Ciying Wang
Engineering and Architectural Design (MEng)
The Bartlett School of Architecture
Year 4
Design Project 3

Harlech Institute of Cancer and Care Research

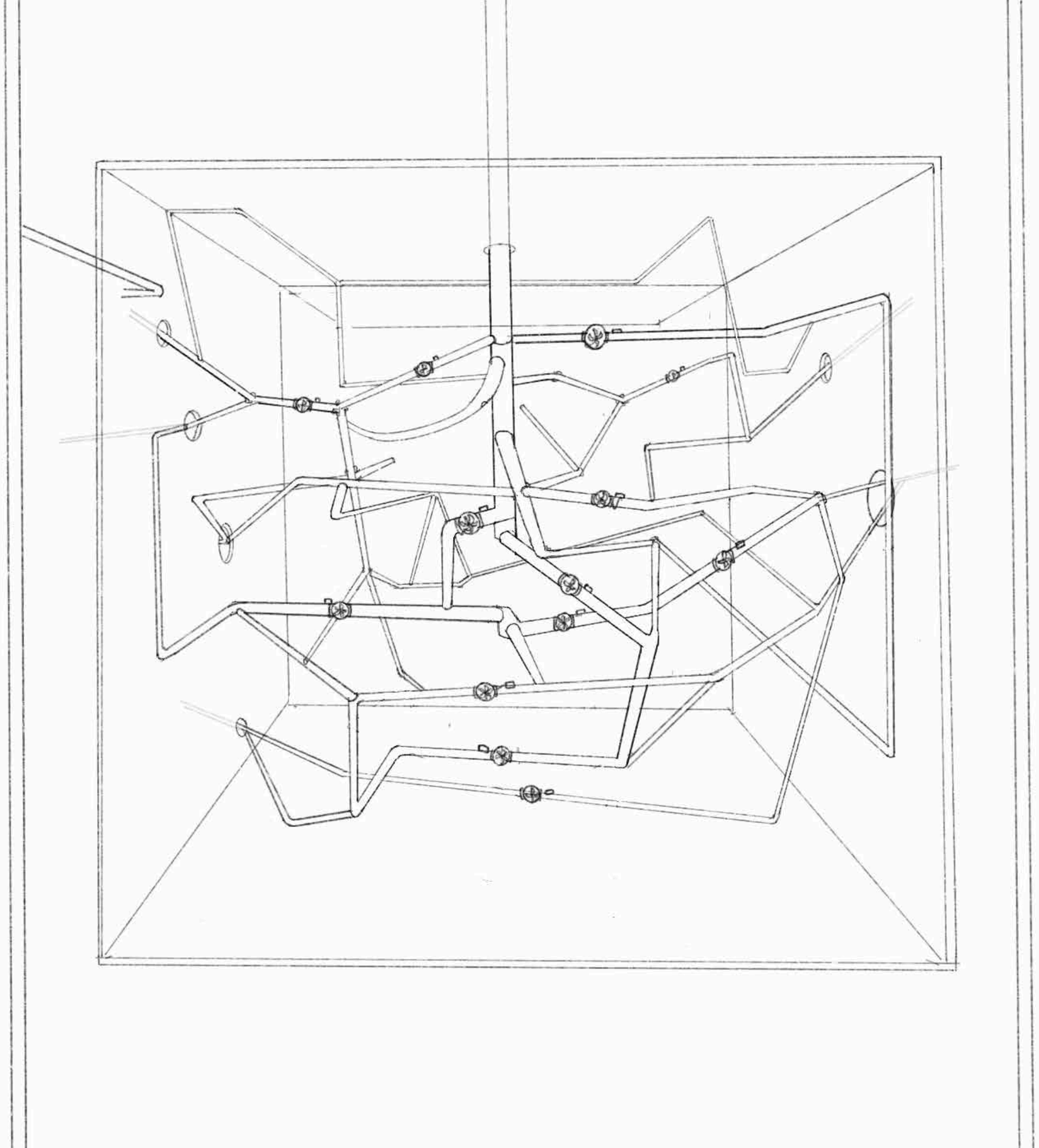
Designing adaptable and interconnected spaces to foster scientific discoveries and promote cancer care
Architecture as interstitial and interconnected spaces
A Vision of the Fourth Industrial Revolution in Harlech, Gwynedd

A FILM BY CIYING WANG
INTERCONNECTIVITY
A VISION OF THE FOURTH INDUSTRIAL REVOLUTION
WE CONNECT WHAT WE ARE AND WHAT WE CREATE; THE PHYSICAL AND THE DIGITAL; THE PART AND THE WHOLE.
BEST TUBE SEWING
BEST TURBINE
BEST ACTRESS
Executive Director Ciying Wang Producer Luke Olsen Technical support Aurore Julien, Filip Kirazov & Matthew Heywood Special thanks Ina and Gabs
AT HERE EAST NOVEMBER 17

'Interconnectivity' is seen as the key word of the fourth industrial revolution for this project. We connect the digital and physical world and create technologies such as 3D printing, additive manufacture, metaverse. We connect what we are and what we create, by editing genes and synthesizing cells and connecting ourselves to machines. We connect members in the societies in different ways, where blockchains deconstructs central powers and can change the form of governance. We connect individuals and central resources in different ways and optimize the process of distribution.

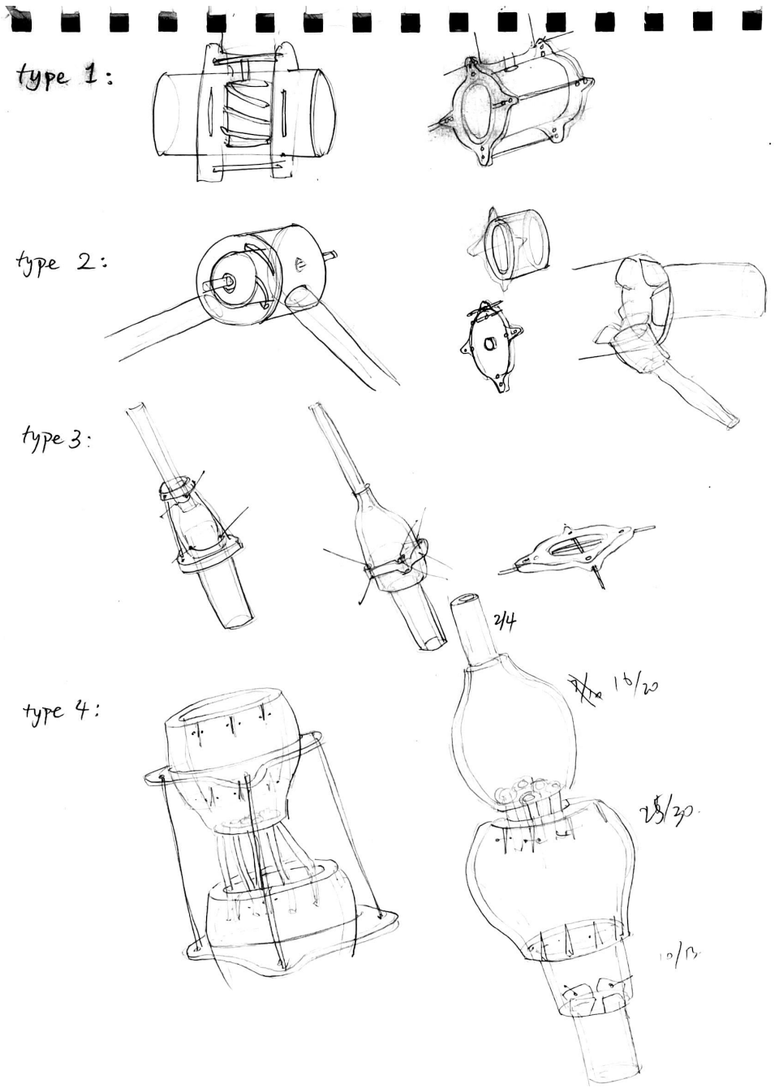
The prop can be intepreted in many ways. First, it can be seen as a demonstration of human's progress of researching into our own brains and the connections of our neurons, with which we use to create artificial intelligence and other technologies to expand our ability to think. Poured from a single source, the liquid flows through the intricate tube system, and lights up different areas. The model is designed by firstly building the connections , and then sewing the connections together with tubes.

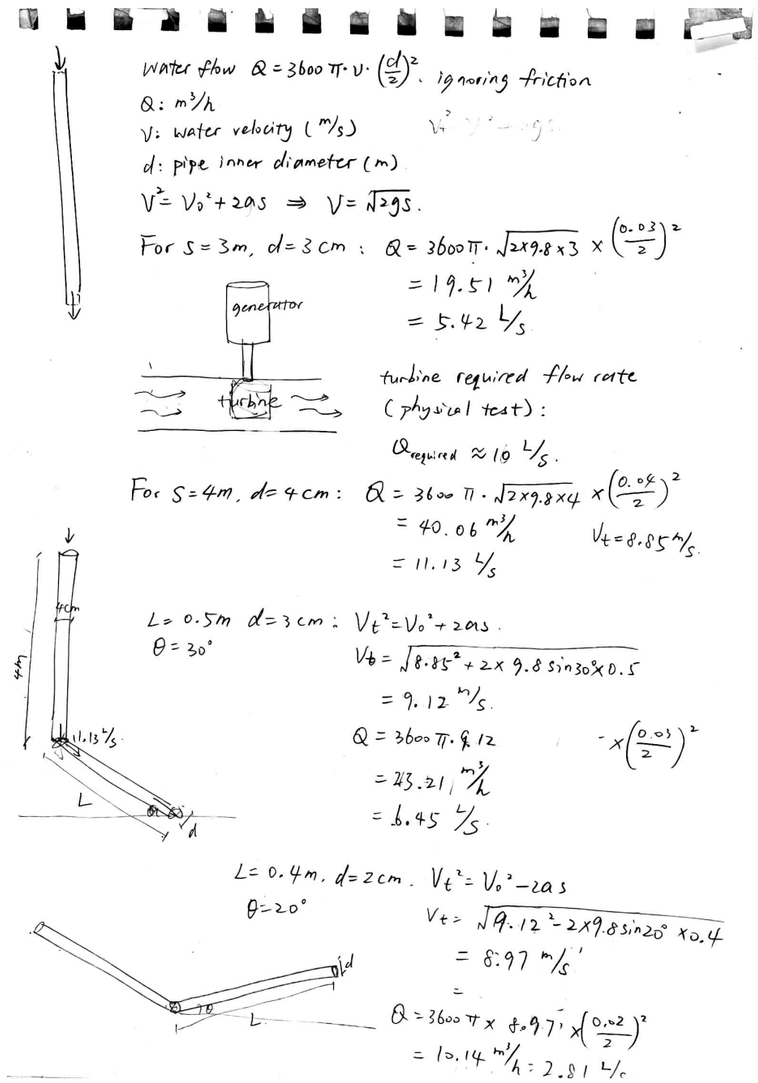
Pouring liquid into the tubes also demonstrates a contrast between the ideological and the reality. Never before have we been so reliant on the digital world to direct our physical world. The transparency and cleanness of the prop shows human's endeavors to build perfect and clean models in the digital worlds, but in the end most energy we are using today is 'dirty' things. The reality is complicated and messy, and it takes the joint efforts of business, politics and organisations to reduce the impact of climate crises by revolutionising the processes of energy production and distribution, and rethinking how human communities and other creatures can co-live under the same biosphere.

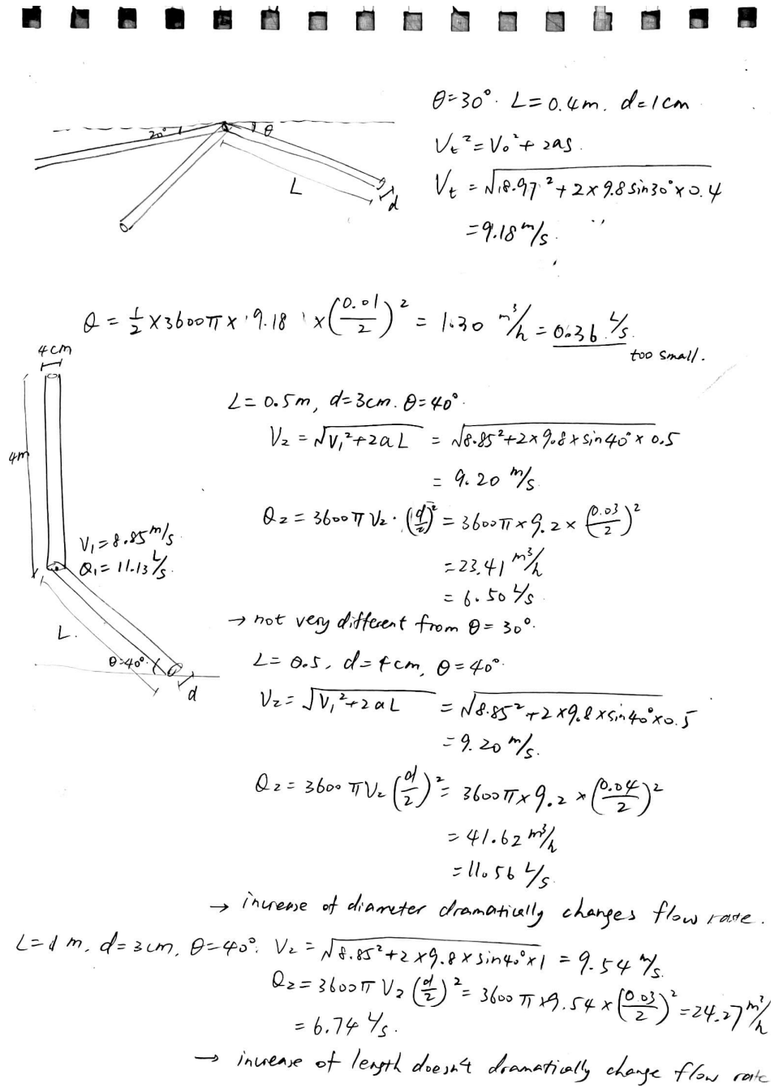


Phase 1: prop

The prop is constructed with polyethylene pipes, 3D printed connections, water turbines and light bulbs. All the connections are designed and engineered in detail, and the lengths of pipes are also calcualted, to ensure there is enough water pressure to drive the water turbines and light up the bulbs.







Phase 1: prop

Phase 1: prop

Building Proposal

The vision of this project for the fourth industrial revolution celebrates the art of scientific research and social care. The designer believes that the next one hundred year will witness a growing understanding of human ourselves - our bodies, our brains, and our diseases. The boundaries between what we are and what we create will be blurred, and virtual models and physical entities will merge. This project looks into both current social challenges and future opportunities, and proposes a model where social care and radical research complement and nurture each other. Inspired by neural connections, it is an interconnected and forward-looking institution which grows and changes in response to its environments and the needs of its communities.

This project is built on the hypothetical provision of nuclear batteries which provides nearly unlimited source of energy - but what do we use do with the energy, and how can it benefit the communities of Harlech? The first step of this project is a holistic research into the socioeconomic situations of North Wales, which suggests: 1. a thriving life science sector, which has the potentials to attract investments and talents ; 2. a strong need for regenerative strategies, with the most urgent one being care facilities to the cater to the needs of a increasing elderly populations. These challenges and opportunities are integrated into the brief of this project.

Contents

1. Brief Formation
1.1 Nuclear batteries
1.2 Industry in North Wales, Gwynedd and Harlech
1.3 Towards an ecosystem of research and care

2. Evolving the Vision
2.1 Spacial Organization
2.2 Adaptive Reuse
2.3 Interconnection of Spaces
2.4 Rethink Lab Layout
2.5 Spaces that promote health

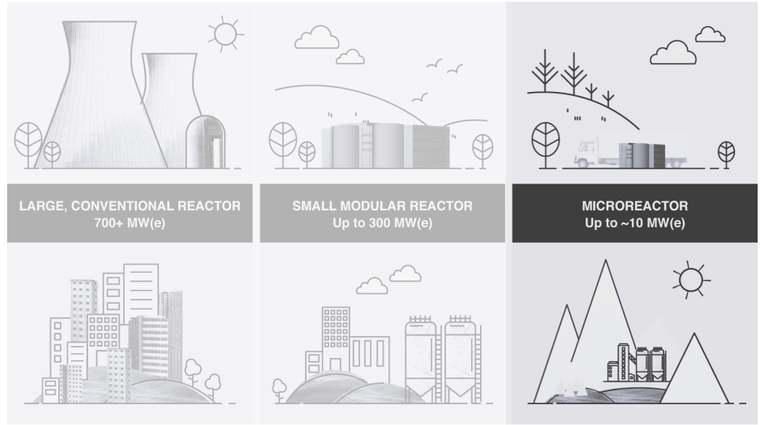
3. Interstitial Spaces
3.1 Case study: Salk institute of biological studies
3.2 A breathing system for labs
3.2 Structure for vertical and horizontal service spaces

4. Interconnectivity
4.1 Energy distribution
4.2 Interconnected spaces

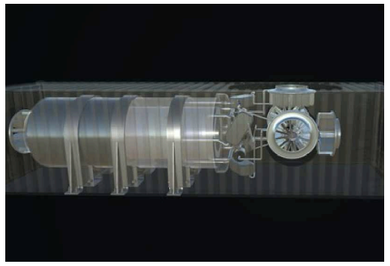
5. Coming Together
5.1 GA sets
5.2 renders

1

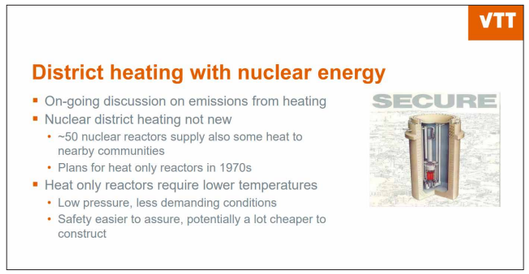
Forming the Brief



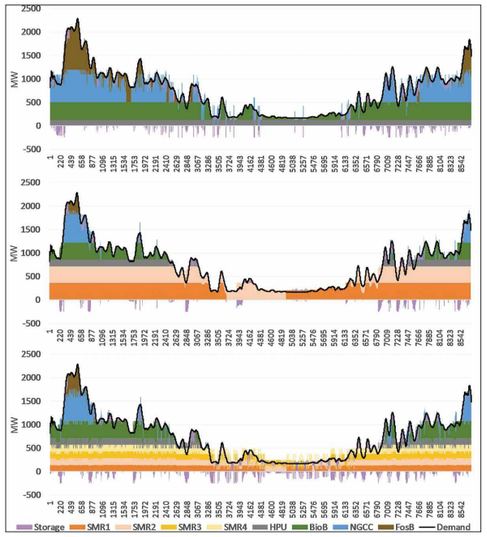
Traditional nuclear plants, SMRs (small modular reactors) and nuclear batteries (microreactors). (Source: International Atomic Energy Agency)



There are already many commercial designs on the market, such as microreactos designed by Idaho National Laboratory and Los Alamos National Laboratory.



Research by VTT: district heating with nuclear energy, where heat-only reactors require less demanding conditions and potentially provide cheat solutions to provide power to communities.

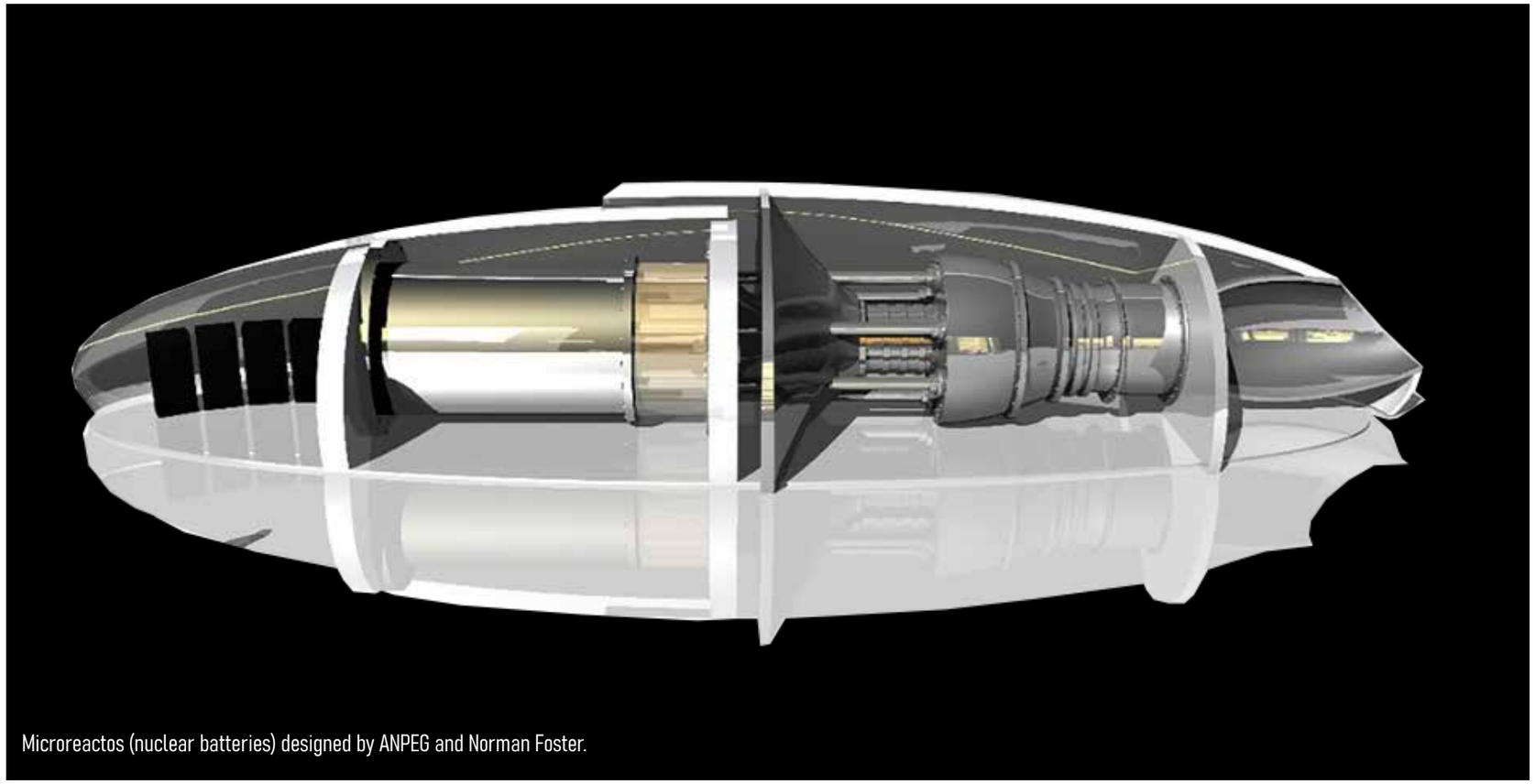


Tomi J. Lindroos (2019) A techno-economic assessment of NuScale and DHR-400 reactors in a district heating and cooling grid.

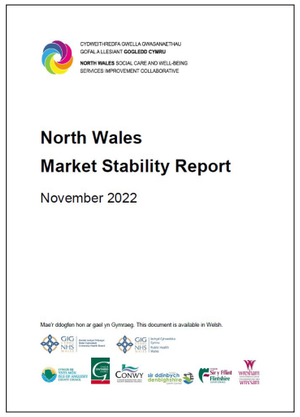
Why nuclear?
- low-carbon
- reliable
- secure

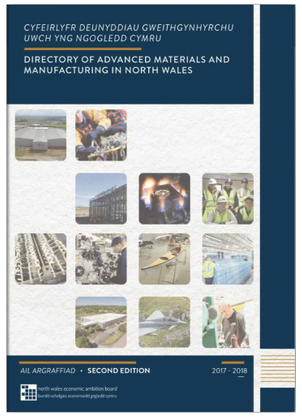
Why microreactors?
- small, modular, easily transported
- short set-up time
- reliable heat and power for long time
- powering remote locations

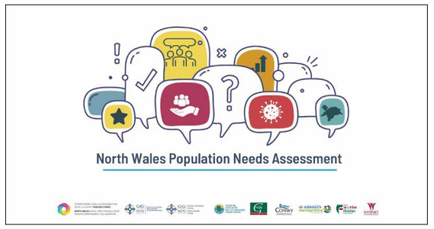
Microreactor (Nuclear battery)

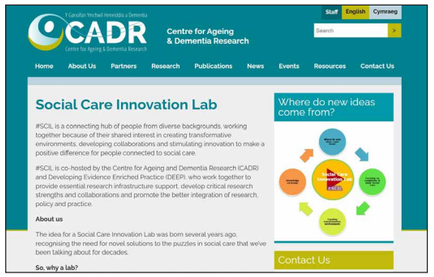


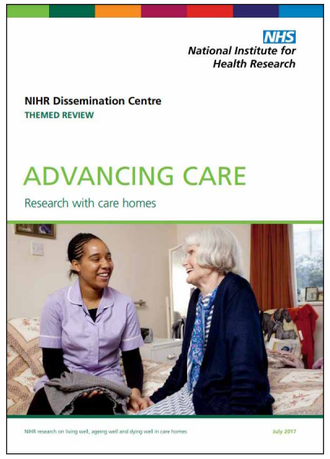
Microreactos (nuclear batteries) designed by ANPEG and Norman Foster.











North Wales: the Thriving Life Science Sector

Incorporating a broad range of sub-sectors including aerospace, engineering, opto-electronics, and materials and coatings, amongst many other advanced materials & manufacturing industries, the life science sector continues to evolve and deliver as one of the key economic drivers for North Wales. With centres of excellence and Enterprise Zones to support industry and innovation across the regionl, alongside the world-renowned landscape and environment of North Wales, it is easy to see and appreciate why the growing innovation of the conomy and its skills continues to attract inward inverstment alongside the expansion of existing employers.

There are a few key reasons that the industry picks Wales: A supportive devolved government that has the ability to make things happen quickly (including supporting initiatives like the Life Sciences Hub Wales); First-class, tailored facilities – including dedicated life science incubators such as the Cardiff Medicentre and Institute of Life Science Swansea; A first-class combination of academic institutions, industry and government developing innovative solutions; Easy access to the UK market (with a population of 65 million); Business-friendly tax – lowest in the G20; A growing talent pool – with more than 12,000 students studying relevant programmes at local universities; "Our universities are renowned internationally for their academic and clinical research excellence. The delivery of health and social care in Wales is evolving to place innovation at its centre and lead in holistic approaches that produce the best patient outcomes."

Gwynedd: Economic and Health Challenges

Gwynedd is proving an increasingly attractive base for new and expanding high-growth business looking to take advantage of what the area has to offer. The county is served by two world-renowned universities - University of Bangor and University of Abertystwyth - providing both a highly-skilled workforce and cutting-edge research & development opportunitgies. The county is central to the creative corridor from Dublin to the Nothern Powerhouse region.

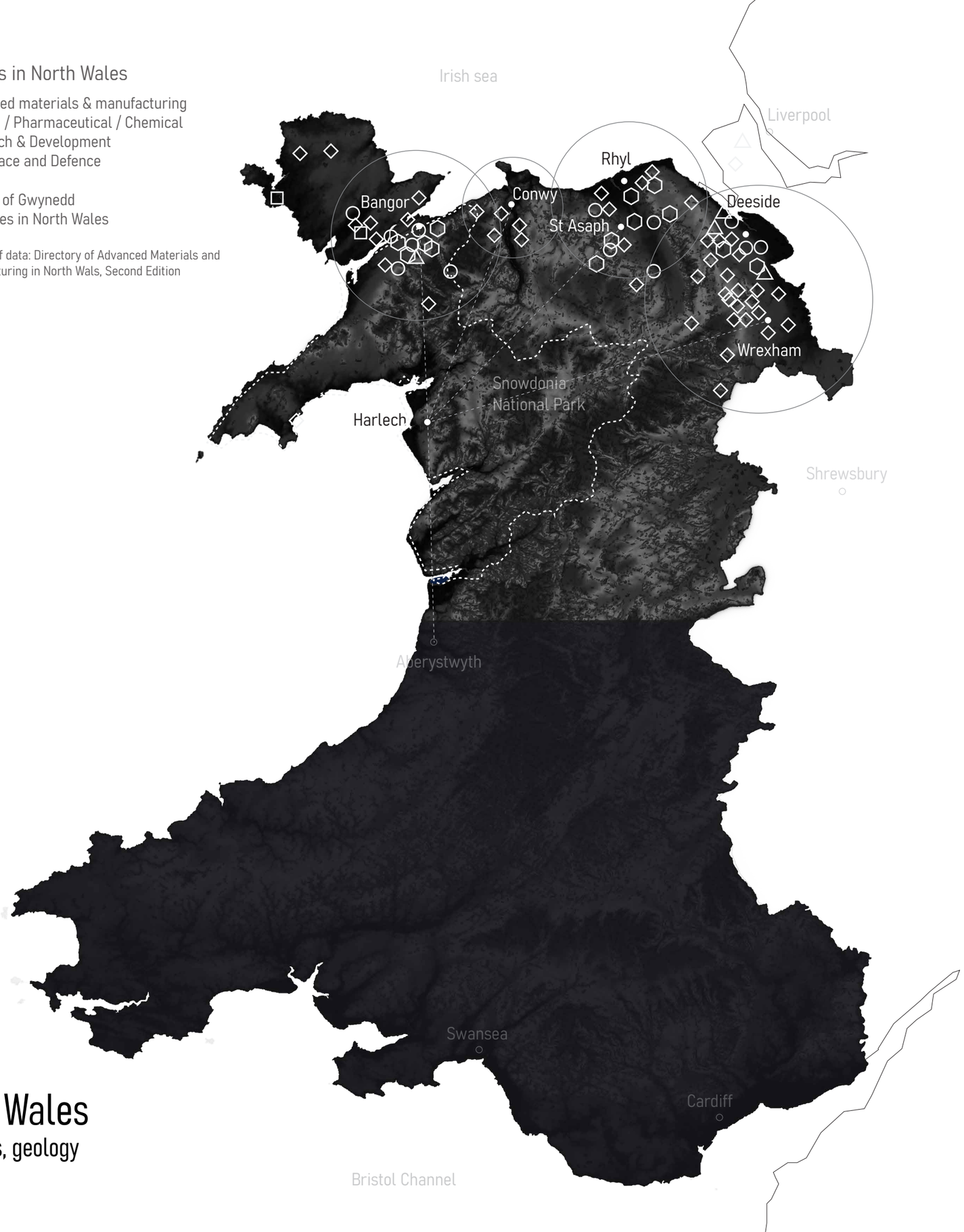
In 2040 there is estimated to be over 61,000 people aged 65 and over who struggle with daily activities in North Wales. Currently Gwynedd is faced with its challenges with economy and health. Tourism as the key employer in Gwynedd is significantly impacted by Covid; salary level is below national average; an aging population lacks the ability to bring enough workforce to the market. Health trends of Gwynedd residents are lower than the national average, with not enough inclusion in sport and fintess activities and a lack of care homes and staff. There is reported to be a serious lack of care facilities for the elderly and cancer patients.

Economy, Populations, Industries and Markets

Industries in North Wales

- ◇ Advanced materials & manufacturing
- ○ Biotech / Pharmaceutical / Chemical
- ⬡ Research & Development
- △ Aerospace and Defence
- □ Marine
- Outline of Gwynedd
- • H Key cities in North Wales

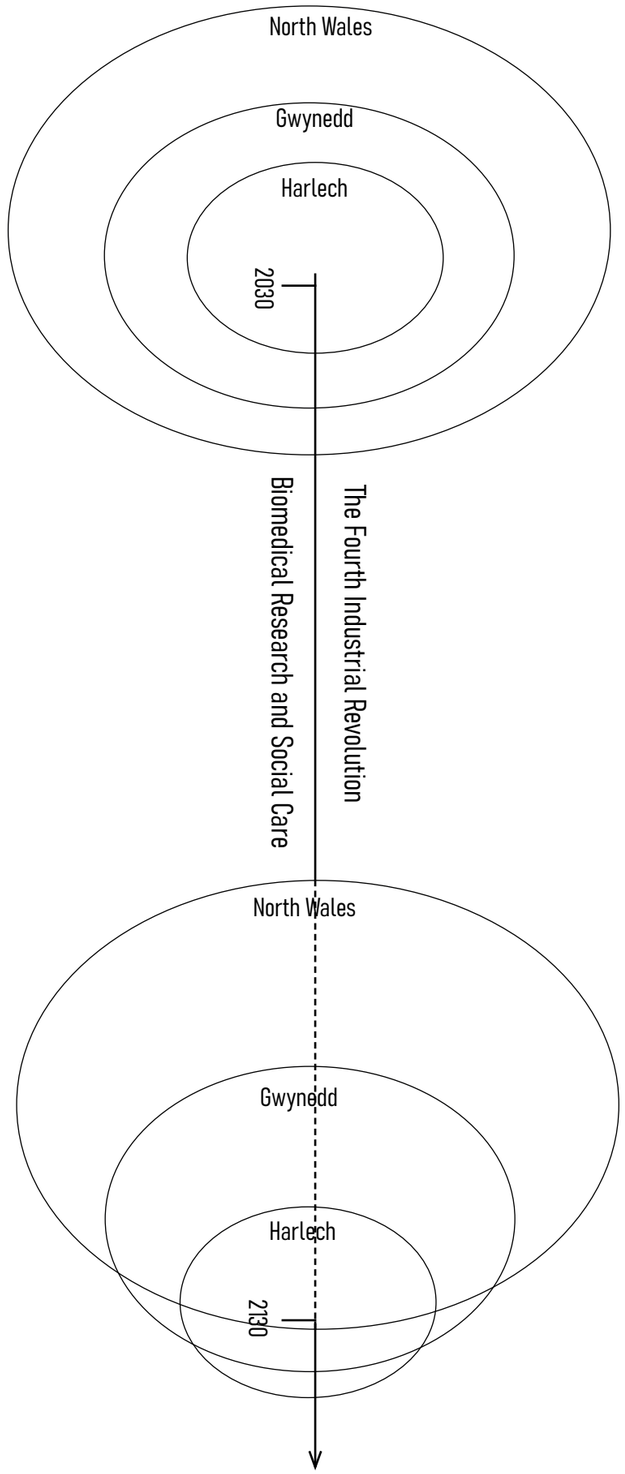
Source of data: Directory of Advanced Materials and Manufacturing in North Wals, Second Edition

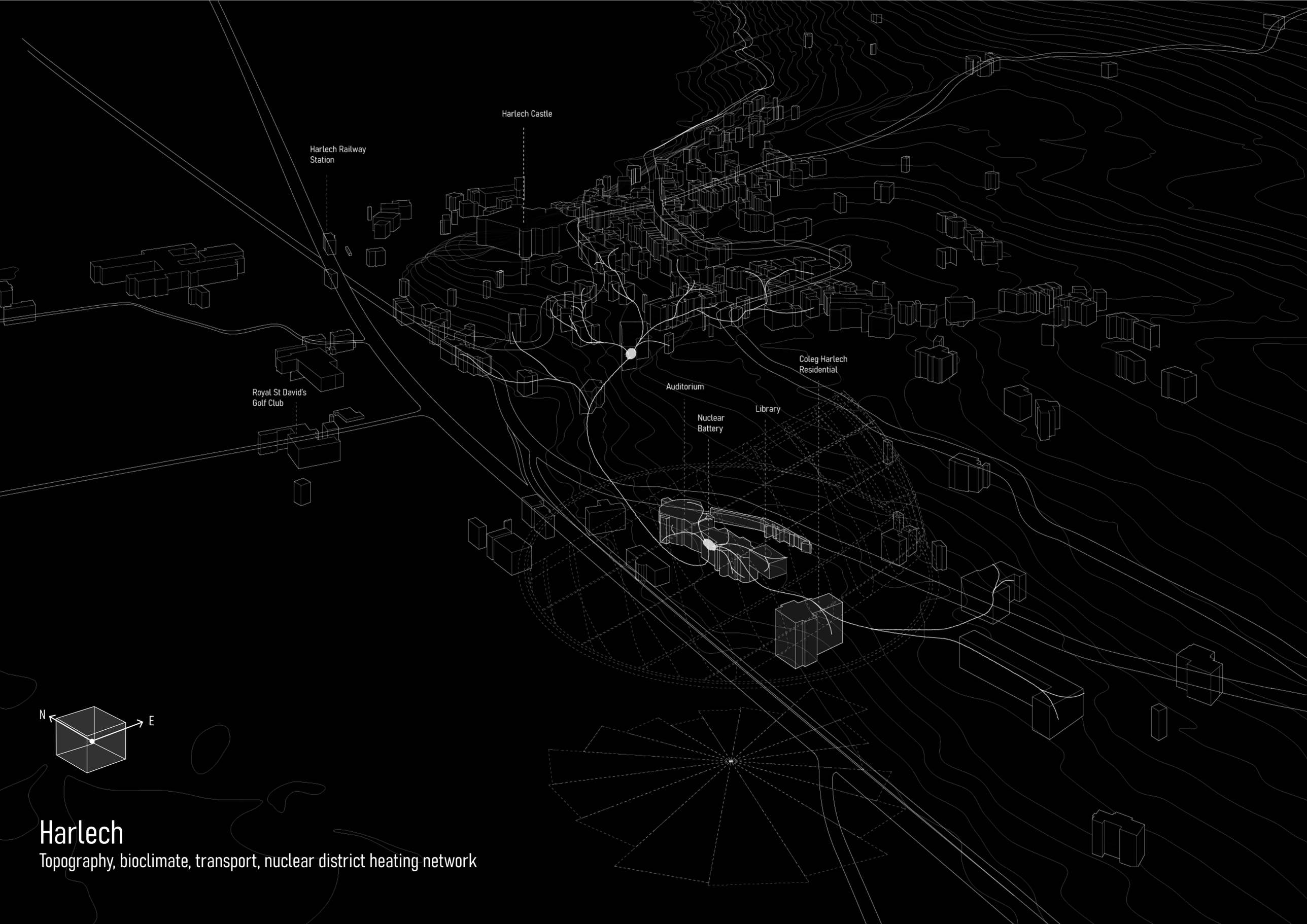


North Wales

Industries, geology

What is the role of Harlech in the development of North Wales?





Harlech

Topography, bioclimate, transport, nuclear district heating network

Connection to the wider community

Science is no longer exclusively happening in isolated and closed off institutions, but is extended beyond into the fabric of its environment, using the urban environment as a testbed for experiments. Increasing importance should be placed on public realm qualities around institutions to engage with the public, forming a kind of social and public infrastructure.

Community kitchen as the core

A kitchen serves as the central space for communication. This is where interactions happen between researchers, carers, patients, and the wider communities.

The art of care

' These spaces should look as if they are acknowledging what people are going through, saluting the magnitude of the challenge they are faing and themselves rising to the challenge of trying to help.' The spaces in the buildings or landscapes should allow the people who use them to take charge of how they want to use them. Something quite small, such as choosing where they feel comfortable, knowing it's fine to pick up a chair and move it where they want, chooseing the cushion to match the chair, or making themselves a cup of tea.

Rethinking the lab layout

Different from any other types of buildings, labs have vstringent requirements for vibration, ventilation, containment, and specialized equipment. A future lab should also be flexible and adaptable to changes and the unpredicted.

Pop-up labs and everywhere labs

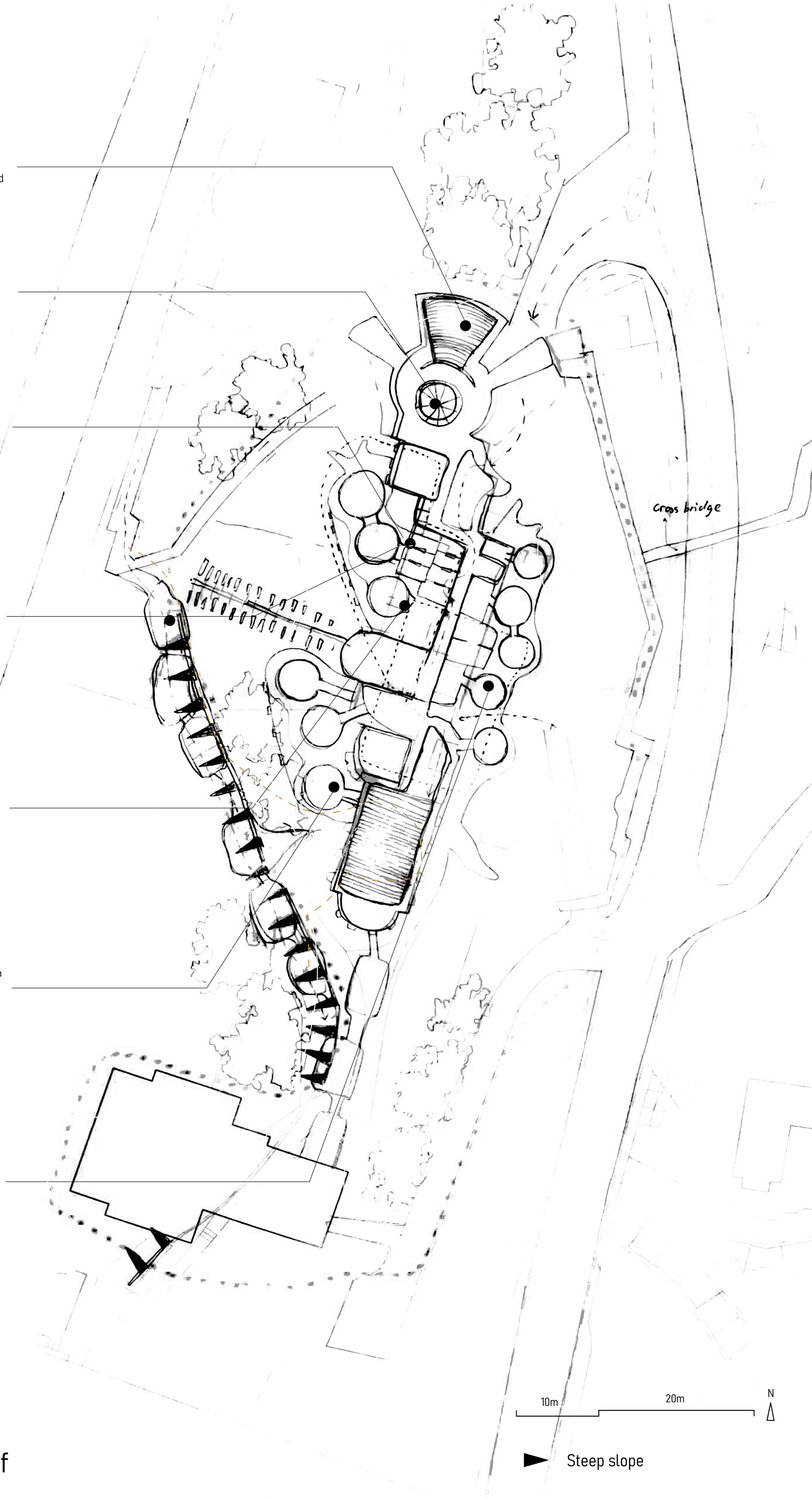
These are mobile and flexible research spaces which can be set up in any context and bring science to the general public. They can also provide scientists with a space to conduct experiments in real-life conditions outside the lab environment. Everywhere labs are decentralised lab spaces empowered by digital networks, which means research can happen anywhere at any time, and previously isolated places can become part of larger research clusters.

Pocket gardens

Distress can lock people in, tempting them to curl up, and to withdraw. Gardens act as a space to open to the outside world, to encourge people to look out. Sheltered inside, it helps to be reminded by a seasonal and changing scene outside, that we are still part of a living world.

Cloud, automation, robotics

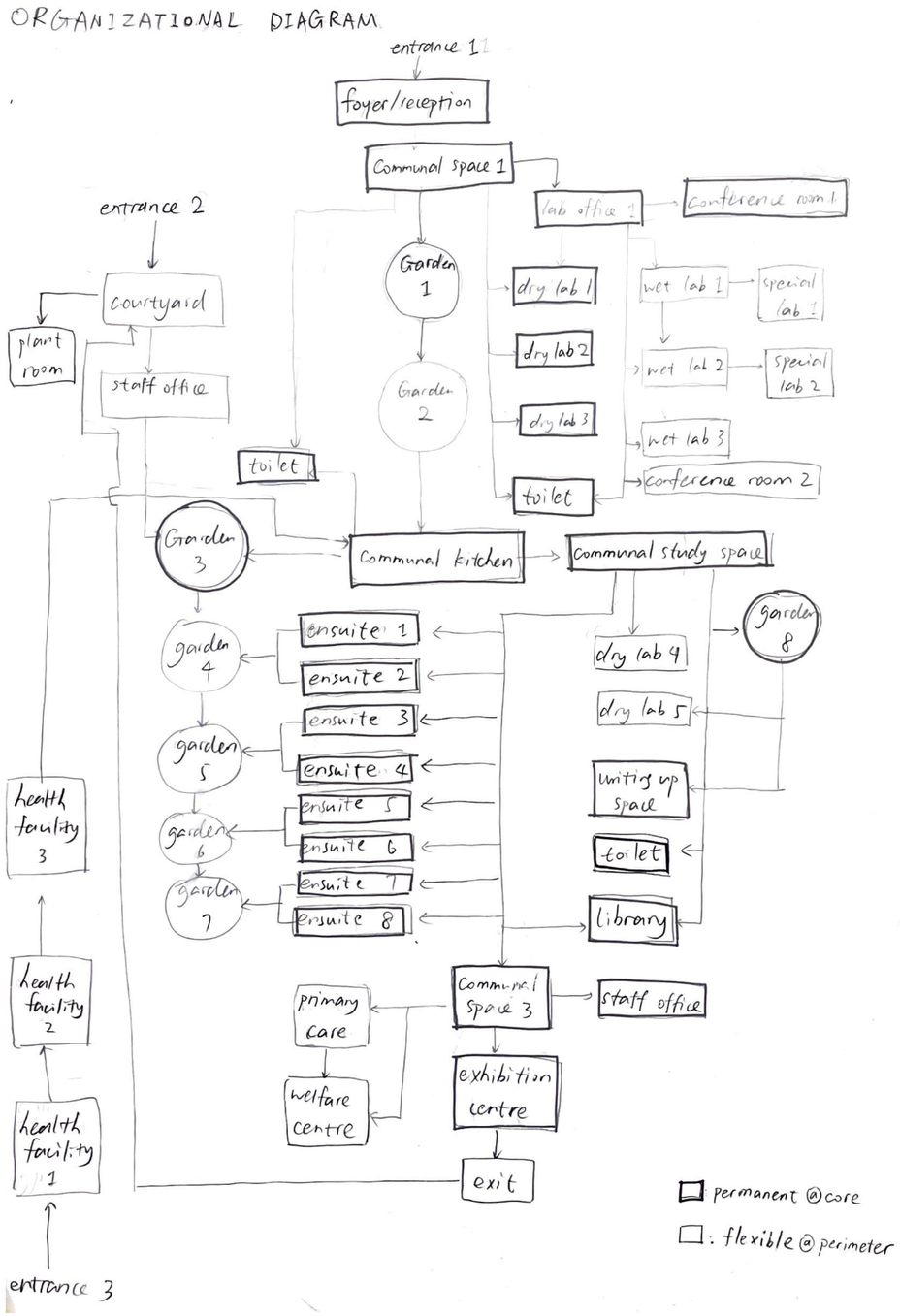
A new wave of data-driven life sciences reseach institutes have emerged and cloud-based experiments and the integration of artificial intelligence are likely to significantly impact scientific workflows and life science research in the coming years. The digital infrastructure that connects a network of research spaces in a variety of locations — from private homes and research clusters - enables a internet of labs to work together closely .

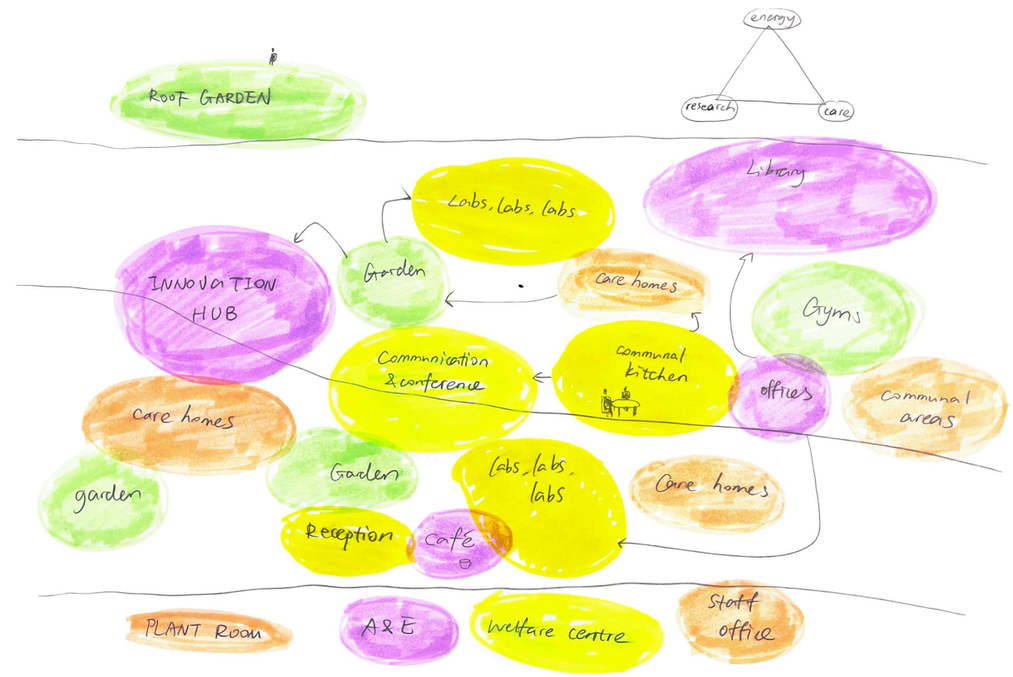


Towards an ecosystem of research and care

2

Evolving the Vision

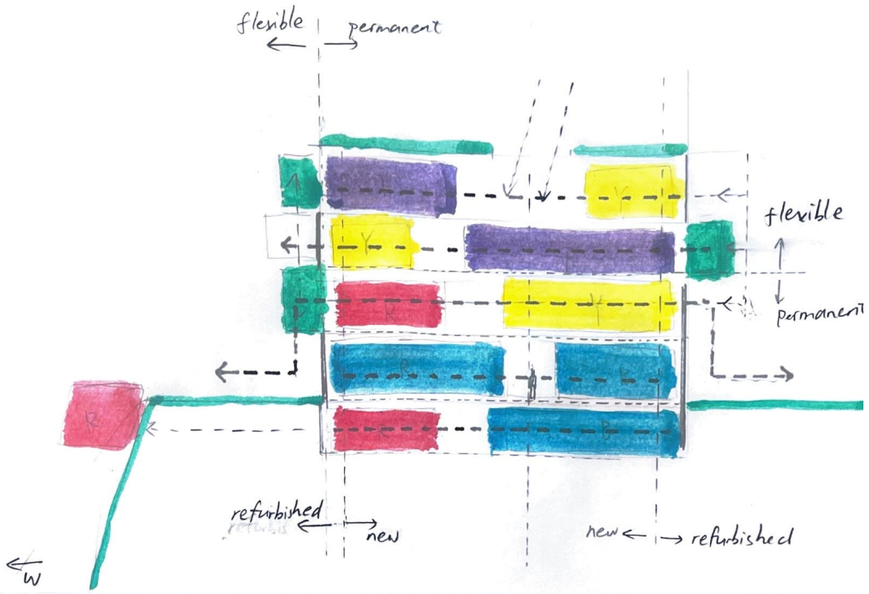


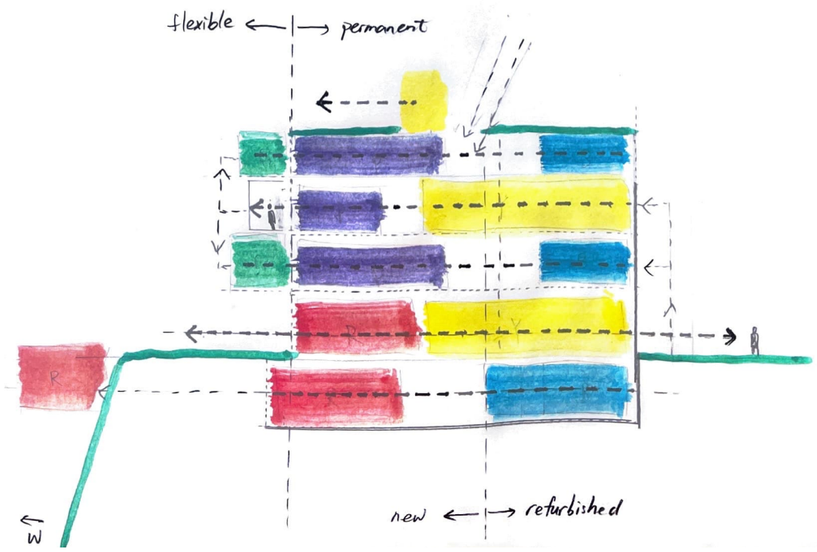


Spacial organization

Public or private ground floor

Ground floors and basements are good for vibration-sensitive lab spaces, but public areas will have to be put on upper floors, which compromise the accessibility of these spaces.
If public spaces are put on ground floors, the supporting structures will be more bulky to satisfy the vibration control standards of labs upstairs.

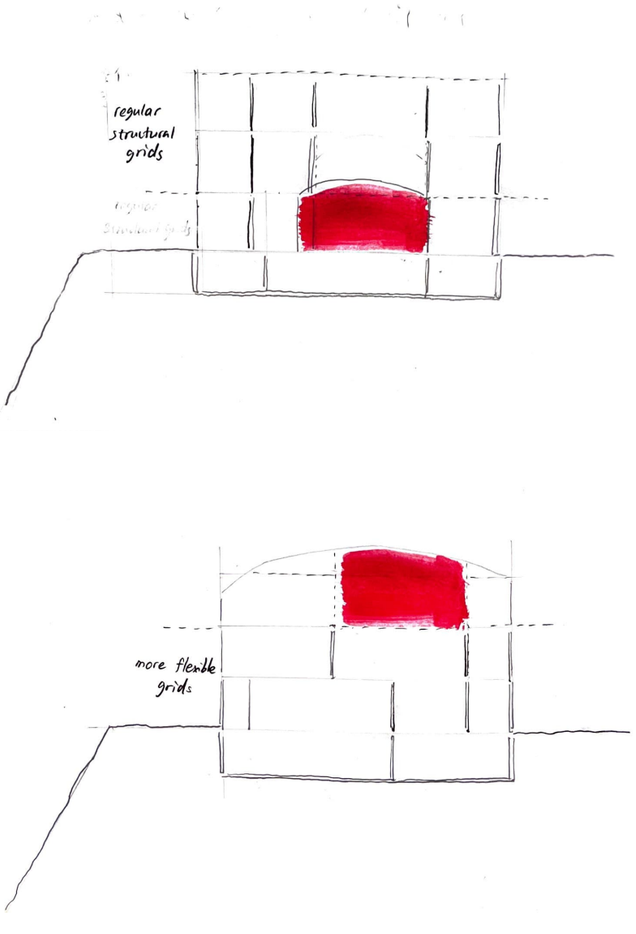




- Labs
- Public spaces
- Care facilities
- Write-up spaces
- Gardens

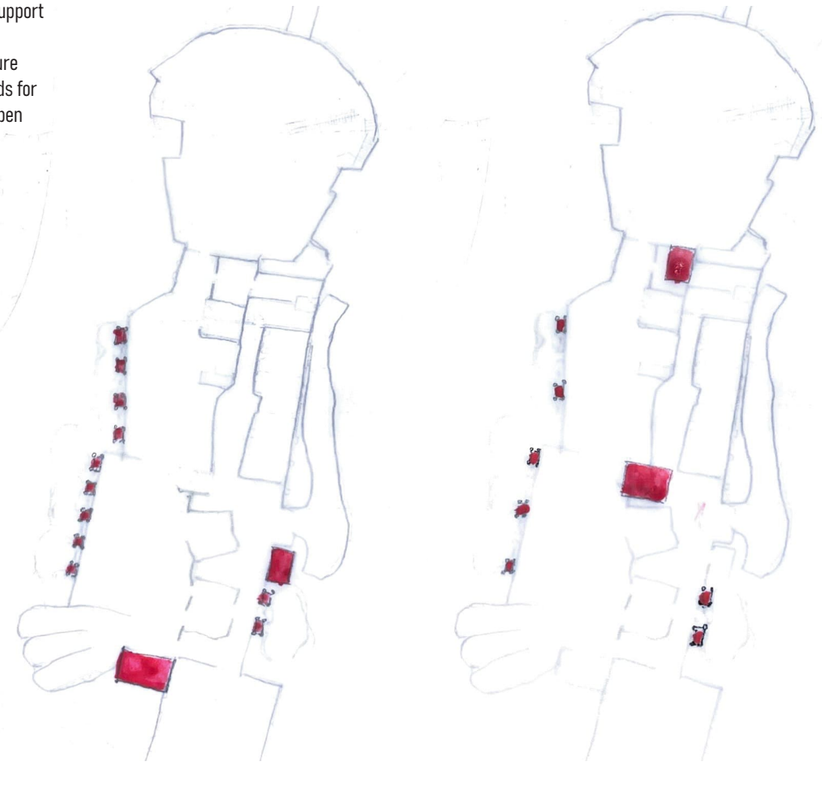
Long-span open spaces

If large-span spaces are on the ground floor, they can be more accessible to the general public, but the upper floors must adopt more regular structural grids.
If large span spaces are put on upper floors, there're fewer limitations of structural grids on the lower floors, but they are less accessible to the public.

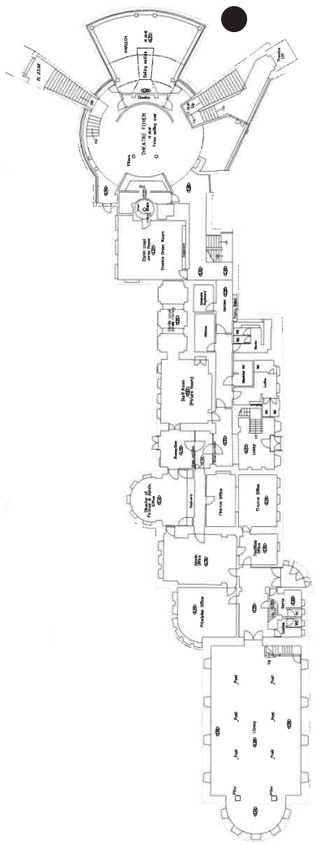


Lift core positions

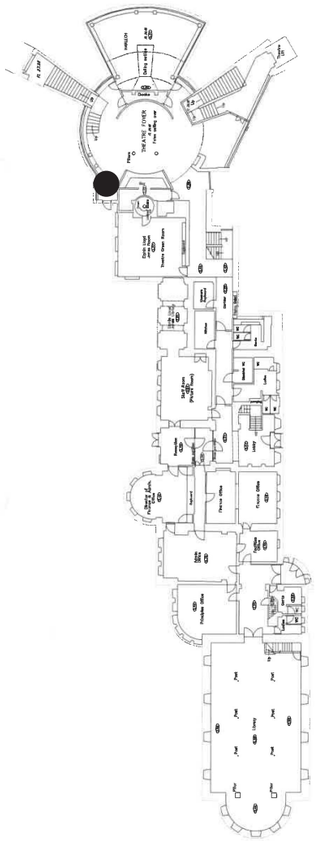
Lift cores put outside of main structures free up more open spaces but require more support structures on the perimeter.
Lift cores put in the middle of the structure helps with stability and reduces the needs for perimeter structures, but enables less open space.



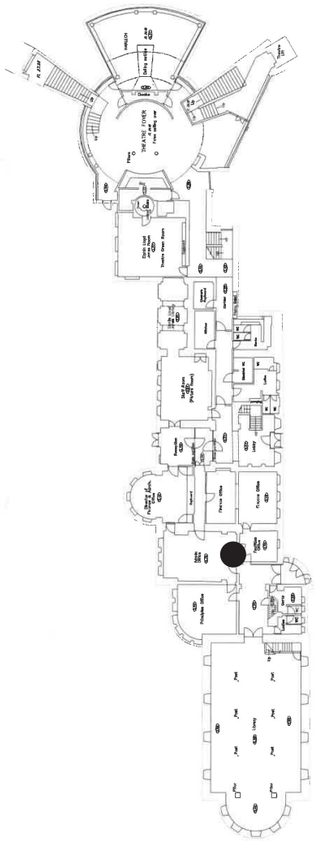
Spacial Organization



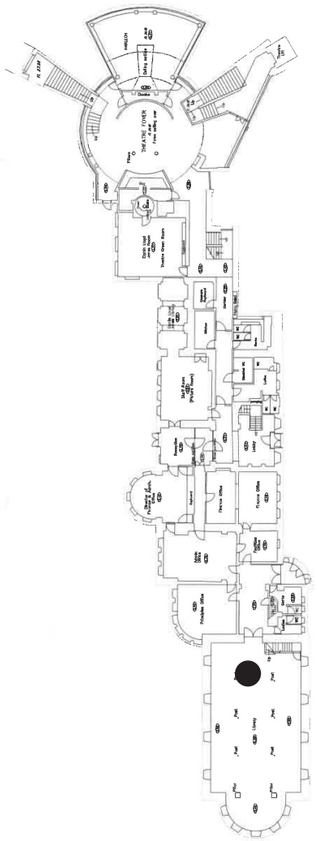
Adaptive Reuse



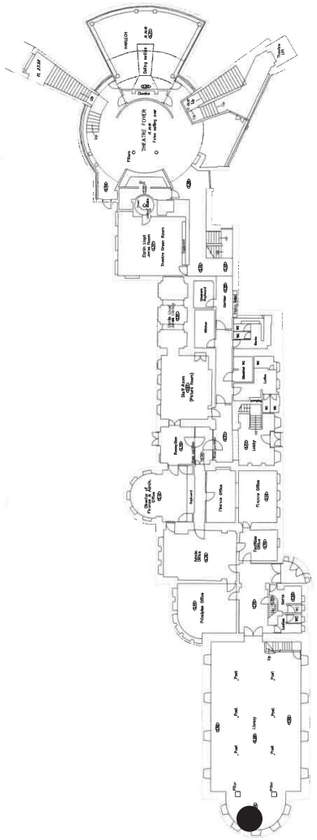
Adaptive Reuse



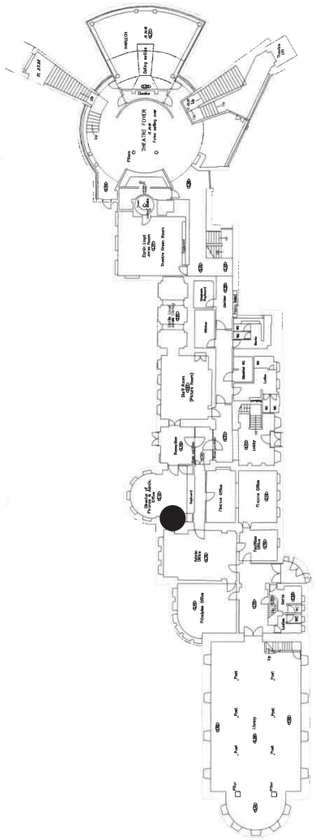
Adaptive Reuse



Adaptive Reuse



Adaptive Reuse



Adaptive Reuse

Stage 1: demolation

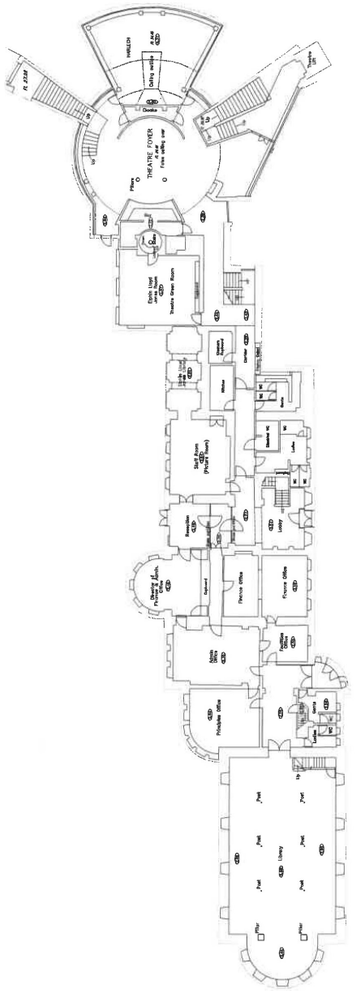
2 years

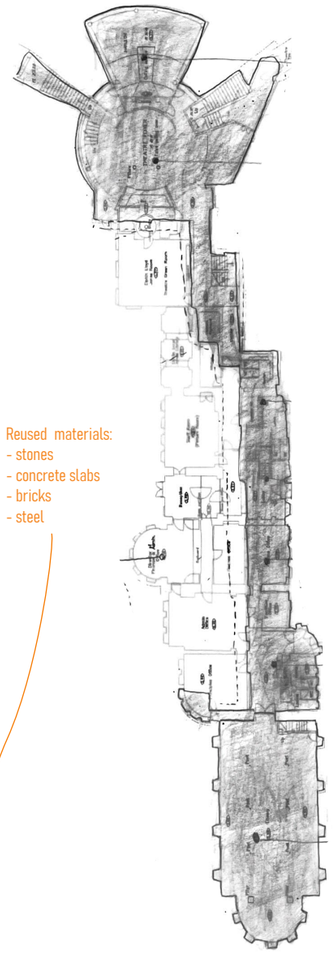
Stage 2: preservation of existing sructures and construction of research facilities

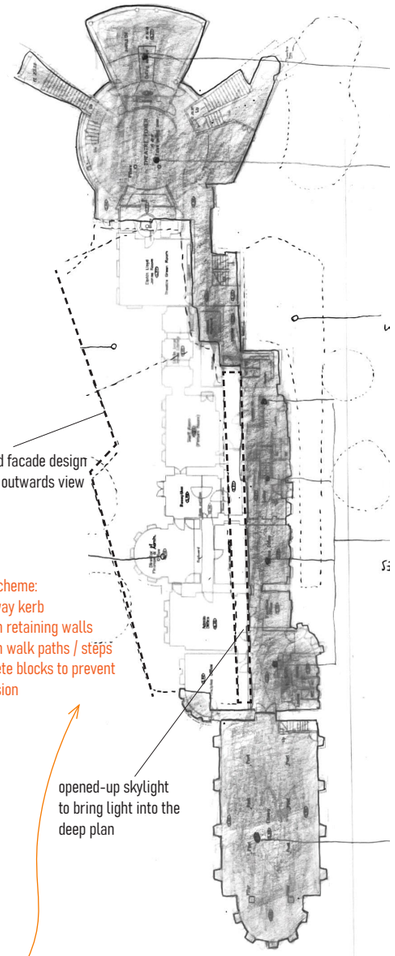
5 years

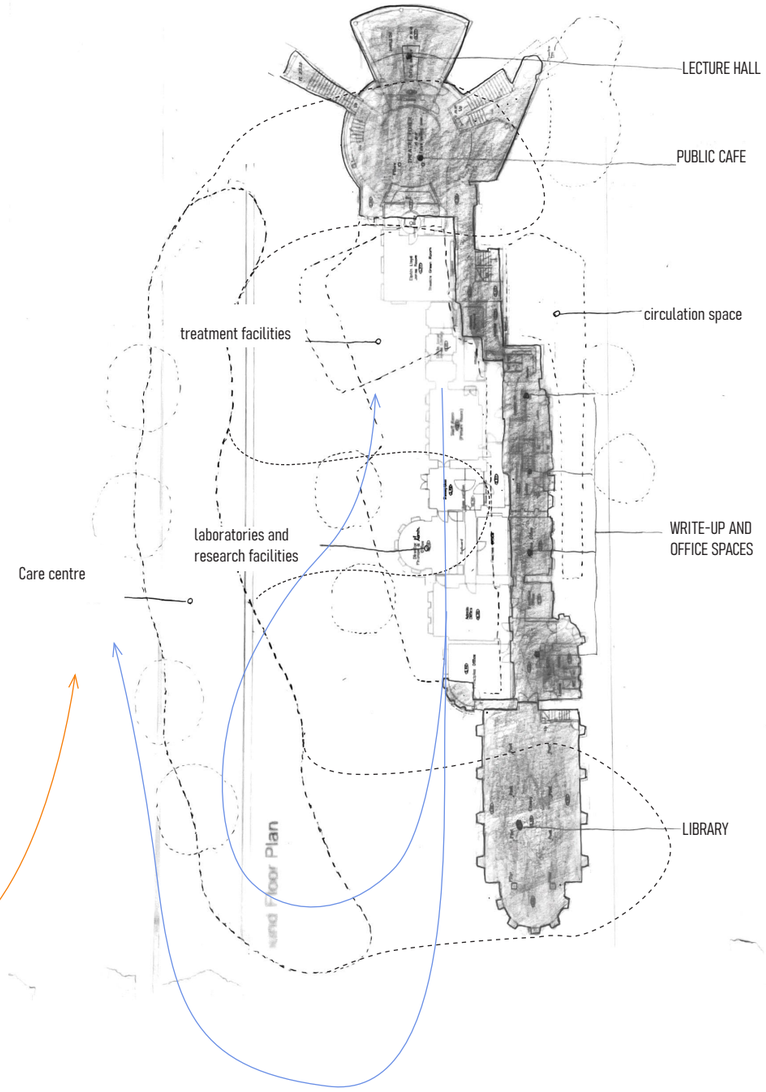
Stage 3: growth of modular care facilities around the cliff

10 years









Reused materials:
- stones
- concrete slabs
- bricks
- steel

plan layout and facade design that maximise outwards view and daylight

Reuse scheme:
- driveway kerb
- garden retaining walls
- garden walk paths / steps
- concrete blocks to prevent sea erosion
...

opened-up skylight to bring light into the deep plan

Reuse of medical/chemical waste in labs:
- plastic can be upcycled into a wide range of products including wall panels, lamps, and facade materials.

- Maximally preserve existing structures
- Using old parts as write-up and office spaces, which have less stringent design requirements, and new parts as laboratories
- Opening up skylight to bring daylight into Eastern spaces
- Maximizing views and daylight from the West
- Creating connections between labs

Recycling and waste treatment

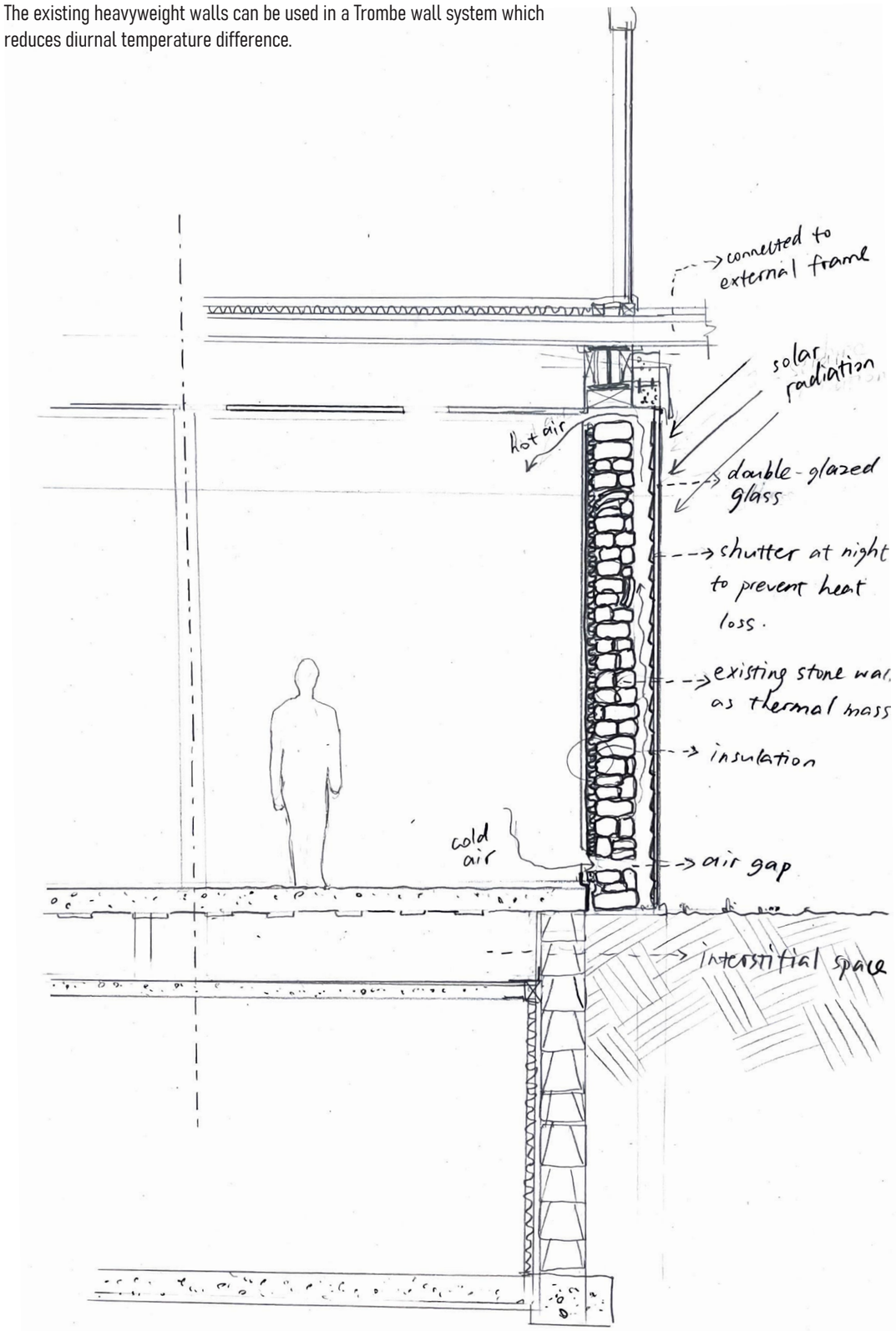
N

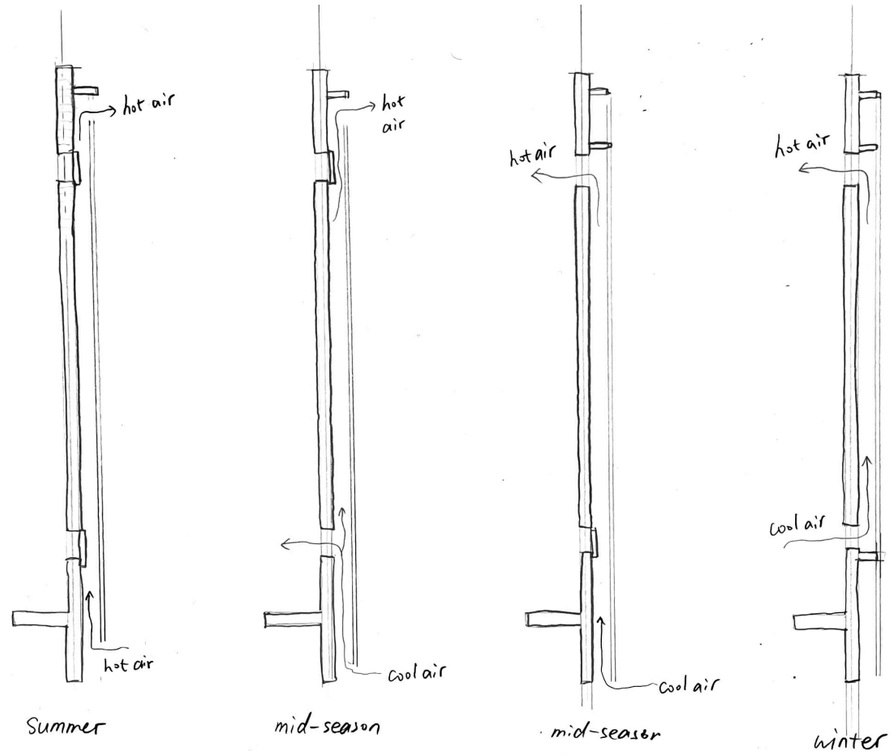
Preserved structures

New spaces

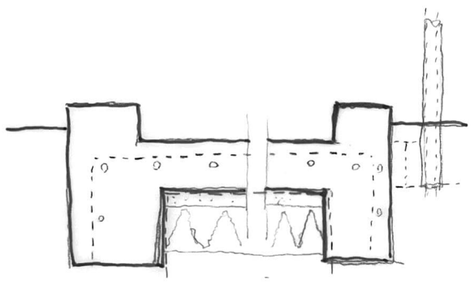
Adaptive Reuse

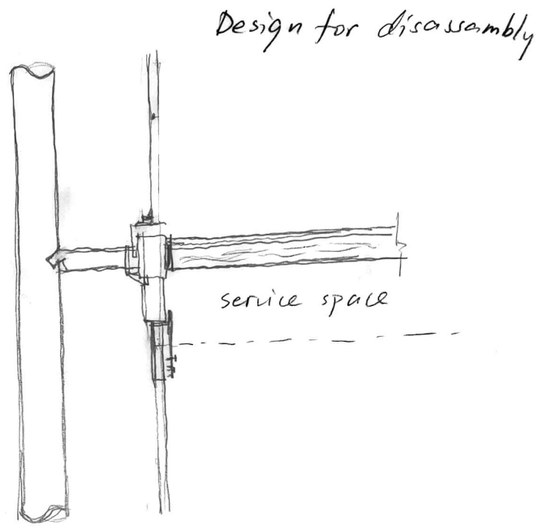
The existing heavyweight walls can be used in a Trombe wall system which reduces diurnal temperature difference.





Operation of Trombe wall in different seasons.



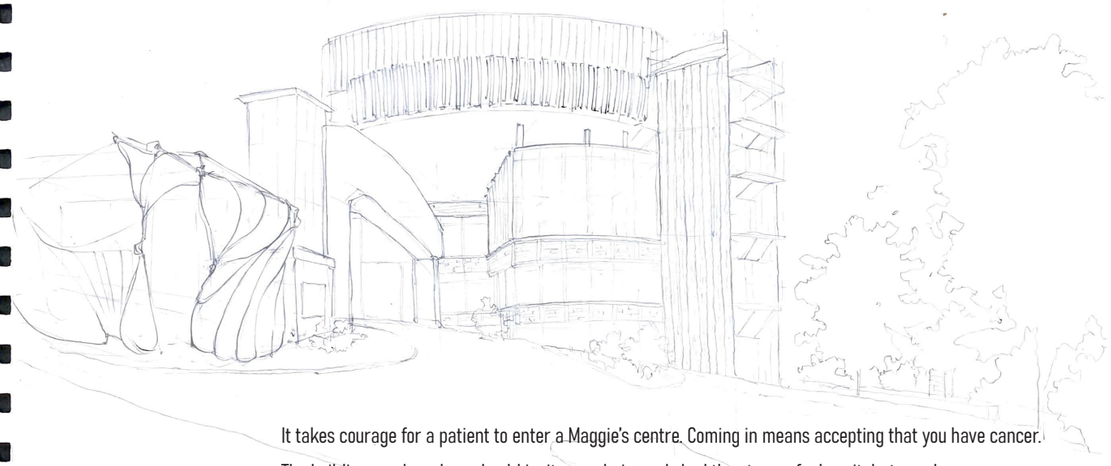


Detail sketches

Adaptive Reuse

Creating actual connecticity horizontally and verti-
cally, in corners, stairs, corridors, and gardens. .

Connection of spaces



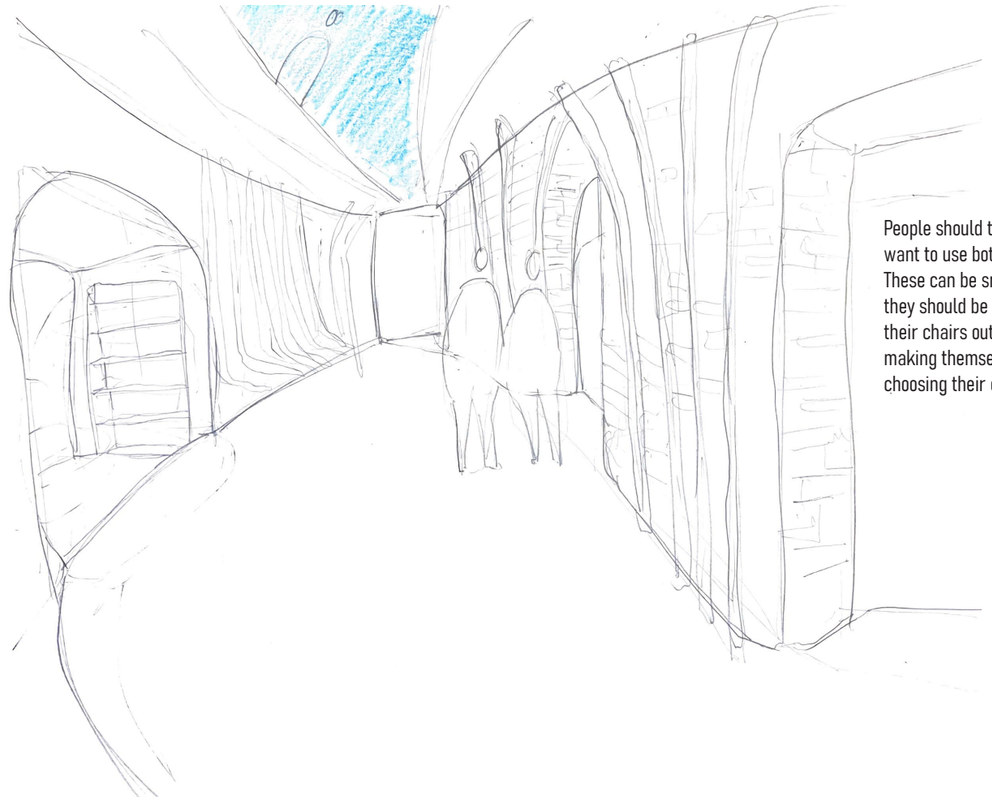
It takes courage for a patient to enter a Maggie's centre. Coming in means accepting that you have cancer.

The buildings and gardens should invite people in, and shed the stress of a hospital atmosphere.

'That must be the Maggie's centre they are talking about, the bright red building!'

Distress paralyses people, tempts them to withdraw, to curl up, to lock themselves in. We want people to be shetered, but also be connected to the outside world.

The kitchen should be the main hub of the building. People should be comfortable with moving around things.

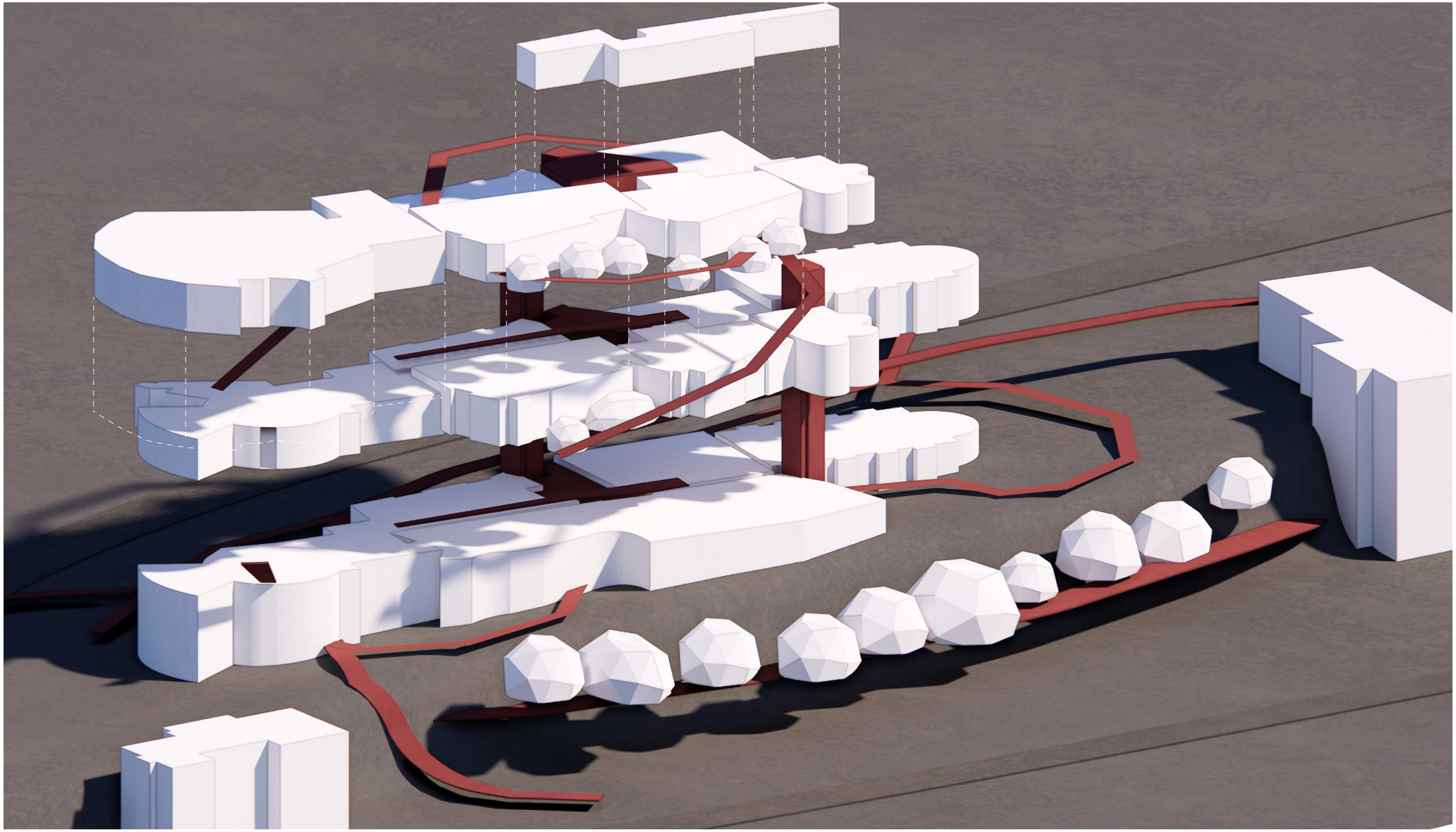


People should take charge of how they want to use both public and private spaces. These can be small things. For example they should be comfortable with moving their chairs outside when it's warm. Or making themselves tea in the kitchen. Or choosing their cushions.

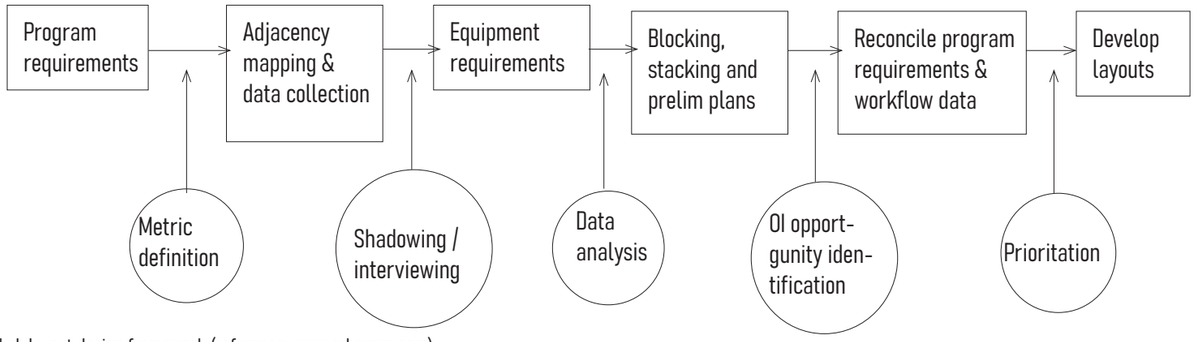
Connection of spaces

A light-filled, joyful, green, and vibrant space for es-
earchers, local residents and patients to use together.

Connection of spaces



Connection of spaces



Lab layout design framework (reference: www.crbgroup.com)

Wet labs and dry labs: biosafety standards & vibration control

Web labs have intense design requirements for live cultures, contamination reduction, sterilization, and vibration reduction. Dry labs have intense energy usage and high internal heat gains, and requires emergency power, proper air supply, humidity levels and exhaust. Wet labs and dry labs have fundamentally different purposes and design considerations, but they have become more interconnected, and can be adpated between them if planned properly. Wet lab space which requires regular delivery of cell culture materials, and experimental equipment should be easily transported to research and testing facilities (level ground, not too many doors, no card tapping). Dry lab space should allow easy access of large testing equipment and robotics.

Segregating lab flows

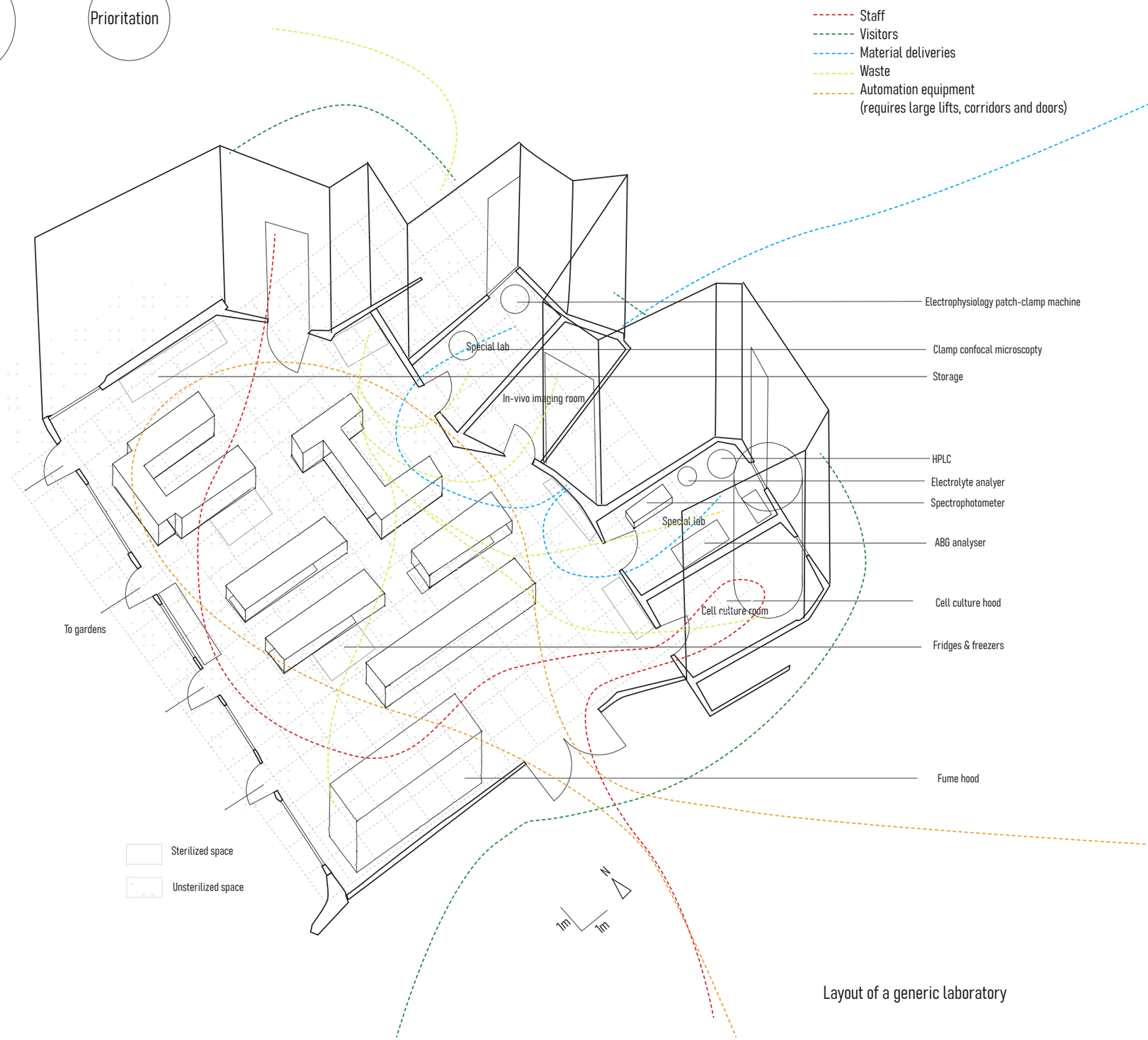
To reduce the risk of cross-contamination, lab layouts should be designed to separate materials by type, and should reduce traffic in areas containing materials that could easily be transferred to other parts of the facility. Also, the layouts should encourage the interations between researchers and allow them to share and communicate easily.

Studio-like benches / hot benches

'Hot benches' allow people to flexibly use spaces, but are sometimes not ideal for researchers who need fixed storage for experiment samples and who wich to have their own spaces. The design for a mixture of studios, hot benches, office-like write up spaces should prioritize the needs of researchers, who need both independent spaces and constant interations with others.

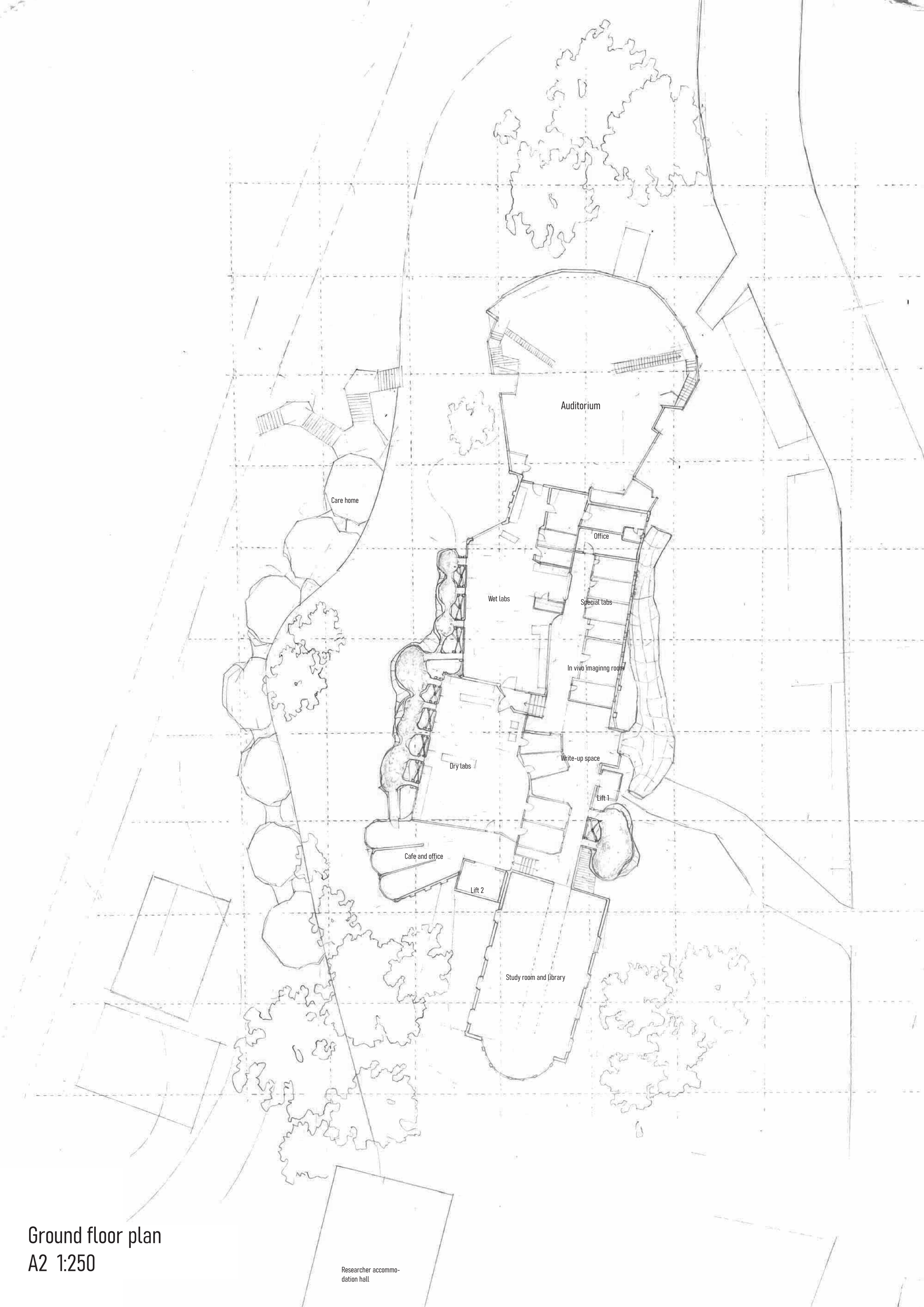
Modular pocket labs built with reused materials

Flexible add-on modular labs can be built with waste materials in research and experiments such as plastic. These labs are raised above floor planes, so that pneumatic isolaters can be installed underneath to control vibration.



Layout of a generic laboratory

Rethinking lab layout

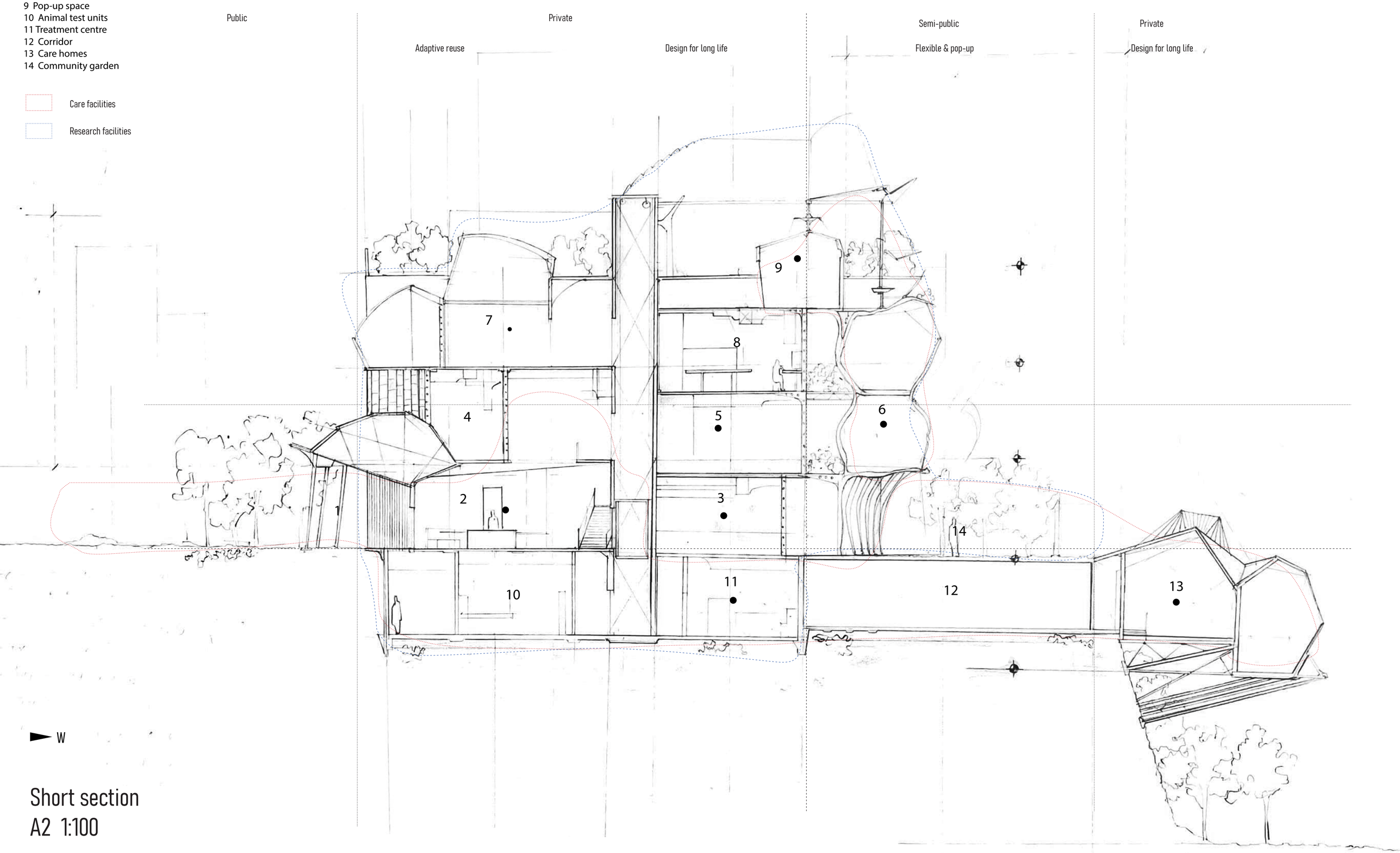


Ground floor plan
A2 1:250

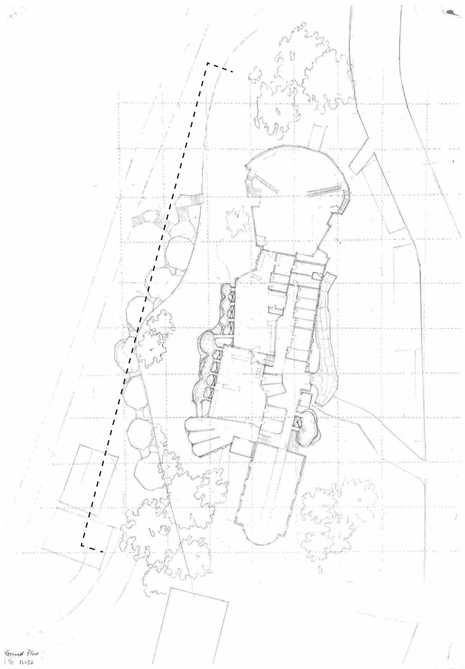
1 Entrance
2 Community kitchen
3 Healthcare facilities
4 Special function labs
5 Write-up space
6 Pop-up garden
7 General lab
8 General lab
9 Pop-up space
10 Animal test units
11 Treatment centre
12 Corridor
13 Care homes
14 Community garden

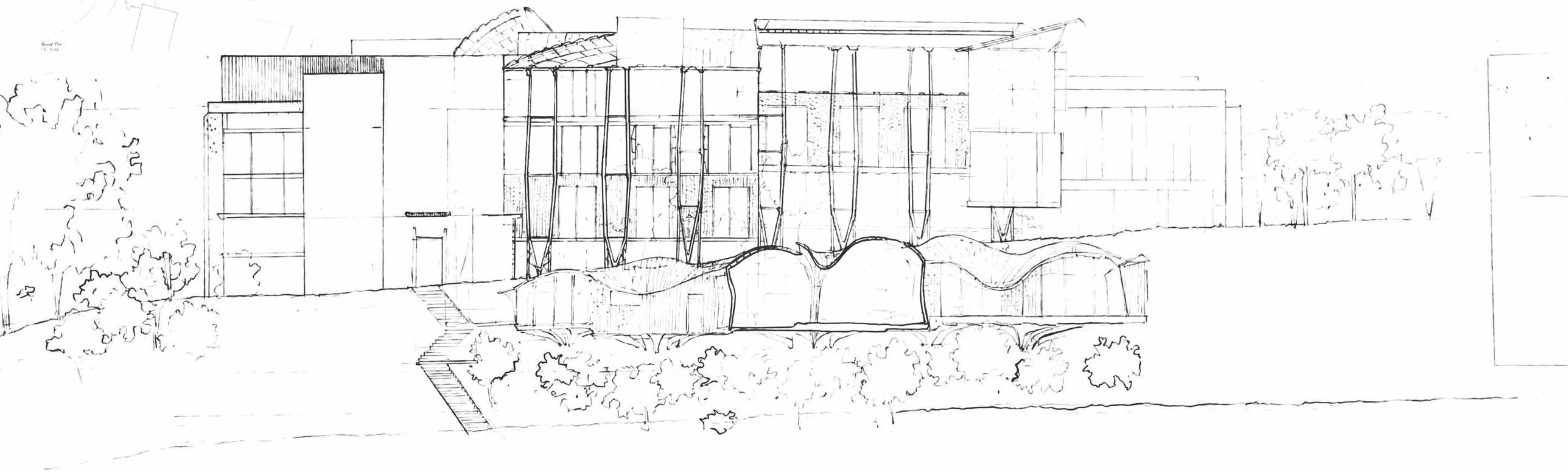
Care facilities

Research facilities



Short section
A2 1:100



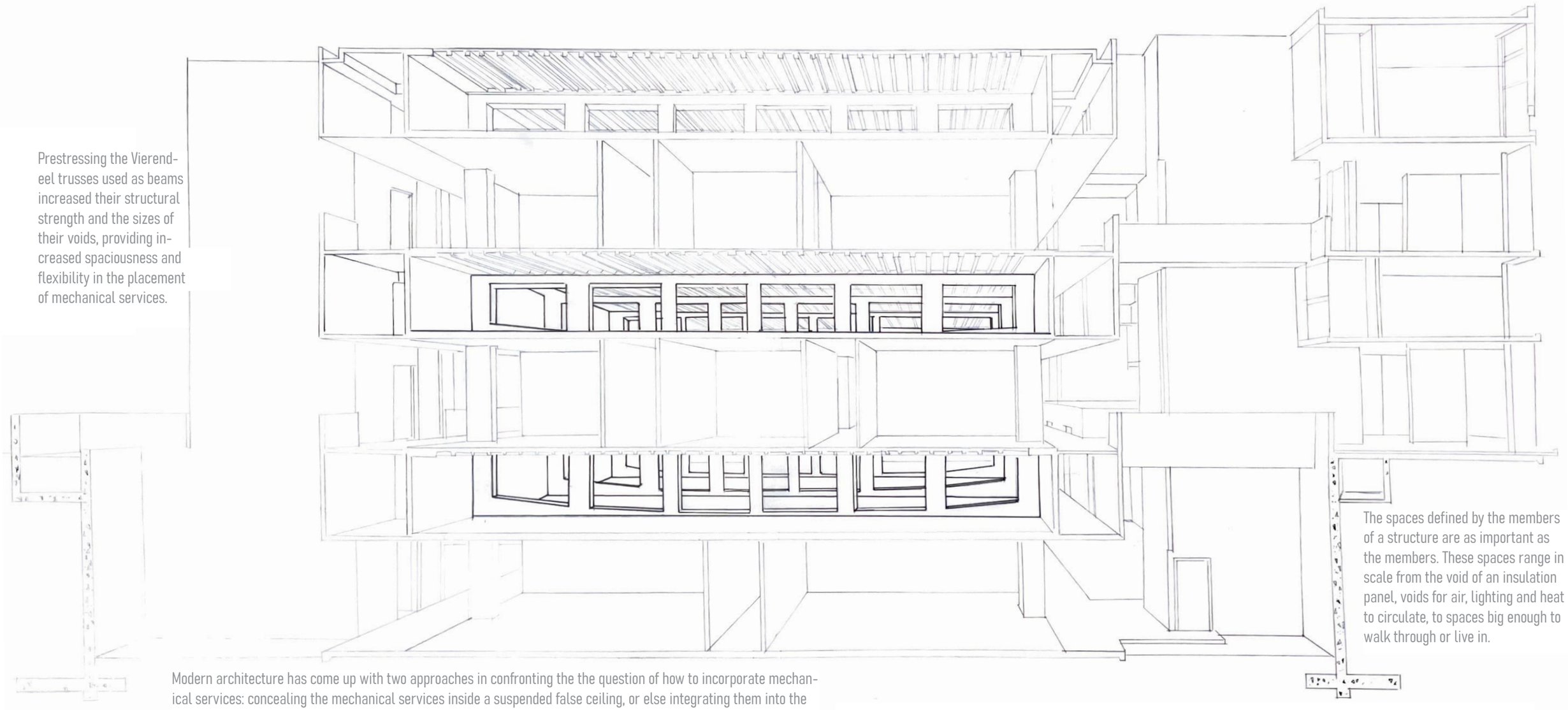


West elevation
A2 1:250

3

Interstitial Spaces

The notion of interstitial space comes primarily from biology and medicine, where it describes the space and fluid surrounding the cells of a tissue. In architecture, interstitial spaces are those that neither fall inside any room, nor are outside the building — the gaps between floors and inside walls. Though we do not inhabit them, they can be integral to a building's function. Entire accessible interstitial levels can be built in to accommodate the plumbing, electricity and mechanical systems of a building, particularly in hospitals, where flexible floor plans and accessible services minimise disruption. More recently, architects have used the term to describe spaces at the margins of built environments. This might mean a sharp delineation between building and natural landscape, or a blurred ground where inside meets outside, a transitional space that can profoundly affect our experience of the site. A covered porch provides a place to sit that is sheltered yet outside; a retractable wall of glass confuses the division between in and out.



Prestressing the Vierendeel trusses used as beams increased their structural strength and the sizes of their voids, providing increased spaciousness and flexibility in the placement of mechanical services.

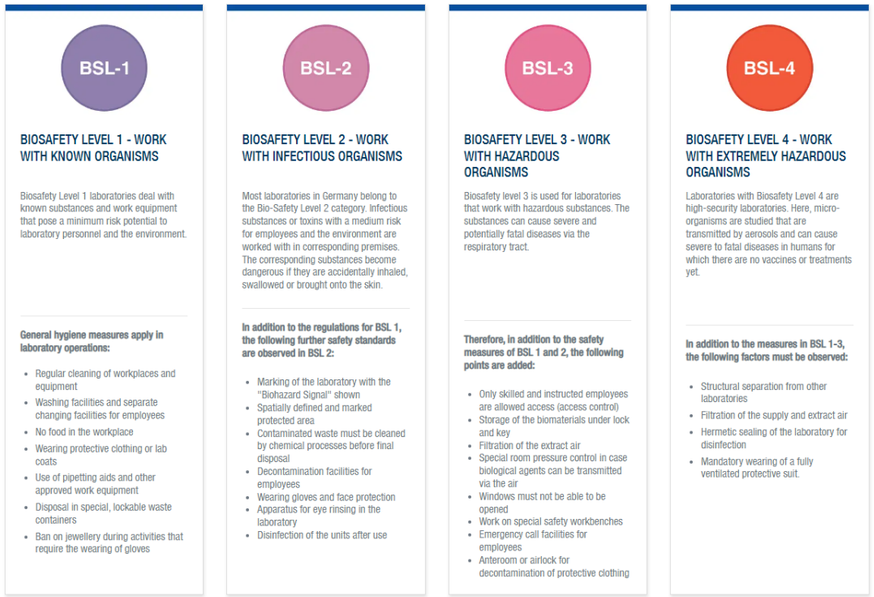
The spaces defined by the members of a structure are as important as the members. These spaces range in scale from the void of an insulation panel, voids for air, lighting and heat to circulate, to spaces big enough to walk through or live in.

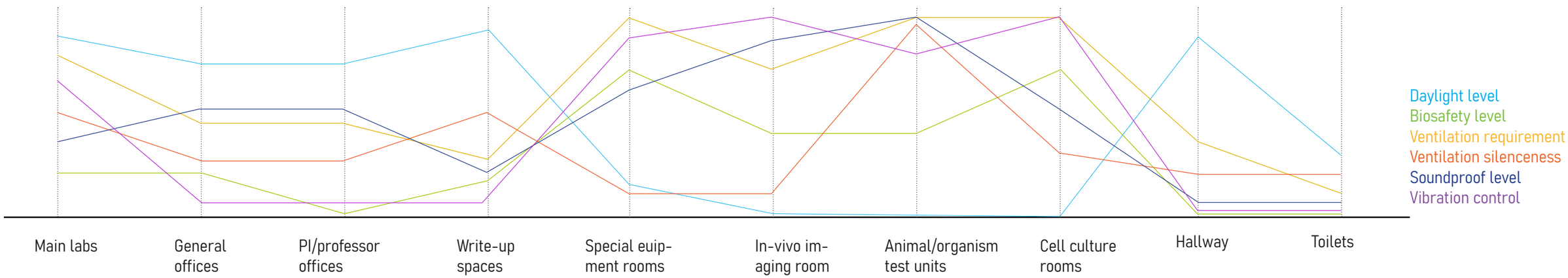
Modern architecture has come up with two approaches in confronting the the question of how to incorporate mechanical services: concealing the mechanical services inside a suspended false ceiling, or else integrating them into the structural design of the building.

Considering the inherent difference between experimentation and research, lab rooms are located in the darker area at the centre of the complex, and the research rooms in the brighter areas on the periphery. Research rooms do not require large amounts of service space for mechanical services, so Louis Kahn separated the research rooms from the labs, locating the former in an independent structure whose height is staggered half a floor in relation to the main building. Such a spatial relationship helps the scientist make a mental shift when moving from experimentation to texual research and writing, and also provides an external sun block for the labs.

Salk Institute of Biological Studies, Louis Kahn

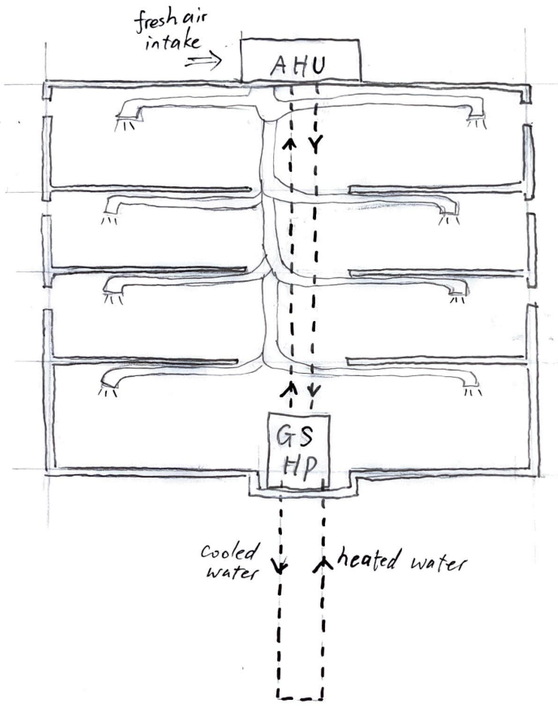
	Key facilities	Daylight requirement	Ceiling heights	HVAC requirement
Main Labs	lab benches, lots of fridges (very important)	High	Normal	High
General Offices	Spectrophotometer, Electrophoresis, Immunoassay autoanalyser, ABG analyser, Electrolyte analyer, HPLC, Autoanalyzer, Nephelometer	High	Normal	High
PI /professor Offices	Desks, Laptops, Office facilities	High	Normal	Medium
Write-up Spaces	Desks, Communal study spaces, Laptops	High	Normal	Medium
Special Equipment Room	Clamp confocal microscopty	Darkness	High	Very high
Special Equipment Room	Electrophysiology patch-clamp machine	Darkness	High	Very high
In-vivo Imaging Room	surgical benches	Darkness	Normal	High
Animal Research Unit	Away from the main building and should be underground	Darkness	High	Very high
Organism Testing Room		Complete darkness	Normal	Very high
Cell Culture Rooms	Cell culture machines (very big)	Darkness	High	Very high
Hallway	Storage, sofa, desks	High	High	Medium
Toilets	light food, cafe machines, tables	High	Normal	Medium





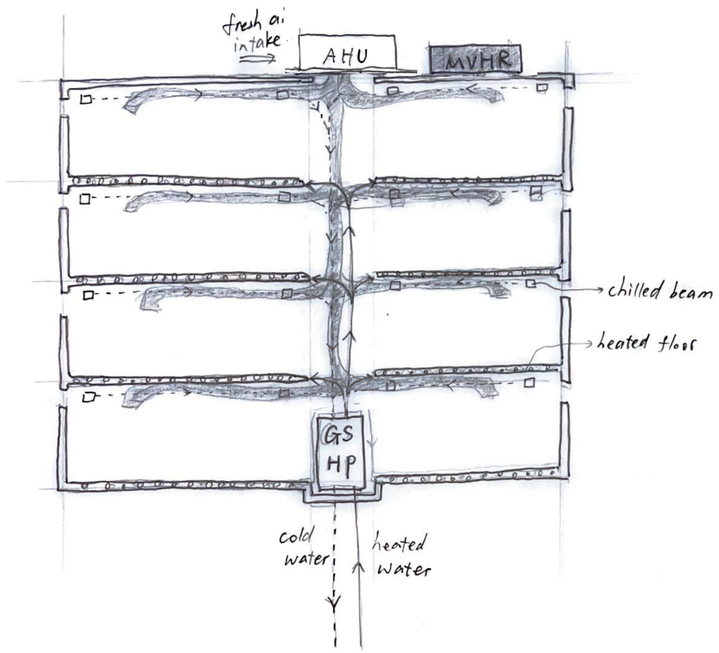
Environmental requirements

Achiving high energy efficiency and adapability of increasing ventilation capacities for new spaces , additional fume hoods, and robotics.



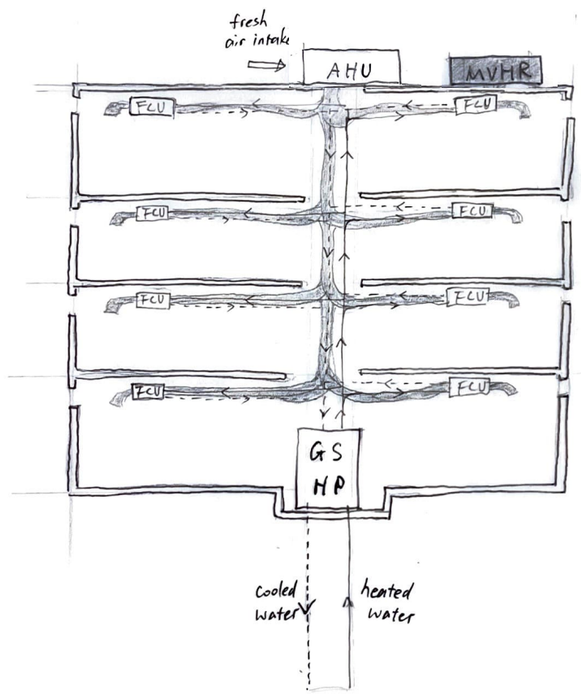
GSHP with AHU (VAV)

- Poorer energy efficiency
- Little flexibility of increasing ventilation capability for new spaces
- Electricity of heat pumps can be provided by nuclear batteries



MVHR combined with heated floors and chilled beams

- High energy efficiency
- Less flexibility of increasing ventilation capability for new spaces
- Long duct runs, more pressure drop
- Not very suitable for labs as it has a very slow response time as underfloor heating responds slowly
- Chilled beams can't deal with very high cooling demand



MVHR and FCUs / ERVs

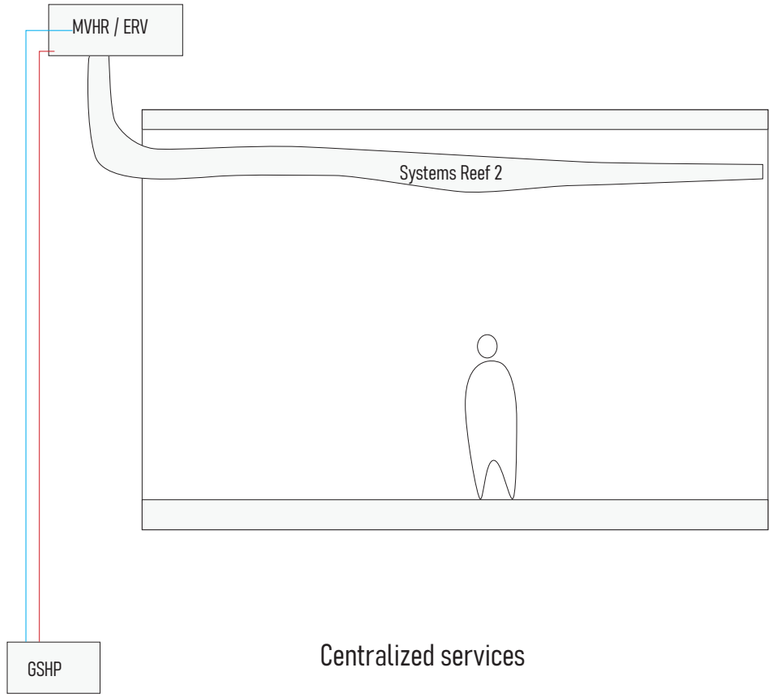
- Good energy efficiency
- More discentralized, which provides better flexibility
- Shorter duct runs
- Electricity of the heat pumps can be provided by nuclear batteries
- Nuclear batteries may also assist the provision of heated water when GSHPs are not sufficient

Interstitial spaces and MEP

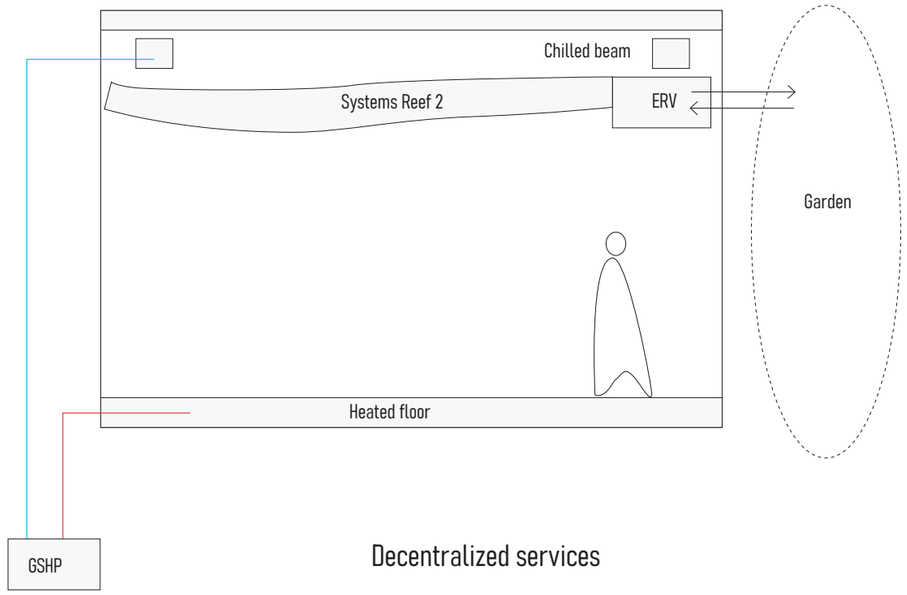
Large buildings with centralized ventilation systems require long duct runs to deliver air to occupied spaces. Ductwork resistance to airflow increases with duct length, causing AHU fans to work harder and consume more energy. Centralized systems may also be designed to operate at lower cost by taking advantage of diversity – knowledge that not all of the building needs maximum heating, cooling or ventilation at the same time.

In this decentralized systems fans aren't working to overcome duct pressure, thus energy is saved. With only short duct runs, decentralized ventilation systems overcome the risk of leaking duct systems. More envelope penetrations are also required, which might affect the airghtightness of building fabrics.

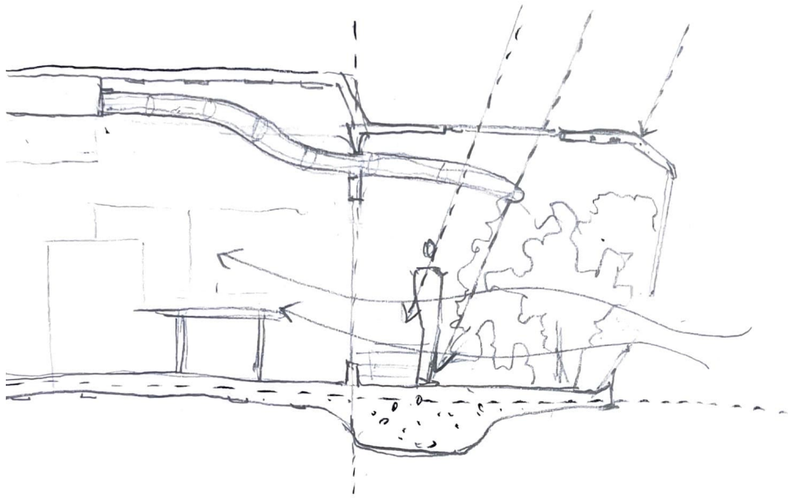
A combination of centralized and decentralized designs is in general more ideal.



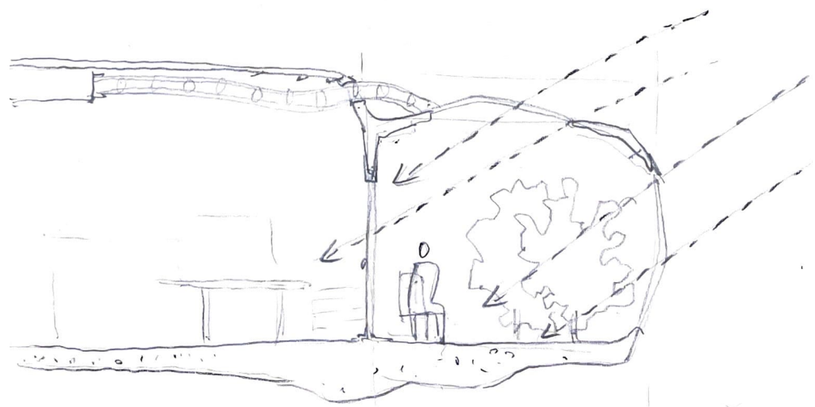
Centralized services



Decentralized services

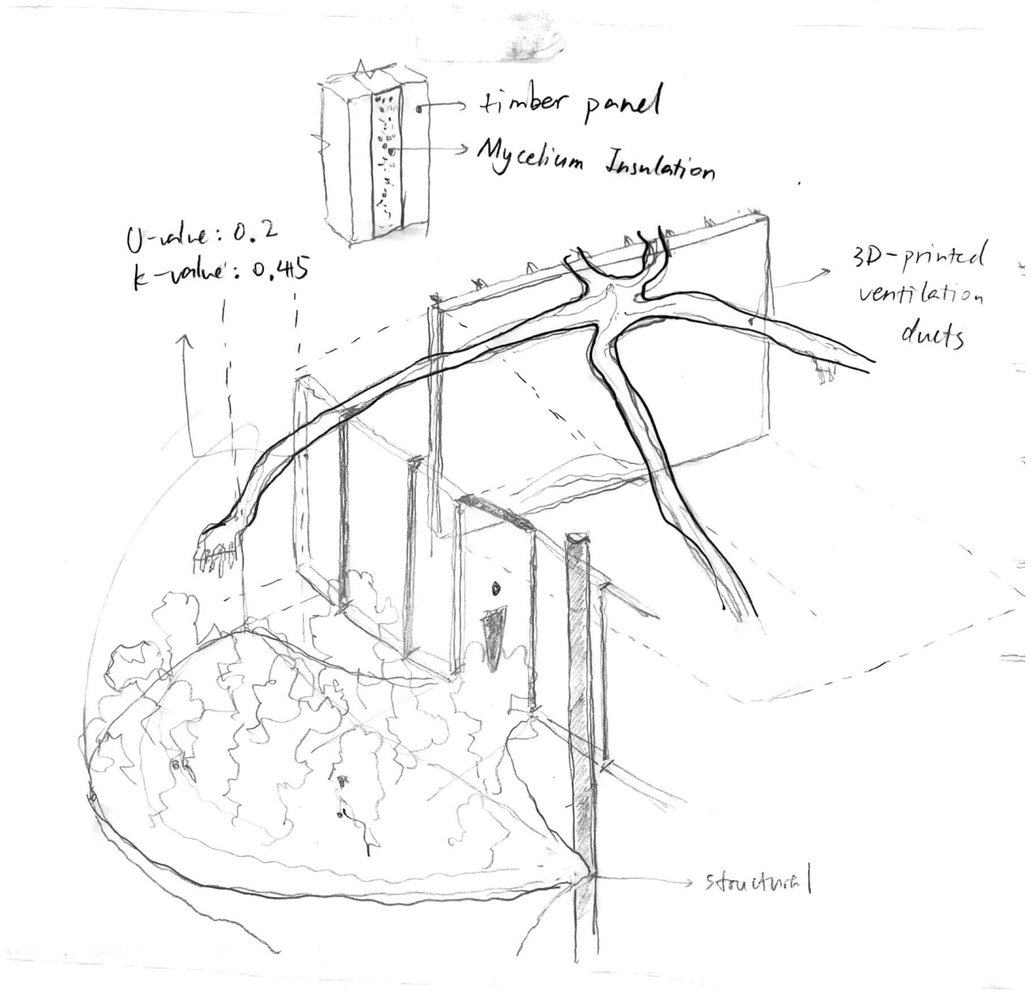


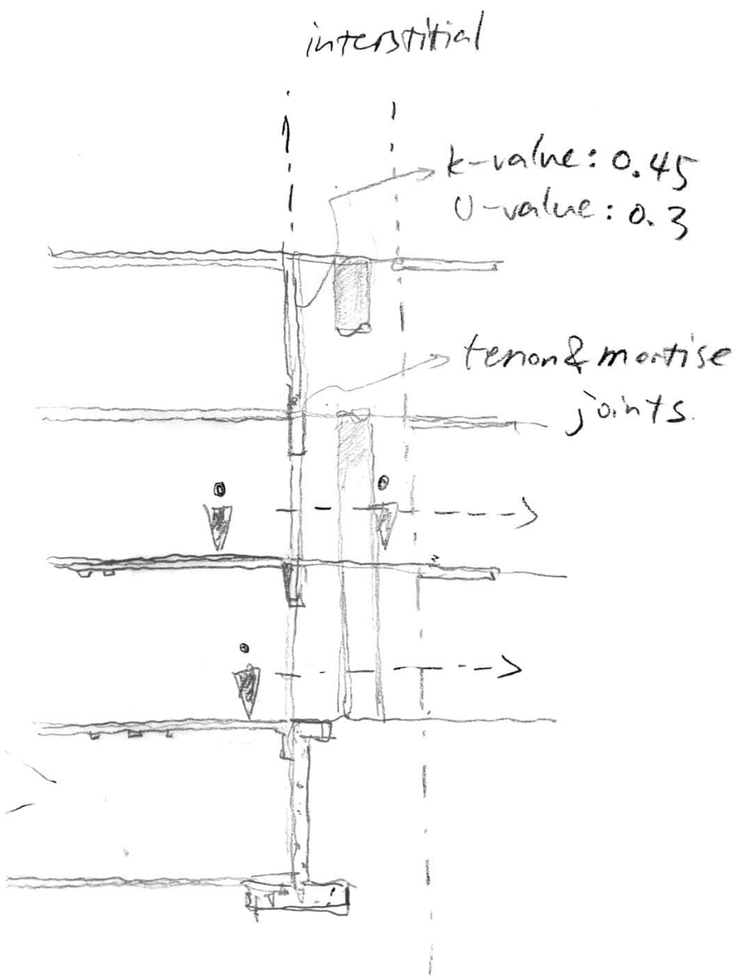
Summer + natural vent



Winter + solar gain

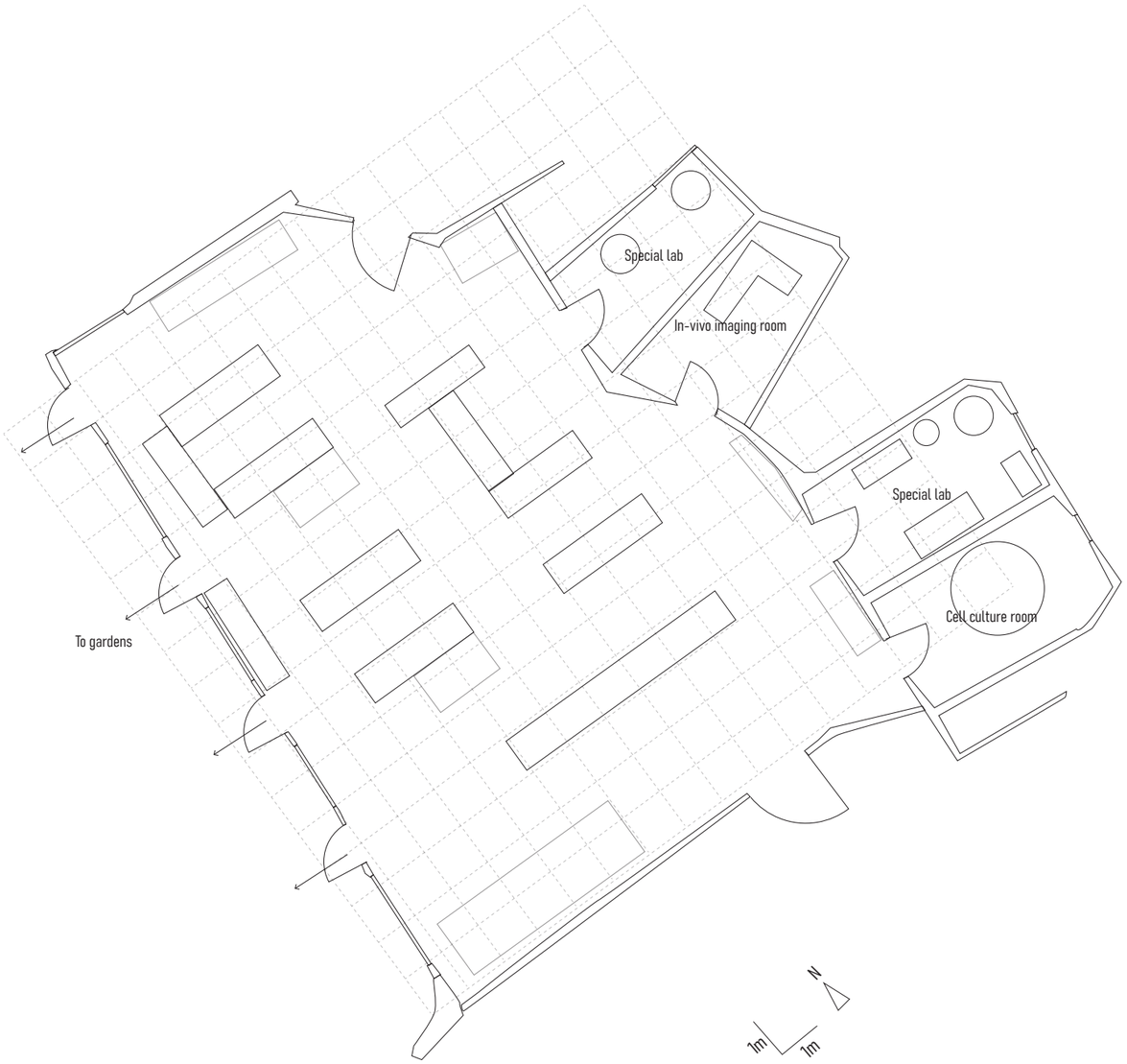
Interstitial spaces and MEP





Interstitial spaces and MEP

- a generic lab space
- investigating heating loads of labs and factors that influence them
- The data for HDD(heating design day) is generated through: https://www.degreedays.net



Degree-day analysis for heating seasons

				unit	Reference
		Floor area	258.7	m2	
		Usable height	4.2	m	
	Internal design temperature		21	oC	
	External design conditions		6	oC	CIBSE Guide A, chapter 2,
	Average outdoor temp		6	oC	'External Design Conditions'

Internal heat gain

Metabolic gain	person	Sensible heat emission (W)			
	20	116	2320	W	CIBSE Guide A, Table 6.3, light bench work
Lighting gain	Floor area (m2)	intensity (W/m2)			
	258.7	10	2587	W	
		intensity (W/m2)			
Equipment gain		10	2587	W	
Solar gain	Assume low g values for west-facing windows		0	W	
			7494	W	

Transmission heat loss

	U value (W/m2K)	Area (m2)	UA (W/K)	
Floor	0.22	258.7	56.914	
Roof	0.18	258.7	46.566	
Walls	0.26	162.8	42.32436	
Windows	0.8	86.8	69.45536	
Doors	1.5	21.7	32.5572	
Fabric heat loss			247.81692	W/K

Ventilation heat loss

Infiltration rate	0.25		
Ventilation rate	10		
0.33*ACH*Volume*(T_ext-T_int)		55128.323	W

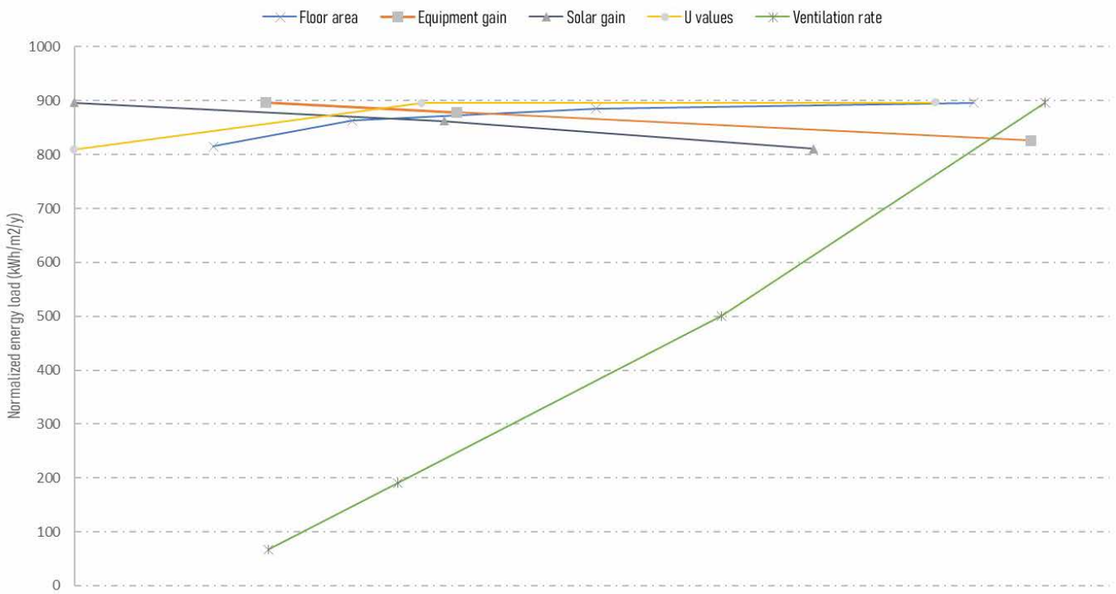
Specific heat loss

(Fabric heat loss + ventilation heat loss)/(T_int-T_ext)	3691.7427	W/oC

Heating energy use

Temperature increase of internal gain		Internal gain / S.H.L	2.0299356	oC	
Total heat loss	(T_int-(T_ext+T_gain))*S.H.L		47882.14	W	
Degree days	Oct 01 - April 31	HDD 15.5	1578.5	h	bizEE degree day generator, Harlech (PPL)
Heating effficiency			90%		
Heating energy use		Total heat loss * HDD	83979.954	kWh	
Normalized energy use	Heaing energy / floor area		324.62294	kWh/m2	

The RIBA 2030 climate change has set a 55 kWh/m2/yr target for operational energy for non-domectic buildings, and the designed space is far beyond this figure. It is explored what factor has contributed to such high energy demand.

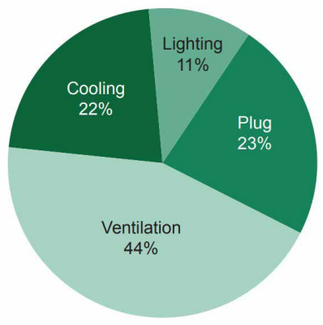


Impact of floor area, equipment gain, solar gain, U values and ventilation rate on normalized heating demand (x-axis mapped)

The graph shows that reducing floor areas, increasing internal gains or improving U values cannot significantly reduce heating energy load, and ventilation rate is the main actor in the heating demand. However, a high ventilation rate (values vary by standards, but 10ach is common) is essential in lab environment for contamination control and occupancy comfort, which means it can be very difficult to reduce the energy load to RIBA 2030 targets.

However, refining the control of ventilaion may reduce heating loads to a large degree. For example, night ventilation can be reasonably brought down to a minimum level for cell cultures, and daytime occupancy sensing controls can be designed. The incorporation of 3D printed duct systems can also reduce pressure loss in ducts when providing ventilated air.

The inherently high energy demand demonstrates the benefits of incorporating nuclear batteries for this project.



Ventilation contributes the most to annual electricity use in Louis Stokes Laboratory

'Breathing' systems for labs

Labs of any kind must be designed to meet the most stringent requirements for ventilation, biosafety and contamination prevention. Aside from these technical aspects, broader questions should also be asked to achieve real flexibility for future labs:

- Is there ventilation capacity for new spaces? Will they require additional units?
- Can the structure support additional equipment such as chemical fume hoods or biodsafety cabinets?
- Can the space meet the requirements for GMP spaces incorporated with automation, robotics and more watts per square meter of power?

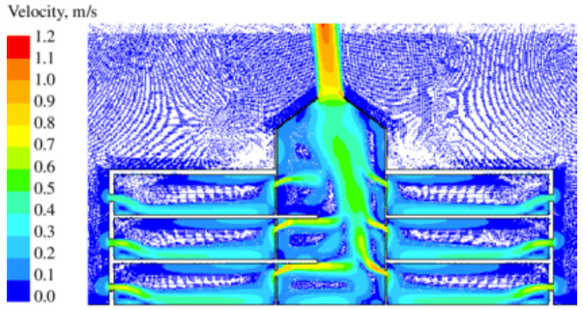
Visions for the future should be incorporated in early designs as increasing water and plumbing systems and sewer lines can be very costly. To achieve the strict environmental requirements and a reasonable level of adaptability, a 3D-printed and typologically optimised duct system developed by researchers is investigated. The advantages of it include:

Less embodied carbon
Reported 90% reduction of embodied carbon compared with traditional steel ductwork. With friction removed from the system the system can be smaller and slimmer, using overall less material;

Better operational efficiency
Achieved by optimising air flow patterns with path-finding algorithms and CFD simulations. The ducts are designed for air, removing the key source of inefficiency in existing systems: right angles, so that air flows do not need extra energy to force out when they are stuck in corners;

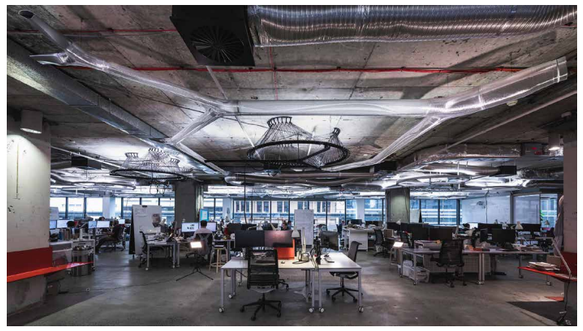
Ocupancy comfort
Air is diffused through tiny pores instead of traditional diffusers, which provide more subtle comfort. It also provides better aesthetics with its crystalline apperance, which can reduce oppressive feelings of lab ceilings ;

Flexibility
Traditional ducts are often seen as subsequent services with shapes and paths designed to avoid clashes with other types of services of structural systems. This can lead to structurally inefficient solutions which are difficult to change after installation. They are Systems Reef 2 has the potentials to achieve a high level of adapability and maintanence ease with the level of ventilation ducts being below other types of service systems.

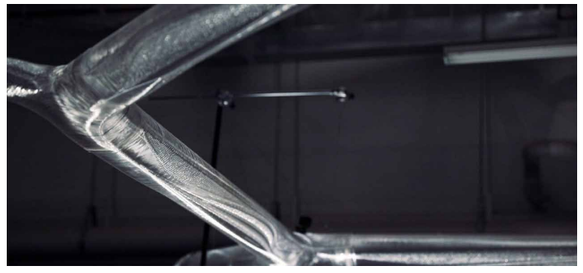


Air flow patterns of a naturally ventilated building. Air never flows in right angles, as is designed in traditional ductwork. Gan, Guohui. (2010). Interaction Between Wind and Buoyancy Effects in Natural Ventilation of Buildings. Figure 5.

Traditional ductwork designs with no aerodynamics simulations and path optimisation.

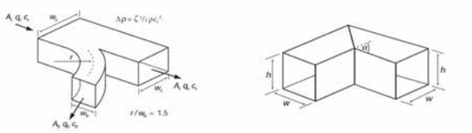


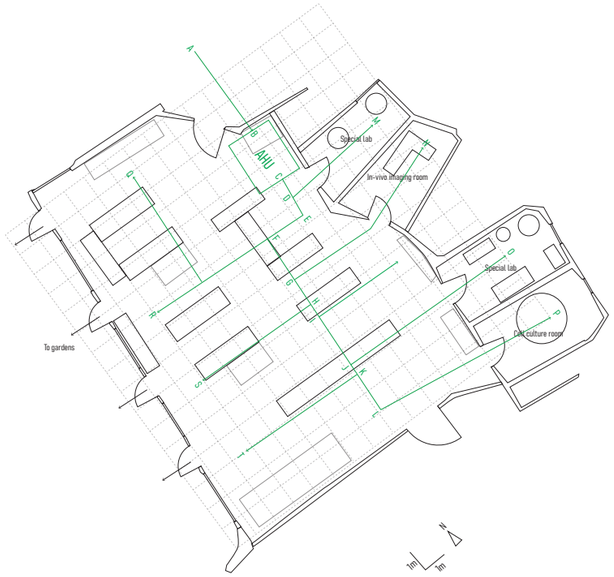
Systems Reef 2, a low-carbon and 3D printed MEP system that 'breathes' like frog skin developed by Australian architecture practice BVN and the University of Technology Sydney.



Systems Reef 2 diffuses air with tiny pores that mist fresh air into the space below, like frogs breathing through their skins. This is to increase the comfort level for people sitting under the contraption.

Duct sizing of a all 90-angle duct system. This gives roughly a 2500mm *2000mm main duct for the space, which takes up considerable service spaces.





	ID	TYPE	volume flow rate (m3/s)	delta P (Pa/m)	Length (m)	Velocity (m/s)[1]	Diameter (m)[1]	closest Rectangular ducts[2]	Refined rectangular ducts w*h[3]	Equivalent diameter (m)[4]	Refined delta P (Pa/m)	Refined velocity (m/s)	Velocity limit[5] (m/s)	Duct Loss (Pa)
ductwork runs	AB	Duct	9.97	1	3	9.8	0.87	2500*2000	2500*2000	0.934	0.63	7	9	1.89
	BG	Branch	0.32	1	8	4.8	0.29	600*450	550*450	0.33	0.65	8	5.5	5.20
	CD	Duct	9.65	1	0.4	9.5	0.85	2000*750	2000*750	0.934	0.65	8.1	9	0.26
	DM	Branch	2.7	1	1.5	8	0.65	700*500	600*600	0.661	0.95	6.9	7	1.43
	DE	Duct	6.95	1	2.5	8.1	0.66	1000*650	1000*650	0.732	0.5	3.7	6	1.25
	FR	Branch	0.23	1	8	4.4	0.26	250*225	300*300	0.33	0.4	6	3.5	3.20
	EF	Duct	6.72	1	10	7.9	0.63	600*800	600*800	0.65	0.85	7.2	7.5	8.50
	QS	Branch	5.84	1	5	7	0.55	500*500	500*500	0.551	0.35	8	3.5	1.75
	FG	Duct	0.88	1	2	6	0.43	600*400	600*400	0.44	0.95	6	7.5	1.90
	GN	Branch	4.96	1	4	9.8	0.87	900*700	900*800	0.934	0.63	8	9	2.52
	GH	Duct	0.32	1	6	4.8	0.29	300*225	300*300	0.33	0.65	4	5.5	3.90
	CD	Branch	4.64	1	3	9.5	0.85	800*750	900*800	0.934	0.65	8.1	9	1.95
	HI	Duct	2.7	1	4	8	0.65	700*500	600*600	0.661	0.95	6.9	7	3.80
	IW	Branch	1.94	1	5.2	8.1	0.66	650*550	900*500	0.732	0.5	3.7	6	2.60
	IJ	Duct	0.23	1	7	4.4	0.26	250*225	300*300	0.33	0.4	3	3.5	2.80
	JO	Branch	1.71	1	10	7.9	0.63	600*550	900*400	0.65	0.85	7.2	7.5	8.50
	JK	Duct	1.71	1	9	7	0.55	500*500	500*500	0.551	0.35	8	3.5	3.15
	KT	Branch	0	1	4	6	0.43	400*400	400*400	0.44	0.95	6	7.5	3.80
	KL	Duct	1.71	1	2	6	0.43	400*400	400*400	0.44	0.95	8	7.5	1.90
	LP	Branch	0.88	1	5	14	0.43	400*400	400*400	0.44	0.95	12	6	4.75

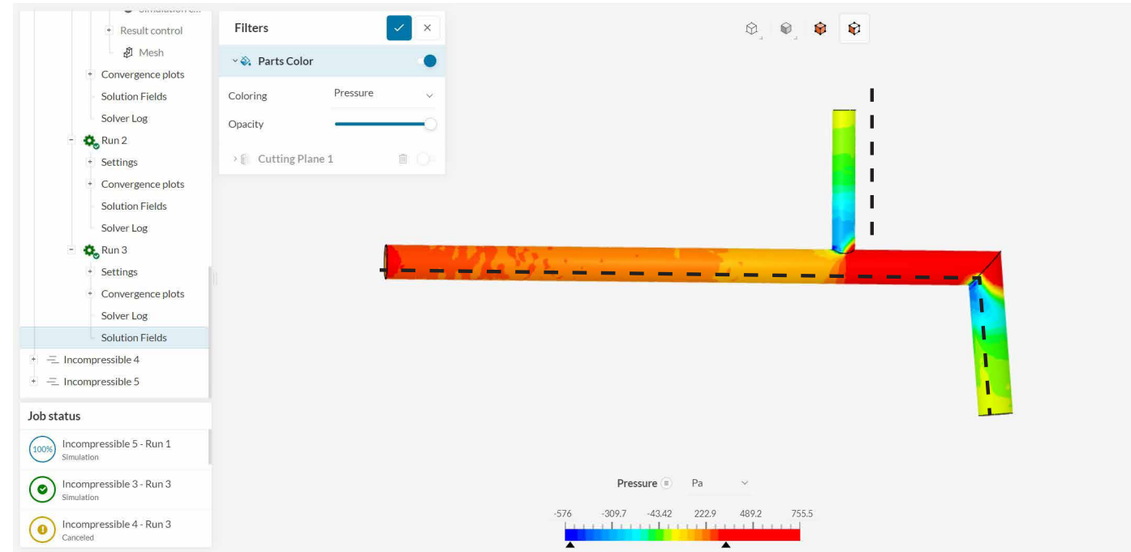
			As/Ac	Ab/Ac	qs/qc or qb/qc	Straight /branch factor[6]	Fitting loss (Pa)
ductwork fittings	B-G	90 sweep	1.00	0.12	0.03	1	38.40
	B-C	branch tree			0.97	-0.005	-0.20
	C-H	90 sweep	0.61	0.50	0.28	0.4	11.43
	C-D	branch tree			0.72	0.01	0.08
	D-I	90 sweep	0.79	0.20	0.03	3	64.80
	D-E	branch tree			0.97	0.06	1.87
	E-J	90 sweep	0.46	0.72	0.87	0.47	18.05
	E-F	branch tree			0.13	0.2	4.32
	F	elbow				1.19	102.82

			Pressure loss factor[7]	locity (m/s)	Pressure loss (Pa)
ductwork terminals	H	air diffuser	2.65	6.9	75.6999
	G	air diffuser	2.65	8	101.76
	I	air diffuser	2.65	6	57.24
	J	air diffuser	2.65	8	101.76
	K	air diffuser	2.65	12	228.96

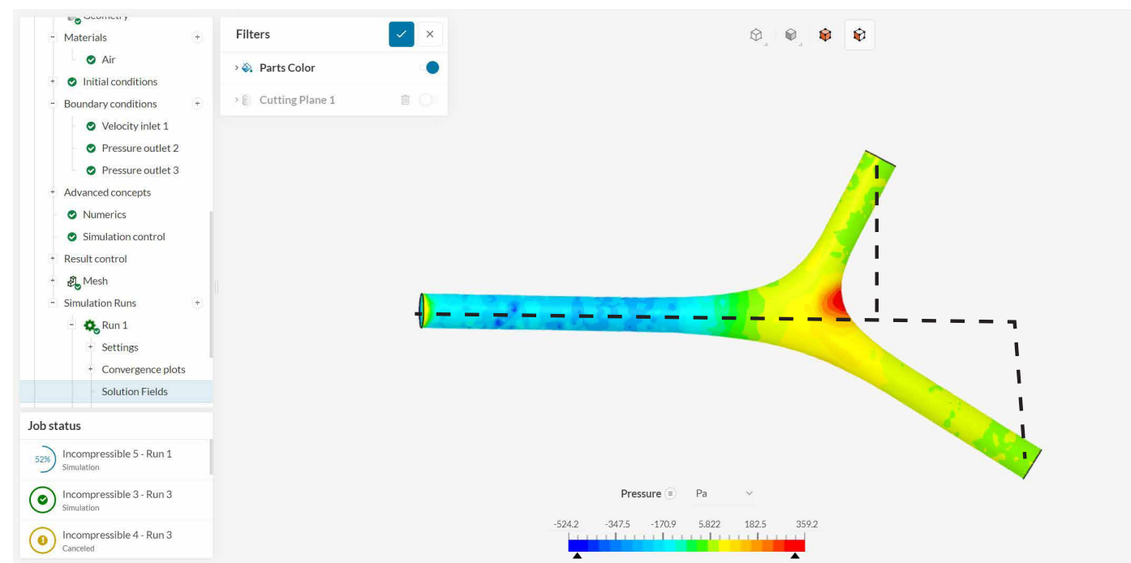
			Pressure loss factor[7]	Velocity (m/s)	length (m)	Pressure loss (Pa)
AHU		air entry	2.15	7		63.210
		AHU components				50[8]
	L-M	intake duct			1	0.63

1. CIBSE Guide C Figure 4.2
2. CIBSE Guide C Table 4.16
3. Refine the size based on maximum pressure drop of 1 Pa/m, and maximum velocity doesn't exceed limits for each space
4. CIBSE Guide C Table 4.16
5. CIBSE Guide B2 (2016) Table 3.2
6. CIBSE Guide C Table 4.124 & 4.125
7. CIBSE Guide C Table 4.103
8. Provided by brand (see Figure 6)

Index run (Pa)	
479.716	AHU to terminal P
247.298	AHU to terminal T
242.480	AHU to terminal O
261.090	AHU to terminal S
204.344	AHU to terminal N
479.716	maximum

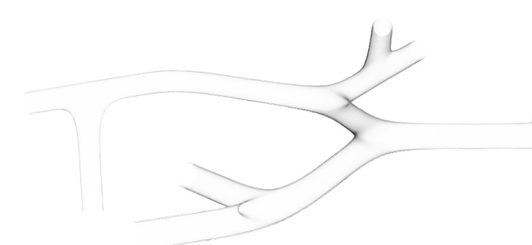


Thermodynamic pressure in traditional ducts



Thermodynamic pressure in geometrically optimised ducts

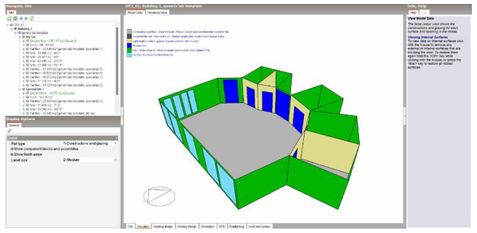
By simulation, 3D printed duct systems which optimise distribution paths can save 40% of pressure loss. In this way, air can be more efficiently delivered and duct sizes can be considerably smaller, which reduces the need for tall service spaces. Transparent ducts also reduces the overwhelming feeling of heavy ductwork.

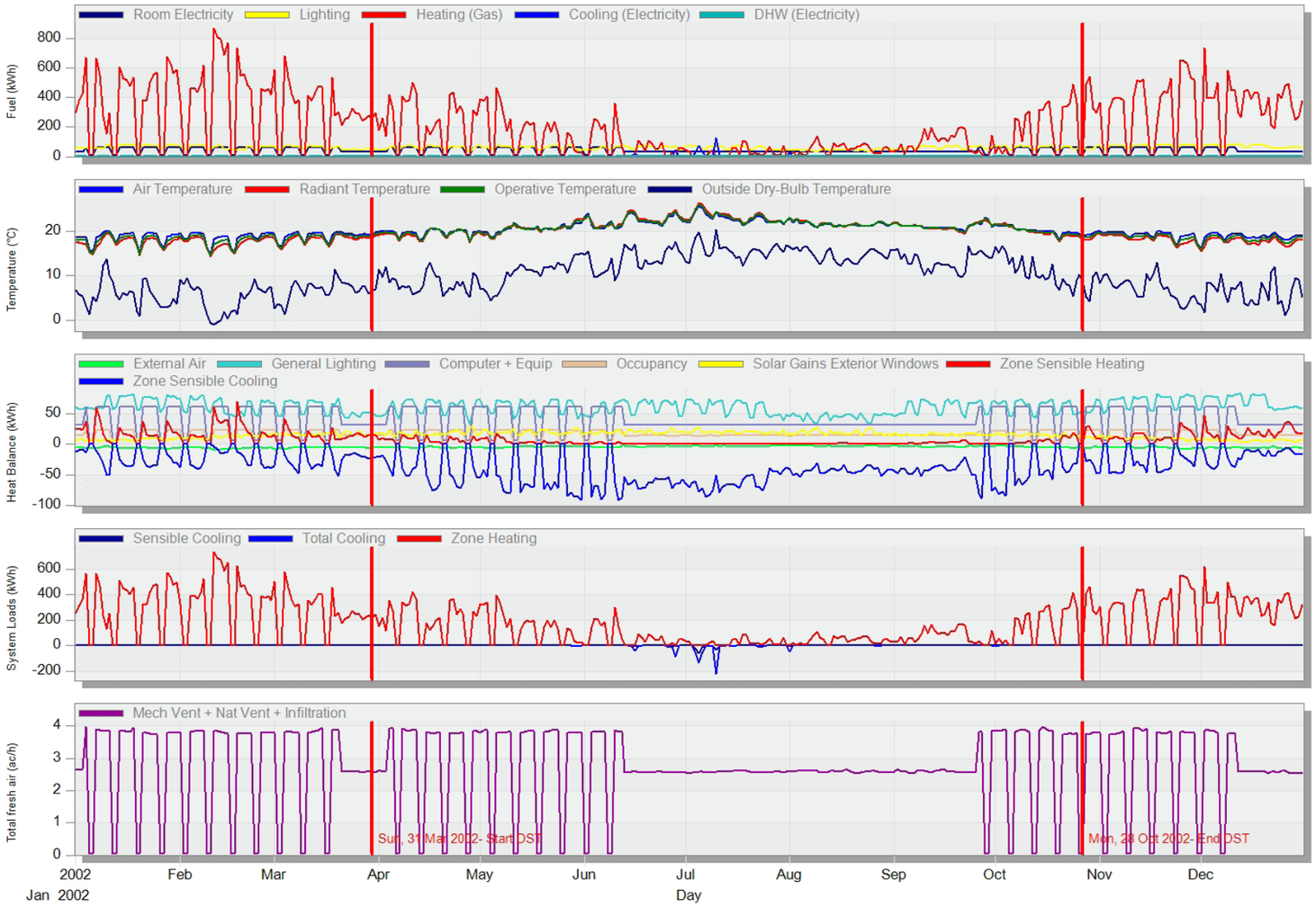


‘Breathing’ systems for labs

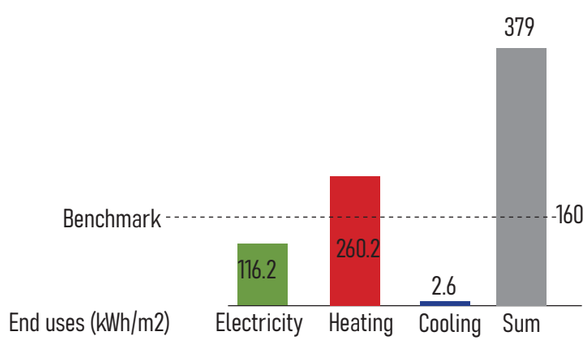
Baseline Model

- Generic dry lab space with adaptable special labs
- Large glazing areas on the West side towards the sea to ensure daylight levels
- No daylight in special lab spaces based on the requirement of darkness
- Mediumweight construction to balance vibration control and material use
- HVAC system set as FCUs with air-cooled chillers
- Double-glazed windows without shading or natural ventilation





Environmental simulation



Comment

The high ventilation requirment leads to a great amount of heat loss and thus heating load. A variety of measures such as natural ventilation control and heat recovery should be incorporated to reduce heating loads. The requirement for darkness in special lab spaces can result in high lighting loads, and thus where possible a high level of daylight should be introduced.

A high ventilation rate leads to high sensible cooling and heat loss in the zone, and at the same time heat gains are also generated by the use of lab equipment and computers, occupants and solar radiation. These two factors together determine the heating and cooling requirements of the zone. It can be seen in the graph that there are large heat gains due to lighting, and thus daylight strategies and lighting controls should be incorporated to reduce them.

Heating loads are high year-long, possibly both due to high ventilation rate and large glazing areas.

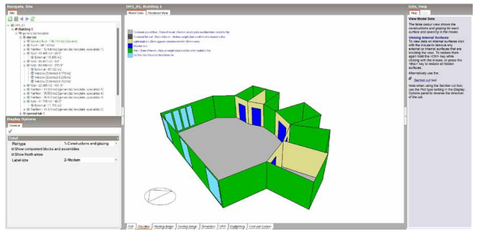
Total fresh air reaches plateau from June to September, mainly due to the setting of activity & schedule that this will be an eduation labratory with summer breaks. Occupancy and ventilation schedules thus need to be tuned to reflect real-life scenarios.

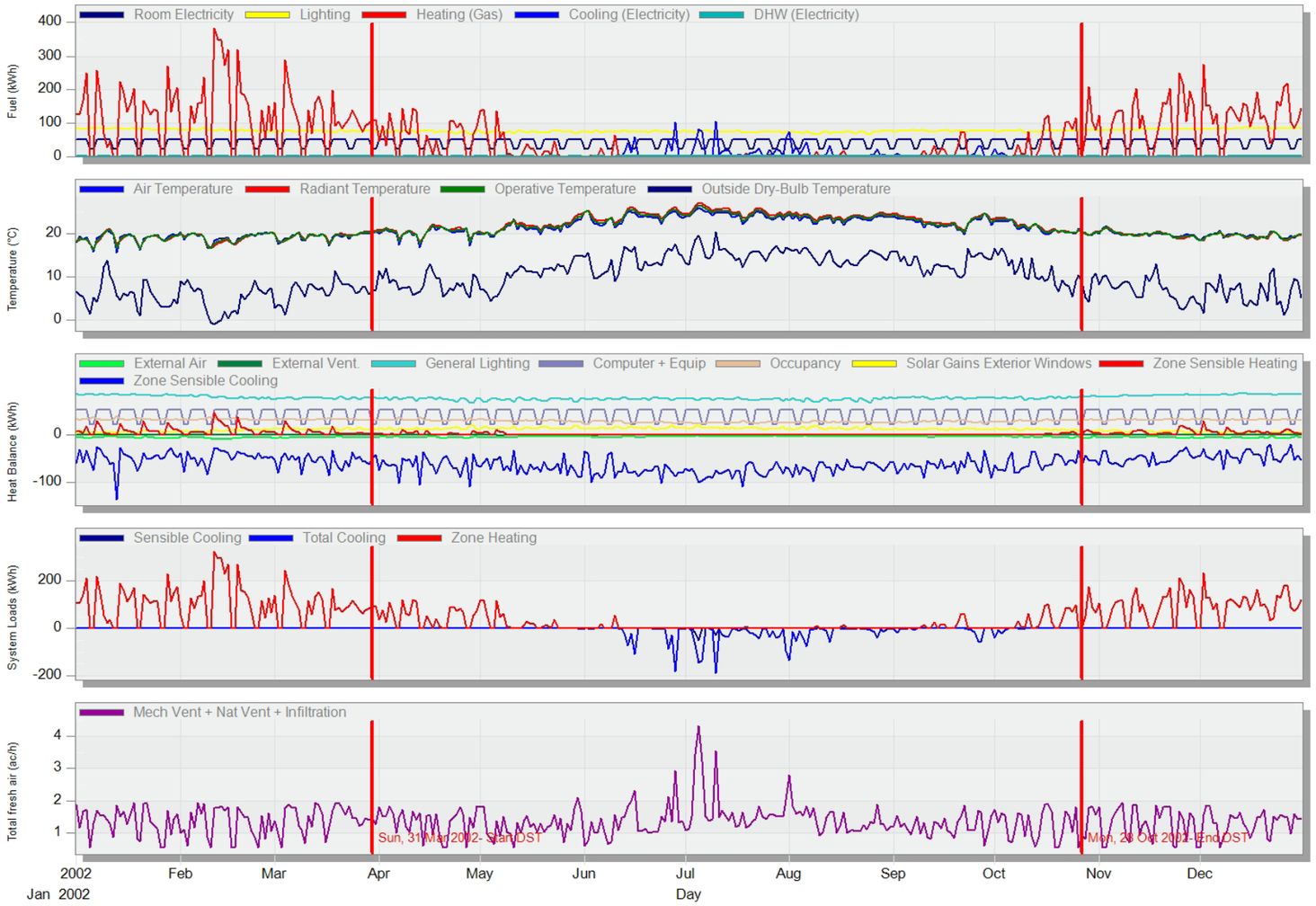
To improve

- Adjustment of mechanical ventilation schedules, by deleting summer breaks and adding occupancy-sensitive controls in generic labs (while maintaining constant ventilation rate in special labs such as cell culture rooms).
- Incorporation of natural ventilation in generic lab space.
- Reducing glazing areas to investigate their effects on heating loads
- Incorporting occupancy-sensitive lighting controls in generic labs

Model iteration 1

- Reduced glazing areas
- Using natural ventilation (trickle vents) in dry lab (not in special labs)
- Adjusted ventilation schedules for special labs: 4 ach for baseline and 10 ach when occupied all-year long. Changing ccupancy-sensing controls from by-zone to by-person for dry lab spaces, with minimum fresh air provision 20 l/s per person
- Added lighting control based on illuminance level on 0.8m plane above floor





Comment

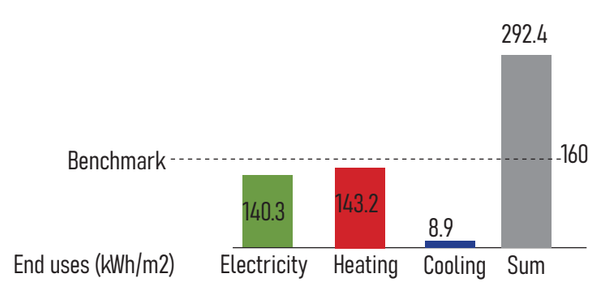
The heating load is reduced to 1/3 of the baseline model, due to the reduced ventilation heat loss. Lighting loads are approximately doubled even with lighting controls, possibly due to the reduced glazing areas.

The reduction of glazing ratios has led to an increase of solar gains, but the effects are not as obvious as the consequent increase of lighting requirements. The glazing ratio in the baseline model should therefore be maintained. The internal gain by increased artificial lighting has led to increased cooling loads.

Heating loads have been brought down tremendously by reducing ventilation heat loss. It should be explored further if heat recovery or other HVAC systems can further reduce this load. Cooling load is increased possibly by increased lighting gains, but is still considerably smaller than the heating load.

The incorporation of occupancy-based ventilation control and natural ventilation in summer has greatly reduced the use of mechanical ventilation.

Environmental simulation

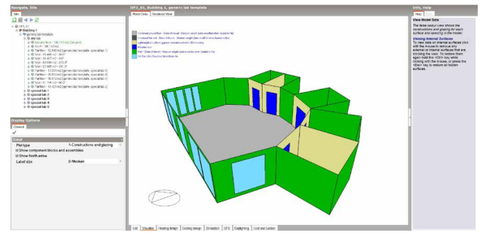


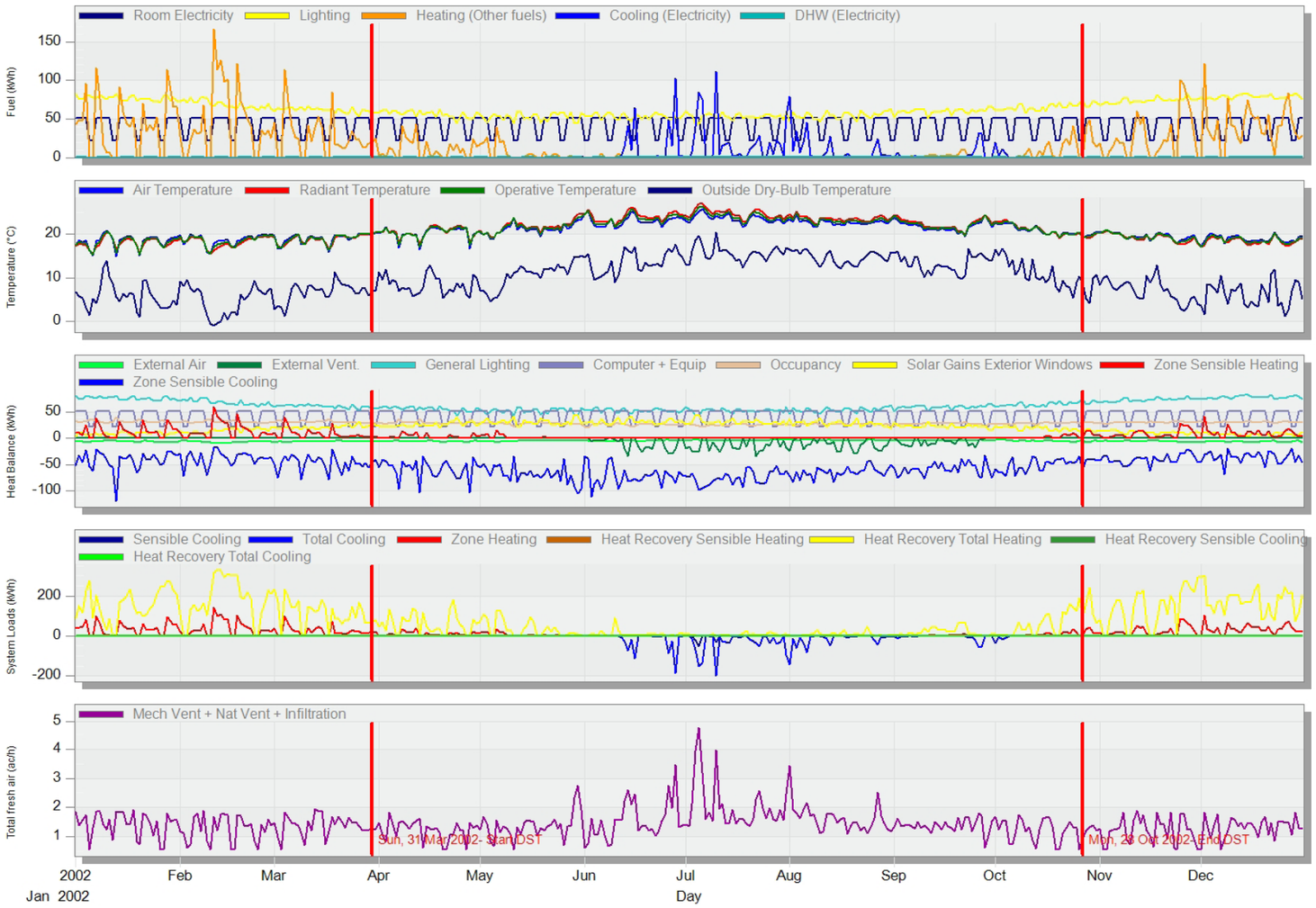
To improve

- Increasing glazing areas to reduce lighting requirements.
- Incorporating operable shading to mitigate overheating due to increased glazed areas.
- Incorporating heat recovery and other HVAC systems and examining their effects.
- Further fine-tune the schedules and control strategies of mechanical ventilation and natural ventilation.

Model iteration 2

- Increased glazing areas on the West and South sides
- Incorporating internal shading controled by solar radiation
- Incorporation of heat recovery (effectiveness 0.7) to the FCU system
- Adjusted natural ventilation schedule: only in summer
- Adjusted heating, cooling and mechanical ventilation schedule: defining weekends, holidays, and different seasons
- Changing heating fuel types from 'grid electricity' to 'waste heat'





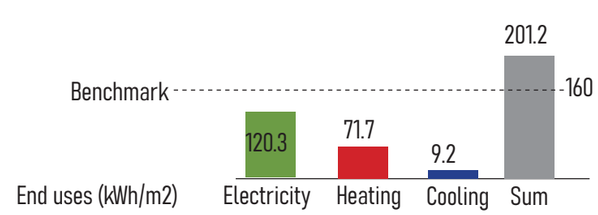
Comment

The lighting load has been reduced by about 40% with the increase of glazing areas. Cooling load in summer is higher, possibly also due to larger windows and greater solar gains. The problem of overheating should be further mitigated by fine-tuning shading controls.

General lighting loads have been reduced by the increase of glazing areas, and excessive solar gains are prevented by internal blinds, resulting in a slight increase of cooling loads but greater decrease in electricity loads of lighting.

The incorporation of heat recovery has reduced heating loads by 2/3 (73.15 kWh/m2 to 21.74 kWh/m2), which is a significant improvement. It can be examined if other HVAC systems can work better than FCUs, such as VAVs or heated floor & chilled beams.

Environmental simulation

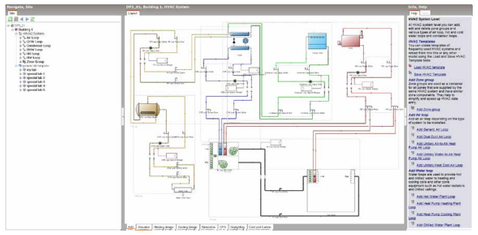


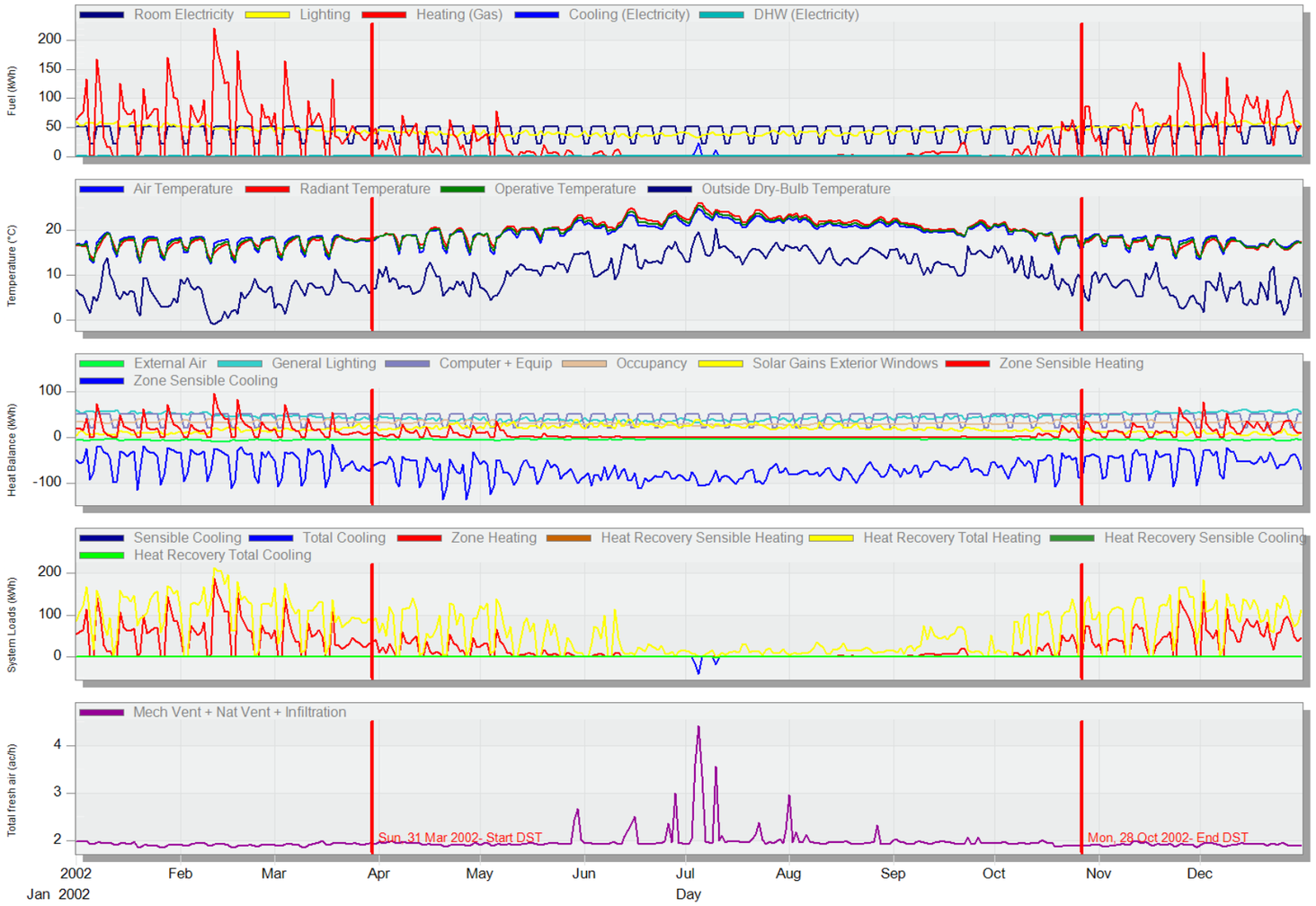
To improve

- Examining the effects of different shading strategies including internal blinds, overhang, and electro-chromic materials
- Fine-tuning shading schedules to balance solar gains and daylight requirements and reduce cooling loads in summer
- Experimenting with other HVAC systems
- Incorporating detailed HVAC designs with fine-tuned heat recovery strategies

Model iteration 3

- Improved internal blind shading behaviours by adjusting shading control type and solar setpoint
- Changing heating / cooling sources to GSHP systems
- Adjusting illuminance setpoints in different spaces
- In detailed HVAC models adjusting the setpoints of the heat recovery loop





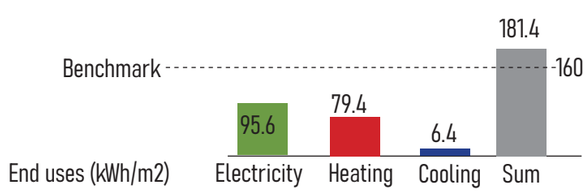
Comment

By reducing the needs for artificial lighting in circulation spaces and adjusting lighting schedules, the overall lighting load has been reduced by about 30%, which has brought down the electricity usage significantly.

The incorporation of ground source heat pumps has reduced the cooling load and has probably increased electricity load.

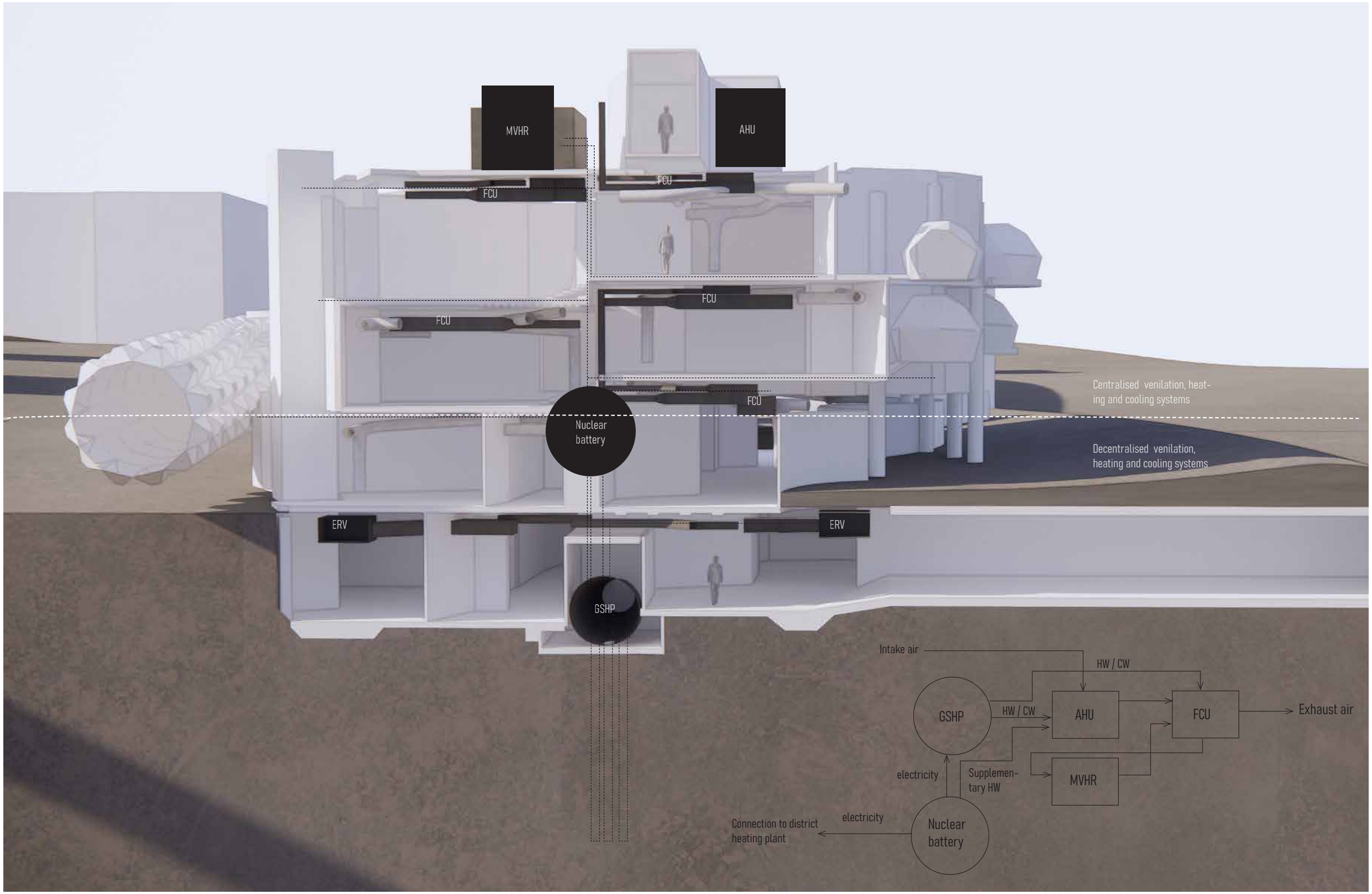
The incorporation of heated floors / chilled beams has led to a less fluctuating ventilation pattern, due to the fact that heating / cooling is provided not only through air provision but also from radiative conditioning.

Environmental simulation



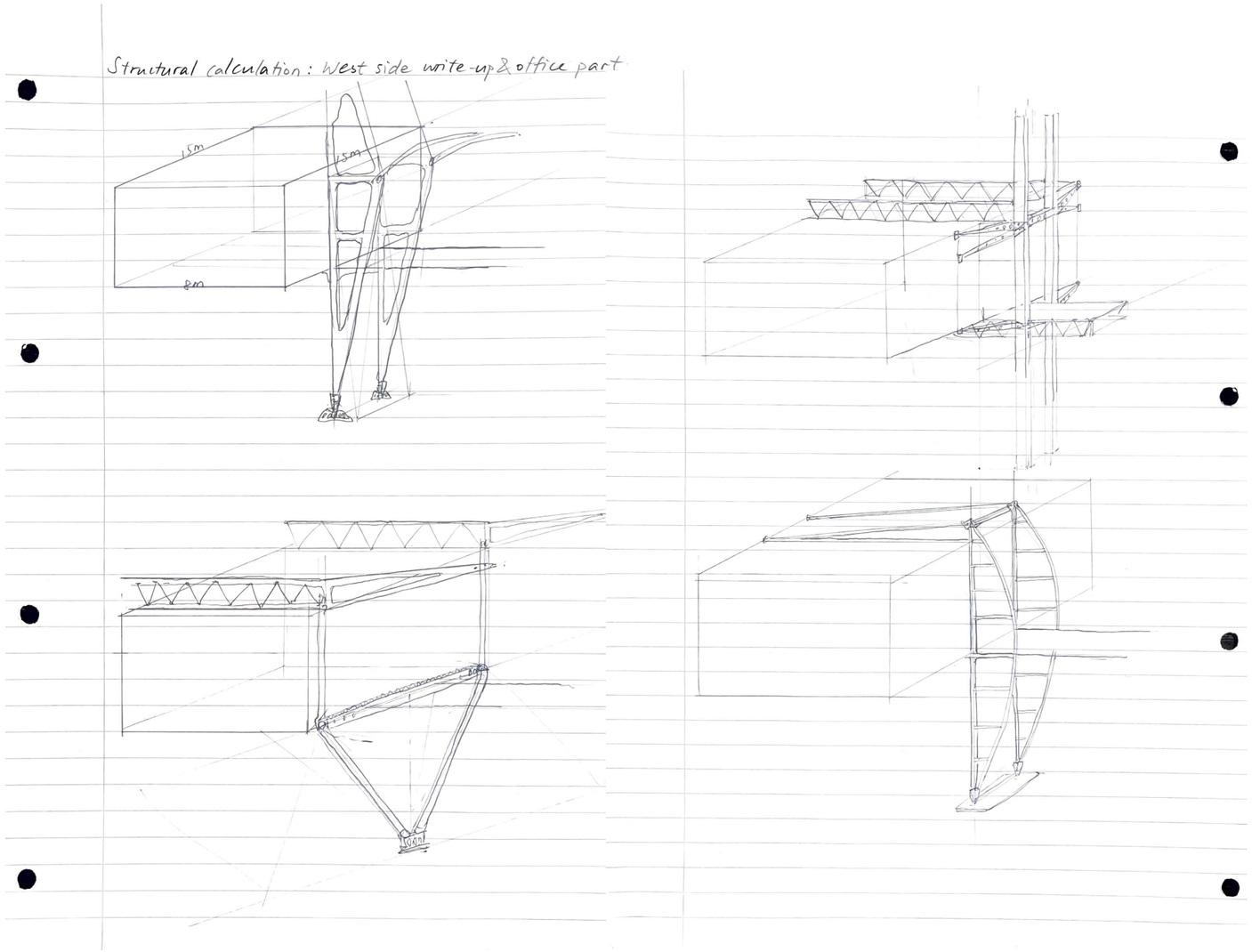
Summary

- Refined glazing ratios, window construction, shading strategies and lighting shedules have reduced the lighting load by about 50%.
- The incorporation of heat recovery has reduced heating loads by about 2/3.
- Refined ventilation strategies include changing the setpoints for different zones, incorporting natural ventialtion in summer and introducing night ventilations have dramatically reduced ventilation heat loss.
- Adjusted schedules of weekdays / weekends, holidays, have enabled the model to better reflect reality.
- Detailed modelling of HVAC systems has improved their efficiency.



Interstitial spaces and MEP

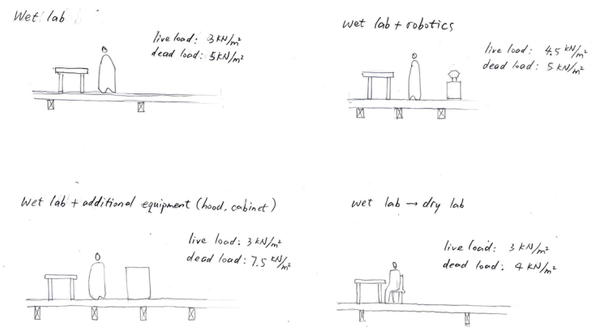
Technology improves increadibly fast and no one can predict what equipment buildings will need to be designed for in the future. We may need to change a dry lab to a wet lab, use robotics to do repetitive experiments or add more chemical fume hoods or spectrophotometers. Interstitial spaces allow easier alteration of structural capacbility, where regular activities do not need to be shut down during maintanence.
The main structure should minimise vibration. Even the slightest vibration of lab structures can ruin millions of pounds of research efforts.

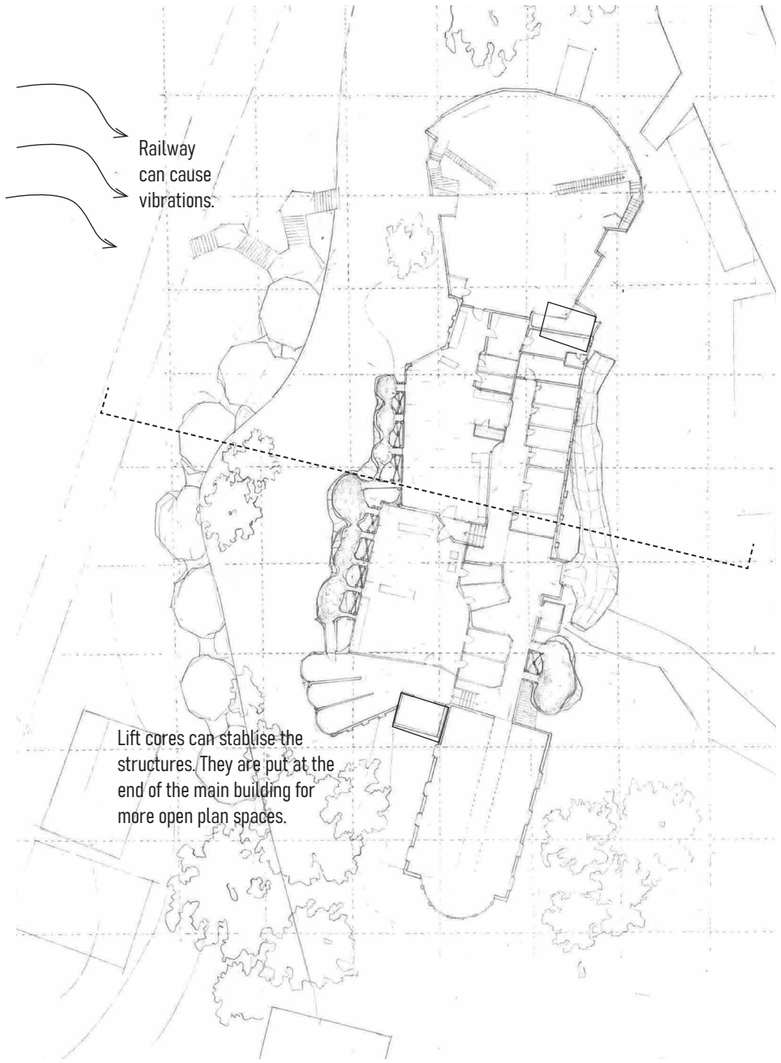


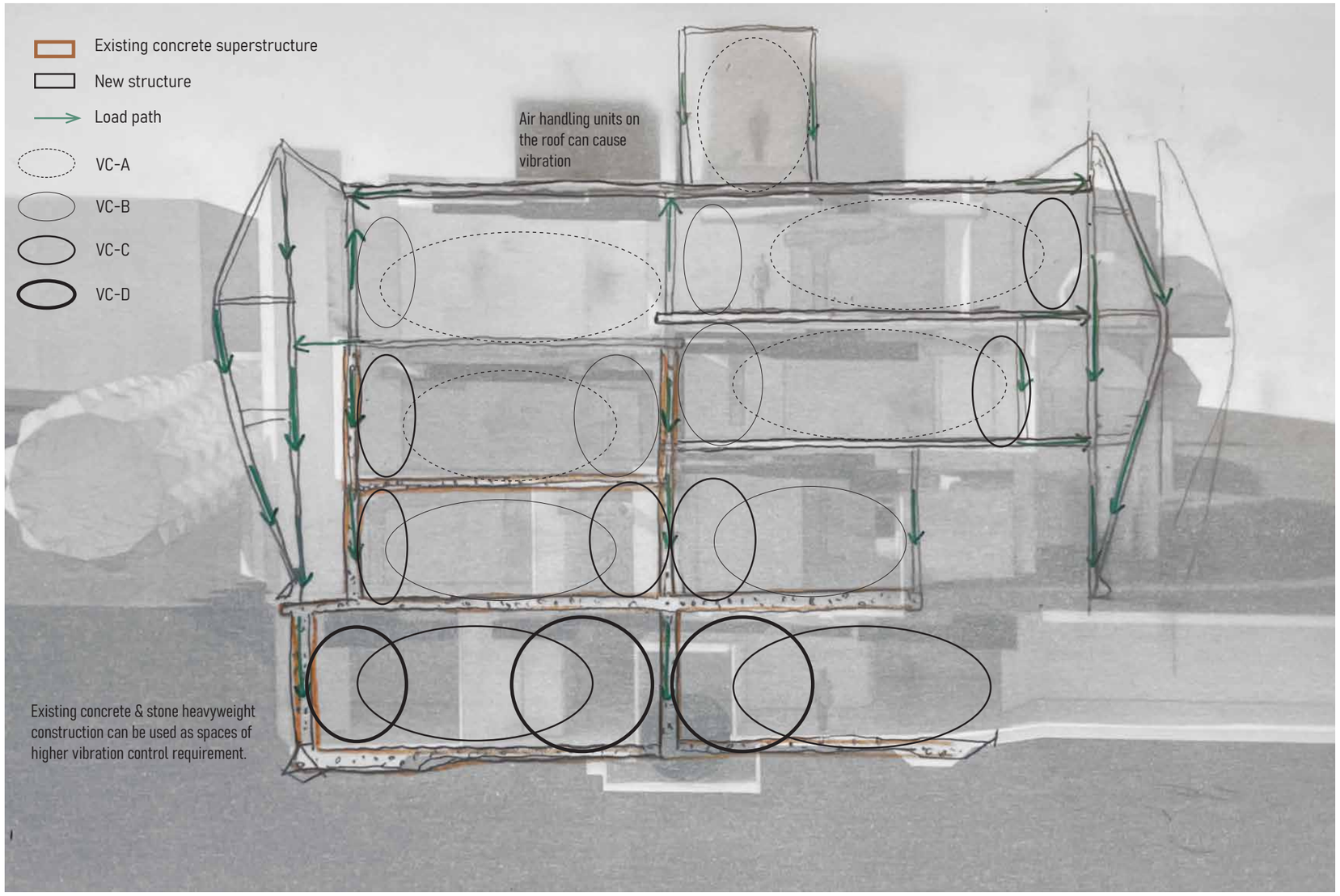
Markup: structural layout

Lateral force-resisting systems

Activities	Vibration source	Vibration criteria	Strutcural requirement	Comments
Write-up	road traffic, railroad proximity, elevators,	VC-A	can be VC-B spaces but in the centres of strutcural bays (far from columns)	Most labs only need a few areas of low vibration to support a few microscopes, which allows for the creation of microscope-suitable spaces without extending the low-vibration area to the whole floor plate. In general, locating a microscope near a column can improve vibration by another whole criteria step (for example, from VC-C to VC-D). Microscopes can be placed on pneumatic tables, which generally cut about 90 percent of the vibration from the floor.
Data Imaging Fluorescene	HVAC, fans, air handling systems	VC-C	minium VC-B , where pneumatic tables are used	
Microinjection Micromanipulation Electrophysiology Confocal Microscopy	HVAC, fans, air handling systems	VC-D	minimum VC-C , where pneumatic tables are used & equipment is put near columns	

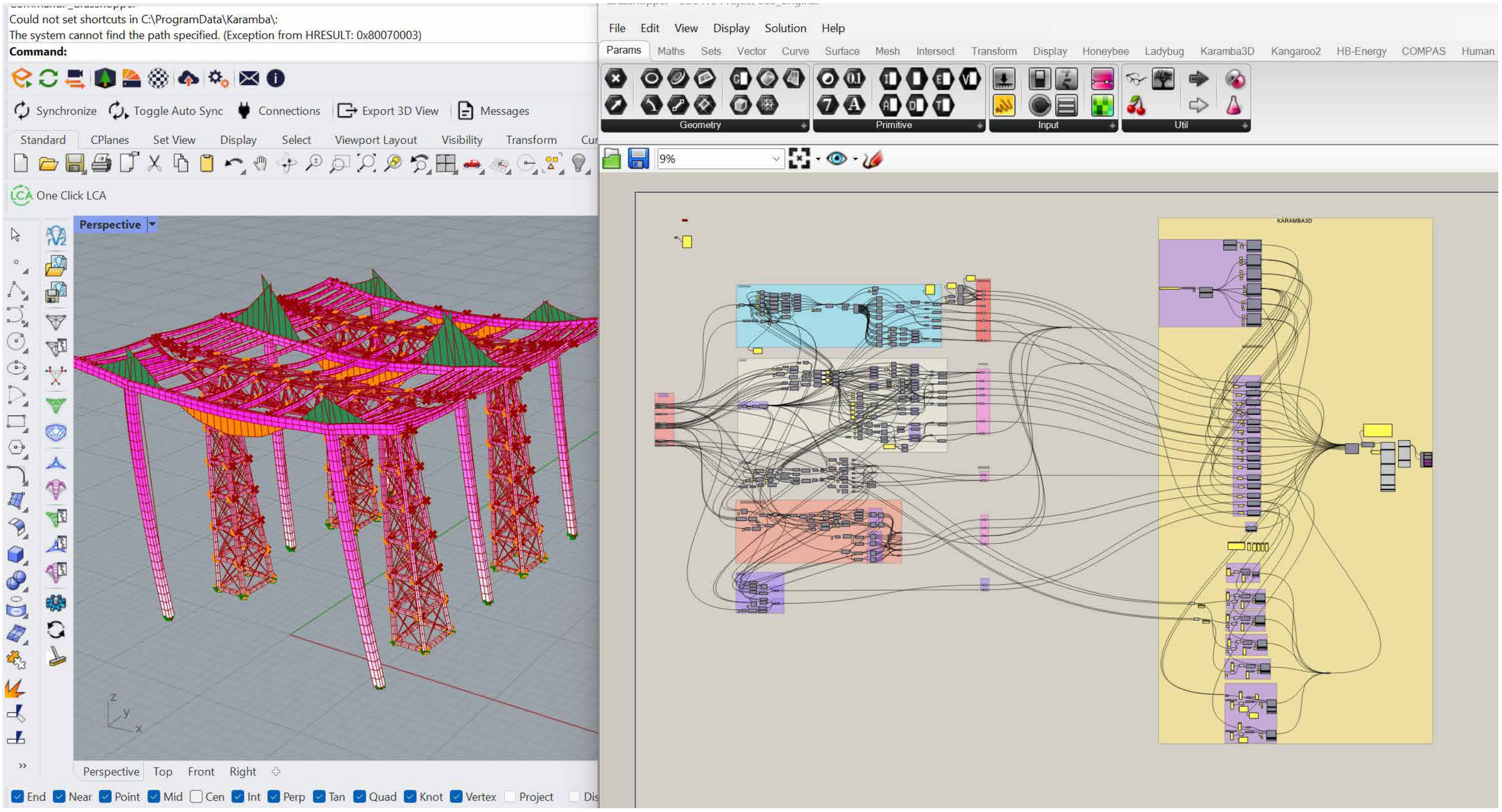






Vibration control

A parametric script is created in grasshopper to investigate the impacts of frame dimensions, column angles of aperture, truss dimensions, material selection, etc., on structural behaviours. Karamba 3D is used as the main analysis tool, where load cases of dead, live and wind are examined. The model is for a qualitative understanding of the dimension, material and appropriate frame systems. The results of bending moments can be used to carry out ULS and SLS calculations for individual structural components.

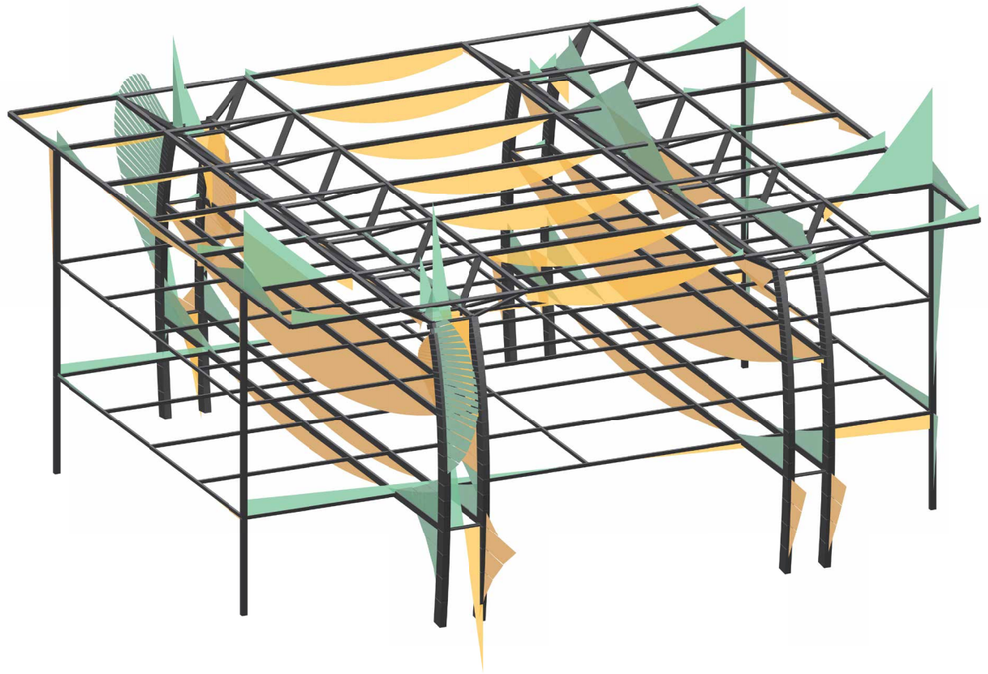


Structural system

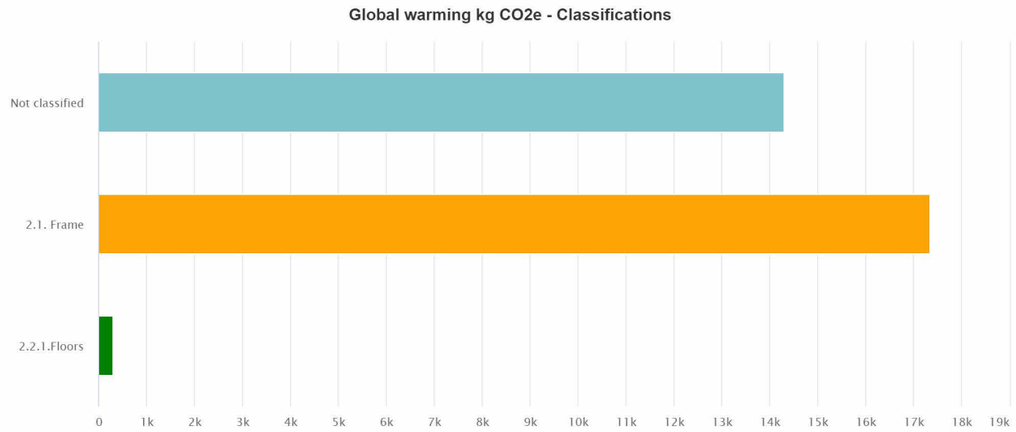
Structure iteration 1

This model futures in a all-steel external frame system.

Structural system



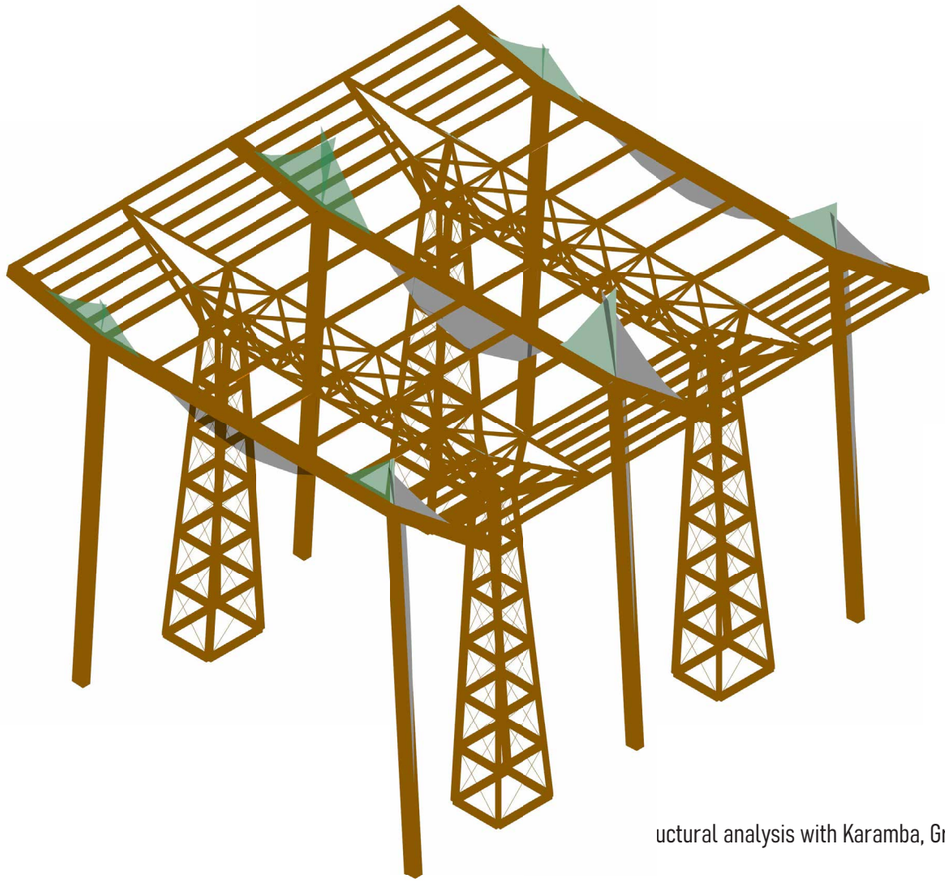
Qualitative structural analysis with Karamba, Grasshopper



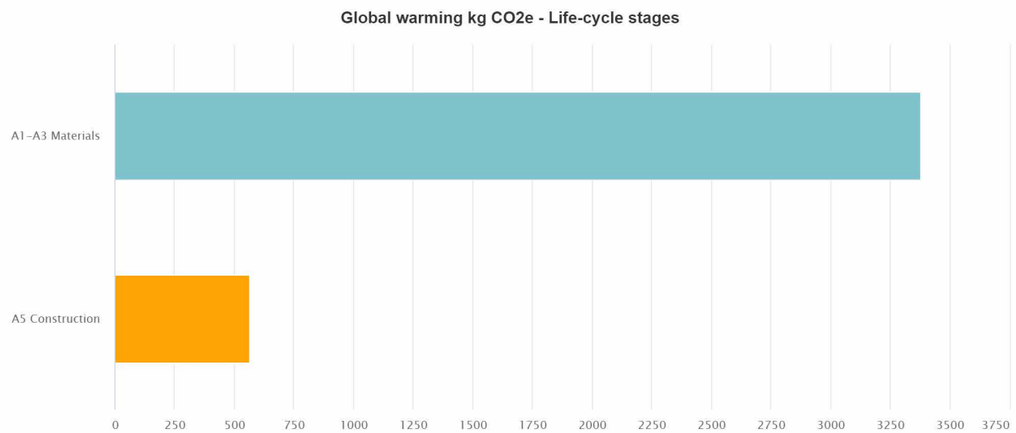
Embodied carbon of structure, calculated with OneClick LCA, Grasshopper

Structure iteration 2

A all-timber lateral force-resisting system can achieve similar structural performance while having 1/5 of embodied carbon compared with an all-steel system.



uctural analysis with Karamba, Grasshopper

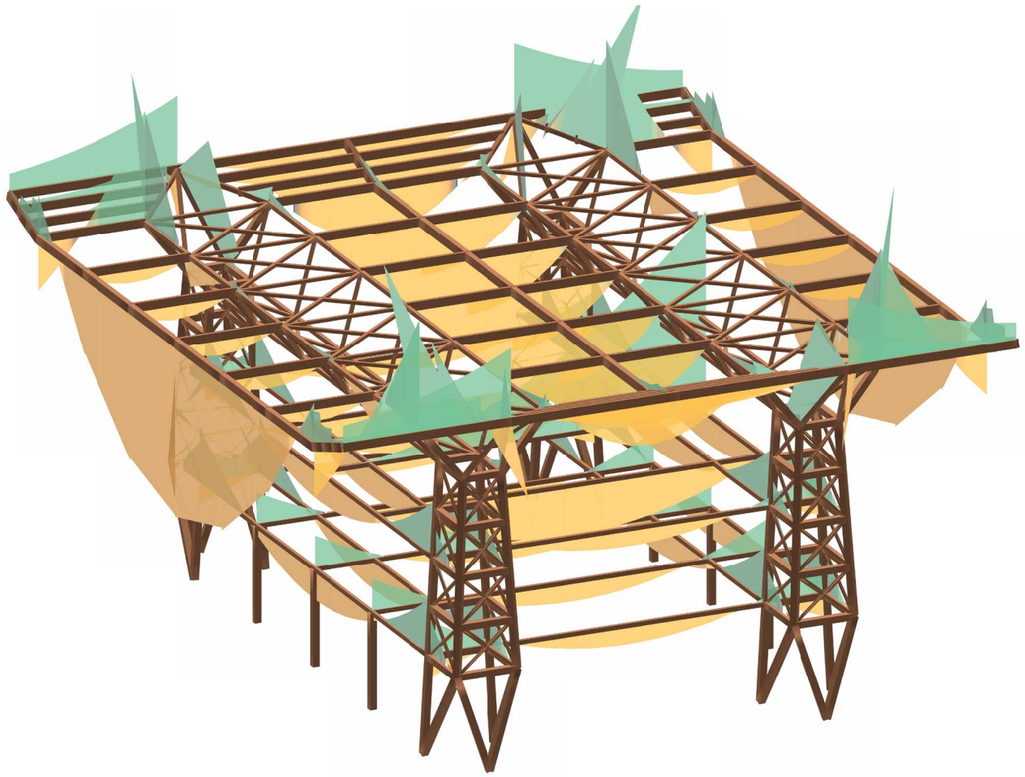


Embodied carbon of structure, calculated with OneClick LCA, Grasshopper

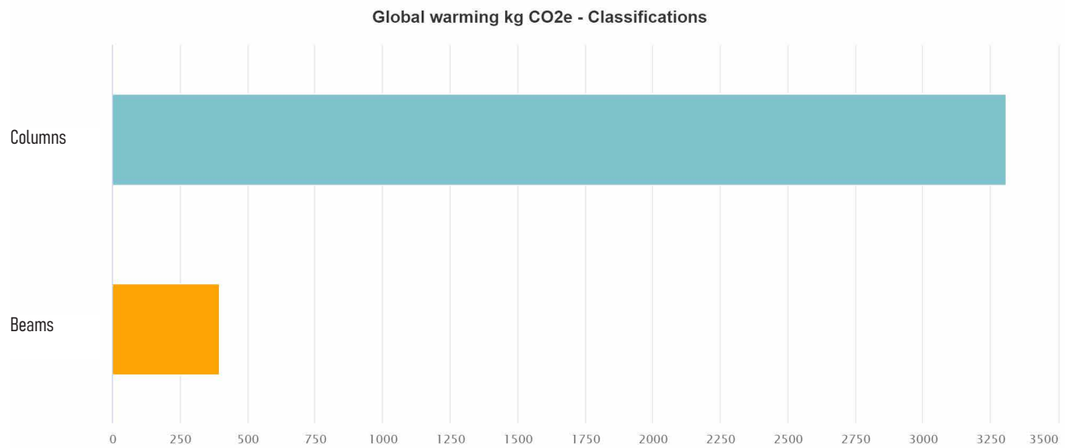
Structural system

Structure iteration 3

An improved timber frame system to reduce the space it takes on the ground floor by changing to triangular support while achieving similar structural performance and embodied carbon.

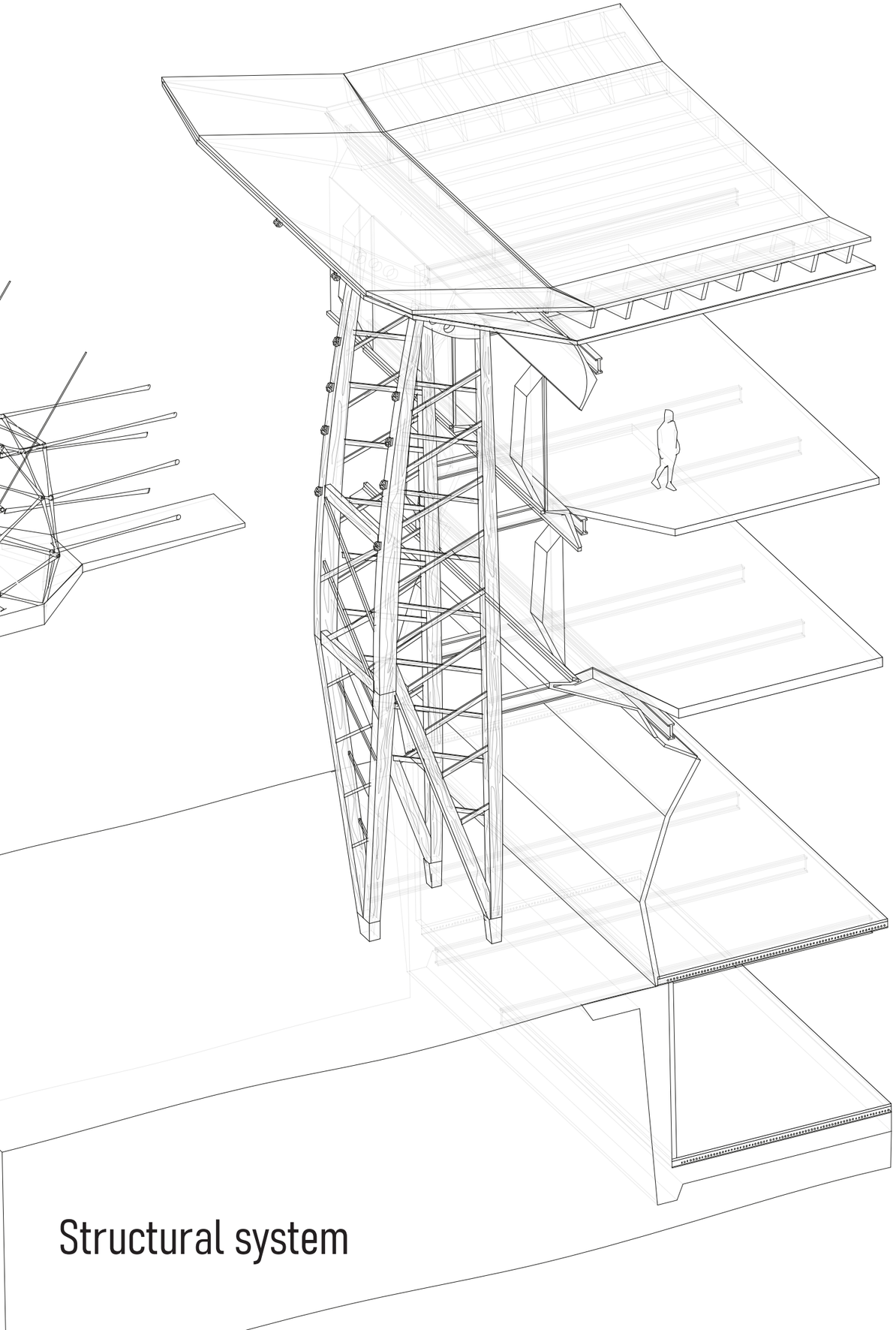


Qualitative structural analysis with Karamba, Grasshopper

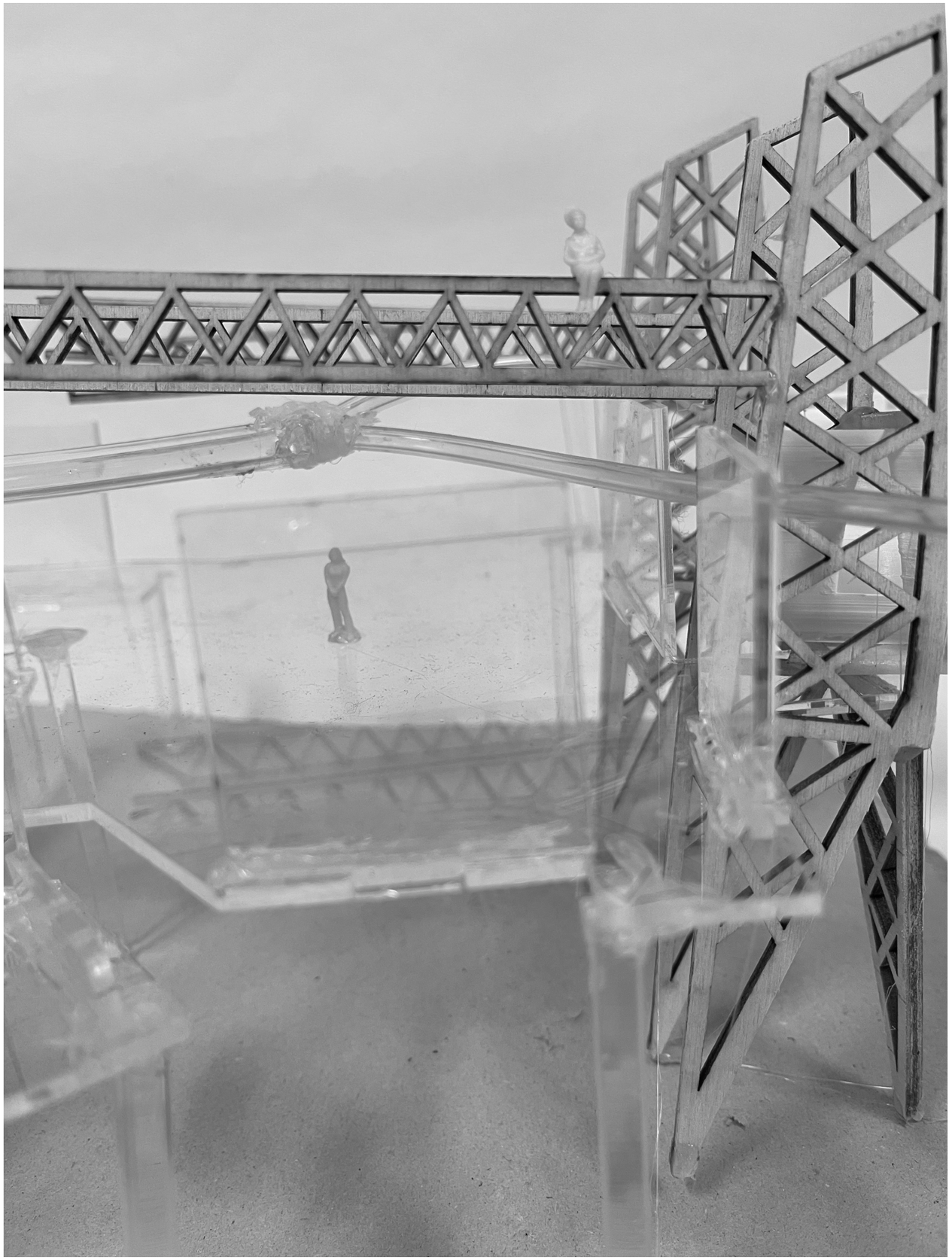


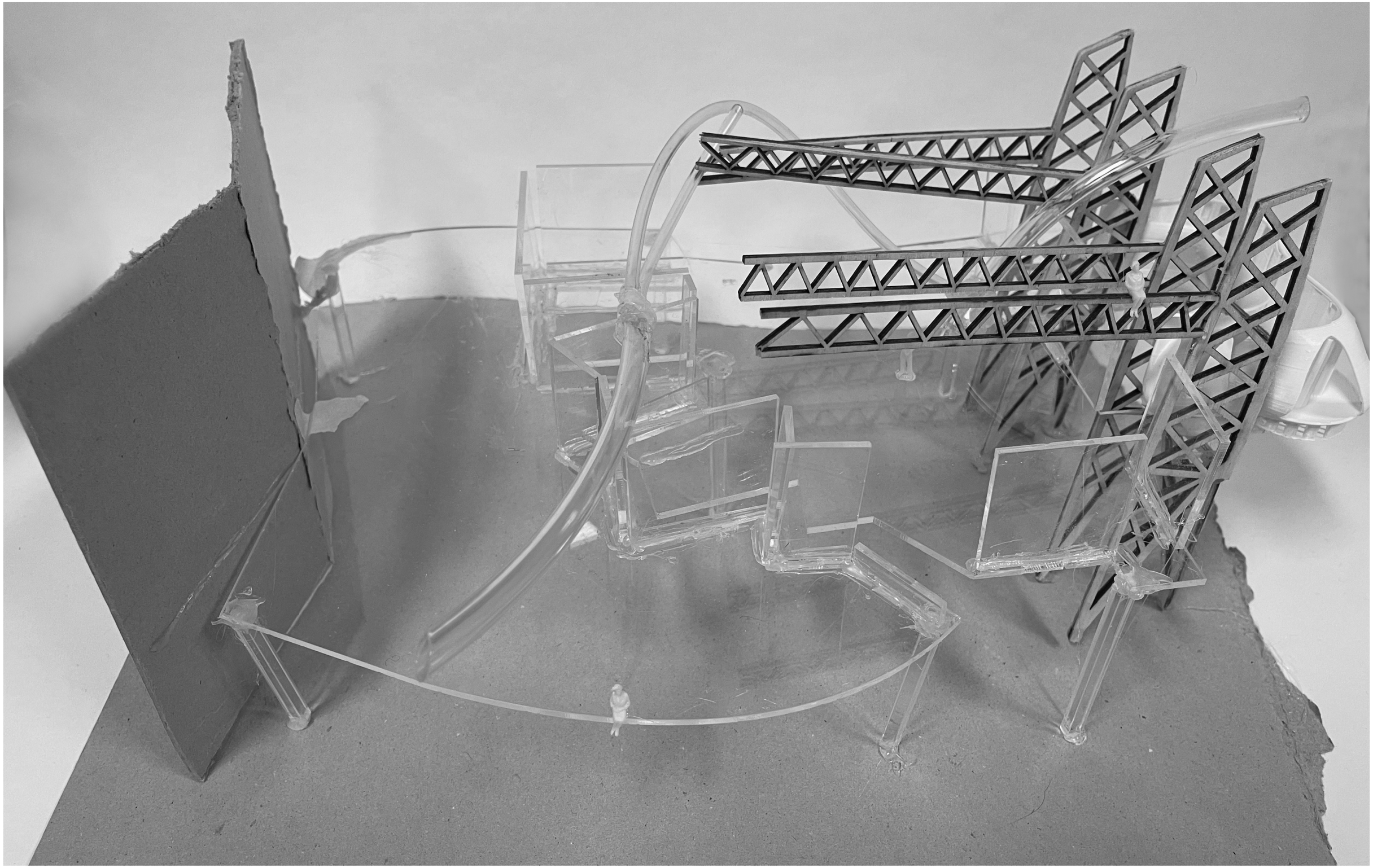
Embodied carbon of structure, calculated with OneClick LCA, Grasshopper

Structural system



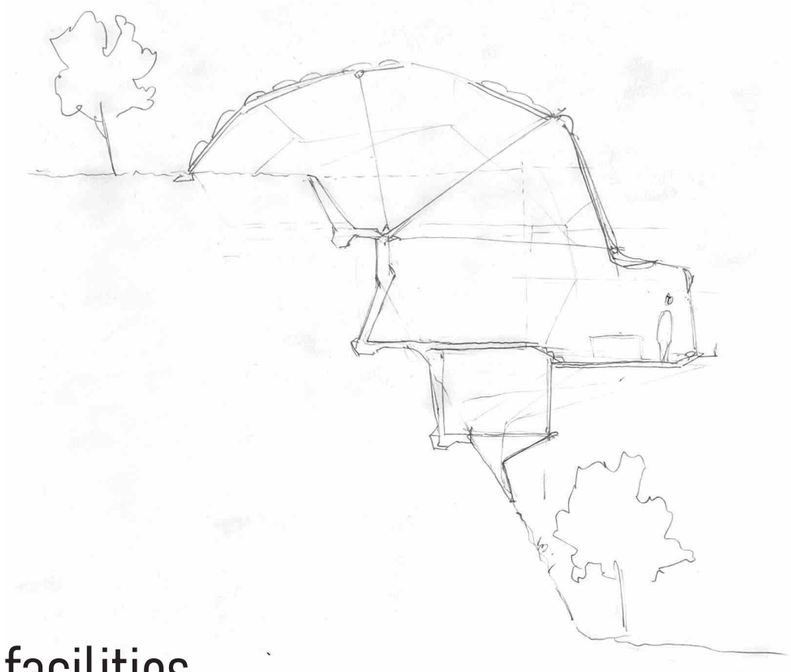
Structural system

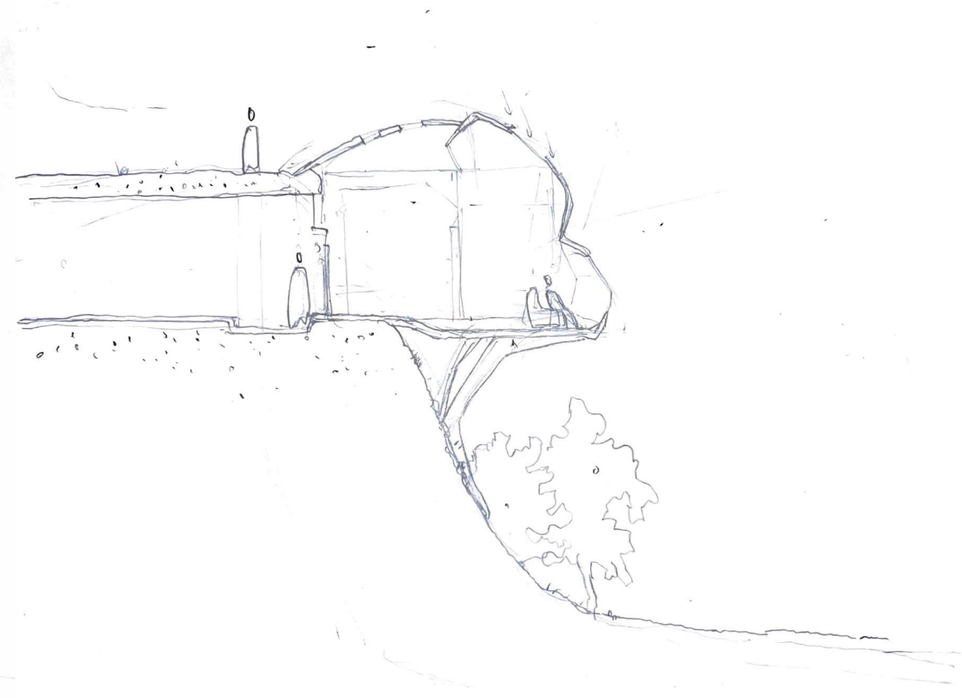




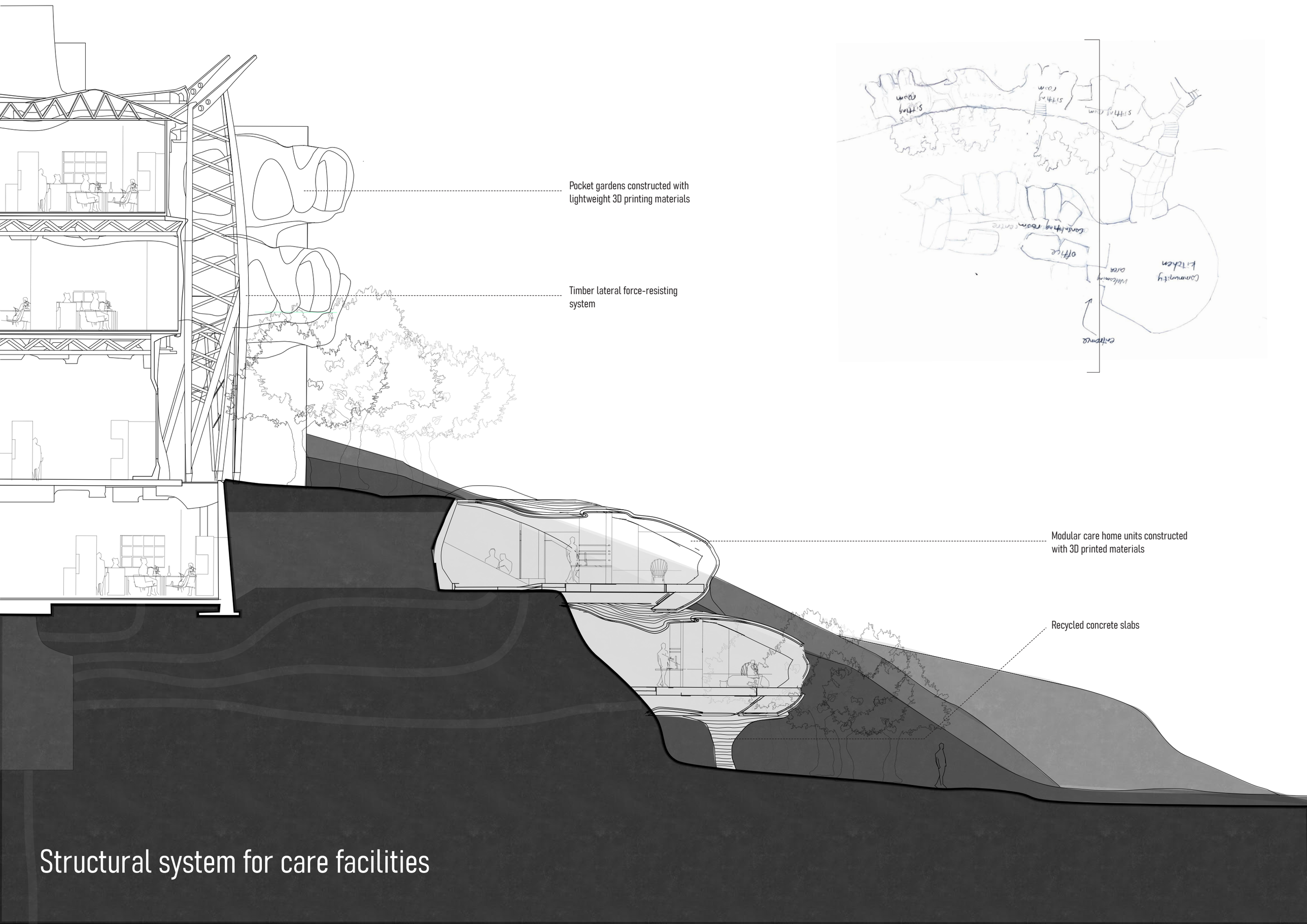
Structural system

Structural concepts of the modular care home units around the cliff.





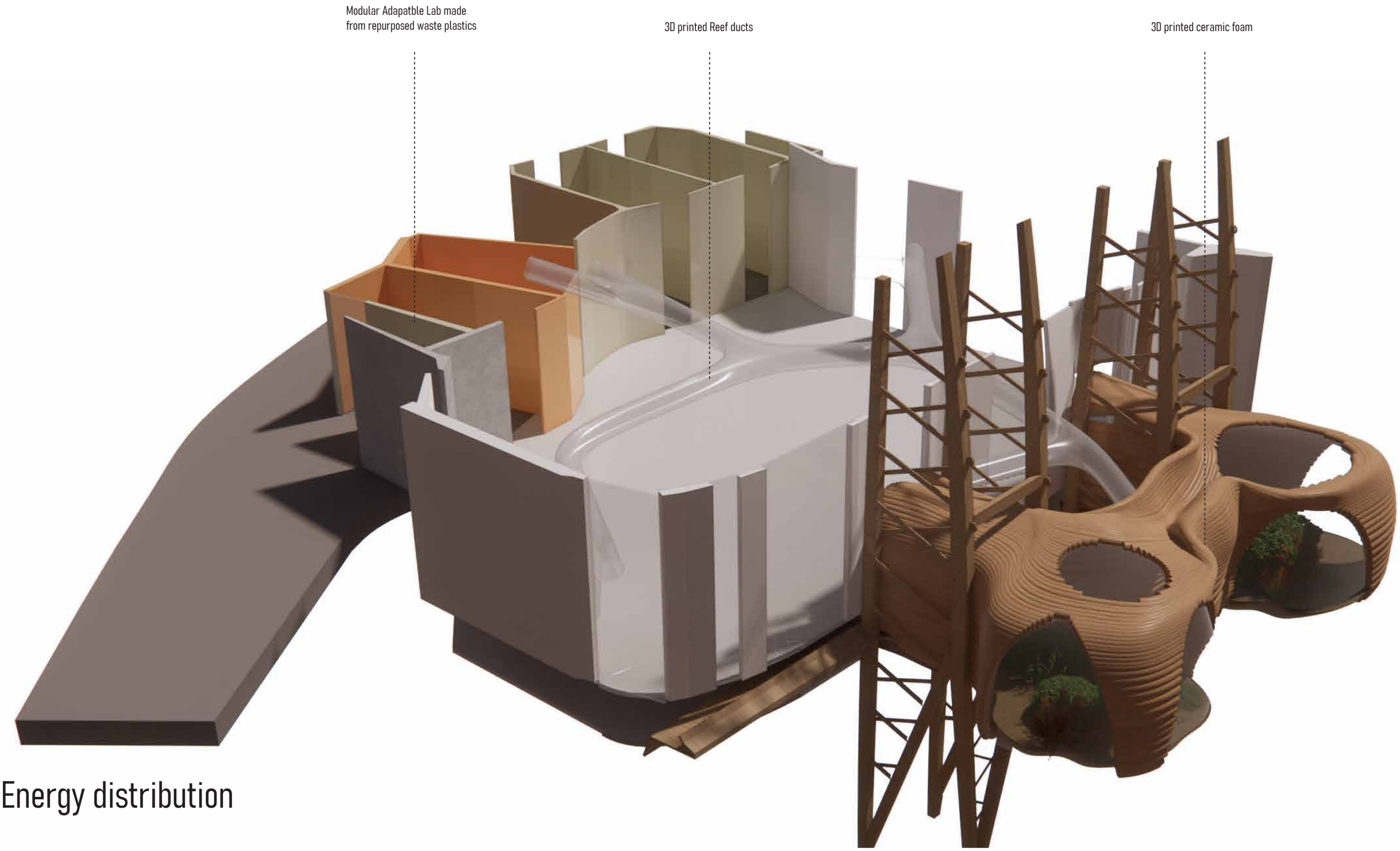
Structural system for care facilities



Structural system for care facilities

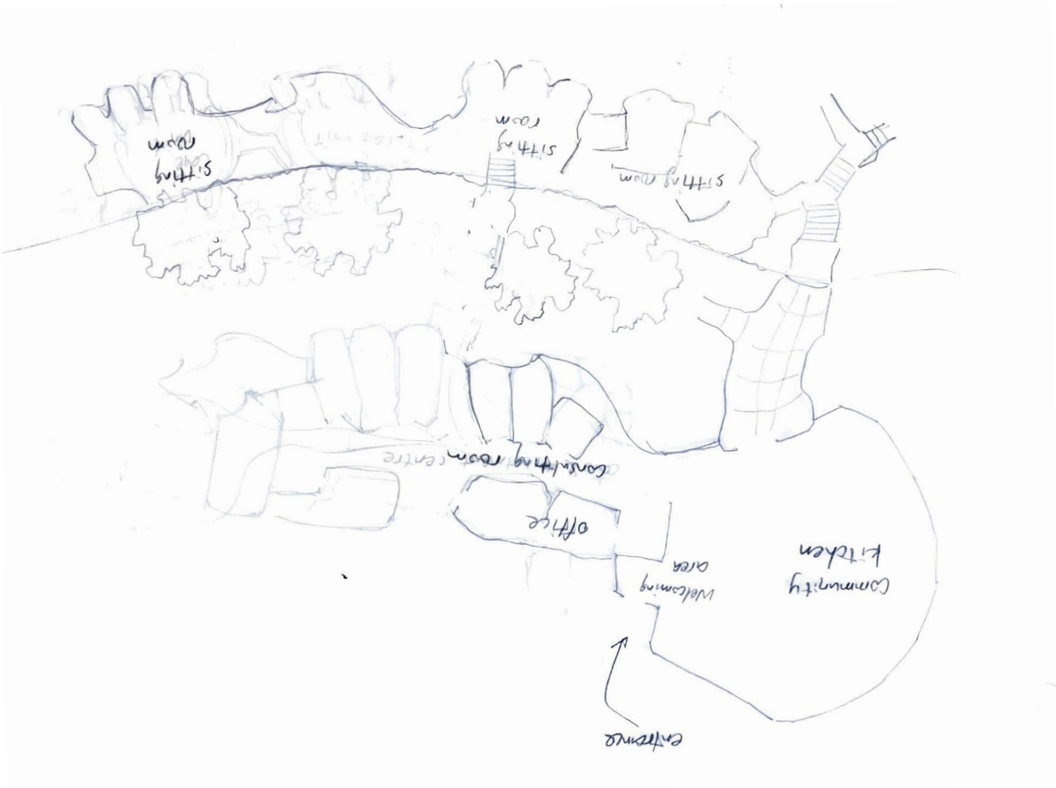
4

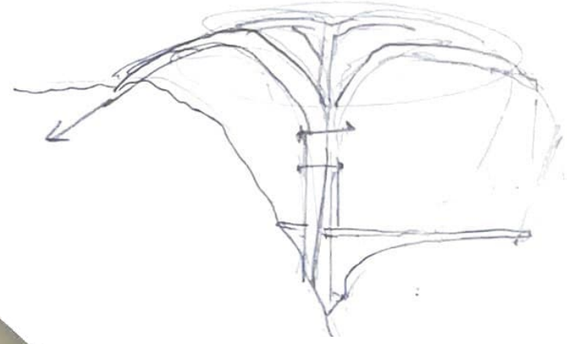
Interconnectivity

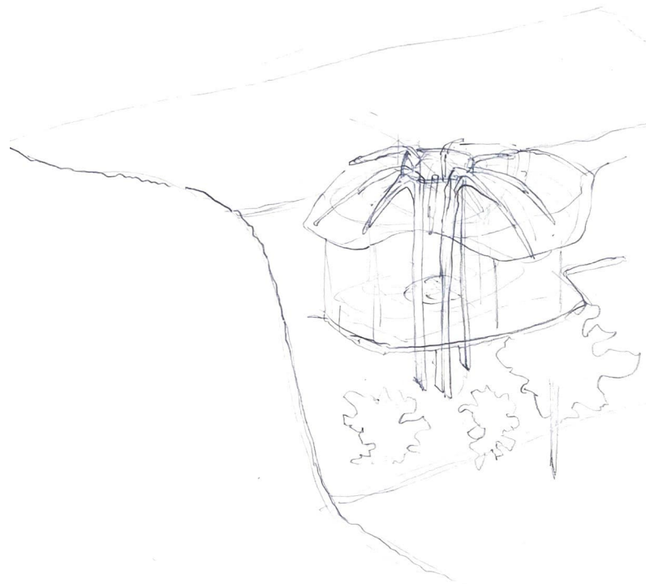


Energy distribution

Gardens as circulation spaces



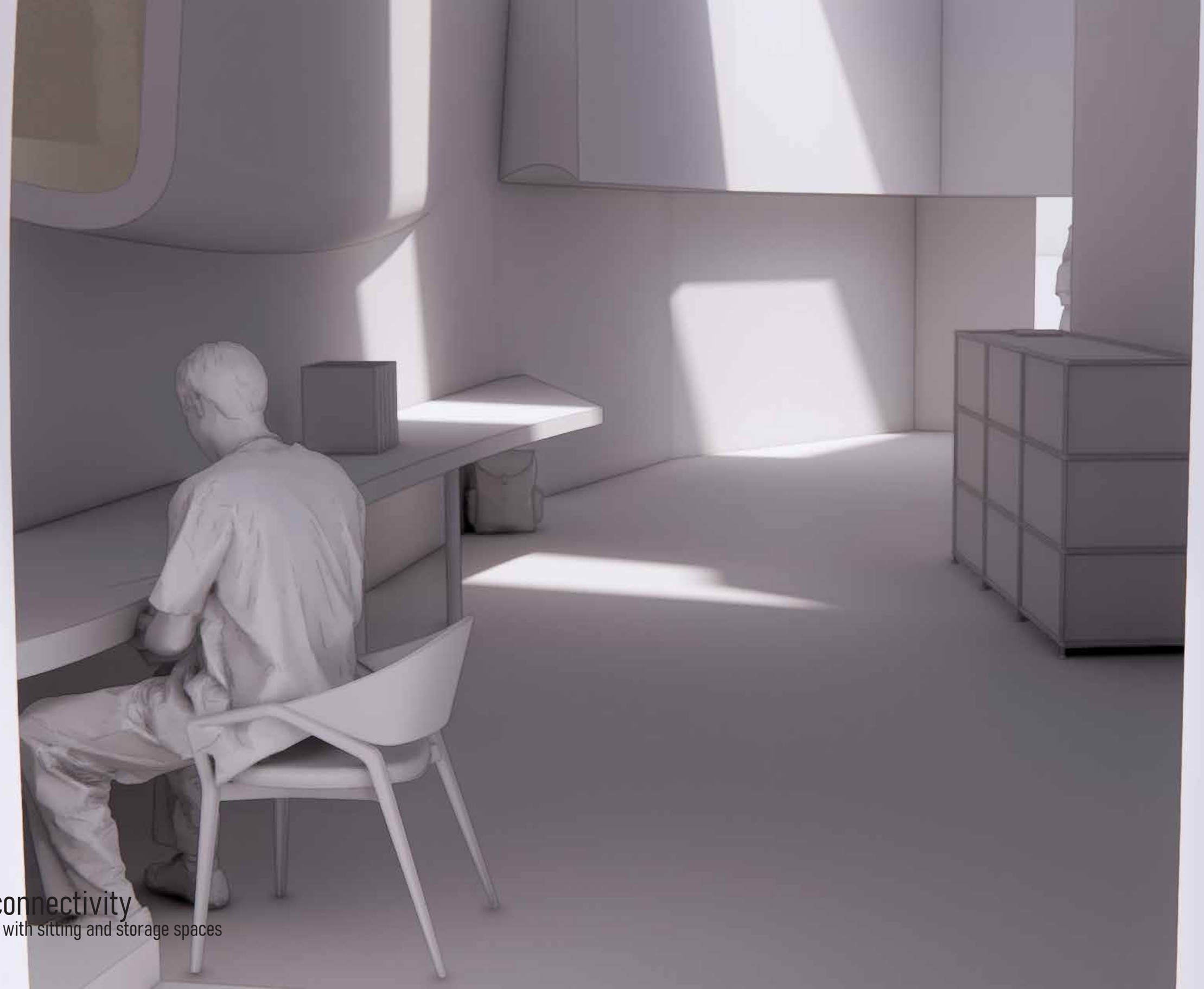




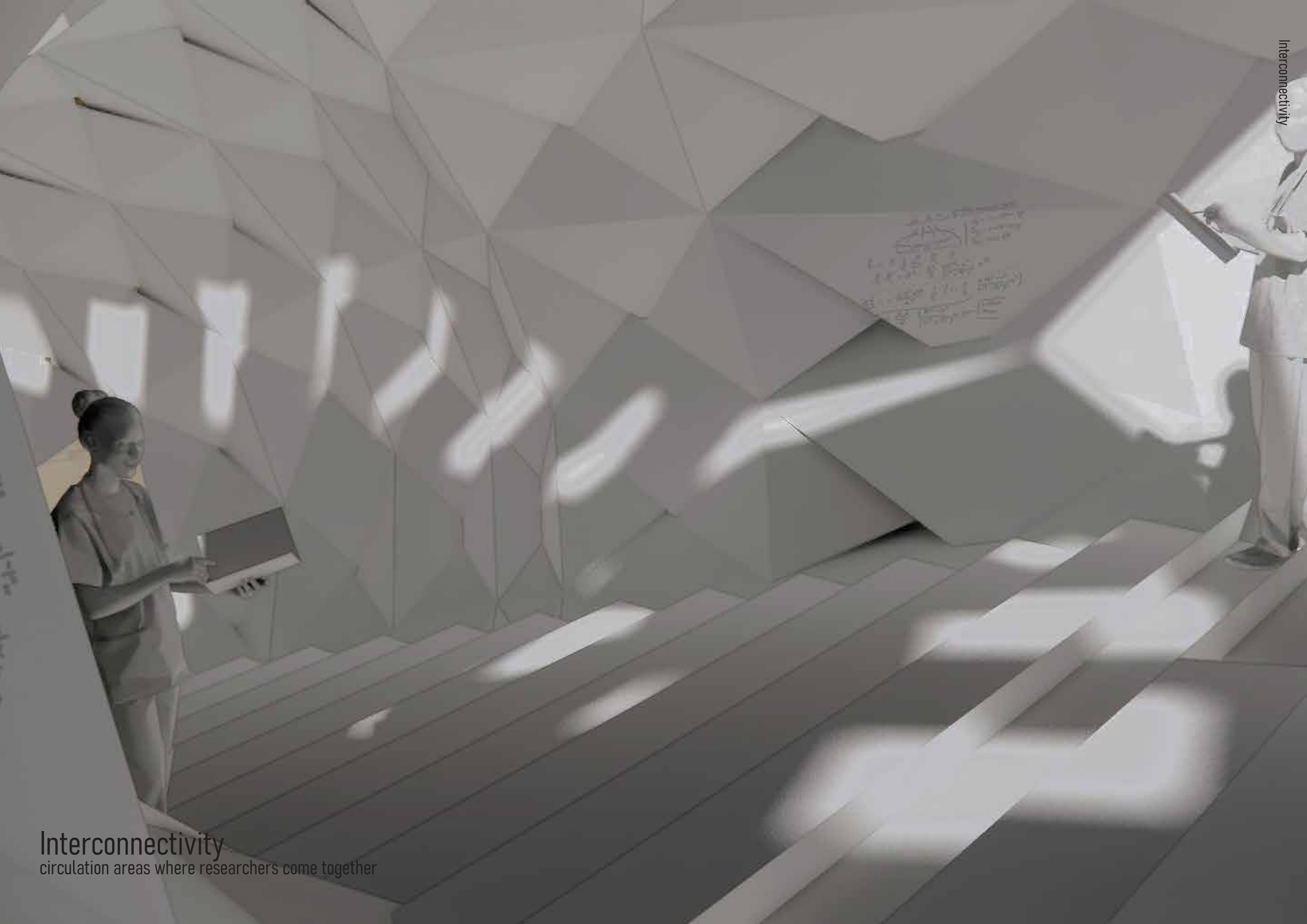
Promoting care

Interconnectivity

corners where people can sit and write everywhere



Interconnectivity
corridors with sitting and storage spaces



Interconnectivity

circulation areas where researchers come together

Interconnectivity

where researchers and patients share the same space

5

Coming Together

Preserved heavyweight wall construction
New wall construction
Glazing

1 Communal area
2 Plant room
3 Communal area
4 Lift 1
5 Office
6 Store room 1
7 Store room 2
8 Store room 3
9 Consultation room 1
10 Workshop space
11 Consultation room 2
12 Consultation room 3
13 Meditation space

Harlech Institute of Cancer and Care Research
Basement Plan
A1 1:200

N

Preserved heavyweight wall construction
New wall construction
Glazing

1 Community kitchen
2 Reception
3 Nuclear battery
4 Workshop 1
5 Lift 1
6 Workshop 2
7 Speicial lab 1
8 Special lab 2
9 Office
10 Dry lab
11 Speical lab 4
12 Special lab 5
13 Toilet
14 Store room
15 Lift 2
16 Storage

Harlech Institute of Cancer and Care Research
Lower Ground Plan
A1 1:200

N

Preserved heavyweight wall construction
New wall construction
Glazing

1 Mezzanine
2 Pocket gardens
3 Wet lab 1
4 Lift 1
5 Special lab 6
6 Special lab 7
7 Office 3
8 Office 4
9 Dry lab 1
10 Modular labs
11 Wet lab 2
12 Toilet
13 Cafe
14 Store room
15 Lift 2
16 Library

Harlech Institute of Cancer and Care Research
Ground Plan
A1 1:200

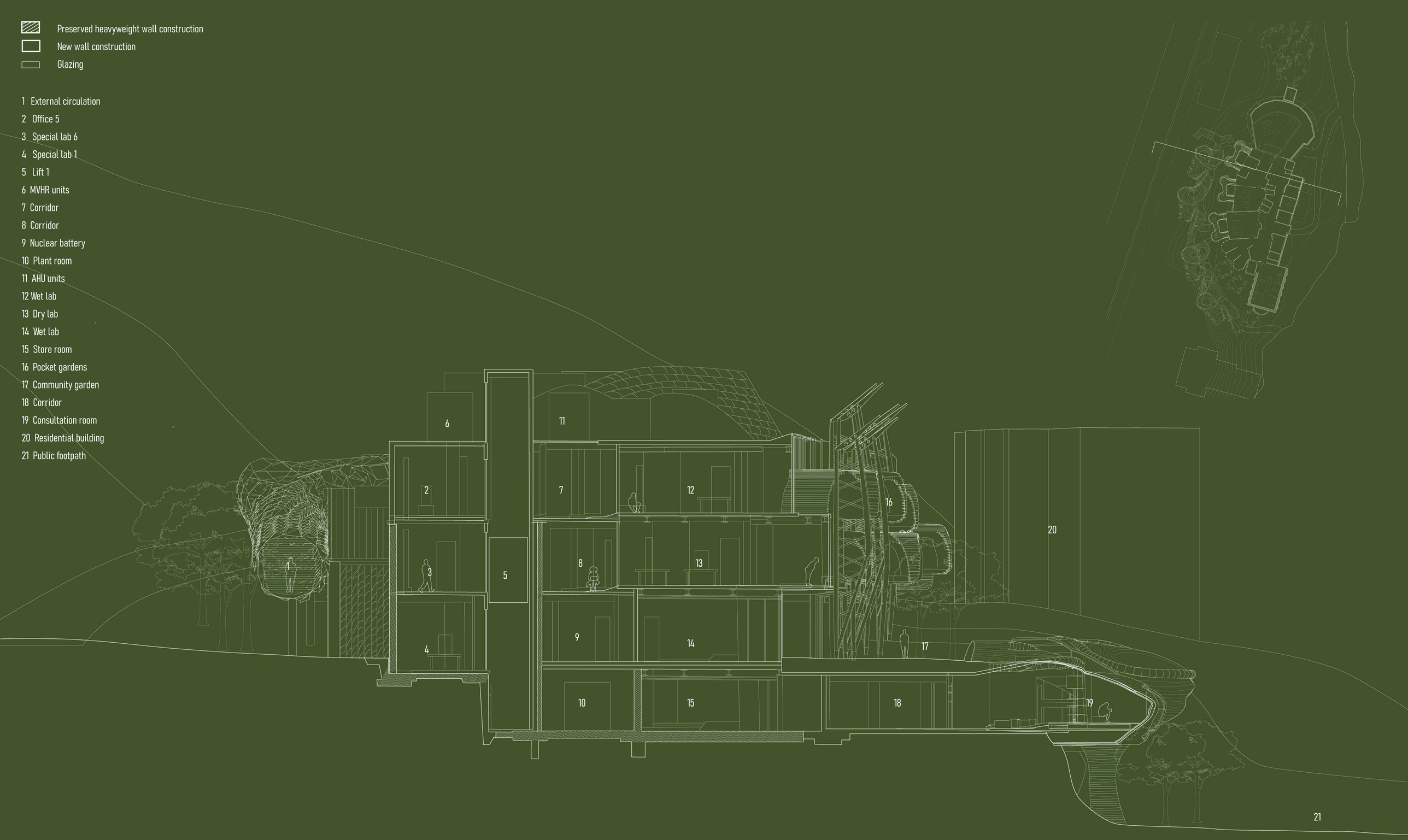
Preserved heavyweight wall construction
New wall construction
Glazing

1 Lecture hall
2 Pocket gardens
3 Wet lab 3
4 Lift 1
5 Special lab 8
6 Special lab 9
7 Office 5
8 Office 6
9 Dry lab 2
10 Modular labs
11 Wet lab 4
12 Toilet
13 Cafe
14 Store room
15 Lift 2
16 Library

Harlech Institute of Cancer and Care Research
First Floor Plan
A1 1:200

Preserved heavyweight wall construction
New wall construction
Glazing

1 External circulation
2 Office 5
3 Special lab 6
4 Special lab 1
5 Lift 1
6 MVHR units
7 Corridor
8 Corridor
9 Nuclear battery
10 Plant room
11 AHU units
12 Wet lab
13 Dry lab
14 Wet lab
15 Store room
16 Pocket gardens
17 Community garden
18 Corridor
19 Consultation room
20 Residential building
21 Public footpath



Harlech Institute of Cancer and Care Research
Short Section
A1 1:100

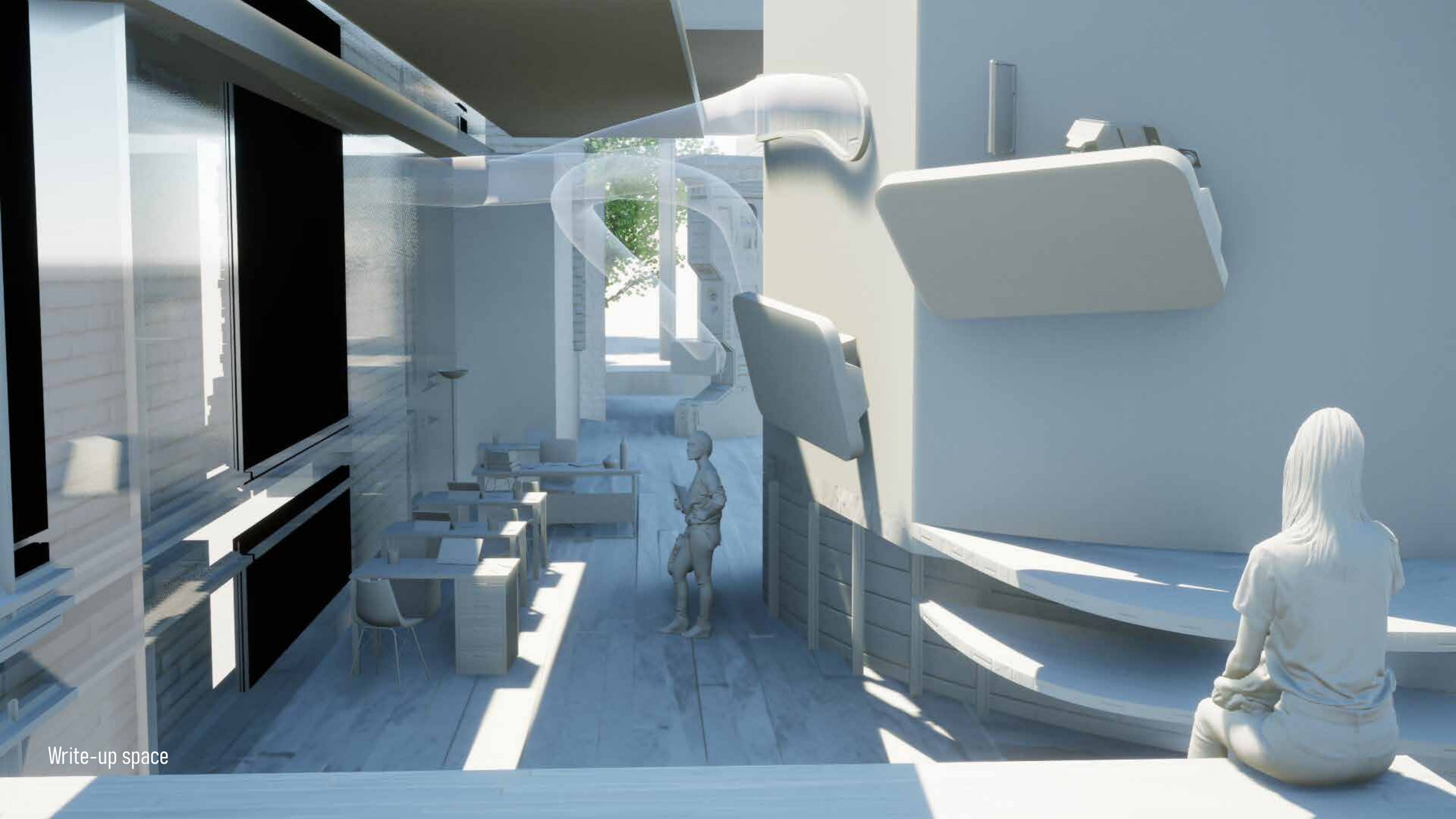
W

Preserved heavyweight wall construction
New wall construction
Glazing

1 Lecture hall
2 Community kitchen
3 Workshop
4 Exhibition
5 Nuclear battery
6 Plant room
7 Wet lab
8 Dry lab
9 Write-up space
10 Consultation room
11 Office
12 AHU units
13 Wet lab
14 Dry lab
15 Consultation room
16 Storage
17 Workshop
18 Pop-up labs
19 Pop-up labs
20 Special lab
21 Cafe
22 Cafe
23 Write-up space
24 Lift 2
25 Library
26 Workshop
27 Residential building

Harlech Institute of Cancer and Care Research
Long Section
A1 1:200

S



Write-up space

Community kitchen

In-vivo imaging room

Entrance to cell culture room

Dry lab leading to pocket gardens

Care centre - onsultation room

Walking from the sea