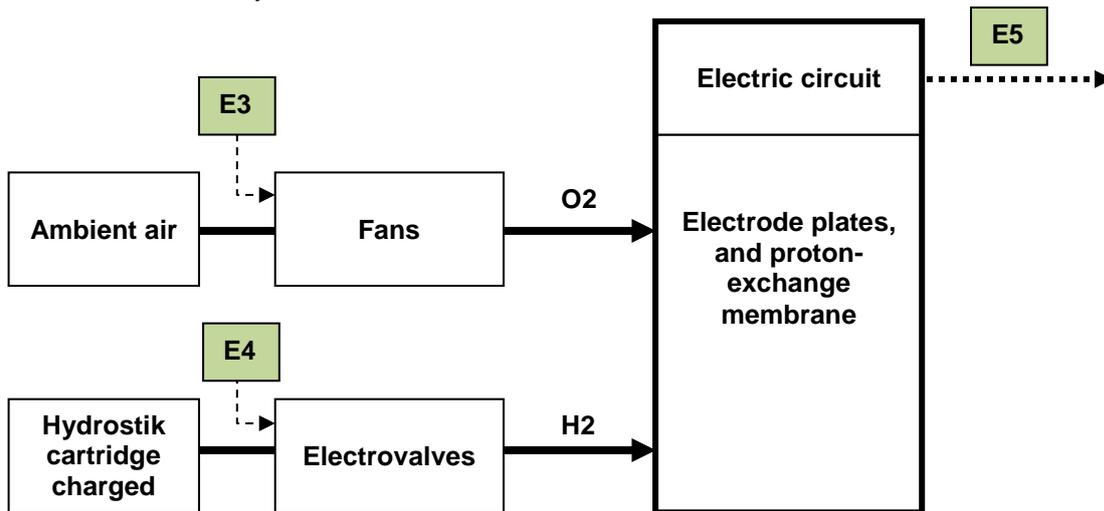
2.1.5

Time required: 5 min

0:40

Question:

Under what conditions could the report on energy consumption (E3 & E4) and available energy (E5) be deemed to be satisfactory?



If the difference "E5 - (E3 + E4)" is not too large

2.1.6

Time required: 5 min

0:45

Question:

In general, what can be said about sustainable development, considering the energy resources useful to charge and operate the hydrogen fuel cell and its form of emissions?

Example opinion on the subject: The only form of external energy the system uses is electricity, a form of energy that could be produced by using natural, renewable sources such as solar or wind energy.

In terms of emissions, warming may be partly offset by the flow of air which, based on actual testing of the reduced model, would result in a rather small rise in temperature, which is reasonable in our eyes. Also, the fact of the cell producing a pure water discharge seems to be particularly interesting.

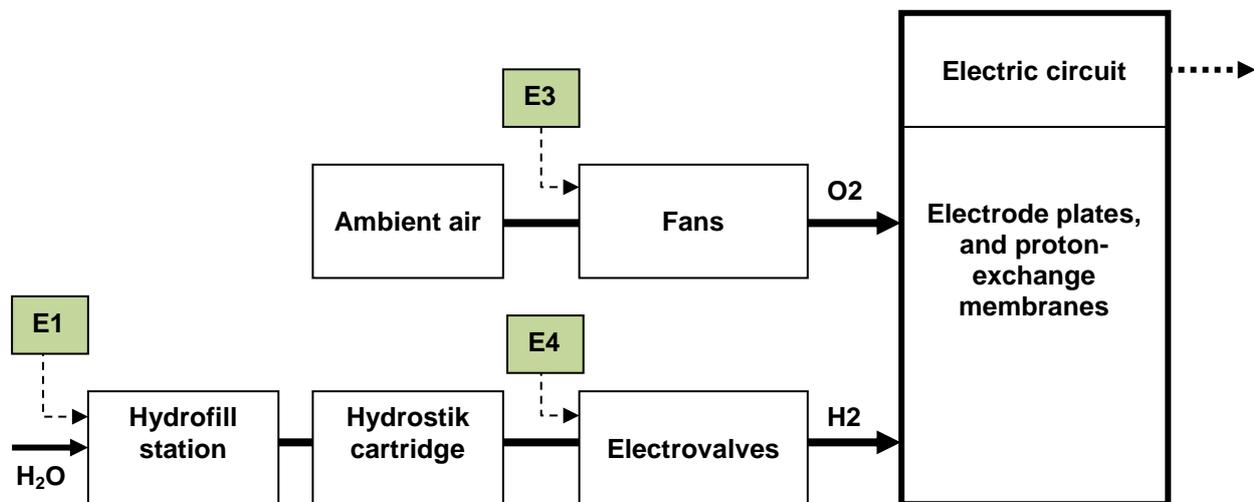
2.1.7

Time required: 10 min

0: 50

Question:

Considering the complete system (charging station - hydrogen cartridges - fuel cell), what can we say about the possibility of using forms of power to operate the system while taking care to protect the environment?



For E1: Example opinion on the subject: Direct current without an AC/DC converter requires additional energy input from machinery or natural energy resources, such as solar or wind power for example.

For E3 & E4: Example opinion on the subject: It would be interesting to get the “E3” energy also renewably, which could perhaps be possible if the movement of the car provided the moving airflow. However, the energy consumption of solenoid valves, unlike the fans, is not continuous, and occurs during a very short time. It is therefore highly likely that such a device can always be suitable in the future.

2 - The Role of Hydrogen

What are the pros and cons of using a hydrogen cell, in terms of sustainability, compared with modern batteries?

2.2
Understanding
modern batteries

Time required: 1h

Study direction

Necessary equipment and resources:

Horizon Equipment:

- **Battery Pack**



Global operational mode

In this activity, we will be looking at documents mainly sourced from internet sites, in order to identify possible environmental hazards associated with the battery, as well as its proper disposal and recycling.

Zero pollution: a utopian idea?

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Technology...

Electrochemical cells

Documentary research

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Examples of keywords for internet research:

Electric batteries

Lithium batteries

2.2.1

Time required: 40 min
(including 20 minutes for documentary research)

0: 10

Internal structure of an electrochemical cell (battery)

Question:

Read multiple sources in order to draft a complete list of materials, focusing on the general composition of different types of batteries. Detail, for the materials mentioned in the following table, what are the main risk factors for health and the environment. (We will limit ourselves to four materials)

Technologies	Main risk factors for the environment and health
Lead	Lead is especially toxic and shouldn't therefore be used any more in our batteries today. Also, the lifespan of this type of battery is short, which increases the risks to our environment due to high consumption of raw material and energy to produce and recycle it.
Ni-Mh or Ni-Cd	These types of batteries are considered less polluting. They also suffer from their reduced lifespan (less important for the Ni-Mh), which is not too good for the energy needs for recycling.
Lithium	Lithium is toxic in aquatic environments, but there's no major pollution risk in our framework of use. The raw materials are very important, however their mining and extraction raises problems.
Bromine	Reserved for fixed installations, bromine being too hazardous material.

Time required: 5 min

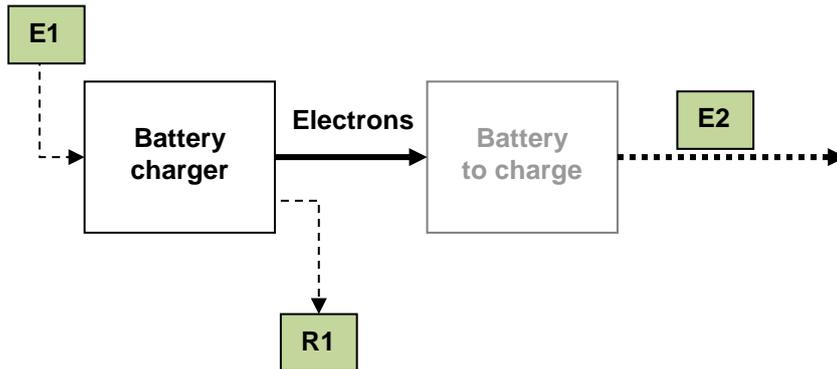
2.2.2

0:50

Charging a battery

Question:

Having examined the battery charging system and studied its specifications, complete the following diagram of its operation in terms of energy consumption, available energy, and emissions.



Operating energy form:

E1: **Electric**

Operating emission form:

R1: **Heat**

Available energy form:

E2: **Electric**

Time required: 5 min

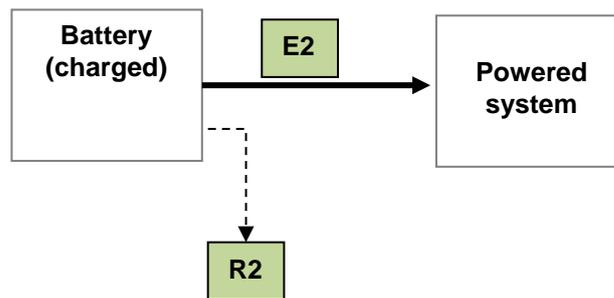
2.2.3

0: 55

Operation of a battery

Question:

Having examined the way a battery works and studied its specifications, complete the following diagram of its operation in terms of energy consumption, available energy, and emissions.



E2: Electric energy

R2: Heat