Progressing Studio Sustainability

BRITISH FILM COMMISSION

Contents

Foreword

In a world facing the increasingly detrimental impacts of climate change, our industry has a key role to play in ensuring that each sector is taking steps to reduce or nullify its overall impact on the environment.

For our studio and Stage space sector, much is already being done. However, there is limited published design guidance on how developers can reduce the carbon footprint of studios. While several industry bodies have published relevant information, it has often not been specifically relevant to feature film and high-end TV needs.

So, to complement these efforts, the British Film Commission team has conducted detailed research, engaging with industry stakeholders, to develop this Sustainability Guidance. The guidance aims to support studio developments and operational teams, highlighting areas and solutions that investors and operators may wish to consider for existing and new developments. They are not one-size-fits-all manuals: we recognise that each site is different, and some of the proposed solutions may not be relevant for each studio or Stage space. Rather, the information in this guidance provides options, a range of variables against which studio developers can set their own specifications in their efforts to tackle climate change.

For existing studios, this guidance can play an important part in determining refurbishment processes or retrofit solutions. For new studio and Stage space developments, key findings put forward options that can reduce a development's carbon footprint. In either case, we hope these guides will provide baseline guidance to help in developing studios and Stage space to the latest and most impactful environmental standards.

I'd like to congratulate all the teams who worked so assiduously to bring this guidance together: Alistair Weir and James Hackett at PRP Architects, Miles Attenborough and Cornelius Kelleher at AECOM and, of course, the British Film Commission team, in particular Jeremy Pelzer and Celie Hanson. I'd also like to thank our principal funders, the Department of Culture, Media and Sport and the BFI, without whose support this report would not have been possible.

We truly hope this guidance supports your development, and the UK's world-leading studio and Stage space sector, to become exemplars of environmental sustainability.

Adrian Wootton OBE
Chief Executive
British Film Commission

Progressing Studio Sustainability

Existing Infrastructure

BRITISH FILM COMMISSION

Introduction

Overview

This guidance has been produced to summarise sustainability research undertaken on behalf of the British Film Commission (BFC), to support film studios and operators seeking to achieve enhanced energy targets and net zero emissions ambitions.

Proposals herein have been identified as commonly relevant to film studios. A 'living' document, this guide has been conceived as a 'base line', where additional measures or solutions are welcome, and may be incorporated periodically to develop a more comprehensive resource for the sector.

Evaluations have been made on those applications more commonly controlled or managed by studio operators; achievable site-specific opportunities including but not limited to control systems, building envelopes and façades, heating and cooling, water supplies, etc. Areas have been subdivided into two main categories: 'site-wide' (master planning) and 'buildings' (architecture). These spaces are further divided into applications and solutions. Each solution has been evaluated in relation to its potential benefits and feasibility indicated via scales of Low-High:

Benefits of implementing strategies:
- Reduction of carbon / energy / water / waste
- Impact on well-being of users

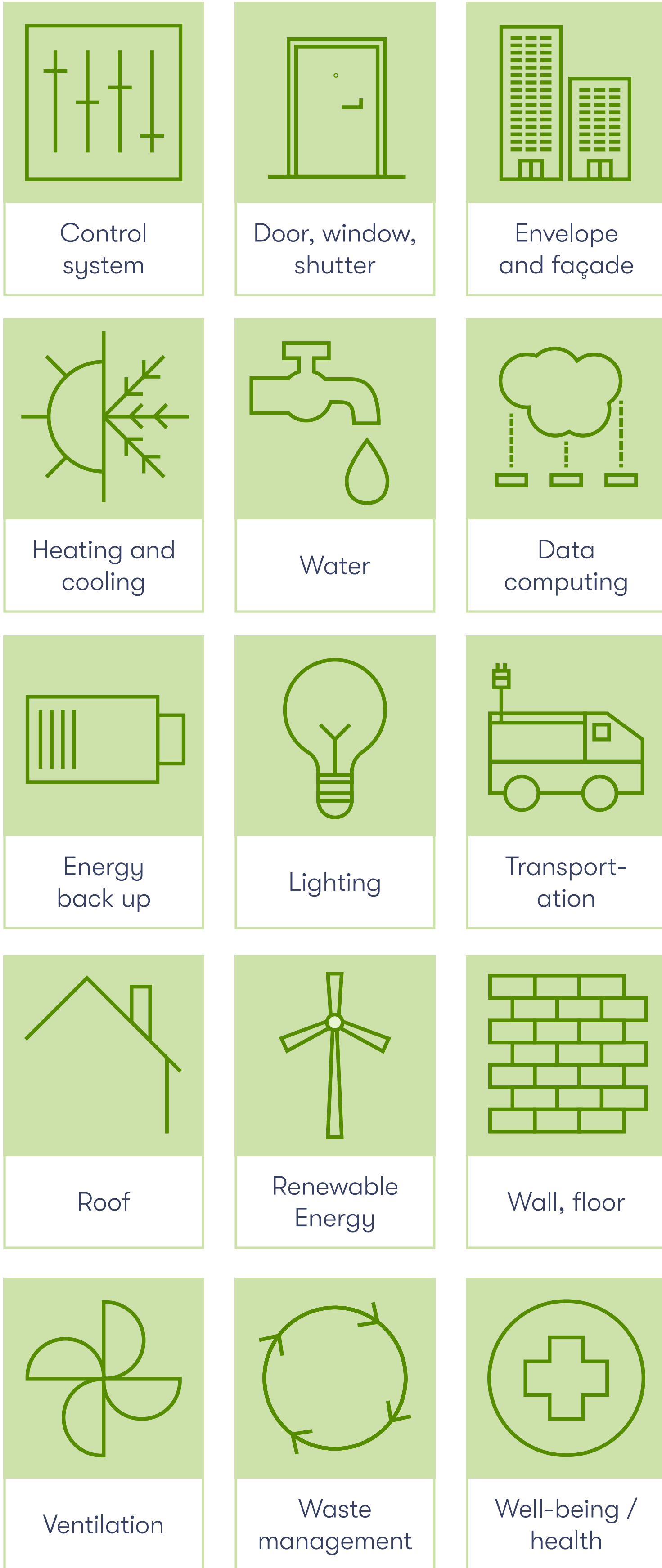
Viability of implementing measures:
- Ease of maintenance
- Technical feasibility
- Timeframe
- Capital cost

Scope

This page illustrates the applications that have been considered. For each application, a list of solutions has been proposed, that may lead to improved energy efficiency and reduction in carbon emissions. Where relevant, some applications have been further sub-divided into different categories, as explained further in the section below.

Production services managed by third parties (ordinarily beyond the control of studio operators), are outside the scope of this guidance and have not been considered. Where relevant, and subject to sector feedback, applications not covered may be considered in future guidance updates.

Applications Considered:



Outside Scope:
Production services
Production departmental activities (including but not limited to):

Catering
Camera, Lighting & Sound
Construction & Art Department
Costume & Wardrobe
Make-up & Hair
Set Decorating & Props
Special Physical Effects
Stunts & Action Vehicles
Visual Effects & Virtual Production

Methodology

As outlined, the scope of this guidance is focused upon measures that may contribute to achieving reductions in energy and carbon emissions for existing studios. This guidance presents strategies under two main subsections, and the applications highlighted in the adjacent diagram:

- Site-wide: this encompasses everything present on the site.
- Buildings: focussing on sound Stages, production support spaces, and ancillary spaces, and referring to everything that involves a building-level strategy primarily focused on the building envelope and services.

Studio sustainability

Studio operations

Outside scope

Production services

Masterplanning
Site wide

Architecture
Buildings

Applications

Outside scope

Production services
Production departmental activities (including but not limited to):

Catering
Camera, Lighting & Sound
Construction & Art Department
Costume & Wardrobe
Make-up & Hair
Set Decorating & Props
Special Physical Effects
Stunts & Action Vehicles
Visual Effects & Virtual Production

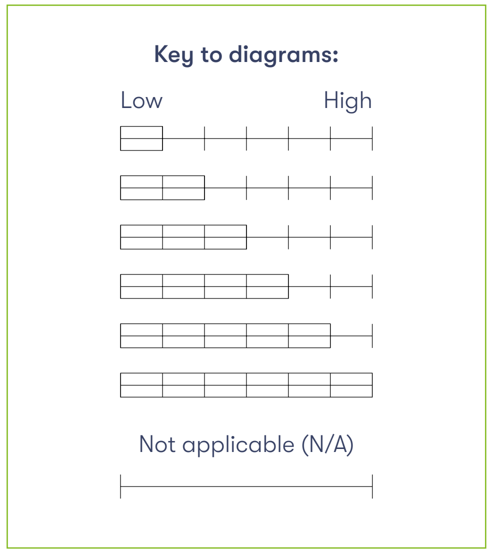
Methodology

A qualitative assessment has been carried out for every strategy.

Preliminary assessments undertaken can vary between buildings based on their shape, conditions and complexity. It is therefore essential to acknowledge that proposals contained herein are for guidance only, and that some solutions may have greater positive and negative impacts.

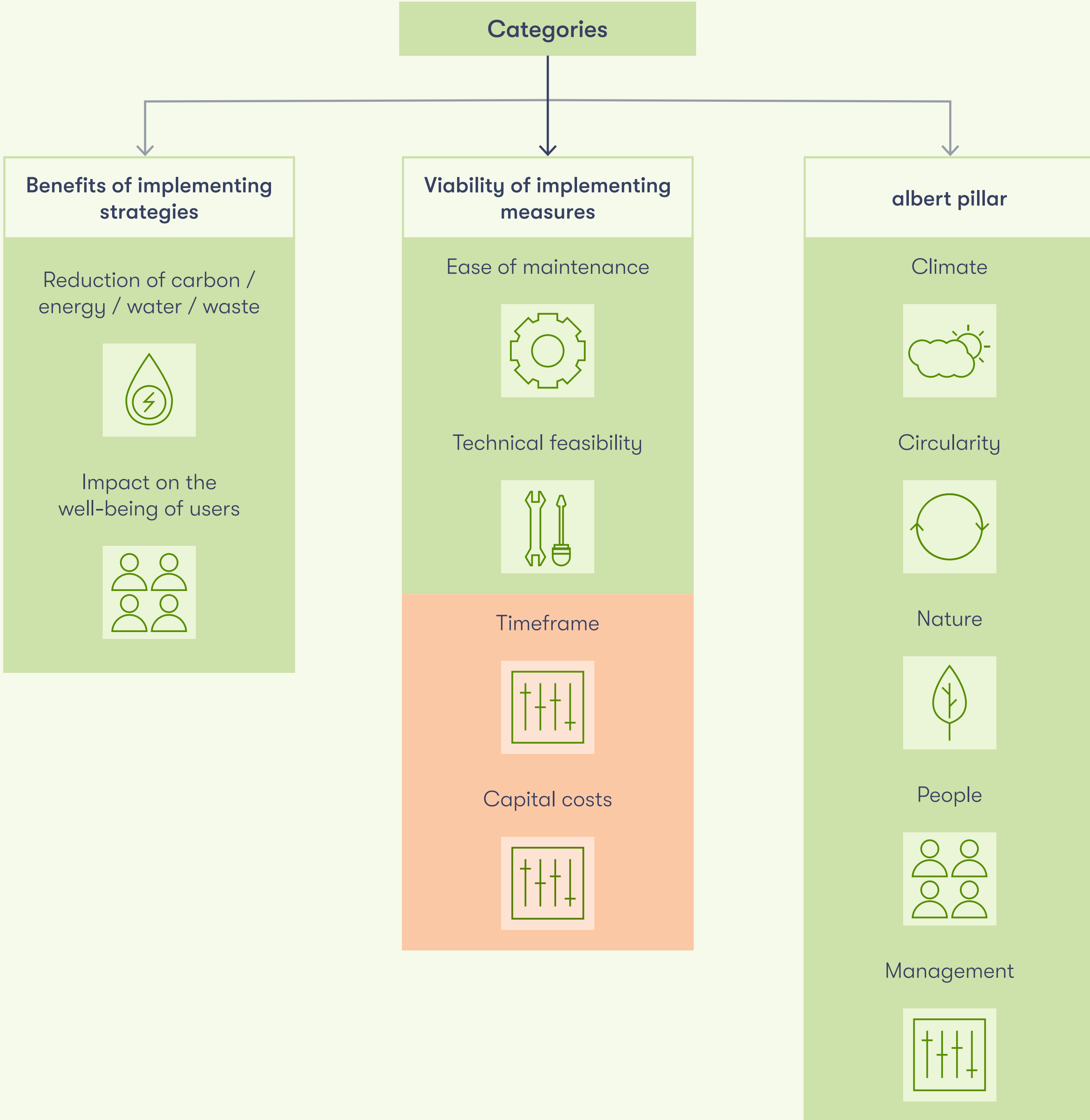
Individual strategies and solutions have been evaluated against six criteria highlighting the benefit and viability of the solution using sliders with Low-High indices. The six criteria are:

1. Reduction of carbon / energy / water / waste
2. Impact on the well-being of users
3. Ease of maintenance
4. Technical feasibility
5. Timeframe
6. Capital costs



The last column of each assessment links the solution with relevant pillars identified within BAFTA albert's Studio Sustainability Standard 2022.

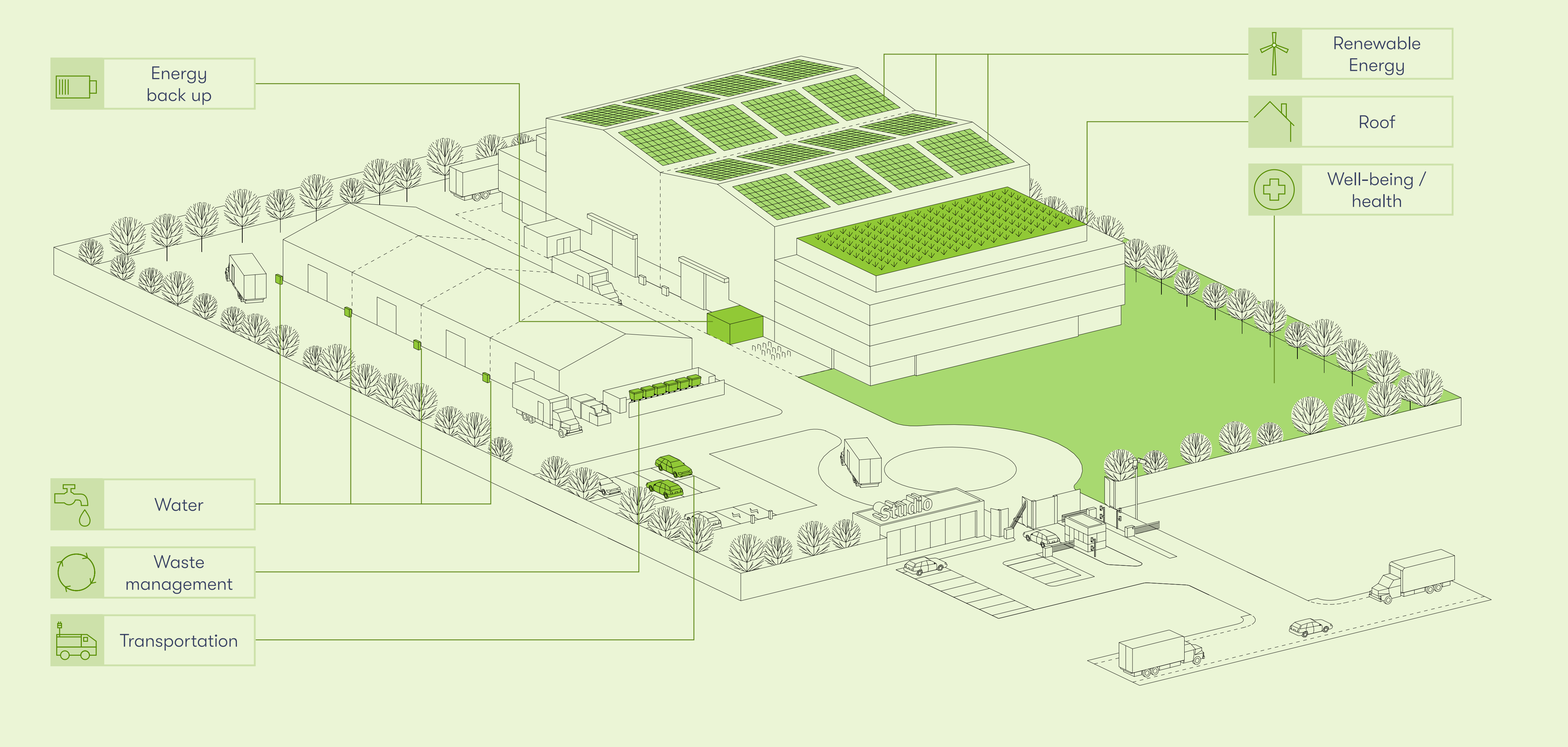
Whilst this guidance does not focus upon management policies and data collation, BAFTA albert stresses the benefits of ensuring studios have policies in place to effectively mandate sustainable ways of working, with supply chain management, environmental targets, sustainability training, local partnerships and independent assurance verification. Studios will benefit from having measures in place that can effectively collect and store the data they require for sustainability and environmental reporting.



Site-wide: Strategies and Solutions

The following section considers potential solutions applicable at a 'site-wide' level, where options may exist for them to be implemented across the whole studio campus.

Brief descriptions accompany each solution to understand how they can be best implemented.



Site-wide:

Control Systems

Smart meter
Smart meters are electronic devices that record electricity consumption on an hourly basis or more frequently, and use a secure smart data network to send the reading to the utility provider automatically.

Water

Air source heat pump water heaters
Air source heat pumps transfer heat from the outside air to an internal water storage tank.

Greywater recycling
Greywater is all the wastewater generated from buildings except wastewater from toilets and kitchens. It involves collecting, treating, storing, and distributing greywater captured using separate plumbing to standard sewage systems and is used, for example, for toilet flushing.

Rainwater harvesting
Rainwater harvesting involves collecting, treating, storing, and distributing rainwater collected from the roofs of buildings for local potable or non-potable re-use, depending on the level of treatment.

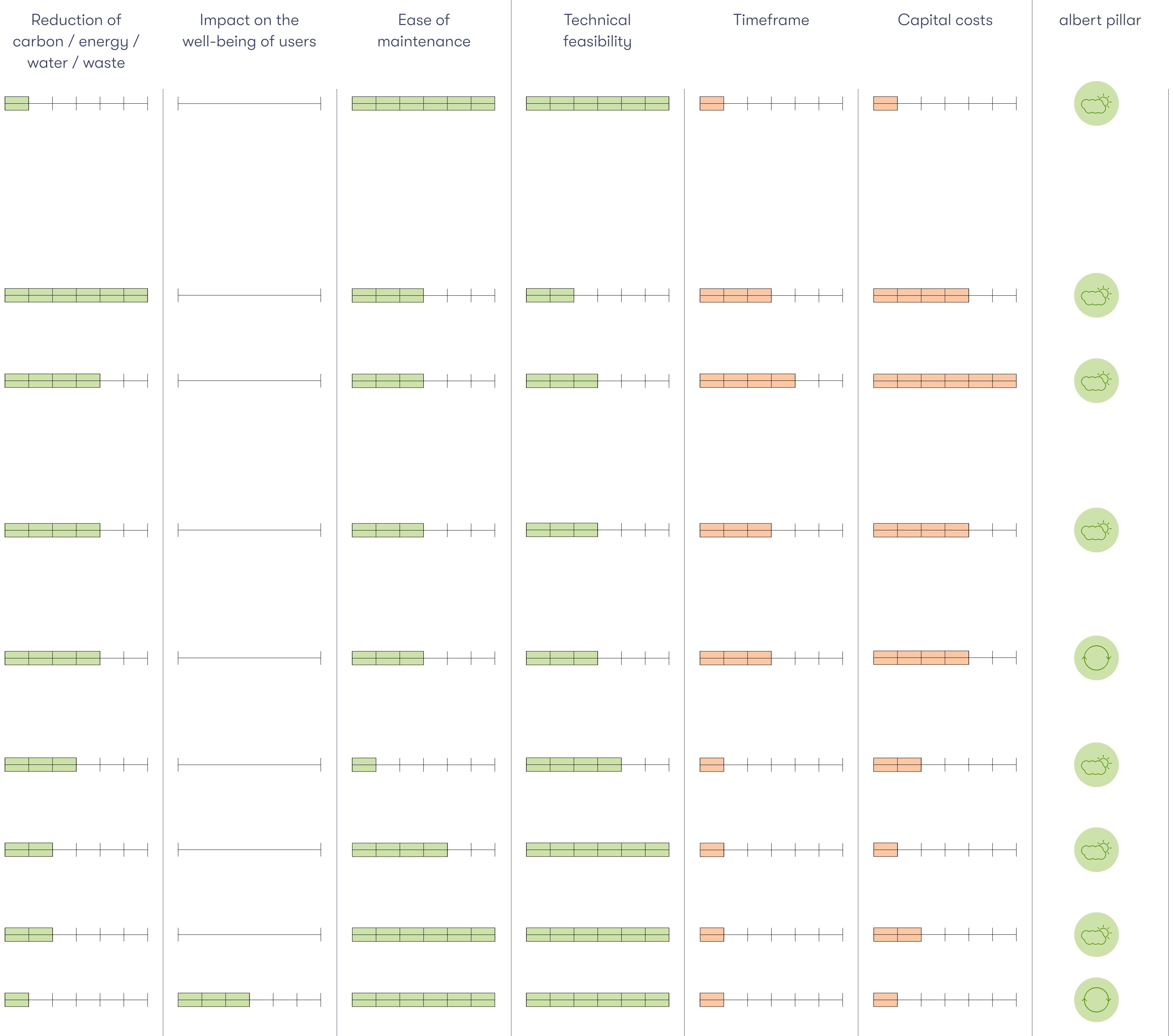
Backlot-Rainwater harvesting
Rainwater harvesting via a water tank located in the backlot. This water can be used to irrigate the green areas and vegetable gardens.

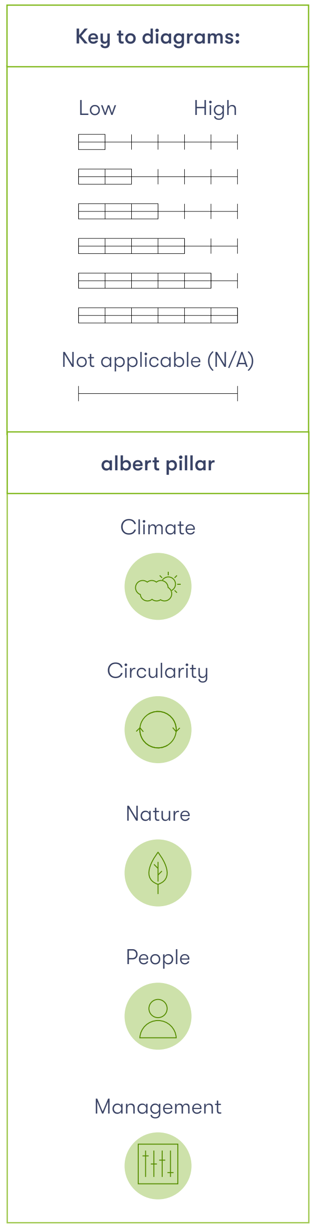
Water Sensors
Sensors to measure water use in Stages / production facilities / showers / toilets.

Water leak detection and low flow fittings
Installation of a water leak detection system and low-flow fittings.

Passive smart water-meter
A smart water meter for tracking water usage and quality.

Water fountains
Installation of water fountains / filtered water dispensers.





Site-wide:

Renewable Energy

Combined solar PV and heat pump
Heat pump powered by an off-grid solar PV system.

PV solar carport
Using the studio car park to deploy PV panels above the parking space.

Small wind turbine
Wind turbines can be installed within a few hours to generate wind energy and reduce energy costs.

Microinverter: self-consumption device of local renewable energy generation
The microinverter is a device that allows any PV panel energy generation to be injected directly into an ordinary wall socket safely and efficiently, lowering £ / W costs and engaging users directly in applying renewable technology solutions.

Energy efficiency modules integrating both energy recovery and passive cooling systems for PV
A disruptive solution that simultaneously addresses PV energy efficiency and the problems created by waste heat in the solar PV industry: i) recycling of waste heat into electricity and ii) passive cooling of the PV device.

Transportation

Electric vehicle charging stations
On-site electric vehicle charging stations.

Waste Management

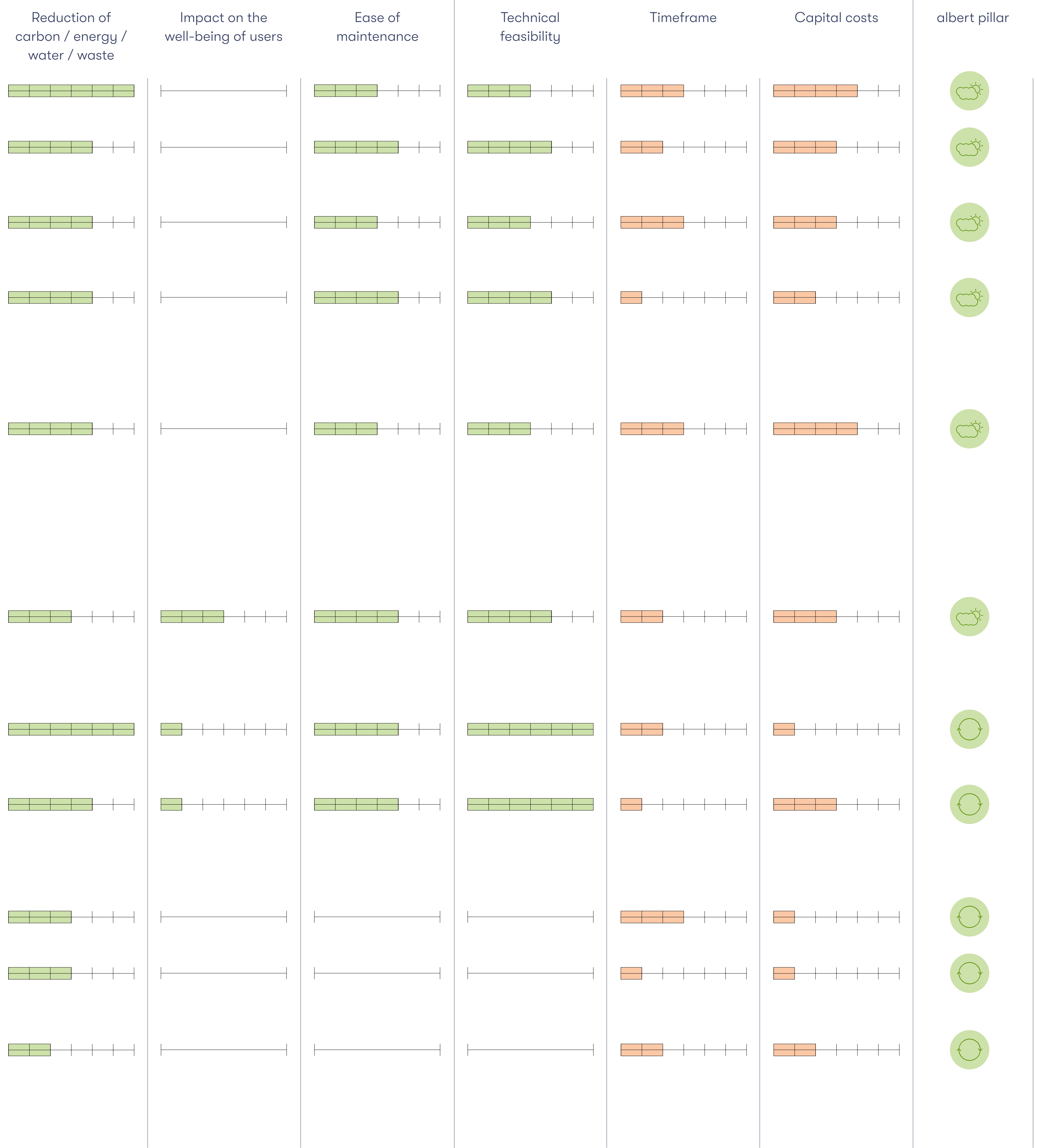
Segregated recyclable waste streams
To increase the quality of recycling collected from the premises and help avoid contamination.

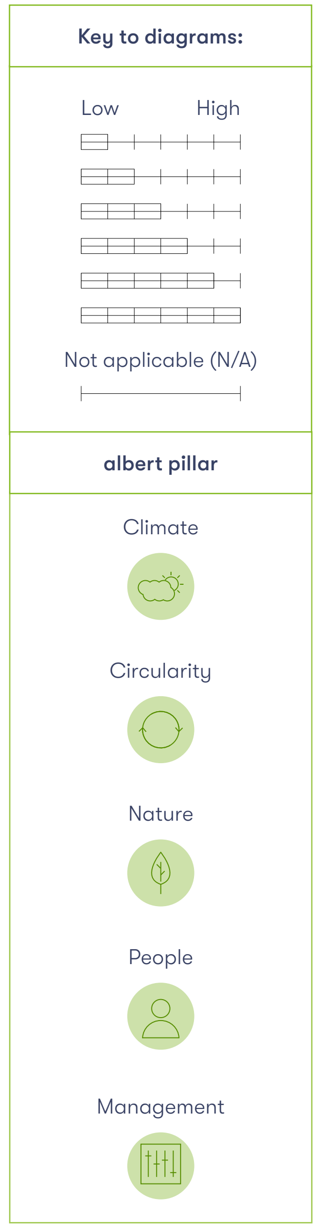
Studio waste contractor
Measures in place and incentivised for the studio waste contractor to handle production waste or provision of a production waste contractor with a minimum of 3 segregated waste streams for collection, e.g., metal, wood, cardboard.

Site-wide policy in place for zero waste to landfill
Site-wide policy in place for zero waste to landfill.

Targets in place for site-wide waste recycling
Targets in place for site-wide waste recycling, which should aim to be at least 50%.

Monthly waste data
Provision of monthly waste data on total waste volumes and recycling rate by a waste contractor.

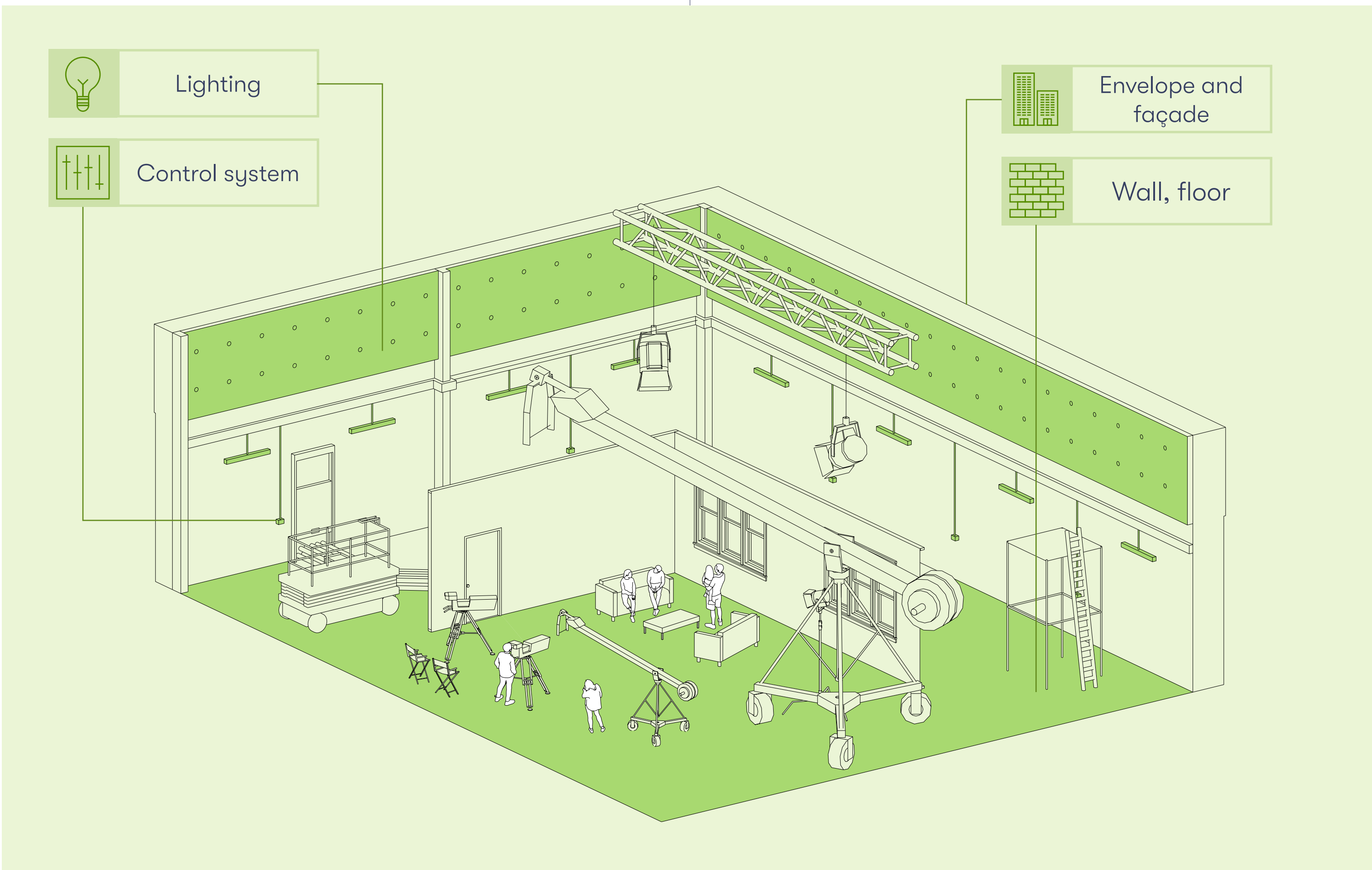




Buildings: Strategies and Solutions

The following section considers potential solutions that may be implemented within specific buildings, focussing on sound stages, production support spaces, and ancillary spaces.

Brief descriptions accompany each solution to understand how they can be best implemented.



Sound Stages:

Control Systems

HVAC smart thermostat
Programmable thermostats allow full control schedules for HVAC operation and can include self-learning algorithms, predictive building controls, occupant level controls, and thermal zoning.

Demand response control systems
Time-controlled studio systems for lighting, heating, and air-conditioning.

CO2 sensor
Carbon dioxide (CO2) monitoring sensor to adjust the ventilation flow. Increased level of CO2 decreases the well-being of workers and reduces their productivity.

Advanced lighting control system
Advanced daylighting systems include a wide variety of controls to optimise the use of LED systems by switching off / reducing lighting when it is not necessary. The system can also adjust electrical input depending on natural daylight.

Data Computing

Power wall charger for batteries
Provide for production staff; a power wall charger for batteries with the capacity of switching on standby mode when all the batteries are charged.

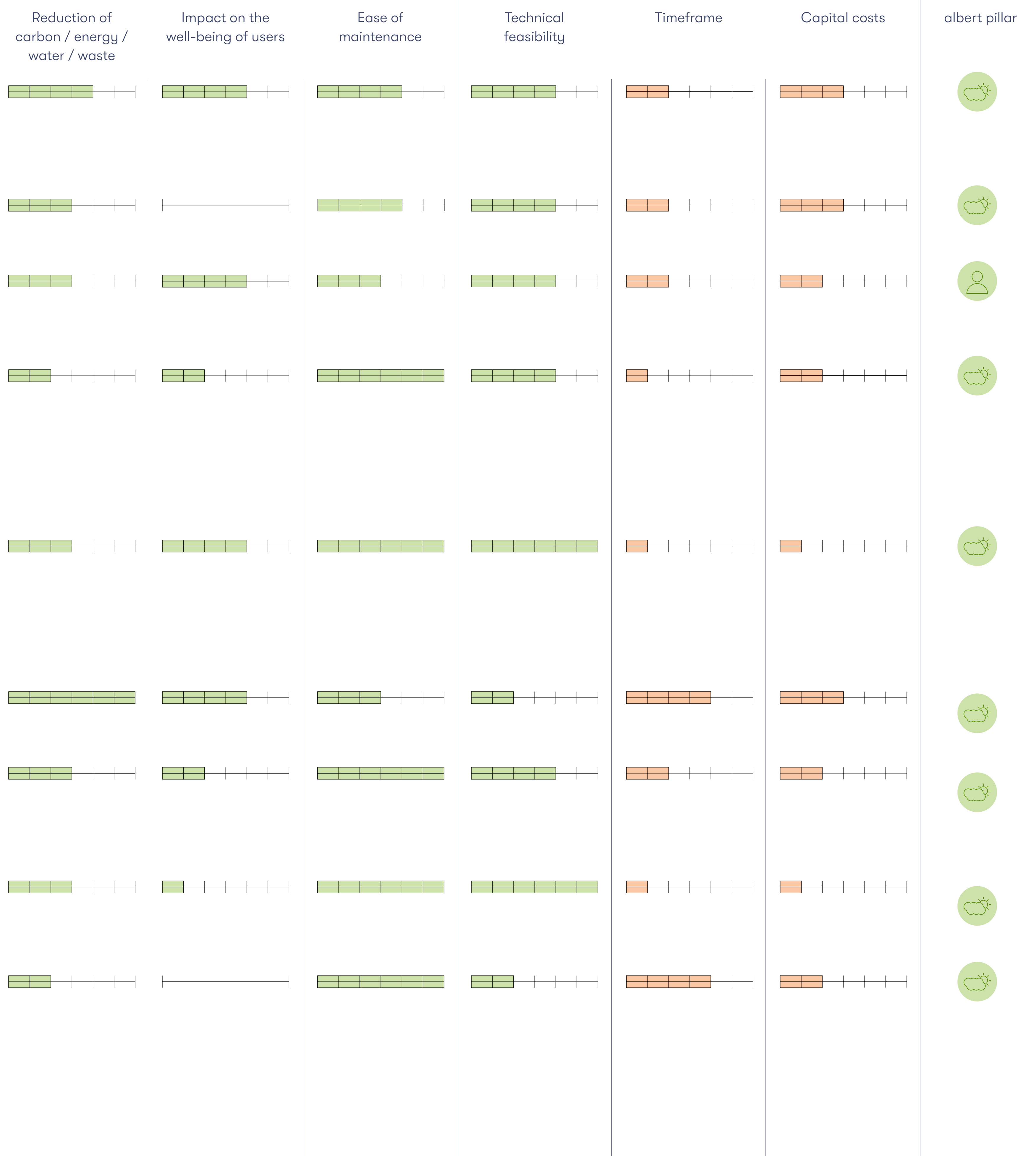
Envelope

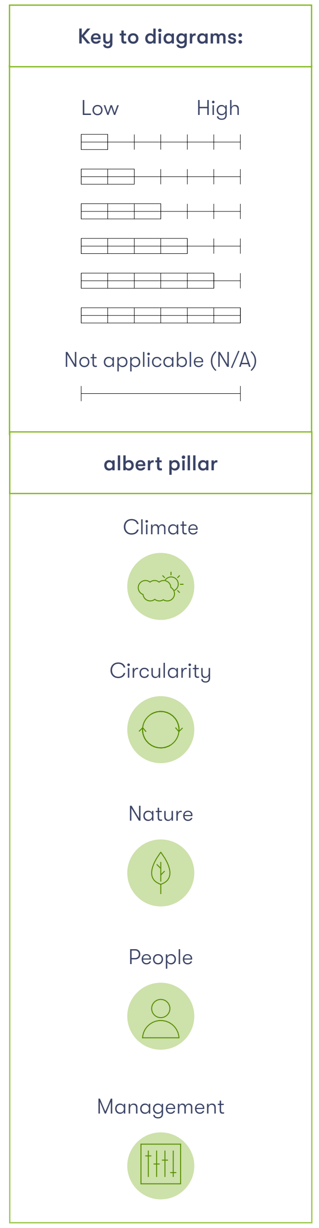
Building retrofit
Prioritise retrofit over new build to reduce embodied greenhouse gases.

Air sealing
Systematic sealing of air leakages throughout the building surface (particularly around cracks, small holes, plumbing, wiring, lighting, and ductwork) reduces heat loss and enhances indoor environment control.

High reflectivity paint
Paints that provide the same visible colour range as standard products but exploit the infrared spectrum to reflect a greater part of the solar irradiation spectrum.

Structural insulated panels
Structural insulated panels consisting of oriented-strand board each side of an insulating core.





Sound Stages:

Energy Back-Up

Maintain filters, ventilation and air conditioning (AC)
Ensure regular maintenance of HVAC systems to reduce energy consumption and extend equipment lifespans.

Heating and Cooling

Air-to-air heat pump (state-of-the-art)
Transfer heat energy from a colder space to a warmer one, providing heating or cooling (using outdoor air or indoor air as a source of heat) using a vapour compression refrigeration and a refrigerant system.

Integrated heat pump with storage for cooling
Integrated packages provide cooling and storage, combined with a specific control strategy.

Ground-source heat pump > shallow
A heat pump transfers heat to or from the ground to provide cooling or heating; it is more energy-efficient than airsource heat pumps, especially in winter, as the underground temperature does not drop as much as other heat sources.

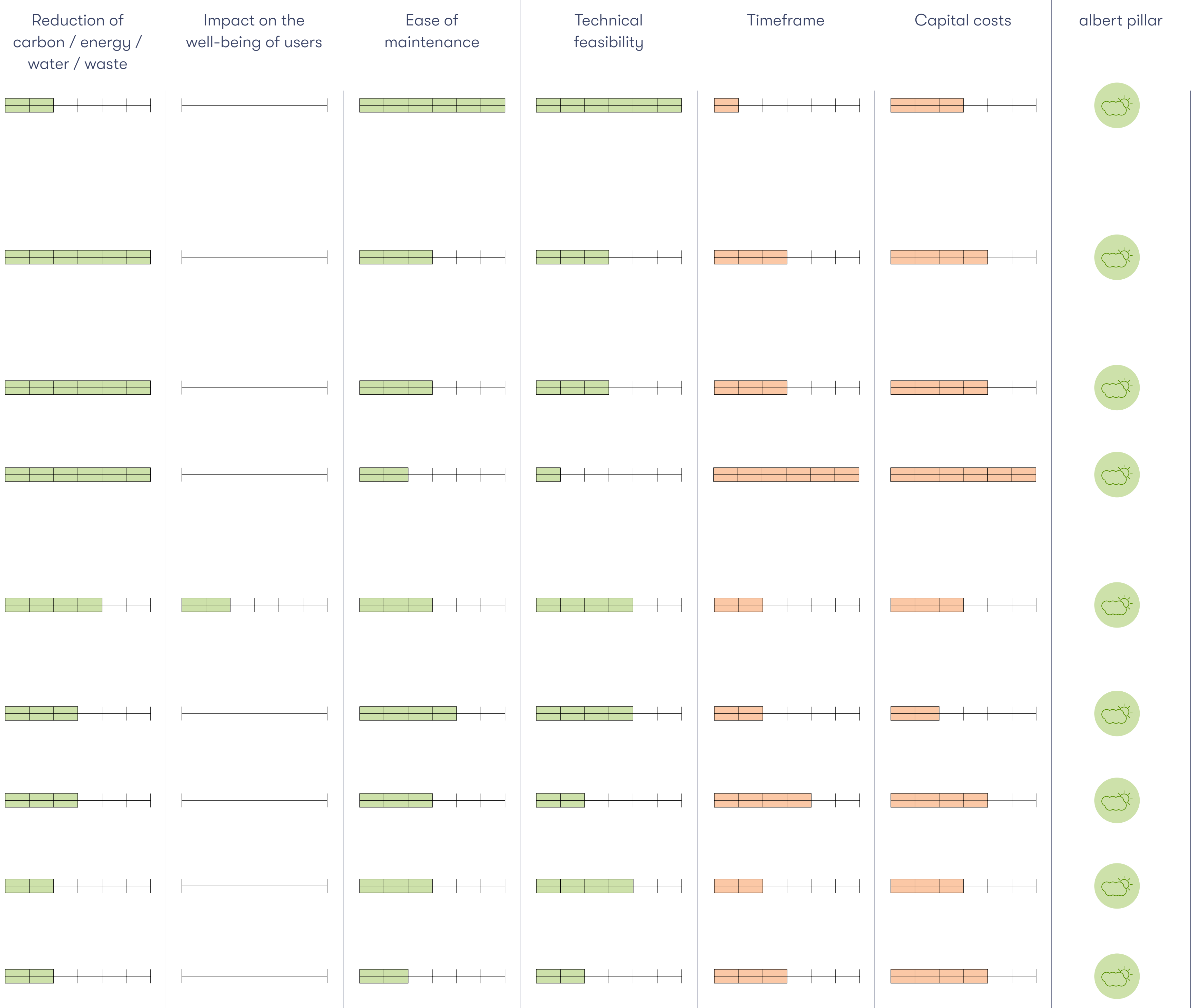
Low global warming potential (GWP) refrigerants
Prioritise coolants with less Global Warming Potential (GWP). Use R32 refrigerant, to achieve a greater reduction in CO_2 emissions.

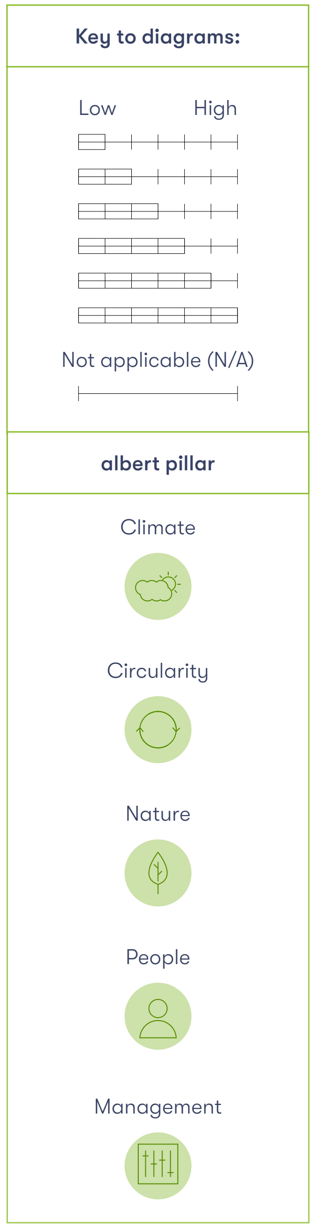
Heat recovery
Heat recovery between Stage and ancillary area ventilation systems.

Solar thermal water heat pump - flat panels
Water-to-water heat pump, transferring heat to or from a thermal storage tank to provide cooling or heating.

Vapour compression split air conditioners
This uses vapour compression refrigeration and a refrigerant system to remove heat from a space and provide cooling.

Standalone liquid or solid desiccant cooling
This is used to pre-cool the environment, recovering both latent and sensible heat. Integrated pieces of equipment to be coupled with air conditioners or evaporative coolers. Uses both electrical and thermal energy.





Sound Stages:

Renewable Energy

Building integrated photovoltaic systems
Photovoltaic systems (e.g., panels, cells, or other products) are integrated into the building envelope.

Passive radiative cooling
Metamaterial film that provides cooling without needing a power input. It uses passive radiative cooling to dissipate heat from the object it covers. It emits the energy as infrared radiation and reflects solar light. Applying the film directly on the roof could save more than 30% of air conditioner energy.

Roof

Radiative reflective roof
Sky-facing surface with optical and thermal properties for dissipating terrestrial heat to outer space.

Green roof
Green roof in 3 layers (grass, high grass, trees) for the purposes of bio-diversification, to absorb pollution, reduce AC needs and improve the well-being of employees and production staff.

Wall, Floor

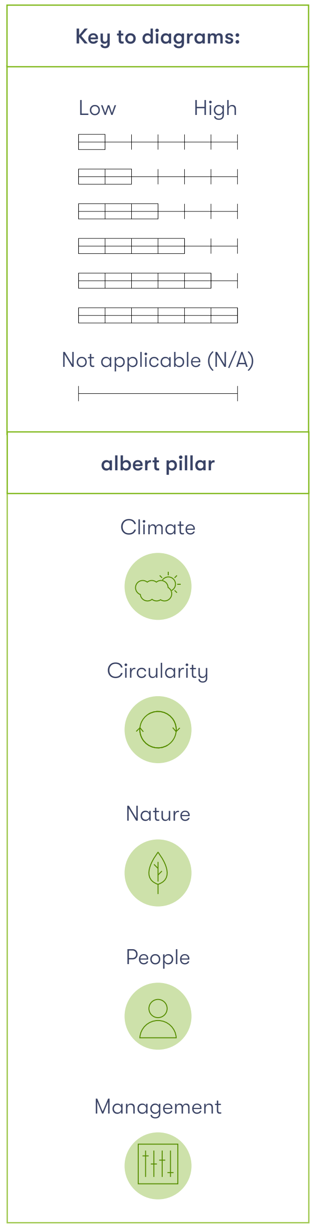
Upgrade existing building envelope
Retrofit / upgrade fabric performance using appropriate products that can achieve building regulation targets and energy efficiency standards.

Water

Fill water tanks via grey water recycling
Use the greywater recycling of the site to fill the water tank.

Switch off the water heating
Switch off the water heating at night and on weekends.

Reduction of carbon / energy / water / waste | Impact on the well-being of users | Ease of maintenance | Technical feasibility | Timeframe | Capital costs | albert pillar



Production Support Spaces:

Door, Window, Shutter, Glazing

Highly insulating window
Window with a minimum U-value of U-1.2 W/(m^2·K) and low emissivity coating, well-insulated double glazed and sealed assemblies, and low conductivity frames.

Insulation glass coating
Low emissivity film is applied to the interior side of windows or to the external window frame to allow or prevent heat gains depending on building energy needs.

Passive responsive shading system
This is powered by air that is sensitive to solar exposure. When exposed to solar radiation, the air inside the unit heats up, expands, and forms pressure that opens the shutters. When this reduces, the air cools, and the shutters close.

Electrochromic fenestration
The window can change transmittance, solar heat gain coefficient and visible transmittance, energised by electrical current.

Thermochromic fenestration
Passive modification of properties in terms of thermal transmittance, solar heat gains coefficient and visible transmittance due to a temperature change.

Smart solar blind
Shading and solar energy generation with the smart solar blind. This retrofit solution can save up to 30% on the electricity bill. Energy generated can be sent to the grid or the energy storage system.

Heating and Cooling

Minimise AC use
Use fans and natural ventilation to minimise AC use. When AC is on, be sure to keep doors and windows closed.

Phase change materials (PCM)
Integrate PCM in the ceiling of a room to alleviate cooling needs passively. It can be based on aqueous salt solutions, salt hydrates and paraffins, fatty acids, sugar alcohols, salt, or liquid-gaseous.

	Reduction of carbon / energy / water / waste	Impact on the well-being of users	Ease of maintenance	Technical feasibility	Timeframe	Capital costs	albert pillar
Highly insulating window	3	1	4	3	3	3	Climate
Insulation glass coating	2	1	4	3	3	3	Climate
Passive responsive shading system	4	3	2	1	4	4	Climate
Electrochromic fenestration	3	2	3	2	3	4	Climate
Thermochromic fenestration	3	2	3	2	3	4	Climate
Smart solar blind	3	5	3	3	3	4	Climate
Minimise AC use	4	3	6	6	1	1	Climate
Phase change materials (PCM)	2	1	1	1	4	4	Climate

Key to diagrams:

Low High

Not applicable (N/A)

albert pillar

Climate

Circularity

Nature

People

Management

Production Support Spaces:

	Reduction of carbon / energy / water / waste	Impact on the well-being of users	Ease of maintenance	Technical feasibility	Timeframe	Capital costs	albert pillar
Lighting							
Fibre-optic daylighting Fibre-optics combined with solar light collectors to transmit natural daylight in zones which are usually difficult to design for natural daylighting.	3/6	5/6	6/6	4/6	2/6	3/6	Climate
Renewable Energy							
Integrated roof wind energy system An energy generation system, roof-mounted, with an internal turbine making smart use of aerodynamics.	4/6	N/A	3/6	3/6	3/6	3/6	Climate
Ventilation							
Natural ventilation Supplying fresh air to an indoor space without the support of a mechanical system by exploiting pressure differences between inside and outside the building.	6/6	5/6	6/6	3/6	3/6	3/6	Climate
Dual flow ventilation Heat exchange between incoming air and exhaust streams.	3/6	N/A	4/6	4/6	2/6	3/6	Climate
Wall, Floor							
Transpired solar heat collectors A perforated wall panel that draws the air heated by the sun through perforations into a cavity. Heat calories are then driven into the building's ventilation system during cold days and ejected directly into the atmosphere during warm days.	3/6	1/6	3/6	2/6	4/6	4/6	Climate
Funicular floor system A funicular floor is a thin concrete element consisting of vaults and optimised stiffening fins. The thickness of the slab and fins is no more than 20 mm, which allows 70% of the concrete to be replaced by low-density insulation materials to improve the thermal performance of the floor.	2/6	1/6	6/6	3/6	4/6	4/6	Climate
Water							
Fill water tanks via grey water recycling Use the greywater recycling of the site to fill the water tank.	4/6	N/A	3/6	3/6	3/6	4/6	Climate
Switch off the water heating Switch off the water heating at night and on weekends.	1/6	N/A	6/6	6/6	1/6	1/6	Climate

Key to diagrams:

Low — High

Not applicable (N/A)

albert pillar

Climate

Circularity

Nature

People

Management

Ancillary Spaces:

Control Systems

Reduce heating and cooling, raise ventilation
Adaptation to specific HVAC needs.

Heating and Cooling

Destratifier to improve heating efficiency (high ceilings)
The purpose of a destratifier is to move the air from the fan located at the top down to the floor. The large volume of airflow ensures perfect air circulation without draught.

Water

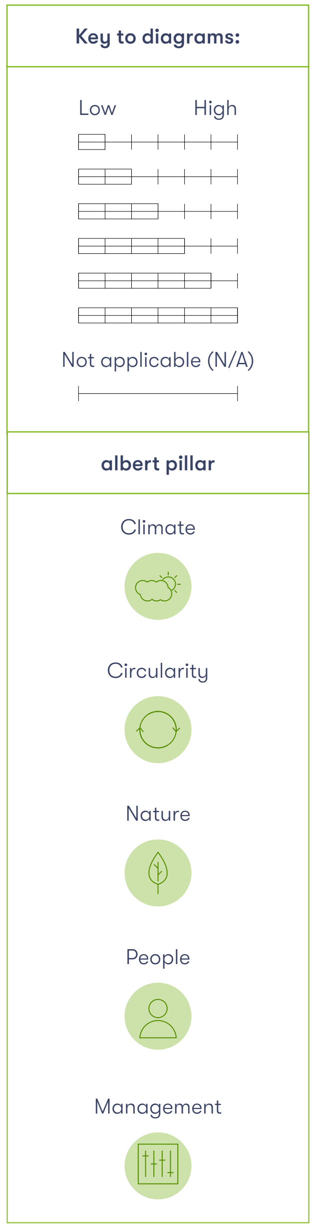
Fill water tanks via grey water recycling
Use the greywater recycling of the site to fill the water tank.

Switch off the water heating
Switch off the water heating at night and on weekends.

Well-Being / Health

Workshops - On-site sensor for air quality monitoring
Advanced air quality monitoring devices.

Workshops - Photocatalytic paint for air purification
Functional paint for indoor / outdoor air purification mainly degraded VOC and Particulate Matter (PM).



Progressing Studio Sustainability

New Developments

Introduction

Background

Film studio developments, while having some similar features to conventional industrial and commercial buildings, are bespoke to the specific needs of the Feature Film and High-End Television (FFHETV) sector. As historically film studio development has only made up a small proportion of new building construction in the UK, there is limited published guidance on design, in particular the '**Stage**[1]' spaces within which filming takes place, and the practical measures that film studio developers can take to reduce their carbon footprint.

In the face of the global climate emergency there is growing pressure from local planning authorities, investors, producers and commissioners to reduce the carbon emissions associated with new film studios and the productions they support. As new Stage space within the UK is predicted to increase, the British Film Commission has undertaken this research to establish low-carbon and energy-efficient approaches to Stage design and construction.

It is estimated that for all new developments globally between now and 2050, half of the cumulative CO_2 emissions in that period will have been emitted prior to occupation (i.e. during the phases of development and building construction). As operational energy efficiency improves, embodied carbon emissions have become an increasingly large proportion of lifecycle CO_2 emissions.

As well as mitigating climate change by reducing greenhouse gas emissions, statutory targets are increasingly focused on creating developments that are resilient to the unavoidable impacts of climate change. In the UK these include more intense storm events with increased risk of flooding, drier summers with increased risk of drought and the more regular occurrence of summer heatwaves that will increase the risk of overheating and discomfort in our buildings.

The building and construction sector have become increasingly aware of the importance of embodied carbon and finding solutions to reduce its impact. Until recently, there has been little mandatory requirement to assess or reduce the embodied carbon of new Stage developments at the national or regional level. Therefore, embodied carbon calculations have been typically undertaken on a voluntary basis.

Professional groups and industry bodies have published a variety of guidance documents and set recommended carbon targets for a range of building typologies. Though these guidance documents are useful, the targets and benchmarks typically relate to domestic, commercial office or educational buildings and are, therefore, unlikely to be relevant to FFHETV Stages which have their own unique requirements.

To complement established industry initiatives for the FFHETV sector (including the Green Production Guide toolkit developed by the Producers Guild of America, and BAFTA albert's Sustainable Studio Standard in the UK), the British Film Commission (BFC) has undertaken a programme of research that includes:

- fact-finding and engagement with studio operators, developers, production companies and film industry technology providers to understand current studio requirements and practice.

- the comparison of the embodied carbon of alternative approaches to Stage construction, in particular wall system and structural solutions, but also exploring more sustainable lower embodied carbon alternatives to materials commonly used in Stage design.

- the assessment of low-carbon servicing strategies for a modern FFHETV production space.

- the comparison of carbon emissions for alternative all-electric heat pump supply options, including a comparison of individual building and campus-wide strategies.

This guide provides a high-level summary of the findings of this research.

[1] Throughout this guidance, reference to Stage(s) are to bespoke built structures, primarily used for the specialist purposes of set-construction and filming activities; in particular, though not¬ limited to, buildings designed as 'sound Stages', incorporating qualities and materials to achieve required levels of sound attenuation and reverberation control for use by the FFHETV sector.

→ Reducing Embodied Carbon in Stages

Introduction

There is limited published guidance on the practical measures film studio developers can take to reduce their carbon footprint. As new Stage space within the UK was predicted to increase, research was needed to establish carbon-efficient approaches to new Stage design and construction. The research undertaken on behalf of the British Film Commission sought to:

- quantify the embodied carbon of contemporary FFHETV Stage construction methods and materials;
- identify opportunities for reducing this;
- understand the cost implications of adopting alternative options that meet the specific functional and performance requirements of a Stage.

This section of the report begins by outlining embodied carbon definitions to inform the analysis of the research results that follow. The research looked at the design requirements of a typical modern FFHETV Stage as a starting point for establishing alternative, equivalent structural, acoustic and façade options using materials with lower embodied carbon to reduce environmental impacts. It then focussed on a material substitution analysis before outlining the impact of site selection and master planning, design specification and procurement on embodied carbon emissions together with relevant cost comparisons.

The research approach was iterative and undertaken by a multidisciplinary team of building consultants alongside embodied carbon experts, supported by an independent FFHETV industry advisor.

While this report summarises key findings, the full research is available upon request via the British Film Commission.

Embodied Carbon Definitions

Embodied carbon is the sum of the greenhouse gas emissions that arise in the life cycle stages of a building. This includes during its manufacture, construction, maintenance and replacement of building components while the building is in use as well as the dismantling and waste processing at the end of life of the building. The greenhouse gas emissions are expressed by mass in terms of Carbon Emission equivalent ($kgCO_2e$). Embodied carbon excludes the operational energy use associated with running the building's services and the equipment in the building.

Current approaches to measuring embodied carbon in the built environment typically refer back to 'lifecycle stages' or 'modules' defined in the British Standard as

- Module A1 to A5 - The Product and Construction stage
- Module B1 to B5 - The In-Use stage
- Module C1 to C4 - The End of Life stage.

There is general industry agreement on how carbon sequestration (the removal and long-term storage of CO_2 from the atmosphere) in biomaterials such as timber and other construction materials should be accounted for to reflect the whole picture, including the carbon sequestered during growth and the potential release of carbon at end-of-life. For the purpose of this report, embodied carbon is assessed as follows:

- Structural and Façade analysis is reported on the basis of life cycle stages A-C and **includes** sequestration as the end-of-life emissions are accounted for in stage C.

- Materials procurement options were assessed on the basis of life cycle stage A only and therefore **exclude** allowance for sequestration.

Structural Analysis

The analysis of a range of structural design options for a long-span frame, which is typical of a Stage, demonstrated that it was possible to significantly reduce CO_2 emissions. Parametric modelling assessed the impact of different span lengths on the embodied carbon of equivalent steel and timber trusses.

At shorter spans (24m), there was less difference in the embodied carbon between steel and timber truss options (around 37%). However, at longer spans (60m), the timber truss option showed a significant reduction in embodied carbon compared to the equivalent steel solution which had more than double the embodied carbon. This relationship was similar even with an assumed additional loading for roof-mounted solar PV or green roofs.

Analysis showed that, in all cases, a timber truss offered a clear route to reducing the embodied carbon of a Stage, particularly for those with larger spans. However, it should be noted that further considerations are required in relation to the use of timber within the sub-structure of Stage construction (notably those that relate to fire regulations).

The use of higher-grade S460 steel also reduced embodied carbon compared with S335 steel which has a lower tensile strength.

A-C embodied carbon for a green roof (incl sequestration)

A common 30,000 sq. ft Stage configuration (48m by 60m) was used to assess how other factors influenced embodied carbon.

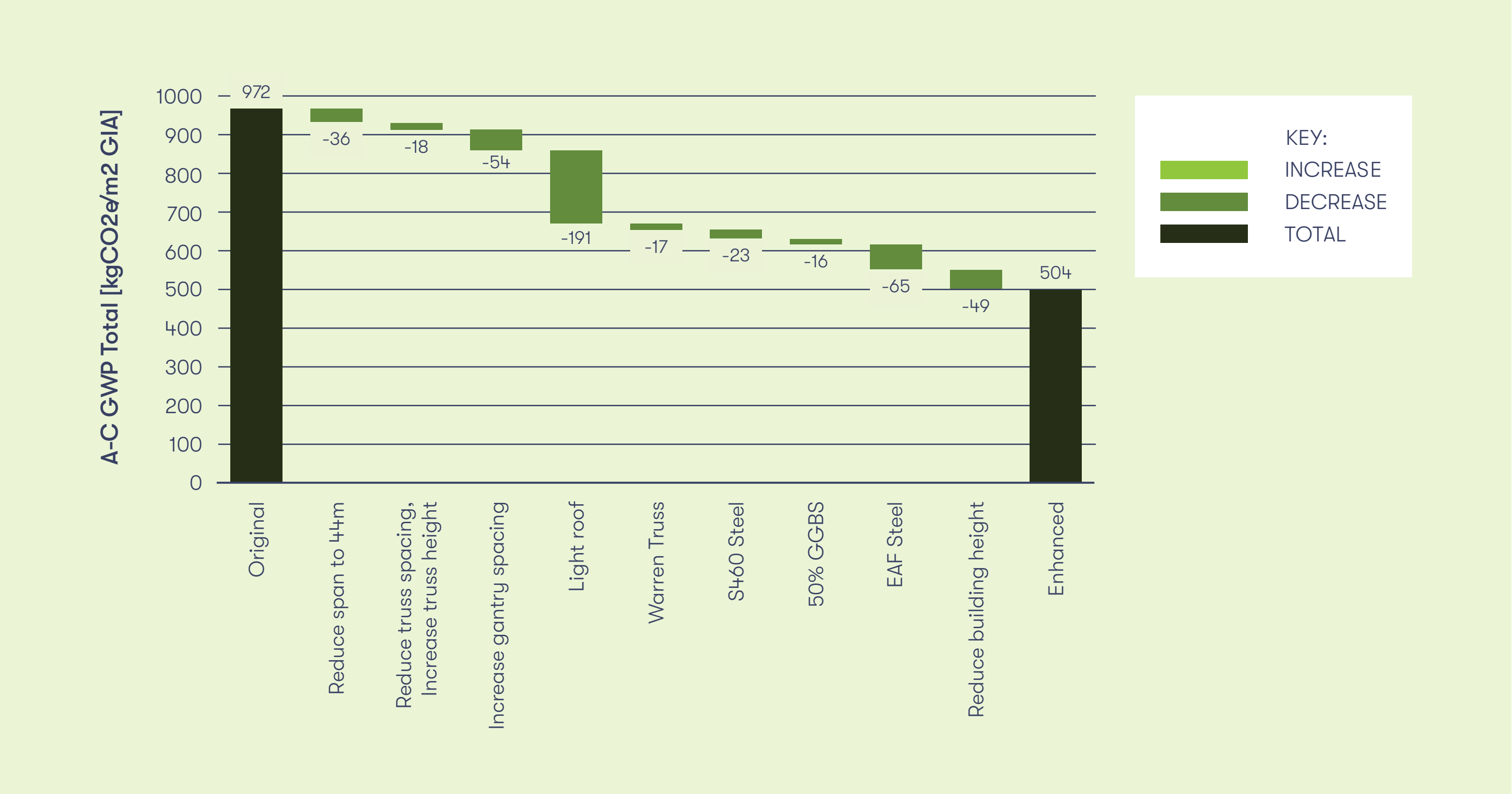
For a 30kN/m2 ground-bearing slab, a site's ground conditions were found to have little impact, however, when loading was increased to 50kN/m², poor ground conditions increased the slab's embodied carbon. Where a suspended slab was required due to poor ground conditions, it significantly increased the embodied carbon in the range of 19%-67%, depending on the rest of the structural solution and whether green roofs or PV were required.

An increase in loading from 30kN/m2 to 50kN/m² for a ground-bearing slab on good ground conditions increased the embodied carbon of the floor slab by between 9%-23%.

Embodied carbon comparison for different slab types, loadings and ground conditions

Other features such as the gantry and runway beam configuration were also found to have an impact on the embodied carbon. This suggests that where operators are prepared to accept a reduced provision, there will be an embodied carbon benefit. Conversely, where these are over-provided there will be a penalty.

Cost and Carbon Comparison for Illustrative Measures
Detailed analysis of alternative truss, roof loading, gantry, height, and material choices identified that a series of incremental changes to the specification and design responses have the potential to deliver a significant reduction in embodied carbon overall. An illustrative example is provided below, which achieved a cumulative 48% reduction in embodied carbon for the substructure and superstructure for a 60m by 48m steel truss Stage with a green roof.



Comparative embodied carbon savings for different specification and performance selections

Comparative build costs impacts on different specification and performance selections

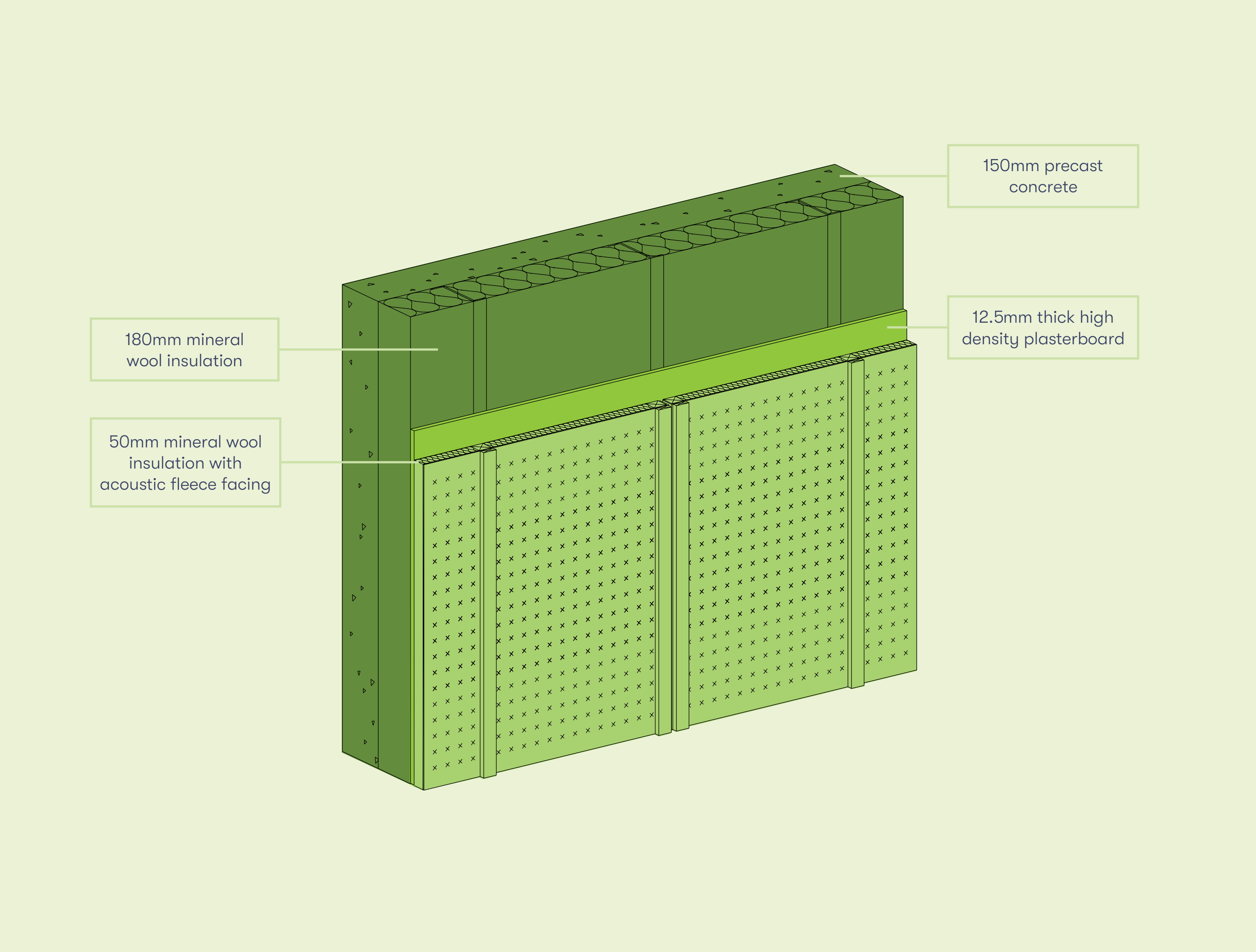
All design changes up to and including the replacement of S355 grade steel with S460 grade steel result in a reduced cost as they reduce the quantity of materials used. However, for some of these measures there is a corresponding reduction in performance and hence utility of the Stage. Increasing gantry spacing from 6 to 12m, reducing the span from 48 to 44m or reducing the clear height from floor to gantry from 18 to 15m may impact adaptability in use and removing green roofs may require flood attenuation and biodiversity net gain to be accommodated in other ways. Warren trusses reduce both embodied carbon and cost compared to alternative truss configurations due to the reduced mass of steel.

Two design changes resulted in an increased cost, namely using 50% GGBS cement substitute in concrete and sourcing steel produced from electric arc (EAF) rather than blast furnaces. These, however, are changes to the material specification rather than the material quantity and for these specific measures there is an additional cost. Despite this, the overall cost per m^2 of a Stage was reduced with these measures.

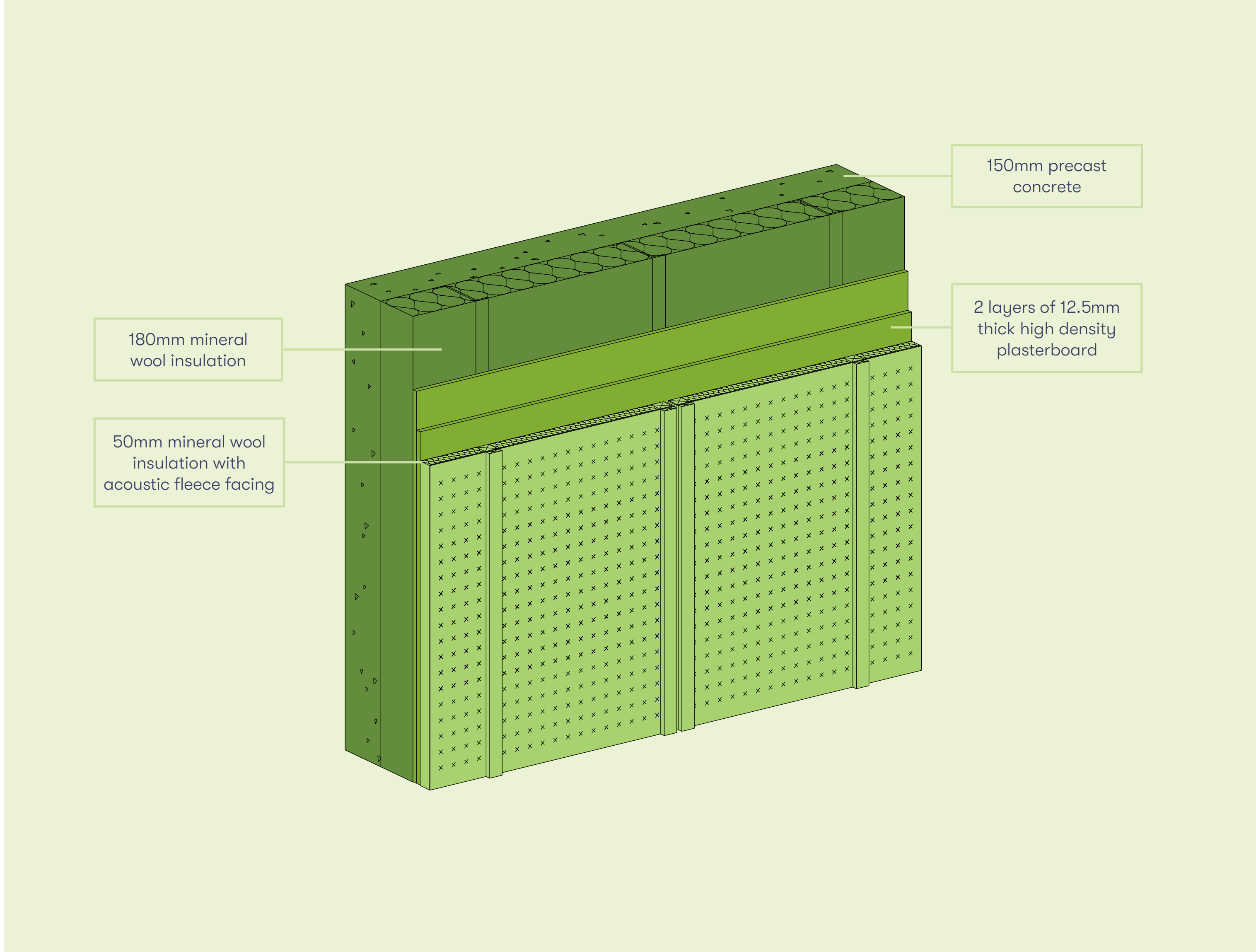
Façade Analysis

The required façade performance of a Stage is heavily influenced by the external acoustic environment, and it must also meet improved thermal insulation standards due to updates to Building Regulations. The following typical façade options were considered and optimised to reflect the embodied carbon emissions associated with low-, medium- and high- noise environments.

A pre-cast concrete wall system

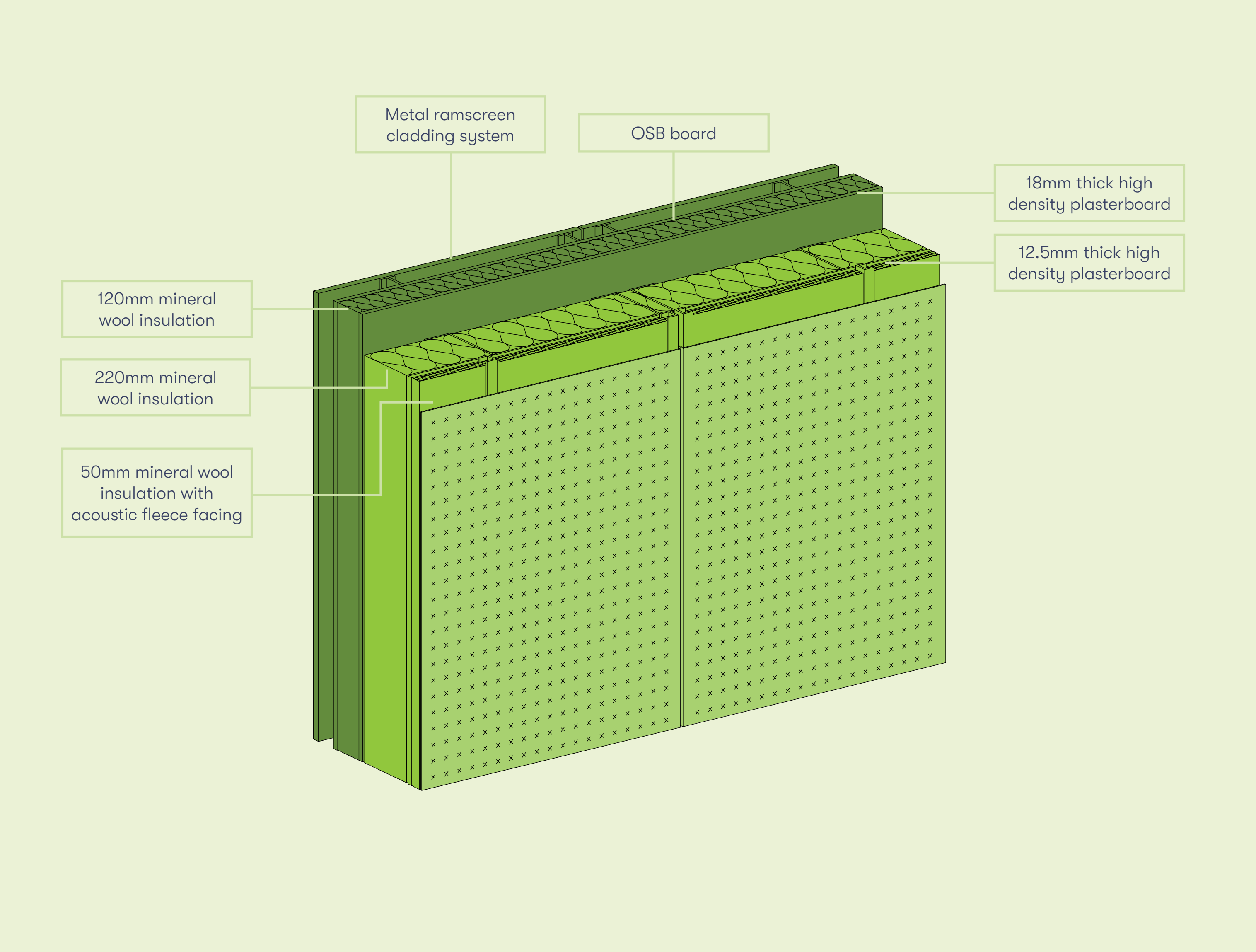


Base spec (meets low and med)

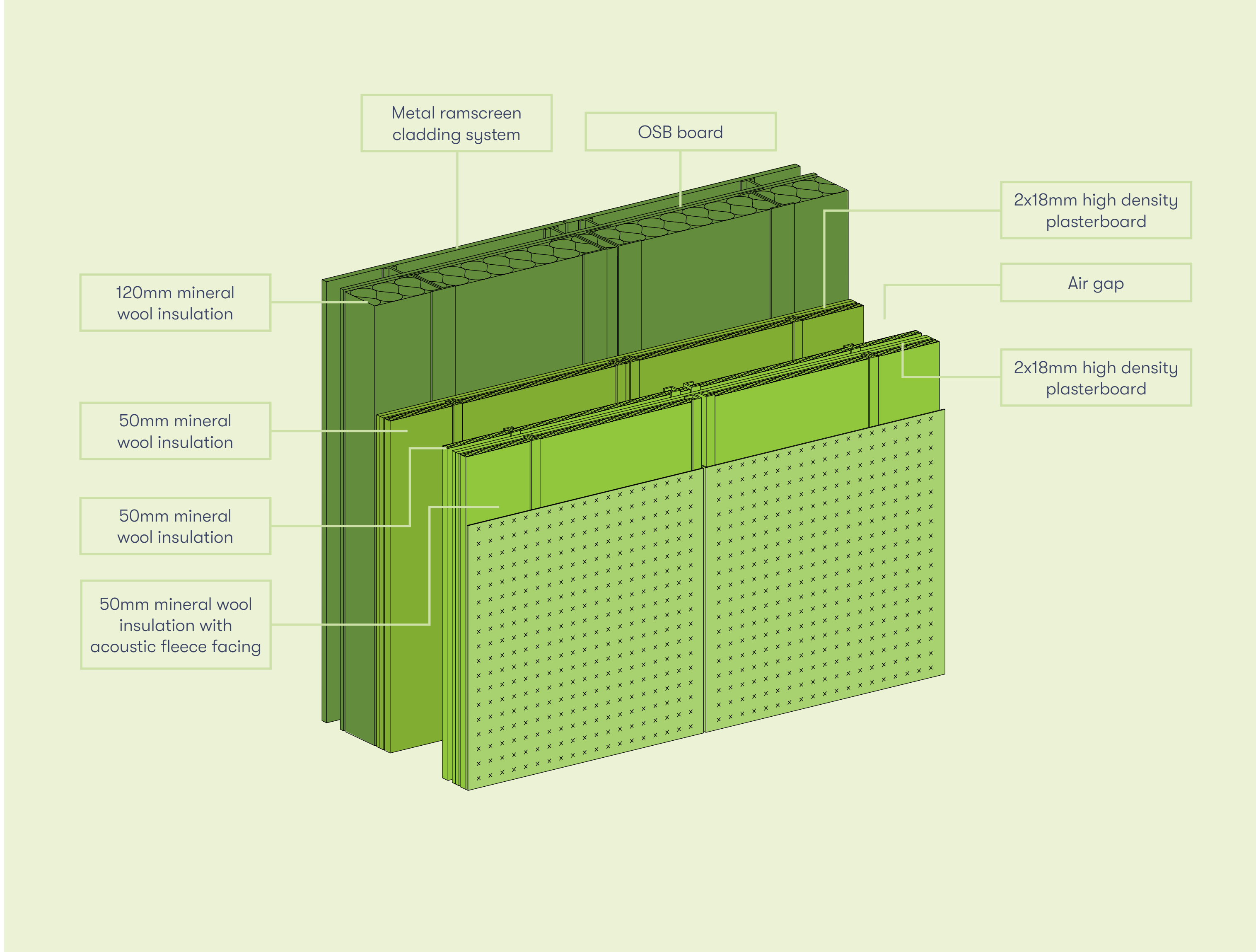


Enhanced spec (medium and high)

A steel stud wall system with metal cladding

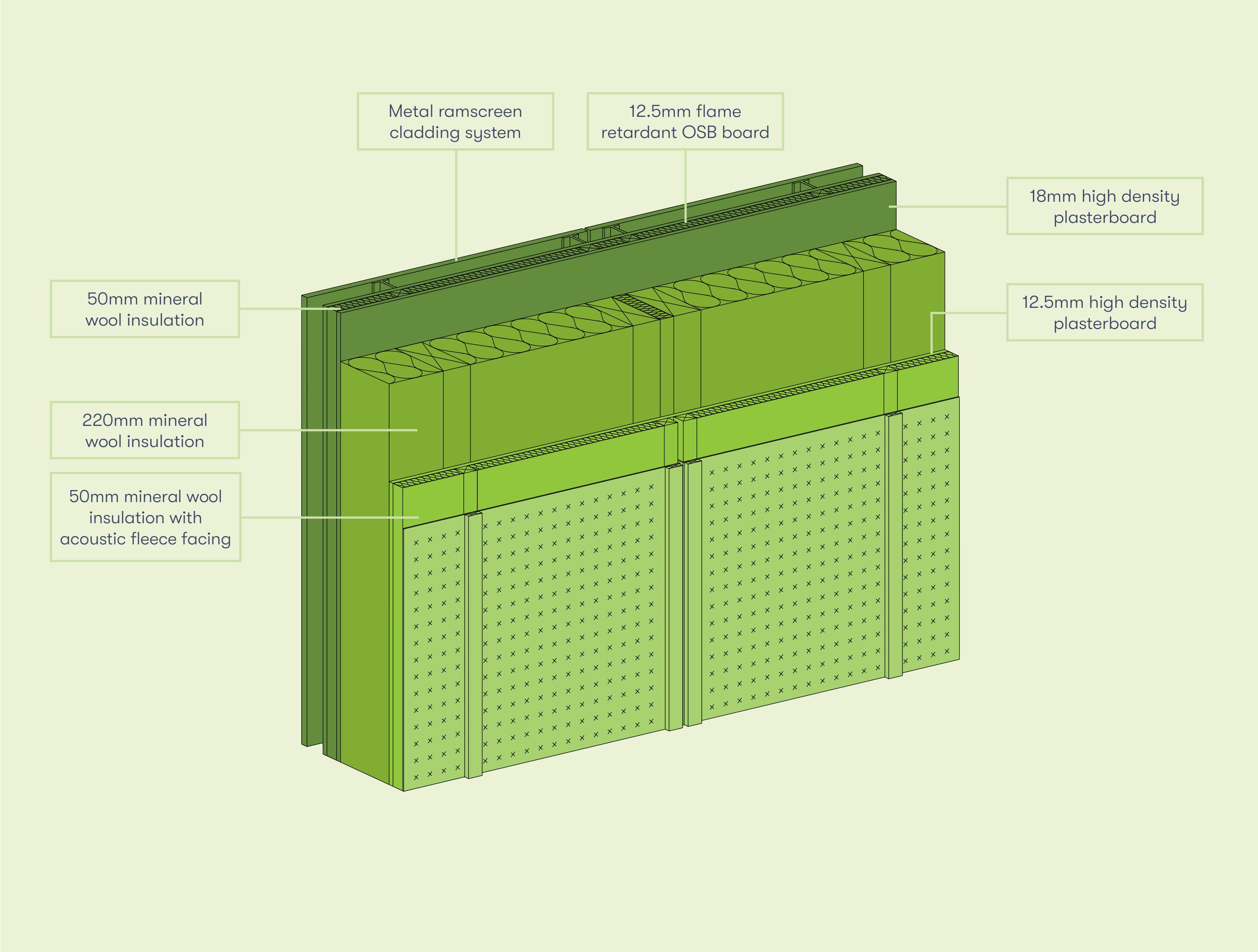


Typical Metal Stud façade build-up in low to medium noise environment

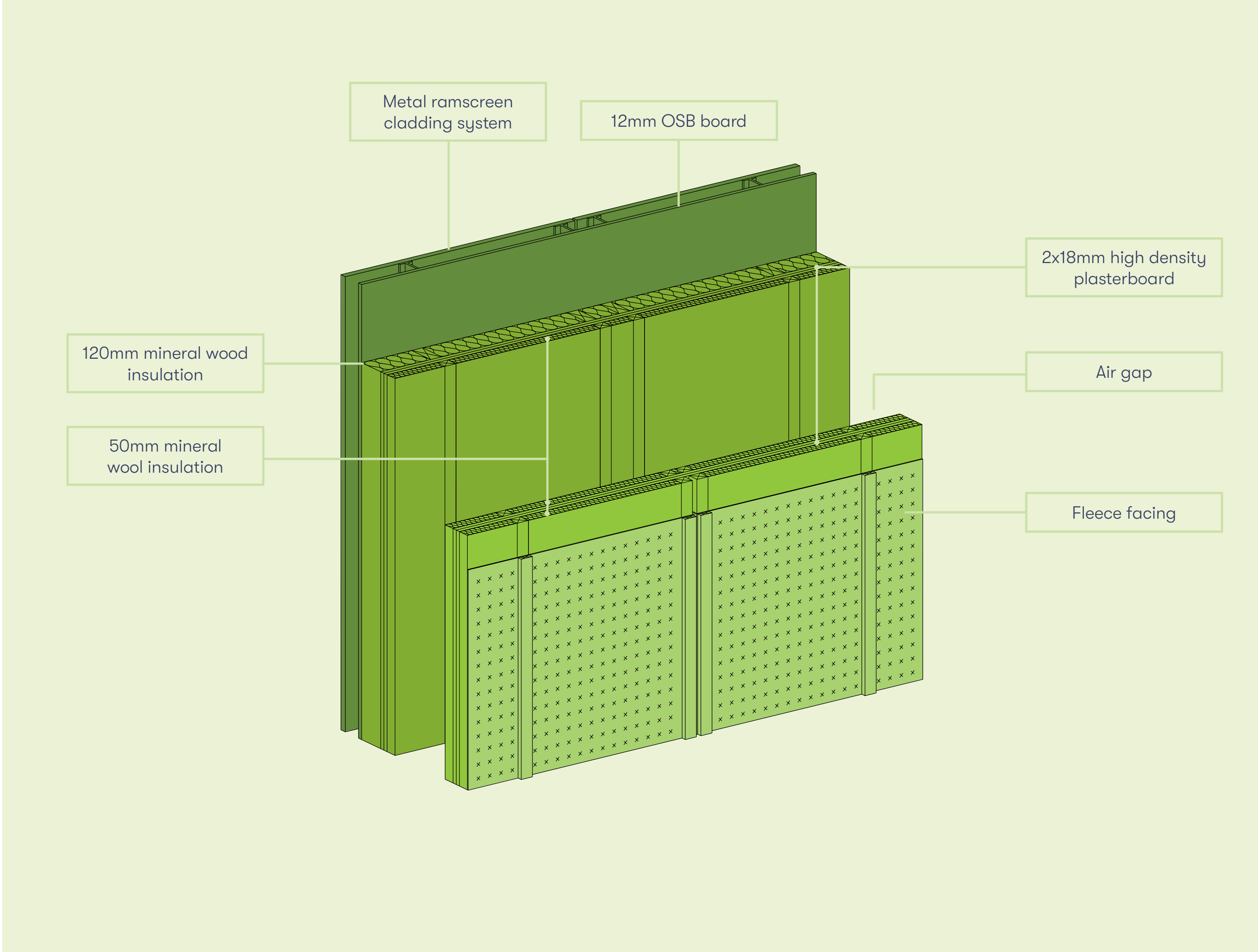


Typical Metal Stud façade build-up in medium to high noise environment

A pre-manufactured timber cassette system with metal cladding

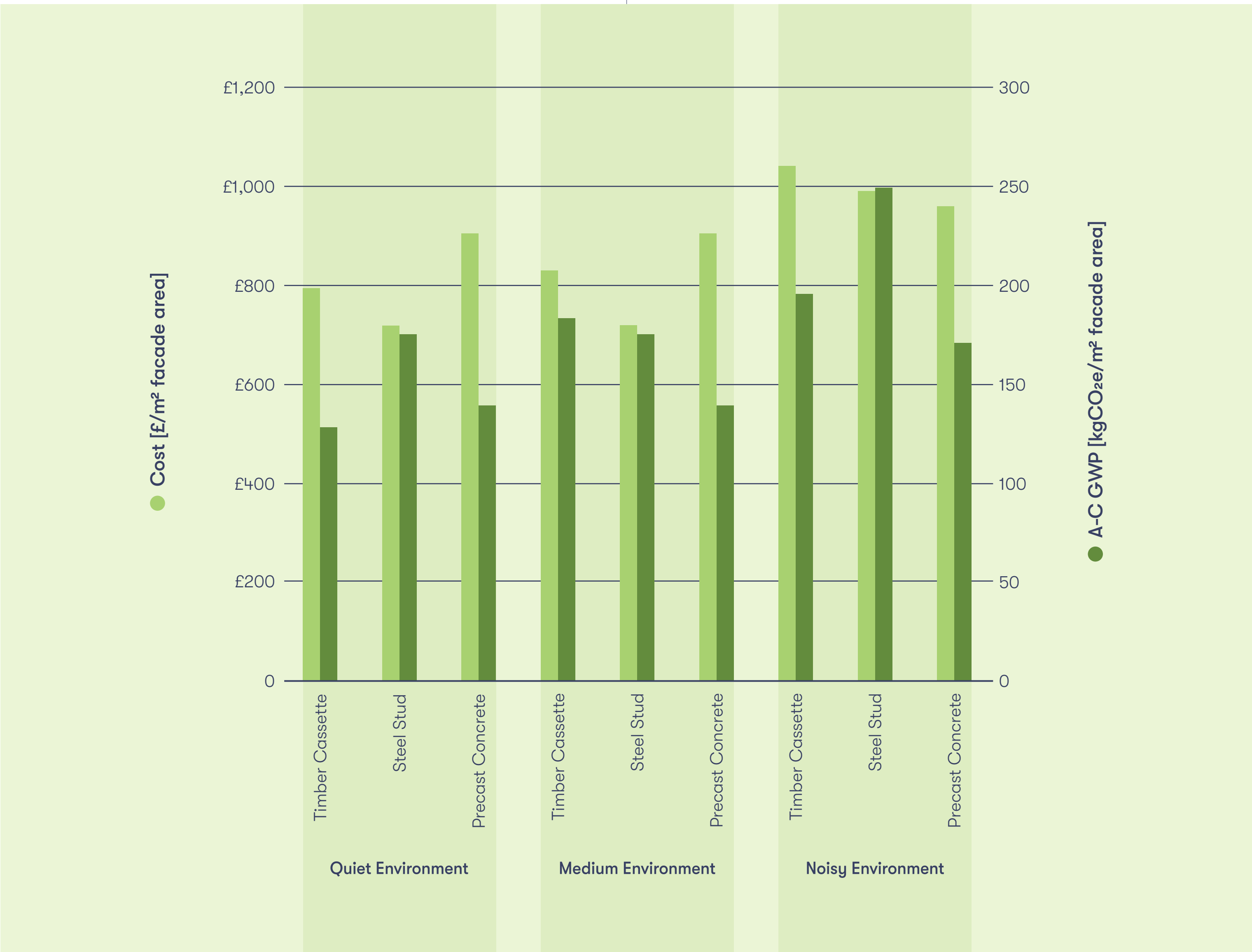


Typical Timber Cassette façade build-up in low to medium noise environment



Typical Timber Cassette façade build-up in medium to high noise environment

The costs and embodied carbon for each of these assumed façades build ups are as follows:



Comparative embodied carbon and costs of façade options in different noise environments

In a quiet environment, a timber cassette offers the lowest embodied carbon, but its cost is 10% higher than the cheapest steel stud façade option. In a noisy environment, a pre-cast concrete option provides both the lowest embodied carbon and lowest cost. This is due to concrete having good sound attenuating properties. The use of concrete also avoids the need for a separate high embodied carbon cladding material.

For a noisy environment, both timber and steel options needed an increased material build-up to achieve the required attenuation increasing both embodied carbon and cost. Steel was found to be the lowest-cost solution for both the low- and medium-noise environments.

Metric	Quiet Environment	Medium Environment	Noisy Environment
Cost	Steel Stud	Steel Stud	Precast Concrete
Embodied Carbon	Timber Cassette	Precast Concrete	Precast Concrete

↑ Optimal façade options in different noise environments

The results of the analysis showed that the façade build-up required for a low-noise environment reduced the façade's embodied carbon emissions by 18-35% when compared to a high-noise environment. The timber cassette showed the greatest reduction of 35% when moving from a high to low-noise environment. Steel showed a 30% reduction and the concrete based solution an 18% reduction for the façade. This highlights how a local environment's background noise, and the measures which need to be undertaken to attenuate it, can have a significant impact on a Stage's embodied carbon emissions.

Within each of these different façade build-ups, the materials used significantly influence a wall's total embodied carbon. In the low-noise environment, the external aluminium cladding is the single-largest source of embodied carbon for both the steel and timber options. After aluminium, plasterboard contributes the next largest source of emissions. In the high-noise environment, however, plasterboard provides the largest source of emissions as additional layers of plasterboard are required to provide necessary noise attenuation.

For the pre-cast concrete option, the concrete is the largest source of emissions for all noise environments as this solution does not require external metal cladding. Concrete, however, has excellent sound attenuation properties and, therefore, requires less plasterboard for noise attenuation, in fact, in high-noise environments a concrete façade has the lowest overall emissions.

This highlights the opportunity to reduce embodied carbon for the façade through tailoring the choice of construction to the specific local design environment and to consider how the embodied carbon can be further reduced for each material element of the façade.

Comparison of embodied carbon for different façade designs by façade element

Material Substitution Analysis

Analysis of materials typically uses industry average figures to determine embodied carbon. Different manufacturers may use different energy supplies, source materials or production processes that affect the embodied carbon of their product. Some product suppliers can provide independently verified Environmental Product Declarations (EPDs) that quantify the embodied carbon for their specific product. By selecting products with lower upfront carbon (lifecycle stages A1-A5), it is possible to further reduce embodied carbon compared to the UK average figures. For example:

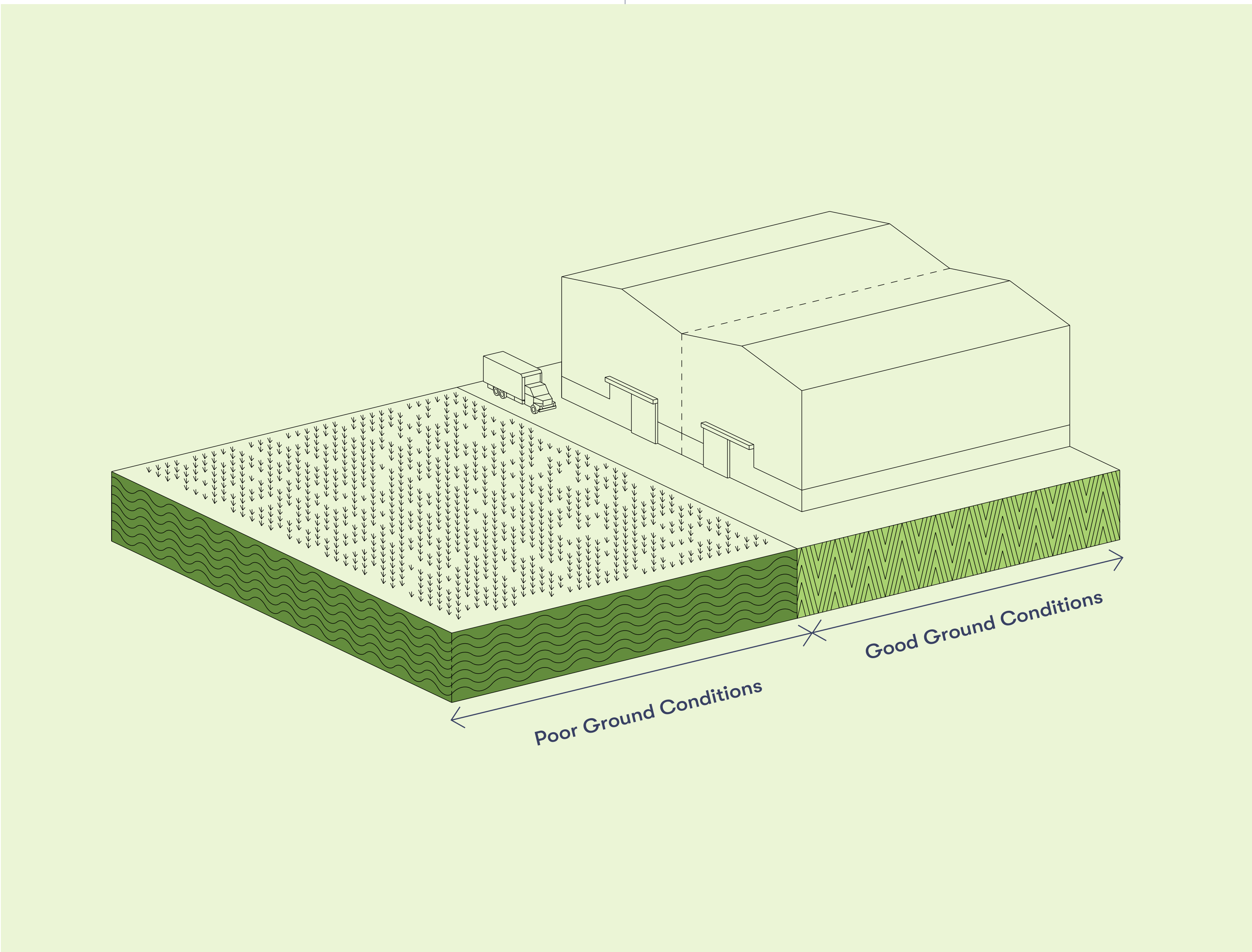
- Aluminium, which is often a key material for a façade, can be sourced from some manufacturers who can supply products which reduce the upfront carbon by 60-80%.
- Plasterboard can be sourced from suppliers whose products show a 30-75% saving.
- Structural steel can be sourced from suppliers where its upfront carbon is 18-25% less than the UK average, while rebar can have 35-61% less upfront carbon than the UK average.
- Cement substitutes can be used to reduce embodied carbon in concrete, which is a key contributor to Stage emissions. Selecting a specific mix can deliver 38-52% less upfront carbon than the UK average for concrete.

If materials and products meet the performance standards set by a project, they can offer a good opportunity to reduce emissions through careful specification at the design and procurement stages. This approach may introduce a procurement risk by limiting the number of suppliers that could be used. It may also introduce additional design considerations such as increased curing times for cement substitutes. These factors will need to be recognised and managed.

Conclusions

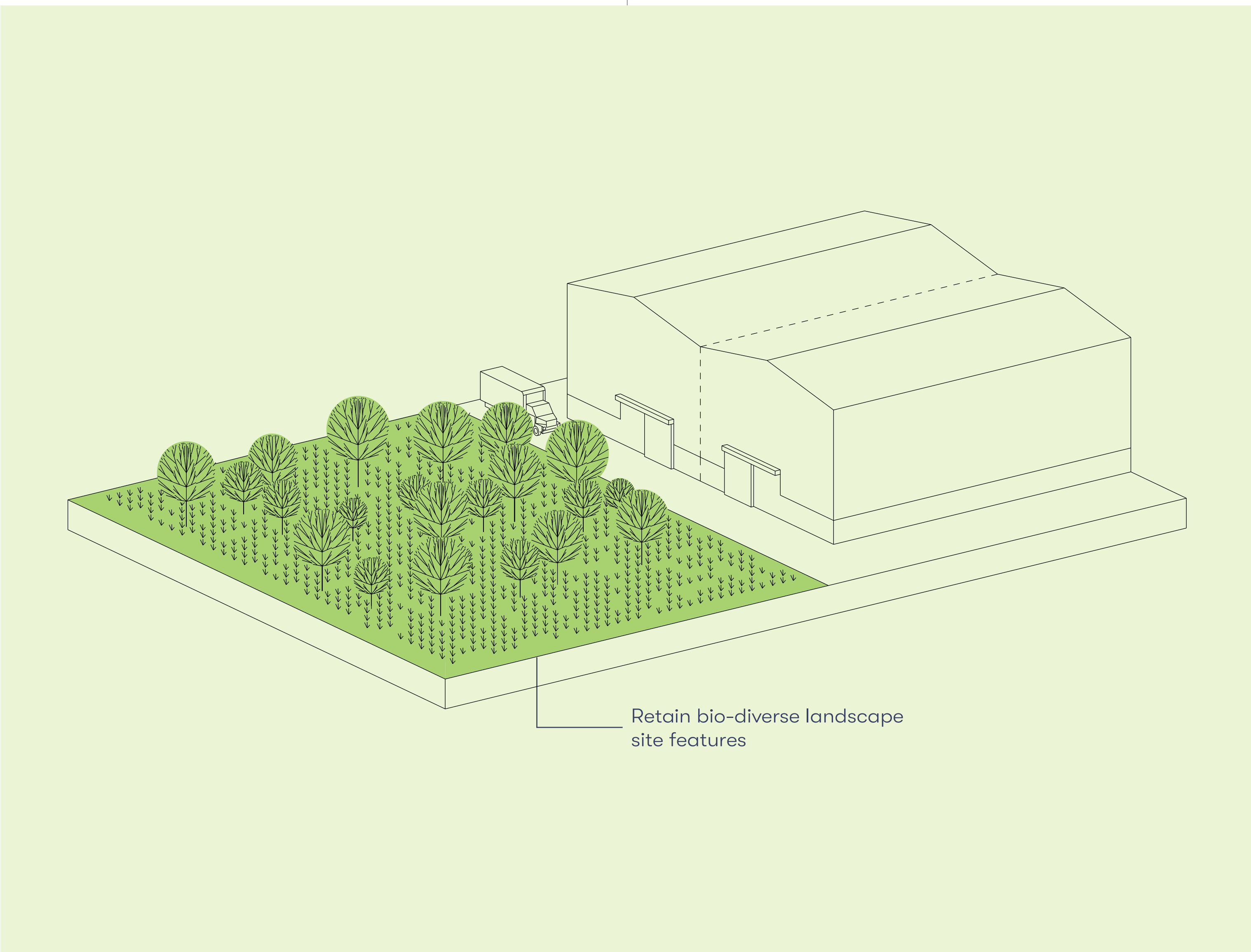
When these findings are considered as a whole, some broad themes emerge around the embodied carbon of a new Stage and how choices throughout each part of the process can influence lifecycle carbon emissions.

Site Selection and Masterplanning
A site with poor ground conditions may increase the embodied carbon compared to a site with better ground conditions.
Site location relative to sources of noise that require greater façade attenuation will also increase embodied carbon.

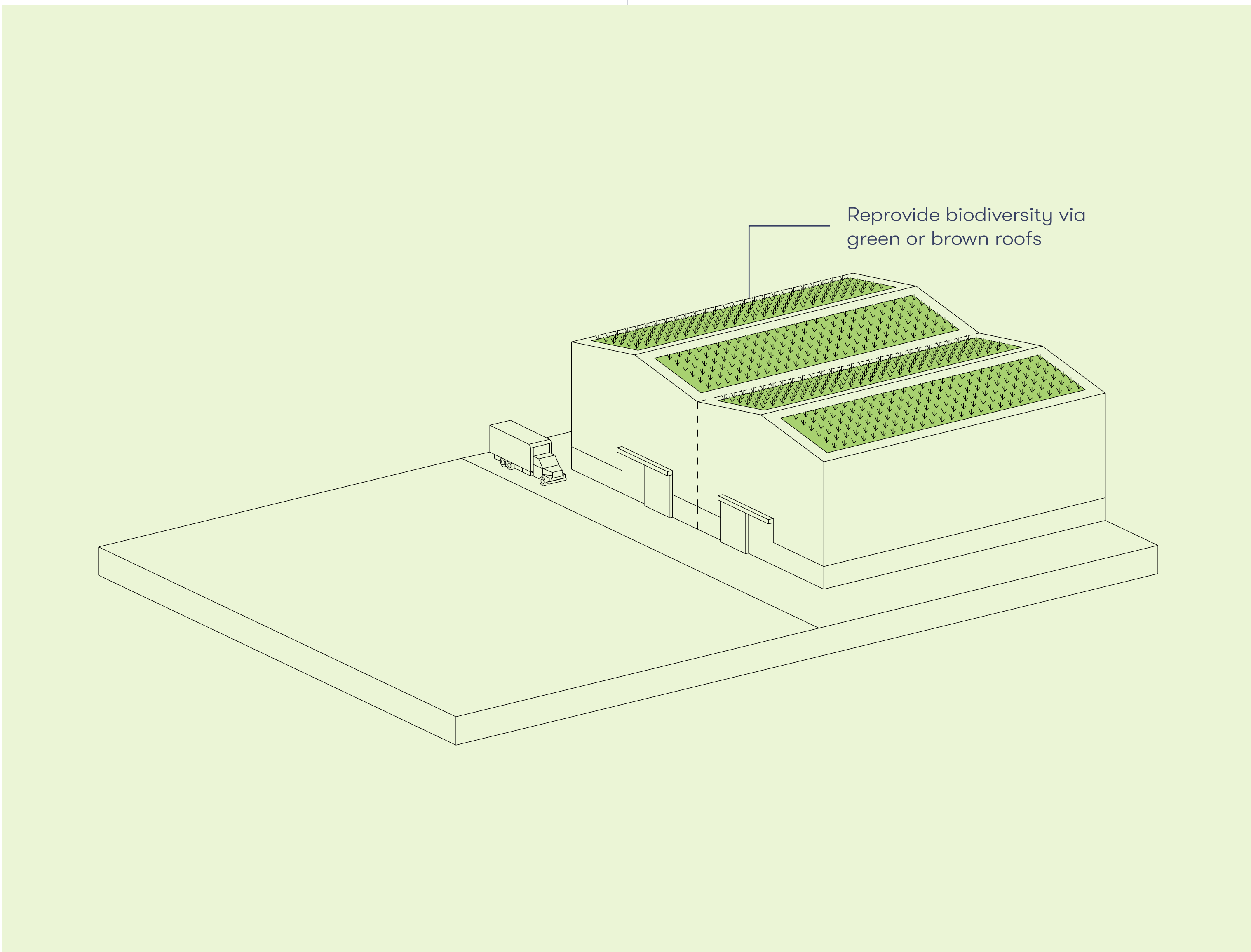


Site Selection: Poor Ground Conditions

The biodiversity of the pre-development site and built density relative to the available site area may mean that, to achieve a biodiversity net gain (BNG), green roofs are required. Green Roofs will increase the embodied carbon of the Stage structure. Where it is feasible to achieve required BNG targets through alternative ground-based measures, these may offer embodied carbon savings compared with green roofs.

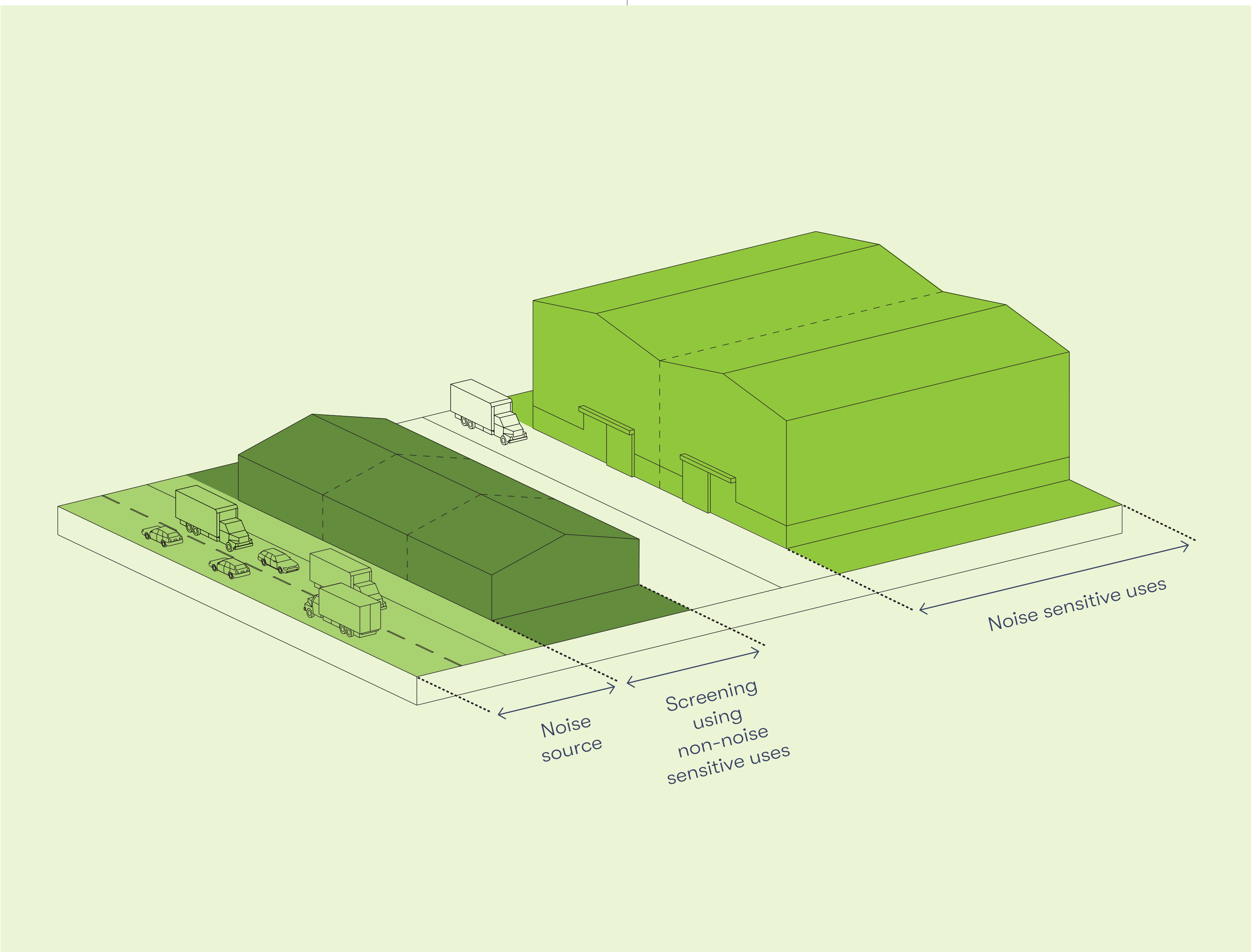


Site Selection: Poor Ground Conditions



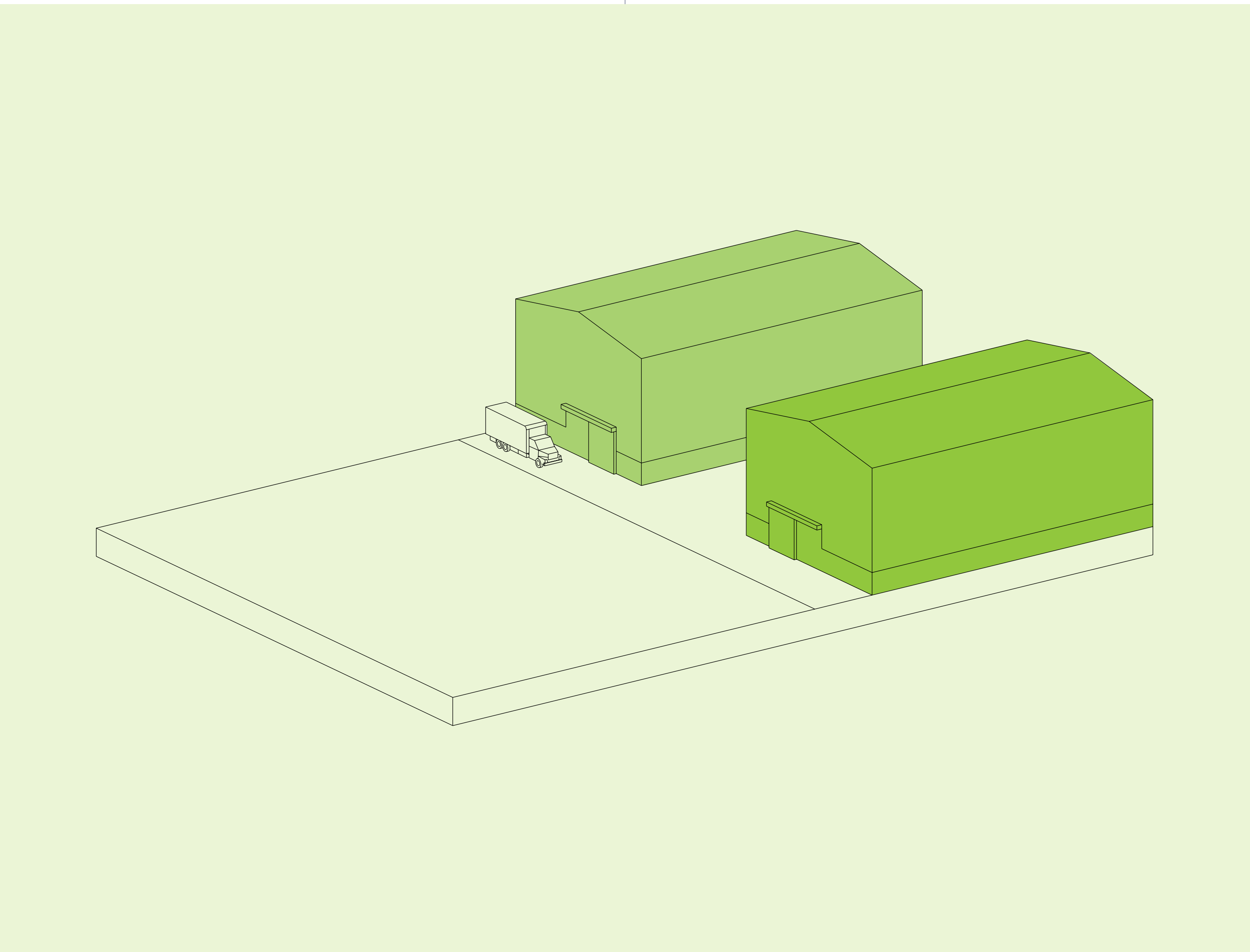
Site Selection: Poor Ground Conditions

The site layout offers an opportunity to reduce embodied carbon. Where possible, placing building types that are less sensitive to external noise in noisy environments could reduce the embodied carbon associated with Stage sound attenuation.

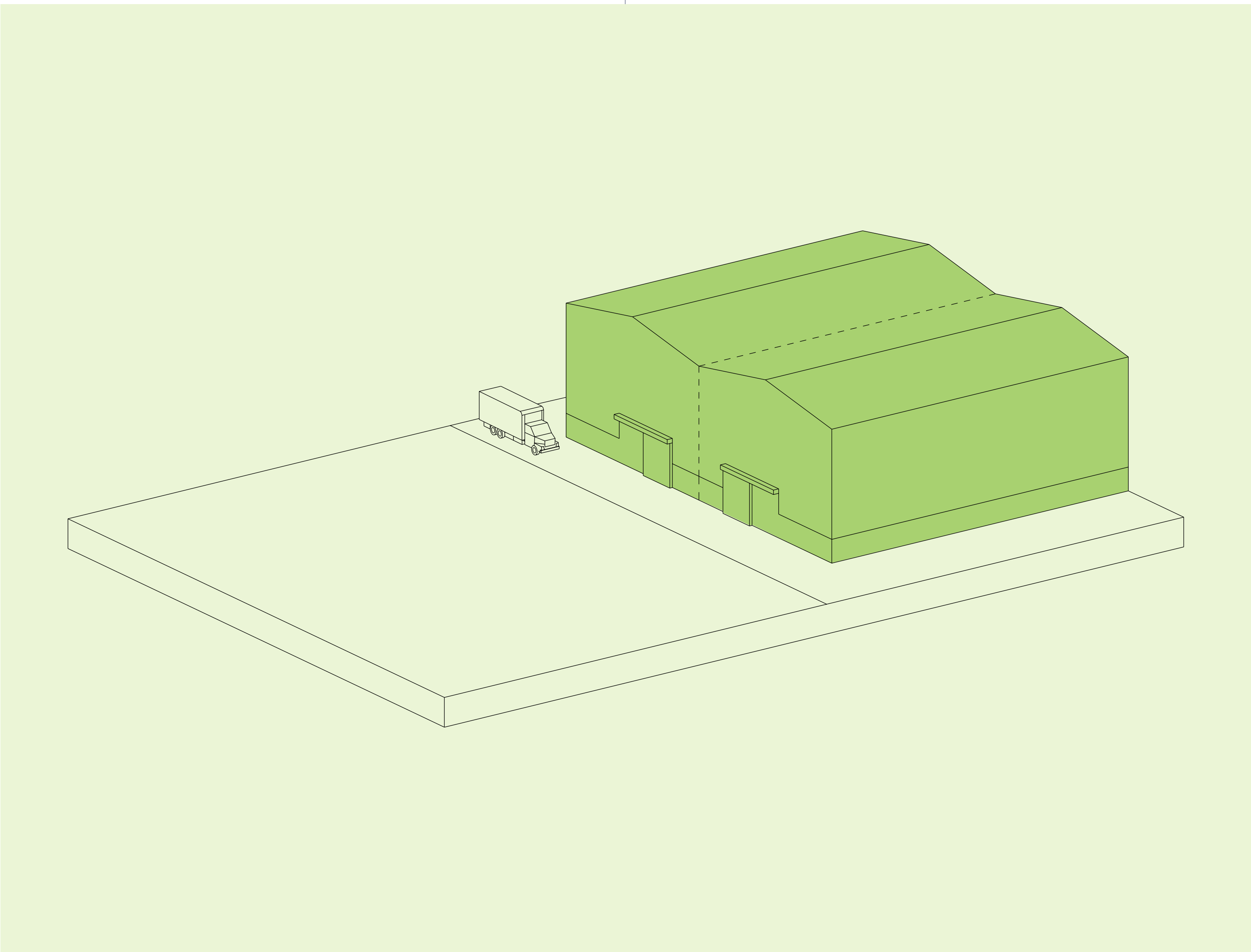


Site Selection: External Noise Sources

There is an opportunity to reduce material quantities by building Stages back-to-back or adjoining other buildings. This can reduce the area of the external façade. This is important as metal cladding materials are responsible for a significant proportion of the facades embodied carbon. This approach would require operational considerations to be assessed, in particular, sound attenuation between the Stages and adjoining uses



Site Selection: Stage Configuration and Layout



Site Selection: Stage Configuration and Layout

Design Specification
Stage design will be developed in response to the project brief provided by the operator and their advisors. Careful consideration of the brief is important to avoid over-specification. The specification of design solutions and features to meet the performance standards of a Stage sets the basis for embodied carbon. This can include:

- selection of the ground floor slab solution (ground bearing or suspended);
- the load criteria and spacing of the gantry and runway beams;
- the Stage's acoustic requirements;
- the type (standard, PV or green) and service load of the roof
- and approach to façade design.

Embodied carbon is inherently linked to the materials selected. It is necessary to consider whether a lower carbon material such as timber can be used in place of steel. For example, whether a timber truss can be adopted for the primary structure or timber cassettes used for the façade in lower noise environments. It should be noted that timber substitution products carry potential fire risks which need to be evaluated and understood for a specific project.

The efficient use of materials also contributes to minimising emissions. For instance, if a high-carbon cladding material such as aluminium is used, there is the potential for its profile and thickness to be optimised to reduce embodied carbon emissions, while still meeting the wind-loading and other performance requirements.

Procurement
The procurement stage of a project is the final opportunity to influence the upfront embodied carbon of a Stage and it is possible to set procurement criteria such that low-carbon options are used for its construction. This may restrict the number of suppliers for a particular product or solution. However, these project risks can be managed with an appropriate procurement strategy and should result in an overall reduction of upfront carbon.

→ Stage Energy Demand

Introduction

Due to changes in filmmaking practice and the technology used in filmmaking it may be difficult for the developers of new studio space and their design teams to confidently predict the energy demand profile, and therefore the maximum electrical demand of new Stages and studio campuses.

Recent changes in filmmaking practice have not only seen tungsten halogen ("tungsten") lighting being increasingly replaced with more efficient LED lighting, but also the greater use of green screens, technologies such as LED panels and data processing equipment for virtual production all come with increased power requirements.

At the same time, the UK rapidly needs to shift energy needs from fossil fuels to electricity and to meet a growing demand for data storage. This is creating an unprecedented demand on district network operators and National Grid ('**Grid**') to reinforce their electricity infrastructure. In some cases, the timescales required to do this are impacting the delivery of a new studio development.

As part of this research, a review of traditional and emerging filmmaking practices and their energy use has been undertaken. This is to assist studio developers and operators in making reliable estimates of future energy demand at both individual Stage and studio campus levels. The aim of this is to help avoid either under-provision of power, or unnecessary Grid reinforcement costs and availability charges.

Establishing Energy Demand

To help inform this review, the British Film Commission has consulted with various stakeholders to provide data based on their experiences. It was clear from these discussions that the maximum power demand of studios was significantly lower than the installed design capacity. It was suggested that this could be for a number of reasons including:

- FFHETV production is variable across a year and even across a day. Demand is influenced by the type or scale of production and the specific lighting and other specialist equipment a production uses. This results in a large variation in demand across a single Stage.
- As lighting is a primary power consumer, a shift from tungsten lighting towards more efficient LED lighting is expected to reduce power requirements.
- Productions often hire diesel generators to provide power when shooting on location. It has been common practice for them to make use of these generators for lighting purposes on Stages as an alternative to the cost of electricity recharges made by studio operators.
- Being able to market a studio as having a large power supply is seen as a positive benefit and under-supplying power is seen as a risk to the attractiveness of a studio.

Discussions with stakeholders identified a lack of available data on the metered energy demand profiles associated with different types or stages of production.

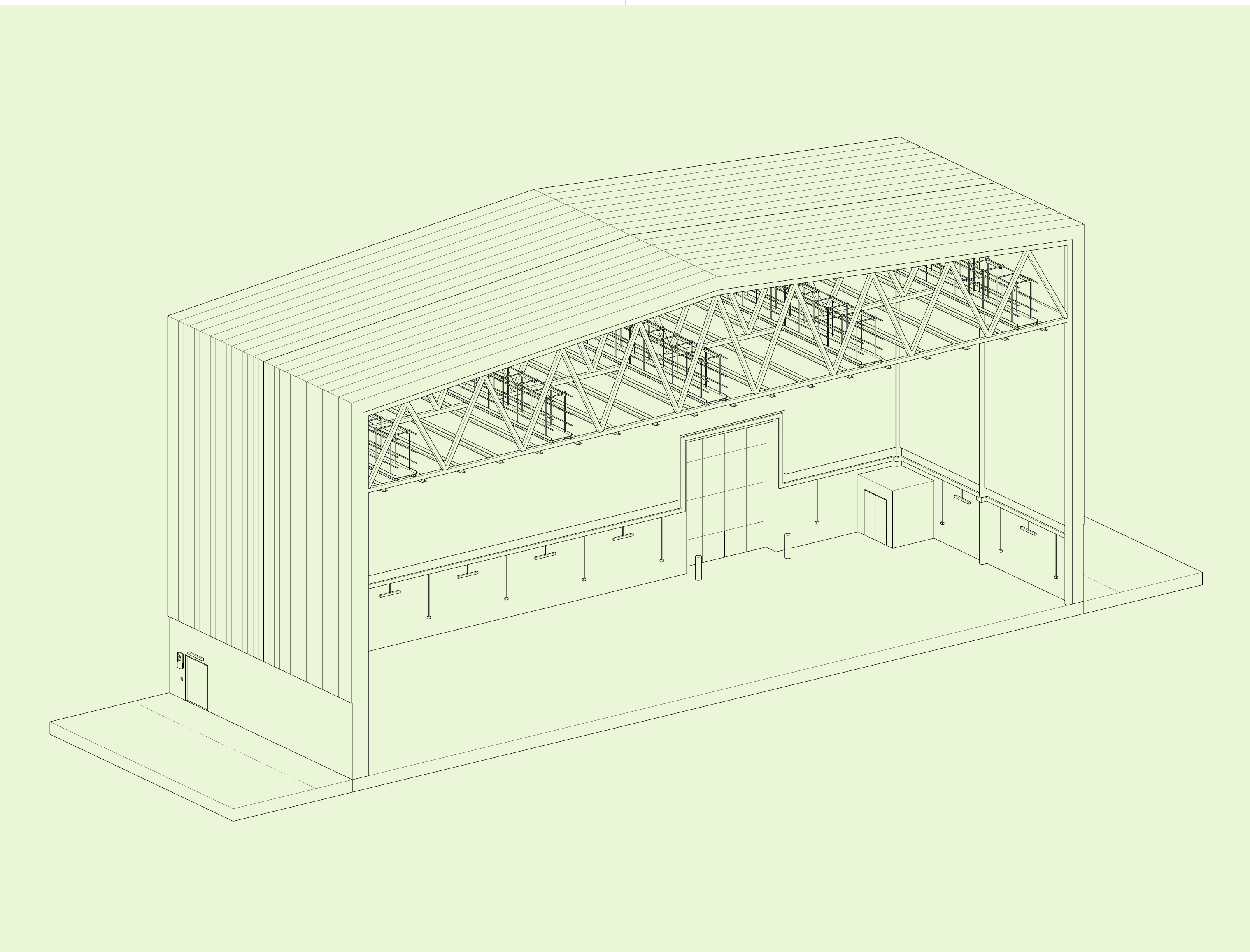
Modelling and Diversity

In the absence of reliable metered energy demand profiles, this research sought to model the likely electrical demand of an 'assumed' studio complex. Since modern studios may have more than one Stage, with different activities potentially taking place concurrently within the Stages, it was important to understand the level of diversity in demand expected for a range of different scenarios of Stage usage.

'Diversity' is a factor used to determine the actual power that might be used by a studio, recognising that it is unlikely that all Stages would be operating in their most energy-demanding production phase (or be in use at all) simultaneously. In determining the power requirements for a new studio, it is common to estimate the maximum energy demand that each Stage (and other buildings) will experience under peak occupancy, to then total this for all buildings, and then apply a "diversity factor" to arrive at the overall likely power requirement for the studio. Typically, consultants and studios are cautious about applying too much diversity to avoid a situation where available power is inadequate to meet production needs.

A lack of available evidence for the actual loads being experienced in Stages makes it difficult for consultants, studio developers and operators to refine diversity estimates. Therefore, models were developed for the expected energy demands for a Stage for its typical production cycle, alongside calculated assumptions on the use and occupancy of Stages for the following production phases:

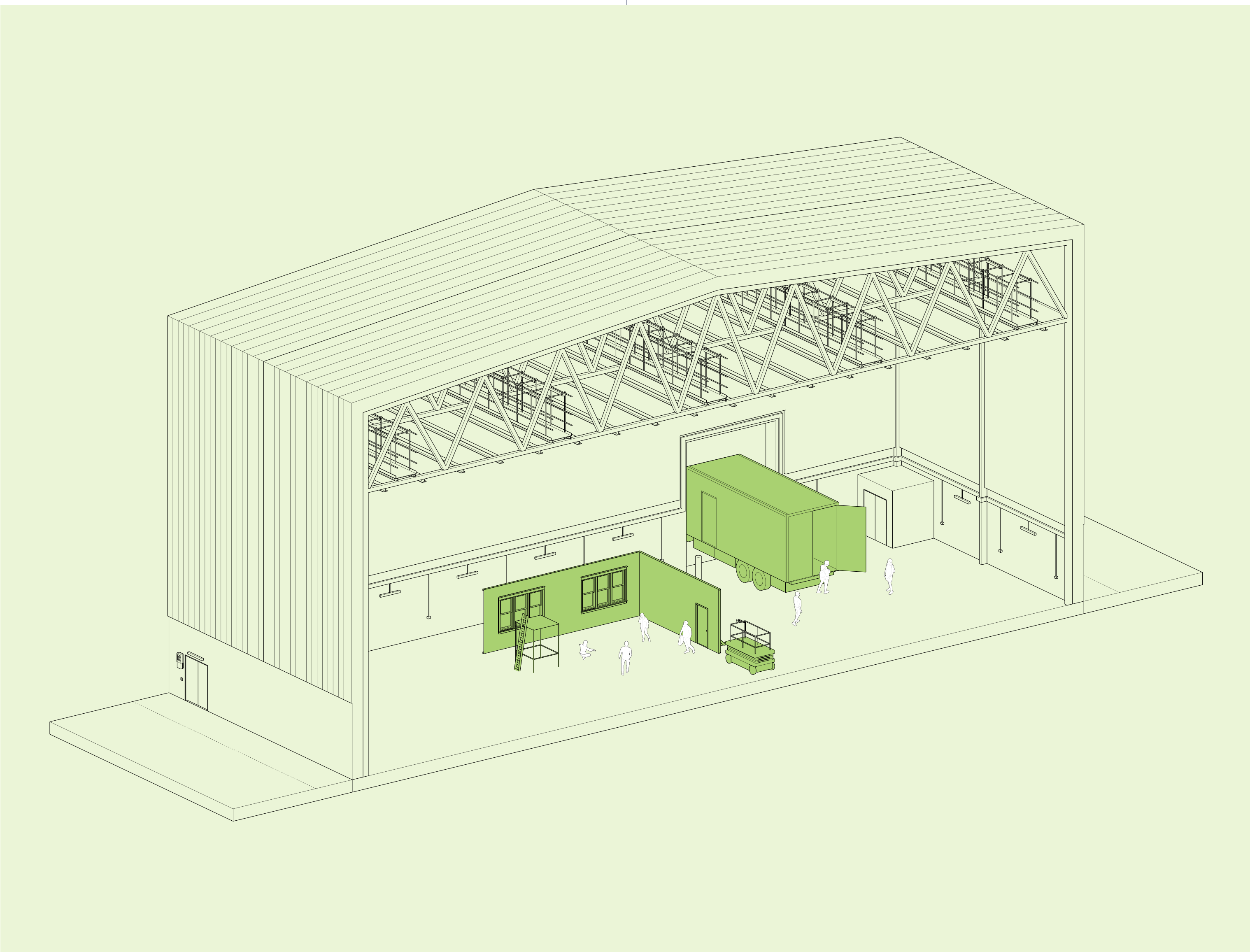
Unoccupied - the space is unused and unoccupied.



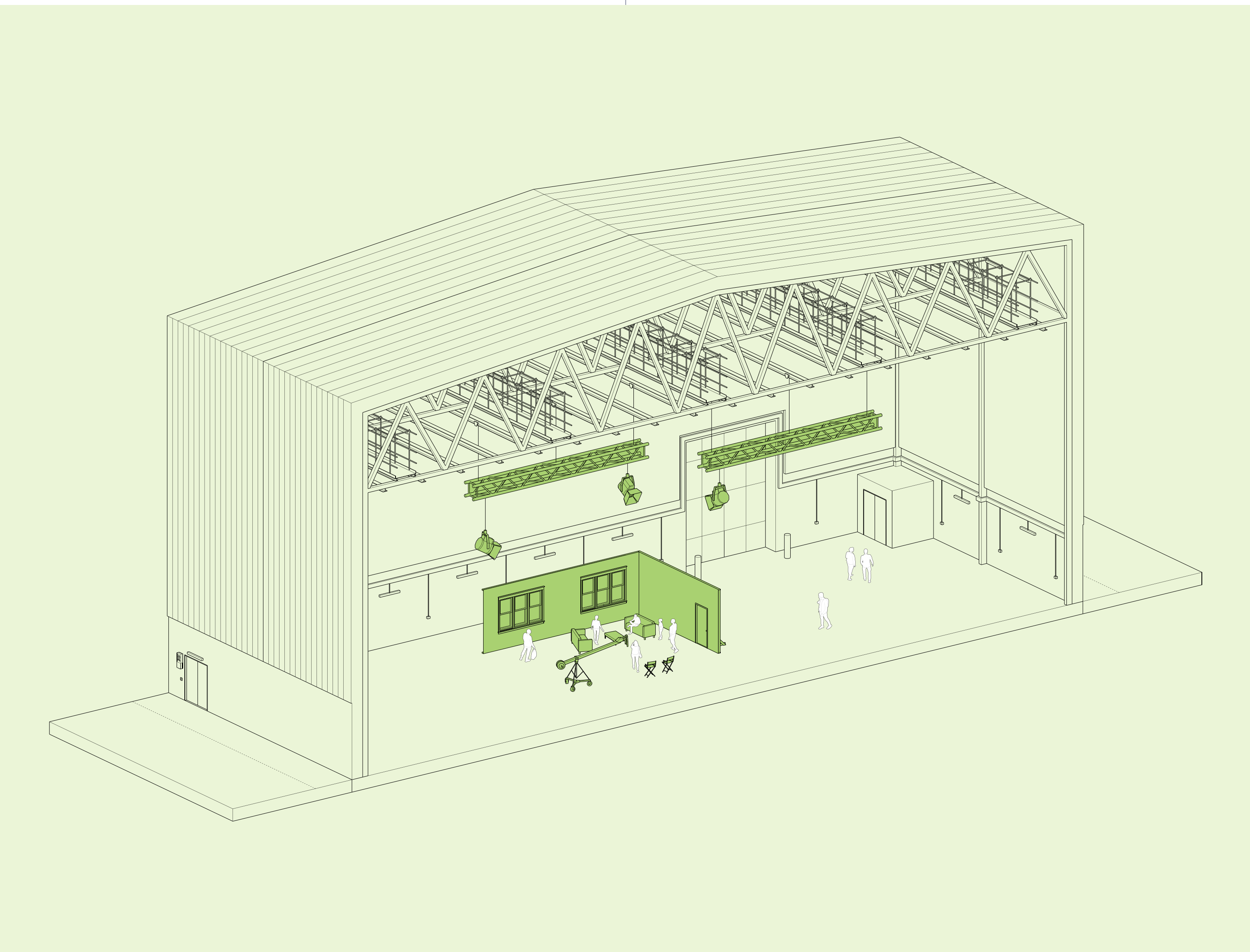
Production Phases: Unoccupied

Build - the first phase of Stage utilisation by a production, where sets are being constructed. This can take a few days or several weeks, depending on the complexity of the production. House lighting is provided, with power required for electrical tools and machinery. Typically, little cooling is provided, with ventilation provided by opening elephant doors. As doors are often used for prolonged periods during this phase, any heat provided is often lost and therefore inefficient - a consideration for individual studio operators.

Rehearse - A shorter phase, after the set is constructed, for rehearsing, testing, or pre-lighting purposes, before the full production is commenced. This phase typically means limited crew on a Stage, but with some services being run, such as production lighting and heating.

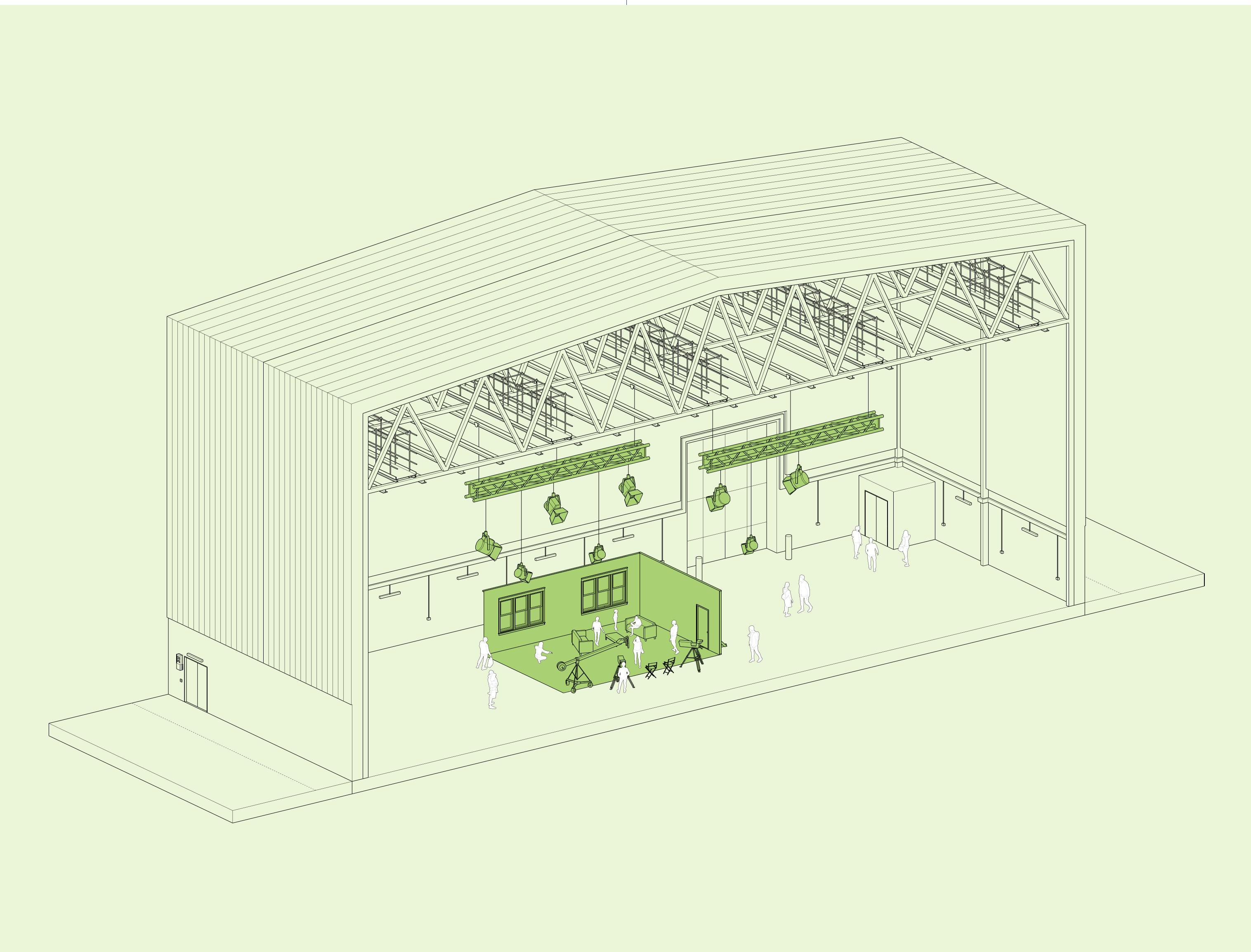


Production Phases: Set Build



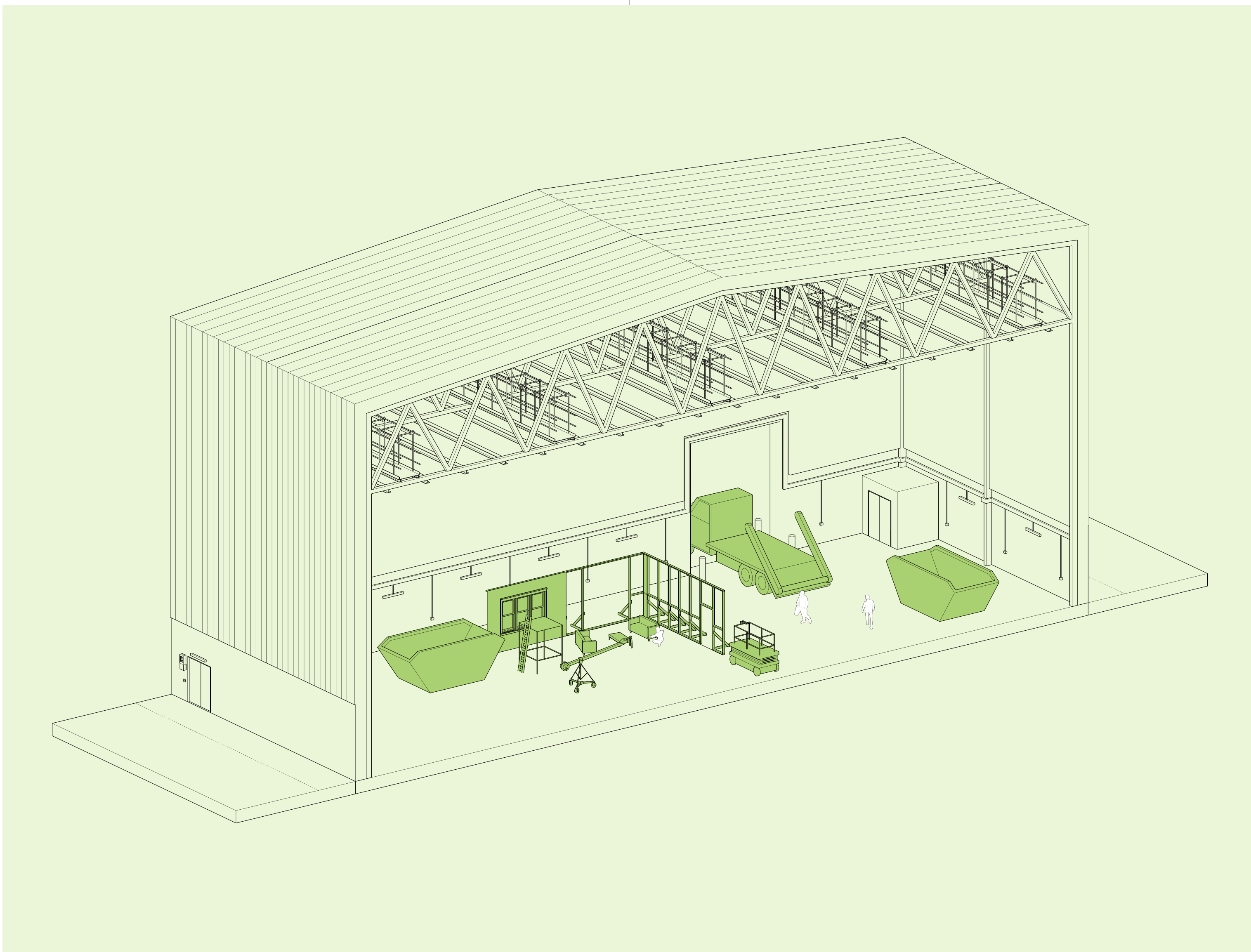
Production Phases: Rehearse

Shoot - the main phase of production filming activity. Set construction has been completed and the full filming crew and cast are in the Stage daily as required. Production lighting has been set up and is in use; noise is strictly controlled; and heating, cooling and ventilation are provided via the Stage's services. The length of this phase varies but can last several weeks. The level of lighting provided for a production during filming can vary significantly from production to production, and models were developed for a range of lighting demand assumptions.



Production Phases: Shoot

Strike – Filming has been completed and the set is deconstructed using house lighting and small power. The Stage is returned to its unoccupied state.



Production Phases: Strike

Results of Modelling

Employing the use of a complex 'random' modeller, many alternative iterations of the above production phases were run for a theoretical studio of 16 Stages, to calculate reasonable energy demand diversity.

Detailed calculations were made in relation to likely levels of energy demand for equipment, heating, production lighting and ventilation. Three differing scenarios were modelled to determine the impact of providing comfort cooling:

- **Scenario A - comfort cooling when needed all year**
- **Scenario B - comfort cooling in summer months only**
- **Scenario C - no comfort cooling**

Varying outputs of this research can be summarised as follows:

	Studio Peak Power [kW] Diversified	Studio Peak Power [kW] Undiversified	Studio Worst Case Peak Power [kW] Undiversified	Studio Worst Case Peak Power [kW] Undiversified	% Diversity based on assumed production schedule	% Diversity based on peak power requirement
Scenario A — Comfort cooling when needed all year						
Maximum	18990	24711	36117	3245	82%	53%
Minimum	9941	16641	36117	1365	49%	28%
Average	**12466**	**19542**	**36117**	**2196**	**64%**	**35%**
Scenario B — Comfort cooling in summer months only						
Maximum	14780	23255	36117	3245	86%	41%
Minimum	9204	15514	36117	1354	52%	25%
Average	**11832**	**18344**	**36117**	**2101**	**65%**	**33%**
Scenario C — No comfort cooling						
Maximum	14242	18071	26082	2345	83%	55%
Minimum	7304	12075	26082	979	49%	28%
Average	**9276**	**14241**	**26082**	**1596**	**65%**	**36%**

Energy Diversity for different cooling scenarios

Conclusions

While it will remain important to enable access to suitably high levels of electrical capacity in any single Stage, it is clear that peak demands are largely during Shoot phases, and that these are periodic and variable. Moreover, on campus studios with multiple Stages, it is possible to take a view on the maximum number of concurrent productions (and Stages) likely utilised in a Shoot phase simultaneously.

- Modelling for the 16 Stage studio, for numerous different occupancy assumptions, showed a diversity factor for overall power which ranged from 25%-55%.
- Results showed similar diversity factors for each cooling scenario and typically, diversified power demand was between 33%-36% of the peak.
- Diversity would be expected to reduce for a smaller number of Stages.

The provision of cooling increases the overall maximum electrical demand for the modelled 16 Stage studio by 38%, compared to a studio that only provides heating. This highlights the need to consider how warmer summers or the greater use of virtual production may impact future power demands. By carefully designing transformer switchgear, electrical distribution and better understanding of power diversity, studio developers and operators can make a more considered assessment of power requirements, reducing Grid connection requirements and associated costs.

It should be noted that research and modelling have only focused on diversity as it relates to Stage utilisation. Individual assessments will be required for studio campus power demands that consider electrical usage within workshops and other ancillary studio buildings, external spaces and backlots.

By focusing on measuring energy use and carbon emissions and improving automated metering, studios can better record energy demand related to Stage usage. This helps accurately determine power needs for future developments and manage associated costs.

→ Low-Carbon Stage Servicing Strategies

Introduction

The Climate Change Act requires the UK to cut CO_2 emissions to net zero by 2050. A key part of the UK strategy is to decarbonise the electricity grid by 2035 and to convert heating away from fossil fuels to electrically fuelled heat pumps and district heating served from low-carbon sources. The UK Government and devolved administrations are working on updated regulations for new buildings that will help enforce this strategy.[2] In England, an interim update to Part L of the Building Regulations in 2021 is already driving this strategy.

To test the impact of this change for England, a Part L 2021 model was run for a representative 30,000 sq. ft. Stage to determine the compliance implications.

While UK Stages have not traditionally been designed with cooling, instead allowing production companies to provide this when required as a temporary solution, the emerging use of air-source heat pumps in place of gas boilers allows for an opportunity to provide comfort cooling to a new Stage, with limited change to its ventilation system.

The level of comfort that might be provided in a Stage has been assessed in the context of this shift away from gas, and for various demand patterns in relation to Stage occupancy and different heating and cooling supply configurations.

[2] England, Wales, Northern Ireland and Scotland each have separate building regulations covering the conservation of fuel and power in buildings. In England the requirements for buildings other than dwellings are currently set out in Approved Document L Volume 2 2021 edition incorporating 2023 amendments. In Wales they are covered by Approved Document L Volume 2 2022 edition, In Northern Ireland they are covered by Technical Booklet F2 June 2022 and in Scotland they are covered by Section 6 of Scotland's building regulations with detailed requirements set out in the Non-domestic Technical Handbook. The UK Government and the devolved administrations are all working towards updated building standards that will ensure new buildings are net zero ready. This will be achieved by promoting a shift from fossil fuel to electric heating systems in new buildings. In Scotland updated standards will come into force from 1st April 2024 that will require zero direct emissions at point of use for heating systems in new buildings. The UK Government recently consulted on Future Building Standards for England that are expected to come into force in 2025 that will eliminate fossil fuel heating systems in new buildings and the Welsh and Irish Governments are expected to introduce similar updates in future.

CO_2 Emissions and Building Regulations

One of the limitations of the current Building Regulation covering the conservation of fuel and power (Part L) is that there is no specific template for a Stage within the calculation model. Those preparing Part L compliance calculations are forced to make a crude representation of a Stage by choosing from the template options available, none of which are well suited.

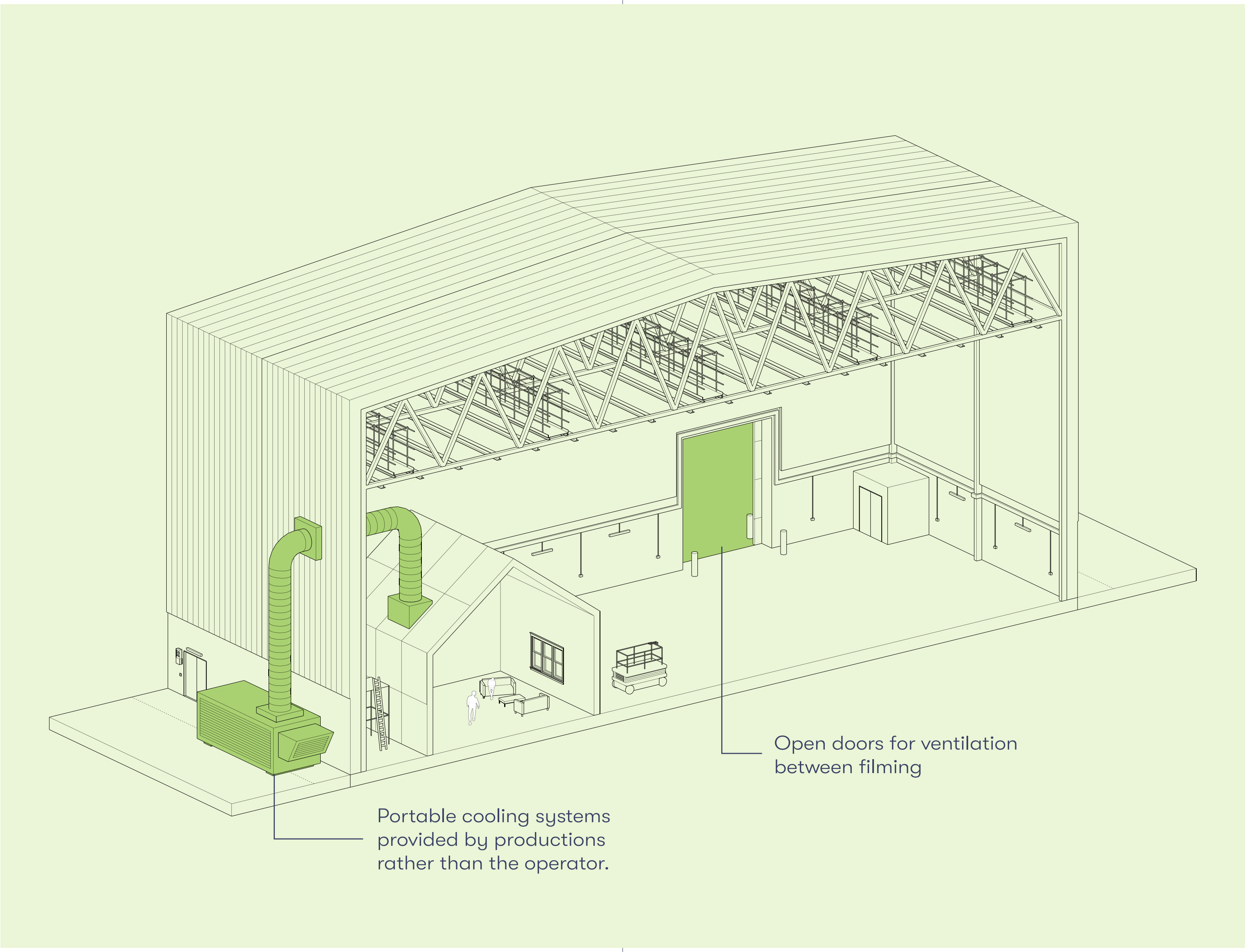
In June 2022, an update of Part L (Part L 2021) was introduced to help reduce carbon emissions in new buildings. The Notional Building used to set CO2 targets for Part L compliance now assumes that PV panels are provided to a proportion of the building's roof area, unless 100% of the heat demand is being met by heat pumps.

Compliance modelling for a representative 30,000 sq. ft. Stage demonstrated that, with a gas boiler and no use of renewables, it would fail the Target CO_2 Emission Rate by **300%** and the Target Primary Energy Rate by **100%**. Therefore, if using a gas boiler, Stage compliance would only be achieved by installing an extensive Photovoltaic (PV) array. By contrast, where an air source heat pump provided heating, a Stage without any other interventions was only found to fail the Target CO_2 Emission Rate by **25%** and the Primary Energy Rate by **28%**. In this case, a much smaller PV array could achieve compliance.

It is therefore expected that ongoing updates to national Building Regulations will drive a shift away from gas boilers to air-source or other forms of heat pumps and increase the insulation and air-tightness standards for new Stages. This will also be driven by the corporate commitments of those developing film studio space and commissioning content, who are increasingly signing up to net zero targets. In the future, the cost baseline for new Stage development will need to reflect this change.

Comfort Cooling for Stages

Engagement with the sector shows that typical air handling plant and ventilation systems in Stages are designed primarily to meet a production's heating requirements, and rarely to provide centralised cooling. It is common practice for production teams to either bring in their own portable cooling systems or to open doors to provide natural ventilation when not filming.



Traditional cooling / ventilation solution

The anticipated increase in the use of air-source heat pumps offers the opportunity for comfort cooling to Stages without significant additional cost of air-handling plants beyond what is needed for typical heating and ventilation. ASHPs installed for heating can be used in reverse-cycle to provide cooling in summer, at the same maximum supply volumes as those provided for heating.

Ventilation Options

There are a range of alternative supply distribution options typically used in a Stage:

- **Conventional High-level Supply**– all the air is supplied at high-level. The ventilation systems are not as efficient as the other options because cool air is heated by the rising warm air, thereby reducing the overall cooling effect.

- **Mid & High-Level Supply** – this allows some air to be supplied from the perimeter, reducing the cooling effect of the warm air rising. Systems need to be designed to allow some perimeter air diffusers to be shut down should air movement disturb scenery.

- **Low- & High-Level Supply** – Flexible ductwork “Elephant Trunks” from the mid-level perimeter ductwork to floor level provide low velocity air at floor level to offer both general cooling as well as spot cooling within enclosed sets. The cool air displaces warm air, improving the cooling effect of the ventilation system.

Modelling

Computational Fluid Dynamic (CFD) modelling has been undertaken to determine the level of comfort cooling that might be achieved in summer by a ventilation system served by ASHPs sized to meet winter heating needs. This modelling was based on a typical 30,000 sq. ft. Stage using the following assumptions:

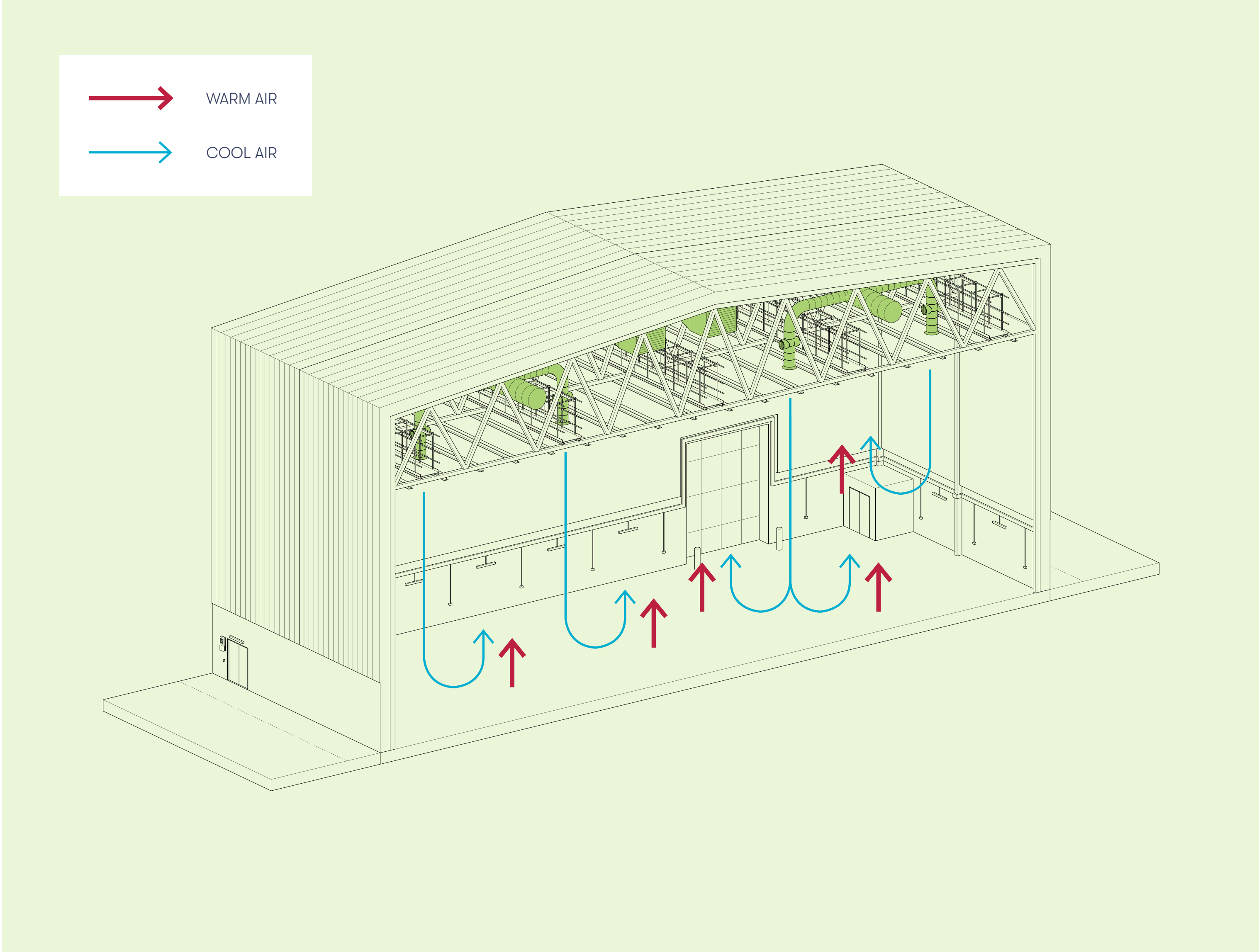
Production Lighting
Lighting loads in a Stage are driven by either the use of LED or tungsten lamps or a mixture of both. Where a film set requires a greater lighting level, any additional required cooling is provided 'locally' by the production company. Although lighting loads can be as high as 500W/m². This is not typical. The modelling assumed 200W/m² as an average to 50% of the Stage (modelled as a uniform 100W/m² across the space) with 80W/m² of heat gain at high-level and 20W/m² at floor level, to reflect the output of lamp types that are currently most commonly used.

Small Power
Filming also requires power for cameras, sound, special effects, and other equipment. There is no defined industry standard for these loads in a Stage, although anecdotally 15W/m² is considered a reasonable allowance for overall equipment gains. The electrical distribution system will typically be capable of handling a higher load, and this is often concentrated in a more localised area to suit a production's filming requirement.

Occupancy
Occupancy on a film set will vary considerably and at times occupancy may be as low as 30 people. For the purposes of modelling, and to establish the optimal efficiency of cooling solutions, an occupancy of 130 people (production crew and cast) was assumed.

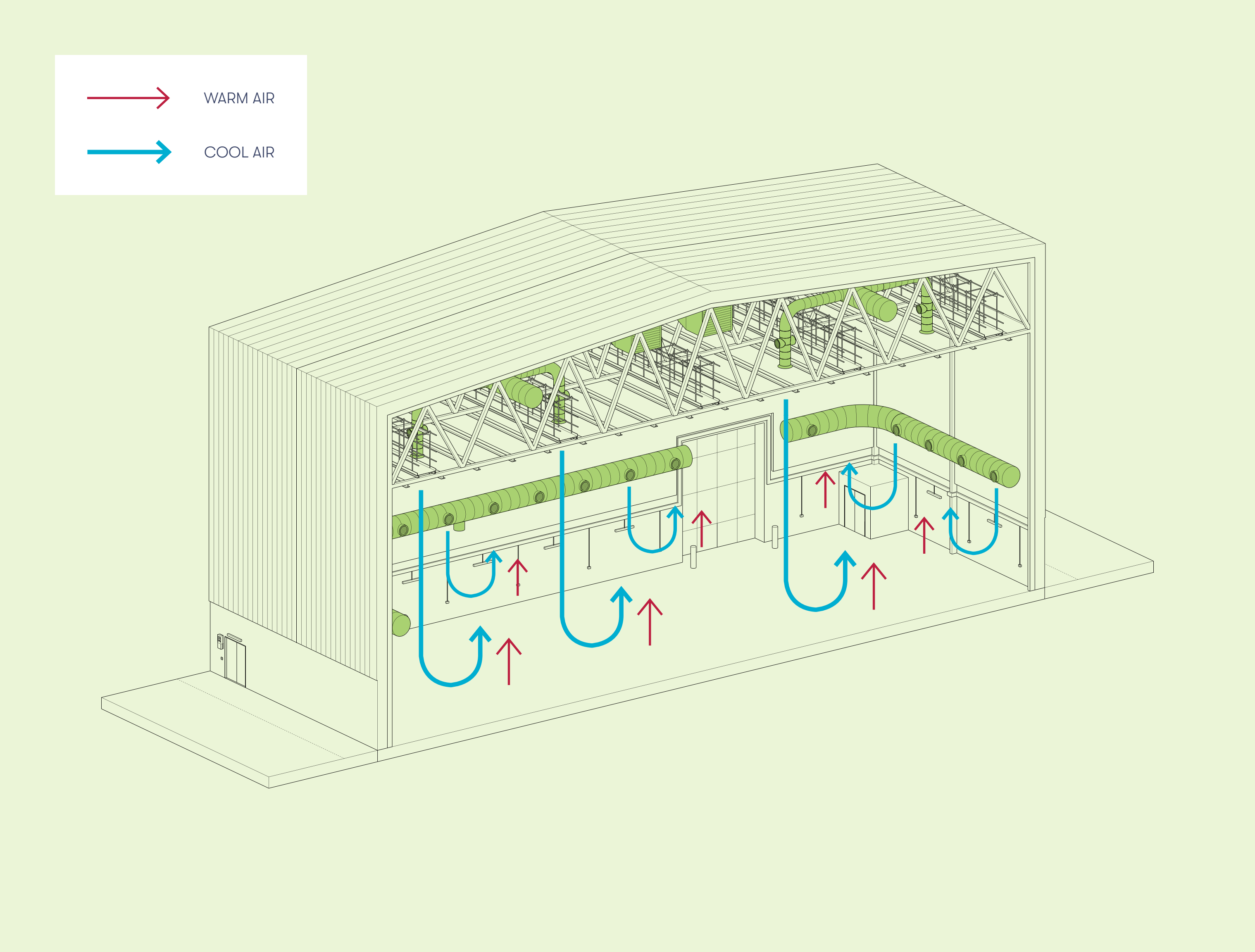
Air Supply Arrangements
Three air supply scenarios were modelled:

High Level
Where all the air within the Stage is delivered at high level - at roof truss level, just below the gantries



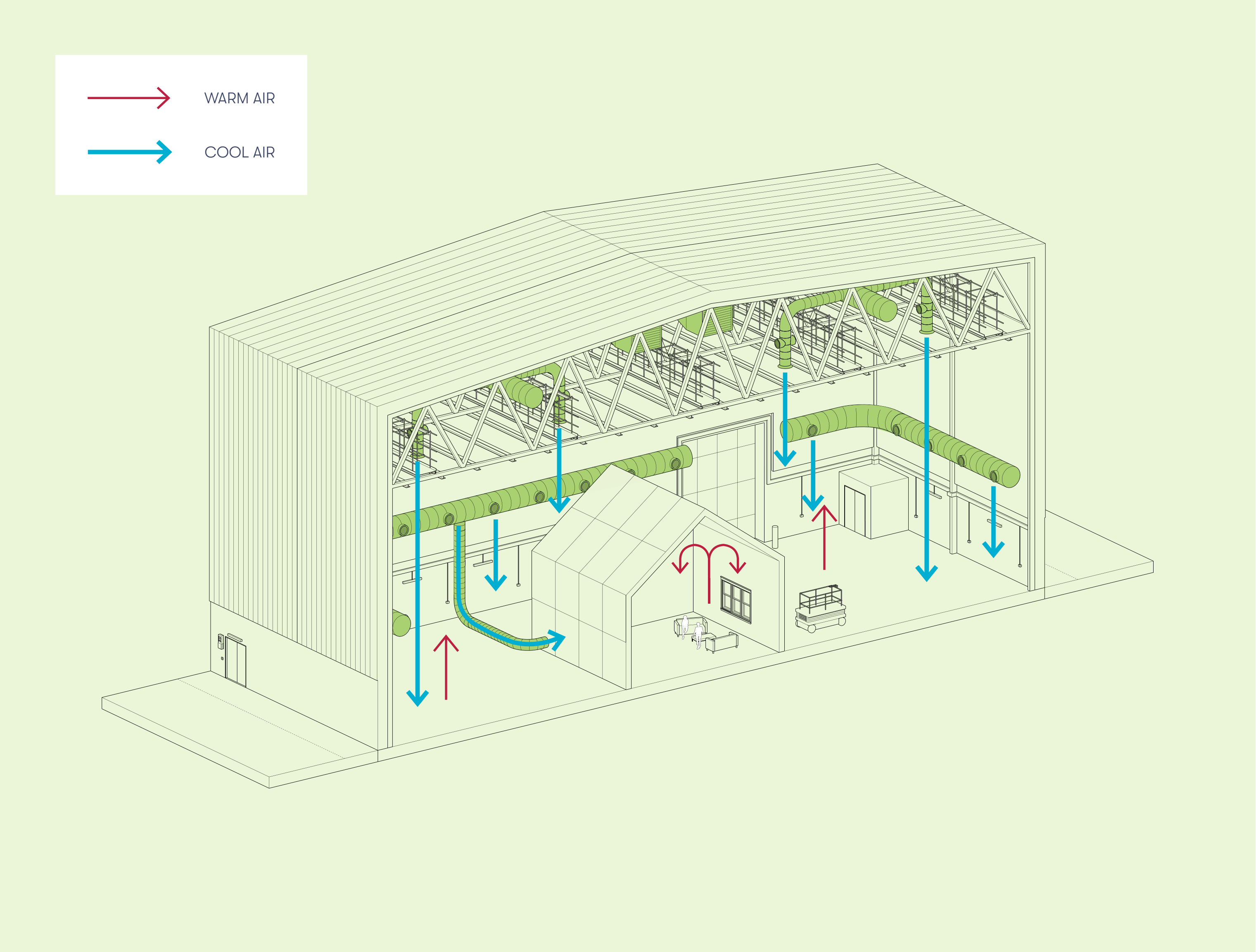
High Level ventilation solution

Mid and High Level
Where 50% of the supply air is delivered at high level and 50% from side vents approximately 6m above the Stage floor



Mid and High-Level ventilation solution

Mid, High and 'Elephant Trunks'
Where 50% of the supply air is delivered at high level and 50% of the air introduced 6m above the Stage floor in conjunction with flexible 'elephant' ducts that can be used by productions to supply air into enclosed sets



Mid, High and 'Elephant Trunk' ventilation solution

Comfort Cooling Results

Modelling shows that ASHPs sized for winter heating loads could, for the assumed heat gain in summer, deliver an average air temperature of 27°C at 1.5m above the Stage floor, and that supplementary cooling would be required to provide 'full' comfort.

Changing the air supply distribution arrangement so that only 50% is supplied at high level and the remainder is supplied through a combination of ducts at 6m and flexible ducts at Stage floor level reduced the average temperature at 1.5m height to 25.7°C. Distributing air at lower levels and directly to the Stage via 'Elephant Trunks' is a way of maximising the comfort cooling benefit of using ASHPs in reverse.

Given the new Part L Regulations are likely to establish a new baseline for the servicing costs of studios, comfort cooling would be available at limited additional capital cost compared with the baseline costs required for compliant heating and ventilation systems.

Conclusions

Compliance with Part L 2021 becomes easier where air-source heat pumps are used to provide heating compared to a gas boiler. Some PV may still be required to achieve compliance, particularly where heat pumps are not meeting 100% of the heating and hot water load.

Tightening Building Regulations and corporate commitments on reducing CO_2 emissions are expected to drive an increase in the use of air-source heat pumps, and in turn, provide the opportunity for an element of comfort cooling without significant additional investment.

Distributing air at lower levels and directly to the Stage via Elephant Trunks can maximise the comfort cooling benefit that could be obtained from using ASHPs in reverse cycle mode during summer months.

It should be recognised that providing comfort cooling all year round, while improving ambient temperatures, will result in an overall increase in energy use. Increasing renewable energy provision through the addition of PV roofs would be one way of helping to offset the associated operational energy cost and CO_2 emissions.

→ Studio site-wide Low-Carbon Strategies

Introduction

To meet the UK's net zero target, energy demands must be reduced so they can be met by renewable sources, with any excess emissions absorbed by natural carbon sinks or man-made carbon capture.

Reducing energy use and reusing wasted energy is essential to this. This shift moves heating solutions away from gas boilers to electric heat pumps powered by low-carbon electricity. These pumps enable the development of efficient low-temperature communal or district energy networks, supplying low-carbon heat or cooling and recovering waste heat.

In the UK more than 80% of District, County, Unitary and Metropolitan Councils have declared a Climate Emergency, along with 8 combined authorities and city regions. Many have committed to reducing their area's CO_2 emissions to zero ahead of the UK target and heat networks are set to become central to policy for the decarbonisation of heat in buildings. The Government's Heat and Buildings Strategy[3] sets out a range of policy actions related to district heating, including:

- capital funding to suitable projects and funding for initial studies in the heat network development process.

- Heat Network Zoning of areas where heat networks could provide the lowest cost and carbon solution. Subject to further development of the policy, connection to a heat network could be mandated for buildings with a large heat load that are situated within a designated zone.

A site-wide energy approach to a studio development can use a wider set of energy sources such as ground or water source heat pumps, improving seasonal building service efficiencies. For example, heat rejected from cooling in one area could be used for heating another area on the studio campus. Regional and local planning policies in some areas promote the development of heat networks. Whilst seemingly attractive these benefits need to be weighed against:

- the additional operational heat losses;
- the associated embodied carbon for distribution infrastructure in a site-wide approach;
- the expected demand profiles of a studio campus, and how often these would allow sharing of energy;
- and the relative capital and running costs of campus-wide and individual building approaches.

This research has assessed the system costs, energy usage and carbon emissions associated with adopting a site-wide heating and cooling strategy for a notional film studio, and compared this with a conceptual building-by-building approach to heating and cooling services.

Whether or not a film studio will explore a heat network will vary depending on the adopted policies of the Local Planning Authority for the respective area. However, several local authorities have planning policies directly related to heat networks, and some require new developments to connect to nearby networks where feasible. If there is no heat network in the area, new developments are often required to be 'heat network ready' to enable them to be connected in the future.

[3] In October 2021 HM Government and the Scottish Government each published a separate Heat in Buildings Strategy both of which set out proposals for decarbonising the UK's heating including the development of a heat zoning policy to promote a greater uptake of low-carbon heat networks. The Welsh Government's 2023 Heat Strategy for Wales also seeks to introduce policies to promote a greater use of heat networks.

District Energy Networks (DENs)

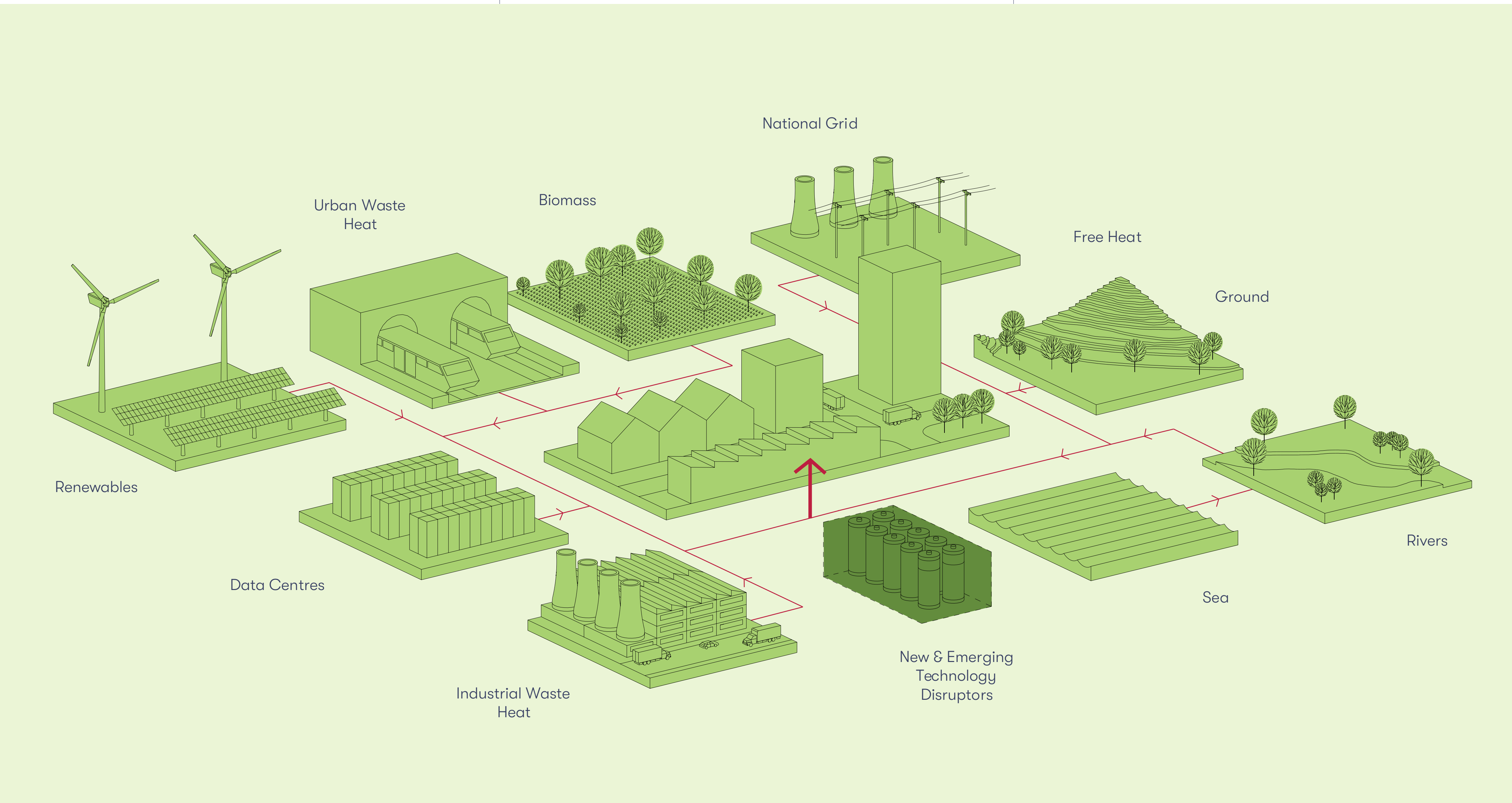
DENs encompass district heating networks, as well as district cooling networks which provide cooling in a similar manner to heat networks, typically through cooled water piped from a central cooling source to where it is required.

District Heating

A heat network distributes heat via a series of insulated pipes from a central source to a range of connected buildings. The pipes are normally buried underground and connect to a building to supply its heating and hot water needs. A heat network can be a good way to access ambient heat from low-carbon sources such as the air, rivers, and the ground, or waste heat from sources such as sewers and data centres. Heat networks can generate heat and cooling from a range of technologies. New heat networks are now increasingly being served by heat pumps or sources of waste heat from industrial processes or power generation.

Heat networks will typically include an energy centre where a centralised heating or cooling plant is located and will include thermal storage in the form of large water vessels. This thermal storage allows the installed capacity of a heat or cooling generation plant to be reduced.

The thermal store can be 'charged' during non-peak periods and then used to meet peak demands to lower heat generation costs. Centralising heat generation for multiple buildings can reduce the overall plant capacity or electricity network reinforcement, as the peak energy demand is lower when spread across multiple buildings and their uses.



Typical Heat Network

Types of Network

Heat network design has developed over time with advances in heating technology and changes in operating temperatures aimed at improving efficiency. The heat network industry refers to alternative modern systems as 3rd, 4th or 5th generation.

This research has explored the potential for both district heating and district heating and cooling networks to serve a modern studio campus. These were compared against an alternative that is currently more typical where space heating or space heat and cooling is provided by individual Air Source Heat Pumps (ASHPs) in each building.

For all the district network options it was assumed that central heating or cooling generation at the energy centre would be from open loop ground source heat pumps.

Individual Building System:
The merits of district heating and cooling systems were compared against a conceptual case where each building on the studio campus was served by its own heating or combined heating and cooling services.

ASHP (Heating and Cooling) – this assumes individual reverse-cycle ASHPs provide both heating and cooling to each building.

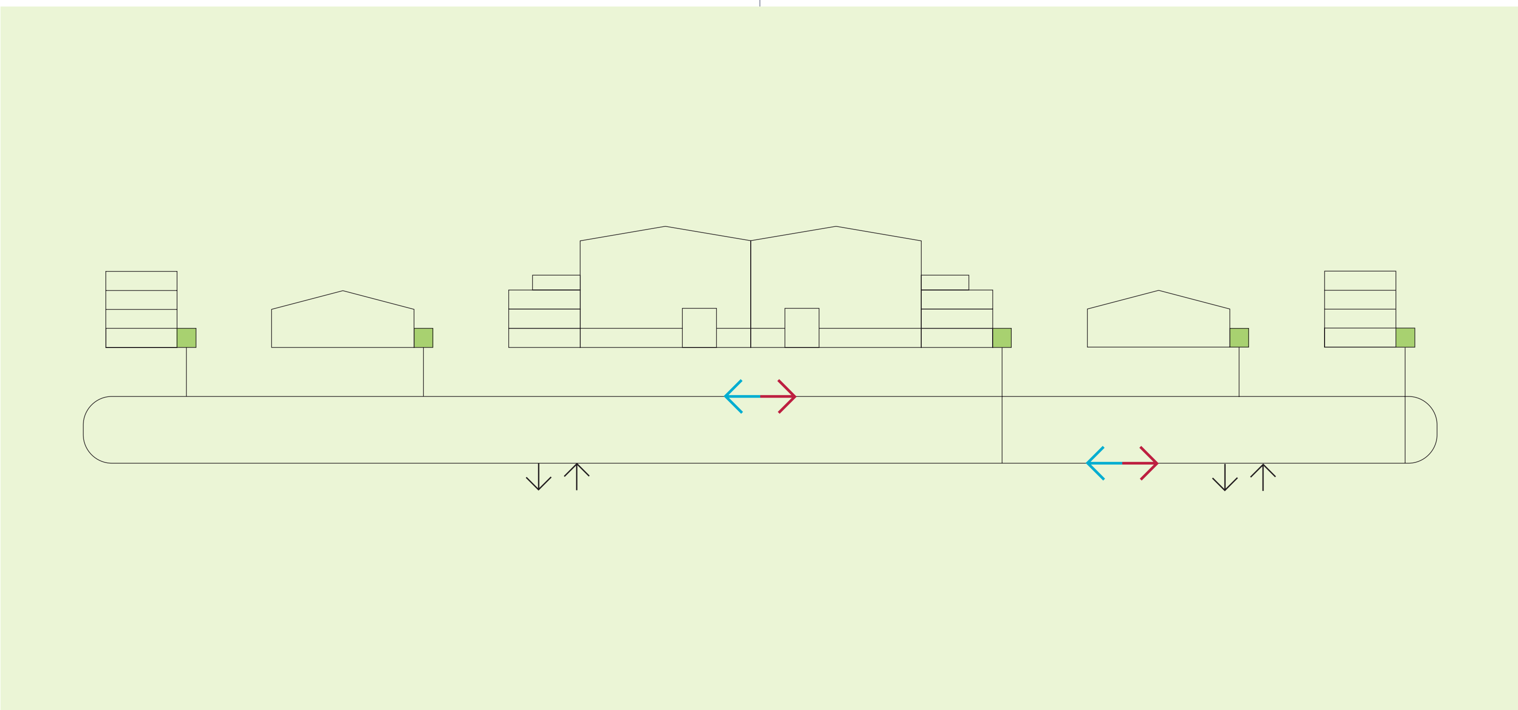
ASHP (Heating Only) – this assumes individual ASHPs provide heating only to each building

Communal Systems – District Energy Networks
The following configurations of DENs for campus-wide heating / cooling solutions were assessed:

5th Generation Ambient Loop (Single Pipe)

A communal low-temperature/ambient pipework loop condenser circuit, serving each building, with local heat pumps in each building rejecting or extracting heat from a communal circuit. This type of DEN is commonly referred to as a 5th Generation system.

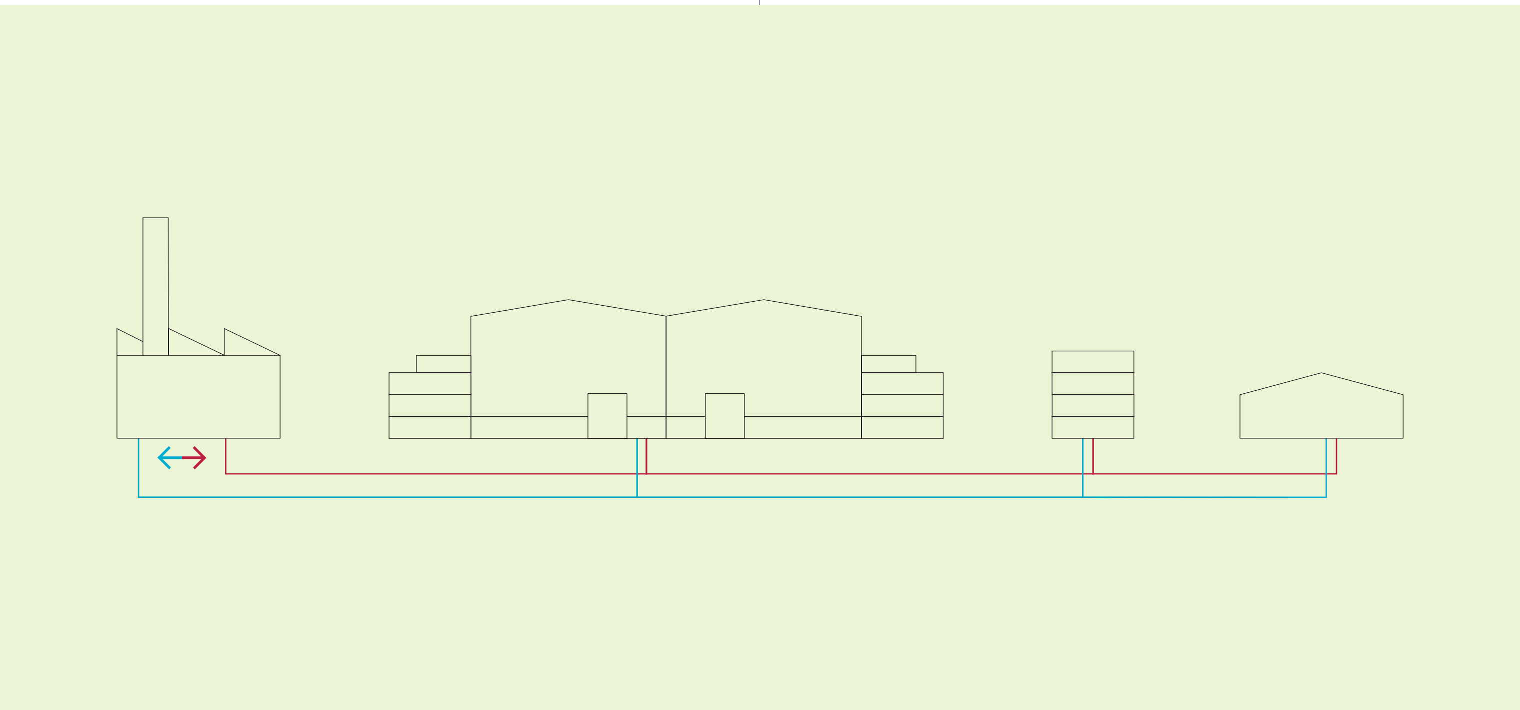
A 5th generation network differs from a traditional design of heating and cooling network, as instead of separate flow and return pipework for heating and cooling networks, there is just one low temperature pipe loop that the buildings extract and reject heat to. This is connected to a top up heat/ coolth source at a central energy centre. This type of system is not currently very prevalent in the UK, but it is most suited where there are year-round, sustained heating and cooling demands of similar magnitudes.



5th Generation Ambient Loop (single pipe)

4.5 Generation Heating and Cooling Network with Prosuming

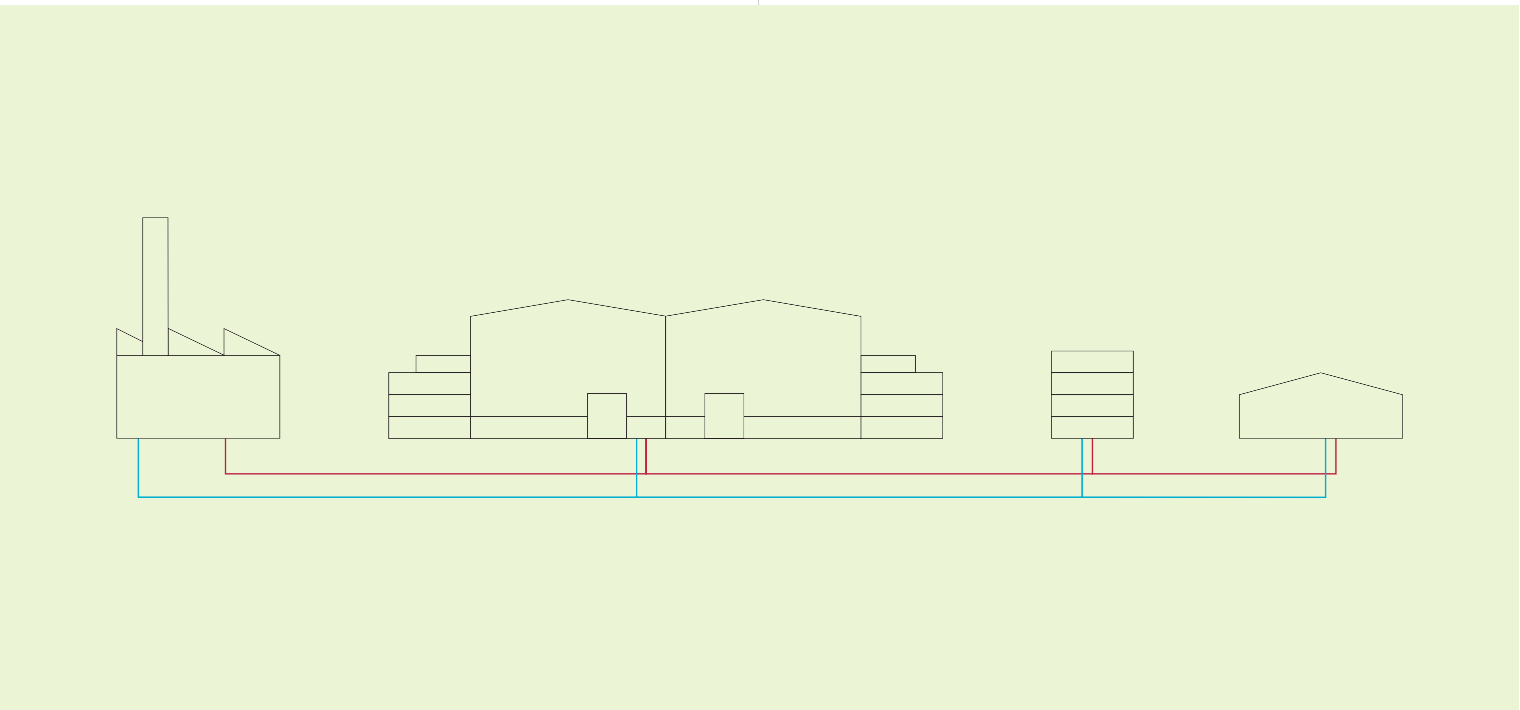
A heating and cooling network served by a central energy centre, that reuses waste heat recovered from its cooling plant. This network serves buildings with heat exchangers in each building, receiving heated or cooled water from the network. This is commonly referred to as a 4th Generation system, although due to the addition of waste heat recovery from the cooling system, it was referred to as a 4.5 Generation system for this study. In this system, pipes are sending and returning heated or cooled water between the central energy centre and the plate heat exchangers (PHEXs) located in each building.



4.5 Generation Heating and Cooling Network with Prosuming

4th Generation Heating-Only Network

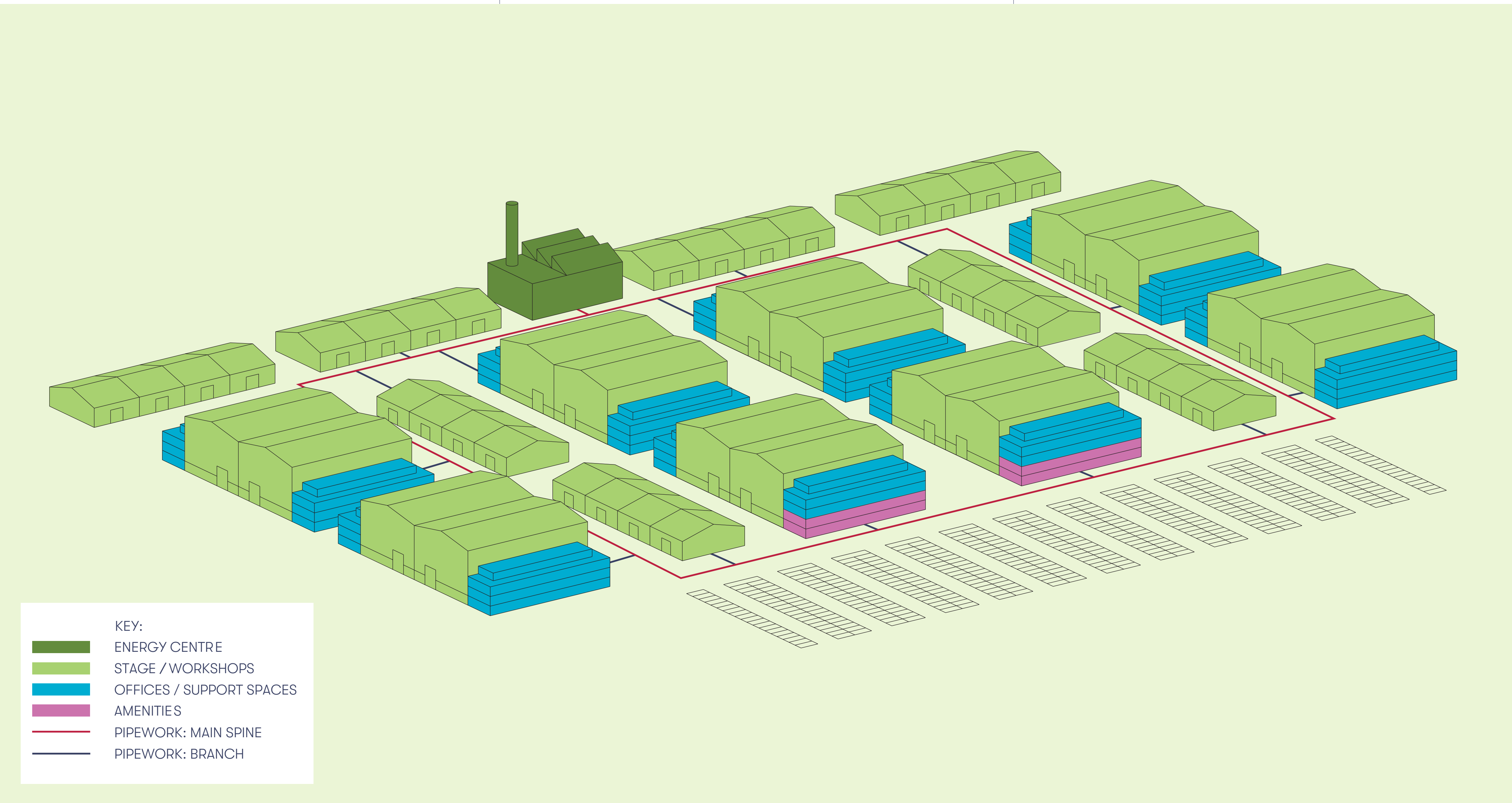
A heating network is served by a central energy centre, delivering heat to PHEXs located in each building. This network is similar to the 4.5 Generation system, albeit, without cooling. Pipework in this arrangement sends hot water between the central energy centre and the building-level PHEXs.



4th Generation Heating-Only Network

Studio Definitions and Assumptions

To assess the merits of a sitewide energy solution the following example studio layout was used to inform assumptions on the number of building types across a typical large studio campus, their projected energy demand, servicing strategy, pipe layouts, embodied carbon emissions and associated costs:



Notional Studio Layout

The example studio is located on a 36-hectare site and comprises circa 16 Stages, with workshops and support spaces, totalling circa 500,000 sq. ft.

Energy demands for offices and workshops are well understood, however, Stages are relatively bespoke and for this assessment it has been assumed that Stage systems provide:

- minimum 2 air changes per hour
- winter heating to 17°C
- summer cooling to provide comfort cooling only (ASHPs sized for winter space heating and used in reverse cycle for cooling in summer)
- provision of flow and return connections, power and water supply for additional temporary chiller use
- much lower supply temperatures (below 45°C) required for space heating compatible with heat pump systems in Stages with improved levels of fabric efficiency

In addition, the following typical operating schedules for each building type were developed:

Building Type	Weekday Operation	Weekend Operation
Workshop/Office	7am-7pm	Not applicable
Studio Facilities & Amenities	7am-7pm with lower usage during the week, and higher weekend usage	7am-9pm with lower usage during the week, and higher weekend usage
Security	24/7 operation	24/7 operation
Cafe	9am-5pm	7am-7pm on Saturdays

Occupancy assumptions for building types

The annual heating and cooling energy use for non-Stage buildings was estimated based on typical industry benchmarks and past project experience. Energy demands for the Stages were based on dynamic energy demand modelling from wider research undertaken in this report.

Conclusions

Comparing the scenarios modelled, a district energy solution can provide CAPEx[4] savings for the representative studio campus in a heating-only scenario. However, individual building ASHPs may have lower up-front costs in scenarios where high levels of cooling are delivered to studio buildings as central plant and pipework costs increase with the provision of district cooling.

	Current Typical Installation (conceptual): Separate ASHP Installations to each building providing heating and comfort cooling	Solution 1: 5th Generation Ambient Loop DEN	Solution 2: 4.5 Generation Heating & Cooling DEN	Current Typical Installation (conceptual): Separate ASHP Installations to each building providing heating only (Heating Only)	Solution 3: 4th Generation DEN (Heating Only)
Capital Expenditure (CAPEx)	£26.7	£28.6	£27.4	£9.1	£8.9
Lifetime Costs (CAPEx, OPEx, REPEx, Fuel)	£78.1M	£73.3M	£64.4M	£25.8M	£22.0M
Lifetime Cost Savings Over Typical Solution	-	£4.8M	£13.7M	-	£3.8M
Lifetime Operational Carbon Emissions	7326 Tonnes CO_2e	5498 Tonnes CO_2e	5395 Tonnes CO_2e	2348 Tonnes CO_2e	2649 Tonnes CO_2e
Embodied Carbon Emissions	6464 Tonnes CO_2e	2164 Tonnes CO_2e	11790 Tonnes CO_2e	1822 Tonnes CO_2e	840 Tonnes CO_2e
Total Carbon Saving Over Typical Solution	-	6127 Tonnes CO_2e	-3395 Tonnes CO_2e	-	681 Tonnes CO_2e

Summary of Modelled Scenarios

- OPEx is the costs associated with operation and maintenance of the plant and network items over 40 years.
- REPEx is the plant replacement expenditure over the assumed 40 year life.
- Fuel is the electricity cost over the 40-year life which is influenced by services systems efficiencies.
- Lifetime Operational Carbon emissions are the carbon emissions resulting from the energy consumed by services equipment over an assumed 40-year life.
- Embodied Carbon emissions are the lifetime embodied carbon emissions for lifecycle stages A to C as defined by the RICS professional standards and guidance for UK Whole life carbon assessment for the built environment.
- CO_2e refers to CO_2 emissions equivalent, this is a term used to quantify the total greenhouse gas emissions from all operational or embodied greenhouse gases in terms of an equivalent amount of carbon emission. It takes account of the different global warming potential of each greenhouse gas.

[4] CAPEx is the capital investment including: all preliminary capital investment from design to contract award stage and all material, installation and project delivery costs, including design work post commercialisation.

Network solutions with centralised plant can provide savings in operational expenditure and replacement costs, when compared to solutions that require large amounts of plant to be distributed around a studio campus, due to having fewer individual components to maintain and replace.

The modelling found that the improved efficiency of ground-source over air-source heat pumps and the ability for DENs to utilise waste heat from cooling, means that DEN solutions can be more energy efficient than individual building ASHPs and offer lower operational carbon emissions.

Heating-only networks for studios with many Stages with minimal heat demands can increase electrical demands and carbon emissions over building only ASHP solutions due to network heat losses in district heating pipework. Clustering heat networks for only offices and workshops within a studio may be more efficient, but detailed options will need individual evaluation.

DENs can offer embodied carbon savings over building-only solutions, although systems with large amounts of steel pipework, backup heating and cooling plant can increase the system's embodied carbon, leading to higher whole-life carbon emissions. For example, 5th generation ambient loop systems have substantially lower embodied carbon than equivalent 4.5 generation systems. This is because they have fewer distribution pipes and their lower temperature allows steel pipes to be replaced with lower embodied carbon plastic ones.

The DENs that have been assessed for the example studio campus deliver reduced lifetime costs compared to individual building ASHPs. For film studios that have sustained heating and/or cooling demands, DENs could provide a beneficial long-term investment with fewer plant items to maintain and replace. Where there is an opportunity to connect to an area-wide energy network provided by others, this could substantially reduce capital costs and space requirements for plant on site. However, the network operator may seek to recover some of this cost saving through a connection charge.

Energy networks have the additional benefit that thermal storage and diversity of heat loads allow the system to have a lower peak electrical demand than those that adopt ASHP to individual buildings. This could be of particular benefit when developing a new film studio campus in an area with electrical grid constraints.

The analysis undertaken suggests that for Studios with multiple sound Stages and ancillary facilities, there will be merit in appraising district heating solutions against individual building solutions. This is because they may offer lifecycle cost and carbon savings. The anticipated introductions of Heat Zoning policies will aim to create greater certainty for those investing in and operating heat networks and may mandate buildings to connect to energy networks where they are in a defined Heat Zone.

	Capital Cost	Lifetime Costs	Operational CO_2	Embodied CO_2	Lifecycle CO_2	Peak Power Demand
Heating and Cooling						
Building Level ASHPs	3	1	1	2	2	1
5th Generation Ambient Loop DEN	1	2	2	3	3	2
4.5 Generation Heating and Cooling Network	2	3	3	1	1	3
Heating Only						
Building Level ASHPs (Heating Only)	4	4	5	4	4	4
4th Generation (Heating Only)	5	5	4	5	5	5

Comparison of Modelled Scenarios