FCHGO EPDM TRIALS

TEACHER'S TOY GUIDE

FCHgo EPDM Team, October – December 2019

GENERAL GUIDELINES

Toys serve an important purpose for investigations carried out by older and more mature pupils. They allow direct experience of technical devices where chains of physical and chemical processes can be studied "hands-on." Here are some toys that might be investigated:

1. **Dynamo torch**
2. **Fuel cell car**
3. Windmill generator
4. Solar car
5. Electric car

The first and second one in this list are described in detail in this *Guide*. The others are suggested for more in-depth studies of the role of energy in technical systems. They are all useful for practicing a method of exploring, describing, and discovering *energy carriers* and *coupling devices* (couplers or energy exchangers).

[For the concepts used in describing the toys, please refer to the document *Introduction to FCH technology (Hydrogen and Fuel Cells—How, What for, and Why?)*]

The description of the toys covers both "how it is made" (the parts and their connections) and "how it works" (how it works in general and how the parts interact and work together).

When the components are being described, the pupils are invited to pay close attention.

In the "how it works" phase, pupils are invited to look into the different ways these toys work (specific information for the first two toys are found in the following sections).

It is important to explicitly emphasize the analogy between the first two toys—the dynamo torch and the fuel cell car. This particular analogy can be carried quite far (Tables 6 and 7 below).

We suggest starting with explorations in small groups, followed by group comparisons and finally, a discussion by the entire class.

The description of the toys given here has two sections: "How it is made" and "How it works." There are corresponding sections in the *Toy Work Sheets* given to the pupils. There is a table with the relevant energy carriers and couplers/exchangers (the entries suitable for older pupils are in *italics*), as well as process diagrams.

Here, you find a list of important *energy carriers* (Table 1), with their everyday (common) names, their associated *potentials* or *intensities*, plus the carriers' scientific names. We suggest using the

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everyday names for the energy carriers as they are closer to the shared language and the experience of the pupils.

Table 1: Energy Carriers and Potentials

Carrier (common name)	Potential/Intensity	Carrier (scientific name)
Hot water	Temperature	Entropy/Caloric
Compressed water	Pressure	Fluid
Water in motion	Velocity	Motion
Hot air	Temperature	Entropy/Caloric
Compressed air	Pressure	Fluid
Air in motion	Velocity	Motion
Heat (Caloric)	Temperature	Entropy/Caloric
Food	Nutritional value/quality of food/chemical potential	Chemical substance
Fuel	Chemical potential	Chemical substance
Hydrogen	Chemical potential	Chemical substance
Electricity	Electrical potential	Electrical charge
Light	Intensity (of light)	Light
Motion	Velocity	Momentum
Rotation	Angular speed	Angular momentum
Weight	Height/Gravitational potential	Gravitational mass

DYNAMO TORCH

How it is made

The relevant components are:

- Handle/crank
- Gears
- Dynamo
- Battery
- LED bulb

How it works

We can more easily understand how the dynamo torch works if we consider the overall process as consisting of two consecutive processes—**charging** and **discharging**. During the **charging** process, turning the handle makes the dynamo turn, which charges the battery. During the **discharging** process, the battery lights the LED bulb.

Table 2: Role of the dynamo as **coupler** during the **charging** process**:**

Input source of energy	Person turning the handle
Input energy carrier	Rotation
High potential of input carrier	*High speed of rotation*
Low potential of input carrier	*Low speed of rotation*
Coupler (energy exchanger)	Dynamo
Output energy carrier	Electricity
Low potential of output carrier	*Low electrical potential*
High potential of output carrier	*High electrical potential*
Energy storage element	Electrical battery

Table 3: Role of the LED as **coupler** during the **discharging** process**:**

Storage element (energy source)	Electrical battery
Input energy carrier	Electricity
High potential of input carrier	*High potential electricity*
Low potential of input carrier	*Low potential electricity*
Coupler (energy exchanger)	Led bulb
Output energy carrier	Light
Low potential of output carrier	*Low intensity light*
High potential of output carrier	*High intensity light*

Energy chart

FCHgo!
Discover the energy of hydrogen

FUEL CELL CAR

How it is made

The relevant components are:

- Photovoltaic panel
- Hydrogen fuel cell (HFC)
- Hydrogen and oxygen containers
- Water container
- Electrical engine
- Wheels

The hydrogen fuel cell is connected with hydrogen and oxygen tanks and with the water container by means of hoses. The hydrogen fuel cell will be connected to the photovoltaic panel by two electrical wires; it will also be connected to the electrical engine with two electrical wires.

How it works

We can more easily understand how the fuel cell car works if we consider the overall process as consisting of two consecutive processes—**charging** and **discharging**. The hydrogen fuel cell is involved in both steps!

Charging. When the fuel cell is connected to the solar panel, it separates water into hydrogen and oxygen (electrolysis of water) and charges a "chemical accumulator" (two tanks containing hydrogen and oxygen, respectively).

To be more precise, *the photovoltaic panel raises the electrical potential of the electricity and makes the electricity flow. As the electricity flows from the higher to the lower electric level in the HFC, the fuel cell creates hydrogen and oxygen from water. This raises the chemical potential of the substances.*

Discharging. When the fuel cell is connected to the engine, the "chemical accumulator" discharges, hydrogen and oxygen combine again to form water, and electricity is made to flow. In turn, the electricity makes the electrical engine run, which moves the car.

More precisely, as hydrogen and oxygen flow into the fuel cell and combine to water, the chemical potential of the substances is lowered. This raises the electric potential of the electricity (creating an electric tension) and makes the electricity flow; this, in turn, allows the engine to run. In other words, the hydrogen fuel cell takes advantage of the fall of chemical potential to create a difference of electric potential (electric tension!).

Table 4: The role of the HFC as **coupler** during the **charging** process:

Input source of energy	Photovoltaic panel*
Input energy carrier	Electricity
High potential of input carrier	*High electrical potential*
Low potential of input carrier	*Low electrical potential*
Coupler (energy exchanger)	Hydrogen Fuel Cell
Output energy carrier	Chemical substance
Low potential of output carrier	*Low chemical potential: Water (oxygen and hydrogen combined)*
High potential of output carrier	*High chemical potential: Oxygen and hydrogen separated*
Energy storage element	Separate containers for Hydrogen and Oxygen

** The photovoltaic panel is a coupler (exchanger), with light as the input carrier and electricity as output carrier.*

Table 5: The role of the HFC as **coupler** during the **discharging** process**:**

Energy storage element	Separate containers for Hydrogen and Oxygen
Input energy carrier	Chemical substance
High potential of input carrier	*High chemical potential: Oxygen and hydrogen separated*
Low potential of input carrier	*Low chemical potential: Water (oxygen and hydrogen combined)*
Coupler (energy exchanger)	Hydrogen Fuel Cell
Output energy carrier	Electricity
Low potential of output carrier	*Low potential electricity*
High potential of output carrier	*High potential electricity*
Output energy user*	Electrical engine*

** The electrical engine is a coupler (exchanger), with electricity as the input carrier and rotational motion as the output carrier.*

Energy chart

ANALOGY BETWEEN DYNAMO TORCH AND FUEL CELL CAR

The Dynamo torch and the Fuel Cell car demonstrate a strict analogy, which is important to point out and highlight. More advanced entries are shown in *Italics*; they can be introduced later for older pupils.

Table 6: **Charging** process:

Element	**Dynamo torch**	**Fuel Cell car**
Input source of energy	Hand turning the handle	Sun
Input energy carrier	Rotatory motion	Light
High potential of input carrier	*High speed rotation*	*High intensity light*
Low potential of input carrier	*Low speed rotation*	*Low intensity light*
Exchanger #1	Dynamo	Photovoltaic panel*
Energy carrier*	Electricity	Electricity
*Low potential of carrier**	*Low potential electricity*	*Low potential electricity*
*High potential carrier **	*High potential electricity*	*High potential electricity*
Exchanger #2	Electrical battery	Hydrogen Fuel Cell
Output carrier	Chemical substance	Chemical substance
Low potential of output carrier	*Low chemical potential: Combined chemical substances*	*Low chemical potential: Water (oxygen and hydrogen combined)*
High potential of output carrier	*High chemical potential: Separated chemical substances*	*High chemical potential: Oxygen and hydrogen separated*
Energy storage element	Battery cells	Hydrogen and oxygen in separate tanks

* There is only one carrier, as the output carrier of Exchanger 1 is the same input carrier of Exchanger 2.

Table 7: **Discharging** process:

Element	**Dynamo torch**	**Fuel Cell car**
Energy storage element	Battery cells	Hydrogen and Oxygen in separate tanks
Input energy carrier	Chemical substance	Chemical substance
High potential of input carrier	*High chemical potential: Combined chemical substances*	*High chemical potential: Oxygen and hydrogen separated*
Low potential of input carrier	*Low chemical potential: Separated chemical substances*	*Low chemical potential: Water (oxygen and hydrogen combined)*
Exchanger	Electrical battery	Hydrogen Fuel Cell
Output energy carrier	Electricity	Electricity
Low potential of output carrier	*Low potential electricity*	*Low potential electricity*
High potential of output carrier	*High potential electricity*	*High potential electricity*

Output energy user*	Led bulb	Electrical engine of the car