HeatHack Reading Materials

HeatHack

Jul 28, 2022

CONTENTS

This programme is dedicated to the Boston Women's Health Collective. Since the 1970s, they have been empowering women to collaborate in their own health care. This is oddly similar to what we want to achieve! It is also dedicated to volunteers everywhere helping to look after our community buildings.

CHAPTER ONE

INTRODUCTION

Knowing how to manage energy use in community buildings and halls is difficult. Many of us manage the most difficult buildings in our local areas, especially if they are churches or ex-church buildings. We are, for the most part, volunteers who know our buildings well, but have no training that helps us understand how the energy systems in our buildings work and how to change them for the better. Meanwhile, there are few professionals who spend enough of their working lives thinking about community buildings or older premises and able to provide us with confident advice. This means sometimes we are told things that are more appropriate for modern construction, houses, offices, schools, and factories. Even when the professionals have time to think deeply about our needs, sometimes the equipment then can buy is designed with very different buildings in mind. It's understandable, then, that we might not be getting the best service from the energy we put into our buildings.

Now that energy is expensive and we understand that we need to move to net zero to reduce the harmful impacts of climate change, it is more important than ever not to waste energy. Getting this right will help our buildings and the services provided within them continue to survive, and we hope, even to thrive.

This programme is designed to help you understand energy use in your premises and what net zero means for you. We hope you find the programme useful in your journey, and that together we can build a better future for all of us.

1.1 Why take part?

This programme assumes your group needs to understand what a net zero future means for your premises. For some groups, this need will arise from a deeply felt ethical concern for the planet and its inhabitants. For others, it arises because of pressure from above, for instance, as organisations and governments make policies requiring net zero action plans. For some, volatile and rising energy prices will be foremost in their minds, or the dwindling resources of an aging or declining community. All of these are perfectly valid reasons for taking part.

This programme is not the place to debate whether climate change exists or whether human behaviour has the power to affect its course for good or ill. It is also not the place to have detailed discussions about climate change and its effects on the planet, although if that is your main interest, you may wish to consider our sister programmes, Climate Conversations and Conversations for Change. Our programme is about how to get the most benefit out of the energy you put into your buildings and how to have what are difficult discussions about whether that energy use can be supported financially and justified ethically in your place and at this time. It is based loosely on our experiences in running Carbon Conversations, structured discussion groups about how to achieve reductions in the carbon impacts of our personal lives.

Much of the programme isn't technical at all - it's discussion about what your building is for and how it should be used and managed in the future. For this, towards the end, you'll need to engage with others in your local community. After all, it's space that serves them. This kind of conversation will be a new one to many groups, and so the programme is designed to equip you for that, too, by showing you some good ways to engage the people you serve. You should come out of the programme with a plan for your building and evidence that will be useful for securing grant funding if you need it.

Further reading

- Carbon Conversations
- Climate Conversations
- Conversations for Change

1.2 What you will learn

In the programme, you will learn

- about thermal comfort, where the temperature a thermostat shows is not the whole story, and what this means for deciding how you use your spaces, with different heat strategies for occasional and frequent use.
- the basics of how heating systems work and how to check whether your current heating systems are fit for purpose and working correctly.
- about ventilation, why ventilation is important for the health of the building and its occupants, and the relationship between ventilation and heat loss.
- where the big heat losses in community buildings occur and the measures that can sometimes be taken to reduce them
- about local generation options like solar panels and lower carbon heating options like heat pumps that might be suitable for your buildings
- how to stage changes to move towards lower carbon if you can't afford everything in one go.

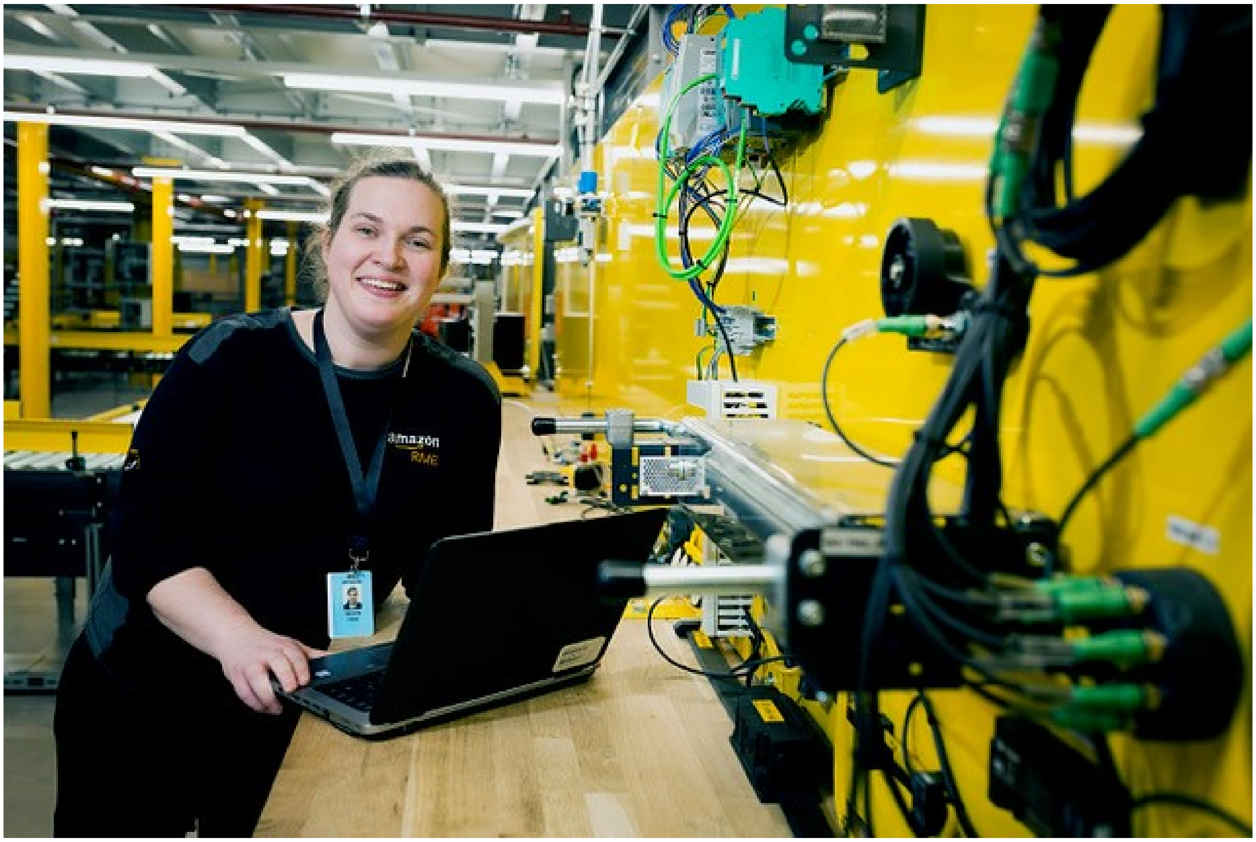
Parts of the programme might sound highly technical, but we will keep it simple. We aren't trying to make you into an engineer or heating specialist. The programme is about equipping you with the information about your building and the knowledge that you need to get better outcomes when you engage professionals.

Most of our past experience is with traditionally built, stone buildings, particularly churches. These throw up some particular challenges, so we will spend some time addressing those. If you find some materials do not apply in your case, feel free to skip these parts of the programme.

1.3 Why Engineering?

This programme is unusual for ones run in community groups, because it introduces what may be a new kind of specialist to your group: an engineer. Engineers use science to solve problems. They're good at thinking about time and budget constraints, because the whole point of engineering is to make things that work in the real world. They are also used to thinking about Health and Safety and carrying out risk assessments. It can be useful to have an engineer involved when you're thinking about your property just because of the way they are trained to think about problems and potential solutions.

(c) Openreach, from This is Engineering



(c) Chris Bull, from This is Engineering

(c) This is Engineering

(c) Arup, from This is Engineering

You should come away from the programme with a new appreciation of engineering and, we hope, able to think a little bit like engineers do.

Further reading

- The Royal Academy of Engineering
- This is Engineering

1.4 About this programme

This programme has been developed based on experiences within HeatHack, a group of community volunteers and students in Edinburgh that have been helping churches and a few other community groups understand how to heat their buildings better. HeatHack has previously been funded by the John Templeton Foundation via Scientists in Congregations Scotland, with small contributions from the University of Edinburgh Schools of Informatics and Engineering and the University of St Andrews School of Computer Science.

It has been developed and is being run in conjunction with The Surefoot Effect, a Community Interest Company that helps communities, businesses and governments put sustainability and resilience at the heart of what they do, and with support from Engineers without Borders UK to help find engineers for community groups who cannot find them for themselves.

Since 2012, Surefoot has been helping communities, businesses and governments put carbon reduction and care for the environment at the heart of strategy. We work at every level, locally, nationally and internationally to support the essential paradigm shift needed to protect people and the planet. Our continued success lies in the values-based, people and process-led approaches we use and tailor to each project.

Engineers Without Borders UK is working to reach the tipping point to ensure a safe and just future for all. Part of a global movement of over 60 Engineers Without Borders organisations, we inspire, upskill and drive change in the engineering community and together take action to put global responsibility at the heart of engineering.

The programme would not be possible without the generous support of the Royal Academy of Engineering through their Ingenious public engagement programme.

Royal Academy of Engineering | Ingenious

CHAPTER TWO

INTRODUCTION

This week is all about two things: discussing what you want to achieve by taking part in the programme, and learning some very basic concepts that can help you understand how heating systems work and why some community buildings are so hard to heat.

In this week's exercise, you'll be taking pictures or videos of your heating system and the parts of your building where most of the heat gets lost, as part of a profile you will be building up that describes your buildings and your aspirations for it. Every week, you'll add something new to this profile, and at the end, you should find it useful for discussions with your local community and with the professionals who serve you.

But first, we need to introduce a little bit of science. We heat buildings for the people who use them. That means the most important question for us is "What makes people comfortable?"

Sign Post

Sometimes the owners of lightly occupied buildings turn the heating on, not to make them comfortable for people, but because they want to keep the building safe. We address this in session 2.

2.1 What makes people comfortable?

When people feel cold, they'll do whatever is most obvious that might make them them feel better. Usually that means turning up the thermostat. In most buildings, thermostats are good at showing how comfortable a space is. They work much less well in our spaces. This is because how people feel depends on much more than the temperature of the air.

:TODO: find picture of a thermostat in Celsius

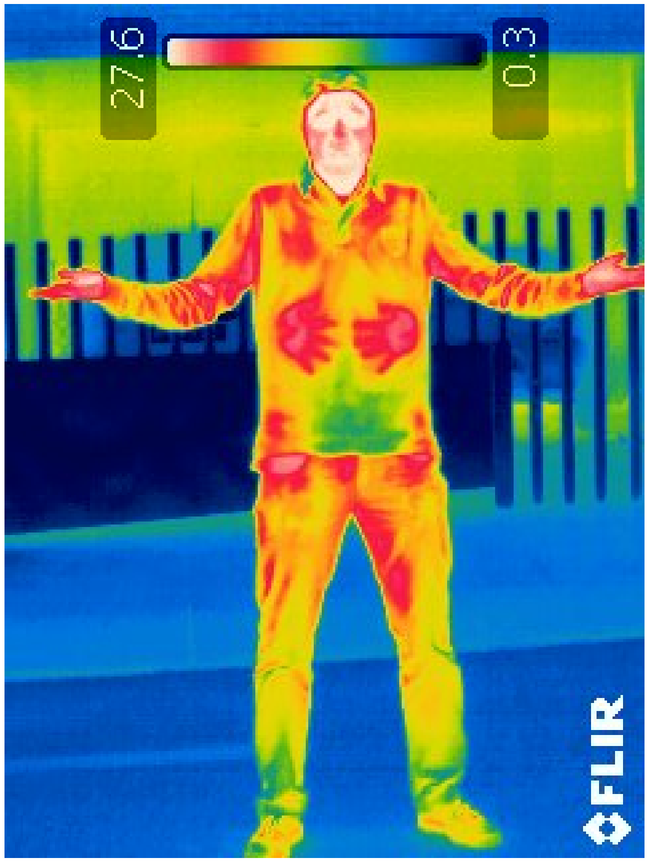
2.1.1 Surrounding surfaces

The temperature of the surrounding surfaces is just as important as the air temperature for how people feel. To understand why, we need a very basic scientific concept: *heat transfer*. One of the ways that heat can transfer from a warm object to a cooler one is by *radiation*, or electromagnetic wave.

Radiation in the sun 

(c) elPadawan, Creative Commons CC BY-SA 2.0

The sun is very hot. Heat transfers from it to cooler surfaces no matter how far away they are. Because the sun is very hot, this radiation is very noticeable!



Radiation in buildings

(c) Aitor Aguirregabiria, Creative Commons CC BY-NC-ND 2.0

People are usually warmer than the surrounding surfaces, so heat transfers from the person to the building. The colder the walls, windows, ceiling, and floor, the more heat the person loses.

We're all familiar with what heat radiating from the sun feels like, but most of the time we're less aware that when we're surrounded by cooler surfaces, heat is radiating from us to them.

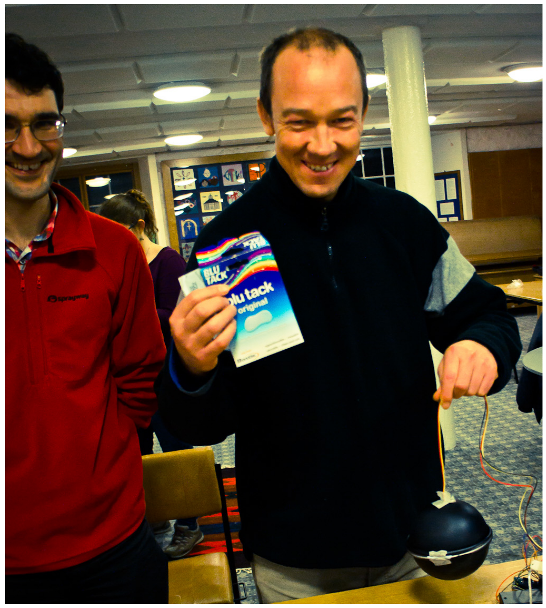
The average temperature of surrounding surfaces is called the *mean radiant temperature*. In comfort assessments, it is just as important as the air temperature. Very cold surfaces, like single-glazed windows in winter, can be very noticeable.

Mean radiant temperature is measured by putting a temperature sensor inside a matte black globe because that absorbs radiation instead of reflecting it and then checking how the sensor reads when the surface temperatures are known. Black globe thermometers are very specialised and expensive as a result. When engineers build their own, they usually use a ping pong ball or copper toilet float painted black.

2.1.2 Other factors

:TODO: Draughts, dampness, clothing levels, and level of activity also all have an effect. Be sure to include that even a warmish draught feels cold. Also that temperature variation is really annoying because then you can't just dress for conditions.

Associated activity: how should people dress for church? What's right in the modern age?



2.1.3 Pulling it all together

:TODO: fill in sketch

Scientists try to come up with numbers that reflect how comfortable people will be in terms of what percentage of people will be dissatisfied under which conditions. That's led to building standards for offices, but the work for churches has never been done.

Fun Fact!

The core science behind thermal comfort assessment standards are based on putting six people at a time in a diving bell modified to control temperature, RH, and draughts, and asking them how they feel.

2.2 Heating strategies

Churches were never meant to be comfortable in the modern sense of the word, but they varied in terms of what their heating systems were meant to achieve.

Some were meant to provide a background level of heating throughout the winter, but no more than that - a lot like heating a chicken shed.

Some were meant to be brought up to a less frigid air temperature for use, not warming the building itself - but more like 12-14C air temp than modern expectations.

In both these cases, there are sometimes fewer radiators now than there were, because they were in the way - so people took them out, not realising the effect on the heating (this is really session2?)

Some were meant to make the people right next to them more comfortable, but not really warm the space properly. Lots of these are gone - internal combustion stoves.

It's useful to think about what the building was designed to do, especially if you still have elements of the original (or at least early) heating system in place. So, how would we know? Looking at your older equipment will give you some clues. But first we have to introduce the two remaining methods of heat transfer: *conduction* and *convection*.

2.2.1 Conduction and Convection

Conduction

Conduction transfers heat by direct contact. Metal is good at conducting heat this way.

Convection

When a fluid, like water or air, comes into contact with something warm, it warms up, becomes less dense, and rises, drawing cooler fluid behind it. This transfers heat by *convection*.

Convection is important in community spaces because it explains two things that people often find puzzling: why are radiators often under windows, and why is it so draughty?

Normally a window lets in some cold air, and is colder than nearby surfaces, so air next to it will sink, causing a cold draught that annoys anyone under the window. A radiator can counter this natural airflow.

The circular *convection current* shown in the picture only happens when a space has reached its set temperature - the one on the thermostat - and is being maintained at it. This is called *steady state*. While a space is still heating up, the airflow is more chaotic and can be colder and pretty strong. Unfortunately, the way we heat our buildings means that many of them never get to a more comfortable steady state. This leads to a perverse state of affairs - sometimes a higher thermostat setting can make you **less** comfortable!

2.2.2 Space heating

Heating the whole space - setting up a convection current to try to get a uniform air temperature at person-level.

2.2.3 Localised Heating

Just drift the heat past people - warm something heats air, convects past people giving them some heat by conduction. Has to be pretty warm air for it not to feel cold. Trench heating, warm floor even better, some heat by conduction and a big radiant surface. Examples: Pew cushions, hot water bottle, heated car seat, tubular heating under pews.

Stoves. St Mary's cathedral, if you want to be warm you sit next to a radiator!

Advantage: better bang for the buck (and the planet)

2.2.4 Radiant heating

:TODO: take photos of SMCRC?

2.2.5 Heating Combinations

Sometimes it can make good sense to combine different kinds of heating or have mixed strategies. Trench heating often tries to warm the whole space but at least drifts warm air past people as it does so.Could have a background level of heat only, giving up on the decreasing gains you get from space heating, and top up with pew cushions or radiant panels. This will become important in the future more modern heat sources like heat pumps give a lower water temperature than gas/oil, but are designed to run all the time, and are likely to change the way we think about heating. We will return to this in session 2.

2.3 Older heating devices

:TODO: gallery of old equipment with pros and cons: old radiators causing convection currents, trench heating, tubular heaters (often very hot, don't meet modern H&S) or little radiators under pews (if you turn them up enough to try to warm the entire place rather than people's feet, also an H&S issue). Include pipework diameter - 4 inch for event heating, 5 inch for constant heating.

Sidebar: Why are there pipes way up there? (CCM example, use gravity instead of pump.)

Sign Post

You may have more modern heating apparatuses in your building, especially your halls - don't worry, we will be talking about them in session 2! They work using the same basic principles so you can probably guess their effects.

2.4 Radiators and pipes

Radiators radiate some heat, but most of the heat transfer is by convection.

Radiators radiate heat, warming the surfaces and people around them - but their main purpose is to warm the air by convection. Cold air moves across the radiator, warms up, and rises, drawing more cold air in its place. The more surface area they have for air to go past, and the bigger the temperature difference between the radiator and the air, the faster the heat transfer.

The heat output of a radiator is measured in kW. To find out what it is, you find the manufacturer's data sheet and look it up by model in a table that assumes a standard difference between the radiator temperature and the air temperature. It can be hard to find the right model, especially for older radiators, as any markings are hidden, usually on the back. We'll be estimating the output by looking at the general type and size of the radiator.

Even pipes shed heat into the space. In systems with old fat pipes, the heat that comes off them can make a very important contribution.

Tip

If you block the air movement around a radiator or pipe, that slows down the heat transfer dramatically. Radiators especially need to be kept clear or you won't get the benefit of them. Sometimes community buildings block the radiators accidentally because they need the space, but sometimes they box them with joinery in because they are worried about the safety of hot radiators if they serve the very old or the very young. It's possible to get low surface temperature covers that will improve safety without obstructing the airflow. :TODO: picture of a radiator with lots of stuff blocking it.

Here are some common types of radiators.

Traditional cast iron

:TODO: Picture of cast iron column radiator

Cast iron radiators take a long time to heat up, but they also hold heat for a long time. That makes them much better for spaces that are used for long sessions than for one hour meetings.

Modern panel radiators.

:TODO: picture of a Stelrad radiator

These are designed to help the air move quickly past the heated fins - they're better at heating the air.

:TODO: tubular heaters under pews, not meant to heat the space so much as to heat the people.

Further reading

- one
- two

2.5 Fan convectors

Radiators take a lot of space. Where space is at a premium, it's possible to use a fan convector instead. This is just a radiator where a fan is used to move the air, drawing heat away from the radiator faster. They usually have multiple fan speeds that can be set under the cover. They can be three or four times as effective as a cast iron radiator for the same space, but they do make some noise when the fan is running.

:TODO: picture of a fan convector.

Further reading

- one
- two

2.6 Heat Sources - Wet System Boilers

A hidden setting - the boiler thermostat temperature

It matters how hot the water is in your pipework - the more difference between it and the temperature of the surrounding air, the faster heat will be transferred. Many people forget that can be set. Unless you have a building management system (BMS), that is done using a dial on the facade of the boiler. The dial usually goes from around :TODO: degrees to 82C. The right setting depends on how you use your heating. On high, the building will heat up faster from cold, but once the building is at the right temperature, it's more efficient to run the boiler at the lowest temperature that will maintain it. This can also be more comfortable for the users because the temperature will change more gently when the system turns on and off.

That means that if your building is only occupied for short times, you want the boiler to run at a high temperature, because it is only used to heat the building from cold. This will make the radiators hotter to the touch, so do check they will be safe for your users. Occasionally worship spaces will be capable of warming up so fast that the organ objects, so if you intend to make a big change to the boiler thermostat, talk to your organist first. If a space with high-output boiler is heated for longer periods, it may be worth investing in a BMS if you don't already have one. A BMS changes the boiler temperature to suit the conditions. It still has settings for the minimum and maximum boiler temperatures to use.

:TODO: @jean check the relationship between the BMS and boiler settings; @andrew will need to decide whether this kind of text is OK.

2.7 Further reading

- How to make a black globe thermometer
- CBE Thermal Comfort Tool
- Fergus Nicol, Michael Humphreys, and Susan Roaf (2012) Adaptive Thermal Comfort: Principles and Practice. Routledge. ISBN 9780415691598.

CHAPTER

THREE

SESSION 2 - MOVING TO NET ZERO

:TODO: ask Roger about old practices of airing the building on a good dry spring day - something I read was concerned about creating condensation inside the building.

Last week, learned about thermal comfort and thought about what the heating is doing for comfort in the buildings.

There's really steps before this - CSE idea of addressing reducing energy use:

1. Reduce demand
2. Reduce losses
3. Generate

Many resources for this, our approach is not to compete with them, but to point to appropriate ones and importantly, to comment where they are missing important insights for our buildings.

CSE figure about where most energy in community buildings goes. (Might be before LED lighting, see if there's a more up to date one or just comment that it will be even more skewed now).

Note importance of thinking about heating.

One of the most important hidden issues relates to what we talked about last week: if a building is only occasionally occupied, the biggest way of of reducing demand is to move from space heating to localised heating or hybrid arrangements.

Particularly important to make this kind of decision because it impacts step 2, reducing losses - which really only apply to spaced heated buildings, not economical (in financial or carbon terms) to worry about secondary glazing/insulation if you're only heating the people.

IMPORTANT: heat pumps as low temperature, heating all the time for a background level of heat, often need more than one domestic to heat fully but the commercial ones are expensive.

HYBRID GOES IN THIS SESSION, THEN.

CHAPTER

FOUR

SESSION 3 - HEATING SYSTEM CONTROLS

It can take a long time to organise the finance to make major building changes - but we all want to reduce the energy we're using right now if we can do it without affecting the services we provide, both to save our pocketbooks and to save the planet. Heating controls are a much overlooked part of the solution. Community building operators are often tempted to skimp on them, or even omit them altogether, to save money - especially if they are faced with having to replace a system suddenly. This week we'll take a diversion from thinking about the future in order to look at how heating controls work, whether you are using what you have correctly, and whether a small investment in the current system would make enough of an impact to make a difference.

If your heating system is very simple - storage heaters, for instance - lots of the materials here might not be very relevant to it. They could be useful for understanding the options for controls on future systems, so we would encourage you to read the basic concepts. If you ever change your system in future, you can always come back to the methods for checking your system's operations as part of the "snagging" process.

:TEMP: The third session introduces reasoning skills to understand automatic and end user heating controls. Even thermostatic radiator valves are not intuitive for most people. Workmen often set weather compensators inappropriately for this application. The materials introduce types of controls, some common problems, and techniques for diagnosing them. In the session, groups will plan how to check their system as well as considering how the controls interact with each other. They may request access to e.g. HeatHack pipe temperature sensors if required. In more complex systems, it is often not obvious how to optimise efficiency. The session will impart enough understanding for groups to commission and snag heating systems, holding the professionals to account, with discussion about how this works.

CHAPTER

FIVE

SESSION 4 - MAKING CHANGE

:TEMP: The final small group session looks at the low carbon futures of these buildings. The materials explain potential advances in heat loss mitigation, local energy generation options, and energy supply decarbonisation. It will use a game based on Carbon Conversations to explore how to plan in the face of uncertainty, stage works, and ensure a good fit to community needs. One of the most interesting properties of these buildings results from their mass: they become more comfortable if they are heated every day because the walls themselves warm. In a low carbon future, most communities will need to choose between greater community use which brings in enough income for maintenance, with the services they provide justifying any carbon expenditure, or less frequent/less comfortable use, with eventual deterioration and closure. The discussions will explore these issues and plan how to engage others in their community.

CHAPTER

SIX

TECHNOLOGY GUIDE

We will send you devices you can use to collect temperature and relative humidity data for your spaces.

If your venue does not have wifi, you have one box, a sensor unit. You will need to put it somewhere representative of the space and then connect to it every week or two to download and send us the data.

If your venue has wifi then you will have two boxes: a sensor unit, and a base station that will take readings from the sensor and send them to us automatically. The sensor unit has to be somewhere representative of the space, but the base station just needs to be plugged in within radio range of the sensor unit.

We built our own cheap devices because it helps to get the readings instantly on line - which we can do for venues with wifi. However, it's perfectly possible to follow along on our materials without our devices, using a commercial logger. They cost around £50 for temperature or £70 for temperature with relative humidity. They just save the data on the device and let you plug them into a computer, usually using USB, to download them. There are sometimes cheaper unknown brands available. We've never tested their accuracy. If you use one it is best to check them against something with known good readings to make sure.

6.1 Where to put the sensor unit

You want your sensor unit to reflect the experiences people have in your space, without being affected by local sources of heat. Place it where no one is likely to sit right next to it, away from radiators, and away from direct sunlight. If you can, avoid having it directly next to a window or external wall, especially if the walls are stone. Near the centre of a space is usually best.

Tip

It can be hard to remember where you put the sensor unit - one easy way is to take a picture on your phone. Then if you forget, you'll know exactly where to look.

You will be able to move your sensor unit around your spaces if you have more than one - you just want to collect representative data from each over a range of weather conditions.

6.2 Batteries

The sensor unit uses AA lithium batteries. These are available, for instance, from Energizer. This is the kind of battery used in things like smoke alarms. They are the same size and shape as normal (alkaline) AA batteries, but should last a year. It is possible to use alkaline batteries, but their performance will be very variable, lasting something between a week and a month.

Safety

- Do not attempt to recharge lithium batteries - these are not the same as lithium-ion like in your phone
- Don't leave them in very hot places
- Don't run battery-operated devices under things where heat can build up

These are the same safety tips as for alkaline batteries, but these batteries store more energy, so it's more important to remember them.

For more information: https://uk.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/aa-batteries-guide

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6.3 Instructions for wifi version

6.3.1 Instructions for Android phones and tablets

Connecting your base station to the internet

:TODO: does this throw up a different network name than the sensor boxes? Otherwise if they're very fast they could get confused…

Start the sensor unit

:TODO: how similar is this to the no-wifi condition? The same apart from the setup screen?

Important

When you set up the device, it asks you for the name of the location - this is because you can move it around your premises, for instance, if you have more than one space. Make sure to get the location right, and if you use the same location twice, try to enter exactly the same name. We use these names to get the data to the right graphs.

6.4 Instructions for no wifi version

If your premises don't have wifi, your sensor unit saves the data for you to retrieve and email to us for processing. You should do this every week or two, or else its memory will fill up. You'll probably want to use a smartphone to do this, but you could instead use a tablet or laptop. The sensor unit starts recording data again automatically.

It's much easier to do this somewhere with wifi first - like your home - because you'll be able to read these instructions as you go.

If you have two devices, read the instructions on one and follow them on whatever you will be using at the venue. Your device will remember some of the details, making it easier a second time. If you don't have two devices, then it will easier if you use the PDF instructions.

:TODO: generate PDF, insert link here.

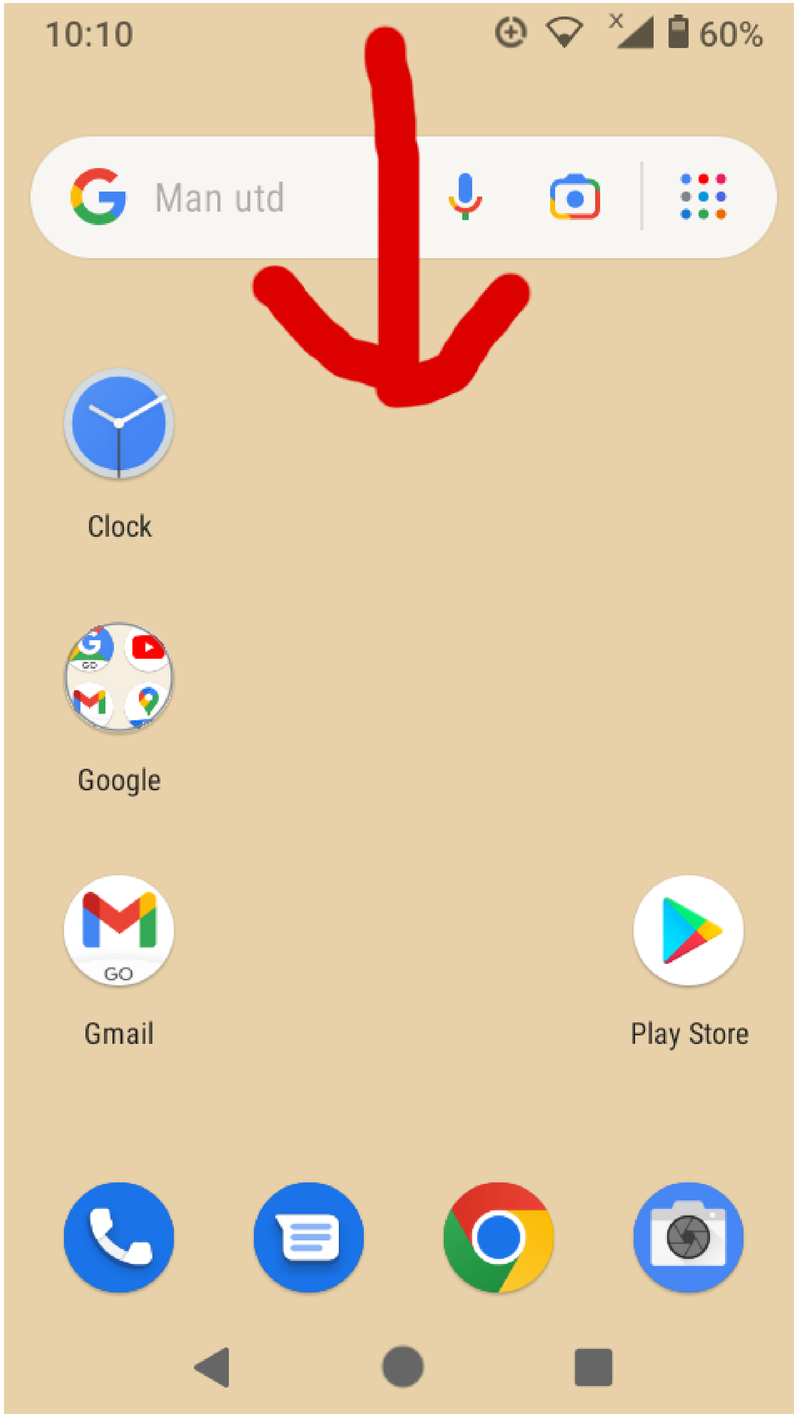
Overview

- turn the sensor box off for ten seconds, then on again
- connect to the "engineer" wifi hotspot using the password printed on the box
- visit 192.168.4.1 using your browser
- enter where the sensor is going next and download the data

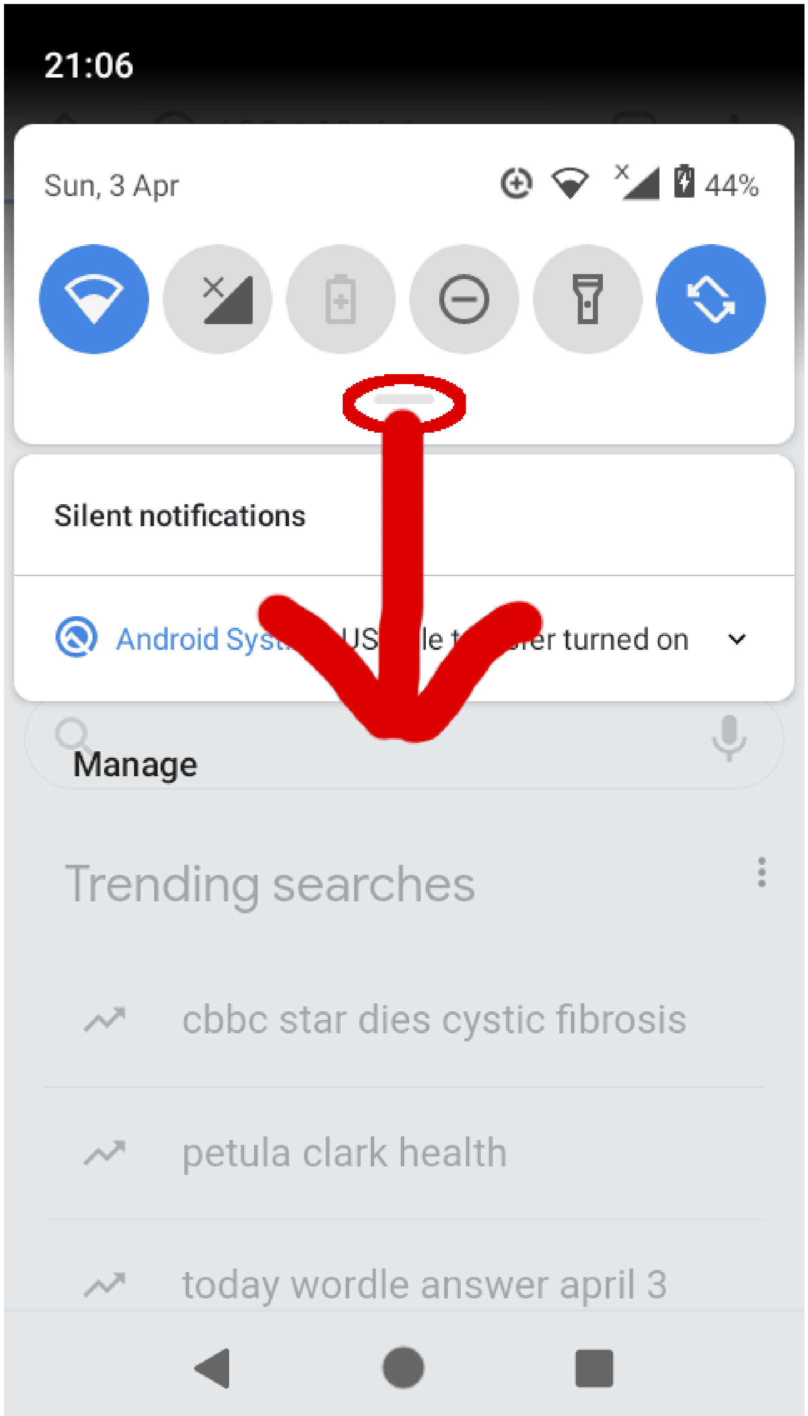
The remaining pages in this section show the full steps to connect. The process is very similar whether you use a phone, tablet, or laptop.

6.4.1 Instructions for Android phones and tablets

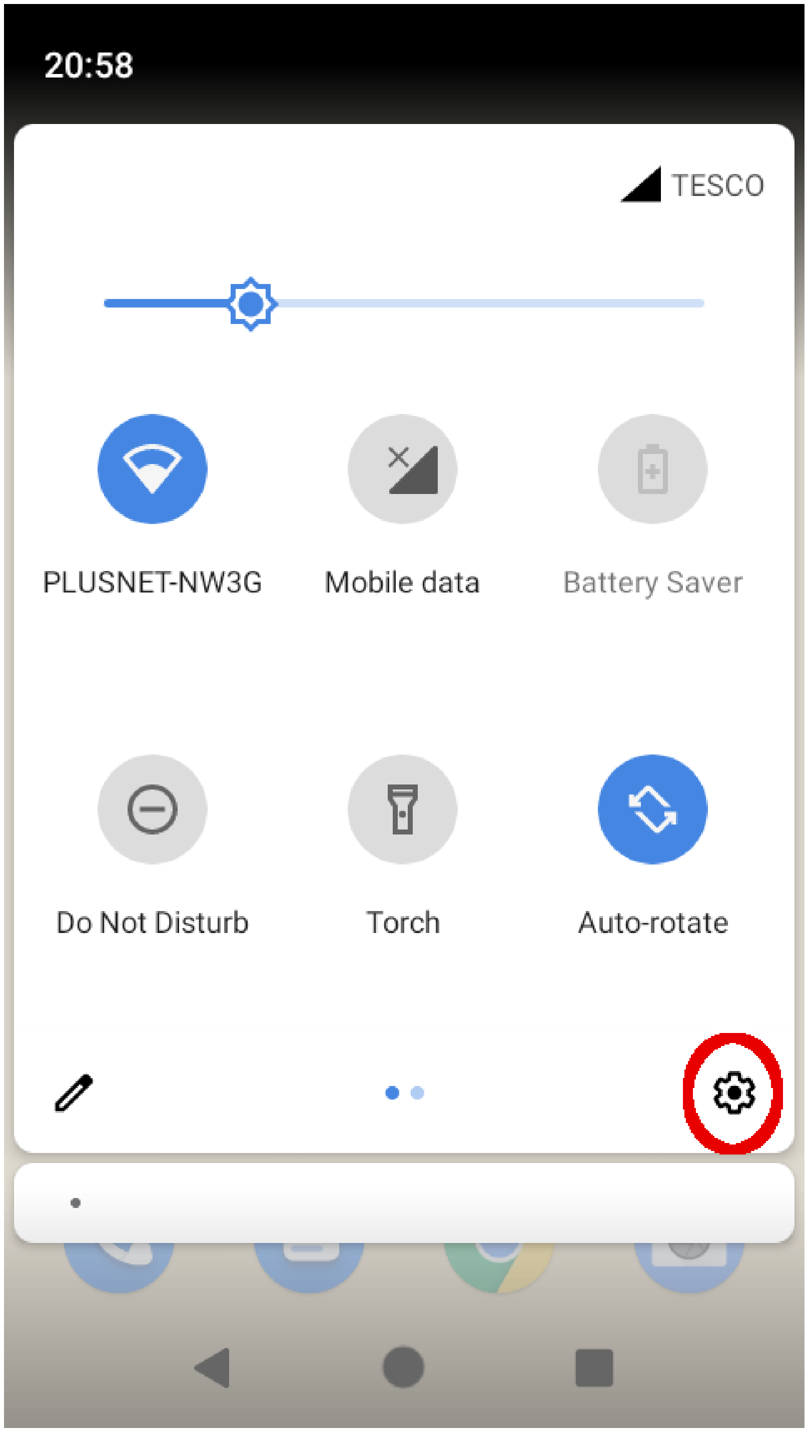
Swipe down to find basic controls



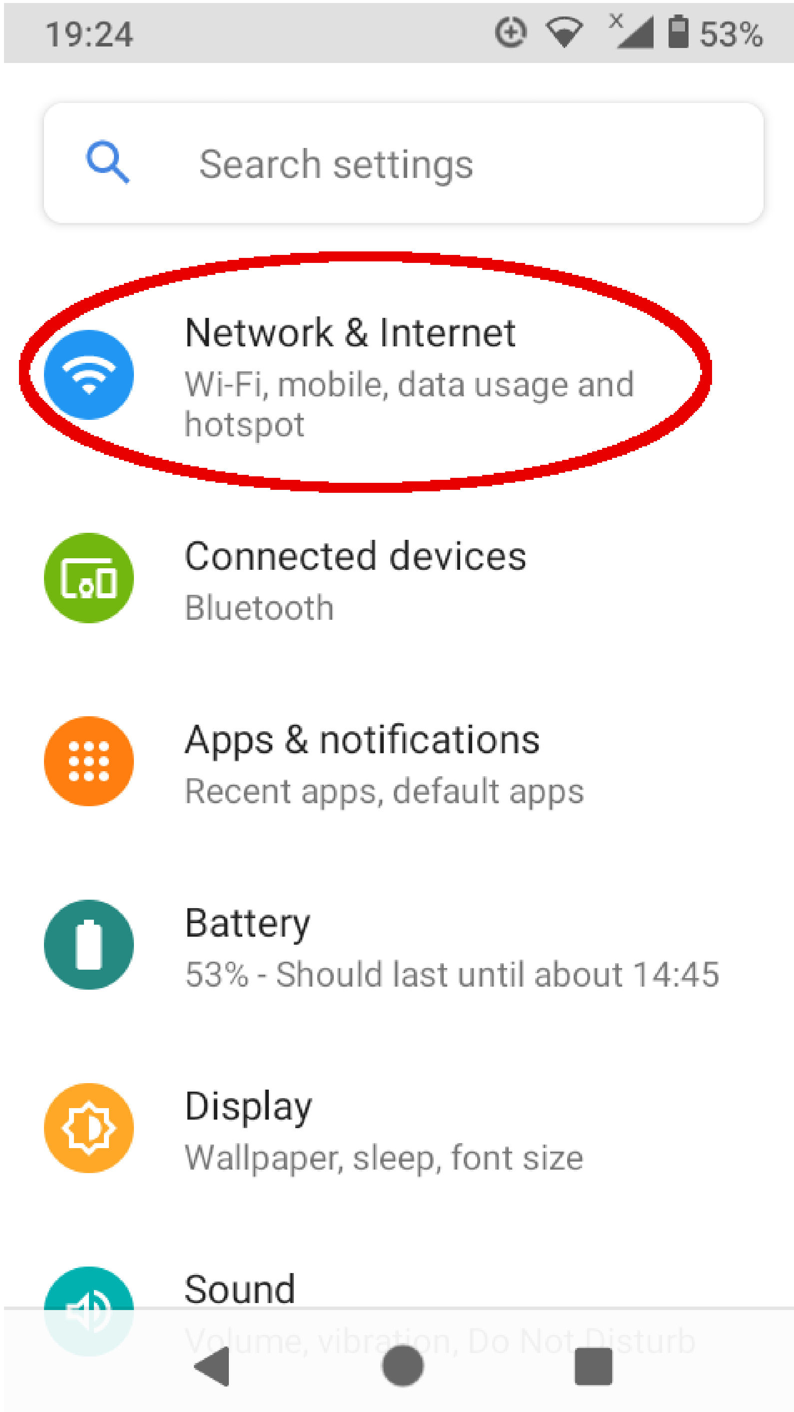
Swipe down again to find more controls.



Open the settings.



Open wifi settings

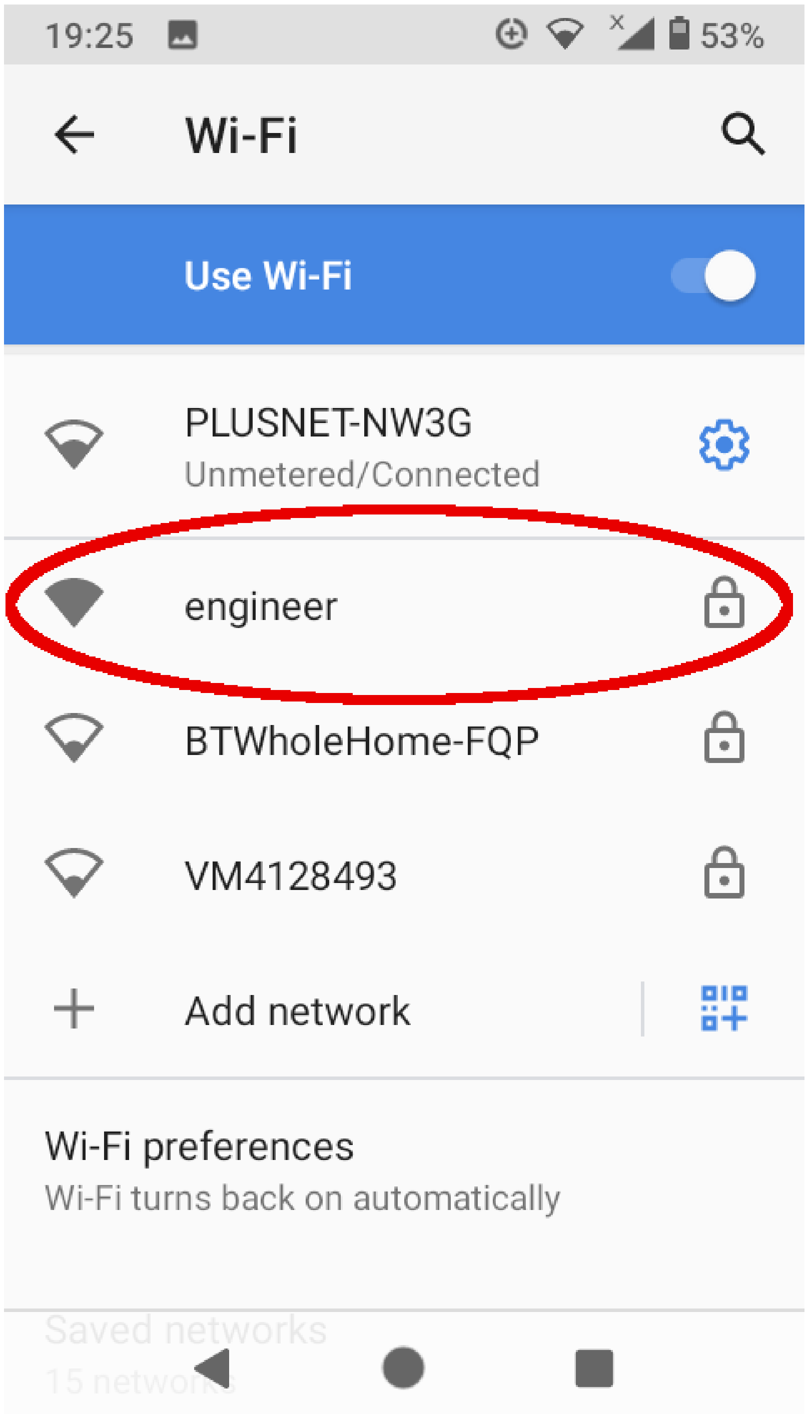


Turn device off, wait ten seconds, then on

:TODO: take a photo of the on switch

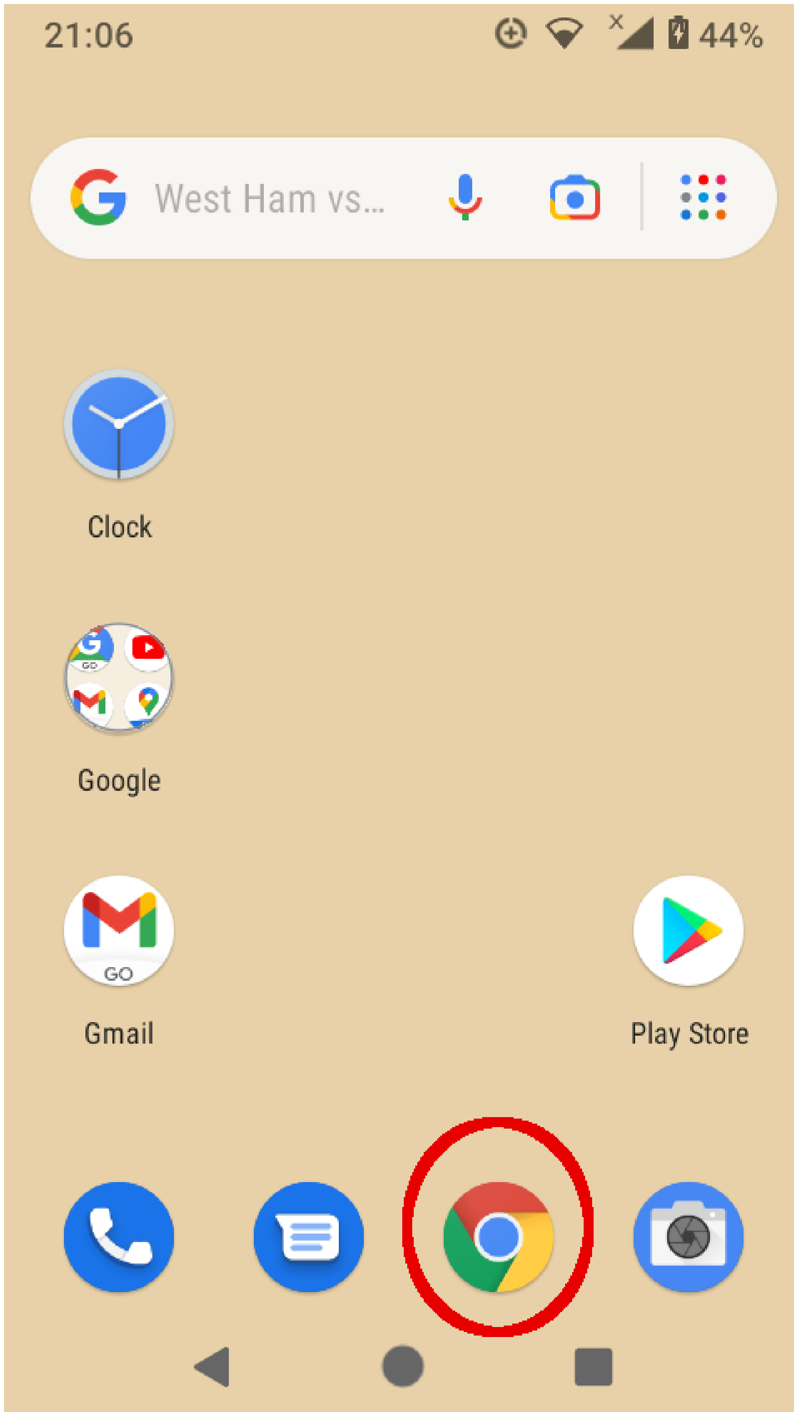
This will start a wifi hotspot and keep it up for one minute. If you do nothing, the device will start logging data.

Connect to "engineer" wifi hotspot using password on box



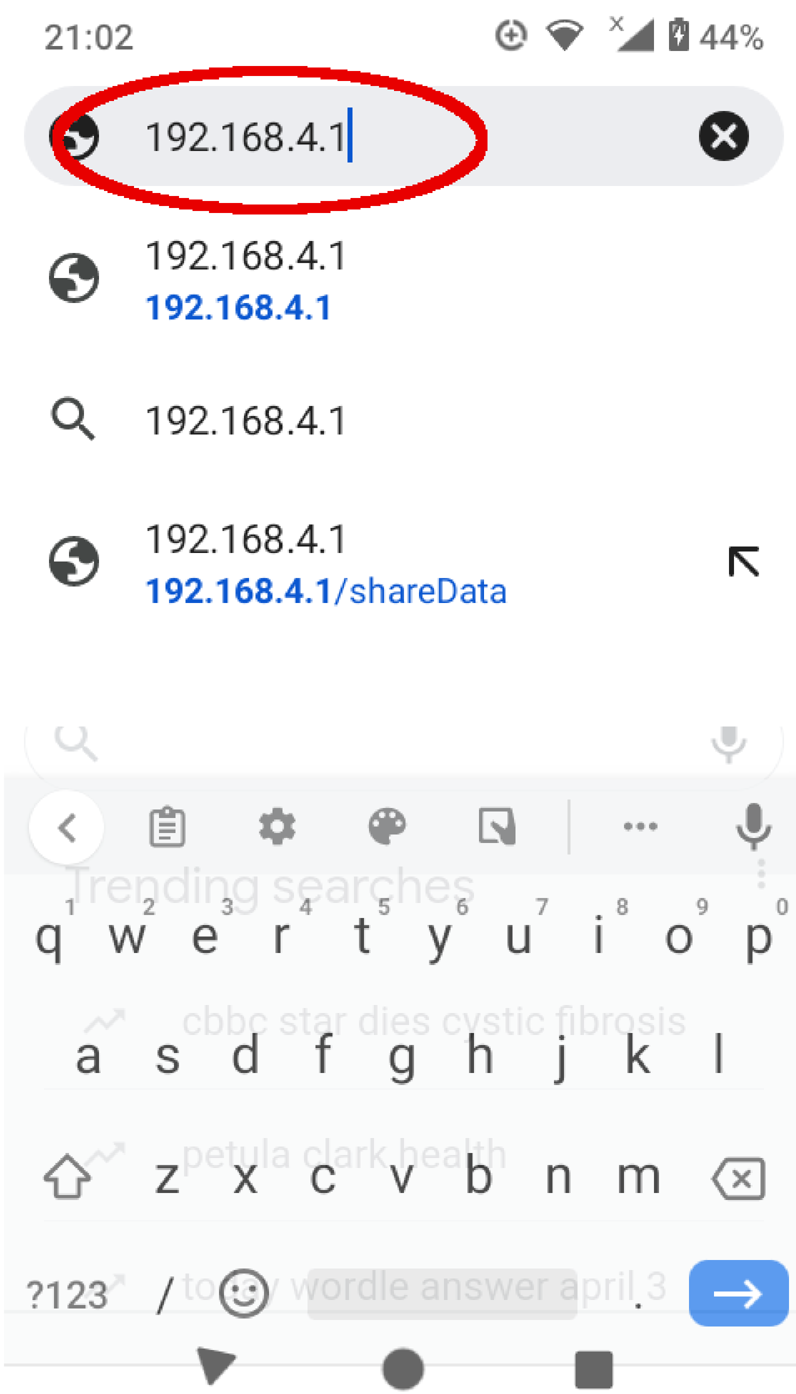
Your phone may show some warnings about security or not having internet access - this is normal and you can ignore them. From this point, you have one minute to do the next two steps, but you can always turn the sensor unit off and on again to start over.

Open the browser



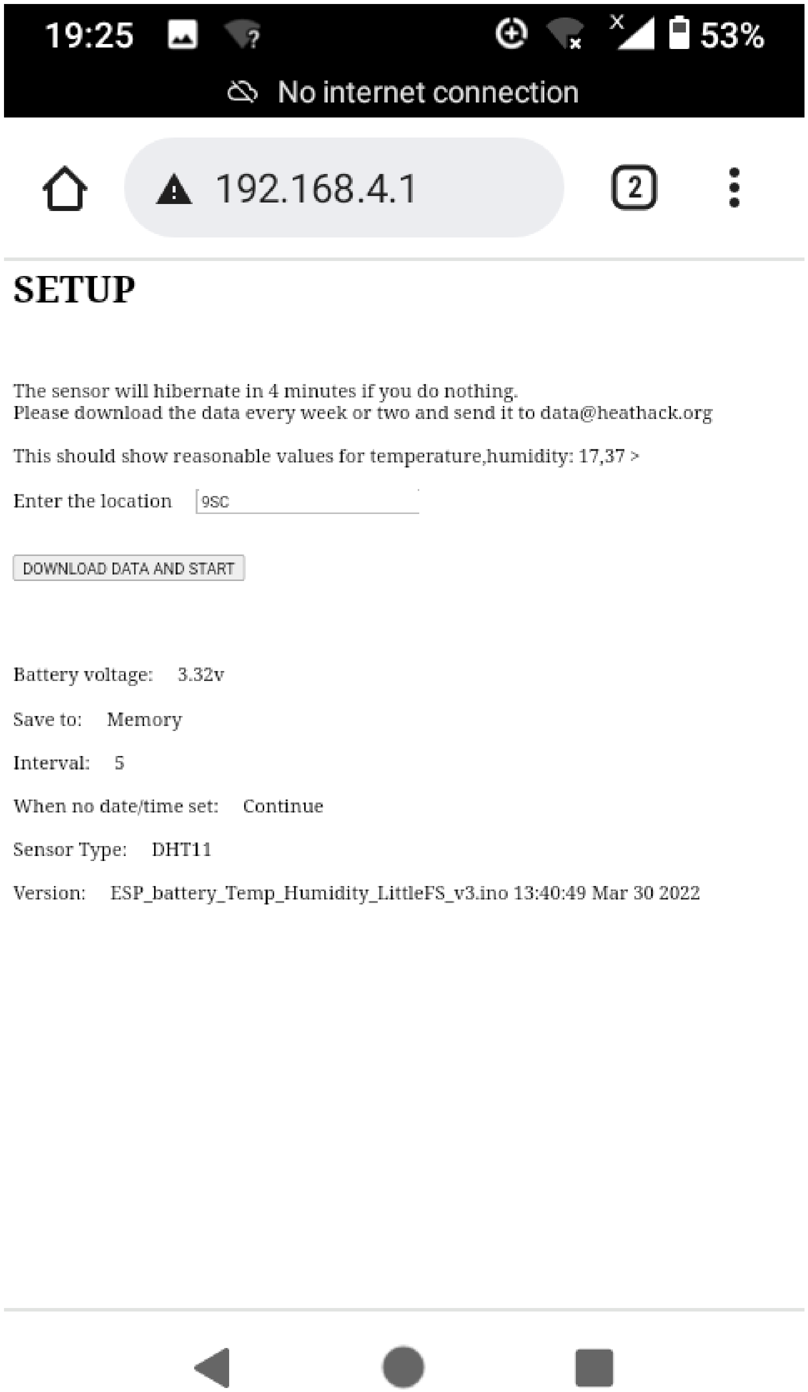
You can find it by using the “home” button or “back” button, and then looking for the browser icon.

Go to 192.168.4.1



You need to type the number into the address bar.

Download the data and restart



Configure the device by identifying its next location. Use your site id followed by a hyphen and a word that will remind you where it is (example: ccm-nave, ccm-hall). When you press “download data and start”, your phone will download a file containing the data. You have four minutes to do this but the battery will last longer if you are faster.

:TODO: retake picture with a proper location id.

:TODO: find out what happens if you do nothing.

:TODO: write the sequence for how to email the file on Android. Is the experience always the same?