TEACHING DOSSIER 6

ENGLISH, GEOGRAPHY, SCIENCE, TECHNICAL LEARNING

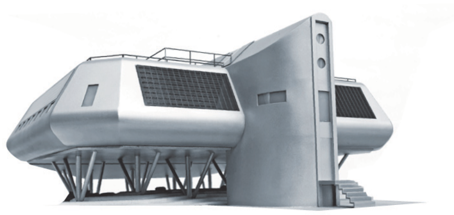
SUSTAINABLE DEVELOPMENT IN THE POLAR REGIONS: PRINCESS ELISABETH STATION, ANTARCTICA

ANTARCTICA, SUSTAINABLE SOLUTION, AERODYNAMIC, PASSIVE HOUSE, WASTE, WASTEWATER RECYCLING

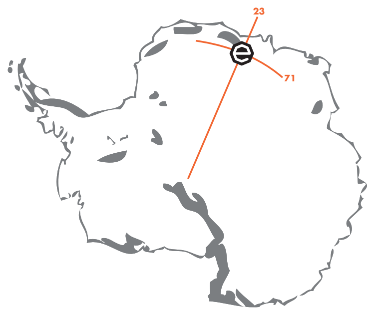
THEORY SECTION

Sustainable development is a complex concept that is often difficult to apply in practice (see our teaching dossier on “Sustainable Development”). However, through the “Princess Elisabeth Antarctica” project, the International Polar Foundation has demonstrated that it is possible to build a passive house and live without disrupting nature - even in Antarctica, where the conditions are the most difficult and hostile in the world. Despite the total isolation of the frozen continent and the extreme weather conditions that prevail there, the new base is able to function self-sufficiently by using various forms of renewable energy. It also has virtually zero impact on its surroundings and the environment. The Princess Elisabeth Station serves to remind us that it is possible to live without damaging the environment, regardless of where we happen to be on the planet.

PRINCESS ELISABETH STATION AT A GLANCE



The first “Zero Emission” polar base
- 100% renewable energy
- Recycling wastewater
- Sustainable technologies
- Can be dismantled at the end of its service life
- Materials then removed from the Antarctic and returned to Belgium



Belgium’s new polar base
- Located 180 km from the coast
- Built on a rocky outcrop on the Utsteinen nunatak (mountain) (altitude 1400 m)
- Estimated service life: 25 years minimum
- Occupancy: 12 persons on average, 20 maximum
- Floor area: 1,500 m^2 of usable space
- Summer station: operational all year round, but occupied only from November to February

The base is occupied only during the austral summer for a number of reasons:
- During the summer months, the Antarctic days are longer, which also means that expedition members can work longer. The base is situated south of the Antarctic Circle (66°33’39’’S) and the “midnight sun” can be observed there for approximately three months during the austral summer, whereas in the winter there is no daylight at all for three months.
- Temperatures are much more favourable in terms of conducting fieldwork during the austral summer than in the winter months.
- Finally, the continent cannot be accessed during the winter on account of the thick pack-ice that builds up everywhere along the Antarctic coastline. Transport in and out by aircraft is also totally suspended, which means that people who spend the winter in an Antarctic base are left to their own devices for at least eight months.

EXTERIOR DESIGN OF THE STATION

The exterior of the station was specially designed to stand up to Antarctica's extreme weather conditions: the temperatures range from minus 50°C to minus 5°C, the average monthly wind speed is 20 km/h, with katabatic winds that can blow up to 250 km/h mainly from the south-east, the average atmospheric pressure is of 830 hPa, there is variable snowfall, snow drift, and, finally, there are 24 hours of daylight for 100 out of the 120 days of the austral summer.

THE SHAPE

The shape the designers decided to use for the base is aerodynamic, which means that the wind and snow have the least possible effect on the structure. The reasons for choosing this design include: safety, easy maintenance and accessibility. The body of the station has been built two metres above the undulating granite terrain. This provides sufficient space to be able to get underneath the building to carry out repairs, for example. The fact that the station is raised off the ground also ensures that snow does not accumulate against the building; the wind blows snow straight out through the support struts. In the past, many stations that were not built above the ground on stilits became partly or totally buried under the snow. The Princess Elisabeth Station is supported by 34 struts that range in height from 2 to 6 metres, depending on the location. These struts are securely anchored to a depth of six metres into the granite ridge, which is stable, unlike the snow and ice, which are constantly shifting.

THE WALLS

The walls of the station perform the essential function of insulating the interior of the base from the glacial cold on the outside. This is why the walls are approximately 53 cm thick and are made up of nine different layers. All of the joints are also airtight, to ensure perfect insulation.

In a conventional house, the layer of insulation averages 12 to 16 cm in thickness. In a passive house, built in the middle latitudes, the insulation is up to 30 cm thick. In the Princess Elisabeth Station, the main insulating layer (made from low-density polystyrene doped with graphite) is 40 cm thick.

There are nine layers of insulation in all, running as follows from the inside wall to the outside: woolen felt, a sheet of aluminium (to prevent humidity from the inside penetrating to the wood), Kraft paper, a layer of lamellate wood (spruce), the main layer of insulation, another layer of lamellate wood, an aluminium vapour barrier (to prevent moisture from the outside coming in), a layer of cellular foam and a sheet of stainless steel.

With its timber weight-bearing structure, the resulting building can withstand winds of up to 300 km/h. The walls also resist wear and the effects of any impact.

The walls of the base are made up of 168 panels of 40 different shapes. Each panel is approximately 7 m^2 in area and weighs 500 kg. The panels were specially designed to fit like the pieces of a jigsaw puzzle into the 120 containers that brought them to the Antarctic.

THE WINDOWS

The windows consist of two double-glazed panes, creating a sort of quadruple-glazing. A 400 mm layer of air separates the windows in each set of double-glazed panes, which also contain a solar filter. The glass that comes into contact with the outside is armoured, which means it can cope with temperatures as low as minus 71°C and winds of up to 280 km/h. The air pressure between the two double-glazed panes can be adjusted with a valve. The windows themselves have been positioned to help to control the temperature inside the building.

THE INTERNAL LAYOUT OF THE STATION[1]

TECHNICAL CORE

01. energy storage room (batteries)
02. water purification system
03. electrical control system for the station

INTERMEDIATE ZONE

04. bathroom
05. toilets
06. kitchen
07. washing machines
08. storage areas
09. storage areas
10. offices

OUTER ZONE

11. day room
12. sleeping quarters (bunk beds)
13. fitness room
14. entrance hall
15. cloakroom
16. laboratory / infirmary
17. control room / observatory

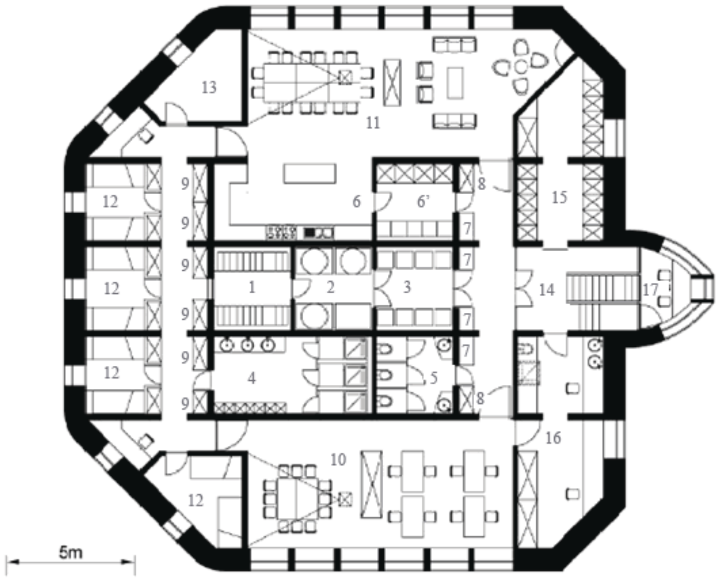


Figure 1

The structure of the station can be compared to the layered structure of an onion. The outer zone houses all of the living areas. The intermediate zone consists of the utility areas required for everyday living at the base (washing machines, toilets, bathrooms, storage areas for provisions, etc.). It also provides a thermal and acoustic buffer that protects the heart of the station: the technical core. All of the base's sensitive systems and installations are concentrated in the heart of the building, a protected area where it is always warm.

To be able to cope with the cold season, when the base is not occupied, the technical core is surrounded by thermal insulating sheets to protect it. Even when there is no one in the station, the temperature, humidity and all internal systems can be monitored and adjusted at all times from Belgium.

WHERE DOES THE ELECTRICAL POWER COME FROM THAT ENABLES THE STATION TO OPERATE?

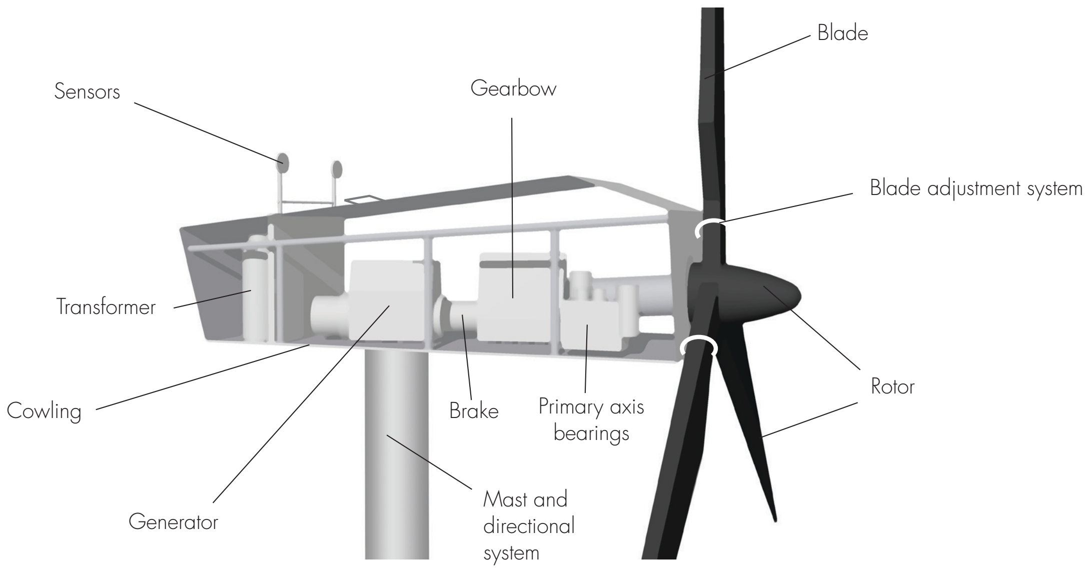
One of the biggest challenges facing a non-polluting polar base is how to supply it with power. How do we generate the electricity needed for the computers, washing machines, cookers and measuring instruments to operate? Until now, polar stations have depended totally or at least partly on fossil fuels carried to Antarctica by ship. The Princess Elisabeth Station demonstrates that a polar base can in fact be totally self-sufficient in its energy needs these days by using nothing but renewable energy.
Specially designed to consume as little energy as possible, the Princess Elisabeth Station has a total energy

1 See the animation at http://www.antarcticstation.org/flash/virtual/

requirement of about 54 MWh per year. Because it is a summer base, power consumption will be greater during the four summer months (7000 kWh per month) than during the eight months of winter (2000 kWh per month). The energy that makes it possible to produce the power needed to run the station comes from a hybrid system that uses two sources of renewable energy simultaneously: the sun and the wind. This dual system enables the system to adjust easily according to weather conditions: if the wind drops, solar energy can make up the difference - and vice versa. Two 44 kWh diesel generators have also been installed at the station, however fossil fuels are only to be used as a last resort in an emergency.

WIND TURBINES

Nine sturdy wind turbines – each with a generating capacity of 6 kW – convert the wind into electricity (230 V). These turbines stand proudly nine metres above the horizon to the north of the base on Utsteinen Ridge. They operate all year round.



➥ Figure 2: The components of a wind turbine

Each wind turbine has three blades, each over two metres in length and made from a strong yet flexible composite material. A direct-drive generator and self-adjusting rotor complete the unit. These wind turbines also include a new feature that even makes it possible to generate electricity from light breezes, while at the same time protecting them against harmful effects of violent storms.

PHOTOVOLTAIC SOLAR PANELS

Photovoltaic solar panels convert the sun's energy into electricity ("photo" = light, "voltaic" = electric). In all, there are 109.5 m² of photovoltaic panels attached to the station itself, with a further 270 m² on the shed areas, generating a total capacity of 50.6 kW (representing up to 800 W per m² in sunny conditions).

To enable them to withstand the extreme conditions of the Antarctic, the photovoltaic cells are protected by toughened glass and a special film, all of which is hermetically sealed. Each unit is placed in a strong aluminium frame that is easy to attach to the station itself or the sheds. The ambient cold prevents any problem with the panels overheating.

WHERE DOES THE ELECTRICITY GO ONCE IT HAS BEEN GENERATED?

The electrical system at the base is designed to use immediately whenever possible all electricity as it is produced. If there is a shortfall in production, certain systems take priority over others, based on a list programmed in advance. Systems associated with personal safety, such as protection against fire, the production of water and ventilation will be given the highest priority. If there is neither sun nor wind to provide power and someone at the base wants to plug a device into the mains system, a signal will alert him or her to the fact that the other systems have priority.

Figure 3: From high priority to low priority: fire safety, snow-melter, temperature regulation, washing machine, television - and so on.

To restrict the consumption of power, the domestic appliances at the station are all energy-savers: A++ refrigerators, induction cookers, energy-saving light bulbs, etc. In fact, the entire base is designed to use as little energy as possible, which is a key point for reducing its impact on the environment.

Only if surplus energy is produced will it be stored in the latest-generation lead batteries located in the technical core of the station (total capacity: 6000 Ah). There are two reasons for being so frugal with power:

- Storing energy in batteries always leads to power losses;
- Charging and discharging the batteries constantly has an adverse effect on their efficiency and service life, which means they have to be replaced more frequently. And because the batteries weigh 12 to 15 tons, it is preferable not to have to replace them too often.

HOW IS THE STATION HEATED?

Because the temperatures outside in the Antarctic can sink to as low as minus 50°C, heating a polar base requires a great deal of power. So, what sources of energy are used to heat the Princess Elisabeth Station? In fact, the station is mainly heated by the sun: water is heated using thermal solar panels, while surprisingly the excellent insulation and special way in which the base is designed make it possible to heat the interior areas mainly using the sun's rays, which come in through the windows (passive thermal solar energy).

THERMAL SOLAR PANELS

This type of solar panel uses energy from the sun to heat water (hence the term "thermal"). These panels are divided into two groups: the first of these groups (6 m^2) is located in the roof of the sheds, where it helps to melt snow. The water obtained by melting snow is recovered and stored in a tank in the technical core of the station, where there is also a tank containing recycled water. The second group of solar panels (19 m^2) is built into the station's roof. These panels heat the melted snow and recycled water (the recycling system is explained later on) to a pleasant temperature, after which it is distributed through a network of pipes to the bathrooms, kitchen and laundry. The thermal solar panels are directed northwards to extract maximum benefit from the sun's rays. If there is not enough hot water, the electrical system provides backup for production.

PASSIVE SOLAR HEATING

As with the design of any passive house, the size and orientation of the windows of the station have been very carefully designed to make the best possible use of the sun's heat. However, unlike a passive-energy house built in the middle latitudes (in which we try to collect as much heat as we can), the area of windows is not focused on the sunniest side of the building. This is because there is a great deal of sunshine during the summer months, at times lasting 24 hours a day! Combined with the excellent insulation of the walls, that constant exposure to sunlight could lead to overheating. As a result, the largest windows of the station are placed on the southern side (which corresponds to the north in the Northern Hemisphere) and are positioned relatively low down, at sitting height, to limit any possible overheating. As the researchers at the base spend most of their time sitting down, they can also enjoy the views out over the vast frozen expanses.

Heating for the internal areas at the base is supplemented by the heat generated by electrical devices and human activity, in line with the principles of a passive-energy house.

VENTILATION AND HEAT EXCHANGERS

The ventilation system at the station is very similar to the one used in a conventional passive-energy house. The windows cannot be opened and ventilation is controlled by an automatic system. The entire system ("dual-flow") is based on an exchange of heat between the warm, stale air being discharged and cold, fresh incoming air, which makes it possible to recover 75 to 95% of thermal energy. The two flows of air do not come into contact with one another, but intersect in a heat exchanger. An electric humidifier then moistens the air until it reaches at least 15% humidity. The aim is threefold: to keep the occupants of the base comfortable, to provide a pleasant living environment and to protect the equipment (by preventing electrostatic charges and discharges).

WHAT HAPPENS TO THE STATION'S WASTE?

The Princess Elisabeth Station produces no waste at all: 75% of the wastewater at the base is recycled, as is all compostable waste. Any solid waste is stored in containers and removed at the end of the austral summer.

WASTEWATER PURIFICATION SYSTEM

The researchers at the Princess Elisabeth Station are the first inhabitants of Antarctica to reuse their wastewater. It is a process already used by astronauts. The purification process goes through several stages: bioreactors (aerobic and anaerobic"digestion" by microorganisms), filters, activated charcoal and UV rays. The entire system for purifying wastewater is controlled by a computer that checks and adjusts the temperature, the pH level, volume and quantity of O_2, etc. Any compostable waste from the kitchen is ground up in a special grinder before a pumping system takes them to the bioreactors.

After being treated, any water that is not recycled is discharged into a gully between the ice and the rock. Any remaining residue from non-bio-degradable waste is stored in a tank in the sheds and taken away at the end of the season.

GLOSSARY:

Aerobic biological "digestion": The breaking down of organic compounds by microorganisms in an environment where there is plenty of air. This system is used at the base to treat "grey" water (from the showers, dishwasher and washing machine, as well as the water produced after anaerobic biological purification).

Anaerobic biological "digestion": The breaking down of organic compounds by micro-organisms in an environment where there is no oxygen. This system is used at the base to treat "black" water (from the toilets and the kitchen). The particles are ground up before they reach the bioreactor.

Direct-drive generator: Generator connected directly to the rotor of the wind turbines to minimise energy loss. As a result, the electrical current generated is directly proportionate to the speed at which the rotor is rotating. Conventional wind turbines have a geared transmission system.

Katabatic winds: Powerful winds generated under the force of gravity by the weight of a mass of cold air (which is heavier than warm air) hurtling along the topographical contours of the terrain. In Antarctica, katabatic winds blow from the interior of the continent down the slopes of the icecap towards the coasts. You can think of it as a kind of wind "avalanche." By the time the winds arrive at the coast, they can reach speeds above 300 km/h.

Solar filter: Filter that blocks out certain wavelengths of the sun's light and prevents the heat from penetrating into the base.

Lead battery: Batteries that work due to the electrochemical reactions of lead and lead dioxide in an electrolyte with sulphuric acid. There are a number of different types of lead battery using technologies of varying levels of complexity. The batteries being used at Princess Elisabeth Station are sealed, stationary lead batteries, known in technical circles as valve regulated lead acid (VRLA) gel batteries.

Passive house: A dwelling that uses very little energy (approximately 70% less than a conventional new house). Passive-energy houses make maximum use of all sources of heat (solar energy and sources of energy from inside the dwelling, such as domestic appliances and even the people living in the house) so that a heating system is not required. These houses are very well insulated and have a dual-flow ventilation system (which takes the heat from the used, stale air to heat the new air brought in). The air from outside cannot penetrate directly into the house.

Self regulation-rotor: A rotor with a mechanism that enables the wind turbine to slow down when the wind is too strong. This means that the wind turbine can keep operating regardless of the wind strength, unlike other wind power systems that shut down if the wind exceeds a certain speed.

Snow drift: Freshly fallen snow, blown by the wind. The snowflakes are put back into the air and carried where the wind takes them. This may give the impression that it is snowing when in reality it isn't.

RESSOURCES:

View the animations on "The Princess Elisabeth Station" and "Polar nights", as well as the teaching dossier on "Man in the Polar Regions" and a whole range of experiments to be conducted in the classroom at EDUCAPOLES, the educational website run by the International Polar Foundation (IPF):
http://www.educapoles.org (NL, FR, EN)

The Princess Elisabeth Antarctica Station website (which contains a wealth of information about the base, including four teaching dossiers: "The BELARE Expeditions", "Belgians and the Antarctic", "The station: from inside out" and "The technical aspects of the station: energy-efficiency and wastewater treatment"):
http://www.antarcticstation.org/ (NL, FR, EN)

Two websites about passive houses:
http://www.lamaisonpassive.be/ (FR)
http://www.passiefhuisplatform.be (NL, FR, EN)

PRACTICAL SECTION

LEARNING ISSUES

Dealing with current topics of interest, particularly those relating to the environment, re-quires a broad, overarching approach. The main idea is not to abandon disciplinary teaching, but rather to use the cognitive tools, concepts, skills and knowledge built up as part of learning each discipline in order to solve general problems in class. In other words, we need to put our knowledge and the things we have learnt into action. Carrying out specific actions provides us with an opportu-nity to bring what we have learnt to the fore and provide direction for activities conducted in the classroom. There are other issues highlighted here, too, especially issues linked to the core principles of sustainable development, such as participation, taking values systems into ac-count, collective and individual accountability, and solidarity between rich and poor countries and across generation.

ACTIVITIES FOR THIS SECTION

1. "WHAT DO YOU KNOW ABOUT THE PRINCESS ELISABETH STATION ?" CARD GAME

Target age group	<12 years	Time required	30 minutes
Aims	To create fun interaction between pupils and arouse their curiosity about the station		

Cut up the 9 cards. They can be used in numerous ways in class: for example, the pupils can play the game among themselves, in small groups or in twos. They will need to think together to come up with the answer(s) they believe are correct. Various "wrong" answers can be used by the teacher as "hooks" for providing additional information. The children can also be asked whether it would be possible to build a house of this type in their country and if it would be worthwhile.

Answers: 1. a / 2. a and b / 3. b / 4. c / 5. b / 6. b / 7. a / 8. c / 9. b

2. "MY OWN WIND TURBINE !" EXPERIMENT

Target age group	12-15 years	Time required	1 to 2 hours
Aims	To relate the experiments conducted in class with situations in the outside world; to understand how a wind turbine works; to get pupils to learn how to work in a team		

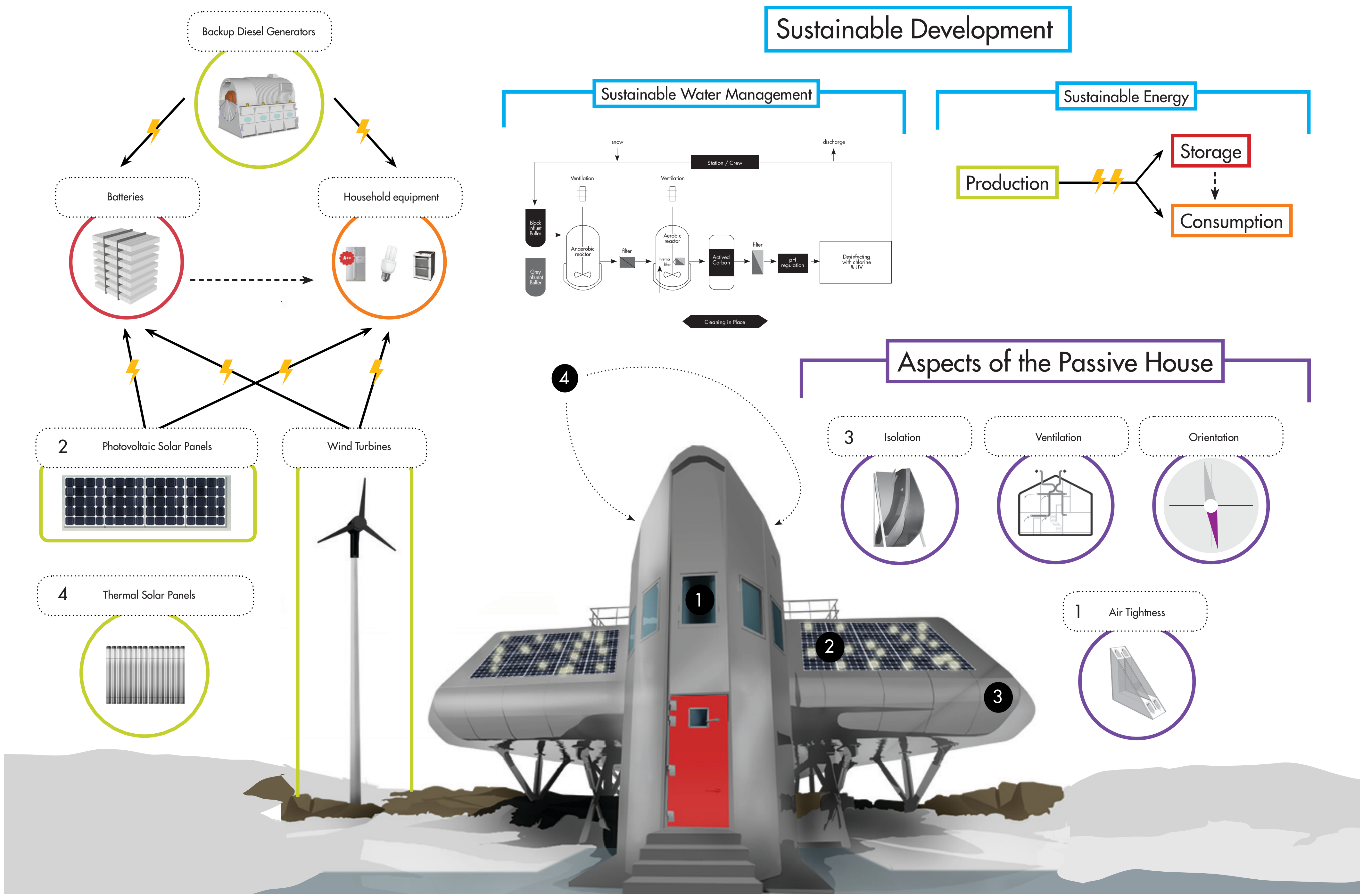
Once the wind turbines are assembled, the children can be asked what they see happening. Example: The LED lights up. The blades of the propeller are all tilted in the same direction. The wind blows on them and forces them to turn in the direction they are tilted in. This turns the propeller, as well as the axis of the motor, which in turn drives the motor's copper wire coil. This movement produces a current in the electrical wires, which passes through the LED. (Source: Energy in Practice, The Energy Box – WWF)

3. UNDERSTANDING THE DIAGRAM "HOW DOES THE PRINCESS ELISABETH STATION WORK ?"

Target age group	15-18 years	Time required	30 minutes
Aims	To understand how it can be possible to live self-sufficiently and having no impact on the environment, without any loss of com-fort; to acquire a fundamental understanding of the technical principles involved (see illustration on reverse)		

IDEAS FOR OTHER ACTIVITIES

- Come up with photo-language or role-playing games that enable the children to think about a whole range of issues that need to be dealt with systematically. The aim of these activities is to develop their sense of observation and analysis while starting a discussion about their opinions. (go to www.educapoles.org – educational tools)
- Identify areas where energy is wasted in the school, tell the school authorities about them and/or introduce systems that allow the rational use of energy ;
- Design a communication programme about an environmental issue and put it into effect (resources at www.educapoles.org - multimedia - flash animations - energy);


Sustainable Development
Sustainable Water Management
Sustainable Energy
Production
Storage
Consumption
snow
discharge
Station / Crew
Ventilation
Ventilation
Black Influent Buffer
Grey Influent Buffer
Anaerobic reactor
filter
Aerobic reactor
Internal filter
Actived Carbon
filter
pH regulation
Desinfecting with chlorine & UV
Cleaning in Place
Backup Diesel Generators
Batteries
Household equipment
2 Photovoltaic Solar Panels
Wind Turbines
4 Thermal Solar Panels
Aspects of the Passive House
3 Isolation
Ventilation
Orientation
1 Air Tightness
4
1
2
3

WHAT DO YOU KNOW ABOUT THE PRINCESS ELISABETH STATION ?

1.

AT WHAT TIME OF THE YEAR ARE THERE SCIENTISTS AT THE STATION ?

A.. In the summer, because there is sunlight for 24 hours a day for 3 months and the weather is warmer.

B. In the winter, because there is no daylight for 3 months and the weather is colder.

2.

THE STATION WORKS LIKE A PASSIVE-HOUSE. THIS MEANS:

A. That the main source of heating comes from the sun's radiation.

B. That it is a building that requires little heating because it retains heat very well inside its walls.

C. That it is a very cold building.

3.

THE STATION IS IN ANTARCTICA. ANTARCTICA IS LOCATED:

A. At the North Pole, where polar bears live.

B. At the South Pole, where the penguins live.

C. On the Equator, where palm trees grow.

4.

WHEN THEY TAKE OUT THE RUBBISH AT THE STATION, WHERE DO THEY PUT IT ?

A. They bury it in the ice.

B. They make a big pile and then burn it.

C. It is put in containers, which are then taken away from Antarctica by ship.

5.

WHERE DOES THE STATION'S DRINKING WATER COME FROM ?

A. It is seawater from which salt has been taken away.

B. It is melted snow.

C. It is rainwater.

6.

IS IT POSSIBLE TO BUILD A HOUSE LIKE THE STATION IN OUR COUNTRY - ONE THAT DOES NOT POLLUTE AND NEEDS NO HEATING ?

A. No, you need a very cold climate, like you find in the Antarctic, for it to be possible.

B. Yes. It's much simpler to build a house like that where we live than in Antarctica!

7.

WHAT HAPPENS TO THE WATER FROM THE TOILETS AT THE STATION WHEN THEY ARE FLUSHED ?

A. The water is treated and then reused to do the washing.

B. It goes into a sewer.

C. It is discharged into the ocean.

8.

WHEN THEY GO OUTSIDE THE STATION, THE SCIENTISTS HAVE TO BE DRESSED PROPERLY. WHAT IS THE COLDEST TEMPERATURE IN ANTARCTICA ?

A. 10 °C

B. - 10 °C

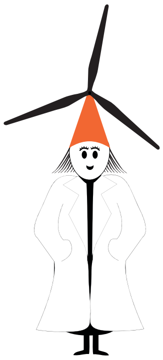
C. - 89 °C

9.

WHERE DOES THE POWER COME FROM AT THE STATION TO RUN THE COMPUTERS, REFRIGERATORS, OVENS AND ALL THE OTHER APPLIANCES ?

A. All of the station's power is supplied by a large diesel-powered generator.

B. The power is generated by the wind and sun. The energy is collected by wind turbines and solar panels.



MY OWN WINDTURBINE !

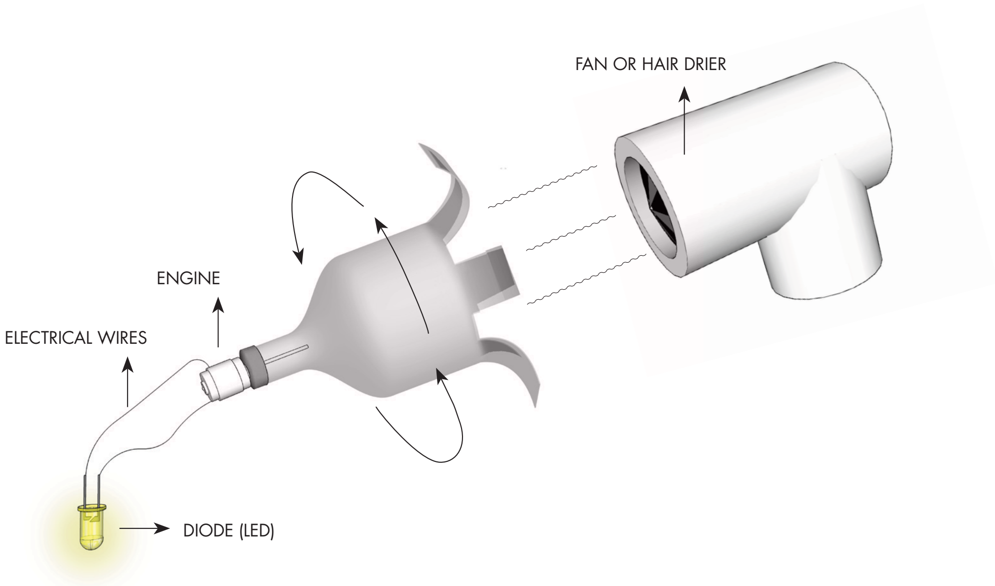
BUILD A WINDTURBINE

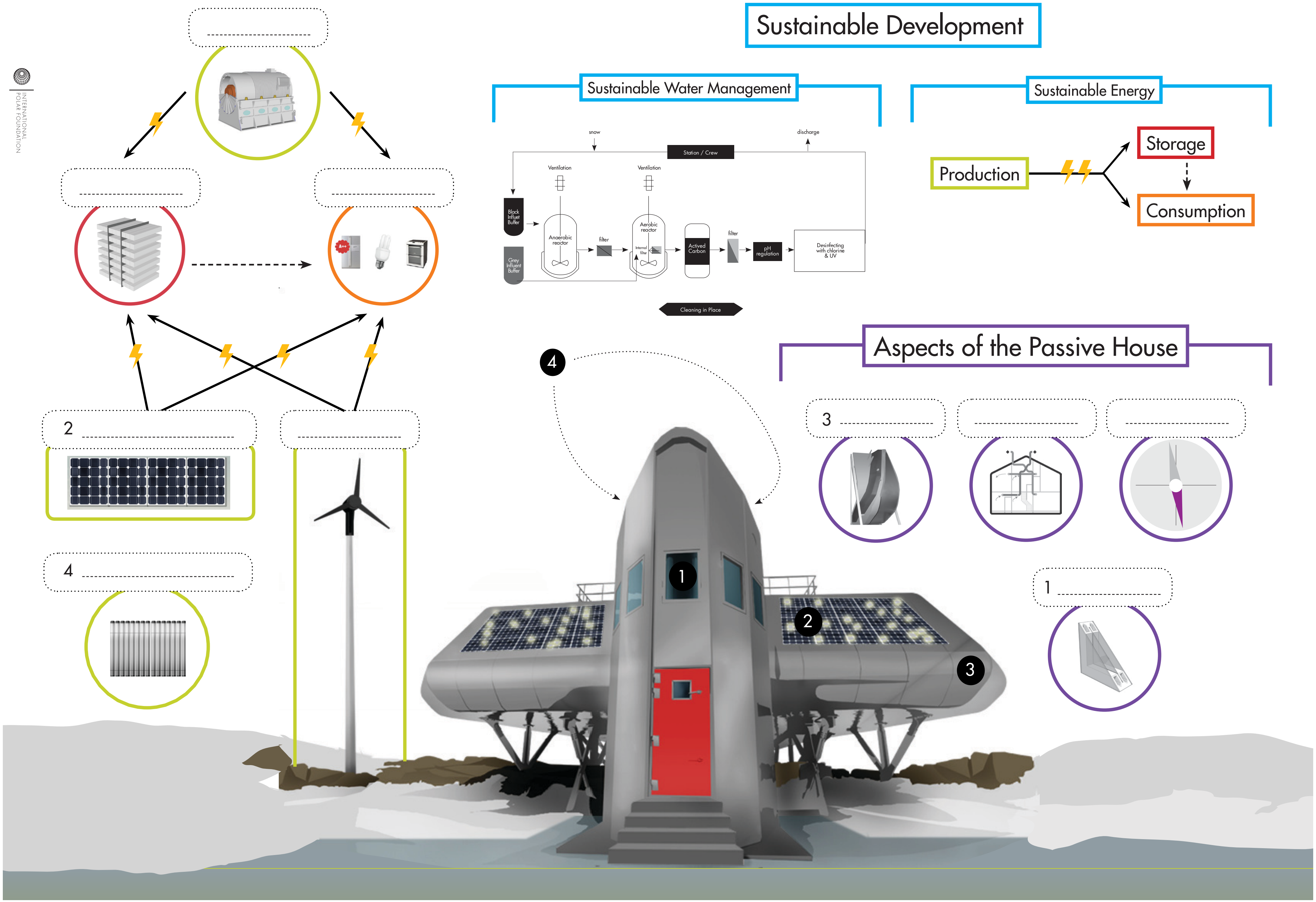
REQUIREMENTS

- A small electrical engine
- Two electrical wires
- A LED (light emitting diode) of 1.5 volts
- A plastic 1.5 litre bottle and cap (choose a bottle made of strong plastic)
- A fan or hair drier
- A pair of scissors
- A compass
- A small nail or tack

THE EXPERIMENT

1. Cut away the bottom of the bottle with the pair of scissors. Make five cuts of 6 cm each, as shown in the image. Fold the blades outwards.
2. Make a hole in the middle of the cap with the sharp point of the compass. Widen the hole with the tack and attach the cap to the axis of the engine.
3. Connect one end of the two electrical wires to the LED and the other to the engine.
4. Plug in the fan or the hair drier and place the screw in the airflow. Watch the LED lamp. If nothing happens, you may need to switch the two elec-trical wires between the engine and the LED lamp.





Sustainable Development
Sustainable Water Management
snow
Station / Crew
discharge
Ventilation
Ventilation
Black Influent Buffer
Grey Influent Buffer
Anaerobic reactor
filter
Aerobic reactor
Internal filter
Actived Carbon
filter
pH regulation
Desinfecting with chlorine & UV
Cleaning in Place
Sustainable Energy
Production
Storage
Consumption
Aspects of the Passive House
3
1
2
4
1
2
3
4
INTERNATIONAL POLAR FOUNDATION