

## Microgeneration – Support sheet

The water treatment works at Glencorse in Midlothian could be used as the context to set the scene for this learning journey. Scottish water are building a water treatment works at Glencorse which will supply up to 175 million litres of clean water a day to residents of Edinburgh and the surrounding area.

The treatment works will use a small scale generator to generate enough electricity for about a third of the plant's energy needs by harnessing the power of the water coming from reservoirs 40km away in the Scottish Borders. The rest of the power will be supplied from the National Grid.

This learning journey could be part of an interdisciplinary project where learners will develop skills in sciences, technologies, maths and potentially other curriculum areas before applying their learning to an engineering challenge.

The teacher's notes below give some further ideas to support the discussions and investigations in the learning journey.

## Engage

### Focus of the challenge

This challenge is aimed at introducing learners to the concept of hydro-electric generation, their function, design and the principles behind how they work. The aim of this challenge is ensure that learners understand these principles and prepare them to put them into practice in further challenges.

### How to approach the challenge

- Provide stimulus to the learners in the form of pictures and videos of water wheels and micro-generators
- Questions the learners, ask them what they notice. Do they have any questions? Could these be answered with further research (this is to be encouraged)
- Discuss energy and energy transfers – concepts which they have met previously.

### Questions to ask:

- What are the main features of water wheels?
  - design - must 'collect' and then 'release' water, must be able to turn etc
  - function – change the potential energy of the flow of water into rotational kinetic energy
  - types (overflow, underflow etc)

Learner responses can be recorded using a mind map and this is where the main misconceptions may be brought forward. Encourage discussion and where possible,

develop the use of proper terms such as kinetic energy rather than 'movement' energy or potential energy rather than 'stored' energy. It is important the learners understand where the energy for the micro-generation is coming from and how it can be converted into useful electrical energy.

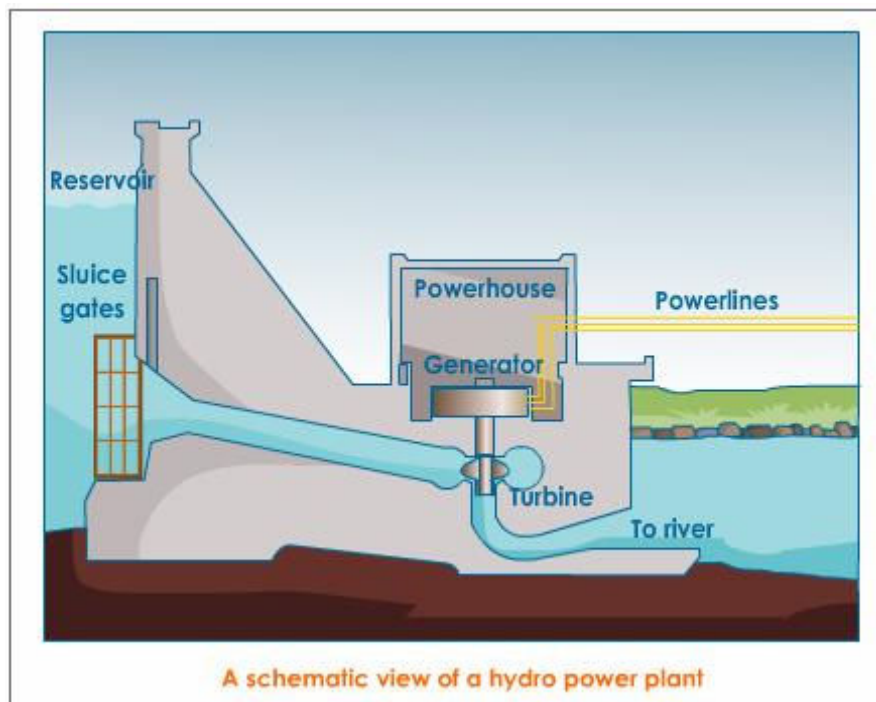
**Matching exercise:** Use card sorting activity (see sheet provided) to find out how much learners know about hydro-electric generation and to help with the flow chart activity.

### Questions to ask:

- What are the energy changes involved? – how are they achieved? (why does the water wheel turn?)
  - turbine/water wheel (potential to kinetic)
  - generator (kinetic to electrical)

The basic design for the hydro-electric generator is developed by the learners throughout this discussion. At the end of the discussion, learners are expected to be able to accurately describe each stage and explain the energy changes involved

### How it fits together



## Explore (1)

### Focus of the challenge

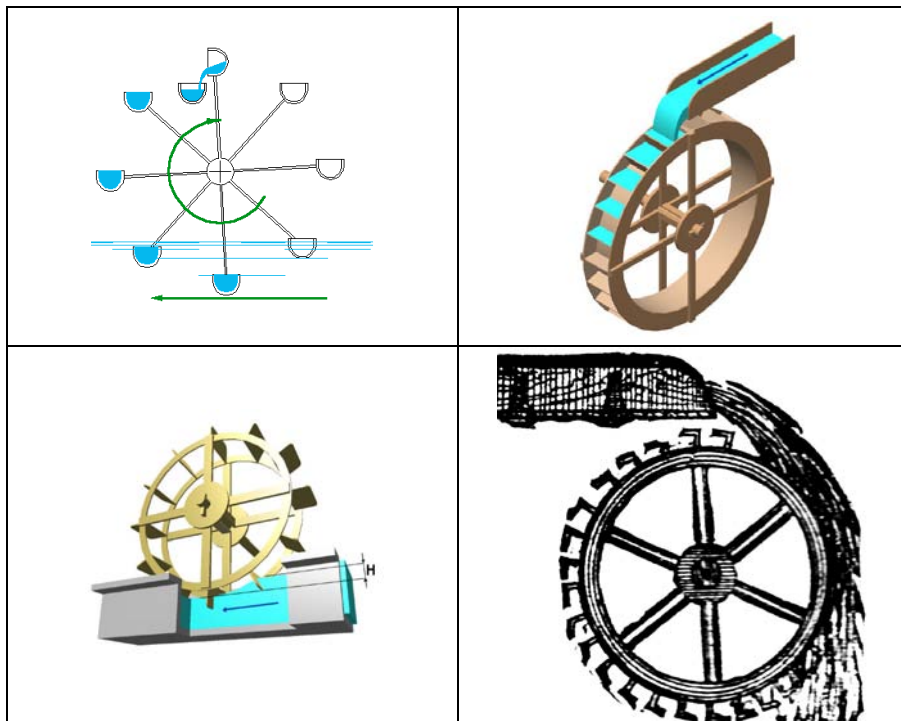
In exploring turbine design, learners should look at the different types of water wheel and design prototypes to test. The main focus of the challenge is providing a practical application for the theory learners will have researched in the previous lesson.

### How to approach the challenge

#### Turbine design

- Re-cap theory covered in previous challenge (refer to pictures/video if necessary)
- Discuss turbine design – what are the options? (see below for some examples)
- Encourage learners the opportunity to discuss the task amongst themselves – this may be an opportunity to provide roles within groups (leader, scribe etc) to facilitate the task

#### Turbine designs



#### Questions to ask:

- What design options are available? (see above)

NOTE: The turbines used in real micro-generators are often a variation on the 'Francis Turbine' (see picture below). It is not practical to make a model of this turbine within a school setting and so learners should be encouraged to look at other designs.



**Francis Turbine**

- What are the key features of the design? (linking to the previous challenge)
- What can I use to build it?

The most important question throughout this challenge is 'why?' At all stages learners should be asked to justify their decisions. Stress that there is no perfect solution to the problem – there is as much to be learned from learners getting the design and construction wrong as getting it right.

NB: An example of how turbines can be tested is given on the next page.

### Water delivery system

This is a good opportunity to open up discussion with learners and bring together some of the knowledge gained from research carried out throughout previous challenges.

In getting started with this part of the challenge, learners should consider the environment around them and the source(s) of the water entering the hydro-electric generator. It is important that the delivery of water is considered in the context of the water treatment infrastructure as well as with turbine design.

### Questions to ask:

- where do we see moving water
  - rivers, streams, from hills, waste pipes
- can water be stored and released in a controlled way
  - reservoirs, dams, tanks
- how do large scale and micro-generation systems differ
  - volume of water
  - delivery

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As stated in the learning journey, the 'best' turbine and the 'best' water delivery system will not necessarily combine to produce the best overall subsystem. In real-life situations turbines are designed *specifically* for a given water source. This provides an opportunity for the groups to share their findings with each other; communications officer is another role which could be allocated at the initial group stage.

## Explore (1)

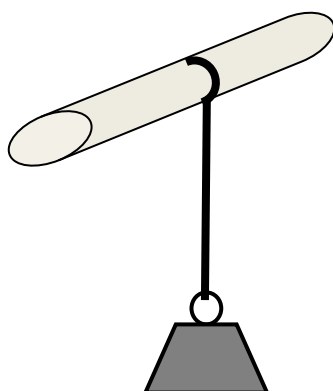
### Testing turbines

Learners should consider the question: “What is the main purpose of a turbine?”

A turbine needs to be able to harness the energy from some a source (such as wind or water) and convert it into useful rotational energy. Ultimately it is how well a turbine can convert this energy which will need to be tested.

This can be done in a number of ways; however it is important to note that with each test the same water supply (volume and application) must be used in order to ensure a fair test is conducted.

- count the number of revolutions produced by the turbine
  - is this a fair demonstration of energy? Think: a mouse moves faster than an elephant but the elephant has more energy
  - how can this be done accurately?
- measure the ability of the turbine to do work (work is a measure of the energy of an object)
  - attach a string and mass to the rotor shaft of the turbine
    - measure how long it takes for the mass to be lifted
    - measure how much mass can be lifted



NOTE: As the mass is lifted it will gain gravitational potential energy; the higher the mass, the greater the potential energy. How long it takes a turbine to lift a given mass is an indication of the **power output** of the turbine (power = energy/time) i.e. the longer it takes, the smaller the power. Measuring how much mass can be lifted by the turbine is an indication of the energy produced by the turbine (potential energy = mass x gravitational field strength\* x height lifted). The consistent use of either method can be used to test which turbine is best for the task.

\*gravitational field strength ‘g’ on earth is approximately 10 N/kg

## Explore (2)

### Focus of the challenge

In this challenge it is hoped that learners will develop an understanding of the basic principles of electromagnetism and the use of these principles to produce electrical energy from kinetic energy.

At the end of the challenge, learners (in groups) will have designed and build a prototype electric generator, be able to explain the principles behind its operation and suggest potential improvements to its design. By considering the previous challenge, learners should be able to integrate this prototype with the water supply/turbine assembly to produce a functioning hydro-electric generator.

### How to approach the challenge

- Introduce electromagnetism by producing an electromagnet as detailed in the references in the learning journey
- Discuss improvements to the design of the electromagnet and start questioning (see below) to develop understanding of fundamental concepts
- Apply principles from the electromagnet and follow instructions referred to in the learning journey to produce a simple electric generator
- Develop understanding further using the theory detailed below (and what was learned when exploring electromagnets) and discuss possible improvements to the generator design
- With reference to the previous challenge, determine the most appropriate design for the generator (appropriate for the water deliver/turbine assembly).

### Questions to ask:

- how can we improve the design of the electromagnet?
  - no of coils, amount of current? (remember safety – too much current and the wire will get very hot)
  - how can we test this? (see how many paperclips you can pick up)
- **explore the link between electricity and magnetism** – What are we providing to the electromagnet to make it work? (current)
  - what is current? (the flow/movement of charges through a conductor).
  - so... if moving charges in a coil of wire can produce a magnetic field, how can we produce current using the same principles? (by moving a coil of wire within a magnetic field OR moving a permanent magnet within a coil of wire.  
*Movement is the connection between electricity and magnetism.*
- after producing the generator
  - how does this work to produce current?

- how could we improve the generator? (strength of magnet, number of coils, (think about what you did for the electromagnet)
    - what are the limits to what we can do (weight, space on rotor)
  - what kind of generator is best for *our* turbine
    - think about how powerful turbine is:
      - can it turn the generator?
      - if not, why not? What can we do to change this?
    - how much current are we producing?
- (at this point teachers should be thinking about guiding their learners towards further experimentation leading to linking the turbine system to the generator system)

## Theory

### Electromagnets

Jefferson Lab – Questions and answers

<http://education.jlab.org/qa/electromagnet.html>

BBC Bitesize – Magnets and electric current

[http://www.bbc.co.uk/schools/ks3bitesize/science/energy\\_electricity\\_forces/magnets\\_electric\\_effects/revise1.shtml](http://www.bbc.co.uk/schools/ks3bitesize/science/energy_electricity_forces/magnets_electric_effects/revise1.shtml)

### Building a simple electric motor

Ultra-simple Electric Generator

<http://www.eskimo.com/~billb/amateur/coilgen.html>

### Generator theory

DIY Electric Generator

[http://amasci.com/coilgen/generator\\_2.html](http://amasci.com/coilgen/generator_2.html)

## Explain/Evaluate

### Focus of the challenge

In this challenge it is hoped that learners will develop an understanding of some of the fundamental relationships involved with energy transfer/loss

At the end of the challenge, learners should be able to appreciate that the amount of energy they can obtain from a water source will be directly proportional to the mass of the water provided and the height from which it is being delivered. Learners should also be aware of energy losses through friction as well as the main energy transfer being considered; potential to kinetic energy in the turbine.

### How to approach the challenge

- Question learners and ask them where the turbine is getting energy from and use this as an opportunity to remind them of the definitions for gravitational potential and kinetic energies.
- Discuss how we could get more energy in or out of the system, energy losses and variables that could be changed to modify the system.
- Get learners to design a set of experiments to test the variables they have discussed.
- Learners can use the results of their experiments (through graphing and guidance from teacher) to develop simple relationships for energies and the variables investigated e.g. gravitational potential energy is directly proportional to height.
- Use the relationships explored to adapt water delivery/turbine system.

### Questions to ask:

- where does the turbine get energy from? – (water supply)
  - what do we call this kind of energy?
  - how is the energy transferred to the turbine? What form of energy is this?
- how can we get more energy
  - into the system? (change water delivery), out of the system? (change turbine)
  - is all of the energy being transferred? (think about losses)
- what variables can we investigate to improve the systems?
  - mass/volume of water
  - height of release
  - design of turbine (does it capture all the water)
  - friction in the turbine (how can we reduce it)
- how can we investigate these variables? (experiments)
- how can we best analyse the results? (graphing), what relationship do we see?

## Theory

Potential Energy

<http://www.youtube.com/watch?v=Rn470XtSYK0>,

Kinetic Energy

<http://www.youtube.com/watch?v=zhX01toLjZs&feature=related>

Converting Potential Energy to Kinetic Energy

<http://www.youtube.com/watch?v=AhhgCOlonwl&feature=related>

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## Elaborate

### Focus of the challenge

In this challenge it is hoped that learners will get a better idea of the 'bigger picture' surrounding hydro-generation.

### How to approach the challenge

- Start off by discussing some of the issues learners have explored in previous challenges
- Think about where and when micro-hydro-generators would be useful
- **Investigate.** If hydro-generators are so great, why aren't they used more – investigate the possible negatives of hydro-electric generation.
- By focusing on one aspect of micro-generation (sustainability, ecological impact etc) write a report/give a presentation on how that aspect has impacted on the use of hydro-electric generation throughout the UK

### Questions to ask:

- What are some of the factors which affect the use of a hydro-generator?
  - think back to the other challenges – water source, how much energy is produced, placement....
- What are the advantages of using hydro power? (on large and small scales)
  - no emissions, renewable etc...
- What are the disadvantages of using hydro power?
  - may require damming, or diversion of water source – this could affect ecological system
  - is it reliable?
  - how much does it cost to install; run; maintain.
  - will I make my money back?