urban science

Living Walls

Students investigate issues surrounding the conservation of energy and calculating energy efficiency. They explore these using the context of a living wall and how these can be used in contemporary school buildings to reduce carbon emissions.

A curriculum linked learning module for students aged 13-15 to develop competences in working scientifically.

Learning challenge: Living Walls

Living walls are becoming more common in our cities, but how can these improve both energy efficiency and local biodiversity? This is important because energy use in buildings is one of the leading contributers to global carbon emissions.

In this module students are inspired to experiement with different ways to improve building insulation, and how a living wall offers both a practical and beautiful solution. In addition, they will become aware of the interlinked nature of energy and biodiversity issues. They will also research how plants can reduce air pollution.

A significant challenge for the teacher is to enable their students to get meaningful results for their required practical investigations. We have, therefore, created a framework (Stage 2) to allow this to happen within a rich diverse context. We describe a local scenario, with some flexibility for students to be creative.

The learning module can be used flexibility within the curriculum to support key knowledge about physics and develop working scientifically competences. The learning links with the Sustainable Development Goals and provides a broader context for student learning. Also suitable for adapting as a STEM activity or Eco Club.

www.urbanscience.eu

Co-funded by the Erasmus+ Programme of the European Union

To deliver this module we recommend:

- Start with the Stage 1 activities to elicit current student understanding. Start a messy wall to record student work throughout.
- Use the Stage 2 activities to introduce the context for the Stage 3 challenge.
- Stage 3 is the practical challenge where students gather data and make conclusions.
- In Stage 4 you will provide suggestions for sharing and presenting results.

Subject

Biology	Chemistry	Physics	Raising Attainment
		✓	✓

Programme of Study reference

• Physics	Energy • energy changes in a system involving heating, doing work using forces, or doing work using an electric current: calculating the stored energies and energy changes involved. • conservation of energy in a closed system, dissipation. • calculating energy efficiency for any energy transfers. • renewable and non-renewable energy sources used on Earth, changes in how these are used.	• Working scientifically	Students successfully completing this module will have had the opportunity to access these statements: 1b,1d,1f,2a,2b,2c,2d,2f,2g.3ai, 3aiii,3av,3avi,3avii,3b,4a,4b, Some will also have completed the following: 1c,1e. See Annex 1 for full statements.

Sustainable Development Goals

All Urban Science modules try to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all' and in addition focus on education for sustainable development and global education - SDG 4.7. Further support and resources here:

http://www.teachsdgs.org/

This module has strong links to SDG 3: Ensure healthy lives and promote well-being for all at all ages; SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; and SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable.

3 GOOD HEALTH AND WELL-BEING | 4 QUALITY EDUCATION | 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE | 11 SUSTAINABLE CITIES AND COMMUNITIES

Activities Overview

Stage 1	Time (mins)	Resources needed
Living Walls Exhibition	40 mins	Student Sheets 1 and 2
Thinking Hats	20 mins	Student Sheet 3

Stage 2	Time (mins)	Resources needed
Creating a Living Walls Poster	40 mins	Student Sheets 4, 5 and 6
The 'X school living wall project ' – pre research and planning	20 mins	None required

Stage 3	Time (mins)	Resources needed
To Insulate or Not to Insulate?	60 mins (need to construct houses in advance)	Details to build kit house and plants to purchase contained within lesson

Stage 4	Time (mins)	Resources needed
Scientific Reporting	60 mins	Student Sheet 7

Health and Safety: please refer to the guidance provided on the Urban Science website before commencing the module.

www.urbanscience.eu/uk/learning-modules/health-and-safety/

STAGE 1 - Living Walls

Inquiry based learning stage

Stage 1 - Initiating and eliciting	✓	**Stage 2 - Defining and responding**	
Stage 3 - Doing and making		**Stage 4 - Communicating, presenting and evaluating**	

Learning objectives

1. Students are able to find out information relevant to the topic.
2. Students can make predictions about their future.

Learning outcomes

1. Students discuss the key scientific facts about energy efficiency.
2. Students analyse information using a critical thinking technique - De Bonos Thinking Hats.

Overview of lesson

In this lesson, students views of buildings and their impact on cities and climate change are elicited using readily available data. They are also given examples of successful insulated buildings including living wall structures and how they are having an impact in cities.

Lesson structure

Introduction:

There are several videos that introduce the topic of living walls:

Living wall videos

https://www.youtube.com/watch?v=Owel8LjIV3Y

Air pollution focus

https://www.youtube.com/watch?v=CcAAeGpLN4c

Energy efficiency

https://greenroofs.org/about-green-walls/

https://www.ambius.com/green-walls/ultimate-guide-to-living-green-walls/

Main 1: Living Wall Exhibition

This activity provides students with an exhibition about living walls, and asks them to interrogate it using the A-Z technique (see Student Sheet 1). This is intended as a quick familiarisation activity.

Print the exhibition from Student Sheet 2* and display in the classroom in advance of the lesson. The exhibition information has been sourced to lead students towards an understanding of the importance of buildings and their energy use on carbon emissions. It then shows the importance of insulation to energy efficiency before finishing with examples of both Passive Haus (highly insulated) and other schools that have living walls.

It is helpful to review students previous work on climate change and greenhouse emissions before starting.

we are particularly grateful to Architype (architype.co.uk) and the Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain who both suppied images for the exhibition.

Main 2: De Bono's Thinking Hats

Split the students into groups according to a 'thinking hats' perspective in order that they can more deeply analyse the exhibition and the implications for UK buildings. This is a critical thinking tool developed by Edward De Bono. It involves using a 'hat' (metaphorical or real) to encourage thinking about an issue with a specific focus. There are six thinking hats in total with each hat offering a different focus. Also, included below, are some teacher facilitation questions to guide students to think in this way. See Student Sheet 3.

Red hat - Feelings and emotions
- Based upon my emotions, do I think this is a good idea?
- How do I feel about these approach/ these ideas?

White Hat - Information and Facts
- What facts, data, and information do we have?
- What facts, data, and information do we need?
- What information is missing?

Yellow Hat - Positives and Strengths in relation to the issue being considered.
- What are the strengths of these ideas
- What are the positive benefits.

Black hat - Problems in relation to the issue being considered
- What are the weaknesses?
- What may go wrong if we implement these ideas?
- What are the potential problems?

Green Hat - Creativity and New Ideas
- What alternative solutions are possible?
- Could a recommendation be done in another way?
- What is a unique way of looking at the issue?

Blue Hat - Planning and organising ideas.
- Where do we start?
- What things should we do first?
- What could be the 'action plan' and next steps for these ideas?

Each of the 'hat groups' feeds back their results to the whole group.

Continued on page 6...

Lesson in detail

When is a wall not a wall, when it is alive!

Lesson structure (Continued)

Plenary: The messy wall

Create a messy wall (sometimes referred to as a working wall) where student ideas and questions can be displayed alongside key scientific concepts. You can extend this technique to include the images and student ideas from the living wall exhibition activity. Ideally this becomes a public exhibition for everyone in the school and added to over time.

Photo by Scott Webb on Unsplash

Starter activity: 'Alphabet square' *(A variation)*

Resources: Students need a pen and an A-Z grid each.

1. Tell students the topic/subject they are working on.
2. Ask students to write down key vocabulary / key terms that they know about the topic. One word or phrase for each letter of the alphabet.
3. Set a time for the activity.
4. Discuss and collect answers from the class or put students into twos then fours … to build up answers.

There is a copy of an Alphabet Square on next page…

Student Sheet 1 - A-Z Grid

Topic: .... **Name:** ....

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P
Q	R	S	T
U	V	W	X
Y	Z	**Instructions:** 1. When you have completed a topic, write down as many key words as you can from memory. 2. Compare your list with a partner and add anything that you may have missed.	

Student Sheet 2 - Exhibition

Climate science graphics

By the end of October 2015, 146 countries had submitted national climate plans on curbing emissions that are expected to form the cornerstone of a binding, global treaty on climate change.

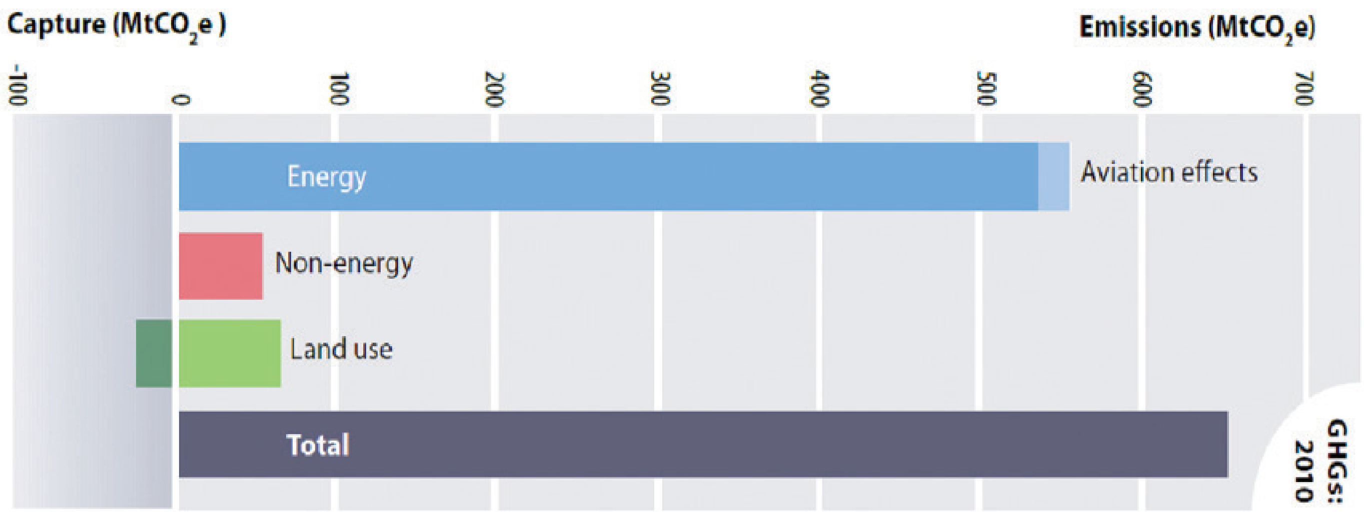
According to a UN report, submissions in their current form point to a rise of 2.7°C above pre-industrial levels by 2100.

Scientists have determined that if temperature rises surpass 2°C, this will lead to substantial and dangerous climate impacts, which will hit the world's poor in particular.

Average warming (°C) projected by 2100

Source: Climate Action Tracker, data compiled by Climate Analytics, ECOFYS, New Climate Institute and Potsdam Institute for Climate Impact Research. Copyright © 2019 by Climate Analytics and New Climate Institute.

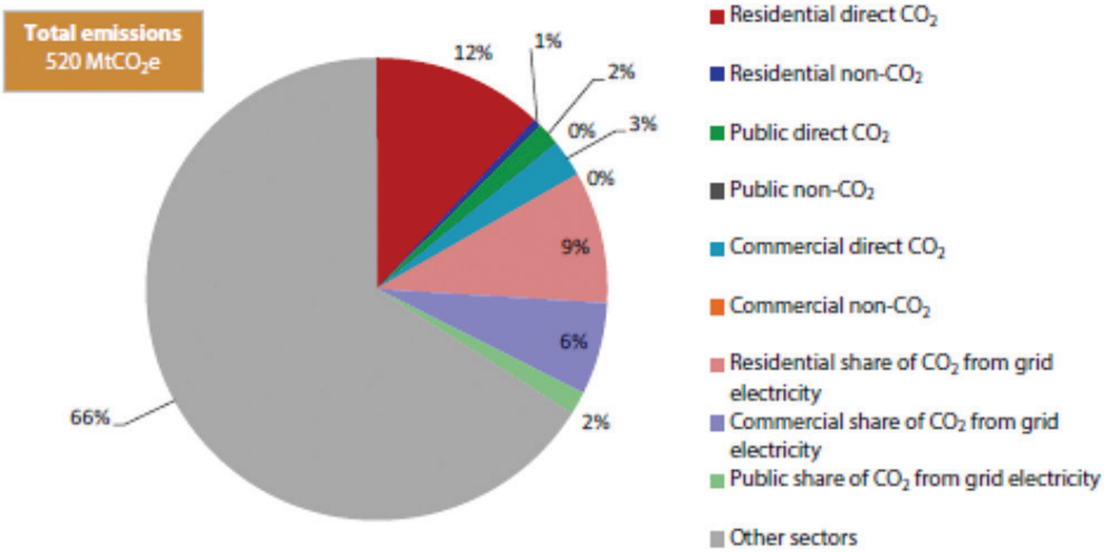
UK Greenhouse Gas Emissions



Source: Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain.

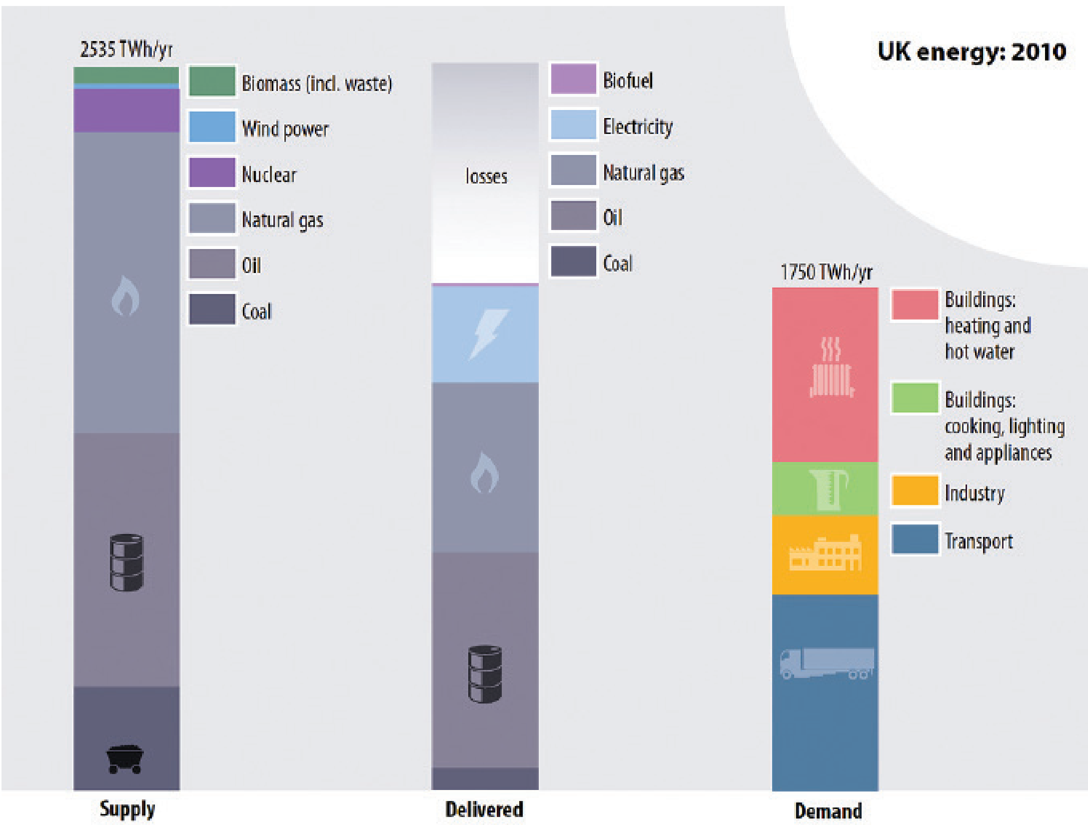
GHG emissions from buildings in the context of total UK emissions in 2014

This is a more up-to date graph that shows the how 34% of our total energy demand is accounted by buildings. Of this 62% is made up of residential and public buildings (for example schools)



Source: DECC (2015) Energy Trends, March 2015.

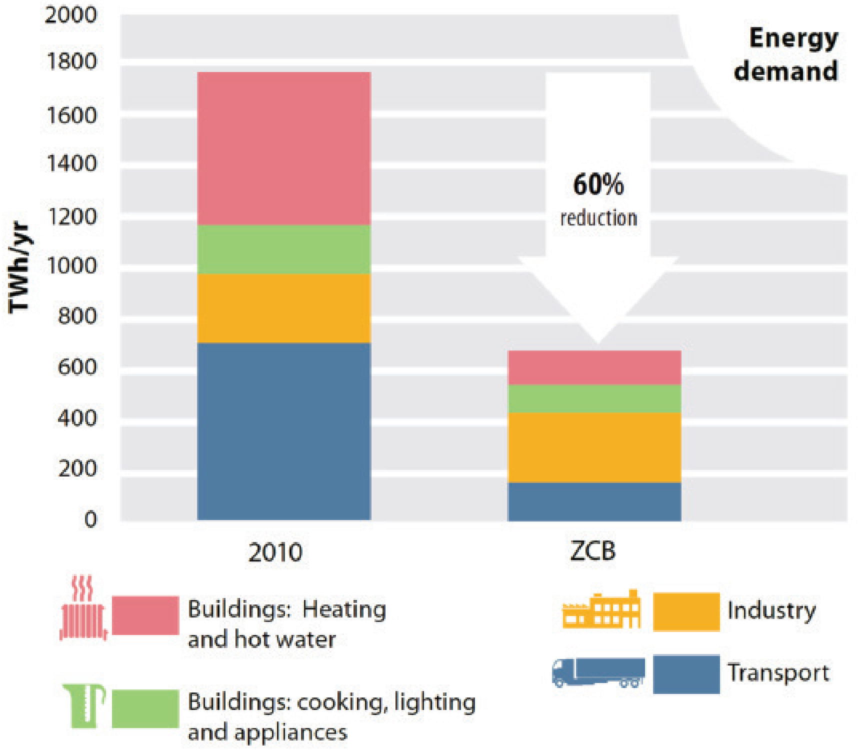
In this graph you can see the large proportion of energy demand that comes from buildings.



Source: Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain.

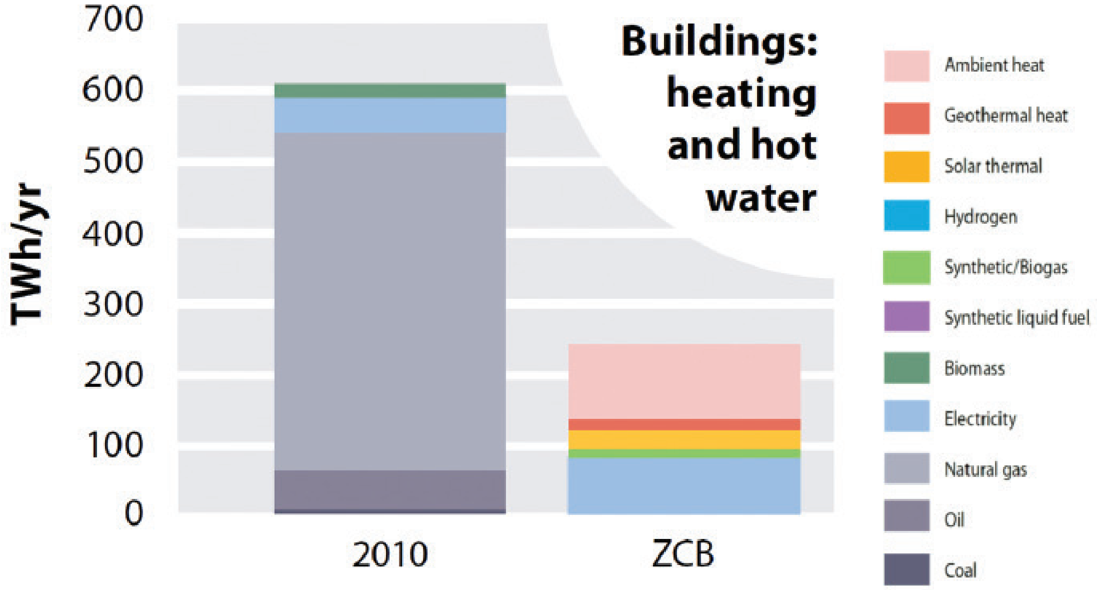
Student Sheet 2 - Exhibition (continued)

Zero Carbon Britain is a project that has analysed how to get our GHG emissions to zero. In this graph it shows how this can be achieved by deep cuts in the energy demand for buildings.



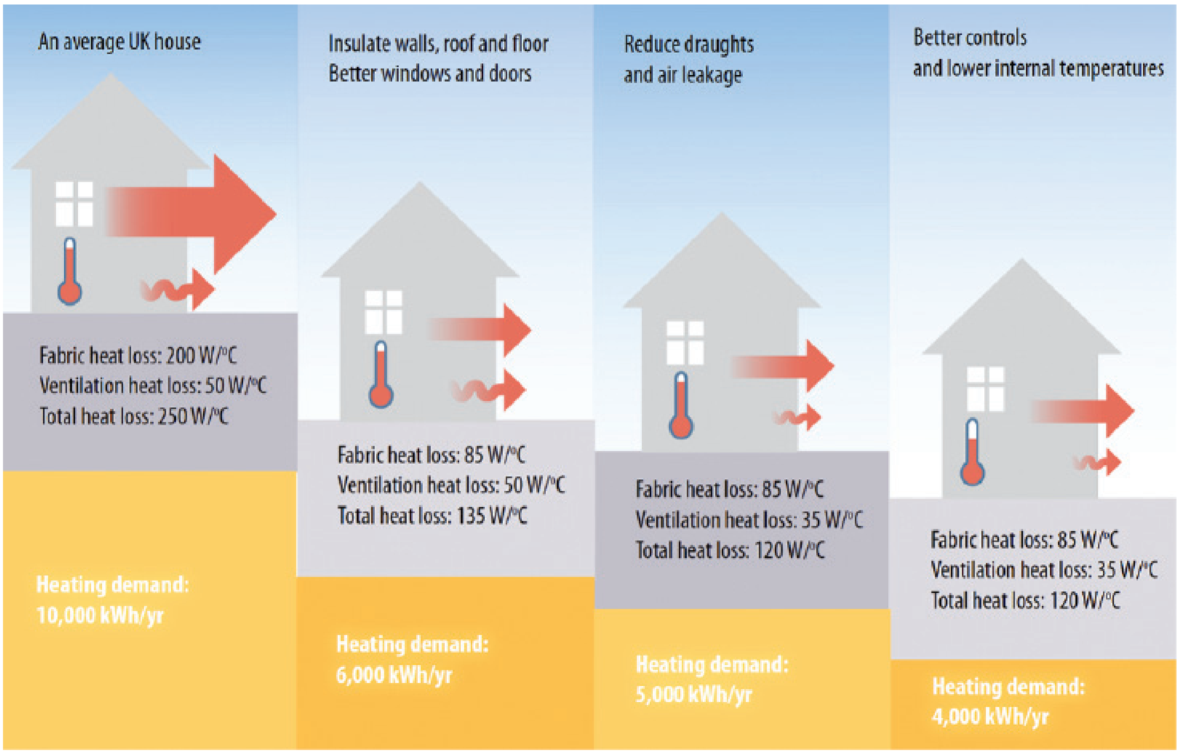
Source: Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain.

How will these buildings be different?



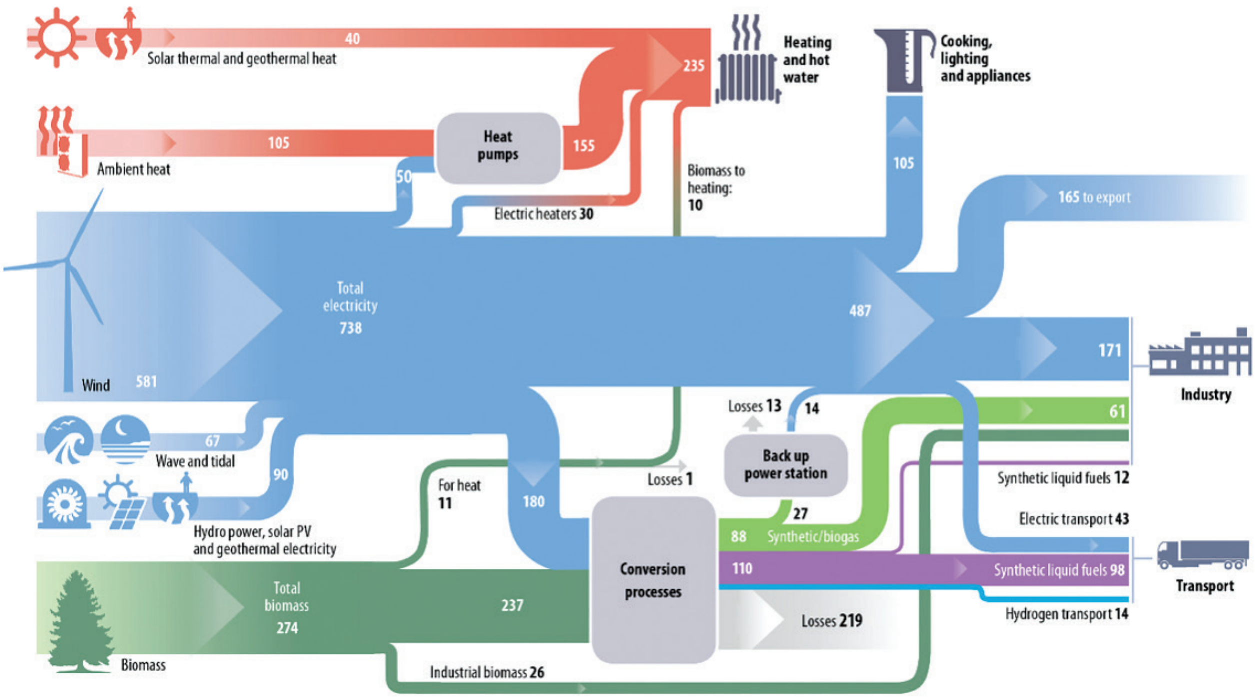
Source: Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain.

This is a key diagram - notice the big impact of insulating the building.



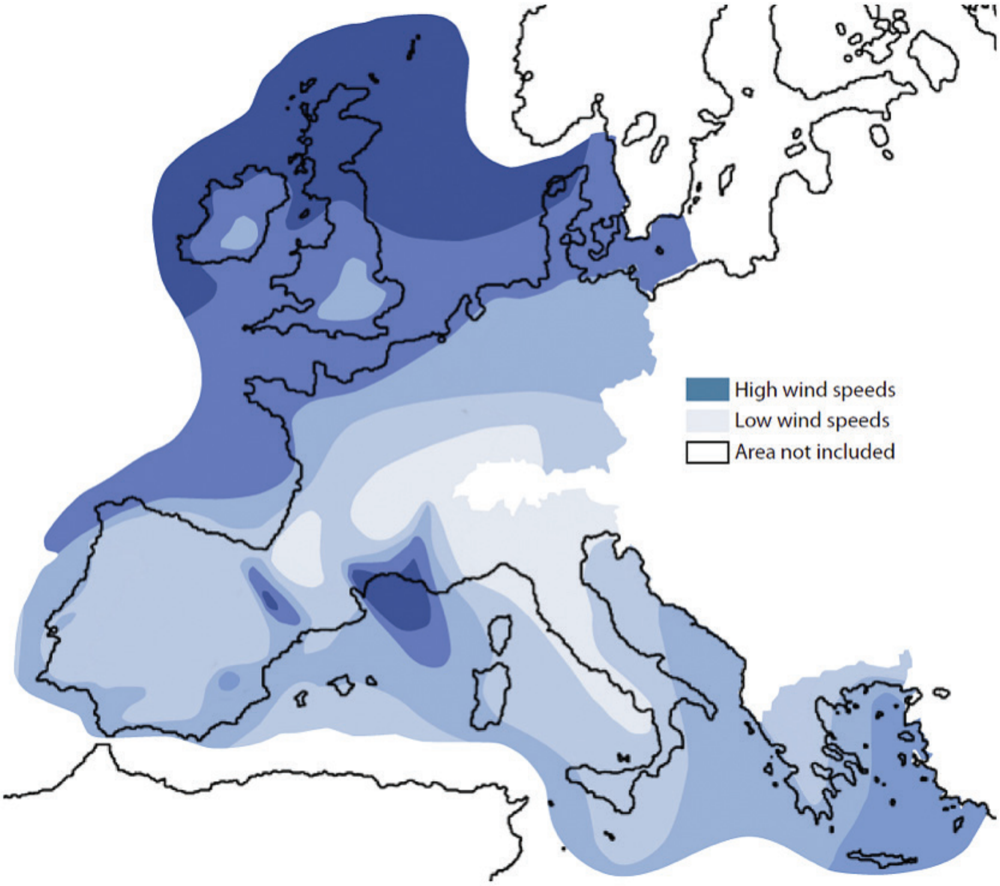
Source: Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain.

This diagram explains what describes an alternative energy make up for the UK including using more renewables and 'ambient'. Also note how much wind energy is used.



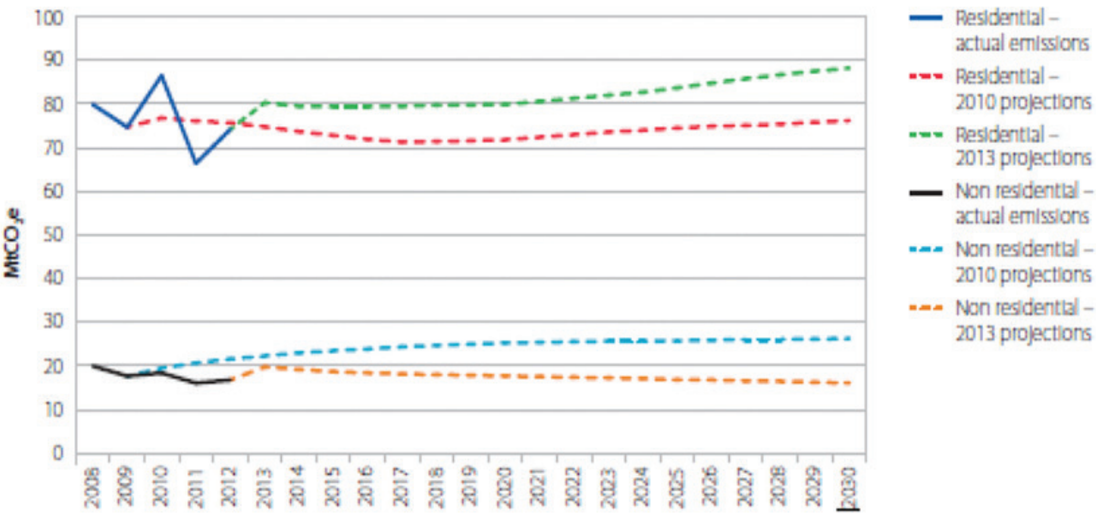
Source: Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain.

We are such a windy Island!



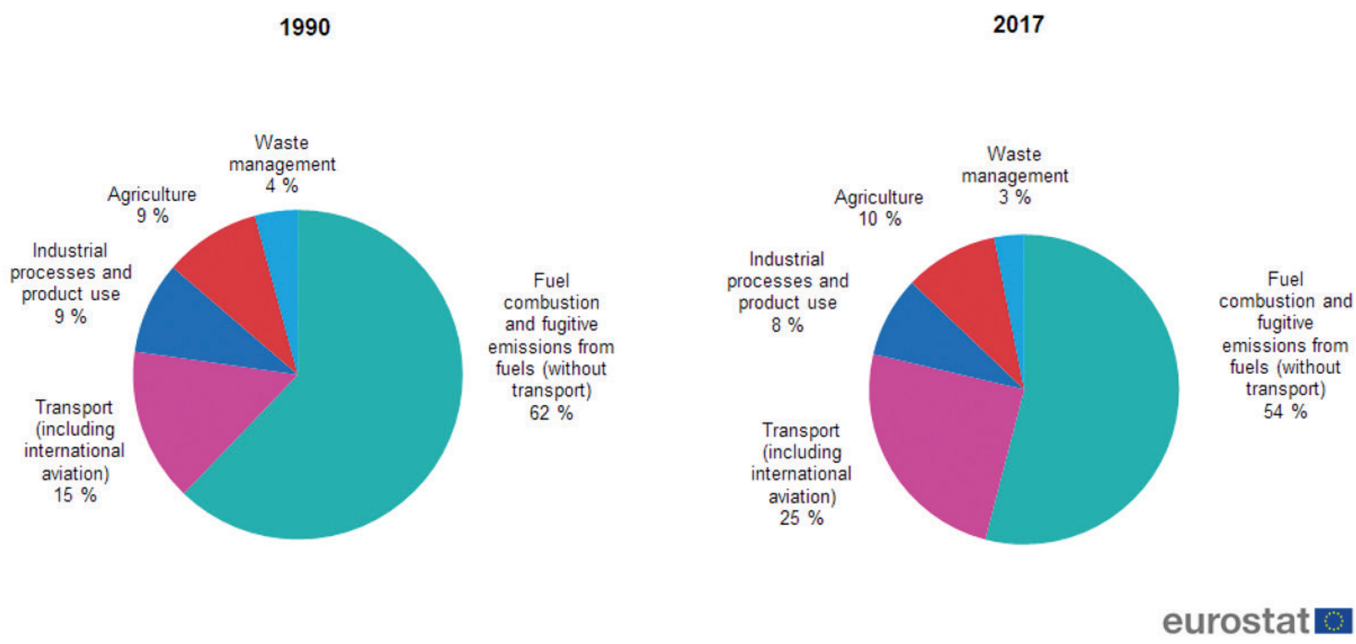
Source: Centre for Alternative Technology (www.cat.org.uk) – Zero Carbon Britain.

This graph shows the large proportion of emmisions of residential buildings compared to non residential buidlings. How we use energy in our buildings is so important.



Source: DECC (2013)

Greenhouse gas emissions, analysis by source sector, EU-28, 1990 and 2017
(Percentage of total)



Source: European Environment Agency (online data code: [env_air_gge])

What do these graphs tell us about building energy use ?

Source: European Environment Agency (EEA) – copright holder; (https://www.eea.europa.eu/legal/copyright).

Sustainable School Buildings

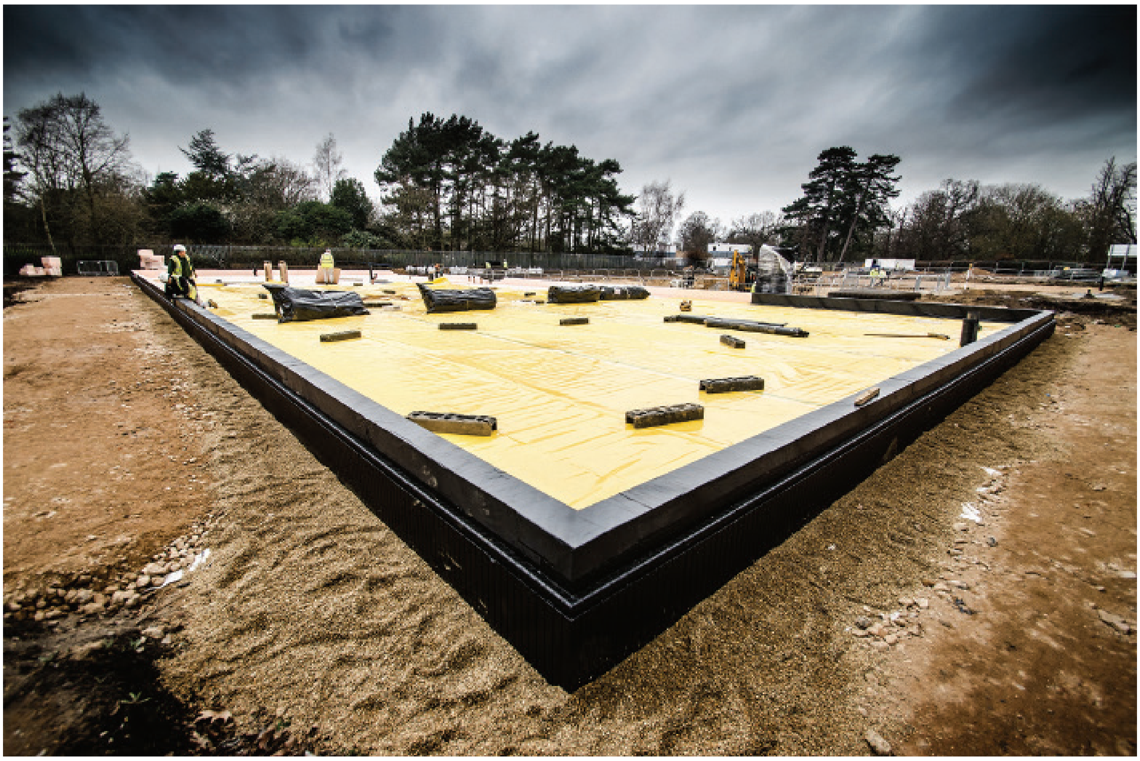
These are examples of buildings that are designed to have very low carbon emissions.

South Elevation: Large windows to enable thermal gains.

North Elevation: Smaller windows to reduce thermal losses.

Insulation

A sustainable 'energy efficient' structure has high levels of insulation not normally seen in the finished building. These are pictures of underfloor 'slab insulation'. The most efficient will also have high levels in the walls and the roof.



We are grateful to Architype (architype.co.uk) for these images; all copyrights retained by Architype.

Brettstapel Panels

This relatively simple method of construction does not use glues or nails and can be used to make beautiful, low carbon, healthy buildings that are quick and easy to build.

http://www.brettstapel.org/Brettstapel/Home.html

Brettstapel is the term commonly used for solid timber construction that does not generally use glues or nails. Fabricated from softwood timber posts connected with hardwood timber dowels, this relatively simple method of construction has the potential to utilise low grade timber that would otherwise be unsuitable for use in construction, to form load-bearing solid timber wall, floor and roof panels.

The system works by using dowels with a moisture content lower than that of the posts; over time the dowels expand to achieve moisture equilibrium thus 'locking' the posts together and creating a structural load-bearing system.

With Brettstapel normally manufactured entirely out of untreated timber, it is important to stress that glue is not necessary. The exclusion of glue and nails (which are seen in other solid timber systems) means a healthier indoor air quality can be achieved, while the timber itself locks in vast amounts of carbon dioxide.

We are grateful to Architype (architype.co.uk) for this image; all copyrights retained by Architype.

Student Sheet 2 - Exhibition (continued)

Energy systems

The boiler room

This is sometimes known as the 'plant room'! Here an energy efficient building will have very high tech equipment and it is where the building is kept cool in the summer and warm in winter. Note the copious amounts of insulation on all of the pipes.

Renewable energy

Some schools where appropriate will have renewable energy sources to provide power. Indeed, there are examples of schools that are so well insulated, controlled and with so much renewable energy they are called 'energy +'. These schools generate energy and provide power for their local community.

We are grateful to Architype (architype.co.uk) for these images; all copyrights retained by Architype.

Student Sheet 2 - Exhibition (continued)

Controlling the temperature of the building

Brise Solei

https://en.wikipedia.org/wiki/Brise_soleil

This is most commonly used to prevent facades with a large amount of glass from overheating during the summer. Often louvers are incorporated into the shade to prevent the high-angle summer sun falling on the facade, but also to allow the low-angle winter sun to provide some passive solar heating.

Electronic controls

Efficient controls enable buildings to work at an optimal level.

We are grateful to Architype (architype.co.uk) for these images; all copyrights retained by Architype.

Living walls

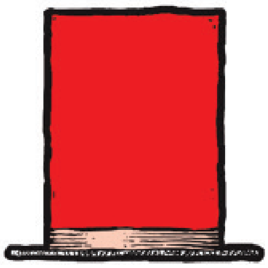
Living walls can be good insulators and keep buildings cool in summer and warm in winter. They are also good for biodiveristy and have been shown to reduce the impact of air pollution. Some plants are better than others – which are the best ones to use in our experiments?

The plants on this living wall are found on Swansea Bay University ‘Active Classroom’. These were grown and planted by a local school - to quote from their website.

https://www.ukgbc.org/ukgbc-work/specifics-active-classroom-swansea-university/

‘A living wall on the east elevation showcases a collection of native species present in the adjacent Site of Special Scientific Interest (SSSI) and some of the plants are being transplanted around the campus and within the SSSI to boost the decreasing number of certain species, such as Sea Stock. It also provides a visual feature elevation and has helped engage people with the building highlighting the connection between the built and natural environment. It has been particularly successful in helping to engage young people in the work being undertaken at SPECIFIC.’

Student Sheet 3 - Thinking Hats

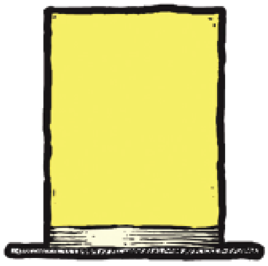


Red Thinking Hat - Feelings

- How does this exhibition make you feel?
- What do I like about it?
- What don't I like about it?
- What are my likes, dislikes, worries, concerns etc?

White Thinking Hat - Information and Facts

- What information do I have?
- What are the facts?
- What information do I need?
- What do I want to know?



Yellow Thinking Hat - Strengths

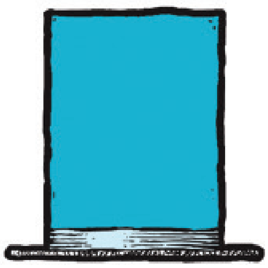
- What are the good points of the exhibition?
- Why can we do this?
- Why is this a good thing?
- What are the strengths/benefits?

Black Thinking Hat - Problems and Limits

- What is wrong with these?
- Will they work?
- Are they safe?
- Can it be done?

Green Thinking Hat - Creativity & New Ideas

- What new ideas are possible?
- What is my suggestion?
- Can I create something new?
- What are the weaknesses?



Blue Thinking Hat - Planning and Managing

- Do you know of any such buildings?
- Where are we now in this school/in the UK?
- What are the next steps to get more?

STAGE 2 - Living Walls

Inquiry based learning stage			
Stage 1 - Initiating and eliciting		**Stage 2 - Defining and responding**	✓
Stage 3 - Doing and making		**Stage 4 - Communicating, presenting and evaluating**	

Learning objectives

1. By learning in a practical way about insulation and sustainable energy design, students will gain an understanding about the fundamentals of energy transfer, namely:
    a. Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.
    b. Energy transfers in a closed system, that there is no net change to the total energy.
    c. How in all system changes energy is dissipated, so that it is stored in less useful ways; this energy is often described as being 'wasted'.

Learning outcomes

1. Students explore the following concepts and then transfer this learning to their peers
    a. Living walls and air pollution.
    b. Heat islands and cities – how a living wall helps.
    c. Insulation principles and living walls.
2. Students are part of a group that creates a poster describing the features of a living wall.
3. Students describe with examples where there are energy transfers in a closed system, that there is no net change to the total energy.
4. Students start to design and plan their living wall investigations.

Overview of lesson

The students are informed that the headteacher has been inspired by the exhibition and has obtained/ is looking for funding to build a living wall as part of a new build school project. He wants the students to improve the exhibition to describe this to the governing body and he also needs some experimental results to convince them. The students create posters that can be used in the exhibition. They also create a design brief after further learning about sustainable energy design.

Lesson structure

Introduction

A letter from the Head Teacher is the starting point for Stage 2. You could exchange this with a letter from a building company working locally or other suitable stimulus.

Dear students

I was so impressed by the exhibition. I particularly liked the beautiful living walls and have come across some funding which could be used to build a living wall in our school. To get the funding, however, we will need some evidence to persuade them to give us the money. We will need to demonstrate:

- How will a living wall help stop climate change.
- How it will help us with our local biodiversity.
- How it will help us with our heating bills.

Can you provide us with some experimental results and some answers to these questions?

Yours sincerely

The Headteacher

Main 1: Creating a living wall poster

Students undertake a group task using the 'Market Place' technique that enables them to understand more about the background of sustainable building design and in particular the science behind a living wall. This technique works well when, as is the case here, there is a large amount of new information for students to learn. In this way the teacher moves away from a more direct instructional role to one of facilitator. Although it takes some time in terms of preapring the source material, students respond in a positive way. Their expert group is the only group dealing with the 'vitally important information' which they are privy to. An important part of the technique is a focus on converting the text to pictures or diagrams to create a group poster. This ensures proper scrutiny of the source material. It can also be an opportunity for re-organising groups for gender abilities, etc.

1. Each group will produce a visual display/poster describing a living wall using the 'Market Place' resources provided (see below). These are:
   - Living walls and air pollution (see Student Sheet 4).
   - Heat islands and cities – how a living wall helps (see Student Sheet 5).
   - Insulation principles and living walls (see Student Sheet 6).
2. Limit the amount of text used and encourage students to use diagrams and pictures to explain these ideas.
3. One member of the group (the stallholder) stays with the display while the others (researchers) go out in the marketplace to visit other 'stalls'.
4. The stallholder can explain the visual display but only as answers to questions posed by the 'researchers'. Researchers make notes as appropriate.
5. All return to their 'stall' and feedback to their team in order to be ready to describe to the whole group via a poster.
6. Each group then presents their posters to the whole class.

Continued on page 24...

Lesson structure (Continued)

Main 2: The 'X school living wall project ' pre research and planning

This section of Stage 2 ineveitably strays into the Stage 3 research part of the module. Stage 3, however, really benefits from a pre trial and some initial thoughts.

1. Refer back to the headteacher letter and that in order to answer these question they will need to carry out some tests.
   - How will a living wall help stop climate change?
   - How it will help us with our local biodiversity?
   - How it will help us with our heating bills?
2. The detail for their tests is outlined further in Stage 3, but explain that they will:
   - Build and test model houses and look at insulation.
   - Add plants to the walls and re-test. Some will also look at air pollution and the impact of these plants.
3. Describe and show students the posssiblities that will be available to them. There are a number ranging from very simple 'cardboard box' plans:

   http://designcoalition.org/kids/energyhouse/pdfs/experiments.pdf

   to detailed nets:

   https://en.seacs.eu/energy-house-kit-secondary-primary-schools/
4. Show a video that explores these concepts for example:

   https://www.bbc.co.uk/programmes/p0118n4j

Allocate the working teams for their Stage 3 research activity aiming for a mixture of their skills: scientific, communication and creative. If the Stage 3 activity is to take the place of the GCSE Required Practical then all students will need to do the core tests on insulation. However, if not there can be some flexibility in the planning briefs and groups could be allocated differing tasks. For example, air pollution tests, sourcing appropriate plants, etc. Students then start to plan the designs for their experiments in order to answer the questions posed by the headteacher letter.

Review initial group plans and discuss equipment needs for the next session.

Student Sheet 4 - Living Walls and Air Pollution

Air pollution and plants in urban areas

Air pollution is a major issue in many cities throughout the world. While reducing emissions at the source is the best way to address air pollution, plants can play an important role in mitigating air pollution. This is a relatively new scientific research area , however, the Museum of London has collaborated in producing this 'Phyto Sense' tool kit:

https://www.museumoflondon.org.uk/discover/phyto-sensor-toolkit-citizen-sense-air-pollution

which has everything you need to investigate and learn more about this important topic.

This Phyto-Sensor toolkit provides resources for learning how to make your own air quality garden. The Phyto-sensor toolkit was tested and refined through a public workshop and walk held at the Museum of London in March 2018 to investigate the ways in which vegetation can improve air quality.

The handbook describes information on air pollution, air quality plants, and planting scenarios. To quote:

Numerous studies have now established that vegetation can play an important role in mitigating air pollution. Trees and plants can capture particulate matter, absorb gaseous pollutants, and also phyto-remediate soils. In addition, vegetation can enhance biodiversity, capture stormwater and reduce flooding, and lessen the urban heat island effect. One study undertaken by the Nature Conservancy, "Planting Healthy Air" (McDonald 2016) found that urban trees could make a significant local improvement in air quality by reducing particulate matter levels between 7 to 24 percent. These effects were most notable within 100 meters of a planting. Additional studies from Imperial College (Shackleton et al. 2012) have shown that vegetation, such as shrubs and perennials, planted near or as barriers to emissions sources can also make a positive contribution to lowering particulate matter levels and absorbing some gases such as nitrogen dioxide. A King's College London report (Tremper et al. 2015) further documents how an ivy screen contributed to the reduction of pollution levels near a playground, with nitrogen dioxide lowered between 24 to 36 percent, and particulate matter 10 levels lowered by between 38 to 41 percent in the immediate proximity of the screen. Strategies for reducing pollution at source by removing polluting vehicles and cleaning up fuel for heating are the most important place to start when working to improve air quality. However, urban planting can make a clear contribution to improving air quality and urban ecologies more generally.

Other sources of information

This newspaper article details lots of up-to-date examples of how plants can be used to make living walls and the issues of keeping them alive:

https://www.theguardian.com/environment/2019/jul/13/living-walls-bloom-cities-tackle-air-pollution

This study has some good evidence about how plants can reduce the amount of particulate pollution. And how green plants can reduce pollution on city streets up to eight times more than previously believed:

https://www.acs.org/content/acs/en/pressroom/presspacs/2012/acs-presspac-august-29-2012/green-plants-reduce-pollution-on-city-streets-up-to-eight-times-more-than-previously-believed.html

This is a very complicated article but there is lots of detail about useful plants:

https://pdfs.semanticscholar.org/da5e/032e9e38c71ef7bb9a4af263460af6bf4c3b.pdf

This study has more detail about particulate emissions:

https://pdfs.semanticscholar.org/da5e/032e9e38c71ef7bb9a4af263460af6bf4c3b.pdf

Student Sheet 5 - The Heat Island Effect

The Heat island effect

What is it ?

An urban heat island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The temperature difference is usually larger at night than during the day, and is most apparent when winds are weak. UHI is most noticeable during the summer and winter. The main cause of the urban heat island effect is from the modification of land surfaces. Waste heat generated by energy usage is a secondary contributor. As a population centre grows, it tends to expand its area and increase its average temperature. The term heat island is also used; the term can be used to refer to any area that is relatively hotter than the surrounding, but generally refers to human-disturbed areas.

Monthly rainfall is greater downwind of cities, partially due to the UHI. Increases in heat within urban centres increases the length of growing seasons, and decreases the occurrence of weak tornadoes. The UHI decreases air quality by increasing the production of pollutants such as ozone, and decreases water quality as warmer waters flow into area streams and put stress on their ecosystems.

Not all cities have a distinct urban heat island, and the heat island characteristics depend strongly on the background climate of the area in which the city is located. Mitigation of the urban heat island effect can be accomplished through the use of green roofs and the use of lighter-coloured surfaces in urban areas, which reflect more sunlight and absorb less heat.

Concerns have been raised about possible contribution from urban heat islands to global warming. While some lines of research did not detect a significant impact, other studies have concluded that heat islands can have measurable effects on climate phenomena at the global scale.

Reference

https://en.m.wikipedia.org/wiki/Urban_heat_island

Some global examples:

https://www.theguardian.com/cities/2018/aug/15/what-heat-proof-city-look-like

What would a heat-proof city look like?

As is obvious to anyone who has sat under a tree on a hot day, vegetation can be a powerful tool in the fight against excessive city heat. Not only does greenery provide shade, it stimulates evapotranspiration, the process by which water evaporating from plants' leaves reduces the adjacent air temperature.

Many cities recognise the value of parks and trees for urban cooling, not to mention residents' psychological wellbeing, but few have embraced greenery to the extent of Singapore. The city-state embarked on its ambitious "garden city" plan in 1967 through intensive tree-planting and the creation of new parks. As the population grew and buildings got taller, the focus shifted to include skyrise greenery encompassing "skygardens", vertical planting and green roofs.

https://www.theguardian.com/sustainable-business/2017/feb/21/urban-heat-islands-cooling-things-down-with-trees-green-roads-and-fewer-cars?CMP=Share_iOSApp_Other

The urban heat island effect occurs because the dense dark surfaces such as bitumen on roads and building materials used in cities accumulate and store heat during the day and then release it at night.

This effect is particularly important during hot summer evenings when the minimum night time temperatures are much warmer, and surfaces cannot cool down. This can have health implication. In Melbourne Australia, 374 people died in 2009 in one heatwave.

urban science

An 'Urban Science' fact checker sheet

Student Sheet 6 - Insulation - source material

Insulation

For building insulation, we need to choose materials that are low in density and have a lot of air pockets. Examples include rigid polyurethane (derived from oil), expanded polystyrene, rockwool, cork, sheep's wool, warmcell (made from recycled newspapers).

Some insulation is more ecologically friendly than others, but any insulation is always better than none.

Fabric Loss - 'U' Values

Materials are given 'U values' to show how insulating they are.

Definition of U value: Heat flow (in Watts) through 1m^2 of a construction at 1 degree temperature difference between the inside & the outside.

Example: A single glazed window has a U-value of 6.0 W/m^{2}K.

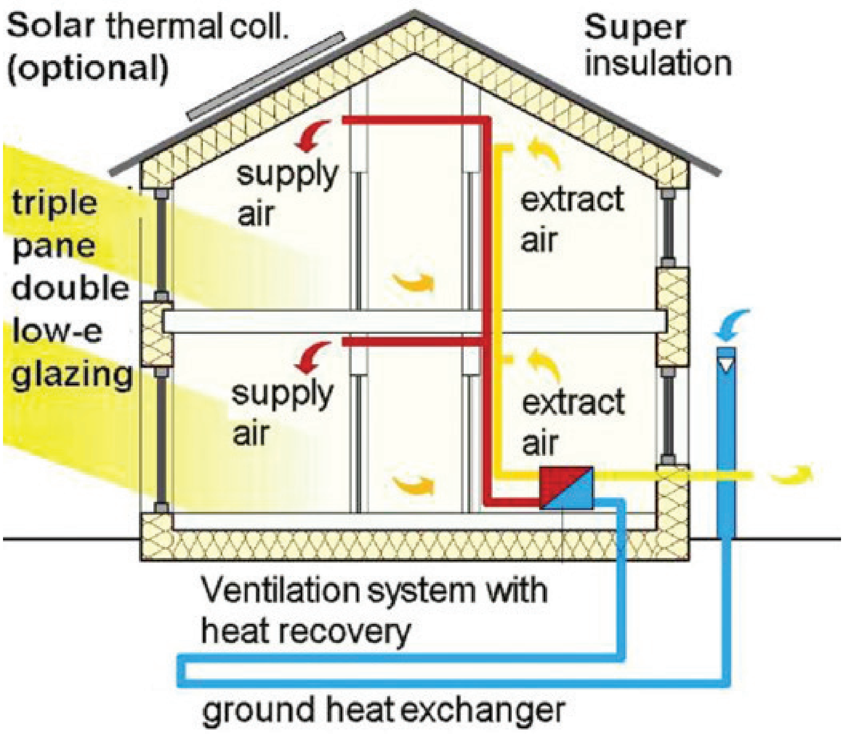
This means 6 watts of heat energy is escaping through each square metre of glass when the temperature difference is 1 ˚C.

Golden rule: The lower U-value , the better the insulation

Insulation - Air tightness

Designing buildings so that they have very few draughts can save a lot of energy, as nearly no heat will be lost from the building.

In Germany, they have developed a type of building called a 'passiv haus' which requires no energy to heat. The building stays warm simply with the casual gains from people and equipment. This is because of very tight details that insure there are no draughts, and large amounts of insulation in the walls and roof. These buildings also make use of thermal gain through south facing windows.



An 'Urban Science' fact checker sheet

Inquiry based learning stage

Stage 1 - Initiating and eliciting		**Stage 2 - Defining and responding**	
Stage 3 - Doing and making	✓	**Stage 4 - Communicating, presenting and evaluating**	

Learning objectives

1. All students are able to investigate:
    - The effectiveness of different materials as thermal insulators.
    - The factors that may affect the thermal insulation properties of a material.
    - The higher the thermal conductivity of a material the higher the rate of energy transfer by conduction across the material.
    - The effectiveness of plants as thermal insulators
2. Some students will also investigate:
    - The effectiveness of plants as air pollution barriers.

Learning outcomes

1. Students explain ways of reducing unwanted energy transfers, for example through the use of thermal insulation.
2. Students describe how the rate of cooling of a building is affected by the thickness and thermal conductivity of its walls.
3. Students test the thermal conductivity of different types and amounts of plants on a model living wall.
4. Students test plants to see if they can act as air pollution barriers.

Overview of lesson

Students will carry out a series of experiments in order to gather results for their living wall report. If students are completing this module as part of a GCSE Science course, they will fulfil necessary aspects of the Required Practical on thermal insulation. Other students can take a broader approach and also complete additional experiments on air pollution.

Lesson structure

Introduction

Students may require additional guidance regarding the structure of their experiments: timing, fixing plants, etc. Essentially their focus should be to gain feasible results for the report and/or explain why this is difficult.

Main: To Insulate or Not Insulate?

This will vary according to whether the students have to stick rigidly to the GCSE required practical. If so, it entails two stages:

1. Type of insulation.
   a. They can compare the effectiveness of insulation. For example, are plants good insulators as compared to other materials?
2. Thicknesses of insulation.
   a. Amount of one type of insulation; discuss how difficult it would be to compare thicknesses of plants.
   b. They should be guided towards looking at thicknesses of insulating materials. They could use newspaper as it is easy to obtain and will give good results.

The basic requirements for the Required Practical reference 'insulation' can be found here pages 37-40:

https://filestore.aqa.org.uk/resources/physics/AQA-8463-PRACTICALS-HB.PDF

and here

https://www.bbc.co.uk/bitesize/guides/z2gjtv4/revision/3.

In this module the context of the living wall takes the place of the standard glass beaker cooling curve experiments. However, the scientific content is the same and it is envisaged that the students will be more motivated to learn the science. In addition, the following is recommended:

- This is a topic with many misconceptions and we recommend the 'Practical Physics' resources:

  http://practicalphysics.org/note-%e2%80%9cwarming-things-up%e2%80%9d-and-thermal-energy.html , http://practicalphysics.org/cooling-corrections.html

  and their practical guide:

  http://practicalphysics.org/heating-and-cooling-curves.html.
- It is important that students are aware that living walls only make sense if they are put onto insulated buildings (see market place activity Stage 2).
- Living walls have other key benefits alongside additional insulation, it will be of benefit to all students to be aware of these, for example reducing air pollution.
- If pupils use the most sturdy nets:

  https://en.seacs.eu/energy-house-kit-secondary-primary-schools/

  they will be able to move their buildings outside and investigate air pollution.

  https://www.opalexplorenature.org/sites/default/files/7/file/OPAL-SE-Roadside-Soot-Activity.pdf.

Fixing the plants to the model building .

There are a number of possibilities and this will depend on local resources. The simplest is to staple 'mini modules' onto the box wall. This also guides the size of the plants. It will be realistic to keep this small and mini module size.

Plenary

Students add results to the exhibition and collate details for their reports.

STAGE 4 - Living Walls

Inquiry based learning stage

Stage 1 - Initiating and eliciting		**Stage 2 - Defining and responding**	
Stage 3 - Doing and making		**Stage 4 - Communicating, presenting and evaluating**	✓

Learning objectives

1. Students are able to communicate their results.
2. Students can apply a range of communication techniques.
3. Students can understand the uncertainty of their results and the concept of validity.

Learning outcomes

1. Students present their observations and other data using appropriate methods as part of their Living Walls Report.
2. Students carry out mathematical and statistical analysis.
3. Students estimate distribitions of their results and understand where these are uncertain.
4. Students interpret their observations and other data, identifying patterns and trends, making inferences and drawing conclusions.
5. Students ommunicate the scientific rationale for their investigations, giving a reasoned conclusion.

Some will go further and:

6. Students evaluate the accuracy of the data and identify potential sources of error.

Overview of lesson

Students collate their results/research to produce the report for the headteacher.

Lesson structure

Introduction

Discuss student results from their experiments. Focus on the best way of presenting these results and recommendations to their headteacher /policy body. Have they answered their questions? Do they have to prepare for a formal presentation?

Main: Scientific reporting

Scientific Reporting

Within this module, the focus for Stage 4 is on producing a scientific report for the headteacher (or other policy maker). The Exploratorium in California (award winning interactive science museum) has useful guidelines on science writing.

https://www.exploratorium.edu/sites/default/files/pdfs/ifi/ScienceWriting.pdf

This is good in this context because it has a very broad approach to this type of writing. It describes ways to include the results of their varied Urban Science activities. For example, their De Bono thinking skills feedback reports, market place posters, messy wall photos, etc can be seen as valid aspects of science writing.

Most schools will have a science writing template already in use that they can adapt, the key features of their Headteacher report are likely to include.

1. An **introduction** that includes their science question backed up by their living wall research (sometimes known as an educated guess but properly as a hypothesis).
2. What they did - **method**
3. Their **results**
4. **Discussion /conclusion** from these results. What they have found out? How they could do it better /change in the future? In this report they have a focus on trying to answer the headteachers questions.

Plenary

This will depend on how the module has been organised. If the class is working as a team to produce the report the component parts need to be reflected on and discussed. If they have produced a set of reports from a number of groups, an initial discussion that scrutinises their work is useful. Groups can review their work and consider ways to improve it in the future (see Student Sheet 7).

Presentation to the external 'policy person/body' whether the headteacher or the governors is a key part of the Urban Science IBSE methodology. By necessity this will need more time for a bigger plenary session.

Student Sheet 7 - Review form

Review plans

This activity can be used to analyse or appraise anything in a structured way.

Student name: ....

Topic: ....

Strengths

Weaknesses

Enablers

Barriers

Opportunities

Threats

Annex 1 - Key Stage 4 Working Scientifically Statements

Through the content across all three disciplines, students should be taught so that they develop understanding and first-hand experience of:

1. The development of scientific thinking

a. the ways in which scientific methods and theories develop over time.
b. using a variety of concepts and models to develop scientific explanations and understanding.
c. appreciating the power and limitations of science and considering ethical issues which may arise.
d. explaining everyday and technological applications of science; evaluating associated personal, social, economic and environmental implications; and making decisions based on the evaluation of evidence and arguments.
e. evaluating risks both in practical science and the wider societal context, including perception of risk.
f. recognising the importance of peer review of results and of communication of results to a range of audiences.

2. Experimental skills and strategies

a. using scientific theories and explanations to develop hypotheses.
b. planning experiments to make observations, test hypotheses or explore phenomena.
c. applying a knowledge of a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments.
d. carrying out experiments appropriately, having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.
e. recognising when to apply a knowledge of sampling techniques to ensure any samples collected are representative.
f. making and recording observations and measurements using a range of apparatus and methods.
g. evaluating methods and suggesting possible improvements and further investigations.

3. Analysis and evaluation

a. applying the cycle of collecting, presenting and analysing data, including:
   i. presenting observations and other data using appropriate methods.
   ii. translating data from one form to another.
   iii. carrying out and representing mathematical and statistical analysis.
   iv. representing distributions of results and making estimations of uncertainty.
   v. interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions.
   vi. presenting reasoned explanations, including relating data to hypotheses.
   vii. being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error.
b. communicating the scientific rationale for investigations, including the methods used, the findings and reasoned conclusions, using paper-based and electronic reports and presentations.

4. Vocabulary, units, symbols and nomenclature

a. developing their use of scientific vocabulary and nomenclature.
b. recognising the importance of scientific quantities and understanding how they are determined.
c. using SI units and IUPAC chemical nomenclature unless inappropriate.
d. using prefixes and powers of ten for orders of magnitude (e.g. tera, giga, mega, kilo, centi, milli, micro and nano).
e. interconverting units.
f. using an appropriate number of significant figures in calculations.