Can a building be a mask?

An investigation into how combining natural ventilation and green infrastructure can create healthy living environments for the homeless.

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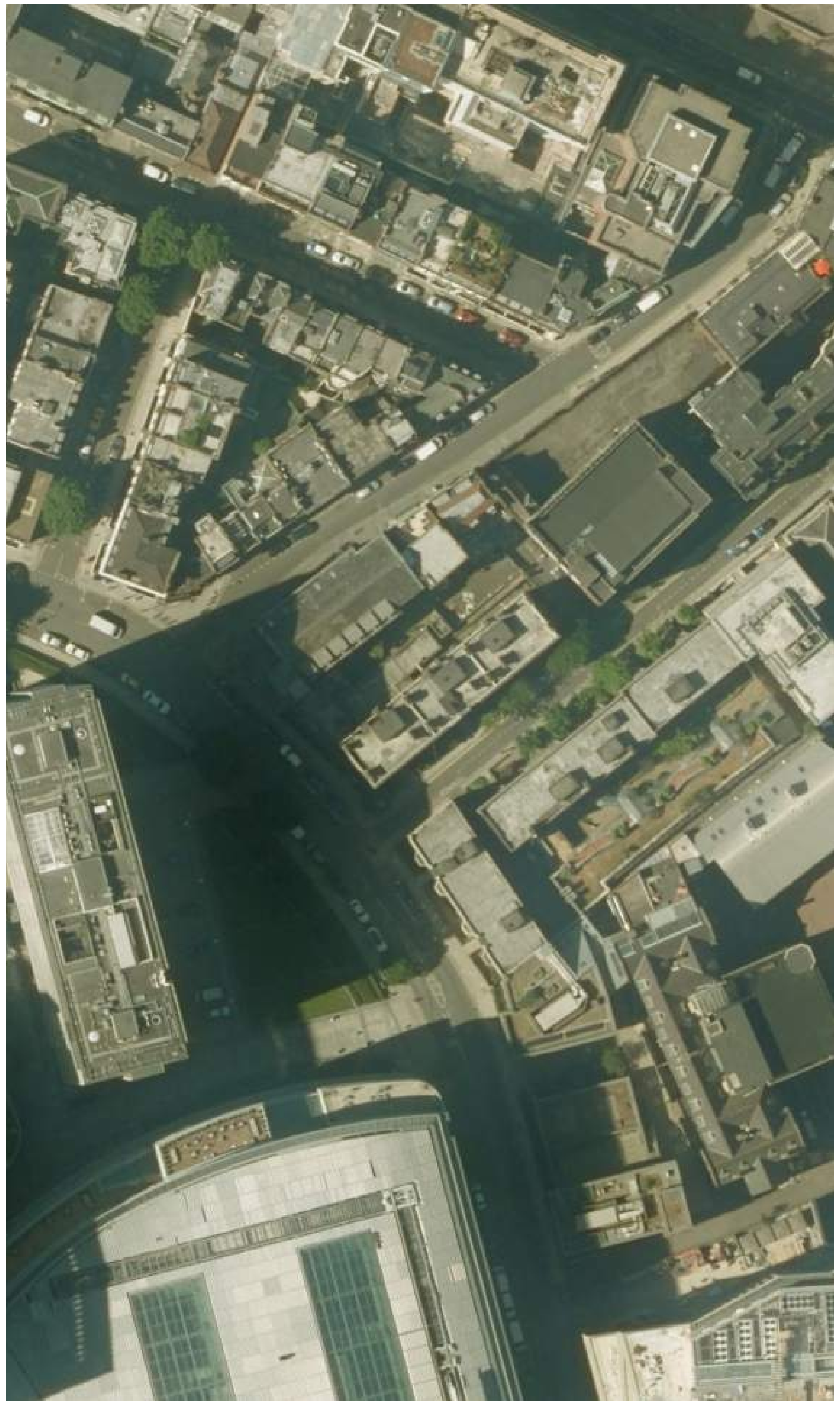
00 Introduction: Site Location

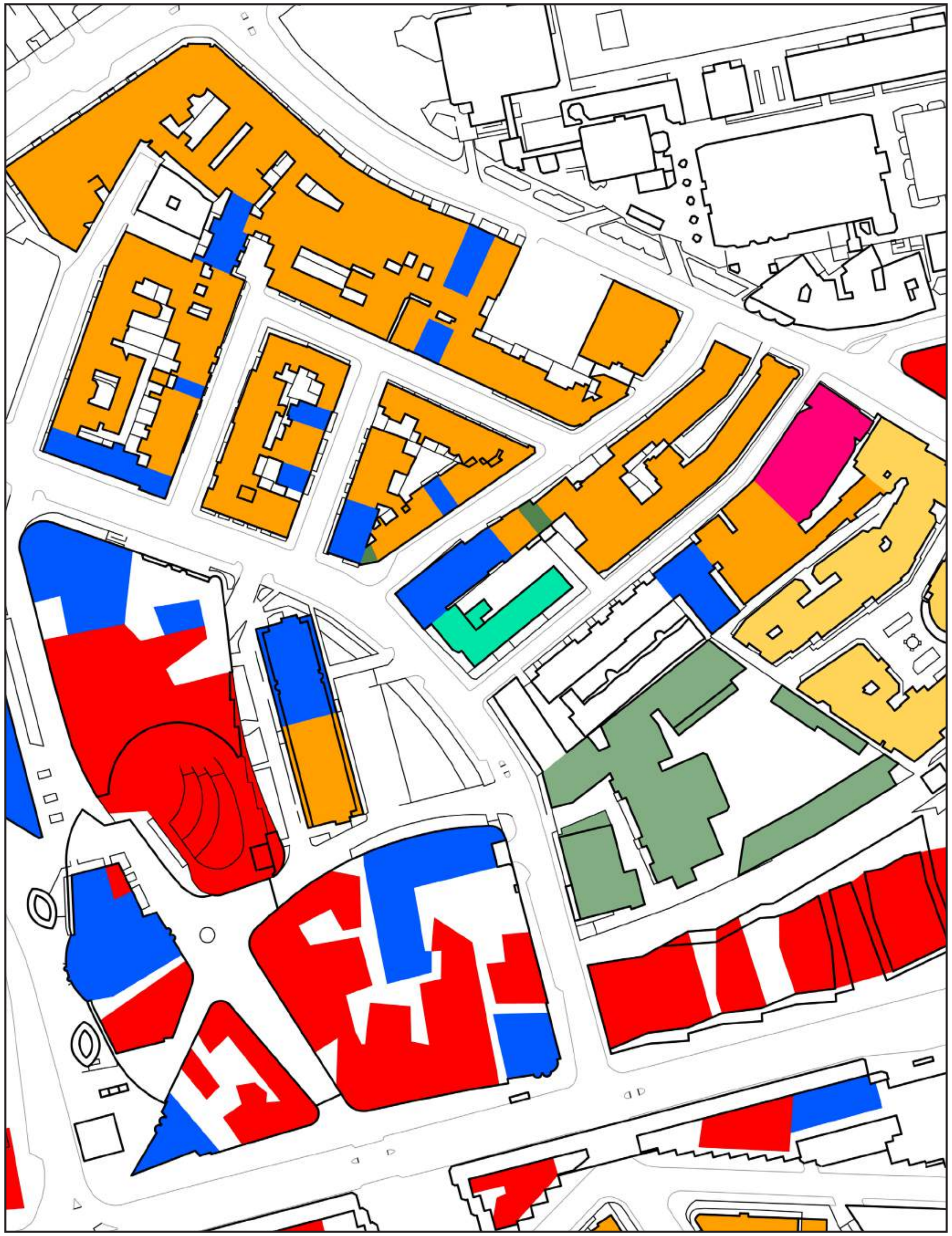
City of Westminster

London Victoria



Castle Lane

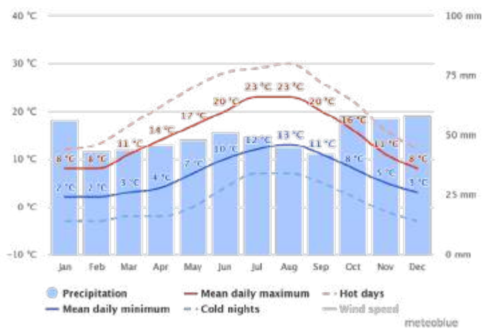
Introduction: Site Context

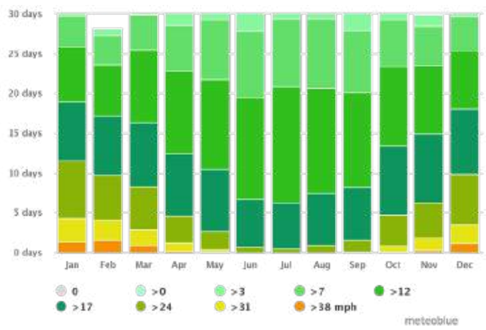


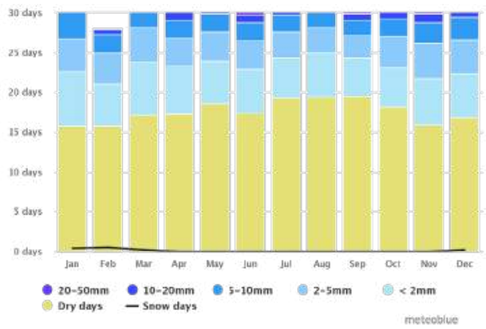
The site lies within a cluster of vacant residential buildings located inbetween Cardinal Place (a large development consisting of retail, office space, and luxury apartements), and areas of older Victorian residential typologies.

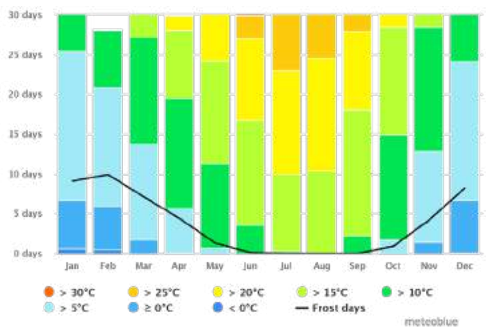
00 Introduction: Existing Building

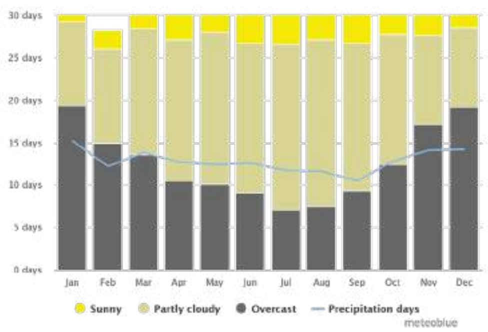
00 Introduction: Environmental Conditions



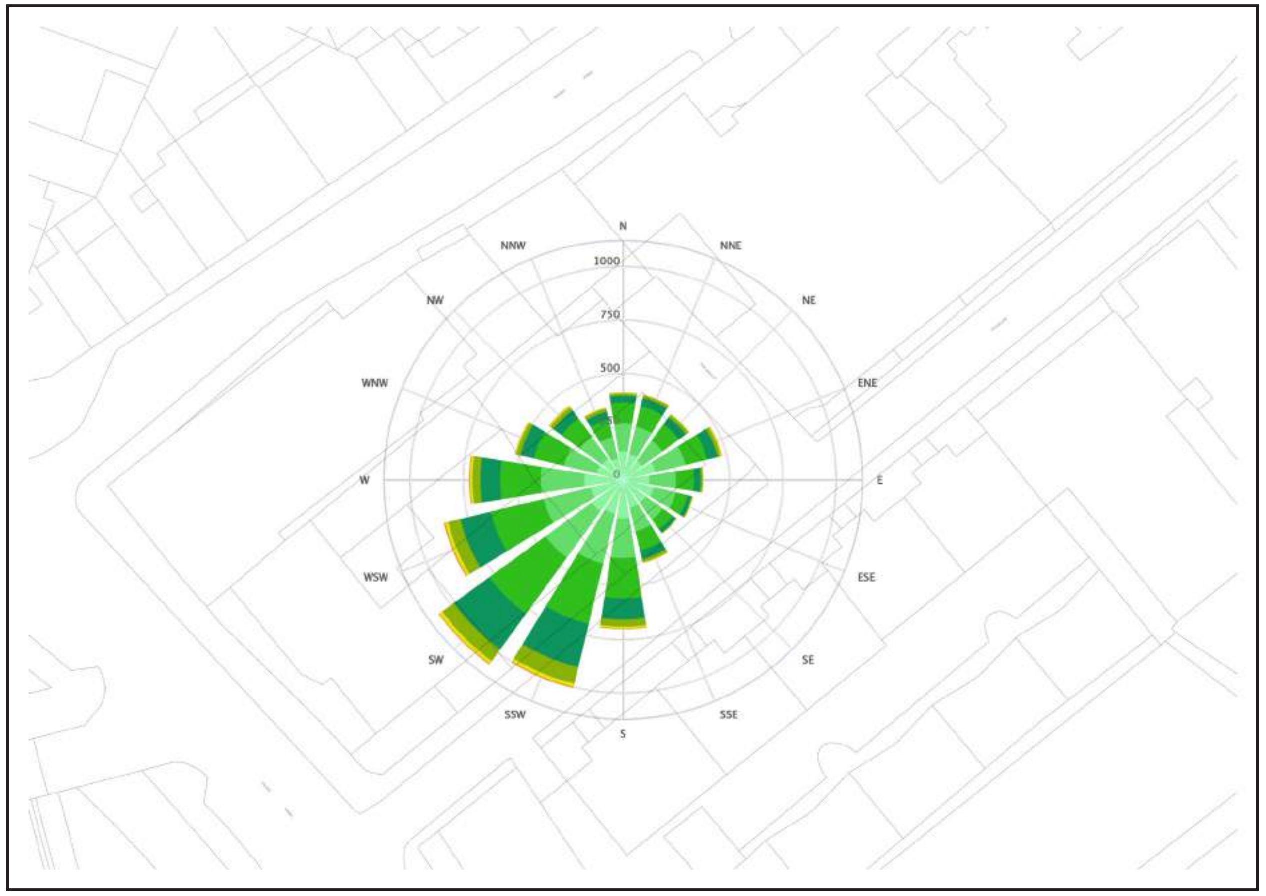


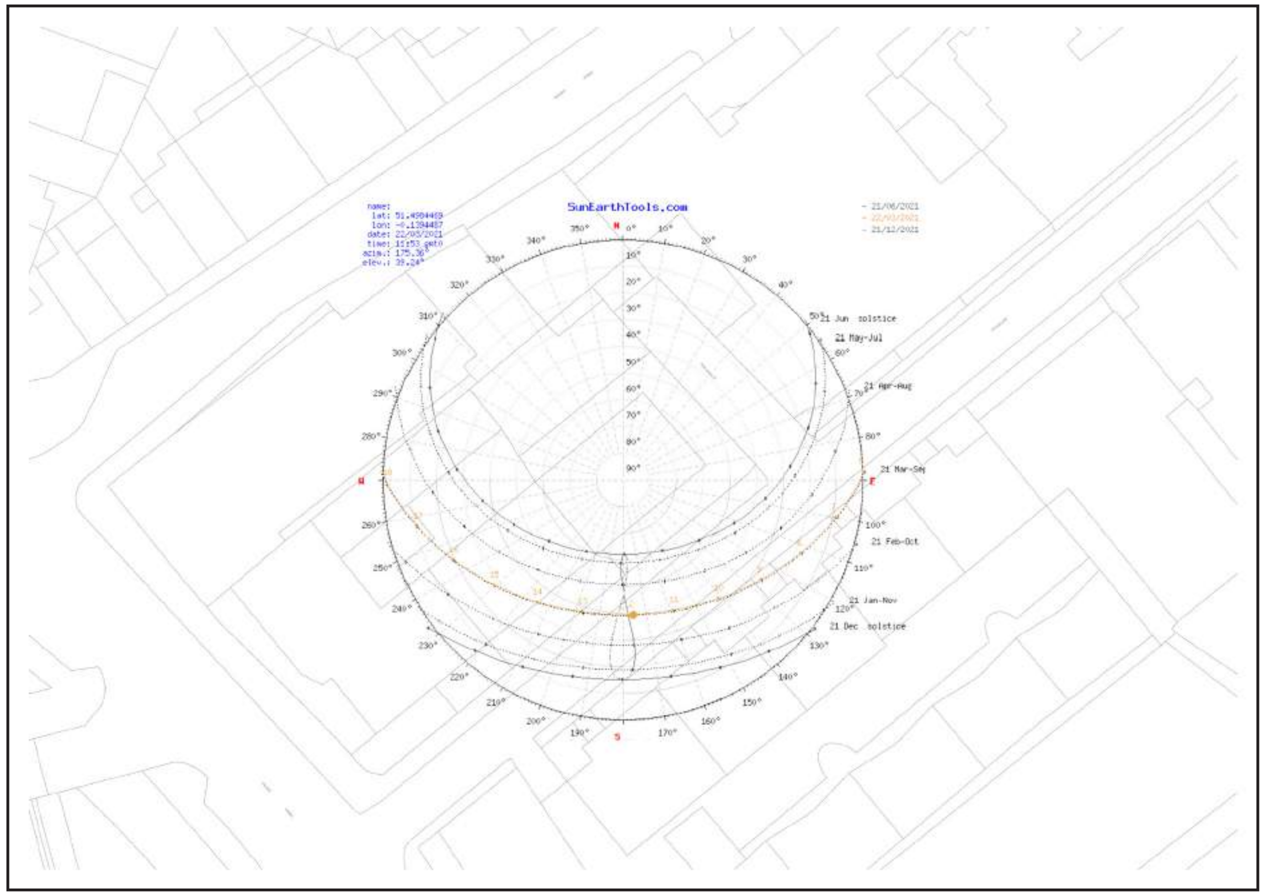






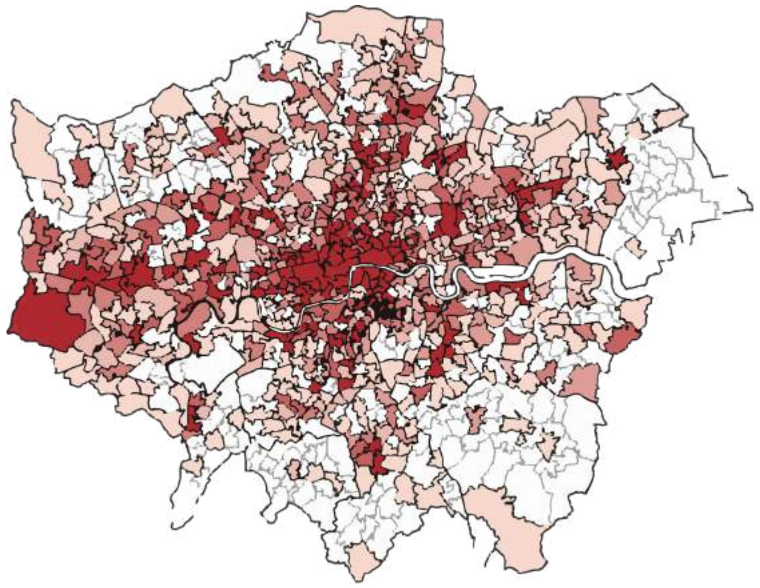
Prevailing wind comes from the south-west.





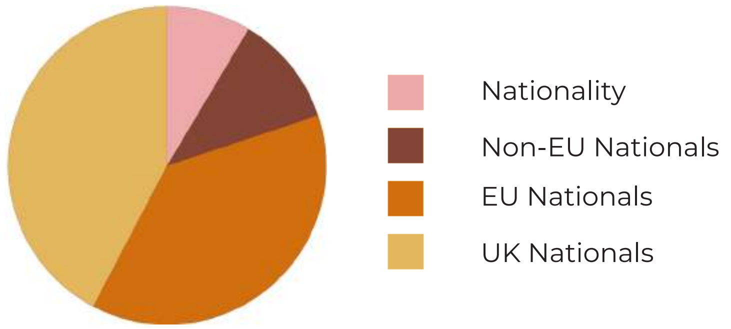
00 Introduction: Programme Context

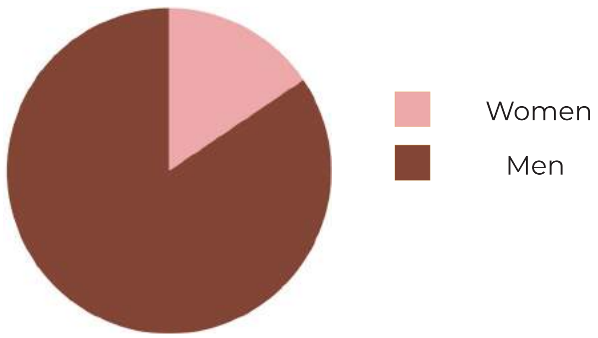
Why is the programme necessary?

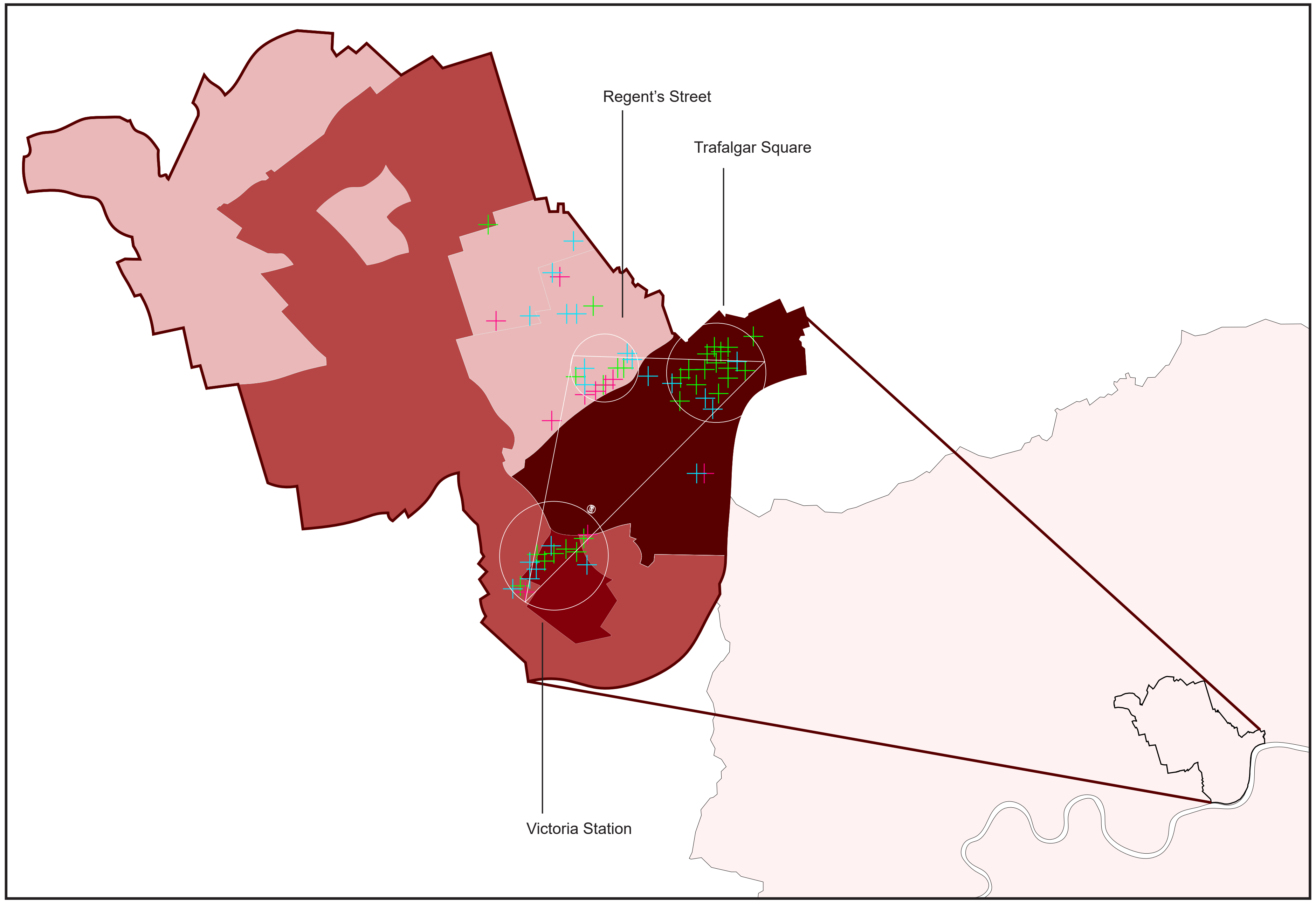


London accounts for 27% of the total number of people sleeping rough in England. Westminster consistently remains as the local authority with the highest number of people sleeping rough in the country.

Demographics of the homeless population in London:







Relation to the site:

Within Westminster there are three areas where there have been high numbers of rough sleepers recorded. These areas correspond to areas that are visited by tourists and mostly commercial shopping areas. By locating the site inbetween these areas, as well as the hostel providing a service to the most relevant areas, it has the opportunity to create a positive engagement within the public. In doing this, the building can possibly improve perceptions of the homeless populations of the city and address stigma.



Hostels generally aim to **support** people progress to **independence**, conceptualised as not only accessing accommodation, but also developing the skills, abilities and resources need for **re-integration** and **personal development**. Hostels also aim to provide safety, security and opportunities for people to access support to address their needs and problems.

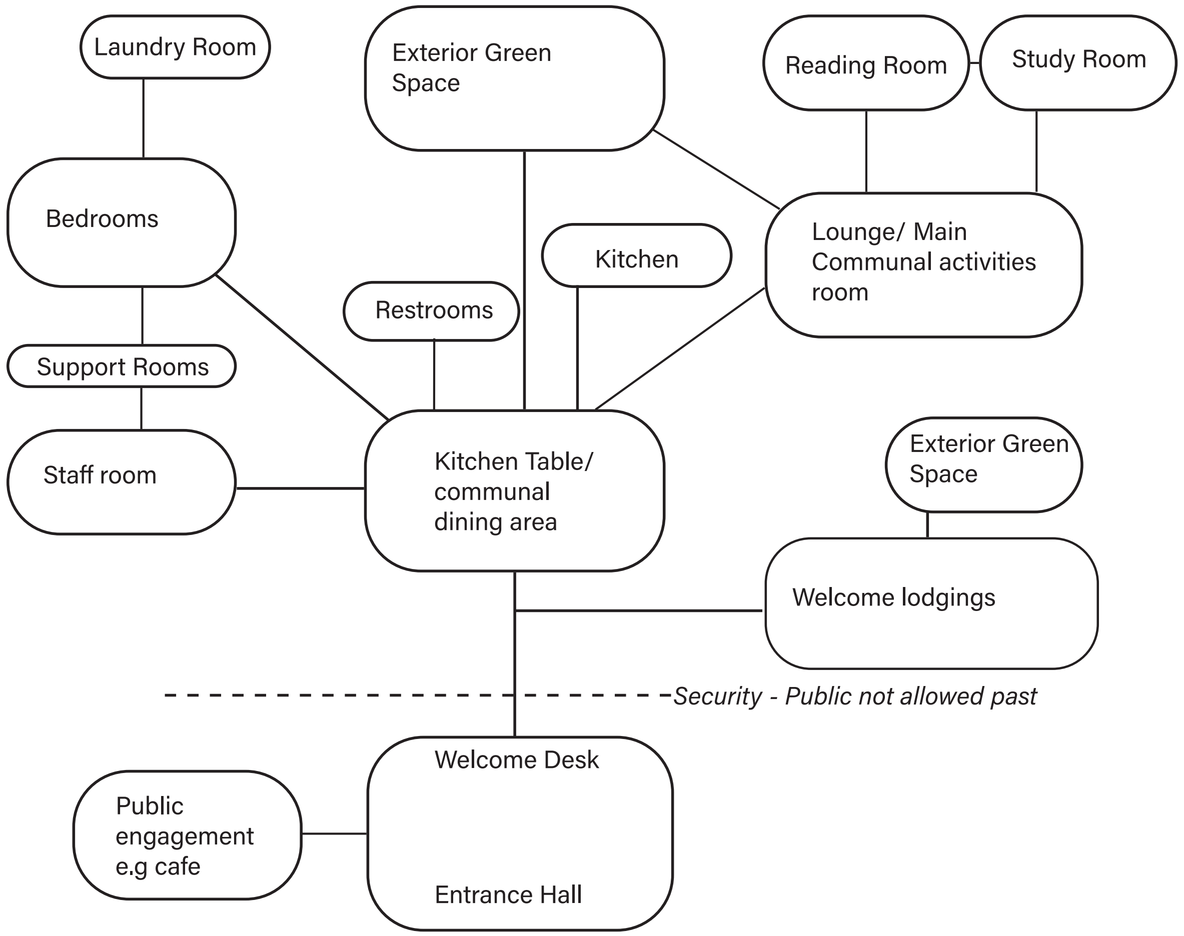
Spaces for 'Meaningful Activity'

Non-primary services are those that fall outside of the mandatory key-working sessions and facilitate 'meaningful activity.' This could be activites suchas as dancing, gardening, cooking, art classes, IT classes, specialist lectures etc.

Left: Maggie's Centre Fife (Jencks)

'Kitchenism'

Following that of Maggie's centres's philosophy that characterises their facilities as anti-institutional. The kitchen table being one of the first spaces experienced on entry - interaction can be informal and across a cup of tea.



Accomodation Adjacency Diagram

The whole idea of kitchenism is to make the hostel feel welcoming. What other ways can a welcoming atmosphere be developed?

00 Air Pollution in London

Air Pollution in London

The UK Air Quality Standards Regulations 2010 sets standards for a number of pollutants than can harm human health and the environment. These are based on EU limit values and include:

- sulphur dioxide (SO2)
- nitrogen dioxide (NO2)
- nitrogen oxides (NOx)
- particulate matter (PM10 and PM2.5)
- lead
- benzene
- carbon monoxide (CO)
- benzo(a)pyrene
- ozone (O3)

In London, most of these pollutants are not at levels that affect human health
The two pollutants of most concern in London are:

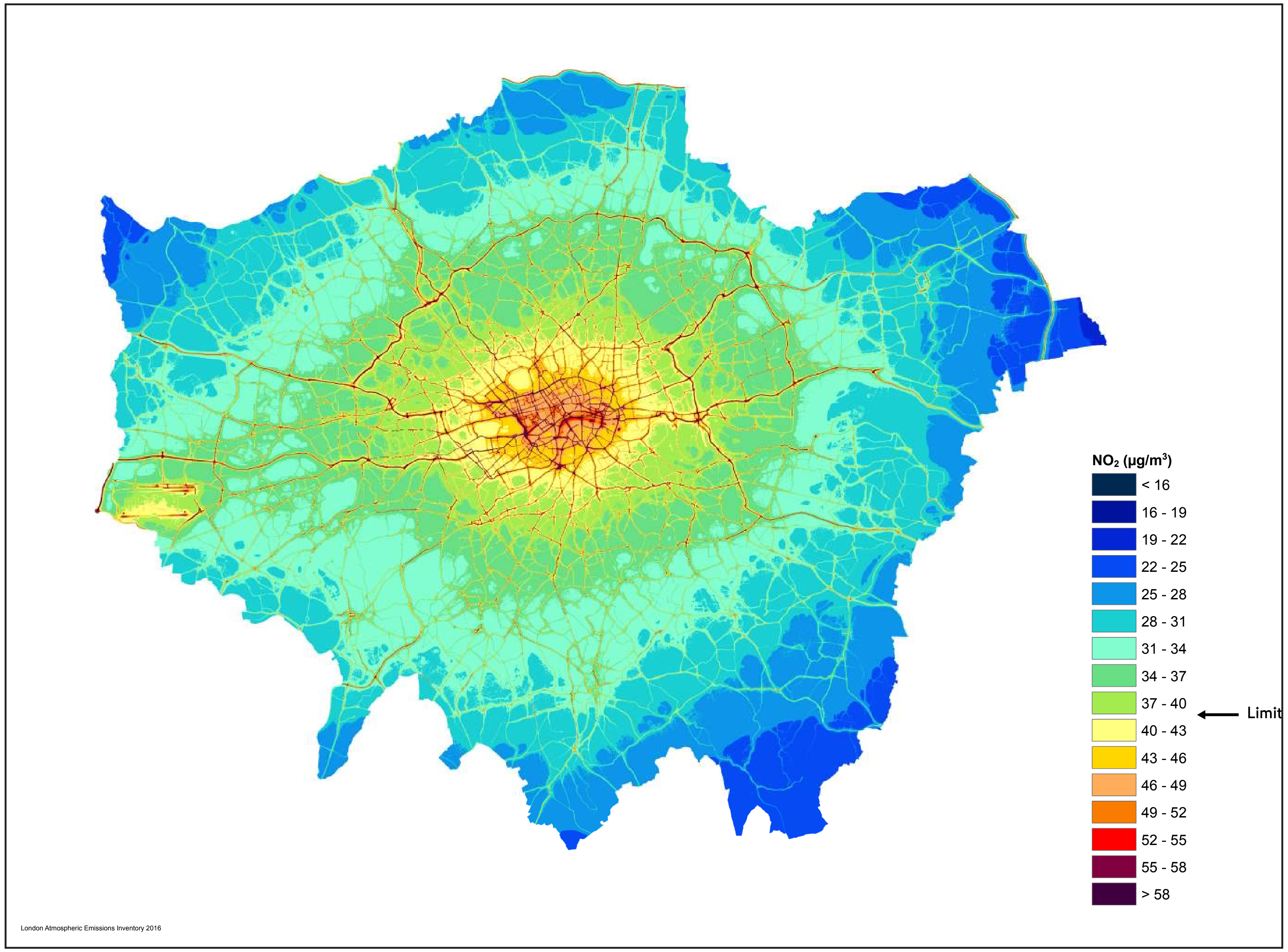
Particulate matter (PM)

Particulate pollution can harm our heart and lungs - it is linked to asthma and death. Research shows that particles with a diameter of ten microns and smaller (PM10) can be inhaled deep into the lungs as smaller particles can penetrate deeper. PM2.5 can have a particularly bad impact on health.

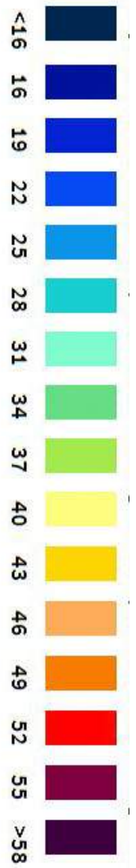
Nitrogen dioxide (NO2)

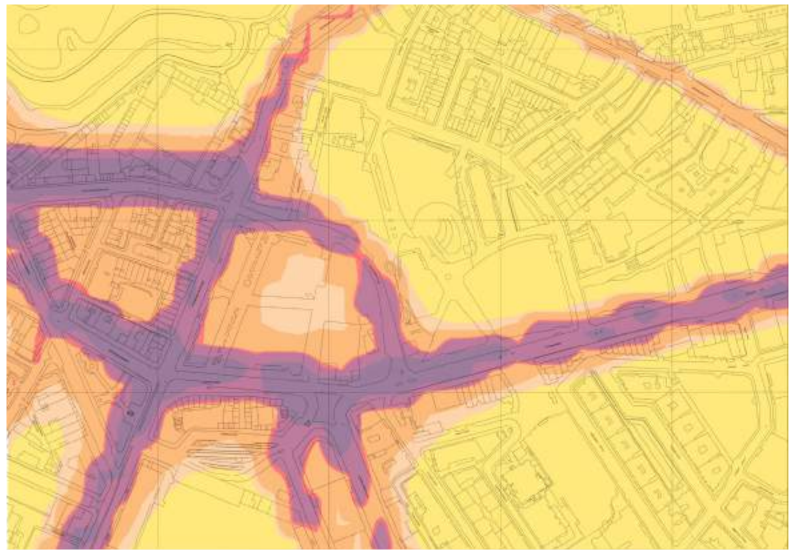
At high concentrations, NO2 can inflame the airways and long-term exposure can affect lung function and breathing - it can also worsen

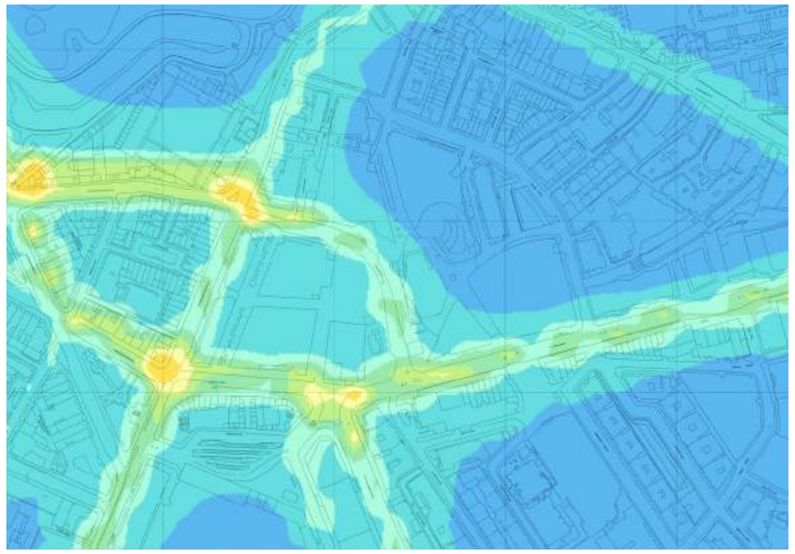
Despite recent improvements in air quality, toxic air pollution in the Capital is still the biggest environmental risk to the health of all Londoners, harming our lungs, worsening chronic illnesses such as asthma, lung and heart disease and putting the health of our children at risk. A study from Imperial College London says that in 2019 over 4,000 Londoners died because of the impact of toxic air.



Air Pollution on site







The Junction of Victoria Street, Bressendon Place, Grosvenor Place, and Bucking Palace Road second largest source of NO2 in City of Westminster.

Short term exposure (a few hours) to high levels of NO2 can irritate the airways and cause severe coughing and exacerbate existing respiratory illnesses, which is uncomfortable at best, and dangerous at worst for vulnerable people (sick and older or younger people for example).[1]

Long term exposure can contribute to someone developing a number of illnesses, such as pulmonary disease and lung cancer.
- increased respiratory symptoms which can include coughing, difficulty breathing, and shallow breathing;
- increased asthma prevalence and incidences;
- increased cancer incidences;
- adverse birth outcomes;
- reduced life expectancy;
- increased mortality.[3]

Nitrogen dioxide and nitric oxide are referred to together as oxides of nitrogen (NOx). NOx gases can also react to form smog and contribute to acid rain. NOx is also central to the formation of fine particles or particulate matter (PM).[2]

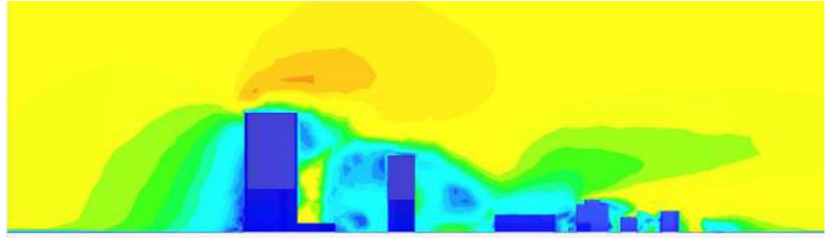
Pollutant	WHO annual mean concentration limit	EU annual mean concentration limit
$PM_{2.5}$	10 ųg/m^3	25 ųg/m^3
PM_{10}	20 ųg/m^3	40 ųg/m^3
NO_2	40 ųg/m^3	40 ųg/m^3

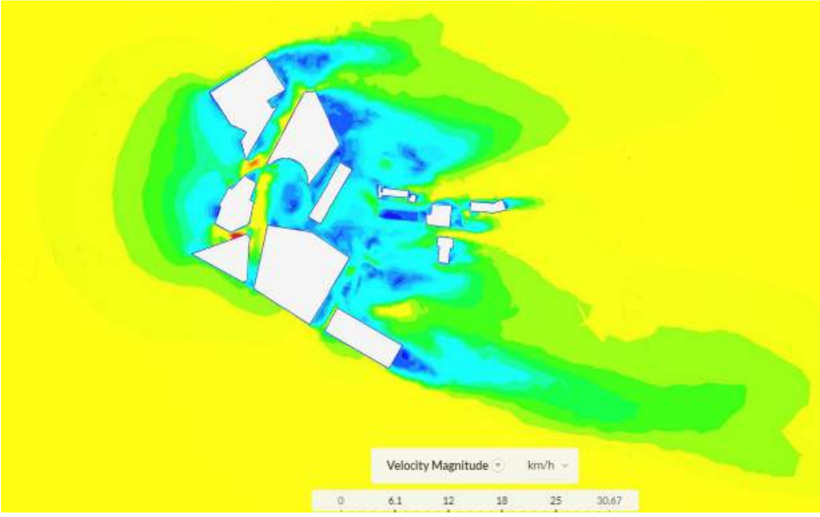
The level of NO2 on the site itself is at the recommended limit of both organisations, however the surrounding main roads exceed these limits and have dangerous levels of the pollutant (greater than 58 ųg/m^3).

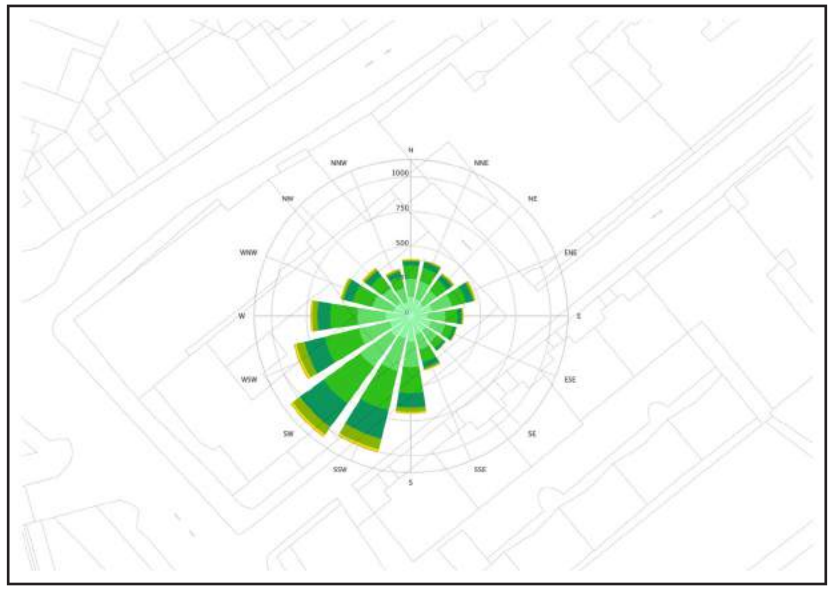
The level of PM_{10} on the site itself is below the concentration limit recommended by the EU, but it is exceeding that recommended by the WHO. The concentrations at the surrounding main roads exceed both of these recommendations.

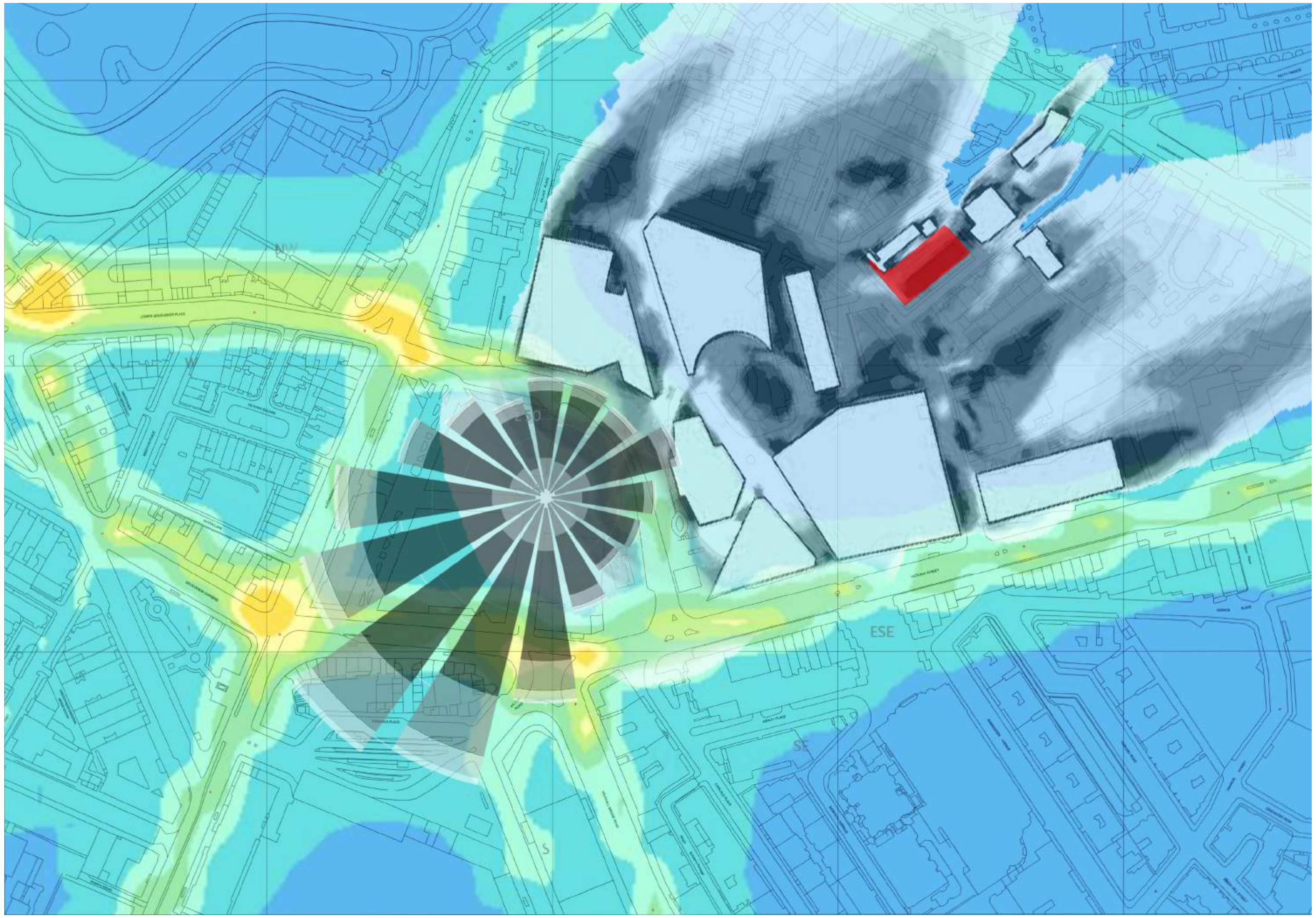
The level of $PM_{2.5}$ on the site itself exceeds the concentration limit recommended by both organisations.

00 Wind’s effect on pollution distribution







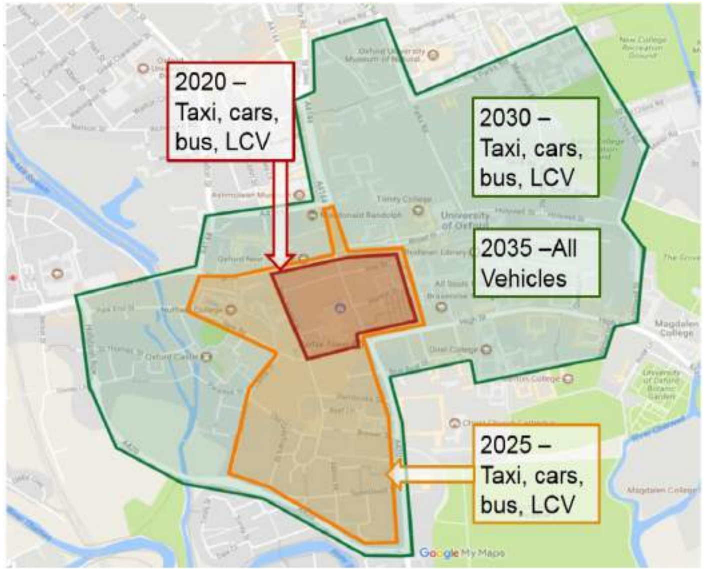


00 Existing Actions to Improve Air Quality

1

Oxford, UK

The city plans to introduce their phasing of the 'world's first' zero emission zone in the city centre by 2021. It would ban diesel and petrol vehicles in the city centre, phasing according to size, purpose, and performance. The phasing would be complete in 2035



2

Paris, France

The city has several bans on cars: in historic districts at weekends; an alternating ban between even/odd number plates; the Crit'Air System bans cars from areas of the city according to their emission performance. It plans to ban diesel engines by 2024 and all petrol vehicles by 2030.

3

Helsinki, Finland

The city is investing in better public transport; imposing higher parking fees; encourages bikes and walking; and is converting inner city ring roads into residential and walking areas. The aim is that by 2050, no one will want a car.

4

Copenhagen, Denmark

The city plans to become carbon neutral by 2025, and has long priorities bicycles over cars (only 29% car use rate) - large parts of the city have been closed to cars for decades. All the cars in the municiple fleet are electric or hyrdogen powered. They aim for 50% of commutes to be by bike.

5

Oslo, Norway

Here there are fees for motorists travelling during rush hours, as well as high congestion charges and the removal of parking spaces in order to deinsentivise driving. 40 miles of new cycle lanes have been installed to promote cycling as an alternative.

6

Vauban in Freiburg, Germany

The suburb has parking fees starting at €18,000 and has no parking spaces to force people to live without cars. The residents are offered cheaper housing, free public transport and plenty of bicycle spaces and 500k of bicycle lanes.

00 Investigation Proposal

The Proposal:

The hostel needs to be providing a healthy living space that will nurture its occupants, and current strategies for dealing with air pollution are on a longer timeline, meaning that occupants of the building will still suffer the effects of breathing toxic air.

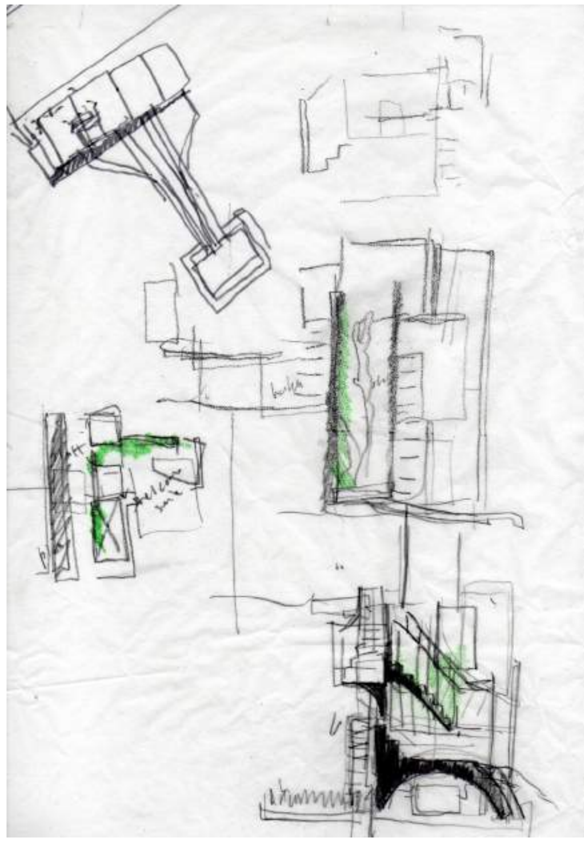
The ethos of the project is to provide a quick solution to accompany existing strategies, in that it is providing temporary accomodation for homeless Londoners while legislation and policy deal with root causes of homlesseness.

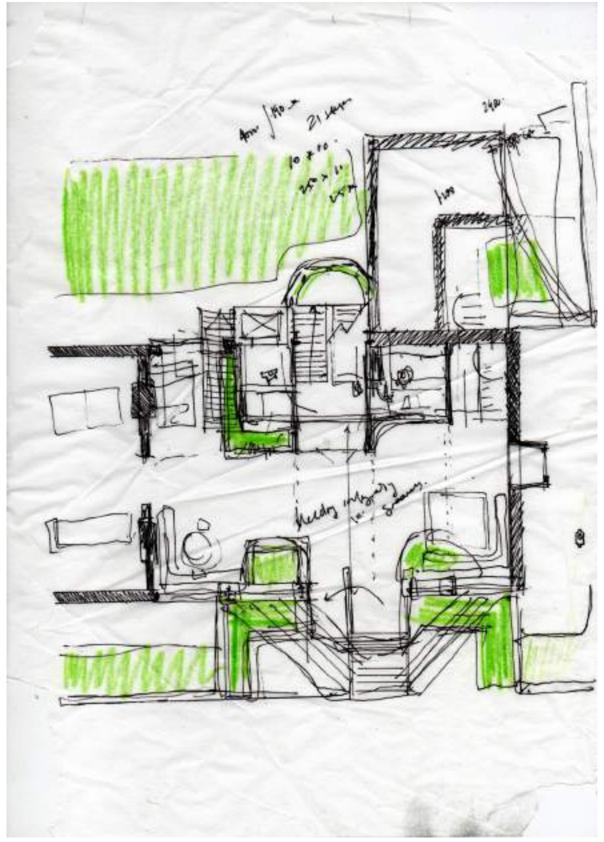
What can the short term strategy be for providing clean air to the occupants?

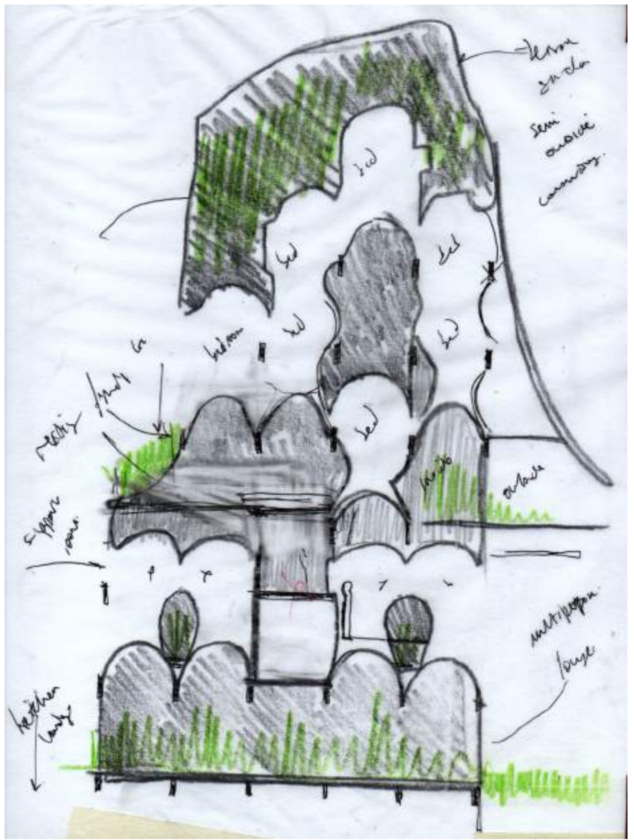
Throughout the design process so far, the consideration of green space has been a priority, so that signs of growth and life with vegetation can improve the atmosphere to the accomodation. However what if the green spaces within the building could do more than just visually improve the surroundings for the occupants. It is known that plants have some affect in reducing air pollution, but would it be possible to create a 'green mask' using green infrastructure.

This dissertation will investigate how might the existing plans to naturally ventilate the building be combined with strategic green infrastructure, so that the air quality can be filtered to within safe levels.

Previous iterations







Current building design

1.0 Types of Natural Ventilation

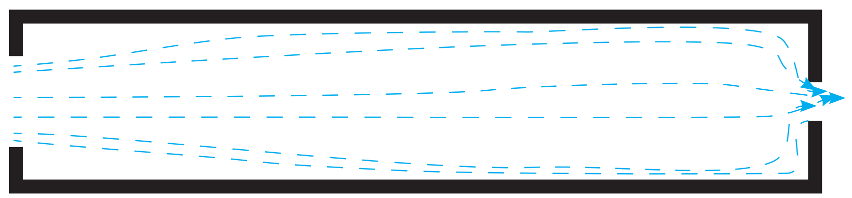
Wind driven ventilation

When wind makes contact with a building it increases the air pressure on the windward side of the building. As the air passes over the building it creates a 'wake' and the air on the lee-ward side of the building is considerably lower than that of the windward.

Cross-Ventilation

The effects of wind-driven ventilation are best used in cross ventilation. The air inlet is placed on the side of the building that faces the prevailing wind. The air outlet is placed on the opposite side of the space, with an airpath taht connects the two. The fresh air must travel across the room to escape. This means that the room is effectively ventilated of stale air.

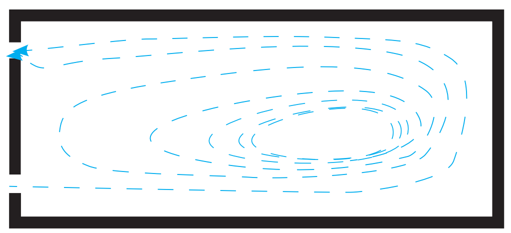
This only provides sufficient air exchange rates with rooms that are x5 the height of the room. (P.175)



Single-side Ventilation

Single-sided ventilation is when the inlet and outlet are located on the same wall as each other. It distributes fresh air as the direction of airflow is constantly fluctuating depending due to wind turbulence and changing the air pressure across an opening. When the interior air pressure is greater, air will flow out of the building. When the exterior air pressure is greater, air will flow into the building.

This only providedes sufficient air exchange rates with rooms that are x2.5 the height of the room. (p.178, design for natural ventilation)



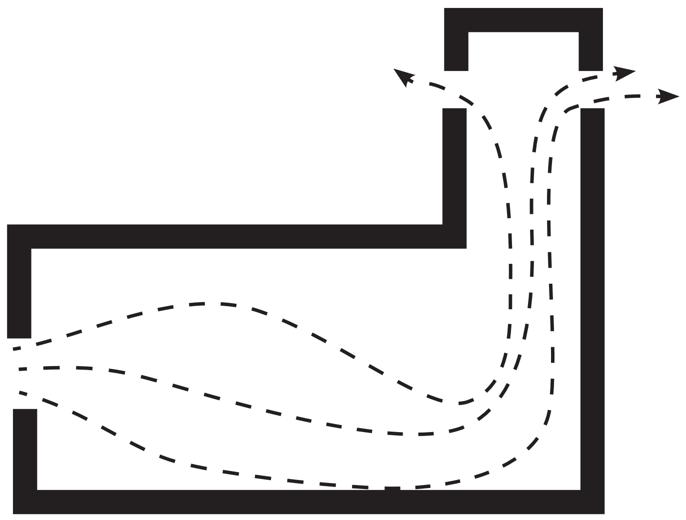
Buoyancy driven ventilation

There is a link between temperature difference and pressure difference. Buoyancy driven ventilation is caused when the temperature within the building is greater than the ambient exterior temperature.

Stack Ventilation

Stack ventilation works best with tall buildings, or buildings with a vertical airpath for fresh air to move through. Warm air will rise up through the building and escape through an exhaust vent at the top of the building. As the warm air rises, fresh cooler air will be drawn into the building through an air vent at the base.

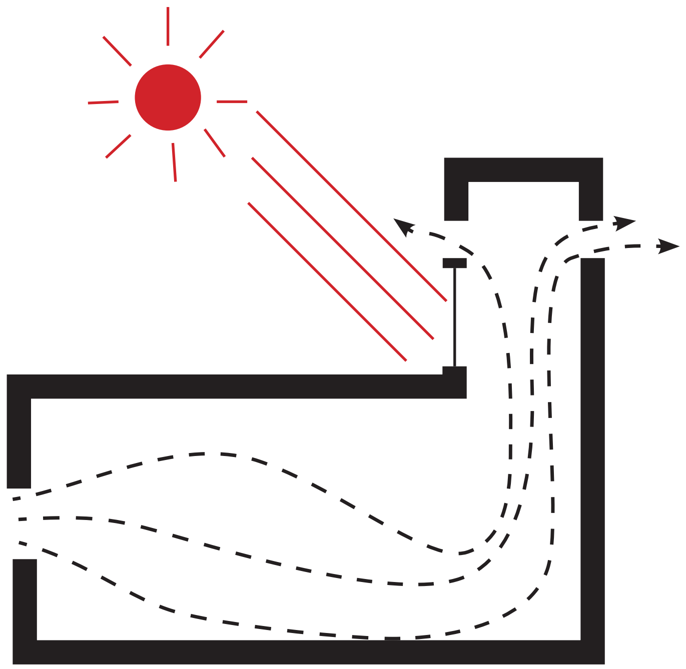
This only works if the interior temperature is greater than the exterior.



Solar Chimney

Ventilation through a solar chimney works with the same principles as normal stack ventilation, but with the addition of the area near the air outlet being heated by the sun. This creates a greater temperature difference between the air within the building and the ambient exterior temperature, increasing the movement of air.

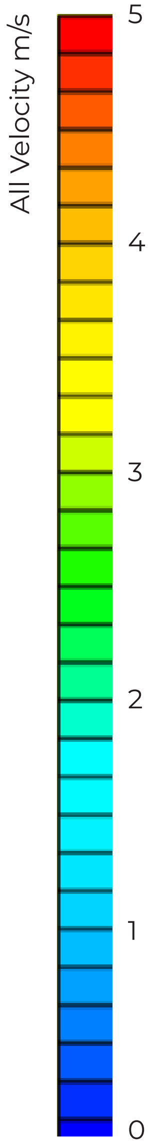
The area of the solar chimney should not be occupied as it won't be thermally comfortable. Furthermore, as most implementations use a lot of glazing, thermal loss through the envelope must be considered.



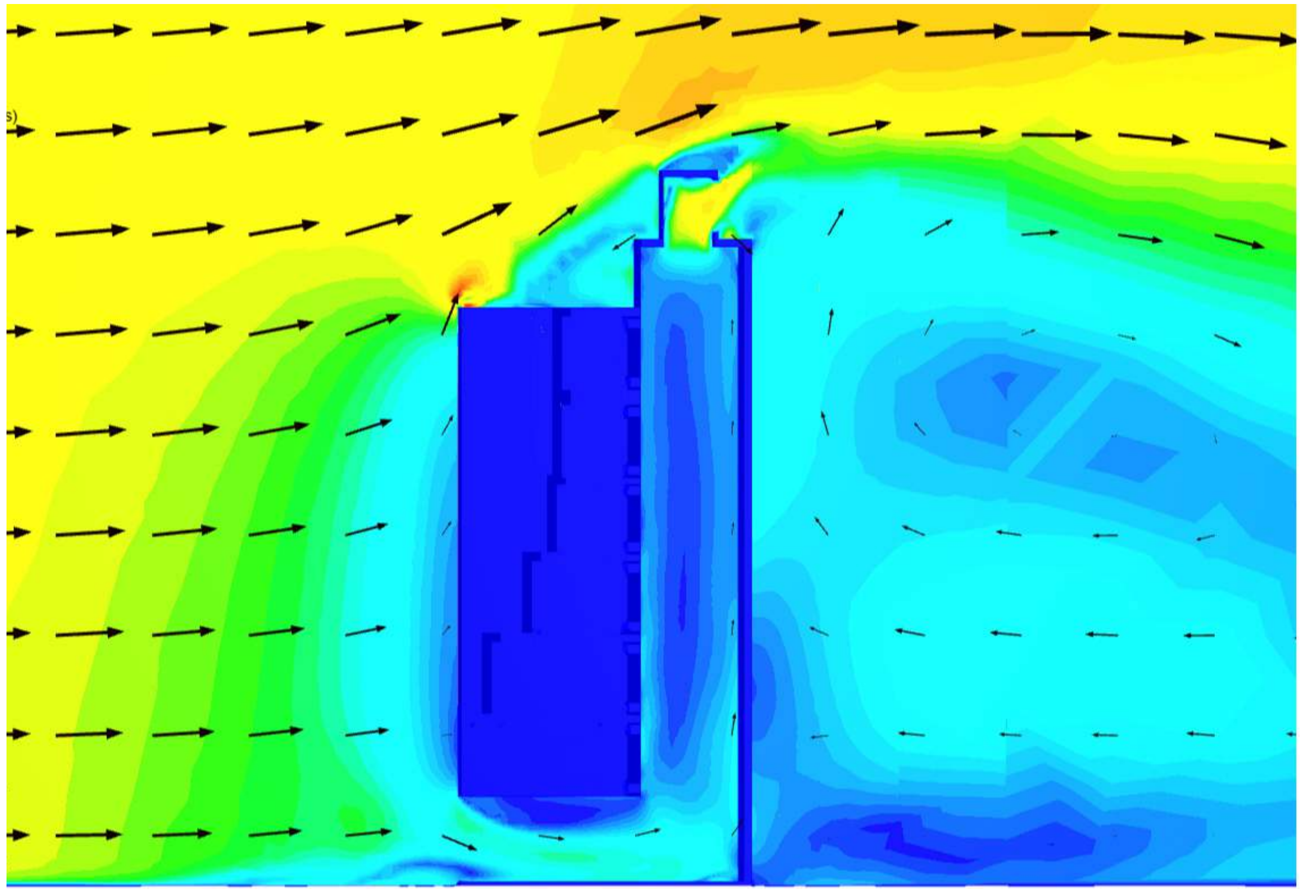
Combining different strategies:

Both wind and buoyancy can contribute to the ventilation of a single building. Wind can drive the air in the building, and lead to a central atrium that acts as teh vertical airpath to the air outlet. The benefits of this is that larger buildings with deeper floor plans can use natiral ventilation.

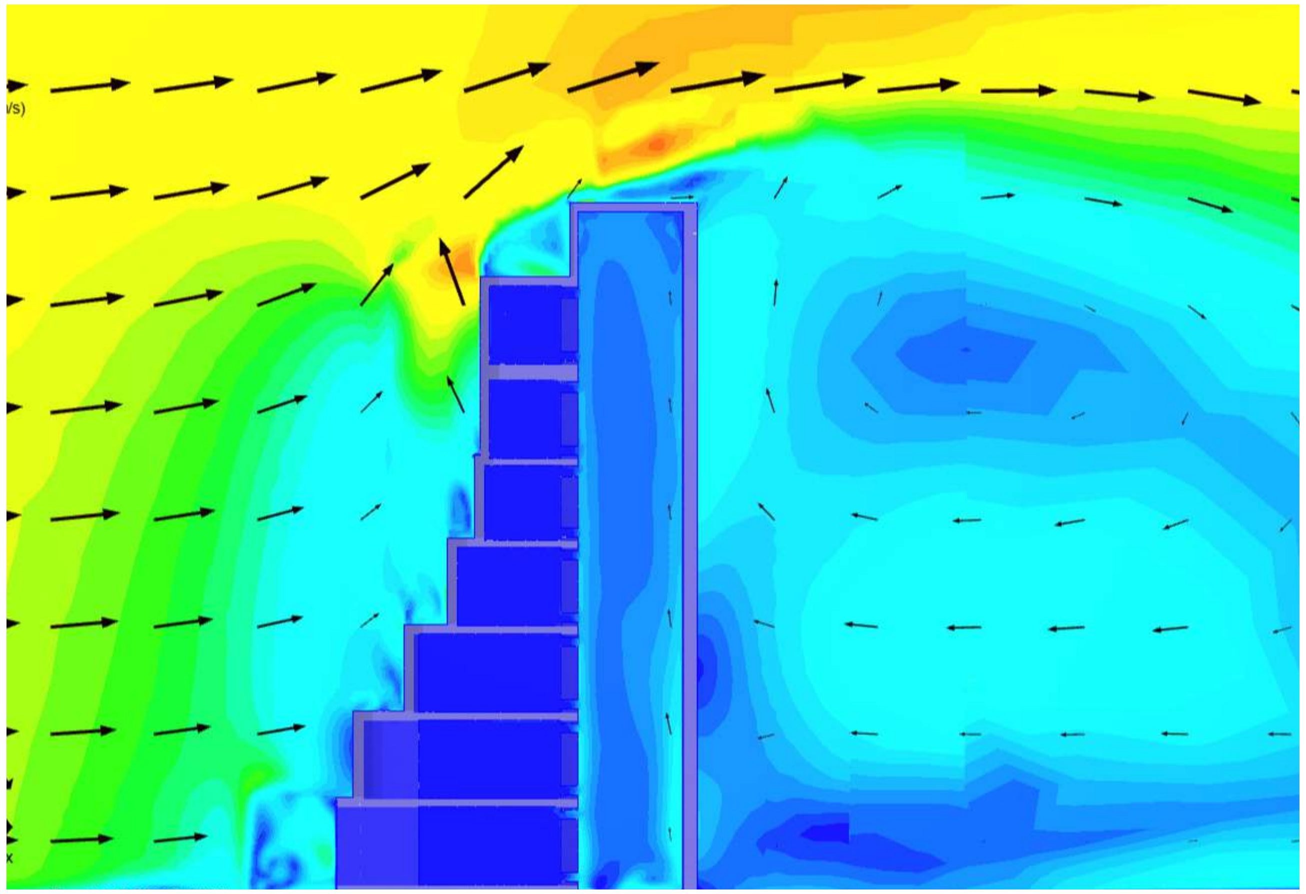
00 Test: Stack ventilation and single-sided ventilation



(A)



(B)



Design:

One main air collumn that will be the path of fresh air and stale air for the building. All rooms will have inlets and outlets lead directly to this shaft.

Test Goal:

Incoming wind velocity set at 3 m/s for the simulation. Testing whether arrangement of the rooms and ventilation shaft will generate air movement and circulate through rooms.

Test Hypthosesis:

- There will be a pressure difference between inlet on windward side of the building and the outlet located at the top of the building in the wind's wake.
- This will cause air movement through the vertical shaft.
- On the way up, fresh air will enter rooms of the leisure core and circulate via single-side ventilation.

Test Findings:

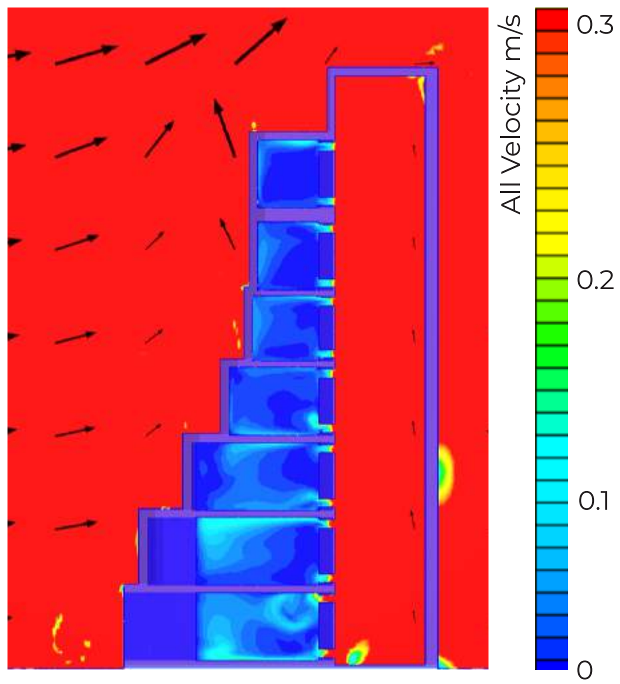
The initial hypothesis was correct about the overall movement of air up through the building. This can be seen in section (A): fresh air enters the building from the southwest (left) and travels up the shaft to leave the building from an outlet facing north-east (right).

However, section (B) cuts throught the rooms of the leisure core and shows that there is no air movement. After an adjusment to the colour scale (section (C)), some areas show air movement at speeds of 0.1m/s, but most of the room appears still.

Test Take Aways:

The air was running parrallel to the air inlets for the leisure rooms, rather than against - this didn't create the pressure difference required to generate air movements. Air inlets need to placed where wind hits on correct angle, or wind needs to directed to do so.

(C)



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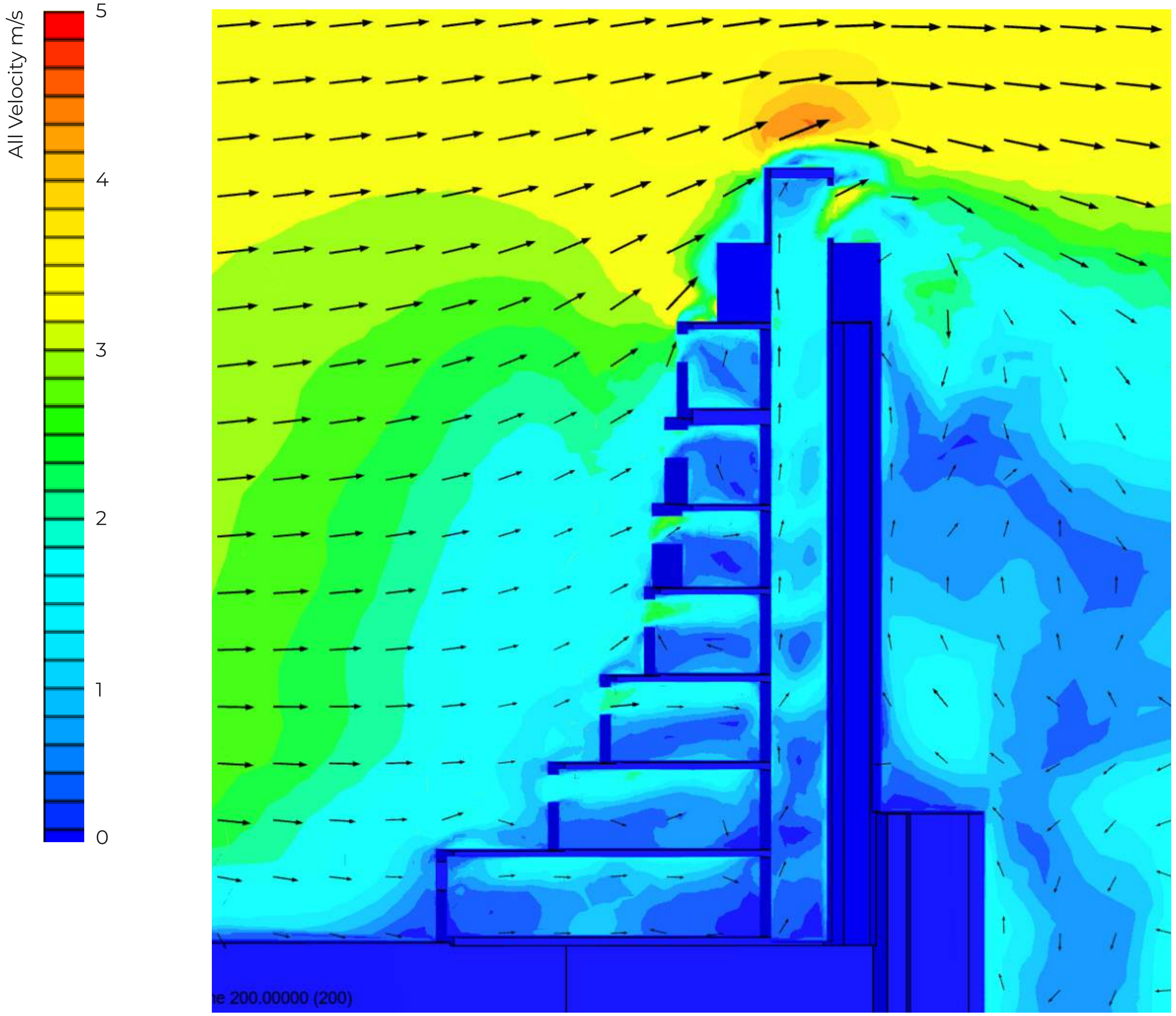
Test: Stack ventilation and cross-ventilation



Design:

One main air collumn that will be the path of fresh air and stale air for the building. All rooms will have inlets to the exterior on the southwestern face, facing the prevailing wind. Air outlets will connect directly to vertical shaft.

Test Goal:

Incoming wind velocity set at 3 m/s for the simulation. Testing whether arrangement of the rooms and ventilation shaft will generate air movement and circulate through rooms.

Test Hypthosesis:

- Air will be wind-driven into the rooms through air inlets.
- Air movement up through the vertical shaft as in the previous test due to low air pressure at exhaust inlet.
- Air will be drawn into the vertical shaft from leisure rooms, moving from low to high air pressures. Rooms will be ventilated with cross-ventilation.

Test Findings:

This is an improvement from the previous arrangement of air inlets, with air velocities in the leisure rooms reaching around 1.5 m/s. (Should not be below 0.5m/s). Saying this, the distribution of fresh air is not good - the air velocity is low near floor height, on each level.

This seems because the air inlets and outlets are positioned at the same height within the wall of each room (near the ceiling), causing a direct path between them and bypassing the space closer to the floor.

Test Take Aways:

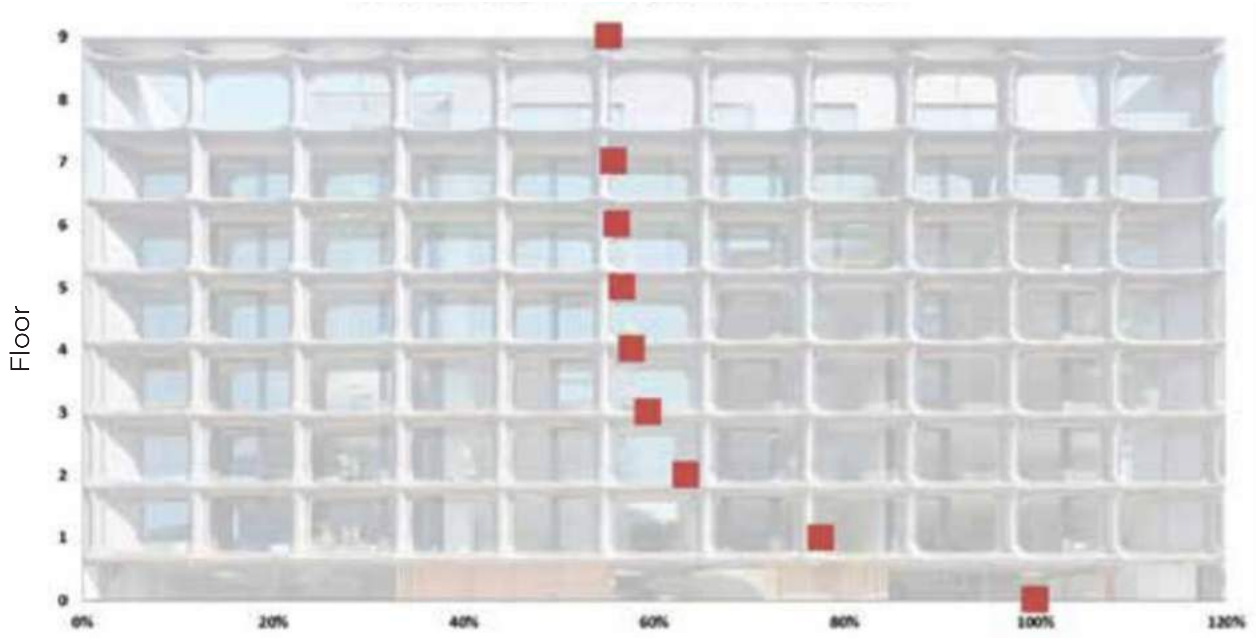
As well as being on opposite sides of the room, the air inlet and outlet should be positioned at different heights to each other as well. This will create 'diagonal' path that will circulate air through more of the space within the building.

Going Forward:

Although this arrangement performed better than stack/single-sided tests it may not be the best approach for the building. Here each room is getting air directly from outside. This would require each intake to have an air filter to clean the incoming air of pollutants. The quantity of vegetation needed is still to be calculated but, it may be the case that the filtering needs to happen from a single point within the building.

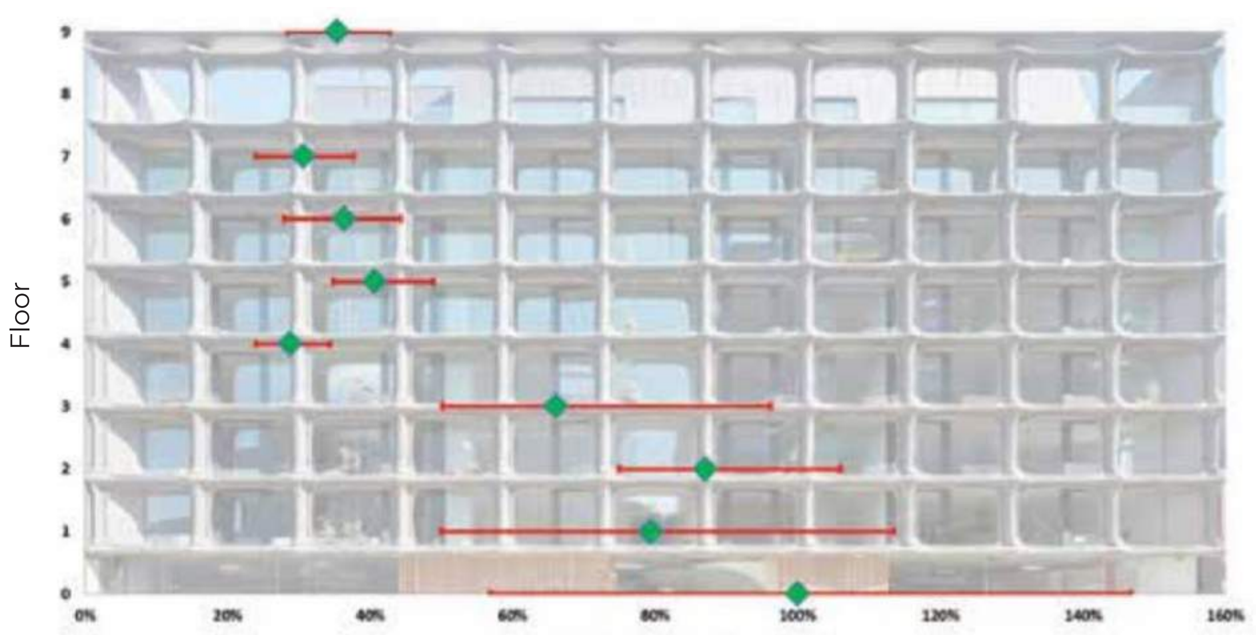
00 Assumptions: Pollution concentration on site

(A) Roadside NO_2 Monitoring Profile with Height



Percentage of Ground Floor Concentration (NO_2)

(B) Roadside NO_2 Monitoring Profile with Height (recorded)



Percentage of Ground Floor Concentration (NO_2)

City Air Quality at Height

The 'City Air Quality at Height' document is provided by Camden Council and it is targeted towards Developers and Planners.

Within it they make recomendations to locate air inlets away from sources of pollution such as main roads, recommending that they be located higher than the fourth floor if possible.

Graph (A)'s data is modelled using ADMS Roads dispersion model, using data that is 'typical of a central London Street in Wesminster'. This is then very likely similar conditions to the site on Castle Lane. According to the model, air located above the fourth floor contains 40% less NO_2 than that found at ground level.

Graph (B)'s data is a calculation of the average of readings taken from 26 different locations within London and Cardiff. The recorded shows even greated reductions in NO_2 concentrations. The air above fourth floor level was shown to have around 60% less NO_2 than that found at ground level.

Assumption 1:

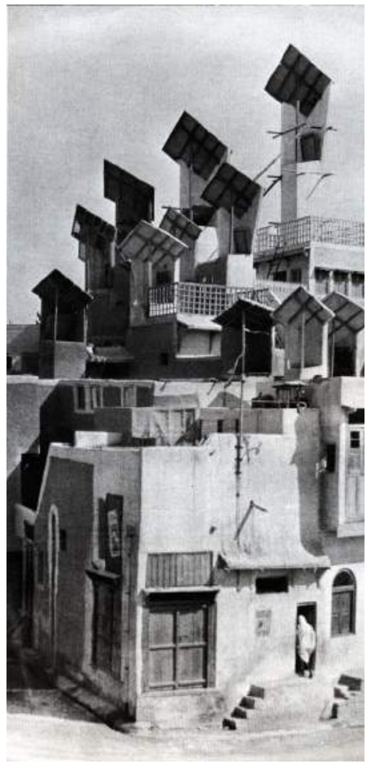
This dissertation is primarily addressing how to reduce the Particulate Matter pollutants within the air being drawn into the building. This study only surveys NO_2 pollution, but going forward it will be assumed that PM pollution behaves in a similar way in regards to its distribution and concentration levels with height.

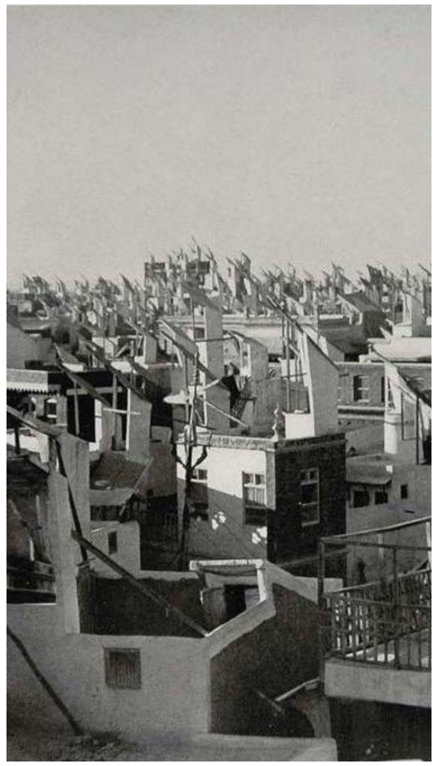
Assumption 2:

This study only has data for up to 9 floors above ground level. It concludes to locate at minimum at 4 levels above ground, and suggests that any higher will not make much improvements to air quality. However the graphs continue to show reductions to pollution levels at higher levels. Going forward it will be assumed that, simply, the higher the air level, the cleaner the intake air will be.

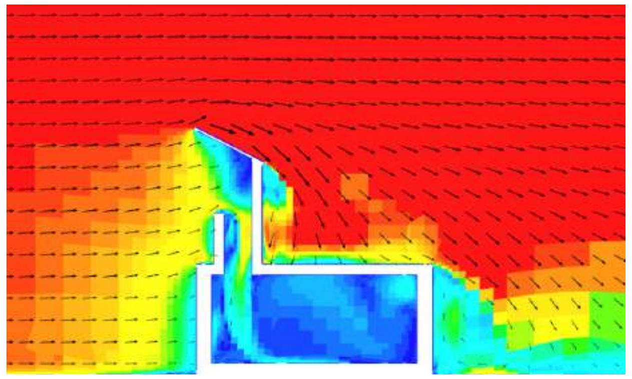
https://www.camden.gov.uk/documents/20142/18667687/8-1+City+Air+Quality+at+Height.pdf/5cfb1877-c72c-869b-23e1-32f06a3cd642

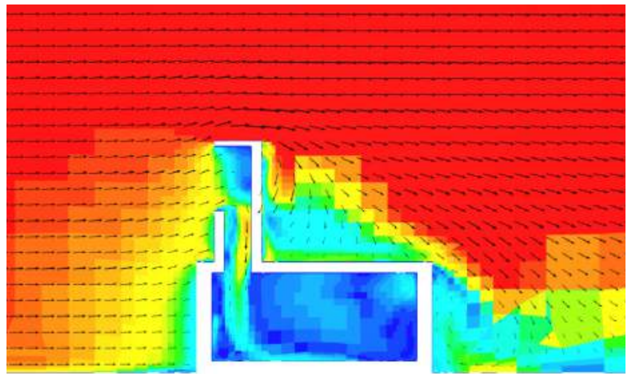
Precedent: Bad-gir wind catcher





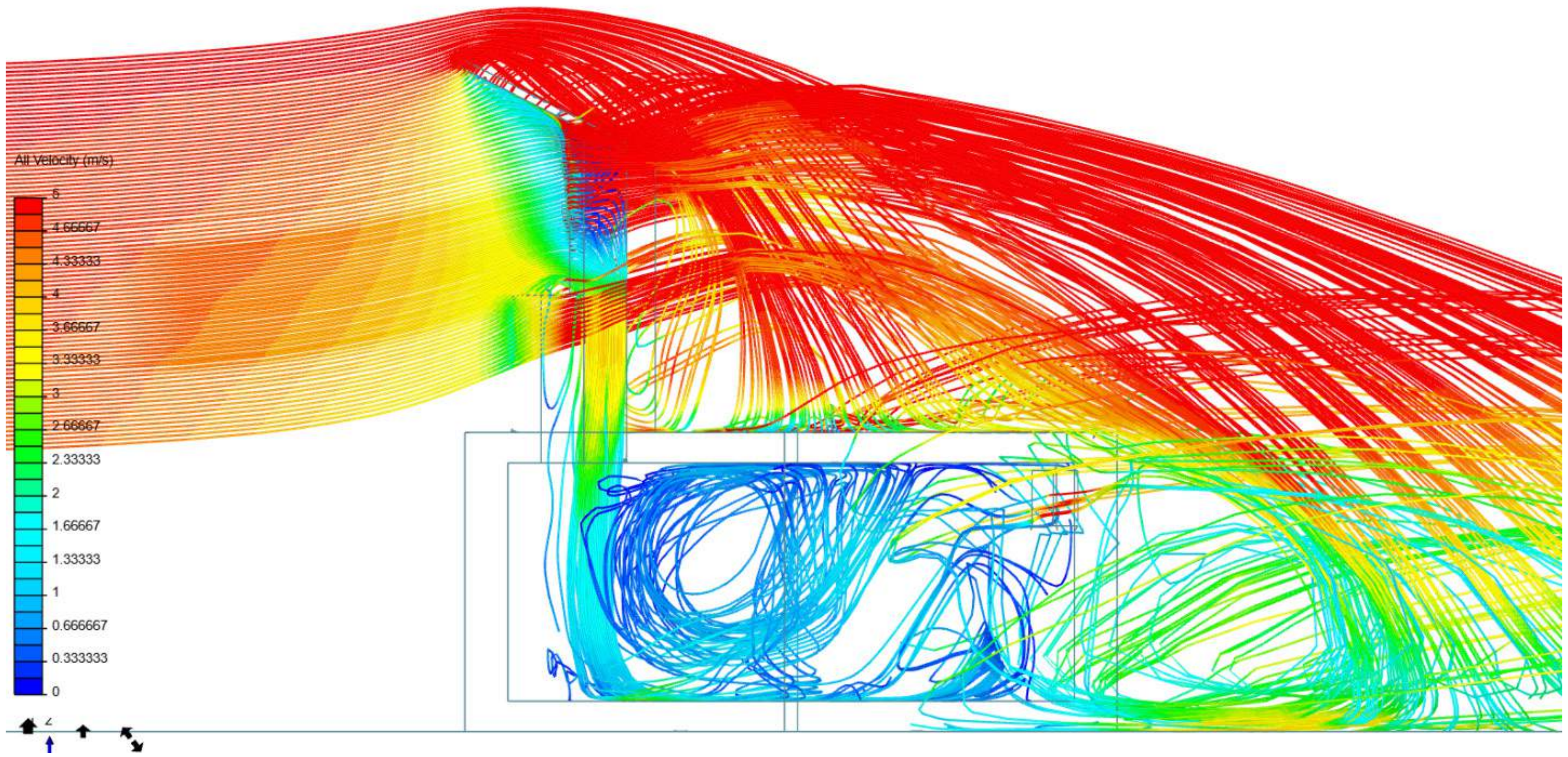
In Hyderabad Synd, West Pakistan wind, “bad-gir”, ‘wind-scoops’ are used to direct the breeze into the houses. The breeze can reduce the temperatrue from 49*C to 35*C. As the wind direction is always blowing from the same direction the angled tops of the wind catchers are fixed in a set direction.
Unlike examples of wind catchers in Iran, there is one bad-gir directing the breeze into every room in the building.



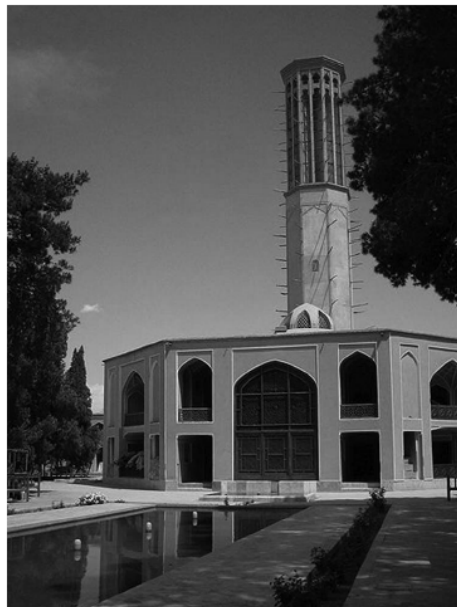


Initital thoughts of angled tops of the air inlet would be that it helped to increase the wind speed entering the interior spaces. However through a CFD simulation of the wind behaviour on the bad-gir, there seems to be no apparent difference in wind speeds between an inlet with a sloped roof and an inlet with a flat roof.

The wake produced from the sloped roof is significantly different between the two models. In the model with the sloped roof the air following the inlet has retained its speed. So it is possible that the sloped roof helps to reduce any obstructive effects that this building may have on others further down the windpath.



00 Precedent: Iranian wind catchers

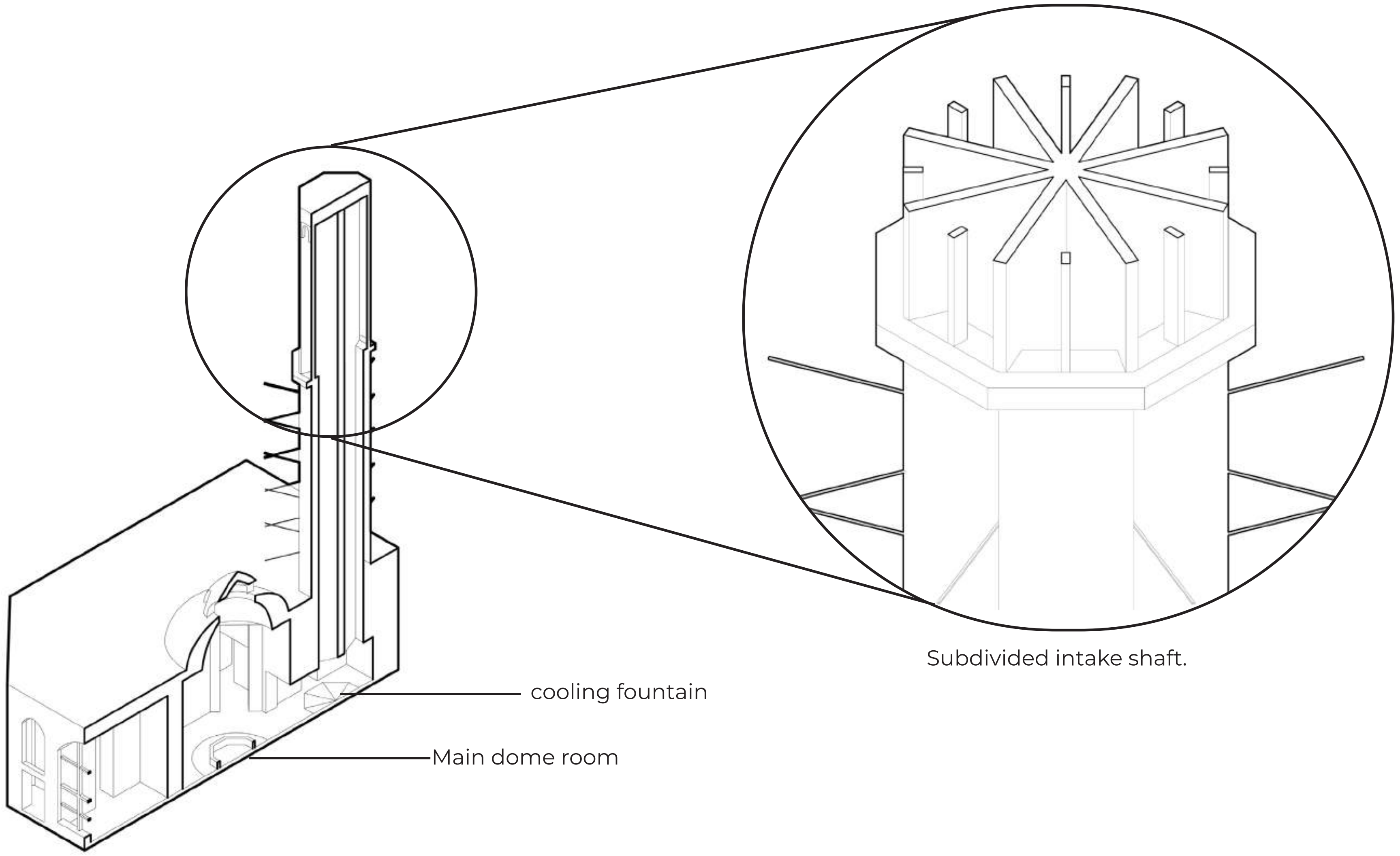


This is the largest wind catcher in Iran. To address if the wind direction changes, and therefore the risk of insufficient ventilation, the wind-catching shaft is subdevided into 8 shafts. Each subdivision has an air intake opening facing different directions.

At the bottom of the air intake shaft is a water fountain. The air passes through the water spray and coolling down as it enters the building. Evaporative cooling techniques such as this can reduce the temperature of the air by up to 15*C.

Other methods of evaporative cooling are wetted surfaces within the shaft itself, or wetted grills at the entrance to shaft.

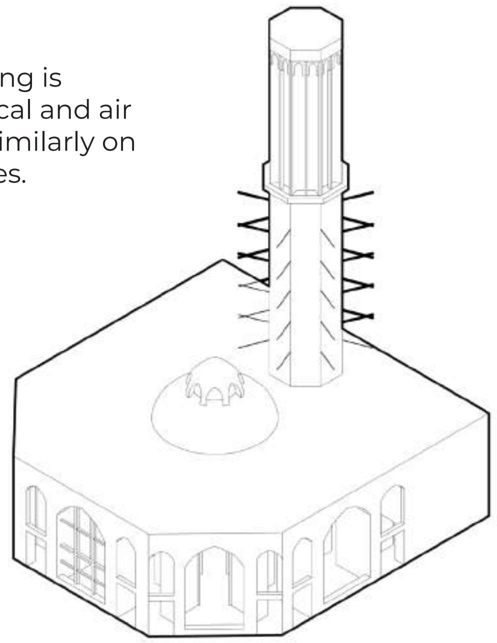
The air flows through the building and exits through outlets at the top of the dome.

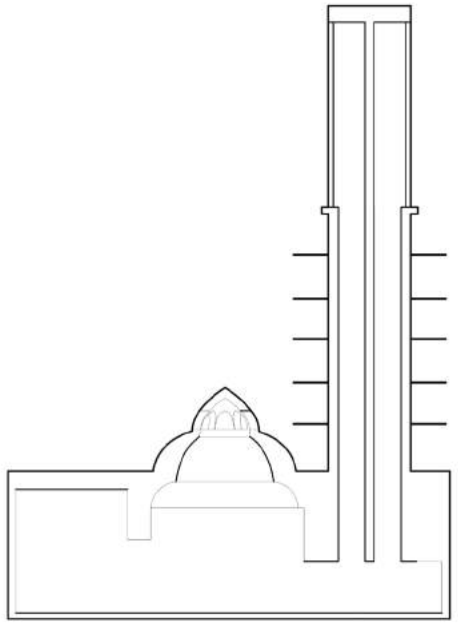


Subdivided intake shaft.

The fountain at the base of the intake shaft.

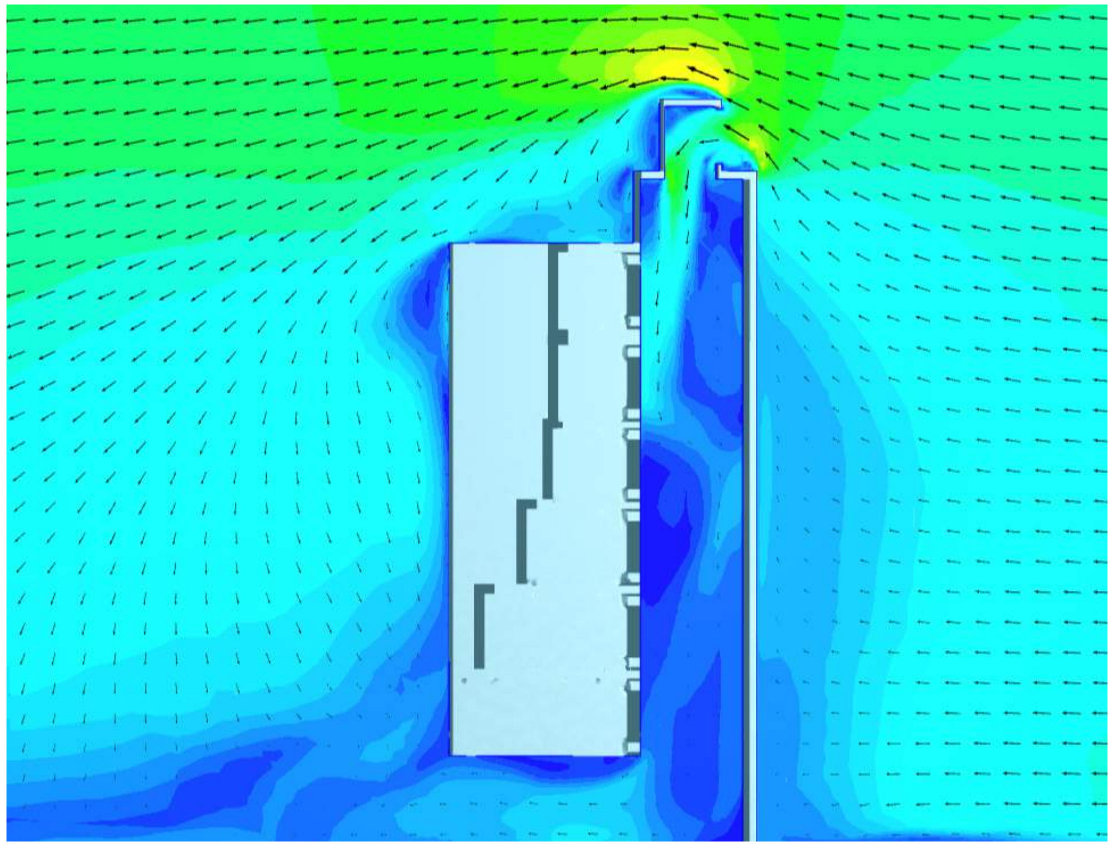
The building is symmetrical and air behaves similarly on both halves.

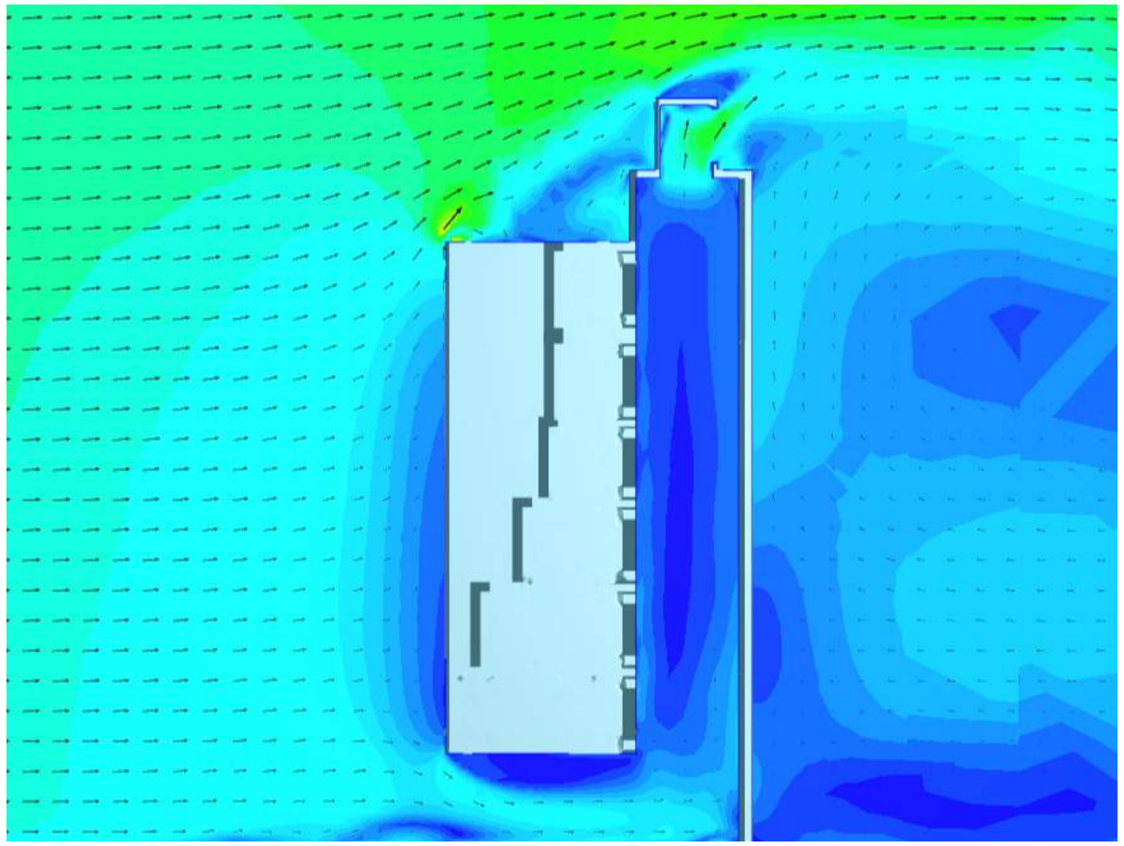


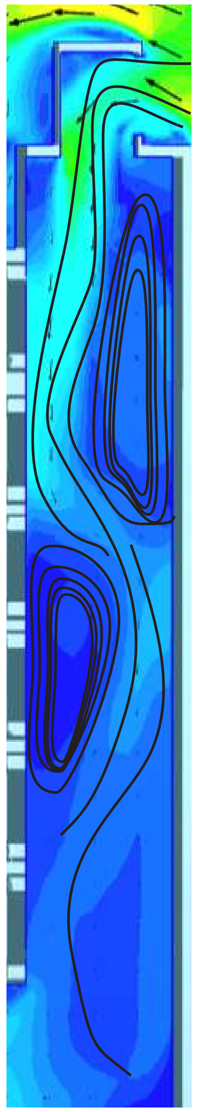


Another fountain keeps the main room cool, warm air escapes through dome via stack effect.

00 Test: Reversing wind direction







Turbulence in ventilation shaft caused by conflicting air movements.

Design:

Air intake at the base of the building facing wind-wards of the prevailing wind. Air exhaust at the top of building facing lee-wards of prevailing wind. Joined by central ventilation shaft that supplies fresh air to leisure rooms.

Test Goal:

The Iranian wind catchers have been built considering that wind changes direction. There is a prevailing wind in London that travels towards the northeast, but the local windrose data shoes that the wind on site does blow in different and opposite directions at times. The building will be aim to be naturally ventilated all of the time, so the effects of a reversed incident wind needs to be tested and evaluated.

Test Hypthothesis:

The reversed wind-direction will create positive air pressure at the air exhaust instead of negative pressure. This will draw air into the building instead of out of it.

Test Findings:

Hypothesis is correct. Air enters the building through the exhaust opening, and the direction of air travel is reversed, with air exiting through the intended inlet. The air however is not being circulated properly - hot air will continue to rise, whilst fresh air is preventing it from leving. This will create a turbulent movement of air in the building with poor air exchange rates. This turbulence can be seen in the vertical shaft of section (B).

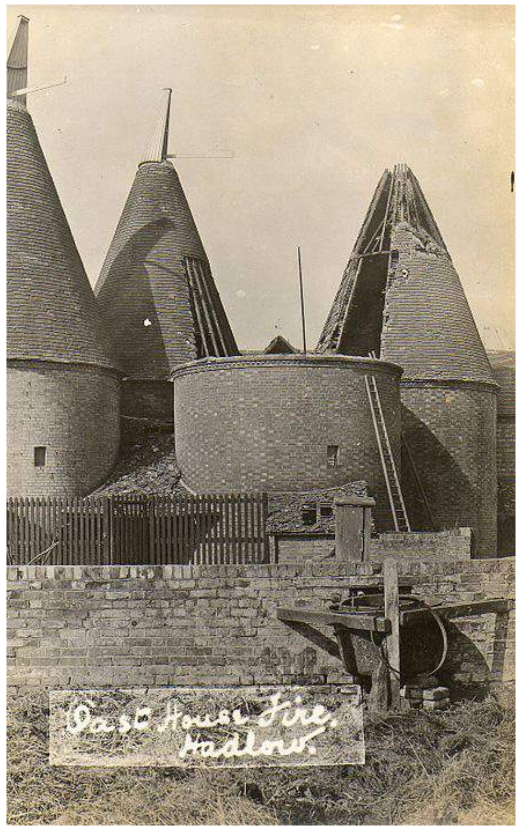
Test Takeaways:

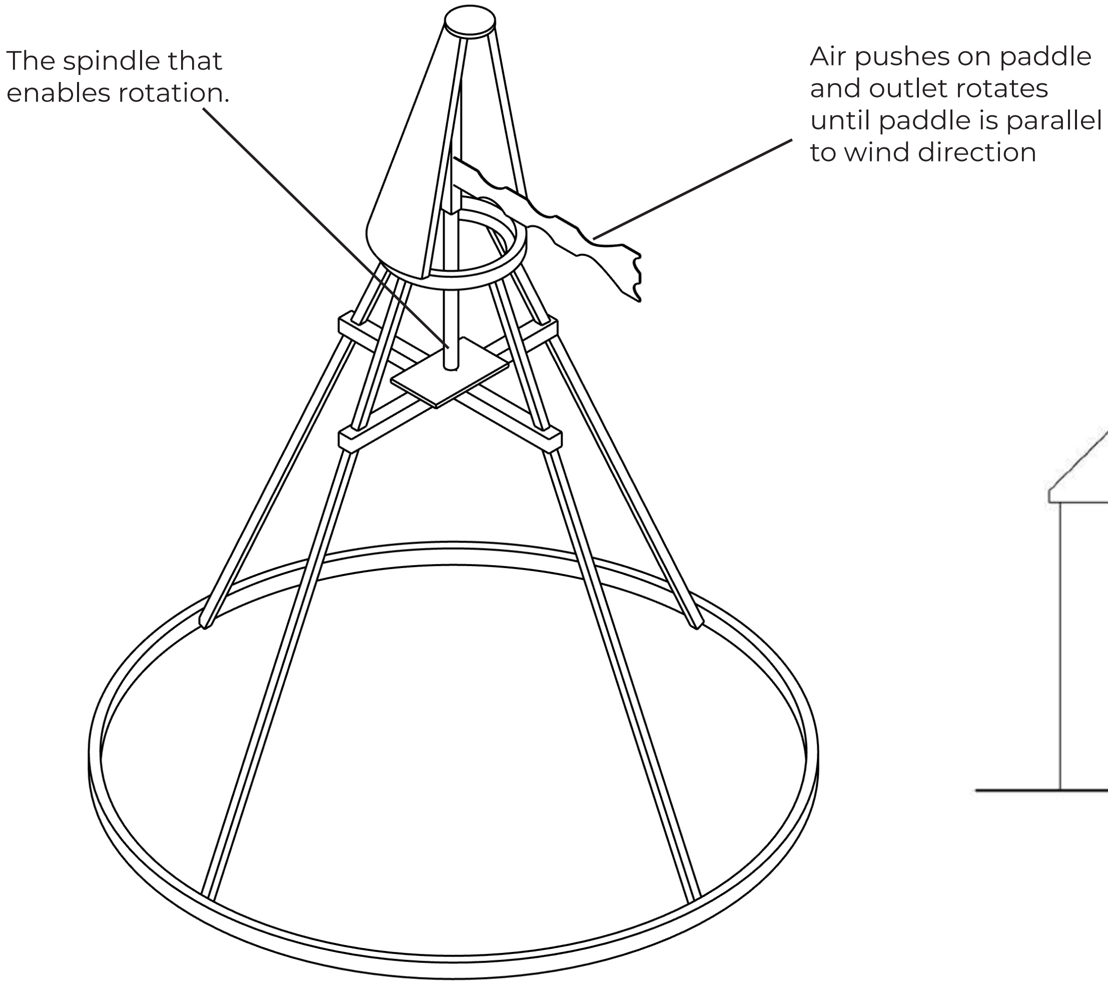
A strategy in the building needs to be implemented so that the correct direction of air movement is taken by ventilating/ exchanging air.

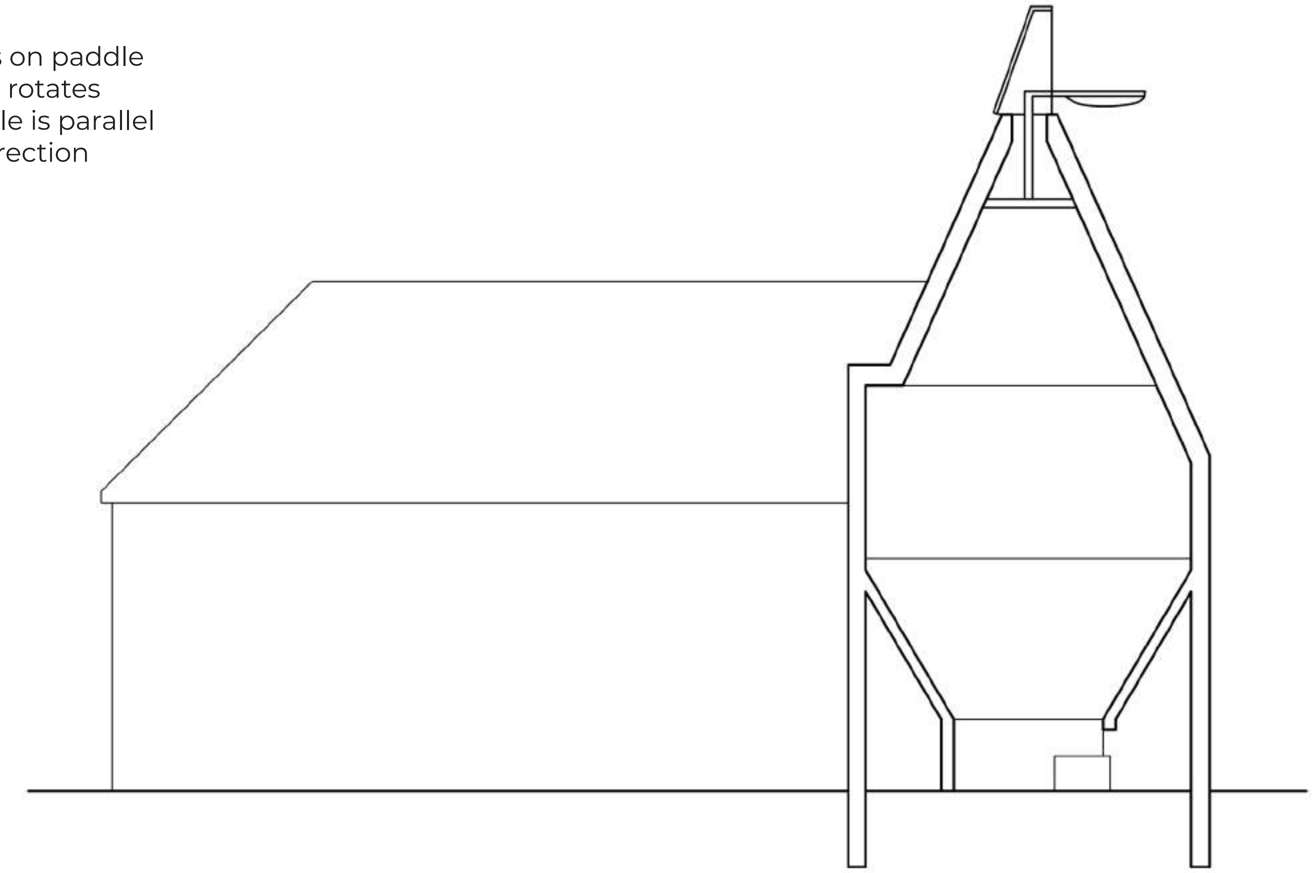
Going Forward:

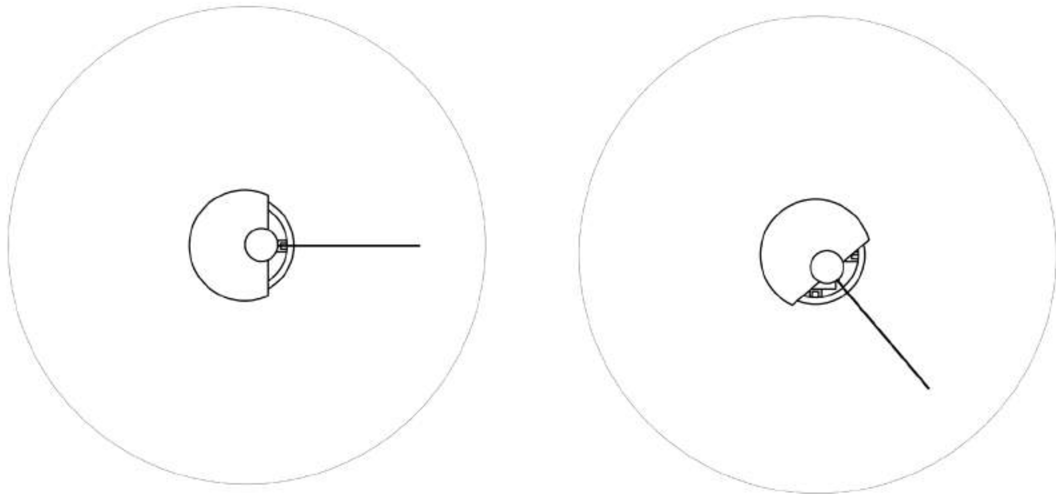
More systems need to be researched as in the case of the Iranian windcatcher system, only a portion of the intake shaft is being used at any one time as it is subdivided. Current design proposals are that the filtering happens within the shaft itself. This would mean that intakes for each winddirection would need to do 100% of the filtering. To implement this would mean having to multiply the resources, green infrastructure and space required, possibly unneccessarily.

00 Precedent: Oasts Houses









Oasts houses are most commonly found in the counties of Kent and Sussex in the UK. They are an agricultural vernacular architecture in which hops are dried and stored as part of the brewing process.

An oast house is split into two levels. The lower level houses the fire that heats the kiln. The upper level is where the hops are layed flat onto the kiln to begin drying. Ventilation of the interior is very important to this process as the moisture released from the hops and the heat from the kiln can cause mold to develop in the hops, if not properly exhausted.

To overcome the possibility of changing wind directions preventing stale air from leaving the stack exhaust, the exhaust outlet of oast houses are able to rotate. The paddle that protudes from the outlet creates a moment on the vent when the wind changes direction, enuring that the opening faces leewards at all times, regardless of the direction of the incident wind.

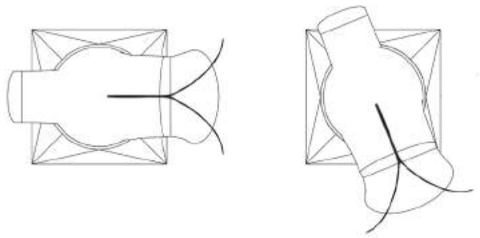
00 Precedent: BedZed Building

The BedZed works with a combination of cross-ventilation and stack ventilation. What is notible is it's use of wind-cowls at the opening of the stack openings. The wind cowl is chosen as the air flow is stronger at the top of the building, as the buildings obstruct wind flow at lower levels, but furthermore as the wind direction often changes.

To combat how the changing wind direction effects the efficiency of the ventilation system, it combines the principles of the Kentish Oats Houses and the functionality of Iranian and Pakistani wind-catchers that have been studied.

The Wind cowl is both the intake and exhaust opening of the ventilation. Using a similar mechanism to the oats houses, a large fin creates air-resistance so that the exhaust opening alligns to face lee-wards. However there is also an opening on the opposite side that faces wind-wards that acts as the fresh air intake.

As the air intake and outake must remain seperated the exhaust is built as two concentric circles with their own rotating colars. Furthermore, there is an intergrated heat recovery system that warms the fresh air entering the building.



Like oasts houses, the cowl has a wind van that turns the cowl until it is parrallel to the incident wind.

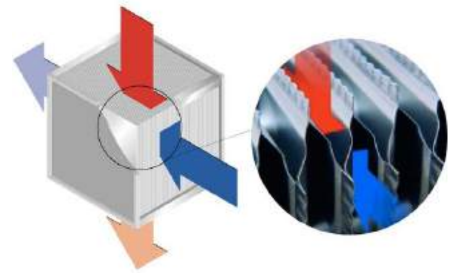
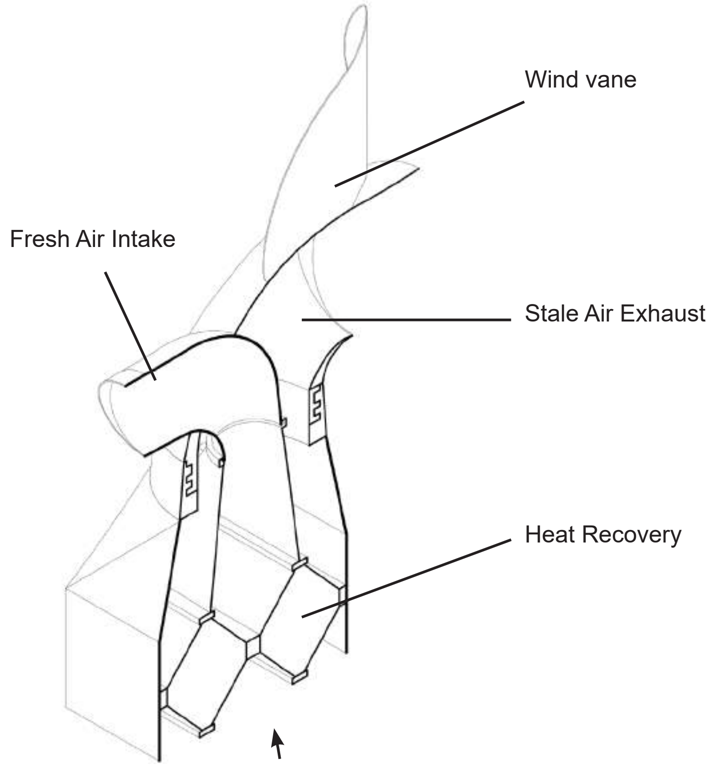
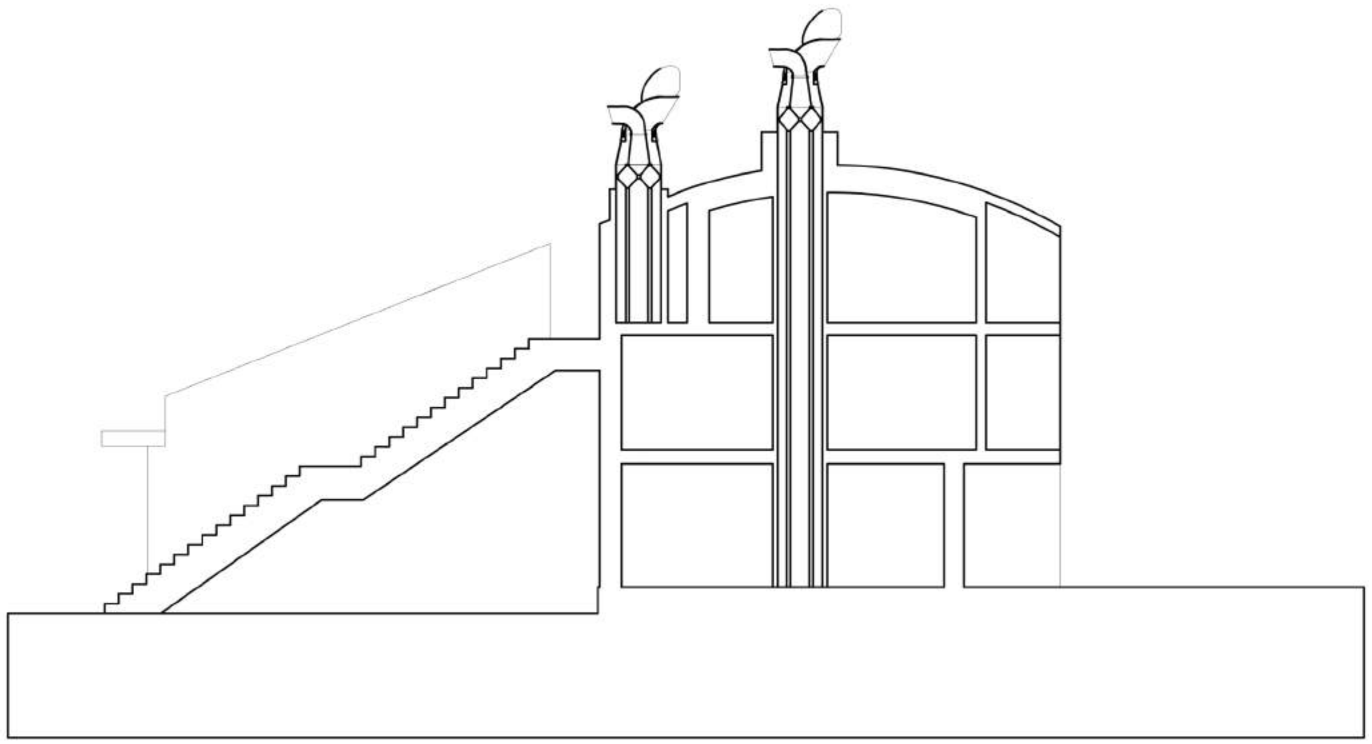
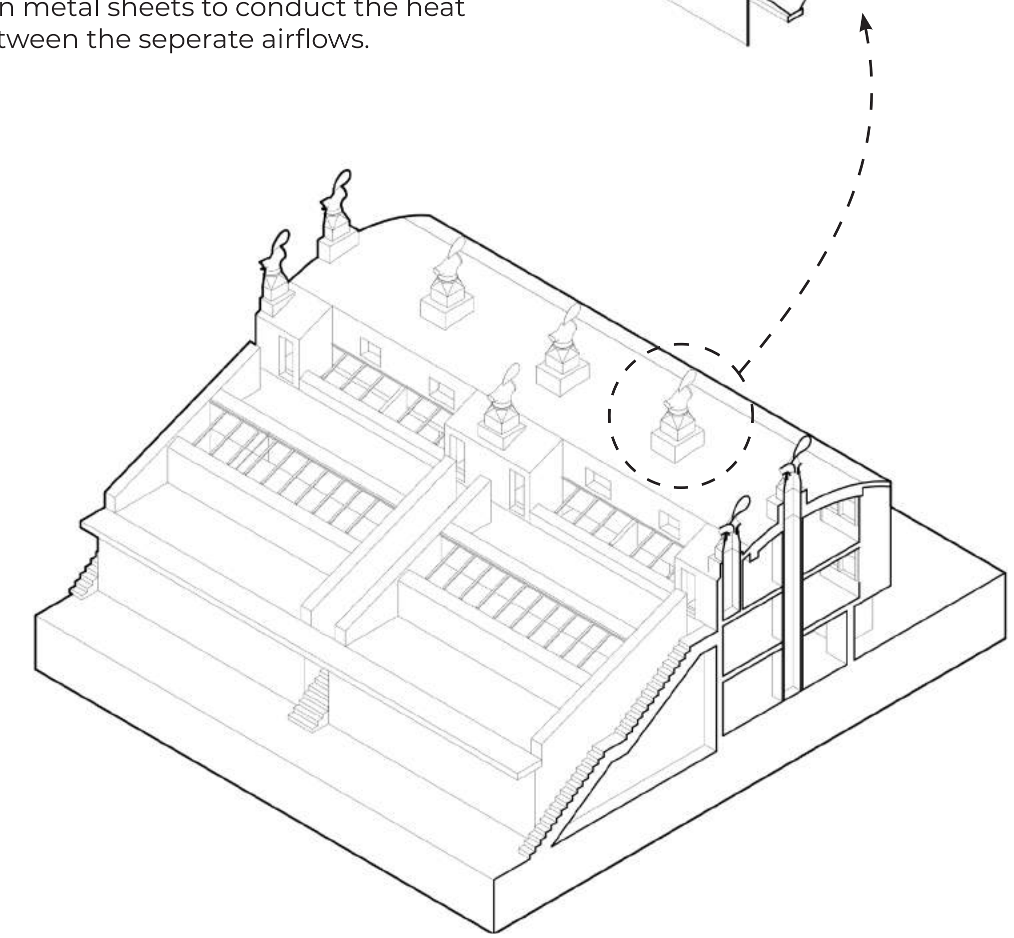


PLATE HEAT RECOVERY SYSTEM, uses thin metal sheets to conduct the heat between the seperate airflows.



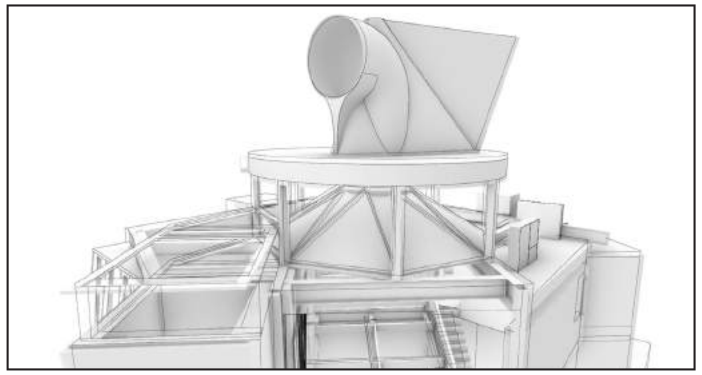


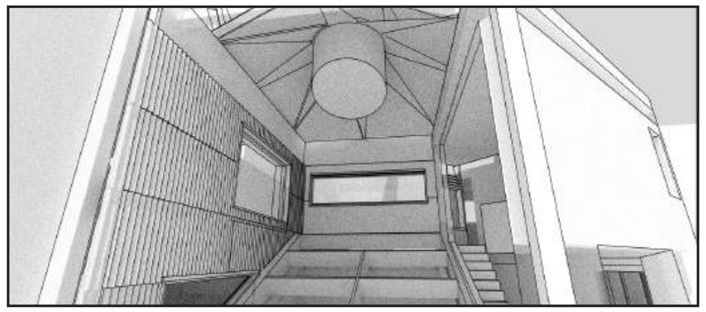


00 Design development: Wind cowl construction

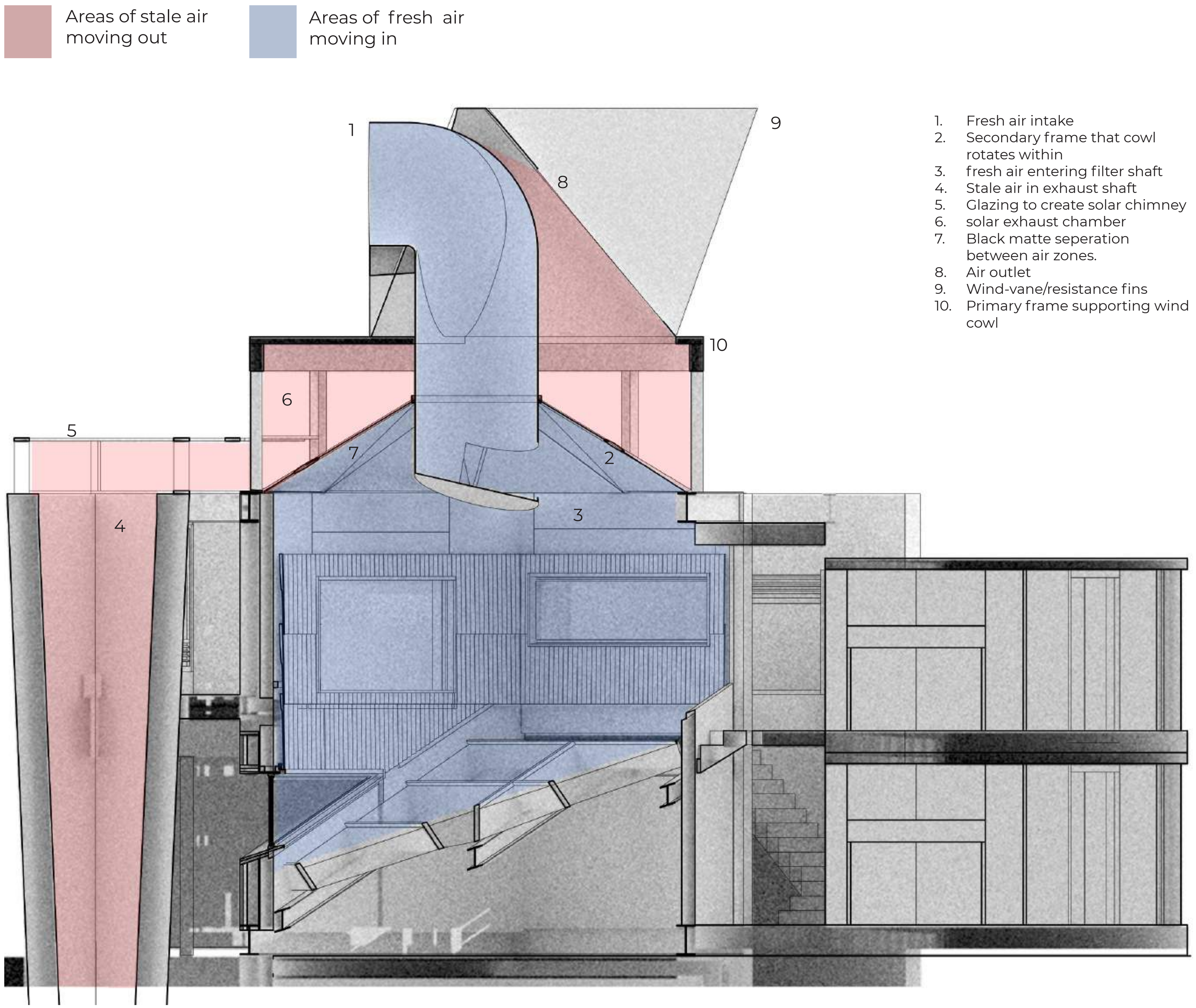
The National Assembly for Wales

This is the largest rotating wind cowl in the world, and operates like a 'modern oast house' - rotating so that stale air always exhausts on the leeward side of the building. This ventilation system uses a 'solar chimney' strategy to increase air movement speeds. The space underneath the wind-cowl is heavily glazed, allowing it to heat up via solar gain. This will aid the movement of even when there is little wind movement to drive fresh air into the building. `





Top: view of wind cowl on accomodation rooftop.
Bottom: view up to underside of wind cowl.

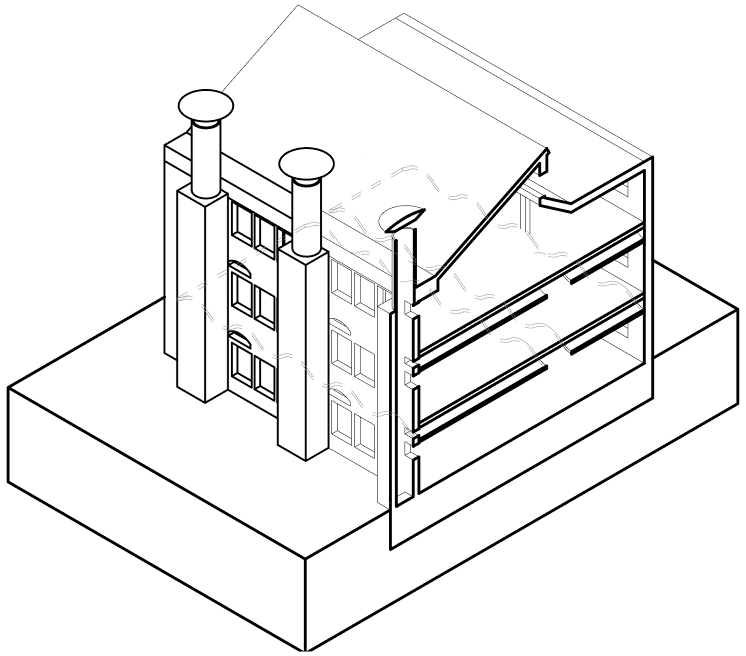


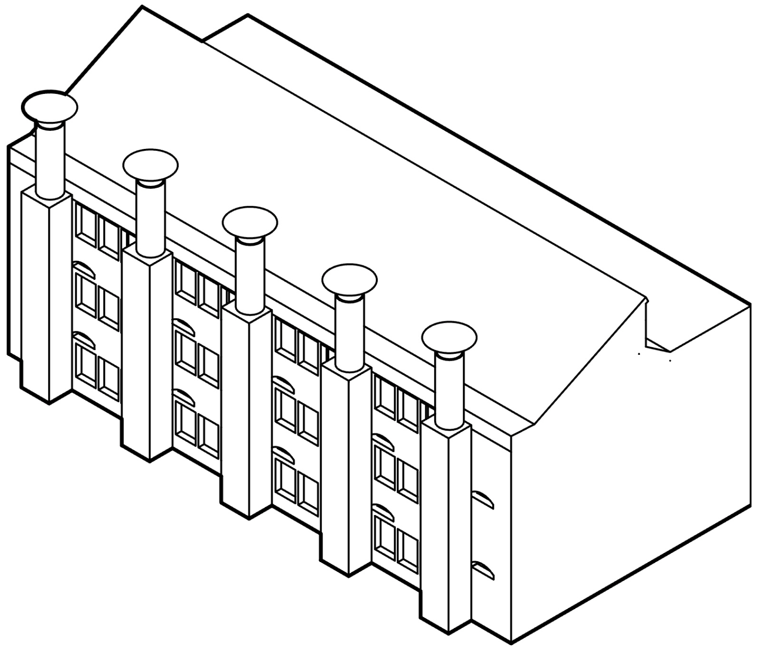
1. Fresh air intake
2. Secondary frame that cowl rotates within
3. fresh air entering filter shaft
4. Stale air in exhaust shaft
5. Glazing to create solar chimney
6. solar exhaust chamber
7. Black matte seperation between air zones.
8. Air outlet
9. Wind-vane/resistance fins
10. Primary frame supporting wind cowl

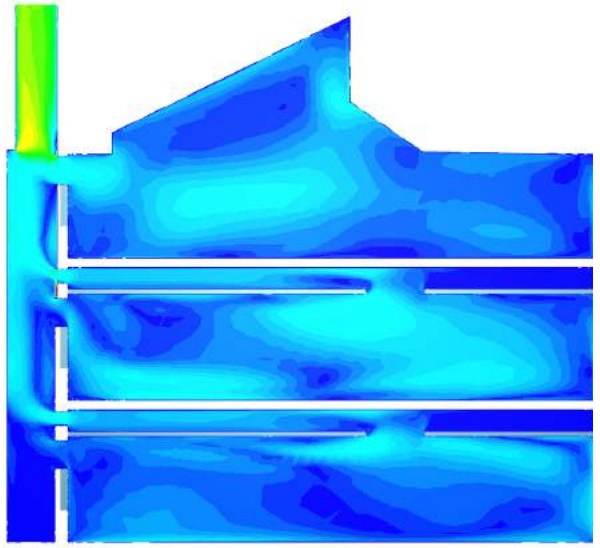
Now implemented is a wind-cowl similar to that of the BEDZED building, in that it is the location of both the air intake and the stale air exhaust. Fresh air enters and passes through a central vent which the whole wind-cowl rotates around. After this vent passes a secondary frame supporting the seperation layer that seperates stale air from fresh air, the air enters the filtering shaft. After the air has been filtered, and circulated through the building, it will run up the exhaust shaft back to the top of the building. The passage that connects the exhaust shaft to the exhaust vent is glazed - this will create a 'over' heated pocket of air that will escape the building faster than normal, and so increasing the rate that cooler air is drawn up through the building to replace it.

00 Precedent: BRE Environmental Building

The building uses a combination of false floors and solar chimneys for its natural ventilation system - utilising both stack ventilation and cross ventilation. As the prevailing wind faces south, both the exhaust vents to the solar chimneys and the fresh air intake are on the same aspect. To make sure that all of the interior space has good air flow, something that single aspect facades do not do very well, a false floor is used. The half of the openings to the solar chimney are within the floor plate and seperated from the rest of the room's air circulation. The false floor is opened deeper into the plan of the building, meaning that temperature driven cross ventilation can still take place when wind speeds are low.

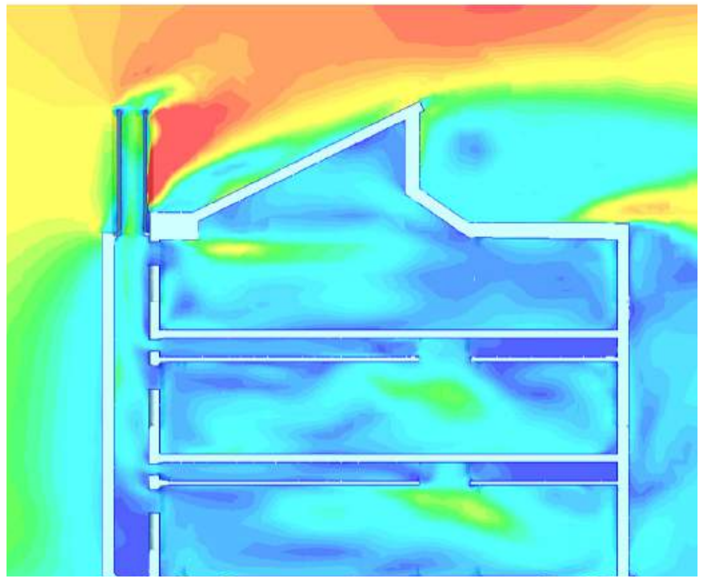




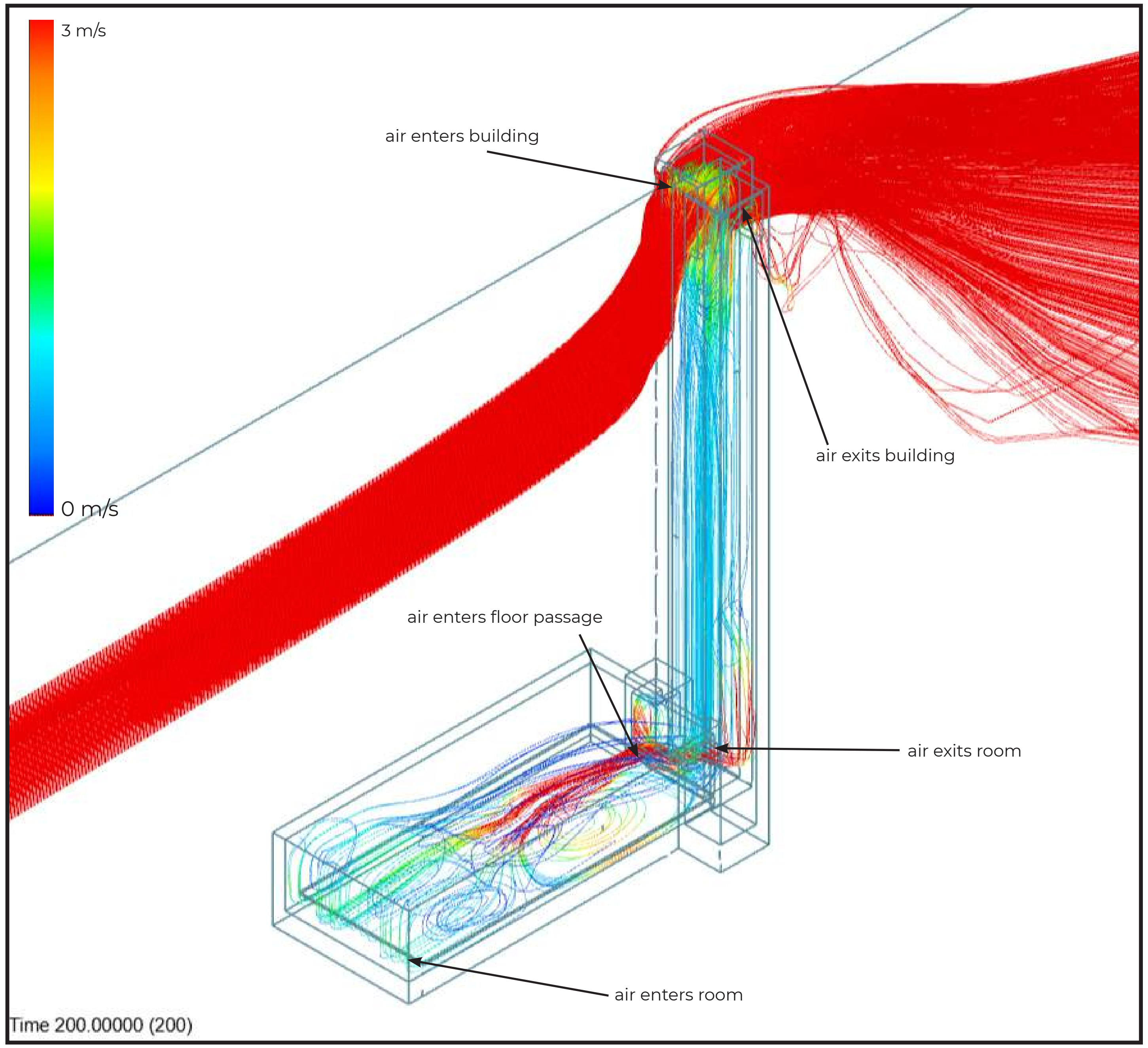


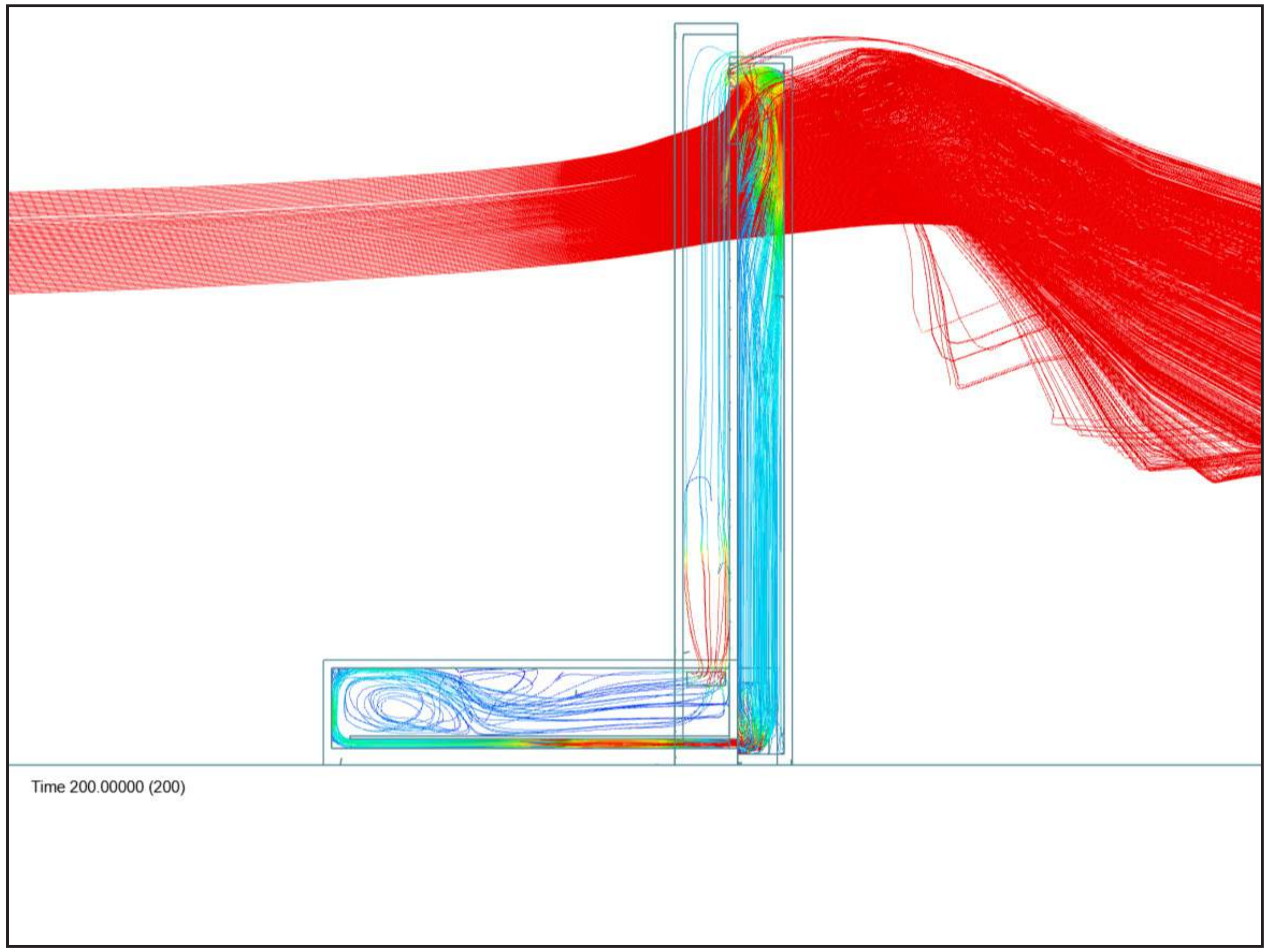
Comparing these two sections of the building the success of using a solar chimney is evident. Good airflow is ensured in summer months when air is mostly likely hot and still.

Top: Still air + solar chimney,
Below: incident 3m/s wind + no solar chimney



00 Test: False-floor ventilation system





Design:

Air Intake for the building is located on the roof. This is connected to the intake shaft that leads down to the lowest leisure room. Each room within the leisure core of the accomodation scheme will have a false floor. The false floor will have one end connected to vertical fresh air shaft, and the other open to the room. There will be an opening to the exhaust shaft located near the ceiling on the side of the room closest to the intake shaft. Exhaust runs the length of the building and leads to the exaust outlet on the roof.

Test Goal:

The BRE Building shows that false floors are a viable sollution for forcing air to move through the length of the space, but the scale of that scheme is smaller to that of this building. This simulation is testing the largest room of the scheme to see if using false floors will work to ventilate the rooms effectively

Test Hypothesis

Air will enter through intake and circulate through down to the false floor, where it will travel across the undisturbed/ uncontaminated to the opposite side of the room. It will then travel in a diagonal path towards the outlet leading to the exhaust shaft. Air velocities will be low as there is a greater distance to travel (greater air resistance) than precedents using this strategy.

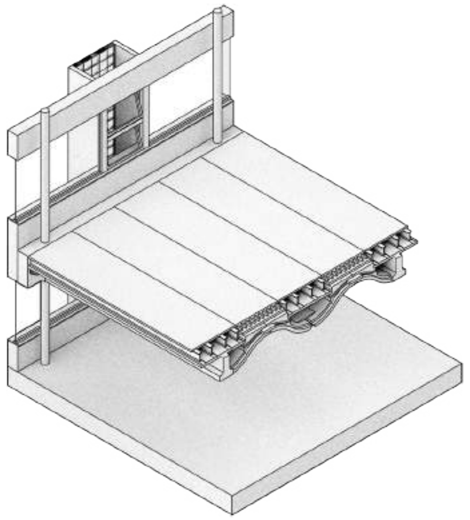
Test Findings

Interior wind velocities are modelled only take into consideration ventilation driven by wind. There would be an additional effect of buoyancy on the air movement also, so circulation will occur at greater velocities than what is modelled here. Even so the simulation shows that air does flow through the entirety of the designed airpath. Modelled air flow is differs from hyphothesis in describing how air enters the leisure room - the air does not flow in a diagonal, but travels vertically up to the ceiling before circulating the room. It is also turbulent around floor level around the room's inlet.

Test Takeaways

It will be assumed that the rest of the rooms not modelled in the simulation are equally successful, as they are unable to be simulated simultaneously due to constraints on computational resources. Using false floors in future design develops will ensure better cross ventilation in rooms.

Design Development: False-floor construction



BRE Building detail

False-floor construction:

One solar chimney to allign with every other airway passage within the floor. Solar chimney is constructed of concrete panels and glass brick.

The depth of the airway passages are within the overall depth of the floor (tops of crests are add extra space the room height). Enabled by precast concrete planks bridging tops of curves.

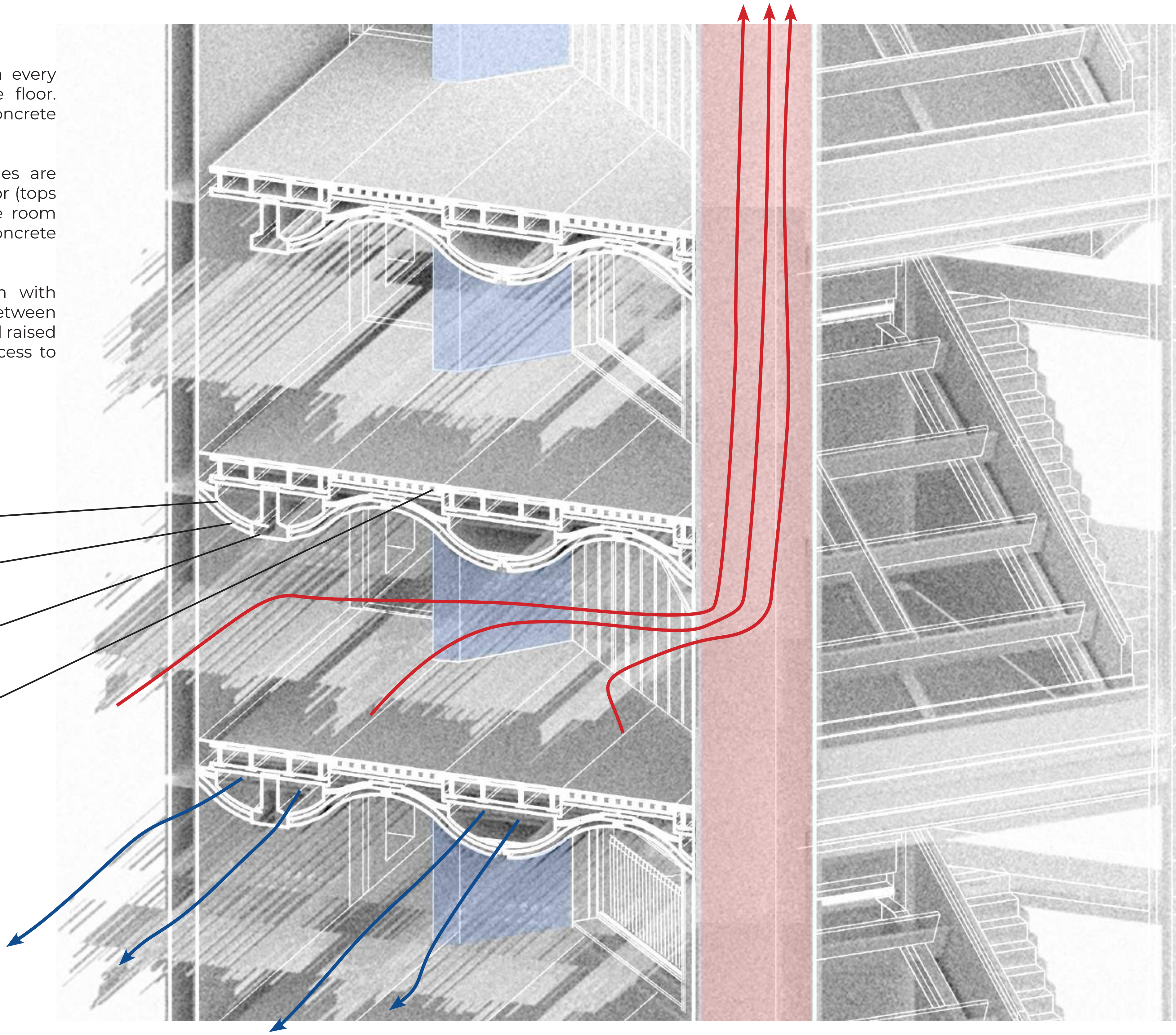
Floor surface is divided to align with 1.5m 'wave' widths - alternating between screed and underfloor heating, and raised access floors which allow easy access to services

75mm in situ slab cast onto 75mm precast slab unit

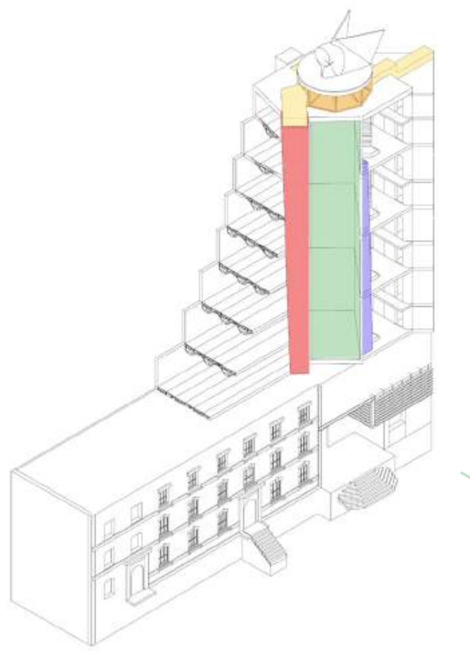
75mm precast sinusoidal pre-cast slab

Toe to beam follows line of pre-cast ceiling

100mm screeded floor with underfloor heating and cooling on 50mm insulation



00 Design Development: Flow path



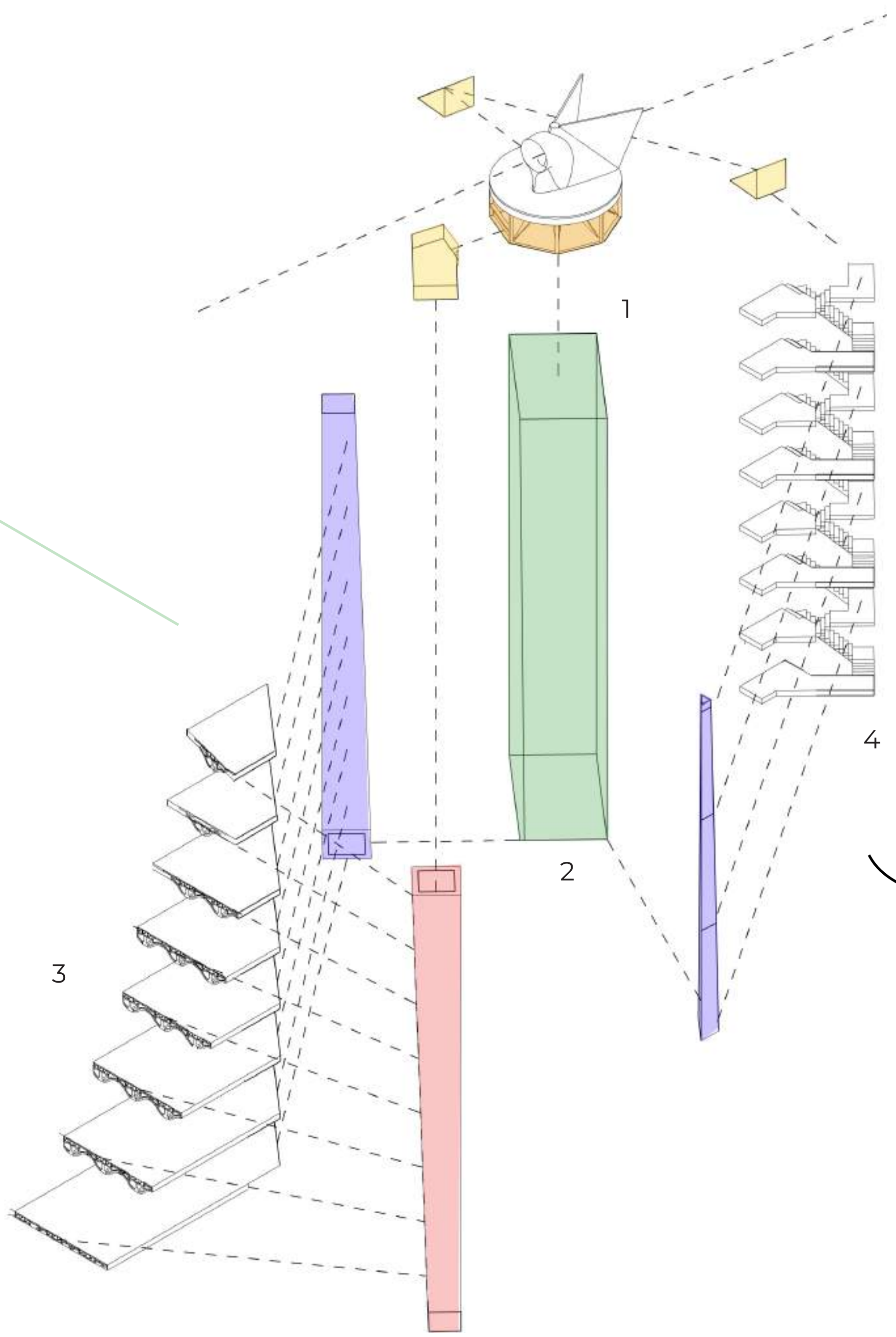
Filtering tunnel

Clean air supply to interior

Stale air exhaust shaft

Connections to cowl

Solar gains chamber



Design Air Path:

1 The building will draw in fresh air and filter out the pollutants as the air moves down a central shaft.

2 The clean air supply is split between two vertical air passages providing fresh air to the leisure rooms and the residential areas

1 Leisure core utilises false floors to create cross ventilation through the rooms. Stale air exits and travels up exhaust shaft to wind cowl.

2 Residency areas use cross ventilation, however instead of a exhaust shaft, the stale air travels up through the stairwell to the wind cowl.

Right: movement of air through the residency communal areas of the building.

00 Selecting filtering plants

These plants have been selected due to being evergreen - meaning that they have leaves all year round. Otherwise in the winter months, there will be no filtering capability at all within the building.

Furthermore plants that have scents have been prioritised so that they can make the building smell nice and improve the living quality for the occupants.

Name	Type	NO2 Absorption?		Max Height	Aromatic?	Soil Moisture
Yarrow (Achillea millefolium)	plant	yes	Semi-evergreen	60cm	Sometimes	Moist but well drained
Lady's Mantle (Alchemilla mollis)	plant	yes	Deciduous	50cm		
Wallflower (Erysium	Plant	yes	Evergreen	50cm	Flower (yes)	well drained
Geranium macalatum	Plant	yes	Evergreen	50cm	Flower (Autumn/Summer)	Moist but well drained
Shrubby Veronica (hebe)	tree/shrub	yes	Evergreen	150cm	Flower (summer)	Moist but well drained
Hedera helix (common Ivy)	Climbing	yes	Evergreen	/		Moist but well drained
Lavendar	Shrub	yes	Evergreen	50cm	Summer	well drained
snowberry	Shrub	Yes	deciduous	1-1.5m	toxic flowers/ berries	moist but well drained
Aster	plant	Yes	perennial	1m		
Silverbush	shrub	Yes	Evergreen		Flower (Summer)	
mediterranean spurge	evergreen perennial	Yes	Evergreen	1-1.5m		
heuchera (coral bells)	plant	Yes	semi-evergreen	0.5m		
delavay osmanthus	evergreen shrub - highly scented white flowers	Yes	Evergreen	2.5-4m		
dward mountain pine	shrub evergreen	Yes	Evergreen	2.5-4m		
salvia nemorosa	deciduous perennial -fragrant foliage	Yes	deciduous	0.5m		
red elder	shrub	Yes	deciduous	0.5-1m		
false spiraea	shrub	Yes	deciduous	2.5-4m		
Lavendar	Shrub	yes	Evergreen	50cm	Summer	well drained






00 Calculation of green infrastructure required

The amount of PM10 pollution that plant infrastructure can remove from the air can be calculated with this formula:

$$\boxed{\Delta C = C_0 \times LAD \times V_d}$$

ΔC = Change in concentration ($g/m^3/s$)
C_0 = Initial concentration ($g/m^3/s$)
LAD = Leaf Area Density
V_d = Deposition Velocity m/s

Initial concentration will be given by the concentration of PM10 and PM2.5 particles recorded on the main roads near the building's site. Both were recorded at levels of 40 ųg/m³.

Deposition Velocity describes the rate at which particles are deposited onto a surface and removed from the air. The deposition velocity for plant leaf surfaces varies considerably from study to study, but this investgation will adopt the value of 0.64 cm/s - the apparent 'average value' that was used in a study by Leicester University.

Leaf Area Density is defined as the total surface area of leaves within a given unit volume. This investigation will adopt the value of $1.6m^2/m^3$ - the value used for trees and hedges in the same study by Leicester University

Change in concentration (g/m^3/s)	initial concentration (g/m^3)	Leaf Area Density	Deposition Velocity m/s
4.096E-07	0.00004	1.6	0.0064

Calculating Volume Required:

$4.096e^{-7}$ $g/m^3/s$ is the amount of pollution deposited onto the plants per cubic meter of green infrastructure. The total volume of green infrastructure needed to filter out all of the pollutants from the air is given by:

$$C_0 / \Delta C = 0.00004 / 4.096e^{-7} = 97.66m^3$$

Calculating Surface Area Required:

Surface Area x Depth = Volume

Depth is given by the height of the plants used in the filter system. The selected plants have heights arounf 0.5m.

Surface Area x 0.5 = $100m^3$ (rounded from 97.66)

Surface Area = $200m^2$

The building requires $200m^2$ of green infrastructure in order to filter out all of the pollutants from the intake air. As the filter system is across 8 levels of the building, the required green infrastructure per floor is $25m^2$.

Surface Area per Floor = 200 / 8 = $25m^2$

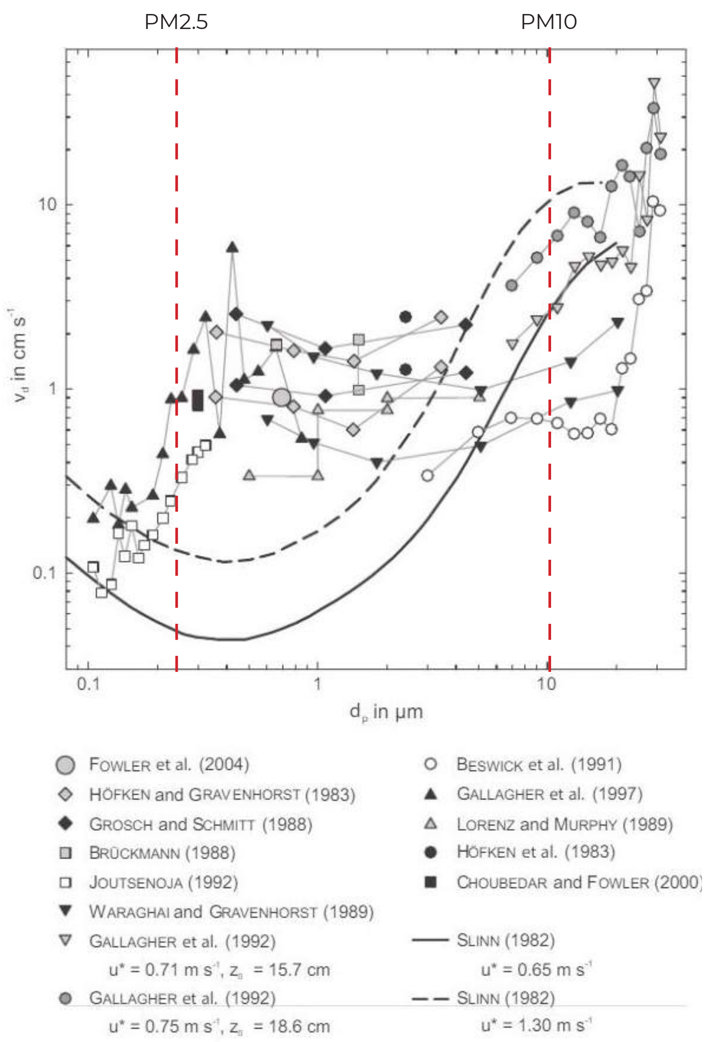
00 Deposition Velocity

Air Filtering and Wind Velocity

According to the study 'Green infrastructure for air quality improvement in street canyans by Mamatha Tomson, PM10 concentrations in the air can be reduced by 60% using green walls. So it is clear that plants have the ability to remove polluting particles from the air, however how effective they are depends on multiple factors including the velocity of the air when it makes contact with the plants.

Up until a certain point, the higher the wind speed then the greater the chance that the particle will stick to the surface of the plants. However, if the wind speed is too high then the particles may bounce off the plants, or already filtered particles may be blown free of the plant and be resuspended in the air.

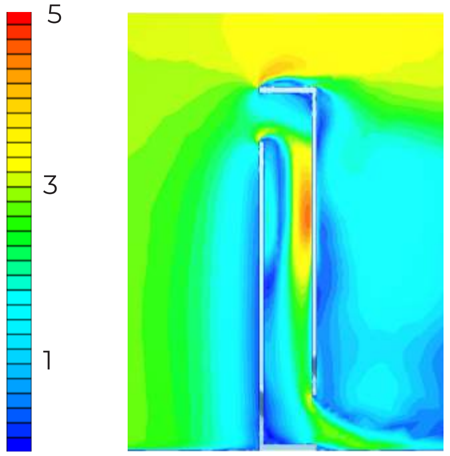
The optimum air speed that particles are deposited onto a surface varies for different plants and species, and different studies have very different concluded values for optimum velocities. So for the rest of this investigation it will be assumed that the optimum velocity is the same for all the plants selected to be used in the building. The optimum velocity will be assumed to be 3m/s, the value concluded from...[find study]



(Left) Deposition velocities against particle size according to different studies. Varying values are a factor in to varying recommendations for wind speeds.

00 Wind Speed and Filtering.

The air speed will need to be maintained at the level within the intake shaft at which pollutants can be deposited onto the green infrastructure.



In this simulation of external wind speeds modelled at 3.5m/s. But the wind speed reduces as it enters the shaft. Except for increased speeds due to turbulence, the air is travelling at 2.5 m/s. This is below the required speed for particle deposition.

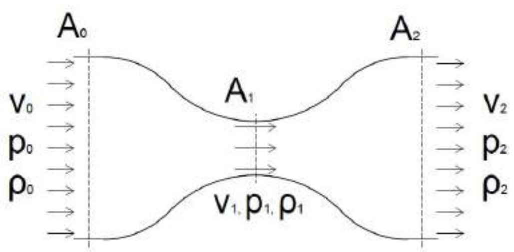
Furthermore this is simulation without any obstructions within the shaft. Green infrastructure will only create more resistance and reduce air speeds even more.

the Venturi Effect

The Venturi Effect describes when the velocity of a fluid flows through a constriction in its flow path, the velocity of the fluid increases. This is due to the fact that the flow rate of a fluid is inversely proportional to the flow section (the cross-sectional area the fluid flows through).

This effect can be seen on a 'street' scale within urban canyons. When wind passes through narrow passages in the built environment, the velocity of the air increases. This is why cities can be very windy places.

$$Q = A_2 \sqrt{2/p \cdot \frac{(p1 - p2)}{1 - (A_2 / A_1)^2}}$$



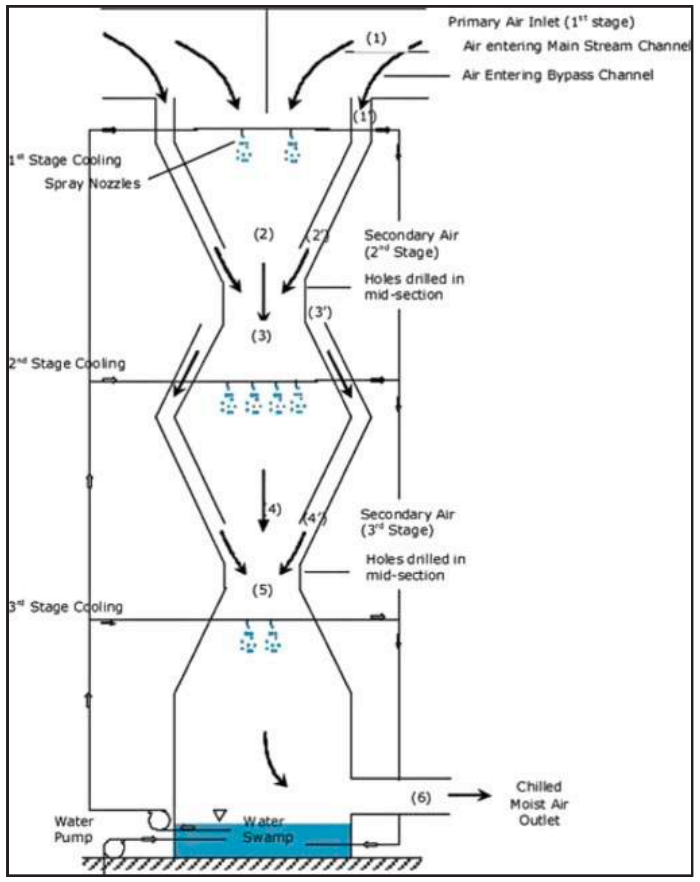
Q = flow rate of the fluid
p_1 = pressure at point 1 (in the narrowing of the pipe)
p_2 = pressure at point 2 (after the narrowing of the pipe)
p = density of fluid travelling in pipe
v_1 = velocity of the fluid at point 1 (in the narrowing of the pipe)
v_2 = velocity of the fluid at point 2 (after the narrowing of the pipe)
A_1 = cross-section of pipe at point 1
A_2 = cross-section of pipe at point 2

3 Stage Wind Catcher:

This is a design of a three stage windcatcher, designed for the dry and hot climate of Texas. It consists of 2 half-nested Venturi tubes. The purpose of them is to drive the air into the building.

As a side note, this design also uses evaporative cooling (similar to Iranian wind catcher precedent) via spraying water droplets in the ventilation shaft. As the water mist evaporates, heat energy is taken from the intake air, cooling the air down before it enters the building.

This is likely not necessary in this investigation as a cooling technique, as the green infrastructure will naturally have an evaporative cooling efffect. However, as the plants will need to be watered, this may be a way to do this.

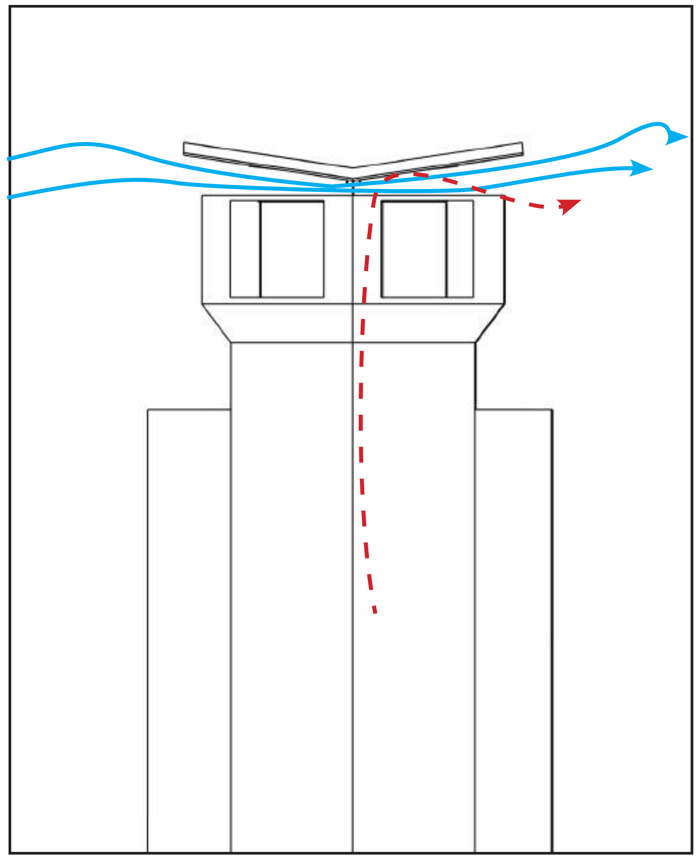


Venturi effect used in stack exhausts.

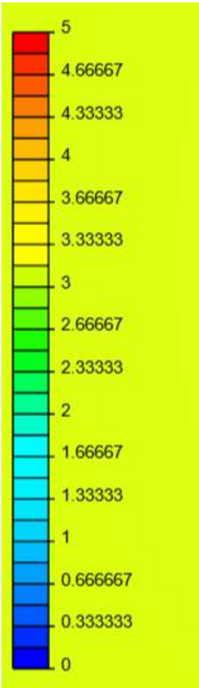
The venturi effect is often utilised at the openings of stack exhausts in natural ventilation systems.

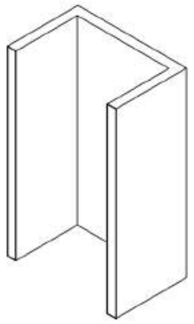
An example is the Frederick Lanchester Library, where the stack exhaust has an angled roof at the opening. It narrows the path that the wind travels through - and increases the air speed/ lowers the air pressure at the opening. The result is in increasing the creating a larger pressure difference between inside/outside and increasing the movement of air in the building.

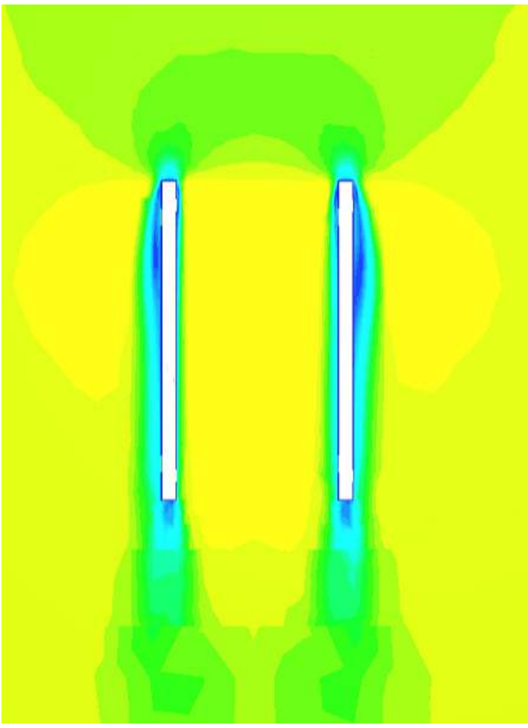
Frederick Lanchester Library, Coventry University.



00 Test: Venturi Effect in open tunnels

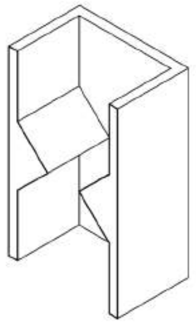


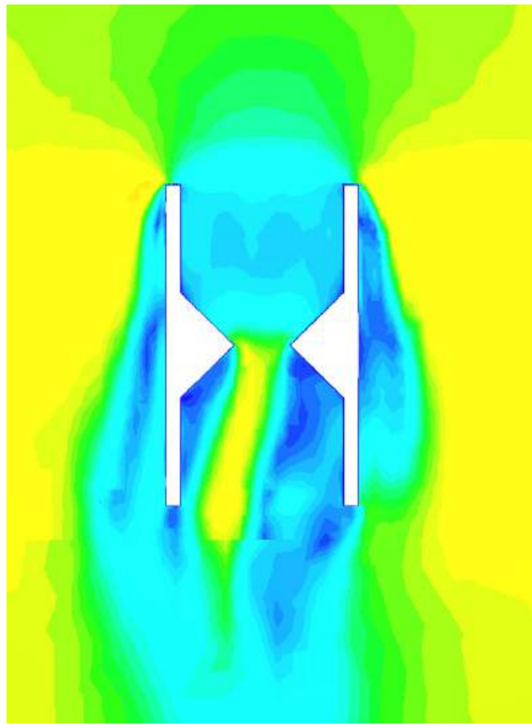




Control: No Intervention to shaft.

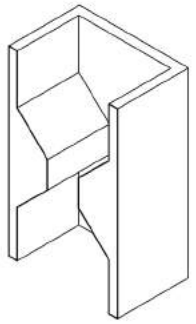
The velocity within the shaft is maximum of 3.5m/s, consitant across the width of the shaft, as well as consistant from the shaft opening and exit.

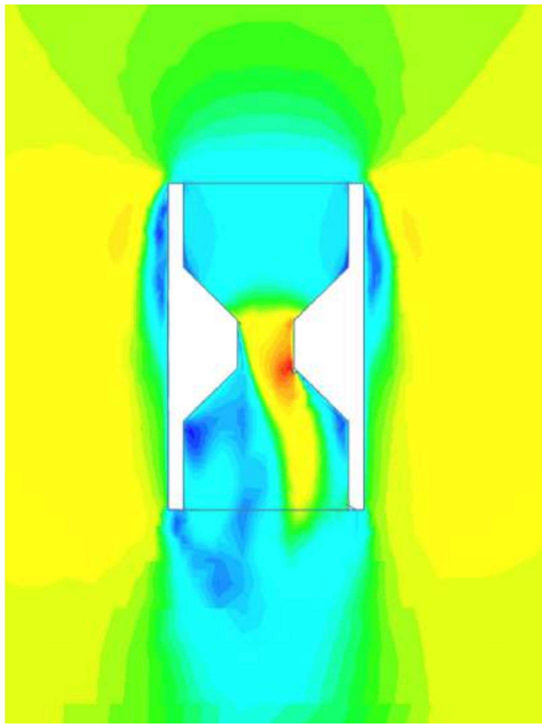




Indentation and Immediate return.

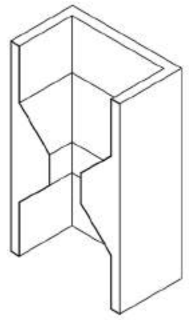
The velocity within the shaft is maximum of 3.5m/s, however air speed varies considerably across the width of the shaft after cross section of the shaft is narrowed. Spaces immediately behind the indentations have velocities of under 0.3m/s. These might be due to the sharp corners of the indentation creating vortexes.

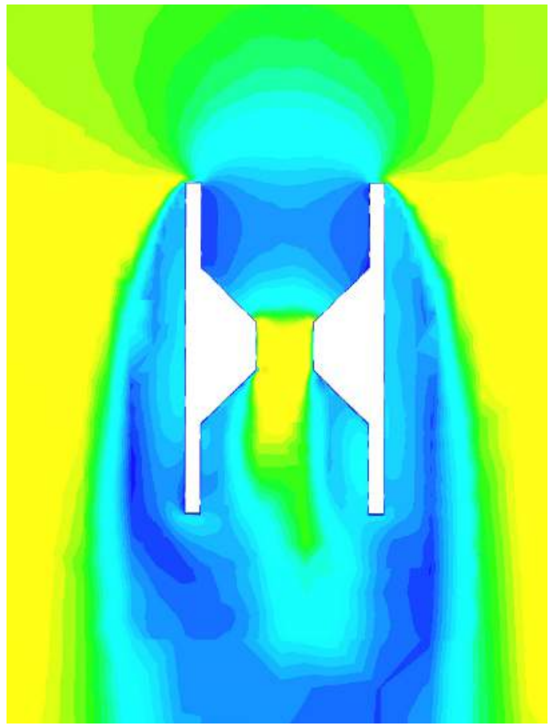




Indentation, sustained cross section before return.

The velocity within the shaft is maximum of 5m/s, however this only occurs shortly as the cross-section of the shaft increases again - it is not sustained through the length of the tunnel. Furthermore there are points where wind speeds drop to less than 0.3m/s, bit not as much as Tunnel B



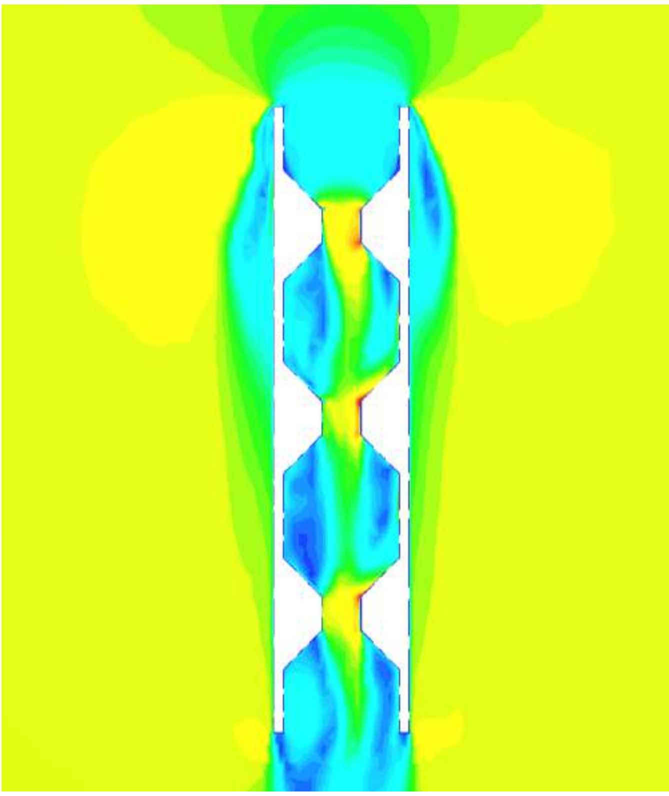


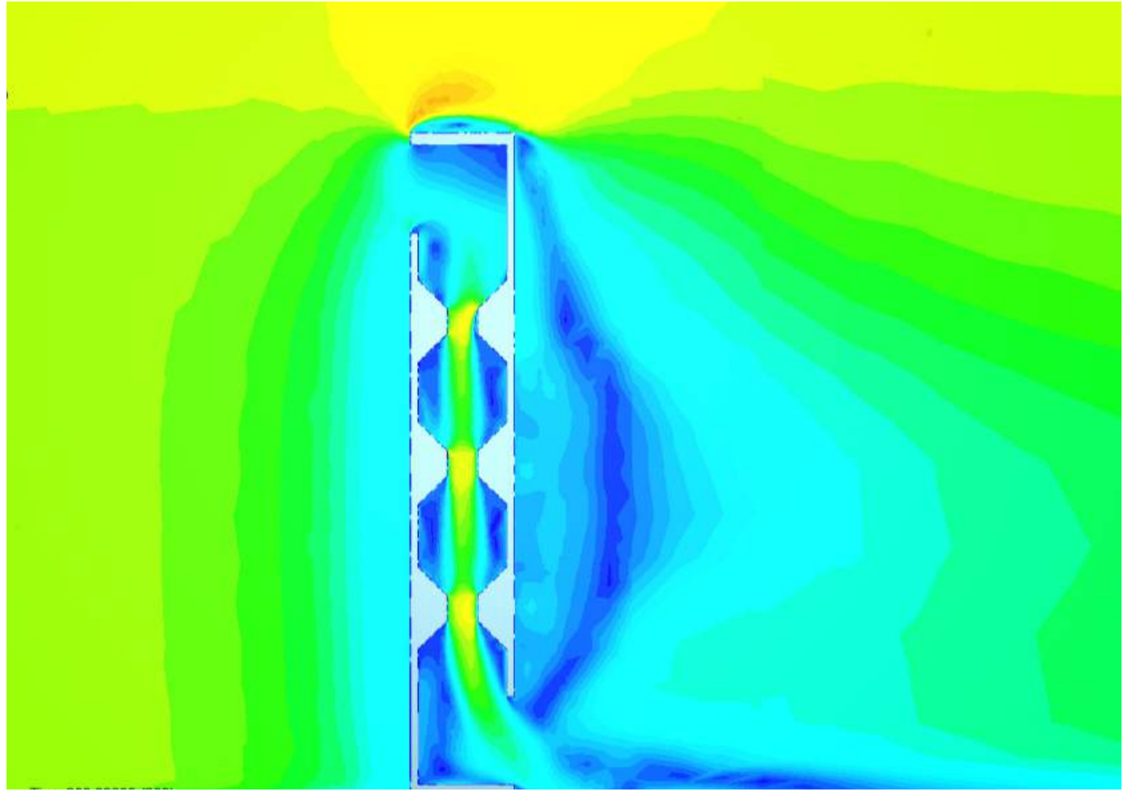
Indentation on all sides, sustained cross section before return.

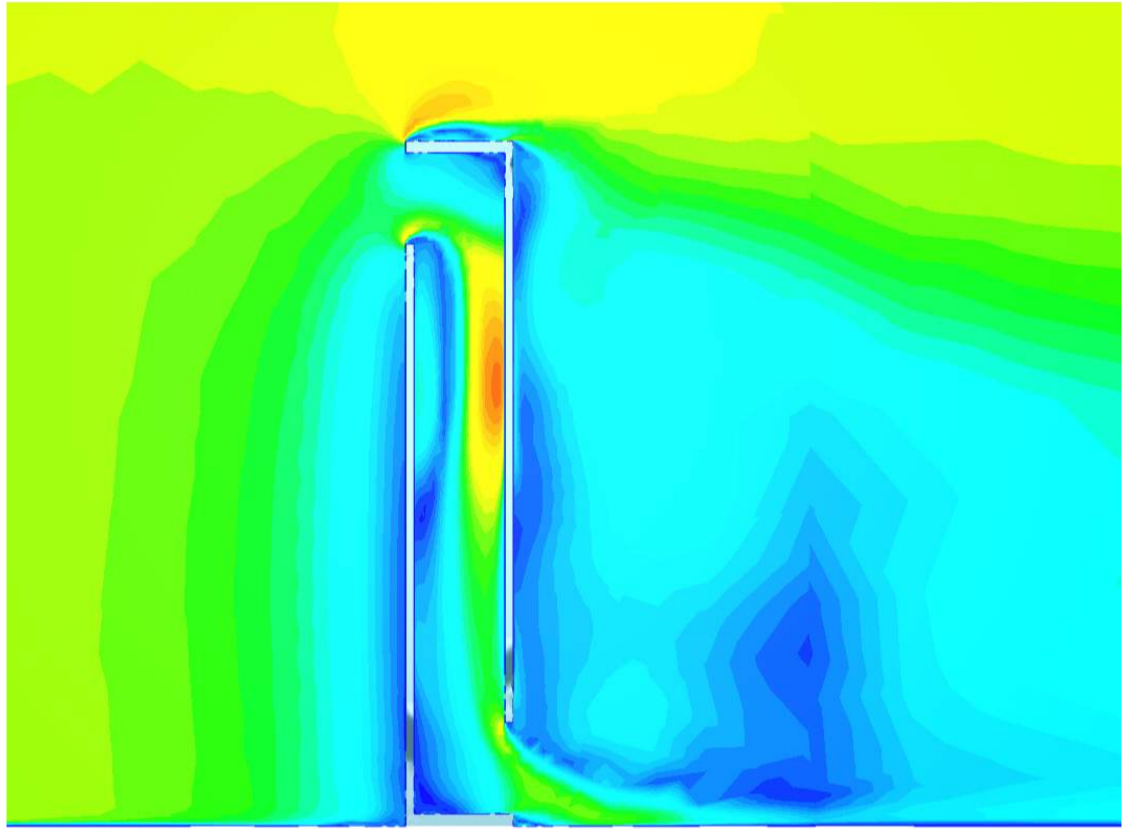
The velocity within the shaft is maximum of 3.5m/s, however this only occurs shortly as the cross-section of the shaft increases again - it is not sustained through the length of the tunnel. Furthermore there are no points where wind speeds drop to less than 0.3m/s, as Tunnel B and C do.

Results:
The alterations in width of the shaft to try and achieve a venturi effect have not the expected results. Rather than the air speeds being consistant after the tunnel narrows, a single 'stream' is created. This may have been useful if the 5m/s speed recorded in Tunnel C was consistant across the narrow opening, but this at certain points. Furthermore, as a consequence to narrowing the opening within the tunnel it has created more air resistance for air to initially enter the shaft opening. This is seen as the air speed is 3.5m/s on the control, but 1.2 m/s on Tunnels A and B. Furthermore, when the indentation occured on 4 sides of the shaft (Tunnel D), the maximum velocity recorded was reduced to 3.5m/s, however after the intial opening to the shaft, where the lowest of all tunnel versions was recorded, subsequent re-widenings of the shaft maintained speeds above 1m/s.

00 Test: Venturi Effect (2)







Design:

Taking most promising geometry from previous test and repeating the geomtry over a greater length. This is to model how the air might travel through multiple floors of the building.

Test Goal:

Comparing the air behaviour when introducing geometry interventions within the intake shaft, to the air behaviour when there is no intervention. Aim is to determine if this intervention is beneficial.

Test Hypothesis:

Through each subsequent constriction of the shaft, air velocities will increase more so than the previous narrowing. Supposed due to how inital speeds of 1m/s turned into 3m/s in previous tests. That will mean intial speeds will be greater when entering the next constriction.

Test Findings:

Hypothesis is incorrect. Each constriction of the shaft appears to produce the same air velocity. Otherwise, the results are similar to what was observed with just a single narrowing. Maximum velocities of 5m/s occuring on the same corner location as the cross section of the shaft narrows.

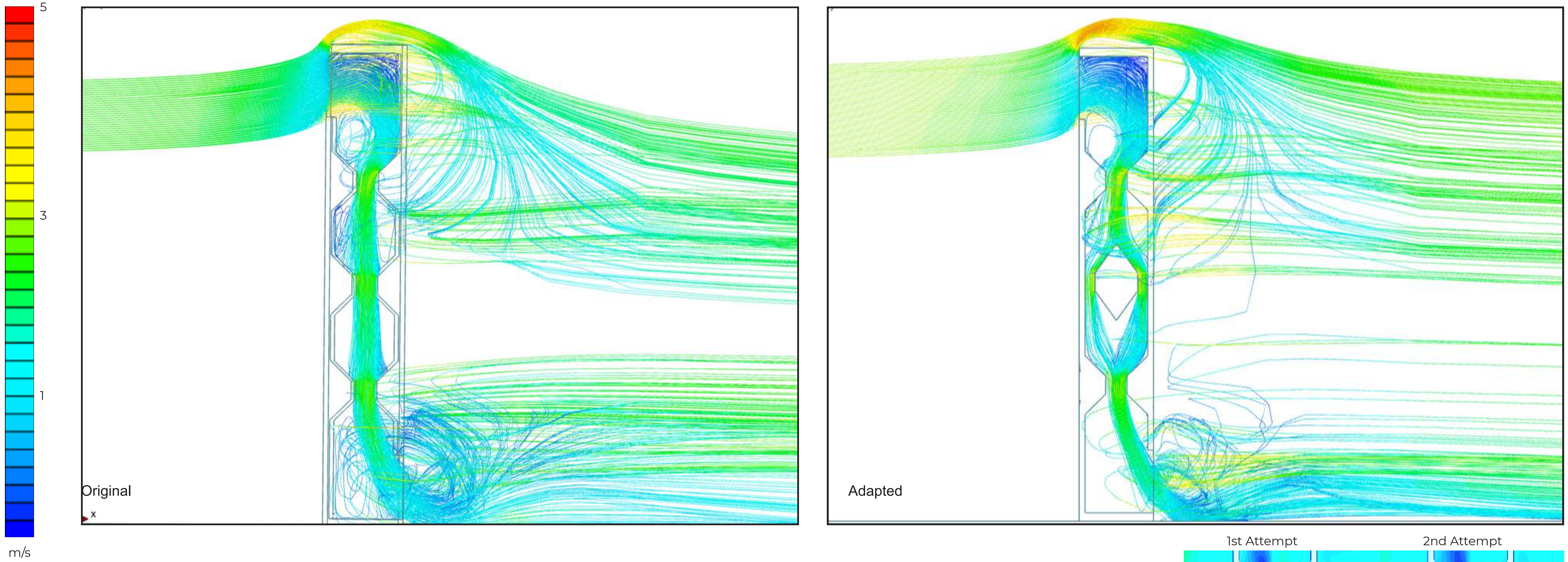
Whilst it is visible that no interventions in the ventilation shaft can result in higher velocities, with max speeds at 4.2 m/s, this only occurs at a single point below the shaft opening. this is due to a vortex created by the change of direction of the air from horizontal to virtical travel. Wind speeds following this are around 2.5 m/s. As the aim is to filter the air throughout the length of the air intake shaft, the interventions effect on the air behaviour is preferable.

Test Takeaways:

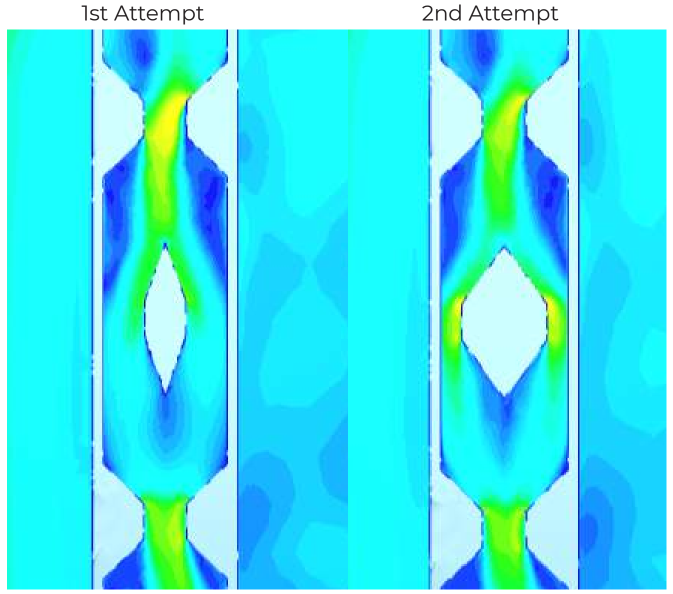
The air speed does not have to be as high as 3m/s for good air exchange or ventilation of stale air, however it was recommended as optimum speeds for deposition of PM on plants and trees. Despite this, substancial deposition still occurs at air speeds as low as 0.5 m/s.

Therefore, although initial thoughts that all of the spaces of the shaft would reach those optimum velocities due a venturi effect, there still are areas of high velocities where this happens. Green infrastructure that is most efficient at capturing PM from the air can be prioritised in those openings.

00 Test: Maximising surface coverage



1st Attempt 2nd Attempt



Initial test maintained the same width for the narrow cross section, but it is clear that the venturi effect did not take place. The design was adapted so that the constrictions at the perimeter of the walls were made to be half of the width as the constrictions located at the centre of the shaft. This alteration was successful in increasing the wind speed to 3m/s at the narrow openings.

Design:

Alternating the location of the filtering surfaces between the perimeter of the shaft and the center of the shaft.

Test Goal:

Using particle trace to track the movement of the air, it can be seen that the current undulating surface successfully creates ‘fast air zones’ that can be which can be used as areas to focus the filtering of the green infrastructure. However it is clear this stream of fast moving air that doesn’t circulate around the shaft as passage re-widens. This means any green infrastructure placed outside of the central stream would not have any cleaning effects. This test sees whether alternating the position of the filter surfaces will result in faster travelling air streams making greater contact with the filter surfaces.

Test Hypothesis:

The contact of faster moving air will increase with the alternating version. The air stream will split at the point and be guided over the surface.

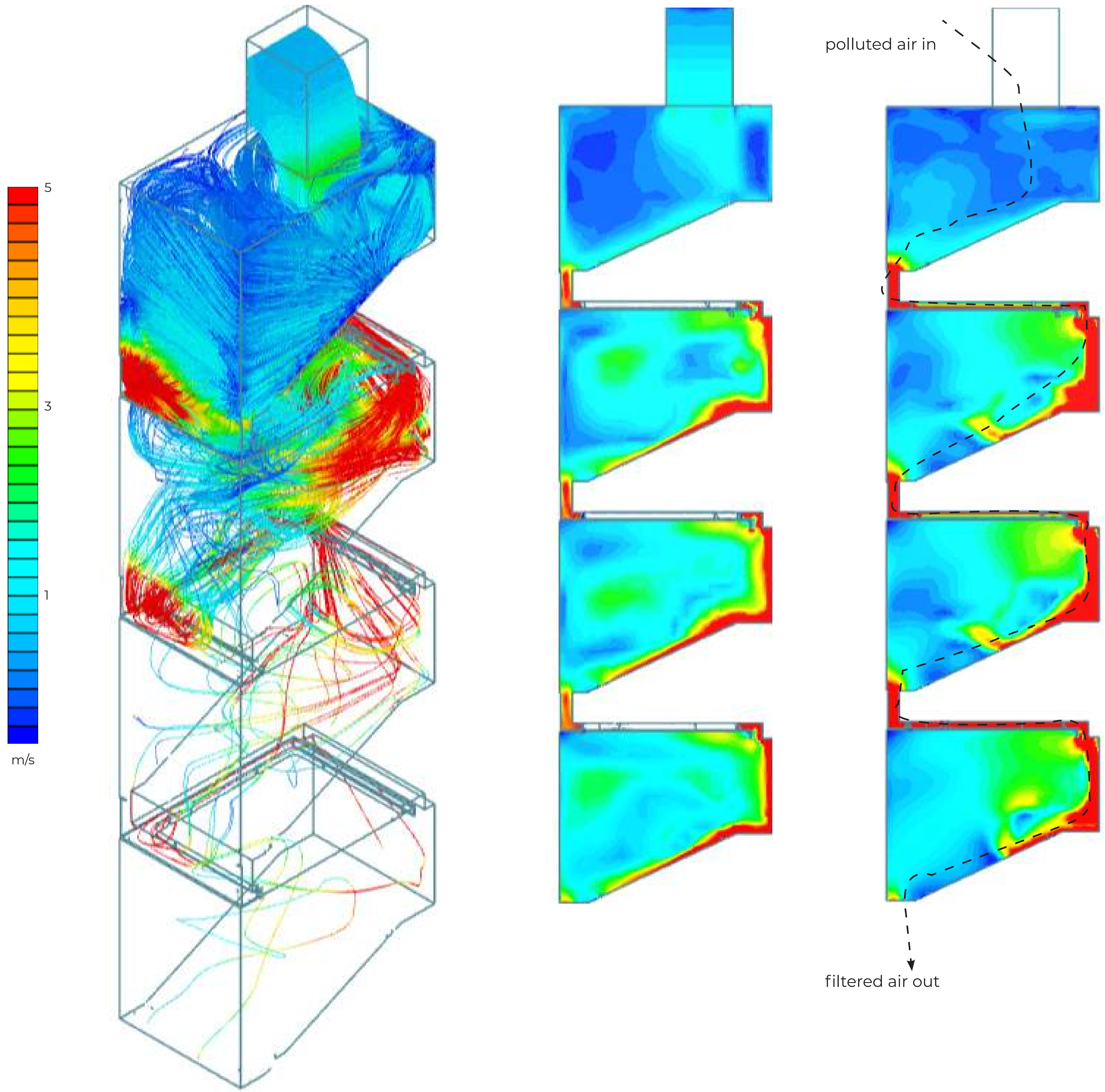
Test Findings:

Hypothesis correct. The alternating placement of the surfaces discrupts the airstream from only travelling down the center of the shaft. The central surfaces have a pointed centrer which splits the airstream whilst allowing the air to maintain its speed.

Test Takeaways:

Redirecting the air stream to make more contact with green infrastructure will maximise the filtering potential of the surfaces.

00 Test: Maximising Surface Coverage (2)



Design:

Surfaces slope in a one direction to face the sun as previous iterations blocked natural needed for the green infrastructure to survive. This system switches from a central air passage and utilises a similar false-floor method used in leisure room ventilation. Intended to the movement of air across the width of the shaft so that it makes contact with surfaces.

Test Goal:

The creation of cross-ventilation as seen in the leisure core, would enable more of the space within the shaft to be caught within faster air speeds. This is to test whether the change in direction and sharp corners of the passage may reduce the speed sinificantly.

Test Hypothesis:

air stream will be directed so that faster moving air makes more contact with the surface so that plants can filter, but the complex air path will decrease overall velocities.

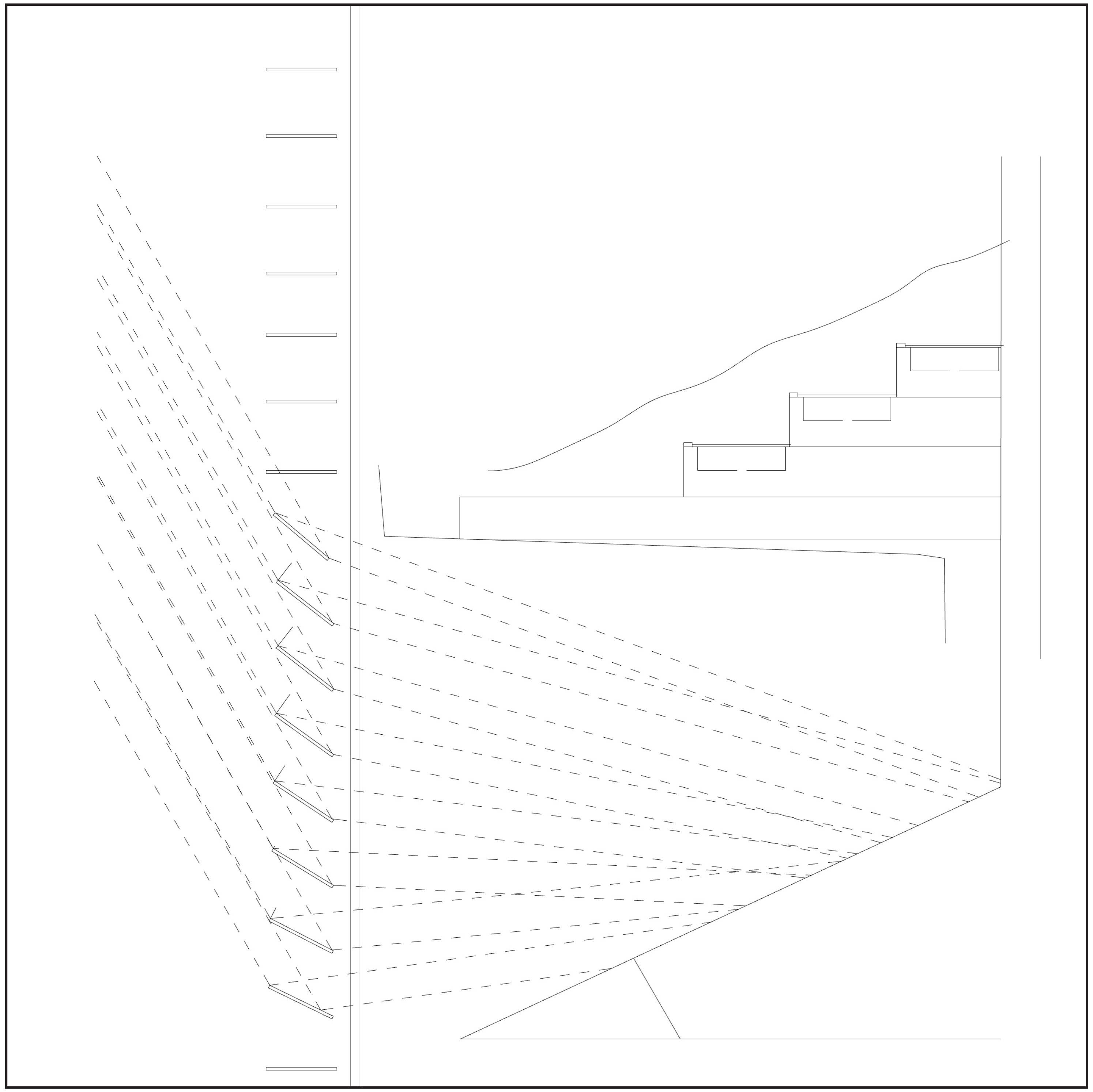
Test Findings:

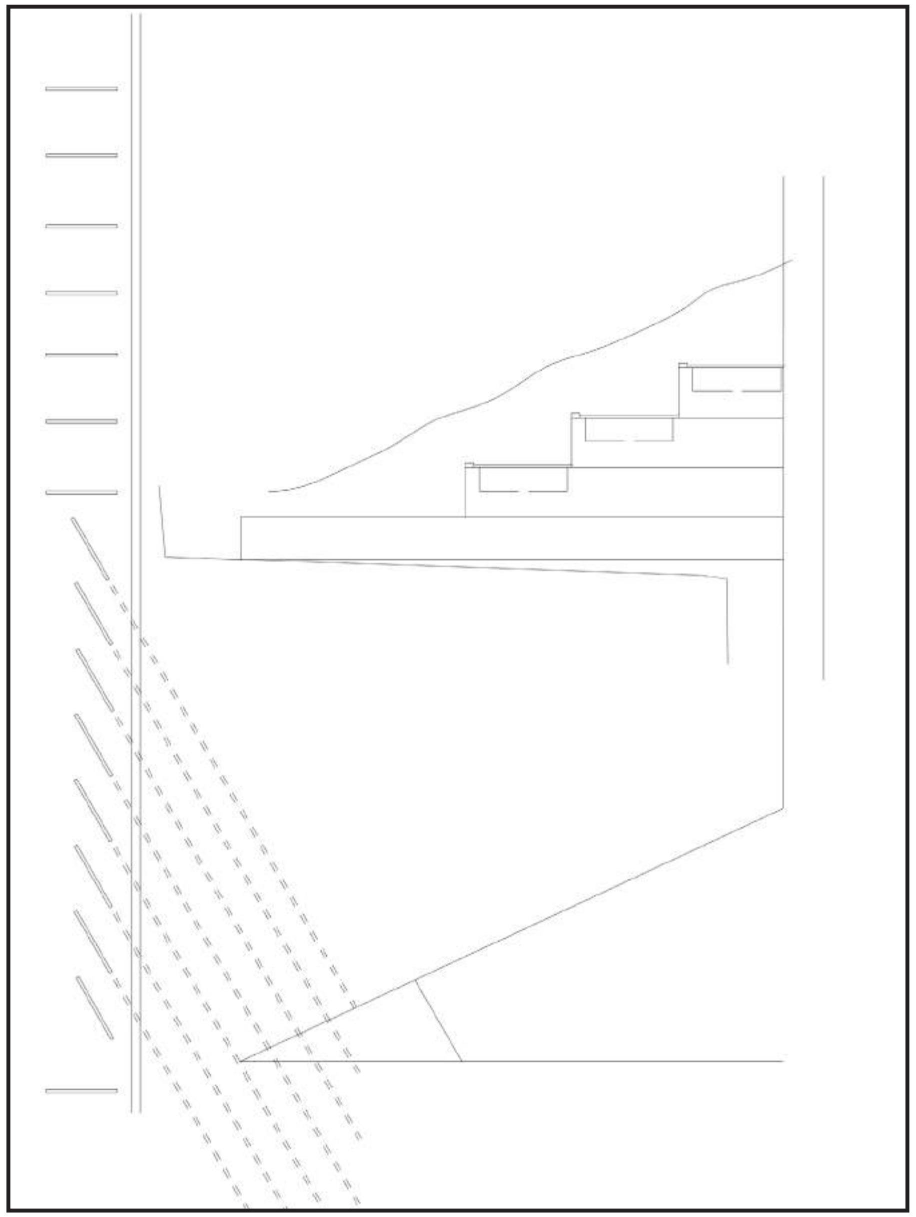
Hypothesis is correct in that more of the surfaces are covered by faster air movement, however it is incorrect in supposing a drop in velocities. This design of the slope also appears to have the best performance on the air velocity within the shaft, with speeds reaching greater than 5 m/s, and as not seen in previous tests this speed is maintained as the travels aross the surface of the slope.

Test Takeaways:

This geometry for the filtering shaft will be implemented into the building due to increaed air circulation and increased air velocities.

Design Development: Reflective louvres/ shuttering

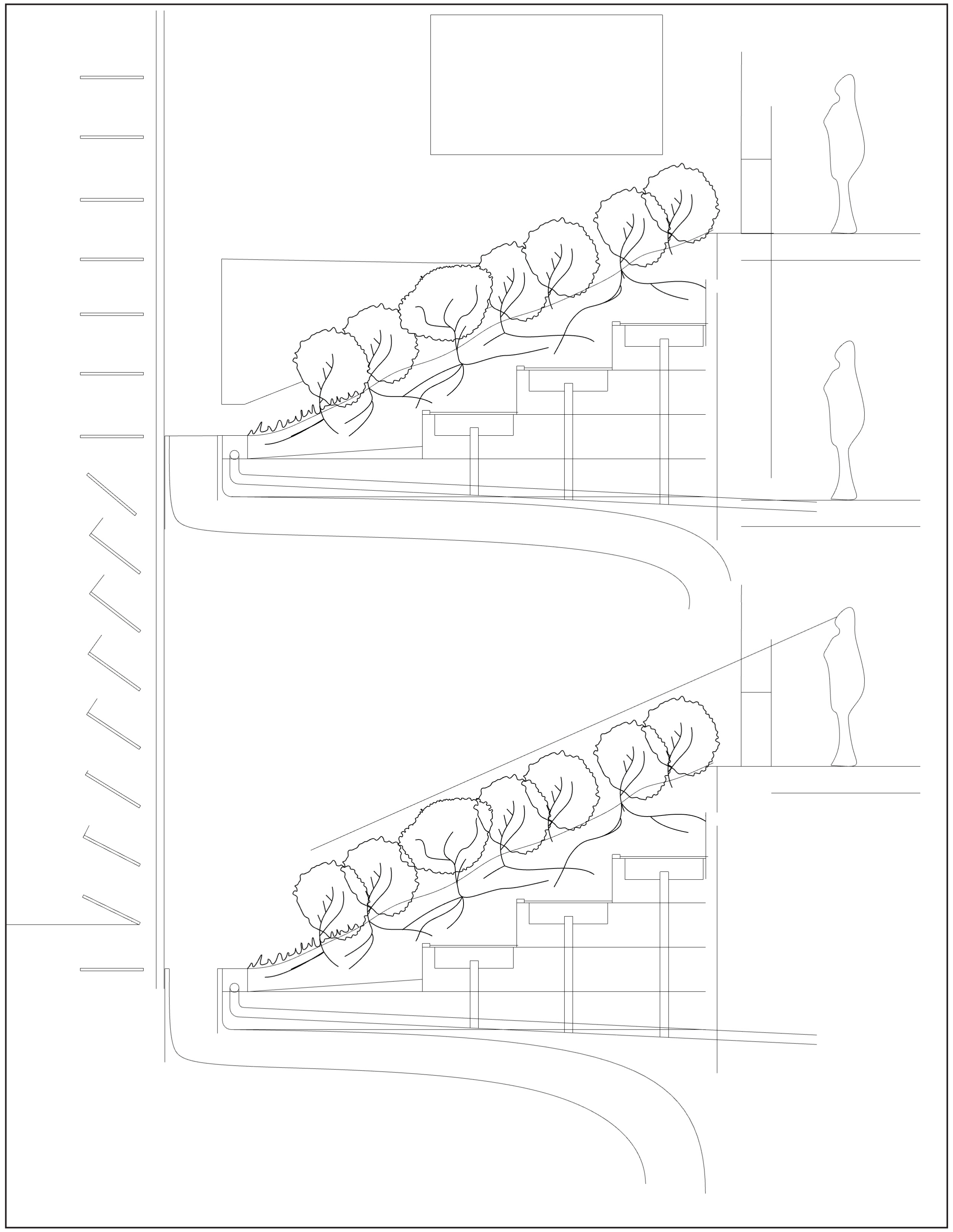


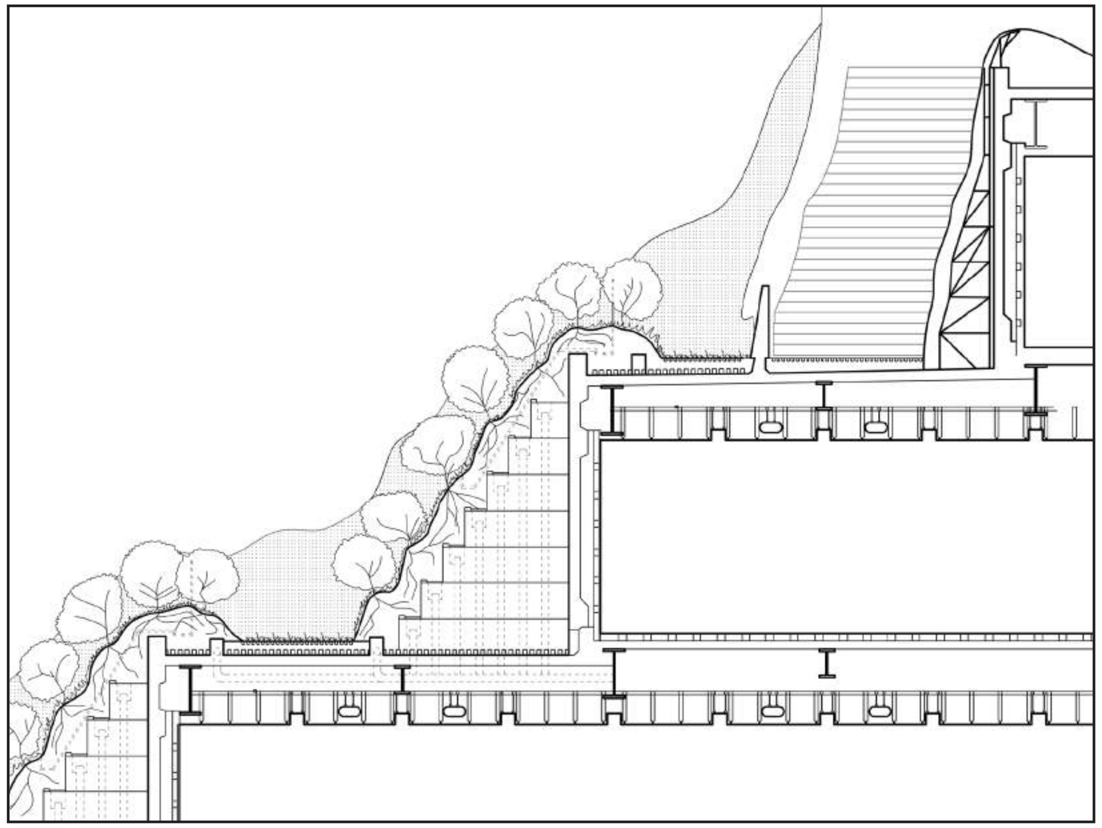


`Having the green infrastructure stacked vertically ovet each other limits the daylight that can reach the plants. The plants chosen can be in shaded and direct sunlight conditions, so although they do not need to be in direct sunlight most of the time, they do need some exposure. A similar use of shuttering can be implemented to that used in the BRE building, however the surfaces would be angled so that the light reflects onto the plants.

Precedent:
The BRE Environmental building uses louvres to shade the interior from direct sunlight to prevent over heating during the summer months. The louvres are made of glasss and are coated with a translucent ceramic coating on their undersides. Similar 'smart' techology is used as the Frederick Lanchaster Library, as depending on the intensity of the sun and the time of day the blinds will adjust their angles to act as shade or 'light-shelves'. The shelves can reflect light onto the ceiling of the office spaces and reduce the need for artificial lighting.

00 Design Development: Construction of green infrastructure

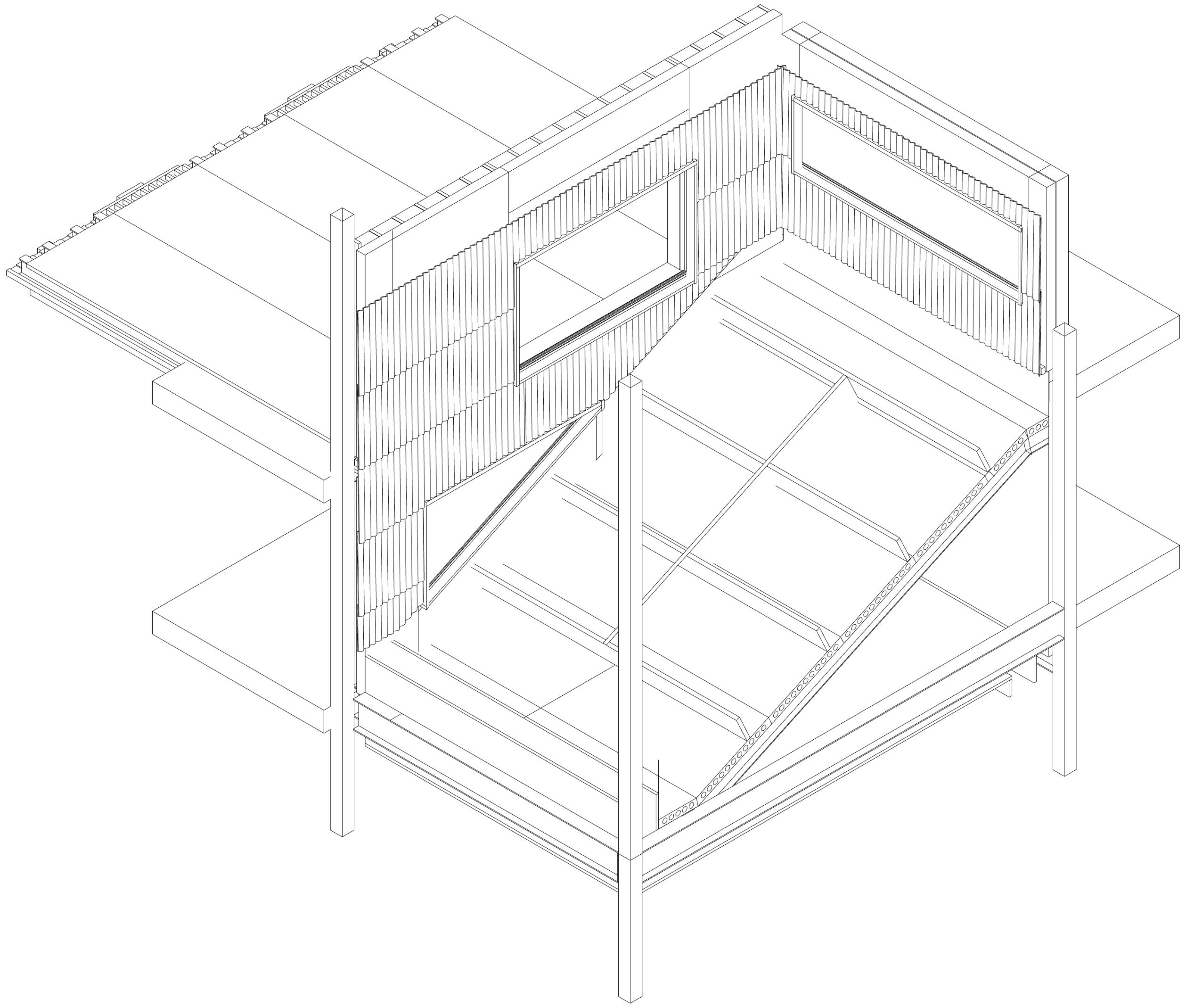


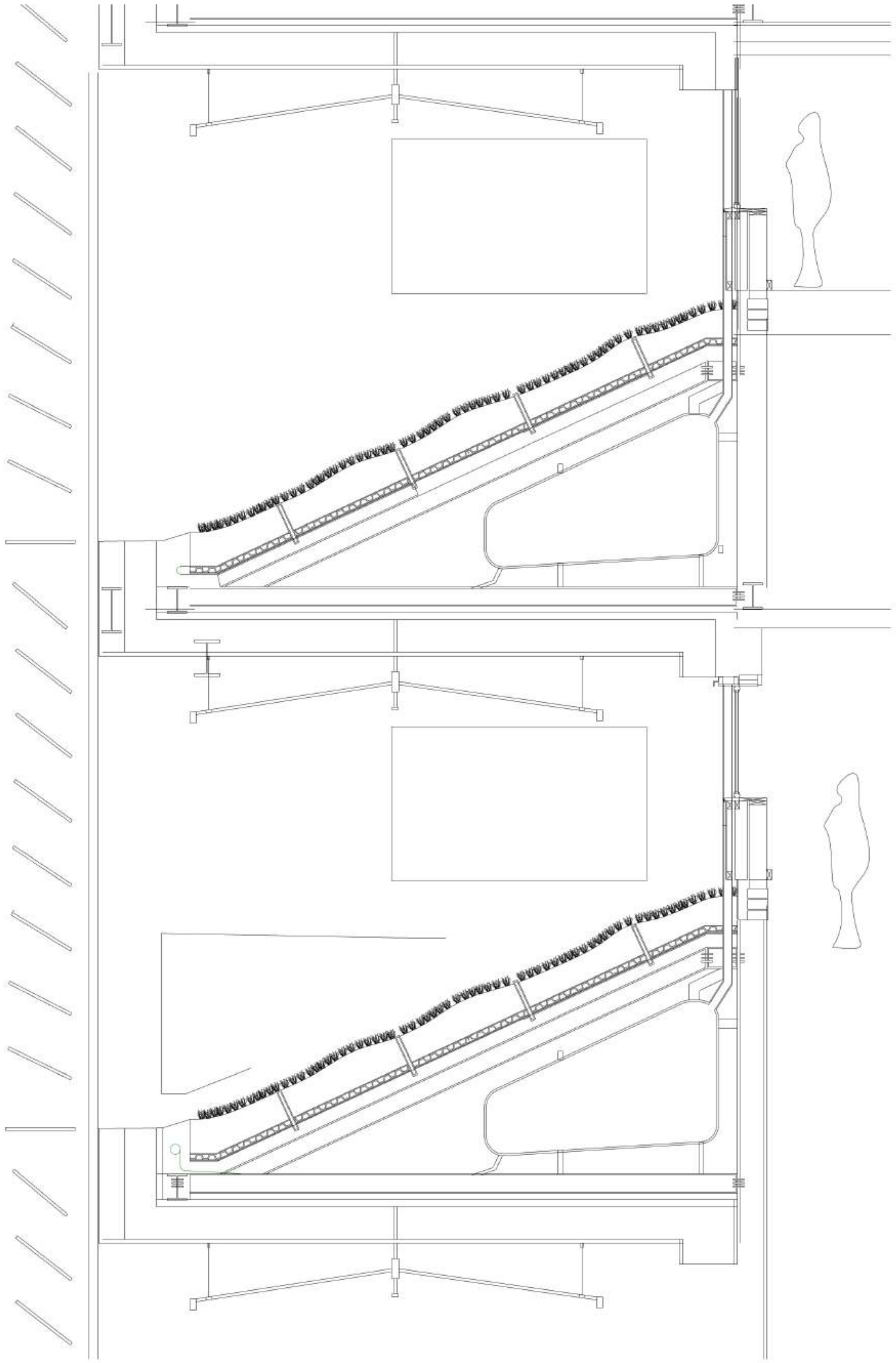


Fukuoka City Hall, is landscaped on one of its faces. The green infrastructure does not sit directly on the structure of the building as is common with green roofs. Geo-foam has been used to create steep gradients for the growing medium to sit on. Geofoam is a styrofoam that is manufactured on large blocks - it is often used for large scale infrastructure as a light weight alternative to earth and sand. Here it enables a simple structure of horizontal and vertical steel beam and precast concrete panels, and it decreases the load on the structure.

Althought this would be a viable solution to constructing a sloped intensive green roof, the material is a fossil fuel based - and so not a environmentally sustainable material. Another method needs to implemented, which can counteract any shear forces on the eath.

00 Design Development: Irrigation





Instead of creating a flat stepped surface for the growing medium to sit on, dividing the growing medium into smaller compartments, this reduces the forces acting directly on the growing medium down the slope. Instead it is acting on the walls of the compartments and going into the structure.

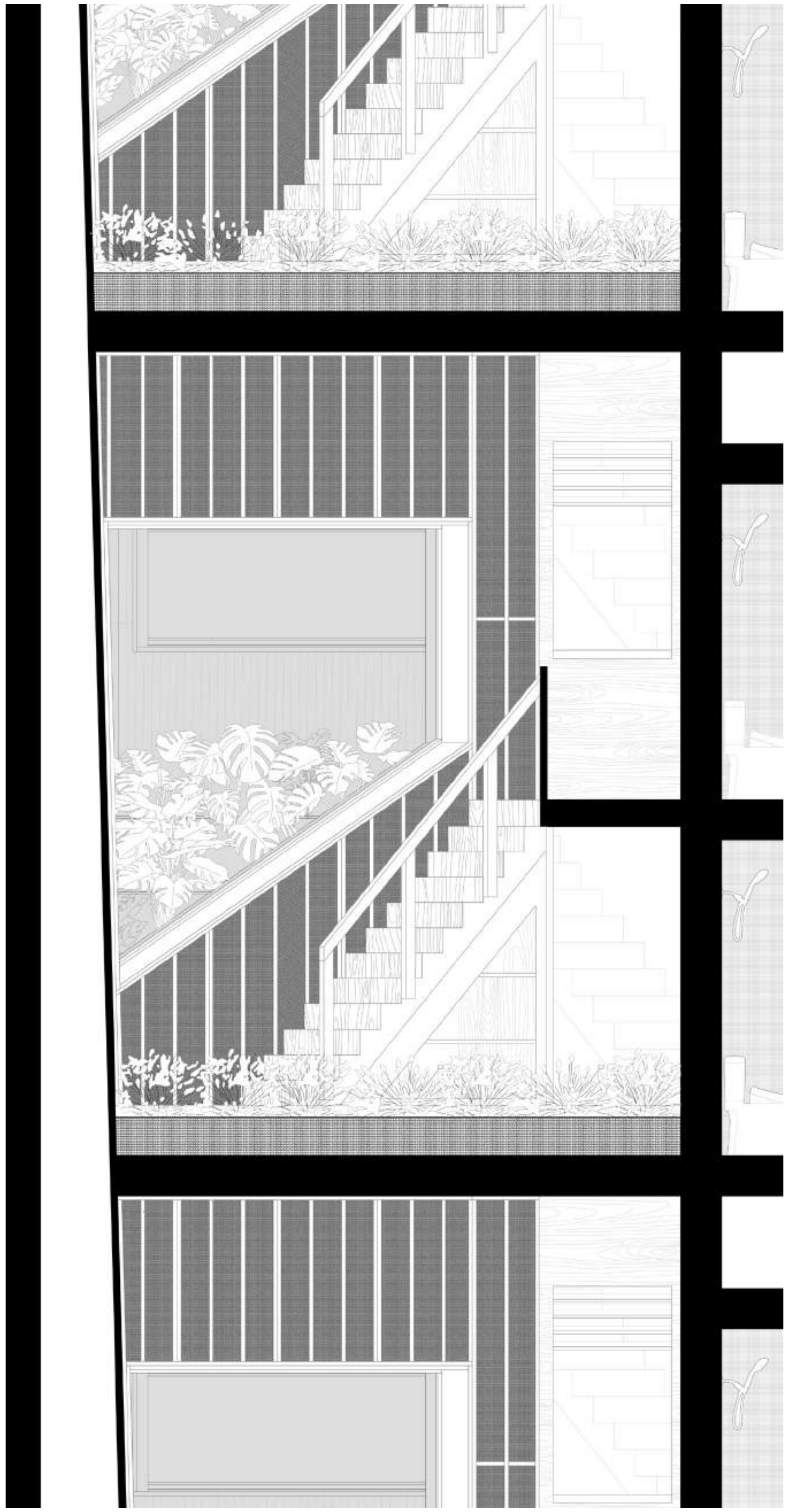
Steal beams are used to support prestressed concrete panels. This construction method doesn't require the area beneath the slope to be occupied, as with the geofoam construction. This opens the opportunity to have water retaining tanks to be stored within this space.

Design Development: Wall construction

To combat the water content that will be released from all of the plants, the walls will be constructed with a similar method of hempcrete compressed between a timber framework. This is however supported within the steal frame of the building, as timber frame buildings are only permitted to be 5 stories high.

The hempcrete will absorb excess moisture from the air.

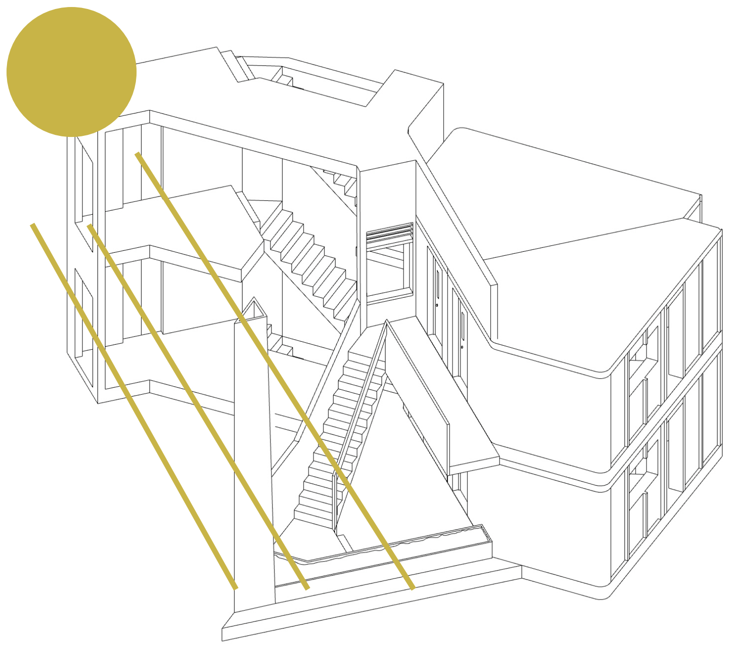
A similar corrugated sheet cladding is used within the filter shaft, as this is treated as external space and outside of the the thermal envelope.



The Flat house by Practise Architecture uses a modular timber frame construction in which hemp crete is compressed into a timber frame. This insulates the building but also regulates moisture.

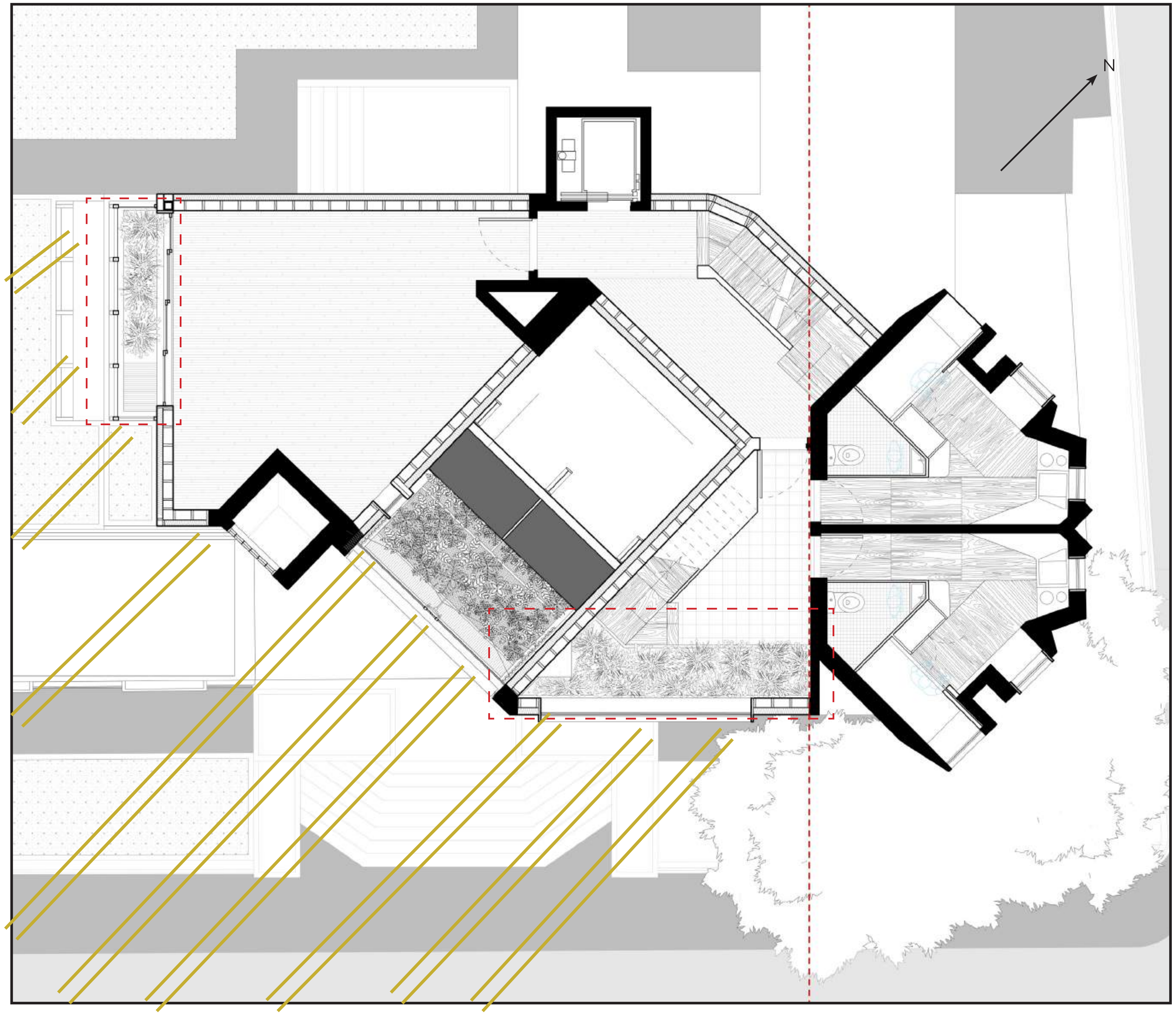
The extrerior is clad with corrugated sheets, to protect the hempcrete from the weather.

00 Locating floral scent boosters

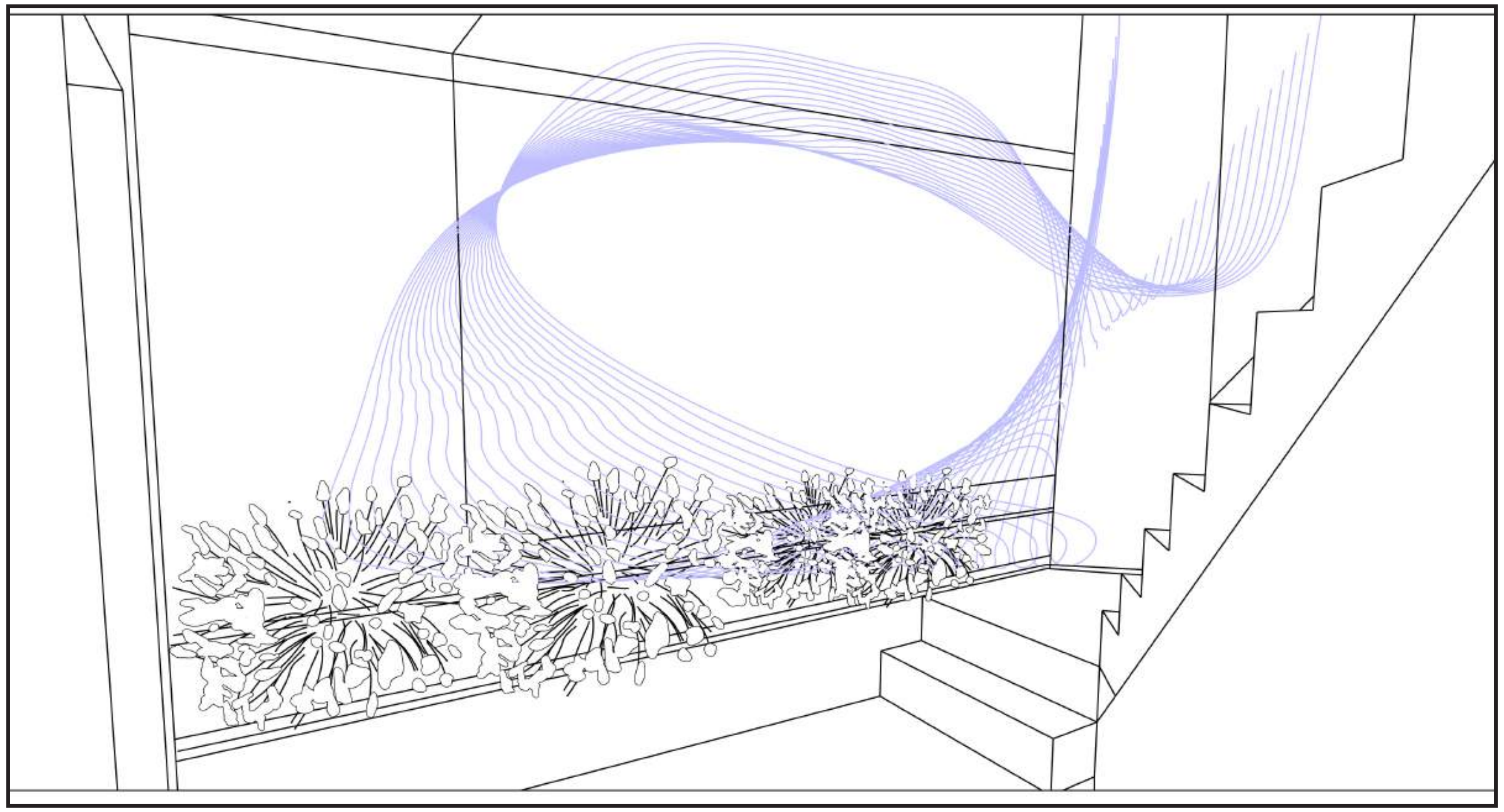


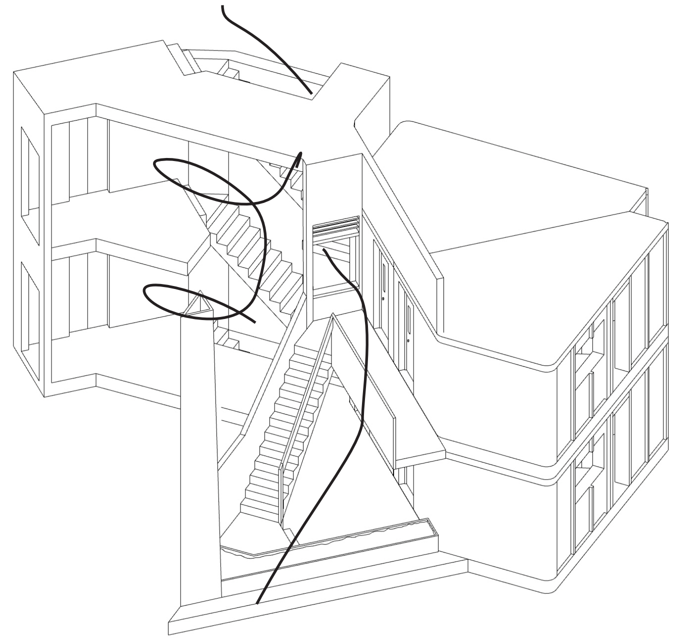
The lavendar beds are positioned on the south facing sides of the building so that sunlight can reach them.

The lavendar beds are also positioned next to the inlets of fresh air into each of the rooms, so that rooms will be filled with floral scents as the air travels across the room.

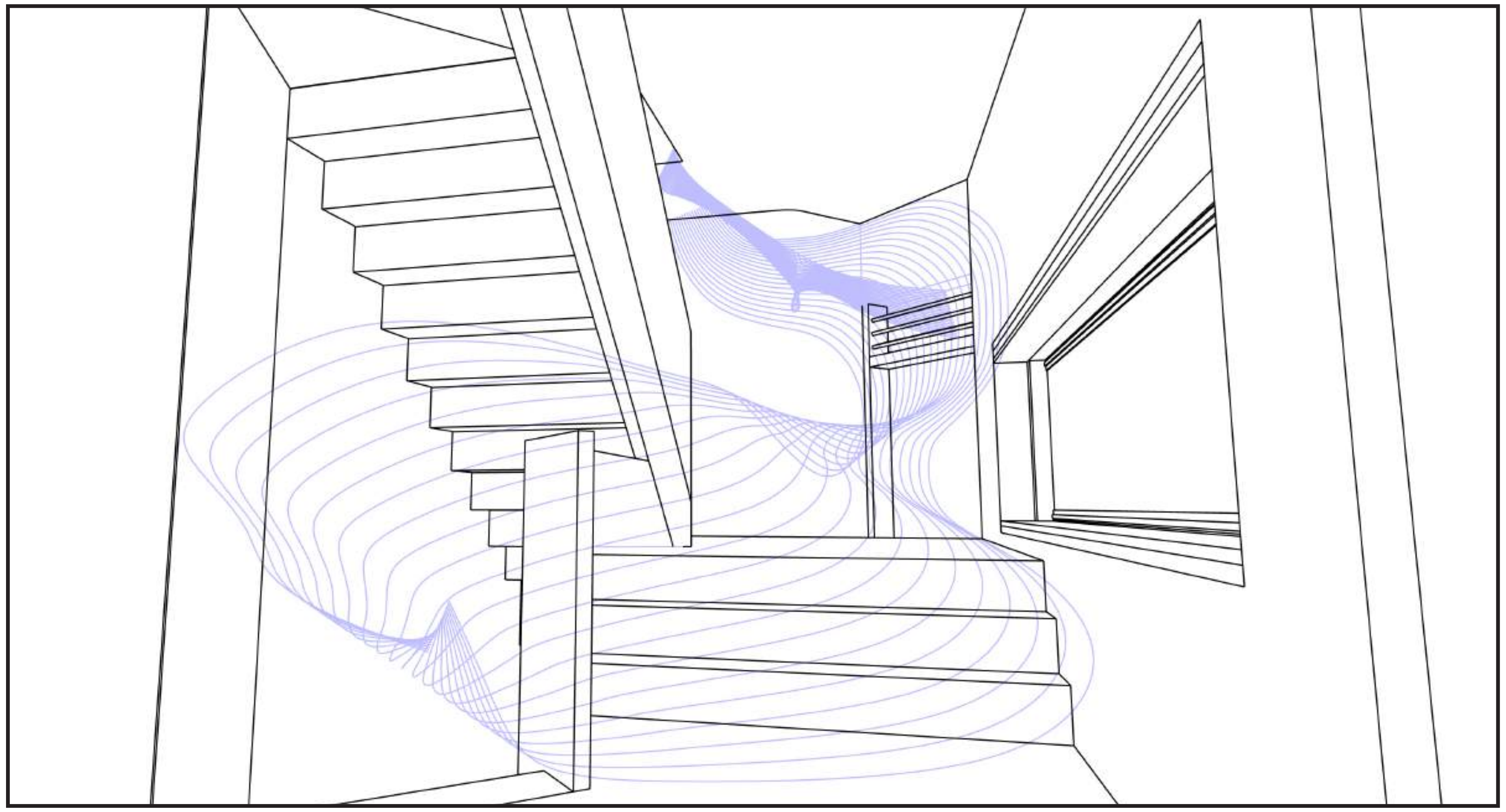


00 Spread of floral scent

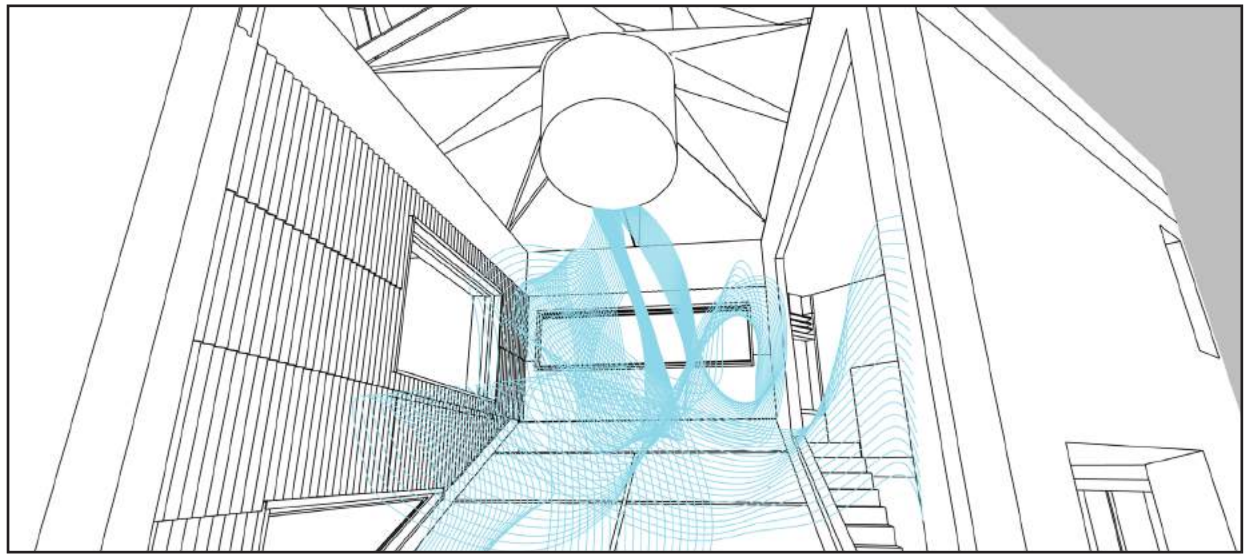


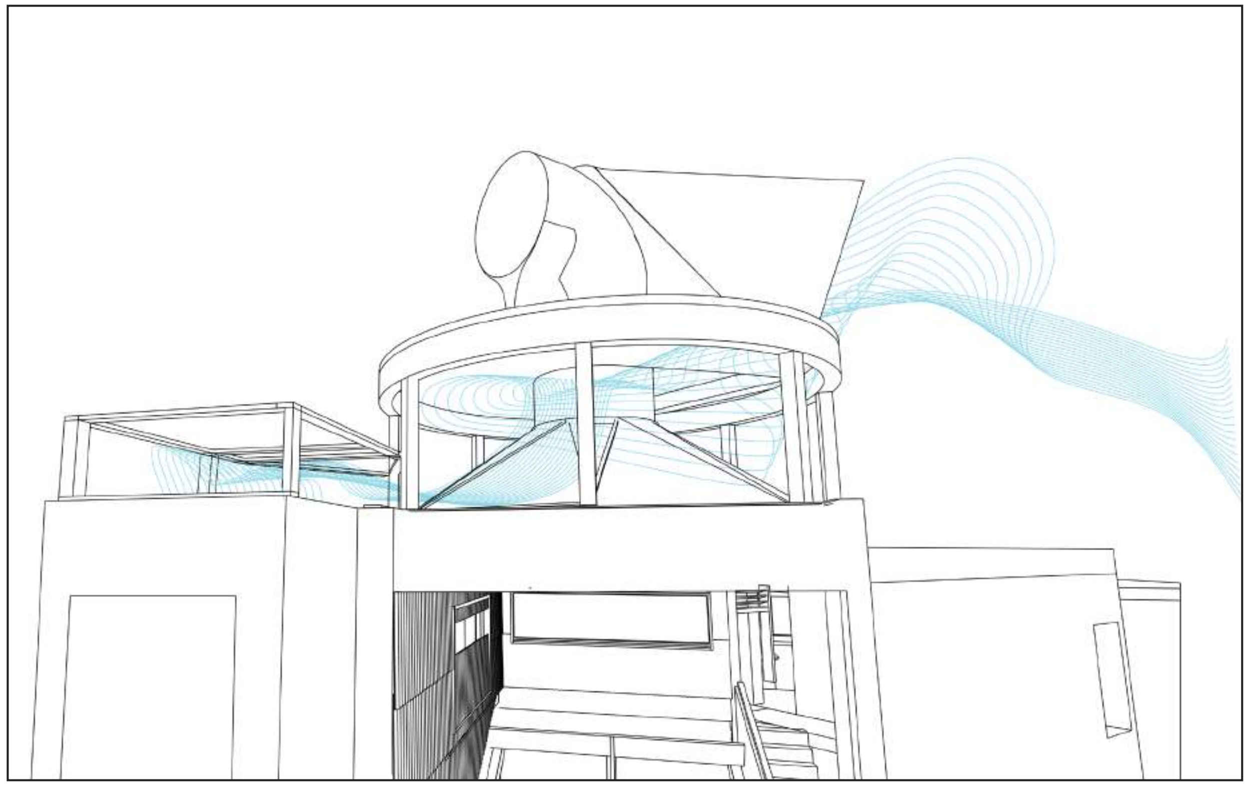


Illustrations of how the scent will follow the path of the air movement towards the top of the building, travelling up the stair wells.



00 Conclusion Living Healthy





Homeless people are disproportionately affected by air pollution in London. One of the main aspects for temporary accomodation/ hostel shelters for this group of people should be to create a welcoming environment and provide for them aspects of a living space that they did not have before. Warm clothes, bed, shelter from the weather, clean water, and clean air.

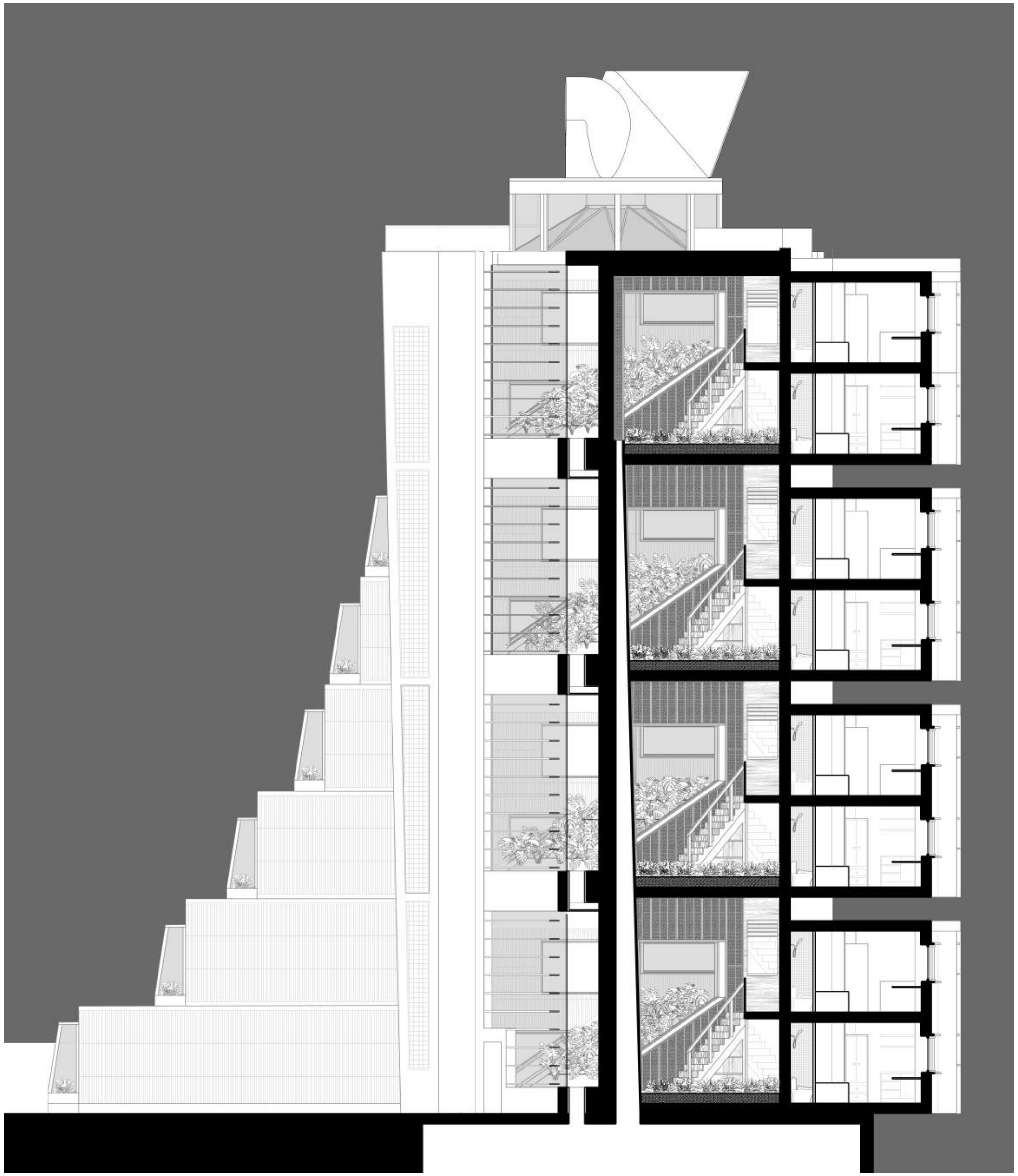
Despite the fact that London has employed several city wide measures to reduce the air pollution, London Victoria still remains one of the most polluted areas in the city, measuring pollutant concentrations that are deemed unsafe by both the EU and WHO. This investigation has explored how a building might be designed so that despite these toxic exterior conditions, the interior of a hostel can provide a healthy living space for its occupants.

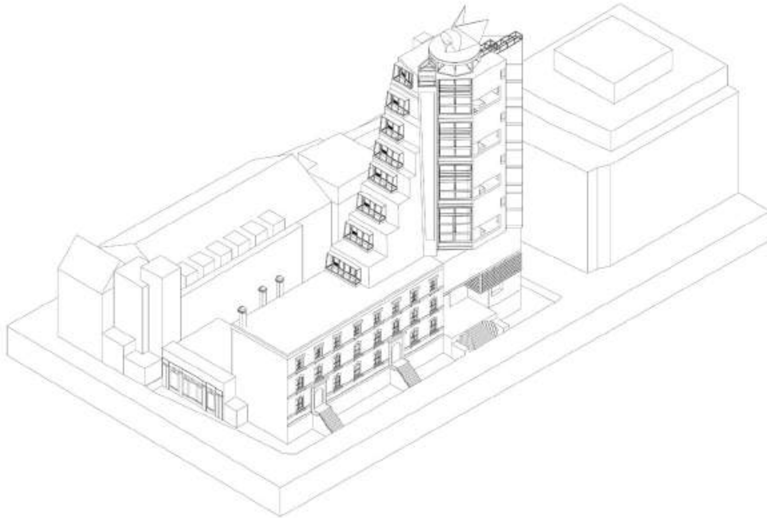
Initial thoughts to use a stack ventilation system that drew air up through the building were found to be ineffective if the direction of the wind changed as well as the discovery that air closer to ground level is found to have more toxic levels of pollutants. Through looking at precedents such as Iranian wind catchers and the BEDZED building's natural ventilation systems, the building was redesigned to draw air from the top of the building.

After this was established in order to maintain effective circulation of air within the building, the BRE Environmental building was studied due to its use of false floors to draw air deeper into rooms. Through this study false floor methodologies were implemented to create cross ventilaition despite the fact that the fresh and exhaust air passages are located at the center of the building.

Then through a rigourous testing process of wind simulations, the geometry of the filtering shaft was able to be stablished, that both implemente the venturi effect, with unconventional usage of false floors. When this is combined with the wind cowl placed at the top of the building, the investigation has developed a plausible sollution for how 100% of PM matter can be removed passively with only naturally driven ventilation and green spaces.

00 Conclusion: living healthy





The final building with the natural ventilations system - a building of three cores:

- leisure/ recreation rooms
- residency
- air filtering and green spaces

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