SMALL SITES PATTERNBOOK

BeFirst design.

VERSION 1.3

Contents

1 Introduction

1.1 Context

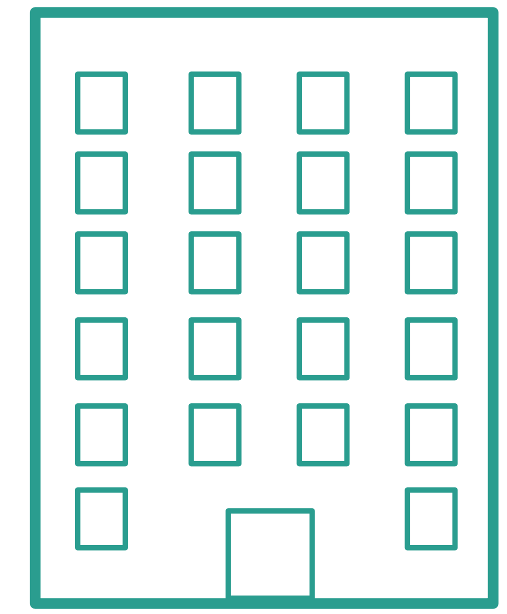
Context for the small sites patternbook

The small sites patternbook is part of a suite of guidance produced by Be First to promote and innovate DfMA across all scales and sites. The Housing Patternbook was produced in 2023, in a process involving consultation with 6 different manufacturers on its use, appropriateness and contents.

The housing patternbook was tested with with architects and main contractors on Be First's framework, with generally positive feedback around demand aggregation. One item that was raised was about demand consistency on included elements which we have tried to build on with the small sites patternbook.

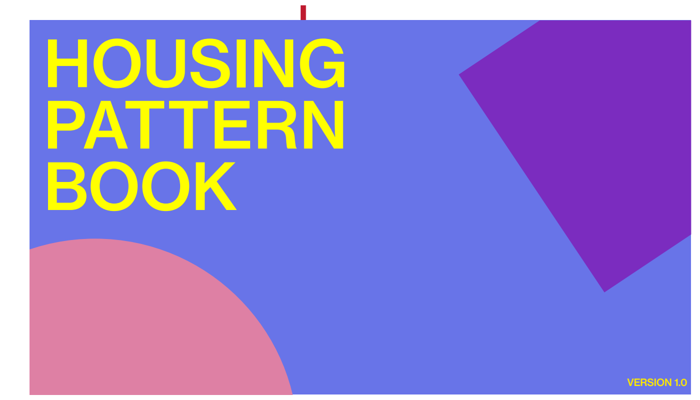
Low Rise / Houses

Apply small sites patternbook principles. Additional design considerations may apply.



Mid / High Rise

Apply patternbook principles. Additional design considerations may apply.



Opposite: Context for the small sites patternbook

1.2 Scope

What is the small sites patternbook?

The small sites patternbook is a Design for Manufacture and Assembly (DfMA) focused guide for the design of new homes on small and constrained sites. Be First has previously completed the development of a housing pattern book with GLA funding focused on the design of higher and mid-rise apartment blocks, with some elements applicable to low rise buildings. This patternbook focuses on the development and deployment of a kit of parts for low-rise housing, focussed particularly but not exclusively on small and constrained aiming to standardise and improve interoperability of construction methods within the industry.

It has been prepared primarily for public housing however the guide is applicable to all tenures. Use of the guide will ensure that DfMA principles are incorporated from the outset of a project and the contractor is not limited in their selection of structural solutions.

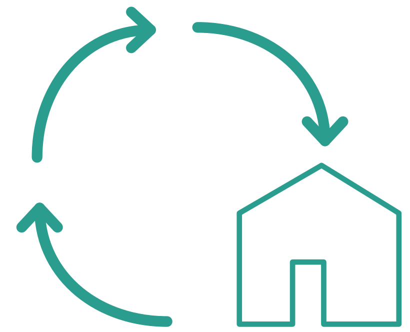
Following the guidance will reduce the time taken to arrive at rational, buildable homes, thereby making time to focus on good placemaking, facade treatment and the more bespoke elements of the design.

The Patternbook aims to reduce build costs by improving efficiency in construction and de-risking complex small sites by providing clear guidance on standard interoperable structural systems which can be replicated in a variety of circumstances, allowing the aggregation of multiple small sites across a programme.

The Patternbook implements MMC Categories 2, 3 and 5. Categories 1 and 4 are not considered to be appropriate, but may be mentioned as benchmarks. Categories 6 and 7 may be implemented but are outside the scope of this guidance.

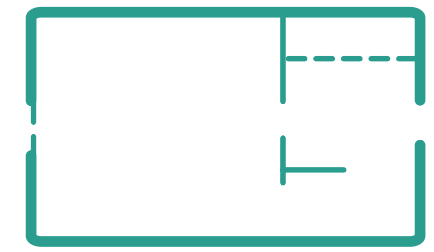
Opposite: Content and scope of the patternbook

Small sites patternbook Key chapters:



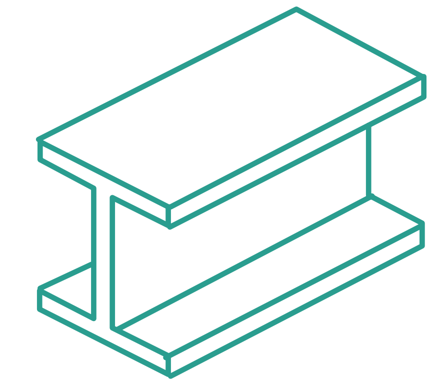
Objectives

Key deliverables for sustainable housing suitable for small sites.



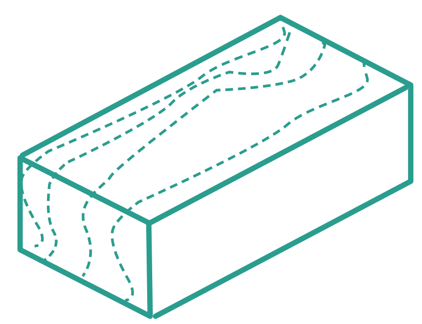
Layout

Principles for sustainable, well designed standardised homes with efficient layouts.



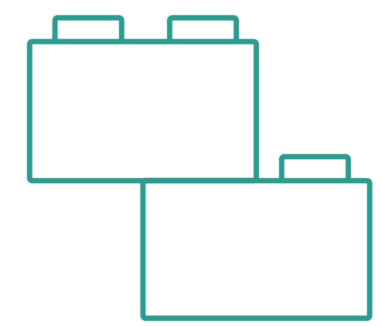
Structure

Structural zones and design principles using four inter-operable structural systems.



Materials

Facade design principles and key considerations.



Construction

Assessment of buildablility and programme implications, as well as constraints and opportunities for DfMA.

Appendices

Evidence of development of patternbook principles.

1.3 How to Use

How to use the small sites patternbook

The Patternbook is a digital asset that aims to streamline construction processes, enhance standardisation, and improve efficiency for MMC, by creating a step by step guide on how to categorise, design and construct houses on small sites. The Patternbook is designed for use around three key scenarios around the development of small sites: in house feasibility studies, briefings for developers, and development research for manufacturers and suppliers.

Each chapter focuses on a different aspect of the process, and by following this step-by-step patternbook, developers and construction professionals can effectively design and build houses on small constrained sites in London using off-site construction methods, whilst having the ability to switch to traditional should this be the optimum approach. This approach complies with the current London Plan, LETI guidance and Future Homes Standards (FHS), and building regulation guidance, while also optimizing efficiency, quality, and sustainability in the construction process.

When to use the small sites patternbook

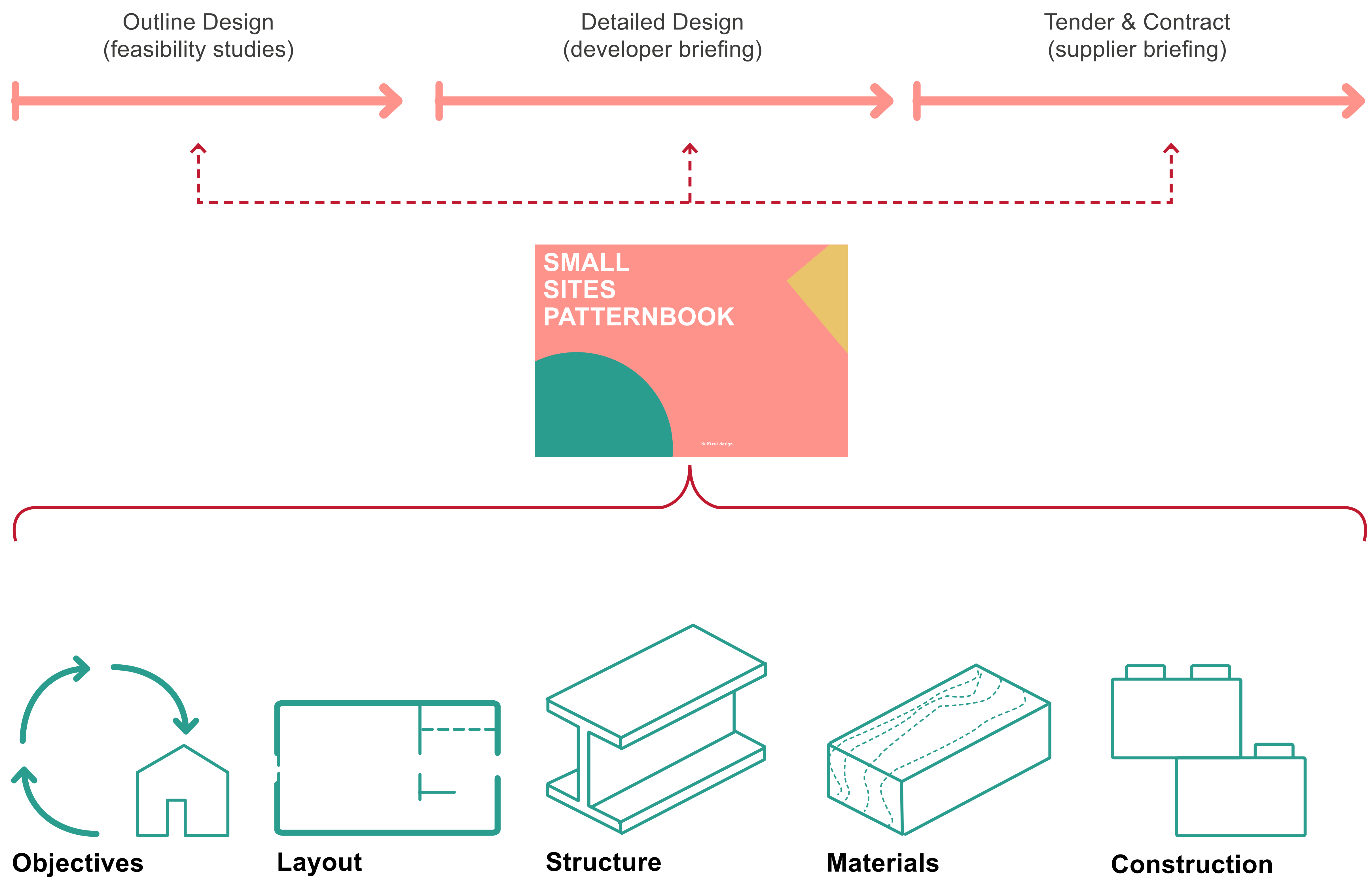
The patternbook brings information typically available at later stages to the project outset to in order to embed DfMA principles from the outset.

‘Traffic Light’ System

To support the specification of systems and materials a traffic light system is implemented to compare factors such as embodied carbon and cost, relative to each other. This is rated as follows:

high ⟷ low

Opposite: When to use the Patternbook chapters



2

Objectives

2.1 Deliverables

Key Objectives

The Patternbook's three key objectives are sustainability, quality and delivery. Utilising modular construction techniques can achieve design flexibility and adaptability for small and irregular sites.

Sustainability

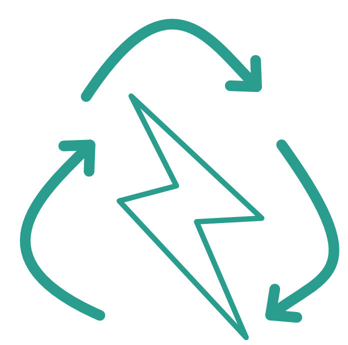
Sustainability objectives aim to progress towards net zero carbon through reduction of operational and embodied carbon.The creatio of sustainable, well designed homes with improved air quality, lack of mould, and lower running costs, can contribute to resident's improved health and well being. Circular design is also an important objective to ensure that design teams actively seek to reuse, refurbish and re-purpose materials and structures where possible.

Quality

The Patternbook is intended to streamline the design process so that less time is spent on resolving layouts and more on improving the quality of design and placemaking. Balancing standardisation and innovation is key to ensuring a consistent level of quality, alongside allowing innovation and improvements to be made. The proposals in the pattenbook are intended to comply with NDSS standards for space and quality.

Delivery

Delivery objectives aim to maximise the benefits of early engagement between consultant team and suppliers to ensure that best value is delivered. A digital first approach should be taken to make use of technological advances. Modular delivery solutions should be tailored to optimise the use of space and resources.

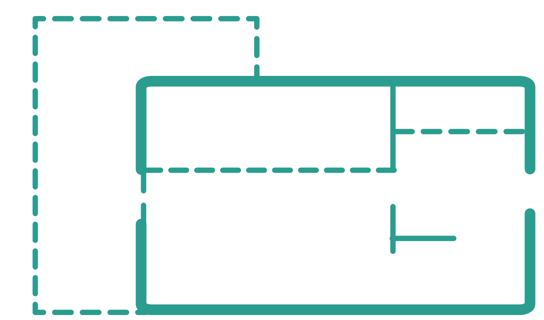


Sustainability

Towards operational zero carbon

Reduce embodied carbon

Circular Design

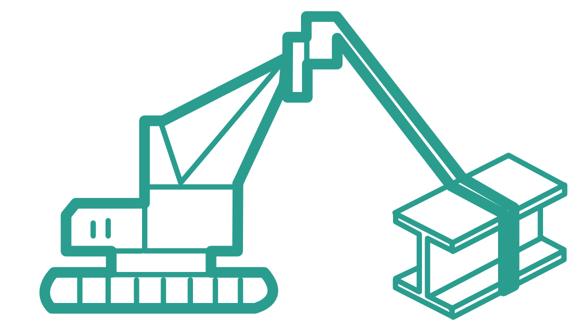


Quality

Flexible and adaptable

Standardise and innovate

Built to last



Delivery

Digital first

Engineered and costed

Deliver best value

Fostering collaboration

Opposite: Key Objectives for the small sites patternbook

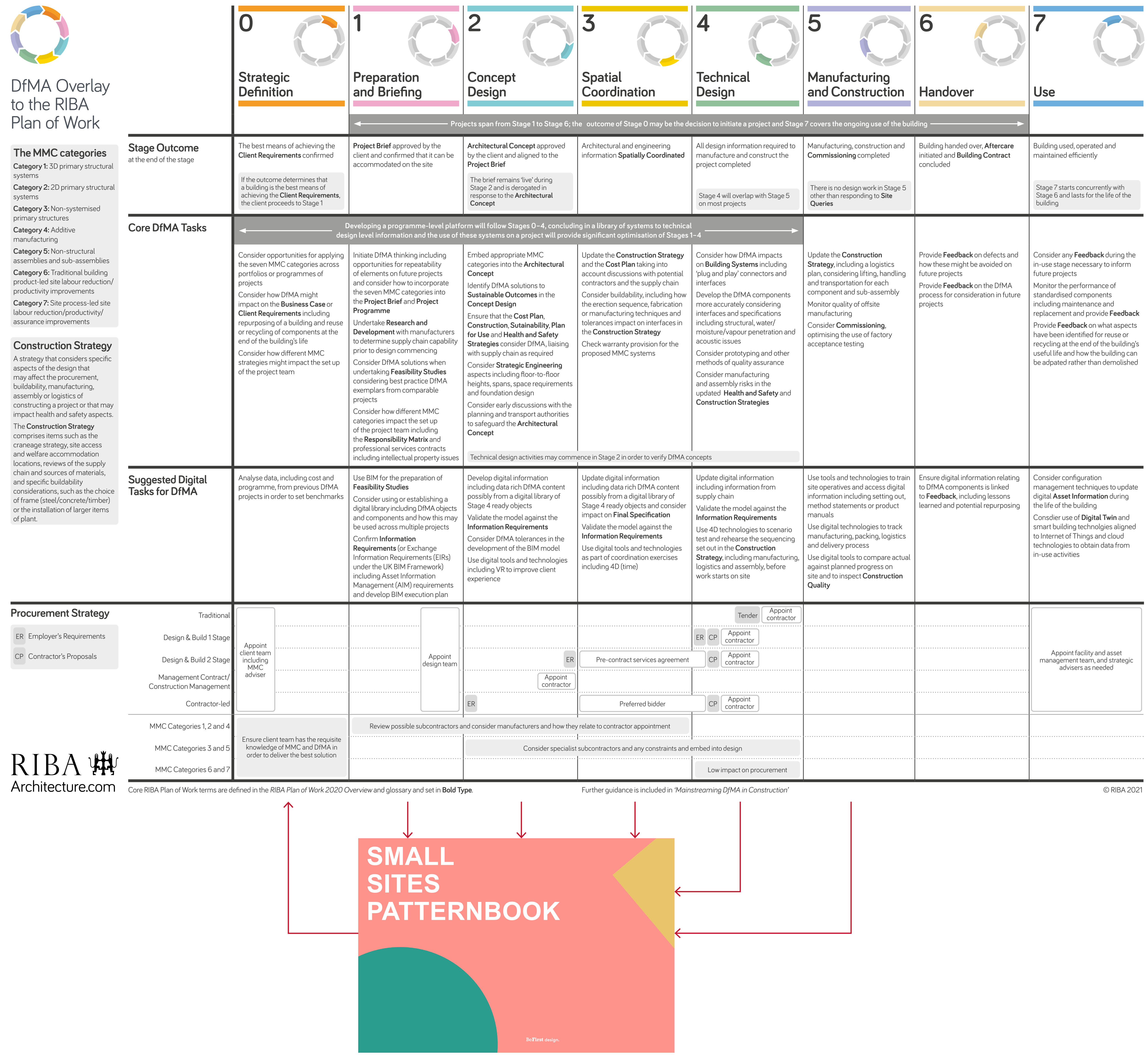
2.2 Plan of Work

The Patternbook has been developed to align with the RIBA Plan of Work. With the focus on DfMA, users of the Patternbook should familiarise themselves with the DfMA Overlay to the RIBA Plan of Work as design and procurement activities may sit in different stages to traditional work stages.

It is important that the client team has the requisite knowledge of MMC and DfMA from the outset of a project in order to deliver the best solution. If MMC categories 2, 3 or 5 are to be used in a project potential subcontractors and manufacturers should be considered from RIBA Stage 2, as well as how their appointment relates to the form of procurement envisaged. Definitions of MMC categories can be found in The MMC definition framework.

A continuous feedback loop is intended to draw upon knowledge from later stages to inform early stage design and briefing. KPIs should be monitored throughout the design process and reported at interim periods and the end of work stages to drive informed design decisions and meet client targets. The collected data will also help with the feedback process to further refine the Patternbook.

Reported KPIs should include the typical client specific KPIs and DfMA Patternbook specific KPIs as a minimum. There may be additional sustainability and performance based KPIs that should be included in the project brief.



DfMA Overlay to the RIBA Plan of Work

The MMC categories

Category 1: 3D primary structural systems
Category 2: 2D primary structural systems
Category 3: Non-systemised primary structures
Category 4: Additive manufacturing
Category 5: Non-structural assemblies and sub-assemblies
Category 6: Traditional building product-led site labour reduction/ productivity improvements
Category 7: Site process-led site labour reduction/productivity/ assurance improvements

Construction Strategy

A strategy that considers specific aspects of the design that may affect the procurement, buildability, manufacturing, assembly or logistics of constructing a project or that may impact health and safety aspects.

The **Construction Strategy** comprises items such as the craneage strategy, site access and welfare accommodation locations, reviews of the supply chain and sources of materials, and specific buildability considerations, such as the choice of frame (steel/concrete/timber) or the installation of larger items of plant.

Projects span from Stage 1 to Stage 6; the outcome of Stage 0 may be the decision to initiate a project and Stage 7 covers the ongoing use of the building

Developing a programme-level platform will follow Stages 0–4, concluding in a library of systems to technical design level information and the use of these systems on a project will provide significant optimisation of Stages 1–4

	0 Strategic Definition	1 Preparation and Briefing	2 Concept Design	3 Spatial Coordination	4 Technical Design	5 Manufacturing and Construction	6 Handover	7 Use
Stage Outcome at the end of the stage	The best means of achieving the **Client Requirements** confirmed If the outcome determines that a building is the best means of achieving the **Client Requirements**, the client proceeds to Stage 1	**Project Brief** approved by the client and confirmed that it can be accommodated on the site	**Architectural Concept** approved by the client and aligned to the **Project Brief** The brief remains 'live' during Stage 2 and is derogated in response to the **Architectural Concept**	Architectural and engineering information **Spatially Coordinated**	All design information required to manufacture and construct the project completed Stage 4 will overlap with Stage 5 on most projects	Manufacturing, construction and **Commissioning** completed There is no design work in Stage 5 other than responding to **Site Queries**	Building handed over, **Aftercare** initiated and **Building Contract** concluded	Building used, operated and maintained efficiently Stage 7 starts concurrently with Stage 6 and lasts for the life of the building
Core DfMA Tasks	Consider opportunities for applying the seven MMC categories across portfolios or programmes of projects Consider how DfMA might impact on the **Business Case** or **Client Requirements** including repurposing of a building and reuse or recycling of components at the end of the building's life Consider how different MMC strategies might impact the set up of the project team	Initiate DfMA thinking including opportunities for repeatability of elements on future projects and consider how to incorporate the seven MMC categories into the **Project Brief** and **Project Programme** Undertake **Research and Development** with manufacturers to determine supply chain capability prior to design commencing Consider DfMA solutions when undertaking **Feasibility Studies** considering best practice DfMA exemplars from comparable projects Consider how different MMC categories impact the set up of the project team including the **Responsibility Matrix** and professional services contracts including intellectual property issues	Embed appropriate MMC categories into the **Architectural Concept** Identify DfMA solutions to **Sustainable Outcomes** in the **Concept Design** Ensure that the **Cost Plan**, **Construction**, **Sutainability**, **Plan for Use** and **Health and Safety Strategies** consider DfMA, liaising with supply chain as required Consider **Strategic Engineering** aspects including floor-to-floor heights, spans, space requirements and foundation design Consider early discussions with the planning and transport authorities to safeguard the **Architectural Concept**	Update the **Construction Strategy** and the **Cost Plan** taking into account discussions with potential contractors and the supply chain Consider buildability, including how the erection sequence, fabrication or manufacturing techniques and tolerances impact on interfaces in the **Construction Strategy** Check warranty provision for the proposed MMC systems	Consider how DfMA impacts on **Building Systems** including 'plug and play' connectors and interfaces Develop the DfMA components more accurately considering interfaces and specifications including structural, water/ moisture/vapour penetration and acoustic issues Consider prototyping and other methods of quality assurance Consider manufacturing and assembly risks in the updated **Health and Safety** and **Construction Strategies**	Update the **Construction Strategy**, including a logistics plan, considering lifting, handling and transportation for each component and sub-assembly Monitor quality of offsite manufacturing Consider **Commissioning**, optimising the use of factory acceptance testing	Provide **Feedback** on defects and how these might be avoided on future projects Provide **Feedback** on the DfMA process for consideration in future projects	Consider any **Feedback** during the in-use stage necessary to inform future projects Monitor the performance of standardised components including maintenance and replacement and provide **Feedback** Provide **Feedback** on what aspects have been identified for reuse or recycling at the end of the building's useful life and how the building can be adpated rather than demolished
			Technical design activities may commence in Stage 2 in order to verify DfMA concepts					
Suggested Digital Tasks for DfMA	Analyse data, including cost and programme, from previous DfMA projects in order to set benchmarks	Use BIM for the preparation of **Feasibility Studies** Consider using or establishing a digital library including DfMA objects and components and how this may be used across multiple projects Confirm **Information Requirements** (or Exchange Information Requirements (EIRs) under the UK BIM Framework) including Asset Information Management (AIM) requirements and develop BIM execution plan	Develop digital information including data rich DfMA content possibly from a digital library of Stage 4 ready objects Validate the model against the **Information Requirements** Consider DfMA tolerances in the development of the BIM model Use digital tools and technologies including VR to improve client experience	Update digital information including data rich DfMA content possibly from a digital library of Stage 4 ready objects and consider impact on **Final Specification** Validate the model against the **Information Requirements** Use digital tools and technologies as part of coordination exercises including 4D (time)	Update digital information including information from supply chain Validate the model against the **Information Requirements** Use 4D technologies to scenario test and rehearse the sequencing set out in the **Construction Strategy**, including manufacturing, logistics and assembly, before work starts on site	Use tools and technologies to train site operatives and access digital information including setting out, method statements or product manuals Use digital technologies to track manufacturing, packing, logistics and delivery process Use digital tools to compare actual against planned progress on site and to inspect **Construction Quality**	Ensure digital information relating to DfMA components is linked to **Feedback**, including lessons learned and potential repurposing	Consider configuration management techniques to update digital **Asset Information** during the life of the building Consdier use of **Digital Twin** and smart building technolgies aligned to Internet of Things and cloud technologies to obtain data from in-use activities

Procurement Strategy

ER Employer's Requirements
CP Contractor's Proposals

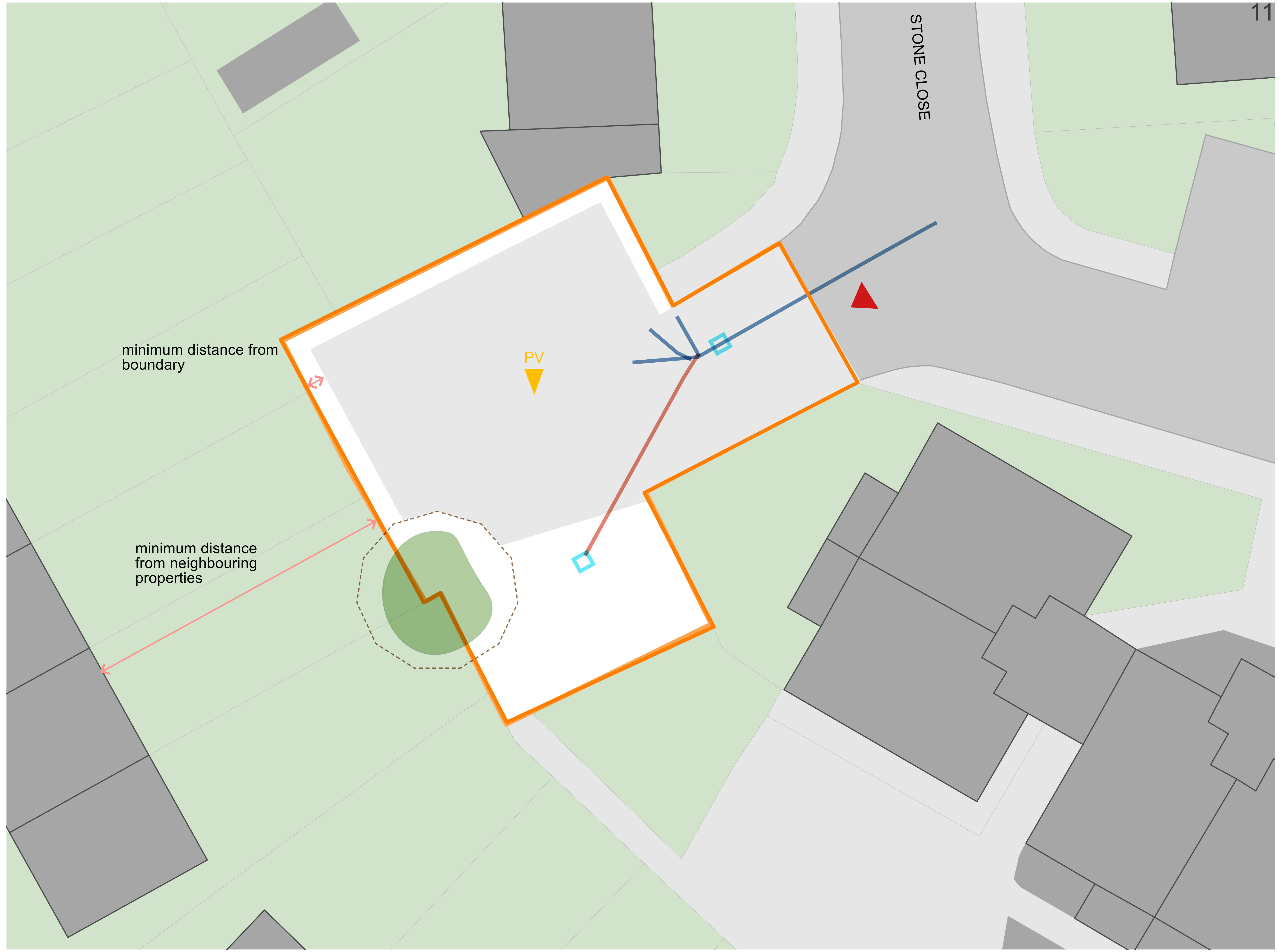
	0	1	2	3	4	5	6	7
Traditional	Appoint client team including MMC adviser	Appoint design team			Tender, Appoint contractor			Appoint facility and asset management team, and strategic advisers as needed
Design & Build 1 Stage					ER, CP, Appoint contractor			
Design & Build 2 Stage			ER	Pre-contract services agreement	CP, Appoint contractor			
Management Contract/ Construction Management			Appoint contractor					
Contractor-led			ER	Preferred bidder	CP, Appoint contractor			
MMC Categories 1, 2 and 4	Ensure client team has the requisite knowledge of MMC and DfMA in order to deliver the best solution	Review possible subcontractors and consider manufacturers and how they relate to contractor appointment						
MMC Categories 3 and 5			Consider specialist subcontractors and any constraints and embed into design					
MMC Categories 6 and 7					Low impact on procurement			

RIBA
Architecture.com

Core RIBA Plan of Work terms are defined in the *RIBA Plan of Work 2020 Overview* and glossary and set in **Bold Type**.

Further guidance is included in *'Mainstreaming DfMA in Construction'*

2.3 Site Parameters



Site Constraints

Assessing site dimensions, topography, and constraints is essential and will help identify potential challenges and opportunities for off-site construction. The development of a site-specific design and planning strategy will be key to the successful delivery of small and complex sites. Where available, indicative detail on below ground services and the location of tree root protection areas should be noted for consideration. Ground conditions such as soil makeup, water table height and proximity of trees may dictate the choice of foundation and ground floor systems.

Analysis of each site specifically can result in a 'Buildable Zone', defined by a suitable offset from the rear of each neighbouring property and any boundary wall. Patternbook users should refer to Building Regulations and the relevant planning documentation for more details of the limitations on overlooking and party wall conditions. Direct overlooking of existing homes and gardens should be limited to guidelines set out in the relevant planning documentation.

Key

- Small Site Boundary
- Buildable Zone
- Main Access
- Suggested PV Orientation
- Tree Root Protection Area (RPA)
- Below Ground Services

Above: Example site parameter analysis

2.4 Approach to site

Standardisation

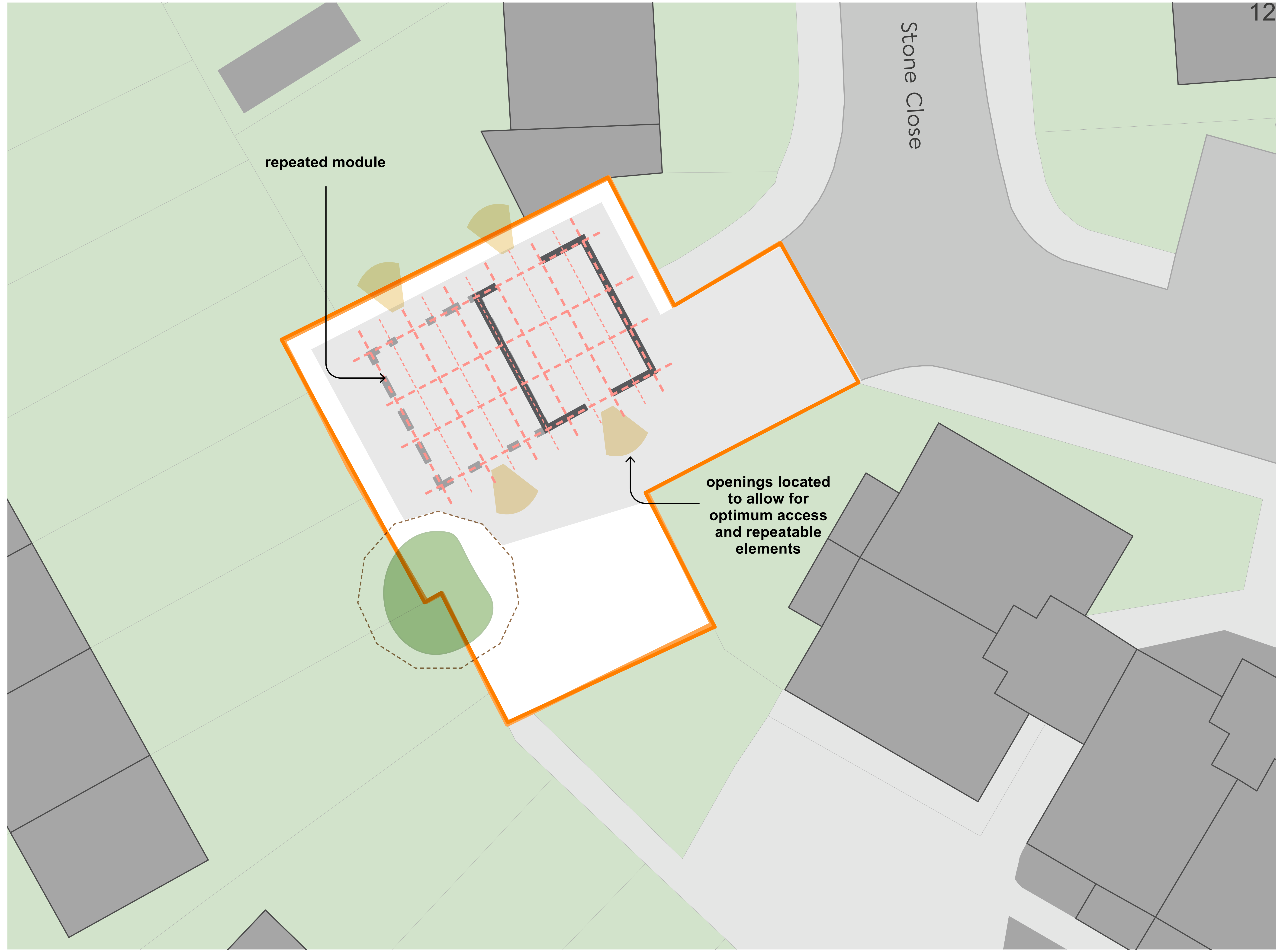
The Patternbook looks at standard home widths and depths to minimise the number of housing types. Across small sites, standardisation is encouraged, however care should be taken to ensure that good placemaking is not compromised. Bathroom and utility cupboard dimensions are assumed as standard and should be replicated across multiple homes to minimise the cost per house. Other elements that should also be considered for standardisation include risers, facade elements, porches.

Use the recommended grids, heights and zone allowances to ensure an efficient structural arrangement and to allow for interoperability of construction types. Initial parameters should be set out to ensure that the proposal is compliant and can be serviced, and zone allowances should be reduced as decisions are made on the structural systems and facade finish. On small and highly irregular shaped sites the use of Patternbook grids may not be appropriate or lead to the most optimum solution for a site. In these instances use of the grid may be loosened but other Patternbook principles should be applied, for example use of pre-made assemblies.

Refer to Building Regulations Part B for more details of the requirements for access for the purposes of emergency access.

Key

- Small Site Boundary
- Buildable Zone
- Outlook / Openings
- Patternbook grid
- Proposed plan



Opposite: Diagram showing standardised and repeatable modules

2.5 Site Optimisation

Efficiency & Sustainability

Site optimisation should be considered at the outset. The Small sites Patternbook includes modules which could be combined in terraced rows to allow for multiple homes on a single site. Whilst servicing and overdevelopment should be carefully considered, the approach to the site should ensure that the maximum number of high quality dwellings are provided.

Patternbook prototypes have limited openings to the front and back of the homes types, allowing for optimisation of orientation where possible, whilst also allowing the repeating of modules. Where party walls are shared, a reduction in material use and a more efficient use of land may be possible.

Provision of multiple homes on small sites can allow for more efficient sharing of resources, such as renewable energy infrastructure and amenity space.

Small sites Patternbook prototypes have been developed to meet LETI low carbon guidance, however if net zero carbon proposals are considered, PV or other renewable energy and additional performance specification will be required.

Key

- Small Site boundary
- Buildable zone
- Solar panels
- ASHP
- Proposed plan

Opposite: Diagram showing terraced / stand alone homes

3

Layout

3.1 Key Principles

The development of a standard grid element which will allow for fixed and flexible elements is key to the Small sites Patternbook.

Design Principles for Homes

The Patternbook home aims to provide adaptable home layouts, to allow for flexible layouts within the main living area, providing residents with ample opportunity to personalise their living space. The partitions can easily be opened or closed to create a variety of layouts, adding to the versatility of the space.

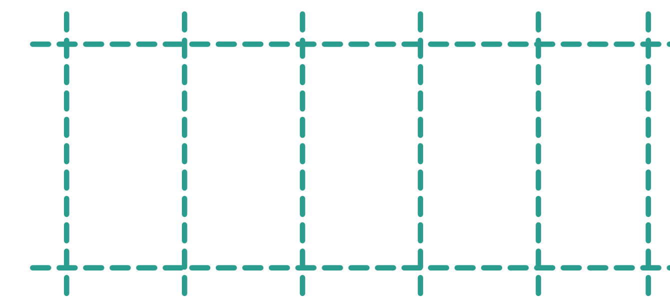
Additionally, the ability to adjust the layout allows residents to make the most of their space, making it an ideal solution for those looking for a home that can adapt to their changing needs.

The patternbook lays out principles to standardise the following as a minimum:

- Standard home width within a grid to minimise the number of types
- Consolidating highly serviced areas of the plan
- Elements that should also be considered for standardisation including facade elements, balconies, windows and door openings
- Recommended grid dimensions, heights and zones to ensure an efficient structural arrangement and allow for interoperability of construction types.
- Simple building envelopes for optimal thermal efficiency and reduced carbon emissions.

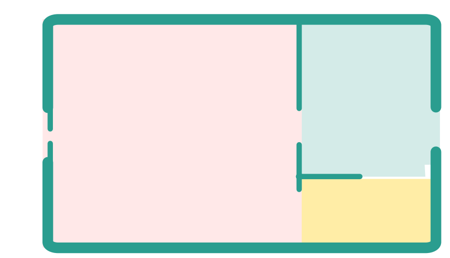
Standardised

Standard types to allow for repeatability of homes.



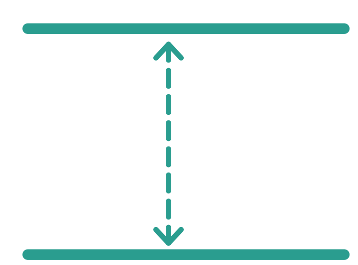
Grid Parameters

Grid dimensions ensure efficient structural arrangement and allow for interoperability of construction types.



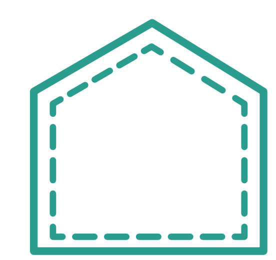
Zones

Structural and servicing zones for inter-operable systems.



Height

Recommended heights for floor to ceiling dimensions and openings.



Building Envelope

Buildups and standardised details for meeting LETI recommended guidance on performance

Illustrative Plans

Comparison of patternbook principles with costed traditional benchmarks (see appendix A & B).

Opposite: Examples of grid formation and flexibility

3.2 Grid Parameters

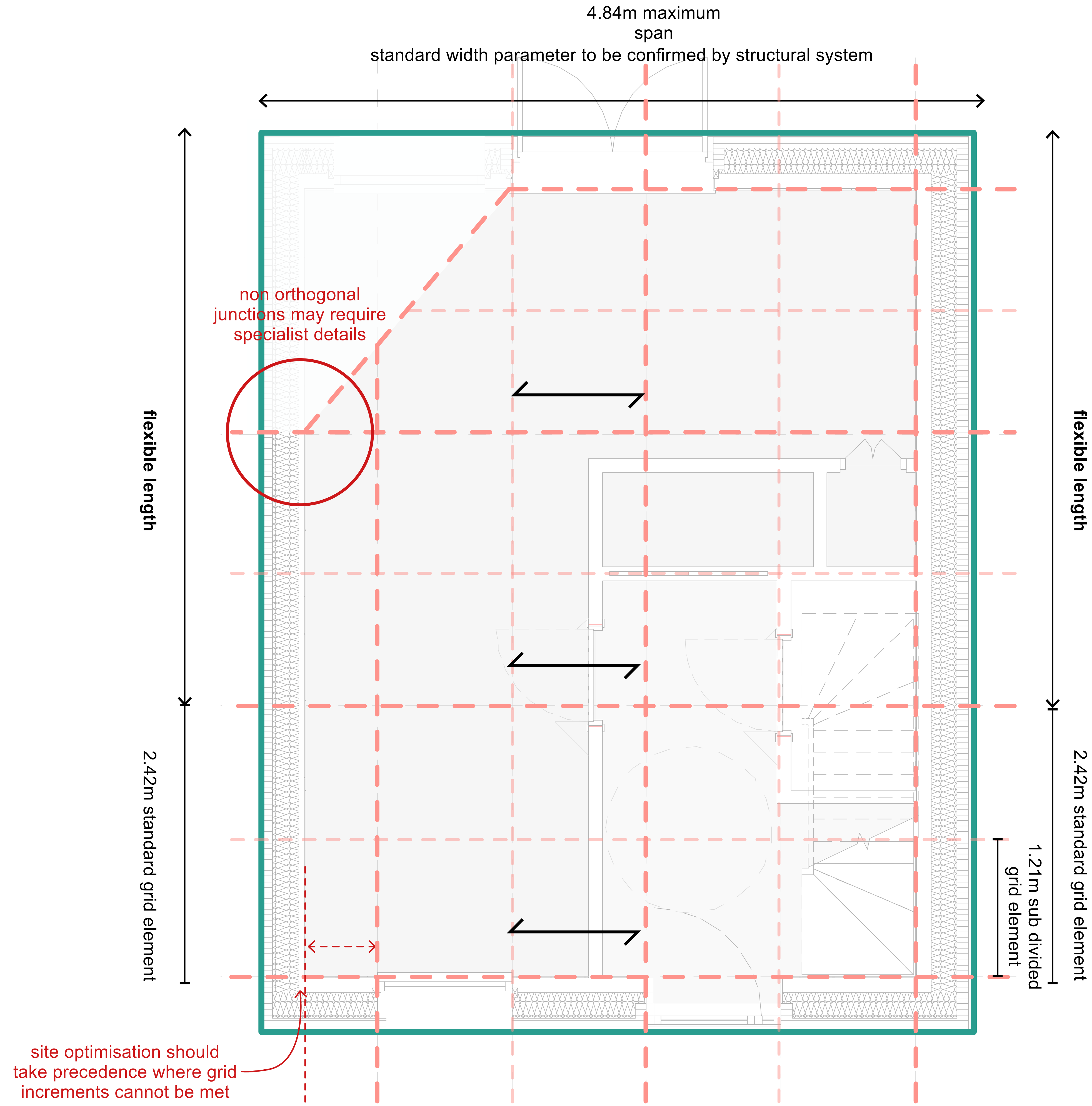
Setting out

The grid dimensions for the small sites patternbook has been set out to reduce waste and facilitate ease of construction. A 1210 / 2420mm grid allows for standard panels to be used with minimal wastage and the possibility of using smaller delivery vehicles. Standardising sizes allows for variation within a set grid which gives confidence to suppliers.

Standardised homes will have a simple footprint with orthogonal party walls. External walls should be flexible to allow for a change in building line, oblique windows or other facade articulation.

The dimensions of the layout should be considered to provide the optimum site occupancy and also to ensure that the preferred structural system can accommodate the maximum span of the home.

While there are options to break from the orthogonal grid, these should be considered carefully to ensure that the form factor and thermal efficiency of the building is not compromised. Non orthogonal junctions may require specialist details.



Opposite: Examples of grid formation and flexibility

3.3 Zones

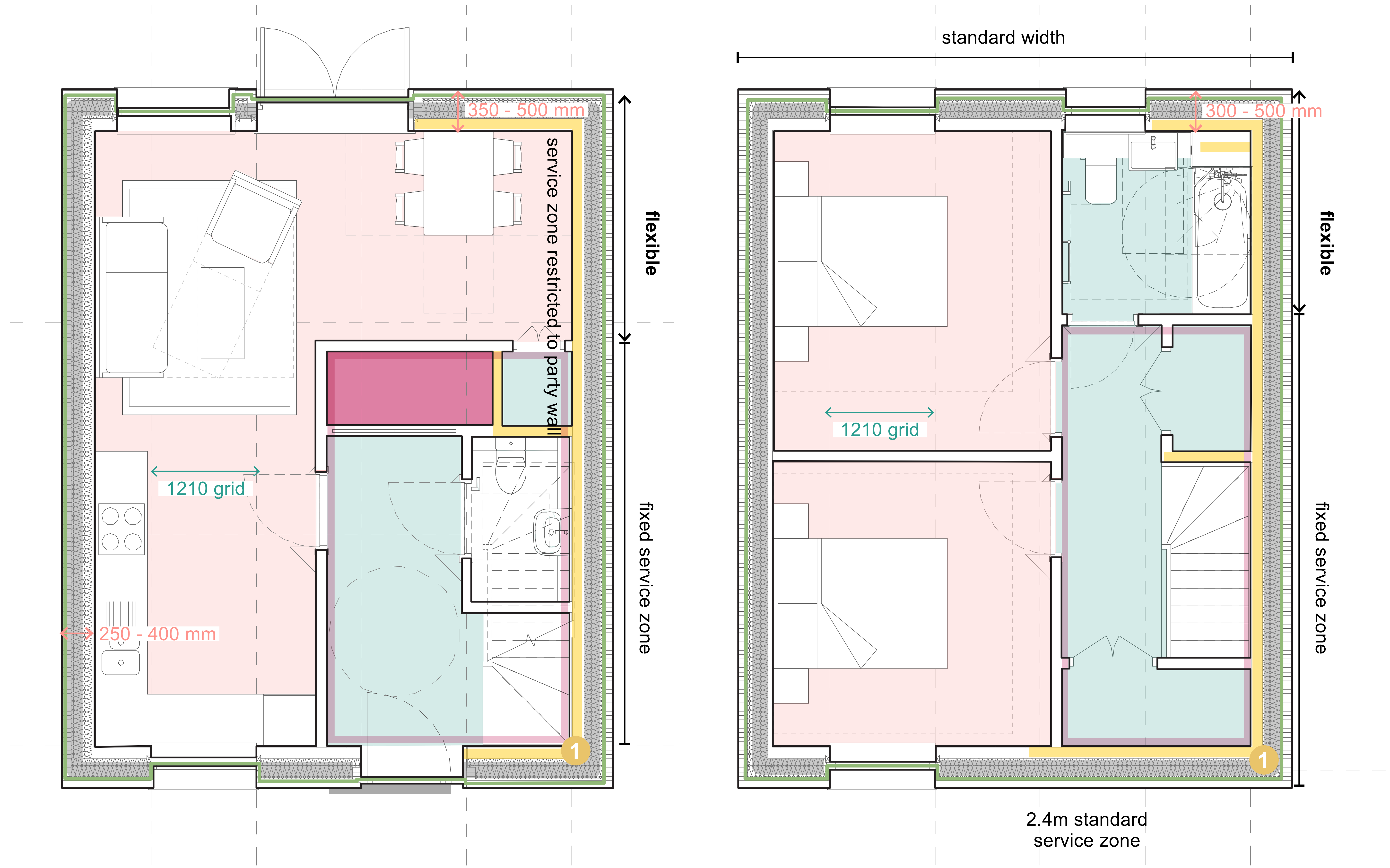
The Patternbook is based on the combination of a series of fixed and flexible components. Services are located in a service zone, with flexible spaces in the flexible zone. This leads to a flexible and adaptable layout, enabling the grouping and easy maintenance of utilities and plumbing. Where service voids are required, these can be limited to the service zone areas.

Serviced Zone

Non-habitable rooms and services are located in the central zone of the plan to minimise service runs and maximise natural light to habitable rooms. This also helps with the installation and maintenance of assemblies. A lowered ceiling within the service zone can allow for service runs, and higher ceiling heights in the remainder of the space. Vertical duct risers to be limited to service zones within walls, however heating pipework can be located within the studwork build up of standard and party walls.

Flexible Zone

Elements within the flexible zone can be added or relocated according to requirements.



Key

- Thermal Envelope
- Service Zone
- Structural Zone
- Utility cupboard
- Build up minimum - maximum

Opposite: Zones for structure and servicing (plan)

Plan Diagram

3.4 Height

3000mm is considered an optimum floor to floor height for a patternbook home provides a minimum habitable room ceiling height of 2500mm and a structural zone which does not preclude any of the preferred systems.

An allowance for adequate service zone for ducts should be included, and where this cannot be contained within a standard ceiling height, it should be adjusted within lowered ceiling sections. Areas with reduced ceiling height should be minimised, and ideally limited to hallways, bathrooms, and utility cupboards.

Each development should have its own energy strategy developed as this is site specific. The maximum depth allowance for MEP services in the ceiling void is 150mm in bedrooms and living rooms and 350mm in corridors, apartment hallways, bathrooms, en-suites and utility cupboards to allow for service crossovers. Services may have to sit below the maximum structural zone to avoid clashes. Wet areas in homes (kitchens, bathrooms, utility cupboards etc.) should stack to avoid transfer of soil vent pipes which cannot be accommodated in typical service zones.

A standard head height of 2.1m is proposed for windows and doors, as it aligns with the standardisation of ceiling, service zones, lintels and readily available, standard components. Structural openings should be sized to maximum 1810mm wide x 2110mm high.

Key

Thermal Envelope

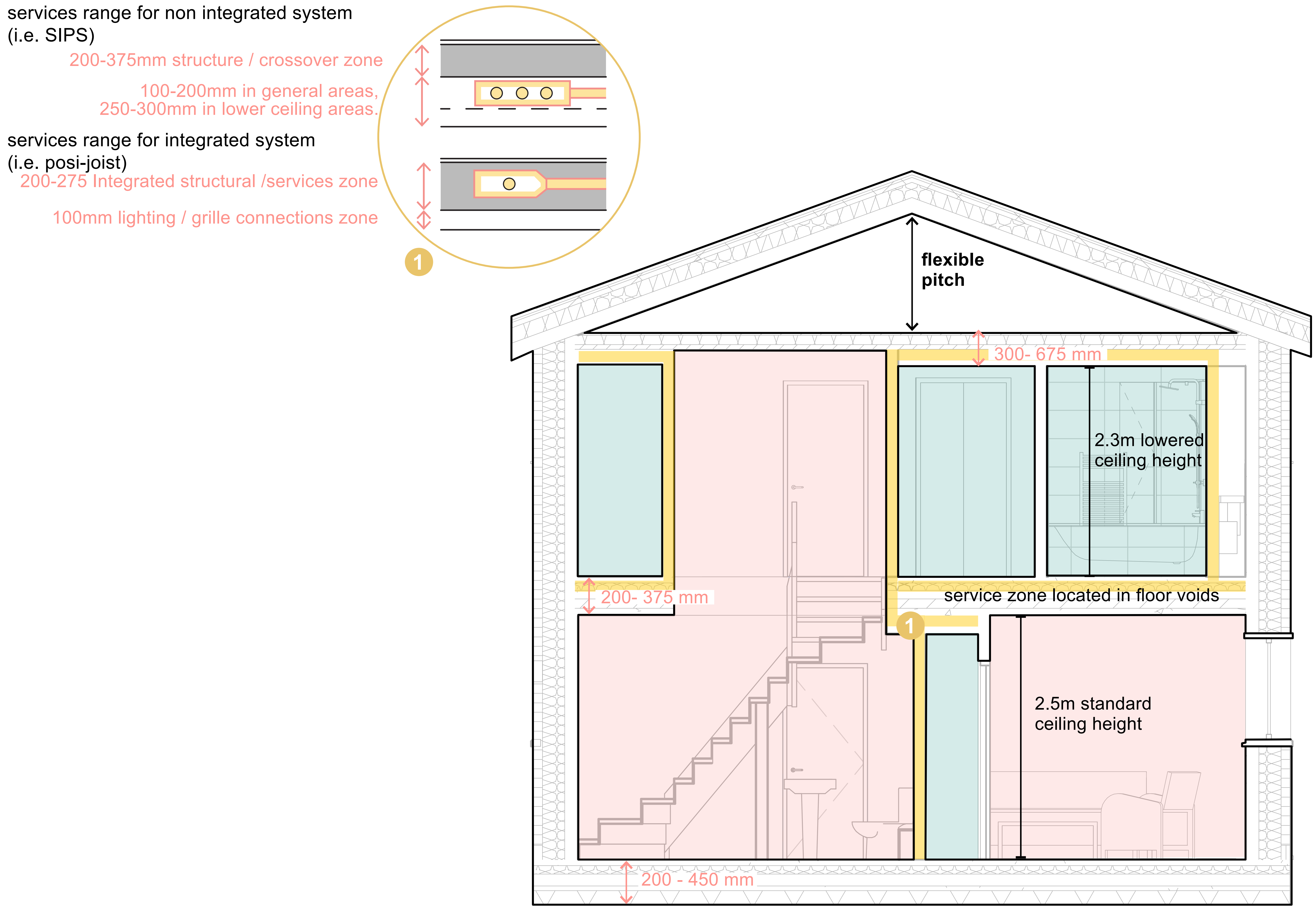
Service Zone

Structural Zone

Utility cupboard

Build up minimum - maximum

Opposite: Zones for structure and servicing (section)



Section Diagram

3.5 Typical Layout

Overview

Patternbook prototypes have limited openings to the front and back of the homes types, allowing for the repeating of modules. Service zones have been limited to non-habitable spaces, and services are not located in external walls. Standard fixed parameters such as bathrooms and utility cupboards are used across all types.

Shown on this page are two arrangements of typical two bedrooms over two stories, with servicing at ground floor frontage and bedrooms at rear.

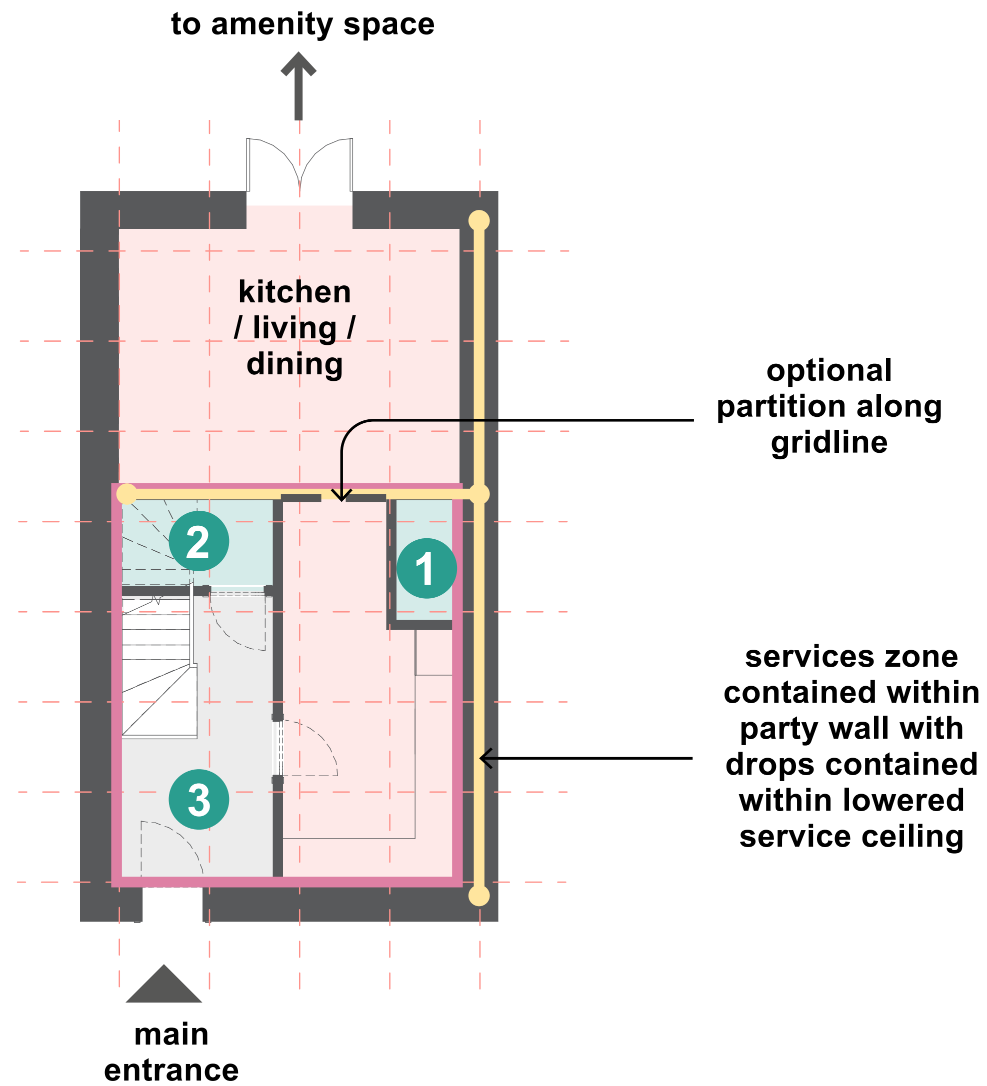
Fixed Parameters

1. Utility Cupboard 1900 mm x 850mm
2. Cloakroom WC 1900mm x 1150mm
3. Corridor 1050mm (minimum width)
4. Standard Bathroom 2100mm x 2200mm

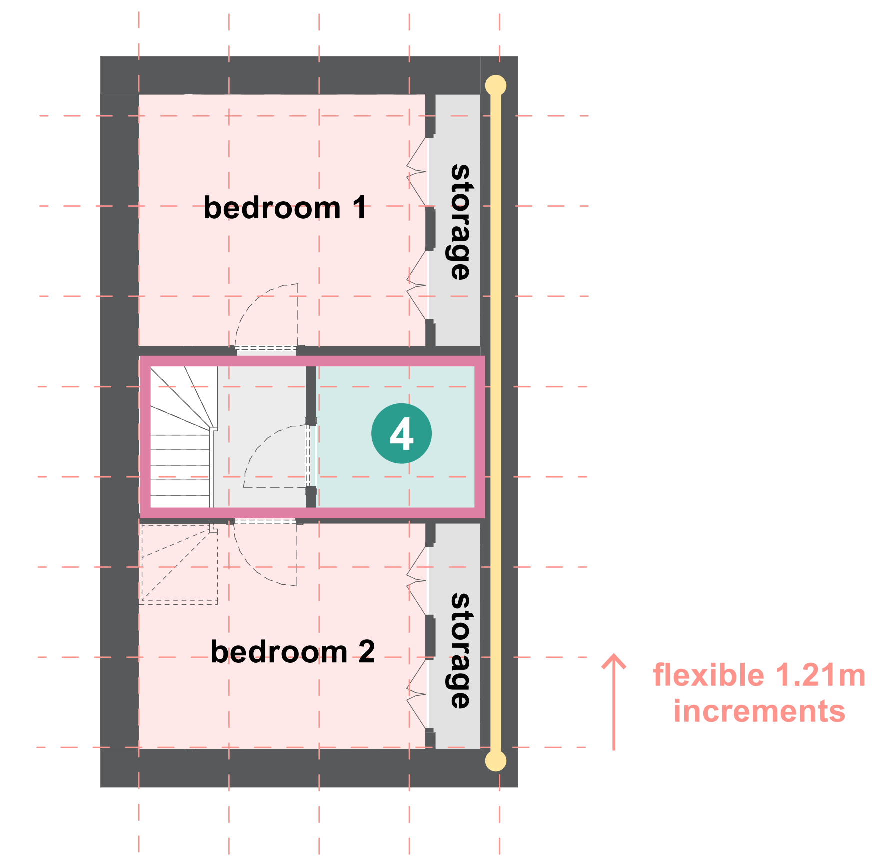
Key

- Services
- Habitable rooms
- Circulation
- Storage
- Services zone
- Potential lowered service ceiling

example layout 1 4.8m width

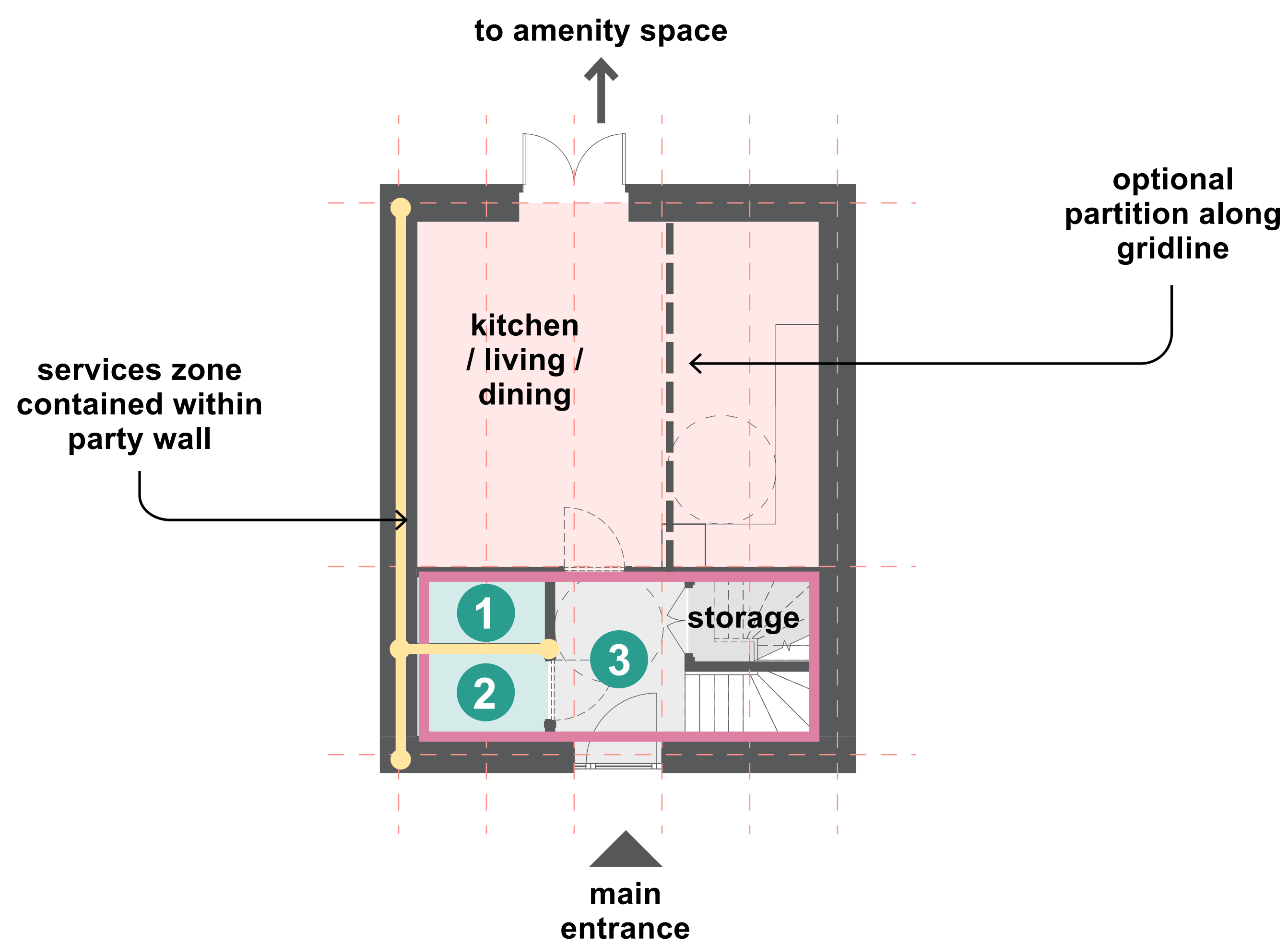


Ground Floor

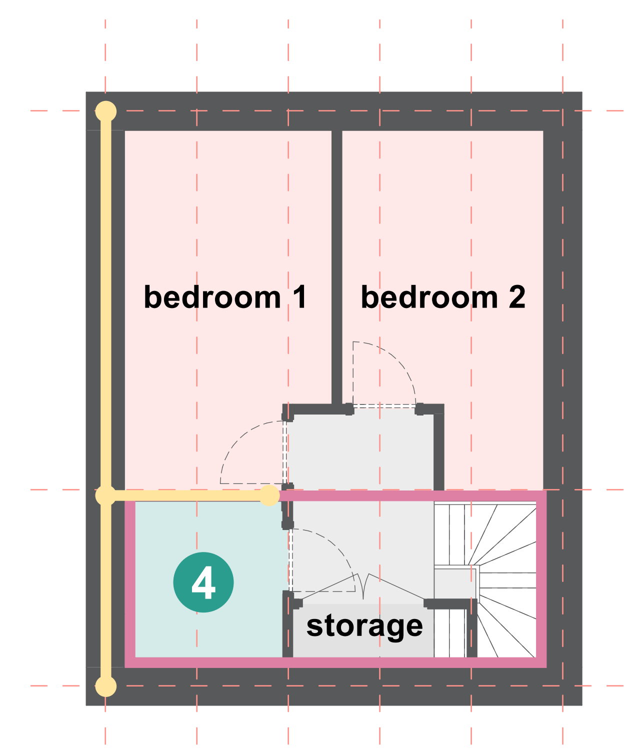


First Floor

example layout 2 6m width



Ground Floor



First Floor

4

Structure

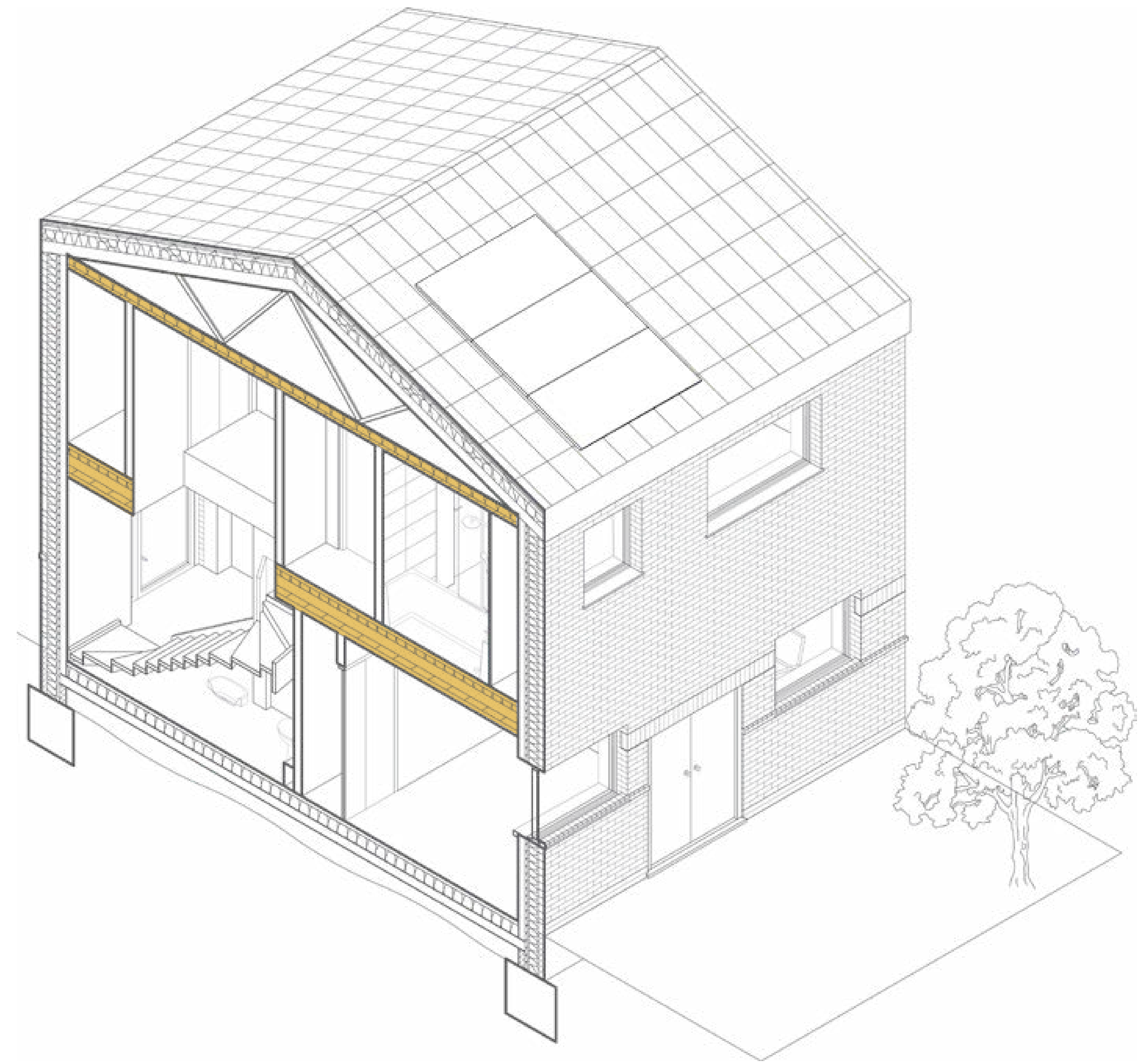
4.1 Horizontal Elements

Structural Floor Systems

System comparisons shown here are based on the performance standardisation recommendations to meet LETI guidance and compliance with Future Homes Standards (FHS), accurate at time of publication.

The following sections are examples of structural floor build-ups for four systems which meet outlined performance and sustainability criteria. Variations may be used as long as they do not exceed the specified structural zone. The sizing has been validated on an isolated home layout. Terraced homes may be able to share structural loading and this should be considered by the project team.

Comparisons of spans have made the assumption of 2-3 storey maximum height for wind loading purposes.



Opposite: Typical house axonometric highlighting structural floor elements

4.2 Horizontal Elements

Overview
A minimum structural zone of 250mm has been determined for internal floors which allows for interoperability of four systems without impacting the layout or design.

The zone does not account for deflection and an additional tolerance zone should be considered by the project team.

Typical Span Ranges

SIPs:

EPS Core ≤ 200mm

0m - 3m

Timber & Woodfibre Panels:

Sawn Timber ≤ 220mm

0m - 4.5 m

Stress skin panels* ≤250mm

0m - 6m

Engineered Joists** ≤ 375mm

0m - 7m

Plywood Cassettes & Wool/ Woodfibre:

Typical Depth 250mm

0m - 4.2m

Typical Depth 300mm

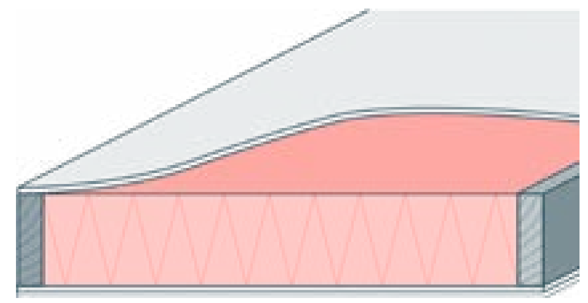
0m - 5.2m

Cold Formed Steel (SFS):

Typical Depth ≤ 220mm

0m - 5m

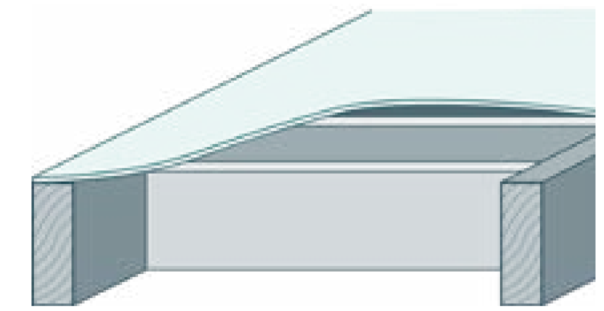
SIPs (EPS Core)



+ Quick construction on-site
+ Simple logistics
+ Good air tightness possible due to interlocking panel joints
+ Lightweight option compared to traditional masonry
+ Low embodied carbon

- Most expensive material (potential for economy of scale)
- Prefabricated panels require specialist contractor
- Embodied carbon dependent on insulation
- Low compatibility (other timber systems typically)
- Short typical span range

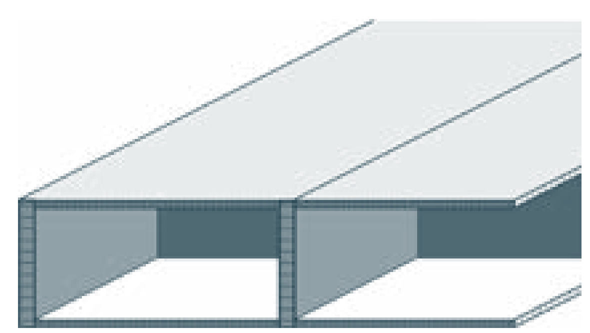
I-Joist / Truss Timber & Woodfibre Panels



+ Low embodied carbon
+ Known construction method - easily procured with contractors
+ Lightweight solution reducing load to foundations
+ Large typical span range

- Stick frame construction - more time consuming on site, unless prefabricated as cassettes
- Typically only compatible with timber joist wall construction

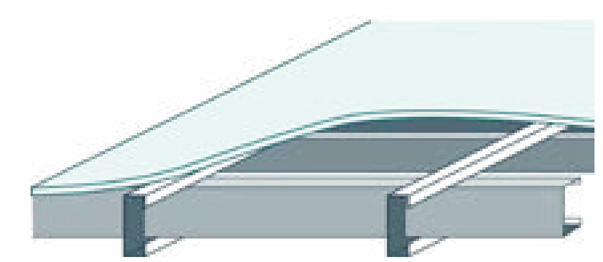
Plywood Cassettes & Wool / Woodfibre



+ Quick construction on-site
+ Simple logistics
+ Lowest sequestered embodied carbon - Insulation options offered are sheeps wool / wood fiber from British farmers
+ Demountable design with adaptable structure
+ Good typical span range
+ Finished internal face

- Highest cost option
- Prefabricated panels require specialist contractor
- Low compatibility
- High structural depth before application of external cladding

Cold-formed Steel (SFS)



+ Common construction type, high availability of labour
+ Can be load-bearing up to four storeys, or non-structural infill
+ Can be recycled at end of life

- Additional acoustic treatment and finishing required
- Typically higher embodied CO2 than timber-based alternatives
- Low compatibility (other SFS systems typically)
- Low typical span range

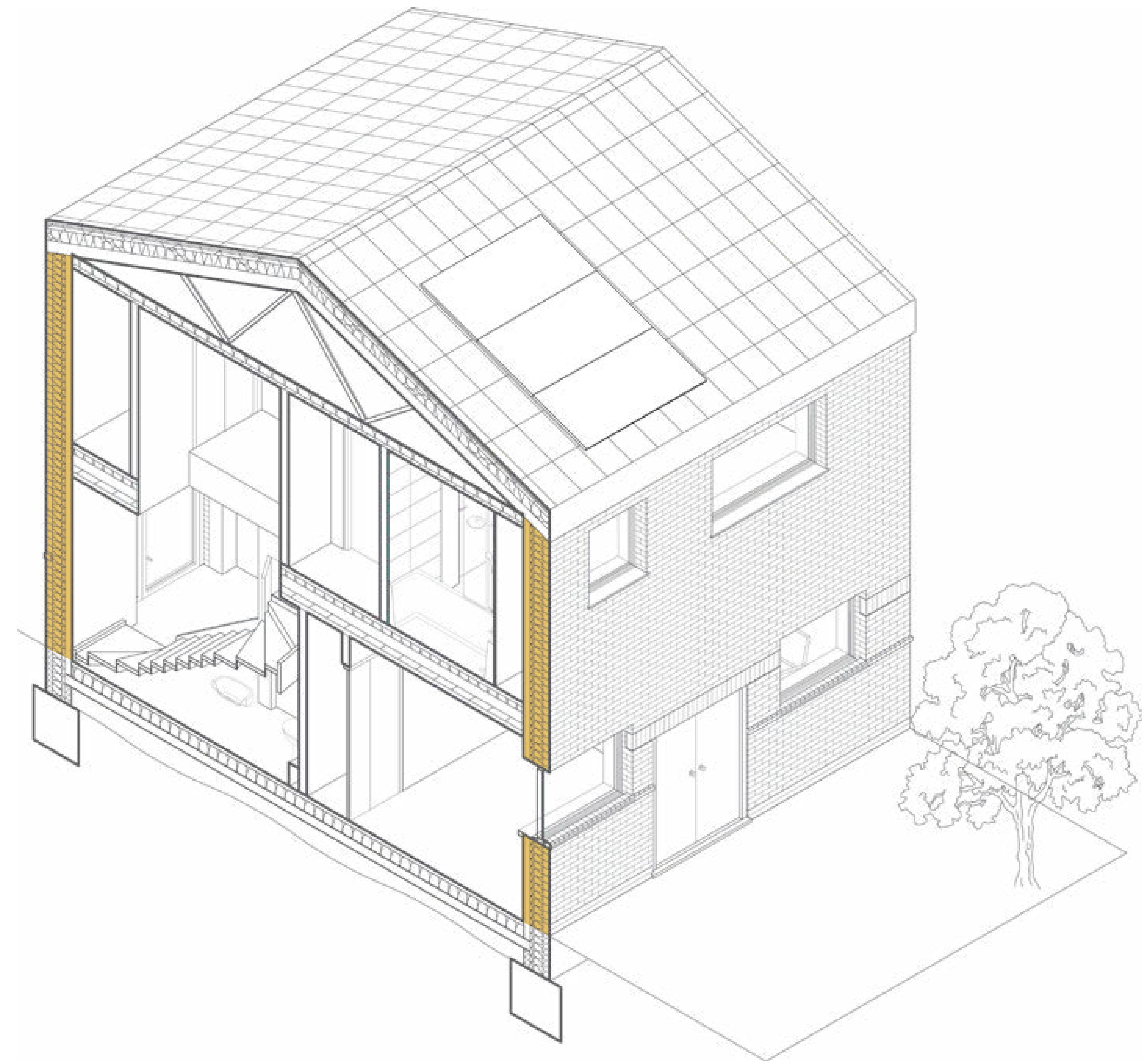
4.3 Vertical Elements

Structural Wall Systems

System comparisons shown here are based on the performance standardisation recommendations to meet LETI guidance and compliance with Future Homes Standards (FHS), accurate at time of publication.

The following sections are examples of structural wall build-ups for four systems which meet outlined performance and sustainability criteria. Variations may be used as long as they do not exceed the specified structural zone.

A minimum structural zone of has been determined for vertical elements which allows for interoperability of the four systems without impacting the architectural design. The sizing has been validated on an isolated home layout, terraced homes may be able to share structural zones subject to project team input. If the maximum depth of vertical structural elements is less than 225mm, the overall wall build-up may be reduced giving space back to habitable rooms.

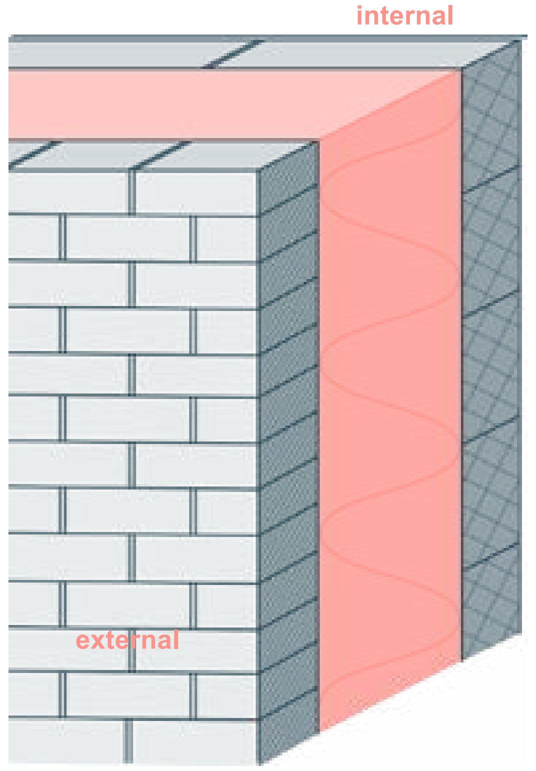


Opposite: Typical house axonometric highlighting structural wall elements

4.4 Wall Systems

Comparison

Cavity Wall (Brick & Block)

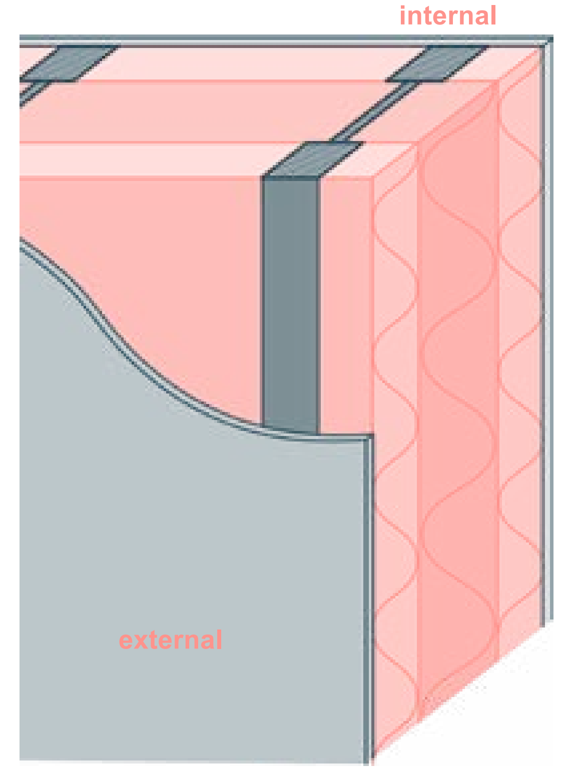


- + Common construction type, high availability of labour
- + Carbon could be reduced with reused brickwork
- + Highly compatible system
- + Structural depth includes external finish
- + Supports systems with high span ranges

- Traditional system, not MMC
- Labour intensive and slow construction method
- Heaviest option so requires the most intrusive foundation
- High embodied carbon
- Re-use options may increase costs associated with labour and salvage time

Benchmark

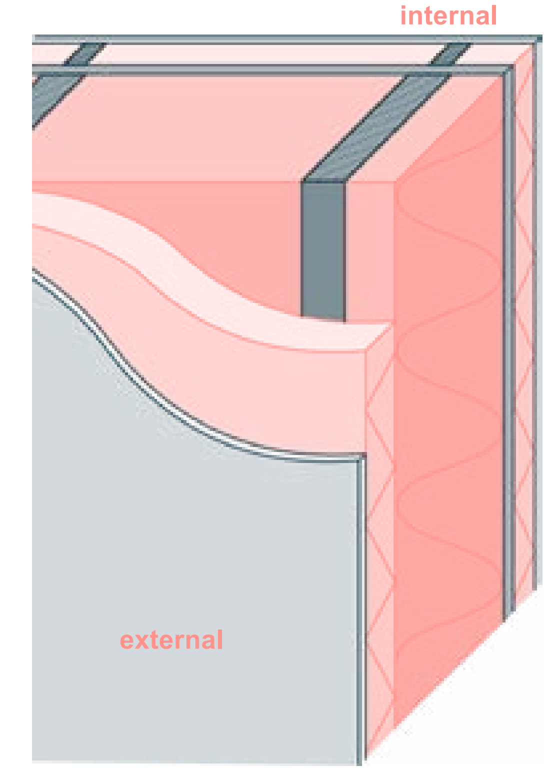
I-Joist / Truss Timber & Woodfibre Panels



- + Low embodied carbon
- + Known construction method - easily procured with contractors
- + Lightweight solution reducing load to foundations
- + Large typical span range

- Stick frame construction - more time consuming on site, unless prefabricated as cassettes
- Typically only compatible with timber joist floor construction
- Excluded from use on GLA Affordable Housing Programme projects*

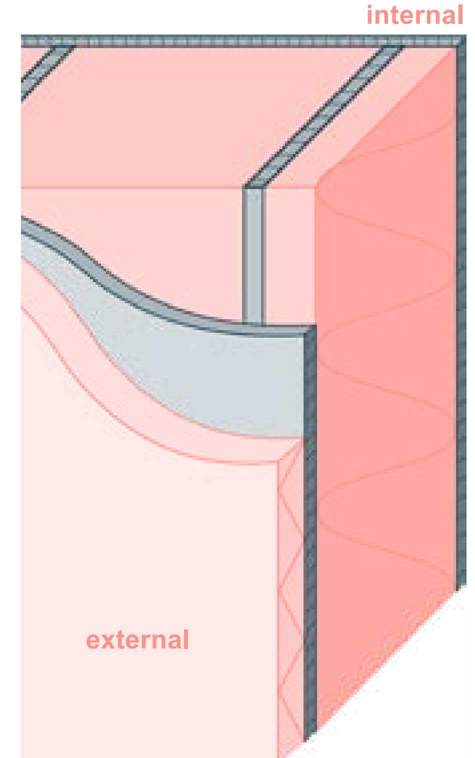
SIPs (EPS Core)



- + Quick construction on-site
- + Simple logistics
- + Good air tightness possible due to interlocking panel joints
- + Lightweight option compared to traditional masonry
- + Low embodied carbon

- Most expensive material (potential for economy of scale)
- Prefabricated panels require specialist contractor
- Embodied carbon dependent on insulation
- Low compatibility (other timber systems typically)
- Short typical span range
- Excluded from use on GLA Affordable Housing Programme projects*

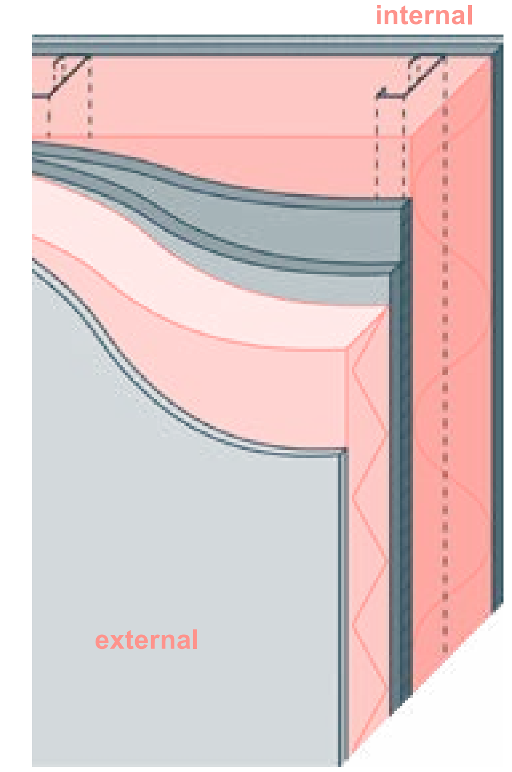
Plywood Cassettes & Wool / Woodfibre



- + Quick construction on-site
- + Simple logistics
- + Lowest sequestered embodied carbon - Insulation options typically include sheeps wool / wood fiber from British farmers
- + Demountable design with adaptable structure
- + Good typical span range
- + Finished internal face

- Highest cost option
- Prefabricated panels require specialist contractor
- Low compatibility (other cassette systems typically)
- High structural depth before application of external cladding
- Excluded from use on GLA Affordable Housing Programme projects*

Cold-formed Steel (SFS)



- + Common construction type, high availability of labour
- + Can be load-bearing up to four storeys, or non-structural infill
- + Can be recycled at end of life

- Additional acoustic treatment and finishing required
- Typically higher embodied CO2 than timber-based alternatives
- Low compatibility (only SFS systems typically)
- Low typical span range

Notes:

* Correct at the time of publication. Following formal classification as a combustible material timber has been excluded from use in the external build-up of projects funded by the GLA Affordable Homes Programme 2021 - 2026.

4.5 Substructure

Foundation Systems

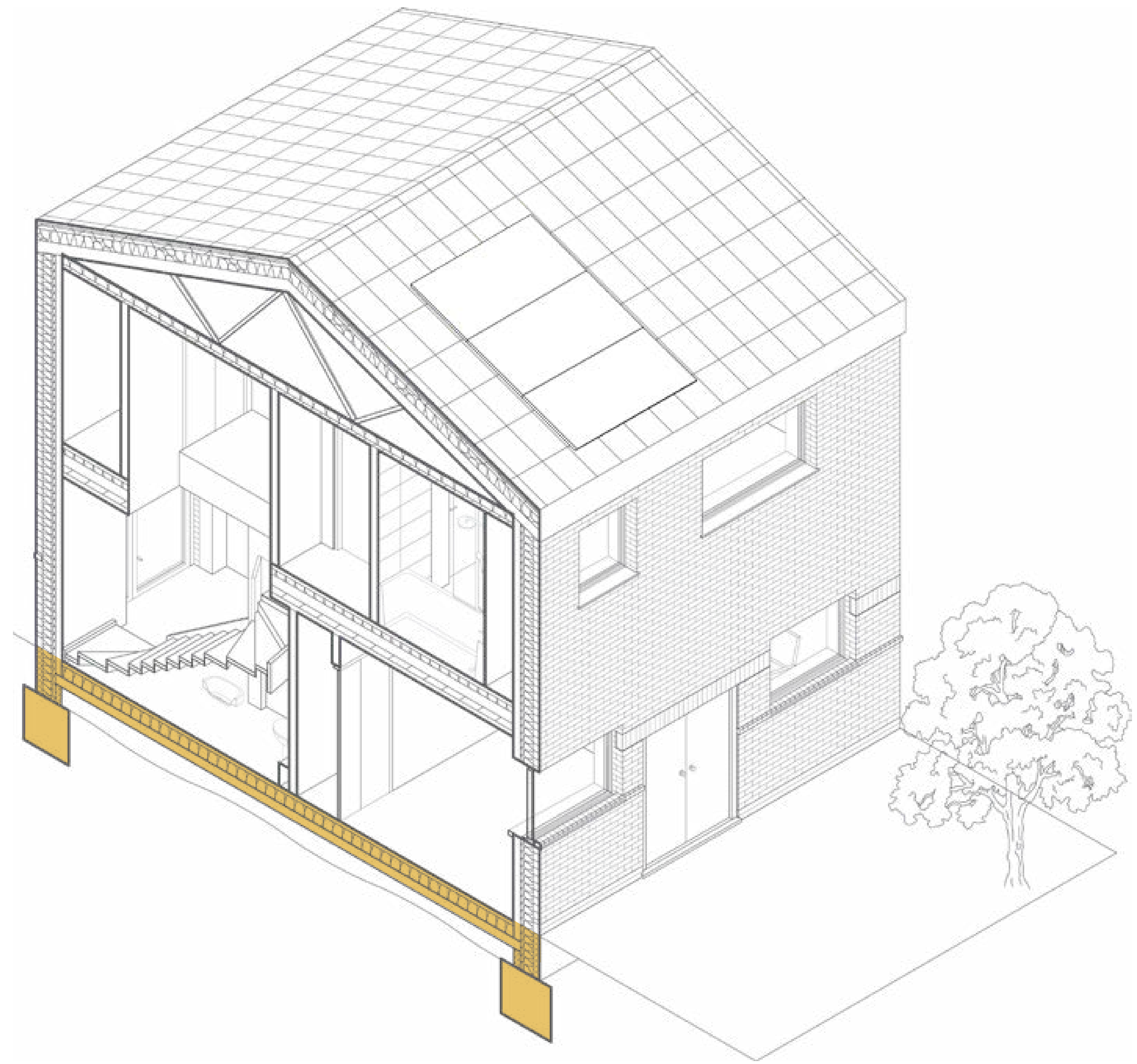
System comparisons shown here are based on the performance standardisation recommendations to meet LETI guidance and compliance with Future Homes Standards (FHS), accurate at time of publication.

Sub-structure typically contributes to around twenty percent of a building's embodied carbon but this can vary greatly depending on ground conditions. Substructure systems will need to be considered on a site by site basis, and will be dependent on site conditions.

Embodied carbon should typically be assessed for an entire block, taking into account the categories excluded in the Small sites Patternbook analysis including sub-structure. Use of a lighter system such as steel may reduce the amount of foundations and sub-structure embodied carbon.

Use of a precast structural slab can bring the following additional benefits compared to in situ:

- Reduced amount of waste
- Improved quality finish
- No on site formwork
- Higher durability
- Higher thermal mass



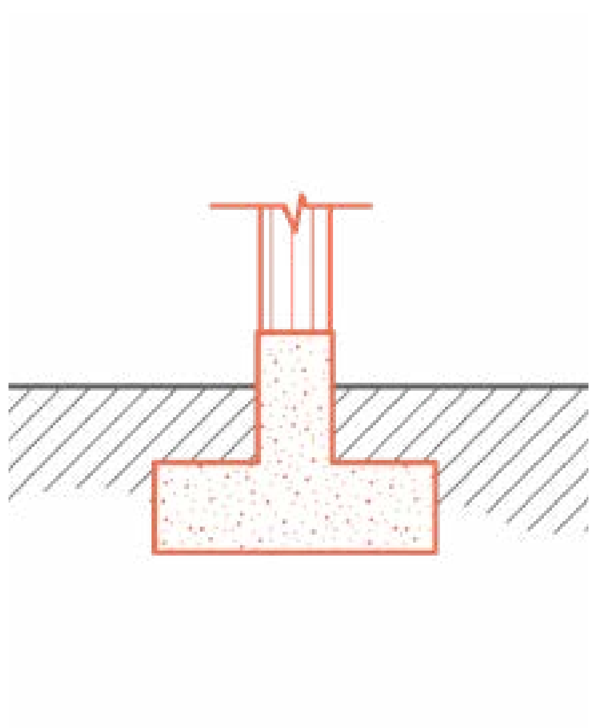
Opposite: Typical house axonometric highlighting the substructure

4.6 Foundation Systems

Comparison

The substructure system should be designed to meet the minimum statutory and client specific targets and KPIs. Passivhaus and LETI performance criteria has been used in these assessments to compare materials.

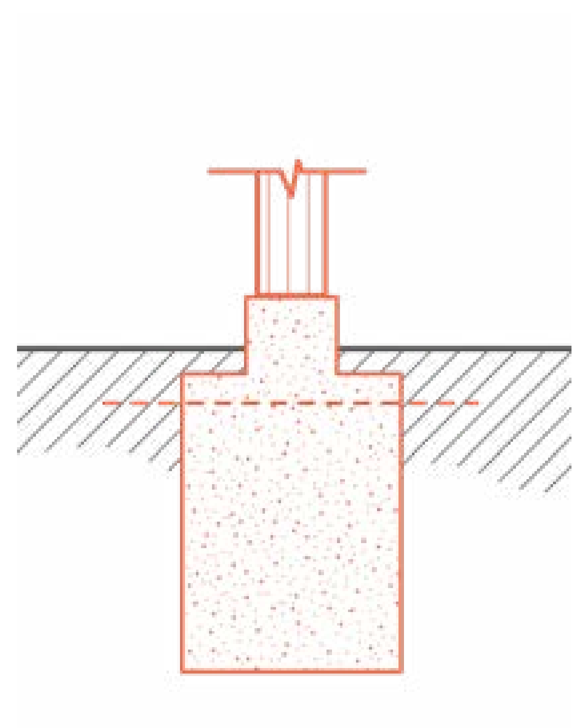
Shallow Concrete Strip



+ Simple to construct with high labour availability
+ More cost effective
+ Can be adopted for light loads

- Excavation required which may not be permissible if protected tree root zones are within the proposed footprint
- Unsuitable if located in shrinkable clay and trees are nearby and cause an influence to the soil - deeper foundations would typically be required in this situation (typically to align with NHBC Regulations)
- Higher embodied carbon

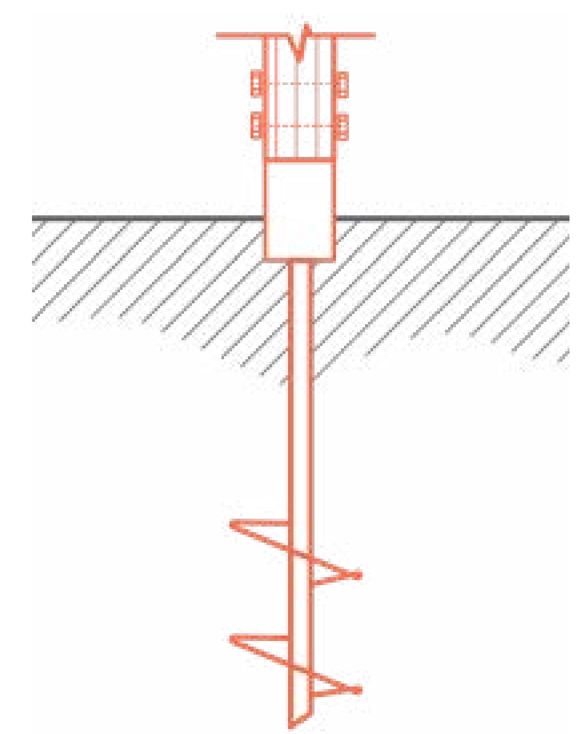
Trench Concrete



+ Can be used if trees are in near vicinity up to a depth of 2.5m
+ Simple to construct with high labour availability
+ More cost effective

- (Potentially) large volumes of concrete required
- Higher embodied carbon
- Excavation required which may not be permissible if protected tree root zones are within the proposed footprint
- Piles required if trees are in the near vicinity beyond a depth of 2.5m

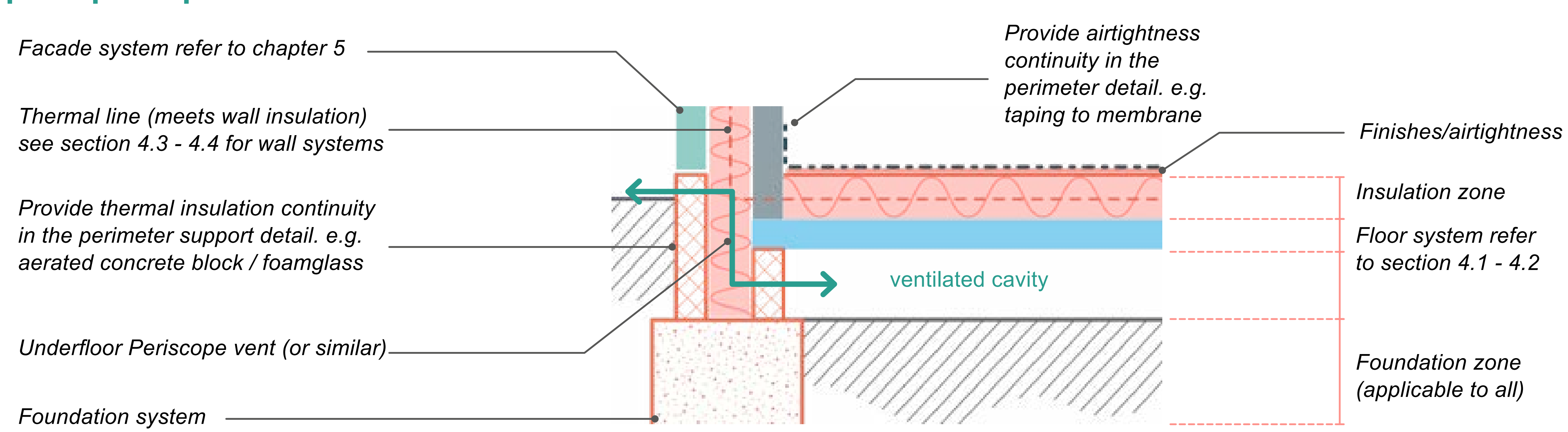
Screw Piles (Steel)



+ Lower embodied carbon than equivalent trench solution
+ Fast to construct and minimum excavation for install
+ Installation process can be reversed and removed at end of life

- Higher cost solution
- Specialist contractor/ manufacturer/ provider required

Typical principles for ventilated floor detail



Notes:

Pros and cons of foundation systems are given as a broad overview. The final suitability and efficiency of different options will be determined by site conditions, e.g. soil strata, water table, proximity of trees or buried services, site boundary conditions etc.

If a timber ground floor is used, the floor typically must be raised above external ground level per current Foundation system Approved Doc C requirements.

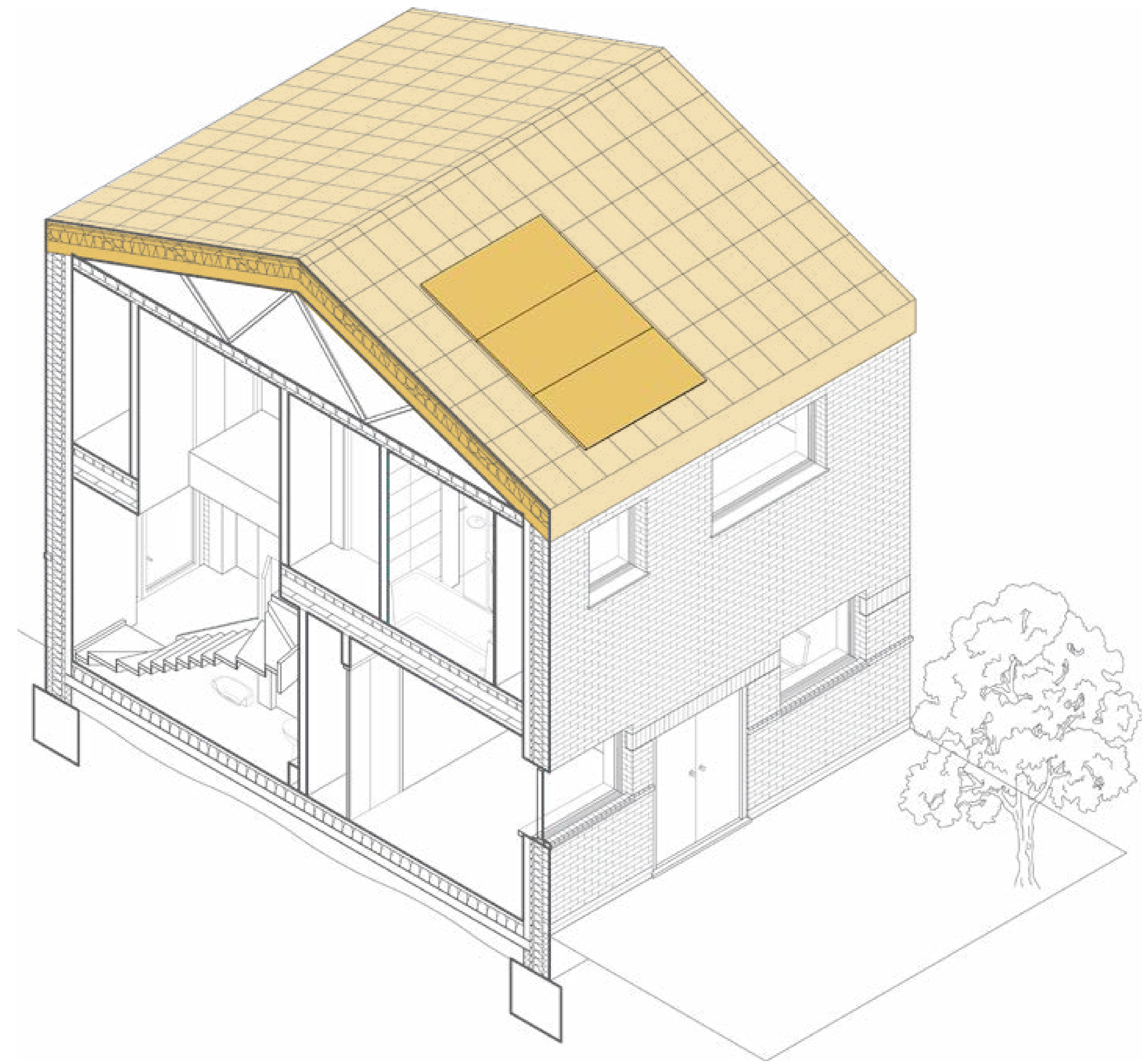
4.7 Roof Systems

Roof Build Up

System comparisons shown overleaf are based on the performance standardisation recommendations to meet LETI guidance and compliance with Future Homes Standards (FHS), accurate at time of publication.

The roof system should be designed to meet project specific targets and KPIs, including urban greening factor and biodiversity net gain. Allow for additional building height to account for roof build-ups and plant screening on green roofs. Roof systems will require allowances for permanent and variable load, which will need to be considered alongside maintenance strategy and provision of PV panels.

Proprietary systems shown here do not include integrated PV surfaces as this will be site specific, however these should be considered at the earliest possible stage.



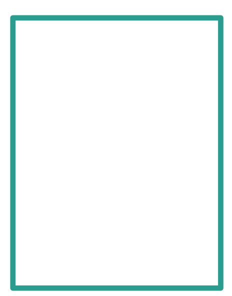
Opposite: Typical house axonometric highlighting the roof system

4.8 Roof Systems

Comparison

The roof system should be designed to meet the minimum statutory and client specific targets and KPIs. The potential MMC benefits of each roof system and compatibility with roofing materials and substructure have been considered in the comparison of systems.

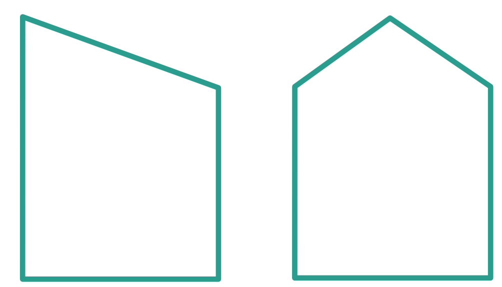
Flat Roofs



+ Simplest geometry, structural system matches floors below allowing for high compatibility
+ Less site-specific approach, supporting standardisation

- Incompatible with tiled finishes e.g. clay, slate or shingles
- Less site-specific, but doesn't take advantage of site opportunities e.g. optimising angle of PV

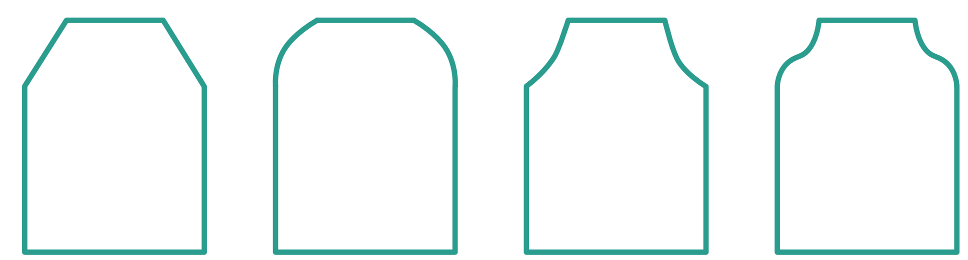
Pitched Roofs



+ Compatible with tiled roof finishes
+ Can be angled to suit site constraint/ opportunities e.g. shading/PV

- Typically more site-specific design rather than a kit of parts / standardised approach
- Horizontal thrust to be considered in design and detailing (see below)

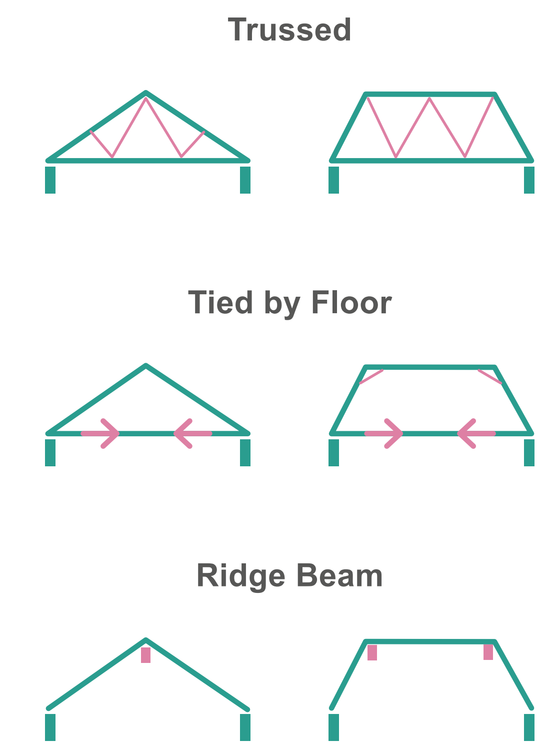
Mansard Roofs



+ Compatible with tiled roof finishes
+ Can be angled to suit site constraint/opportunities e.g. shading/PV

- Typically more site-specific design rather than a kit of parts / standardised approach
- Horizontal thrust to be considered in design and detailing (see below)
- With the roof leaning inward, an outward thrust is generated into the floor below unless ridge beams are used

Horizontal Thrust Considerations



An open pitch is possible for a habitable loft, but the loft floor must be detailed to act as a tie between pitches. Alternatively, a ridge beam could be used but this would require internal vertical structure, unless it spans the full length of the building.

Notes:

Should photovoltaic panels be specified the additional weight and setting out of these would need to be considered during design development.

5

Facade

5.1 Facade

+ Key Performance Metrics

5.2 Fabric & Materials

+ Facade Overview
+ Roof Coverings Overview

5.3 Openings

+ Overview
+ Comparison

5.1 Facade Systems

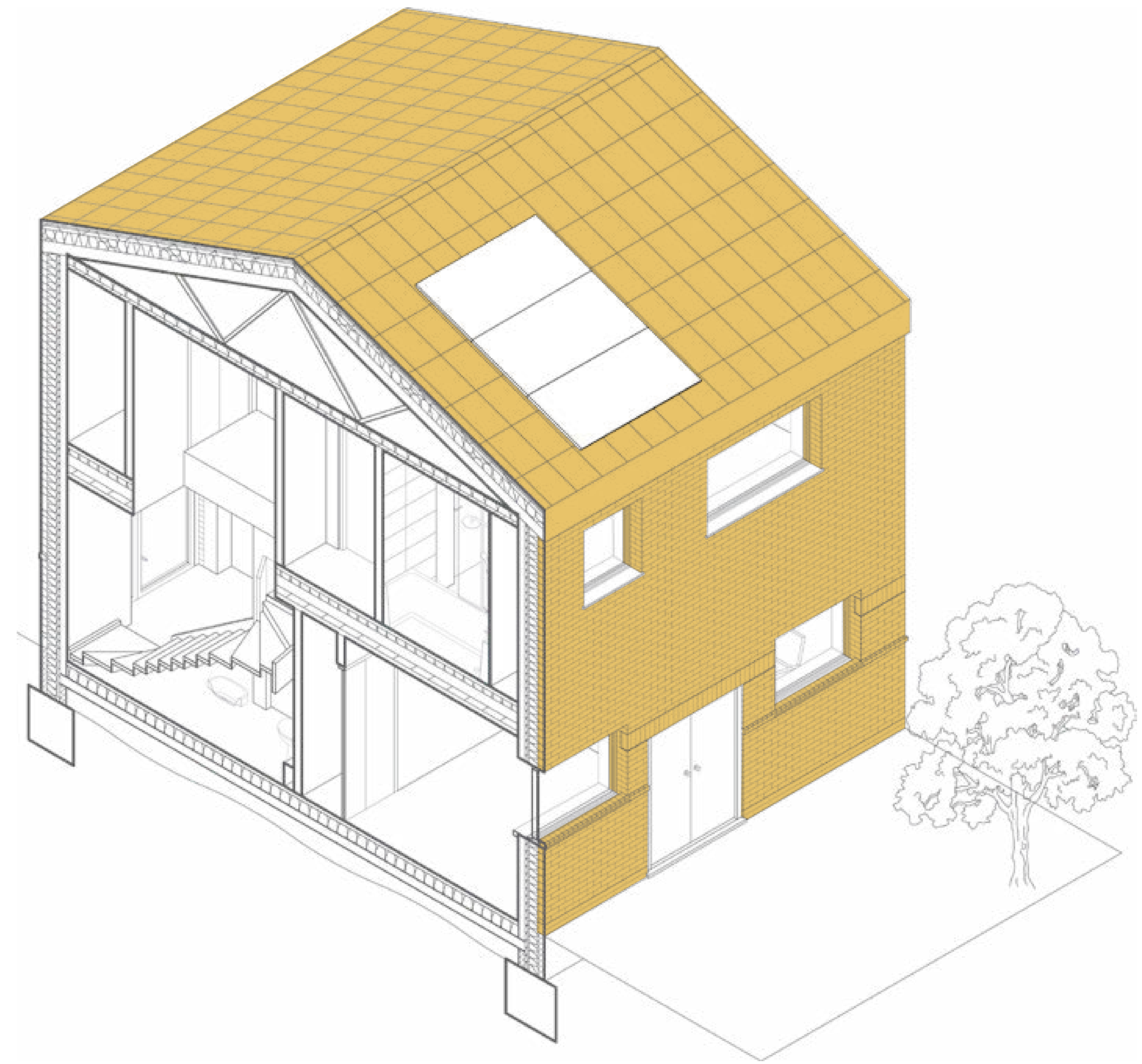
Key Performance Metrics

The façade design should consider the reuse of components and design for disassembly. A clear strategy should be provided as to how the façade could be disassembled. Where off-site testing is carried out, this should be used as an opportunity to test and refine the strategy.

The following points should be considered in the façade design:

- Minimise the number of different types of materials
- Avoid composite materials and introduce inseparable sub assemblies from the same materials to control contamination
- Provide standard identification of material types (incorporate material and product passport)
- Minimise the different types of components
- Use mechanical connections rather than chemical ones
- Make components and materials of a size that suits the intended means of handling
- Provide a means of handling and locating components during the assembly and disassembly procedure
- Provide realistic tolerances to allow for manoeuvring during disassembly
- Use minimum number of different types of fasteners or connectors
- Design joints and connectors to withstand repeated use
- Allow for parallel disassembly rather than sequential disassembly
- Provide permanent identification of component type
- Use a structural grid
- Use prefabricated sub-assemblies and a standard system
- Use lightweight materials and components
- Permanently identify points of disassembly
- Retain all information on the building construction systems and assembly and disassembly procedures

Opposite: Typical house axonometric highlighting the facade elements



5.2 Facade Fabric & Materials

Fabric Overview

The façade design should consider the reuse of components and design for disassembly. A clear strategy should be provided as to how the façade could be disassembled. Where off-site testing is carried out, this should be used as an opportunity to test and refine the strategy.

Face Brick

+ Simple to construct with high labour availability
+ Availability of different brick finishes, types and use patterns
+ High durability and low maintenance
+ Naturally fire resistant material

- Heavy system, requiring separate foundations for use with some structural systems
- High embodied carbon
- Depth of build-up
- Traditional facade system, not MMC

Brick Slips

+ Thin profile for constrained sites
+ Lightweight, increasing compatibility with structural systems
+ Reduced embodied carbon
+ High durability and low maintenance
+ Ventilated cavity supports improved thermal performance and moisture management
+ Availability of different brick finishes and types
+ MMC ready with off-site manufacture of panels

- Higher cost than conventional solid brick facades
- Despite reduced embodied carbon this is still higher than other alternative systems

Timber Board (FR)

+ Thin profile for constrained sites
+ Lightweight, increasing compatibility with structural systems
+ Low embodied carbon
+ Renewable, reusable and biodegradable material
+ Good durability
+ Availability of timber types and finishes

- Requires additional treatment to be fire rated for external use
- Durability is reliant on careful detailing and fixing system

Clay Shingles

+ Thin profile for constrained sites
+ Lightweight, doesn't require a foundation
+ High compatibility with structural systems
+ High durability and low maintenance
+ Availability of different shingle shapes, colours, finish and patterns
+ MMC ready with off-site system solutions available

- Higher embodied carbon than alternative timber shingle systems

Notes:

For the purposes of this document and u-value comparisons a ventilated facade detail has been assumed for all systems.

5.2 Roof Fabric & Materials

Geometry & Material Overview

The exact span of the roof will vary by site, and roof slope is often dictated by design intent, planning constraints, and constraints of the roof finish material. In order to inform a potential standardised roof type for small sites, the constraints of typical roofing materials for pitched roof construction should be considered. The materials which have been considered suitable are outlined on the right.

The roof design should consider whether a product is durable, recyclable, energy efficient, has ecological benefits or is made using responsibly sourced raw materials. Ecological and bio-based building materials are also often categorised as sustainable but may not be suitable in all instances. Green roofs, while providing habitats and biodiversity, have not been included as many types of green roofing materials are relatively heavy and may require additional structural support.

Natural Slate

+ High compatibility with structural systems
+ High durability and low maintenance, long life span
+ Availability of different slate types, colours, finish and patterns
+ Good circular economy credentials, ability for slates to be reused
+ Requires minimal processing

- Higher embodied carbon
- Higher cost than alternative synthetic systems
- Labour becoming more specialised for natural roofing systems
- Heavier than more lightweight sheet systems

Clay Shingles

+ High compatibility with structural systems
+ High weathering durability and low maintenance
+ Availability of different shingle shapes, colours, finish and patterns
+ Typical solution, high labour availability
+ Processing doesn't omit harmful chemicals

- Higher embodied carbon but recycled options are available
- Can be broken on install if care isn't taken
- Heavier than more lightweight sheet systems
- Unsuitable for steep pitches

Metal Clad

+ Lightweight, increasing compatibility with structural systems
+ High availability of finishes and types
+ High durability and low maintenance
+ Increased weathering protection
+ MMC ready with off-site manufacture of panels

- Higher cost system
- Embodied carbon dependent on system specification
- Potential to contribute to urban heat island effect
- More specialist detailing

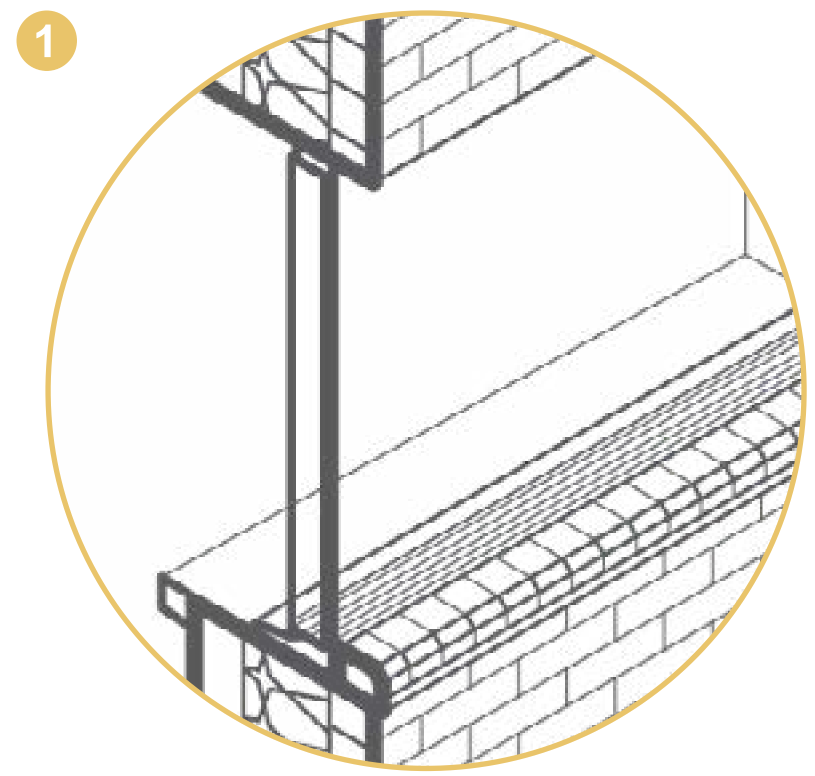
5.3 Openings

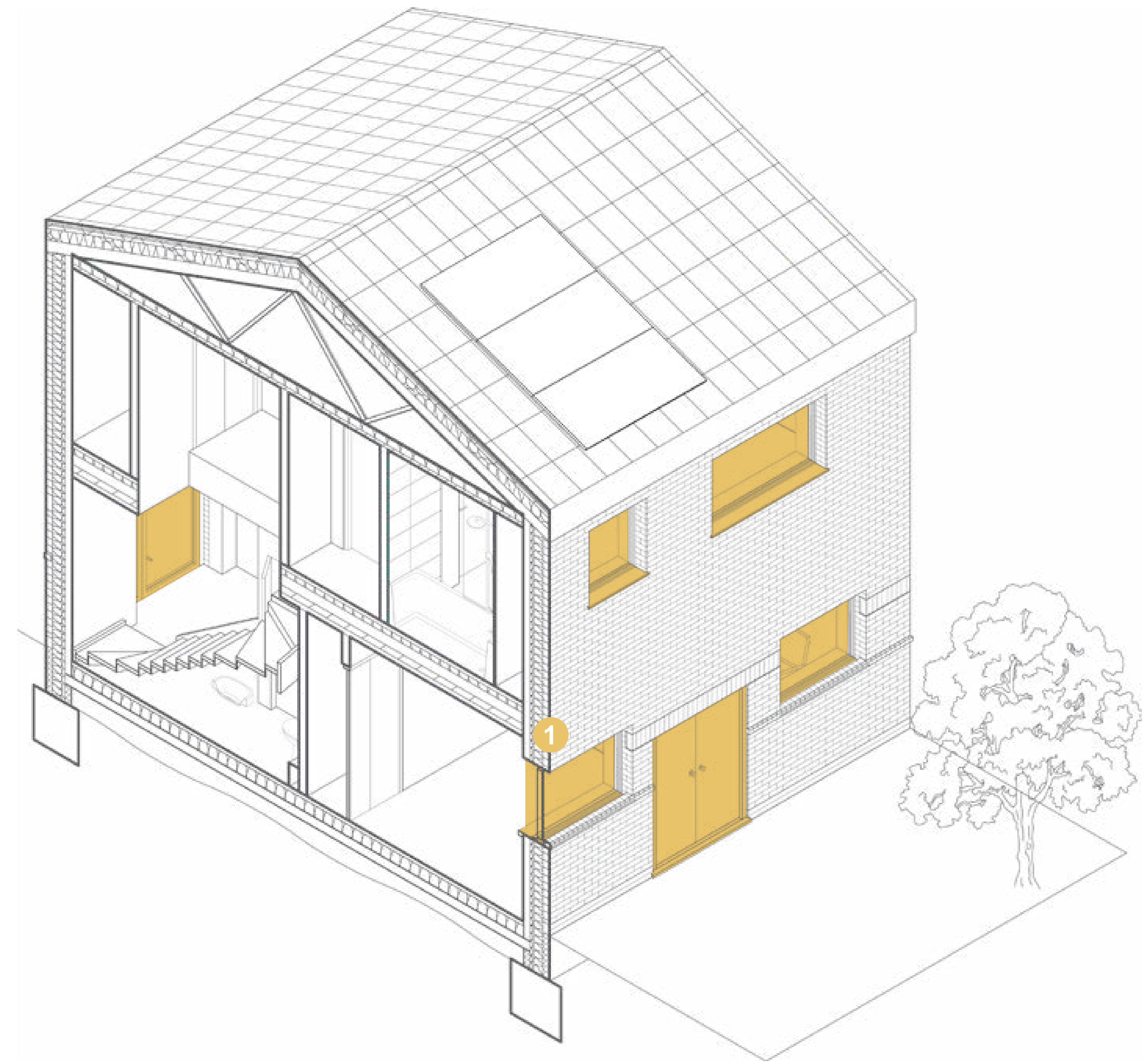
Overview

Sufficient daylighting is key to a successful interiors, however the amount and positioning of glazing needs to be carefully considered. Reducing the window area reduces the operational energy and overheating risk, as well as cooling load, which can reduce the whole life carbon of the building.

Understanding orientation is also key to maximizing solar gains whilst avoiding overheating. Where possible, solar gains should be maximised on South facing elevations and reduced on North, East and West.

All openings should be placed along the insulation line to reduce heat loss and improve operational performance, see detail 1.





Opposite: Typical house axonometric highlighting typical openings

Notes:

Bespoke cassette systems may require non-standard opening sizes

5.3 Openings

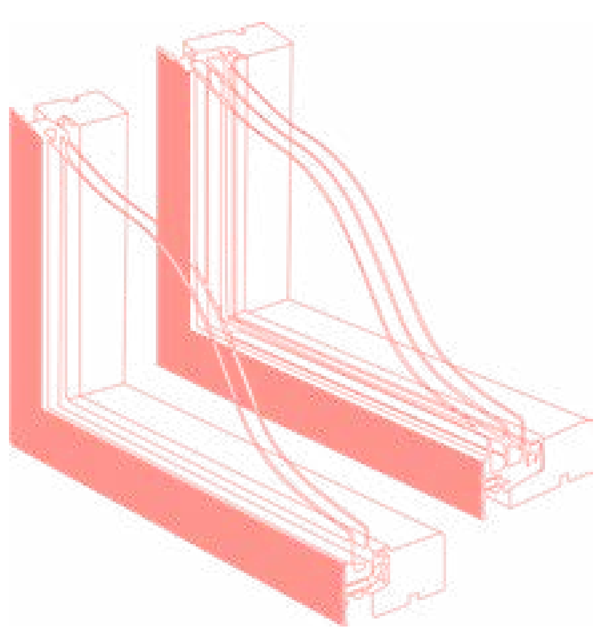
Comparison

Systems shown here assume performance standardisation recommendations to meet LETI guidance, and this may be possible with double glazing, however if Passivhaus performance is required triple glazing will be needed.

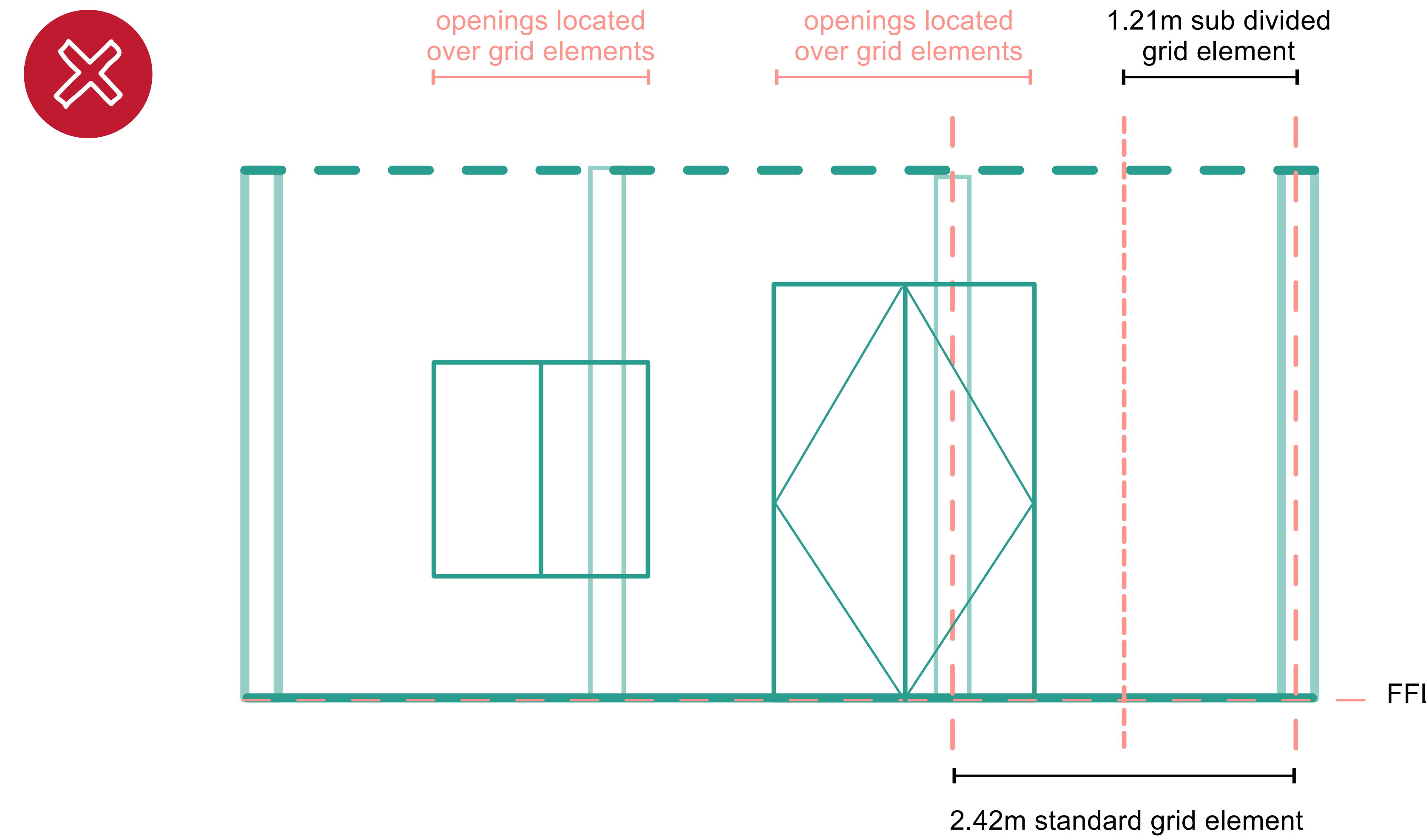
A whole-system approach should be taken when specifying any openings with the embodied carbon and maintenance cycles of framing materials carefully considered alongside the glazing specification.

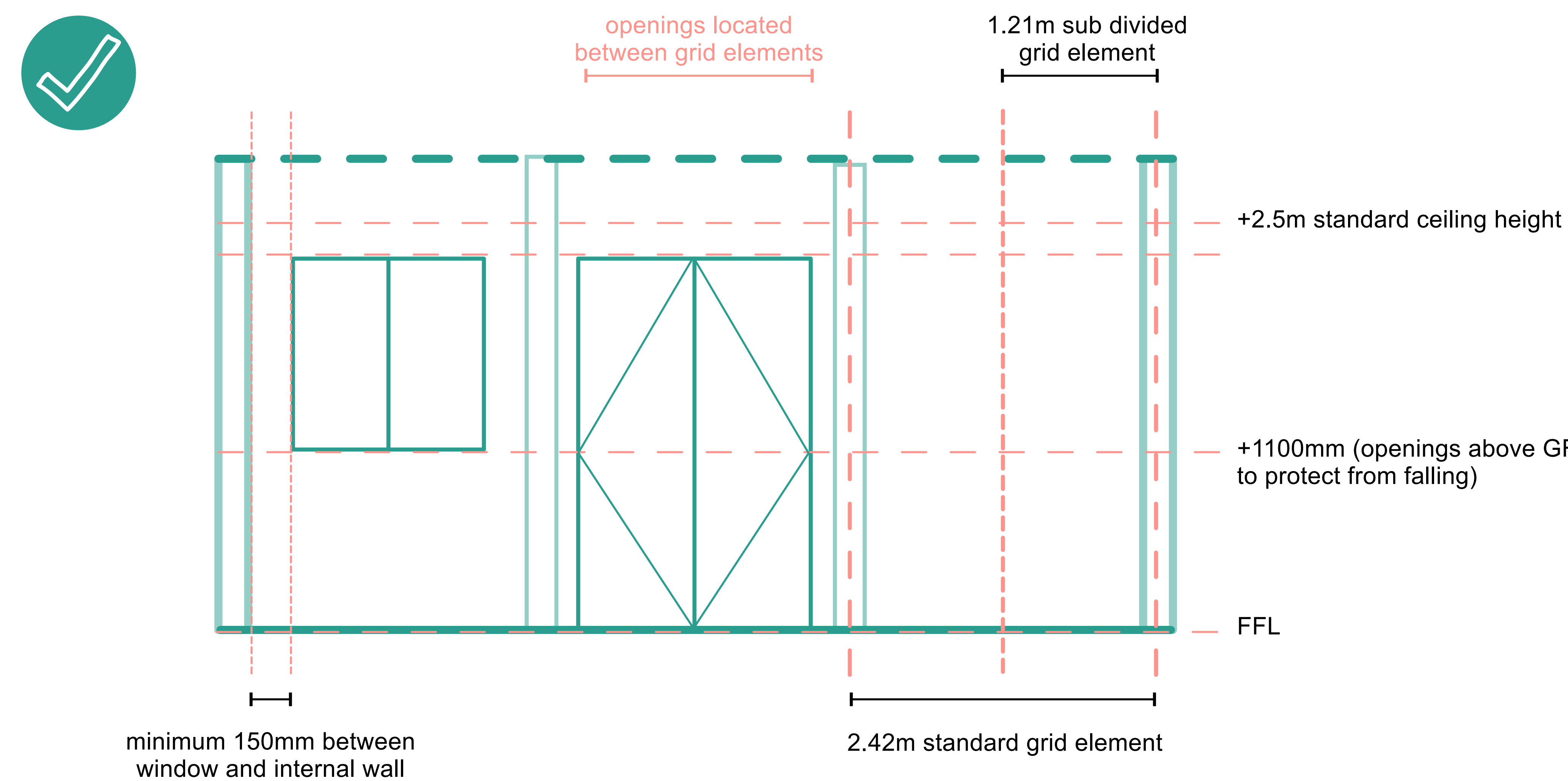
To maintain flexibility, recommendations for windows are to work within the parameters of the grid and limit the structural opening size to maximum 2420mm wide x 2110mm high. The suggested cill heights are indicated in the diagram on the right. This will allow scope to meet the desired aesthetic, any site or planning constraints, and make use of standardised components.

Should a bespoke structural cassette be utilised in the substructure a more bespoke opening approach may be required.



Glazing specification should be considered at the earliest opportunity to meet environmental performance targets.





Elevation Diagrams

6

Construction

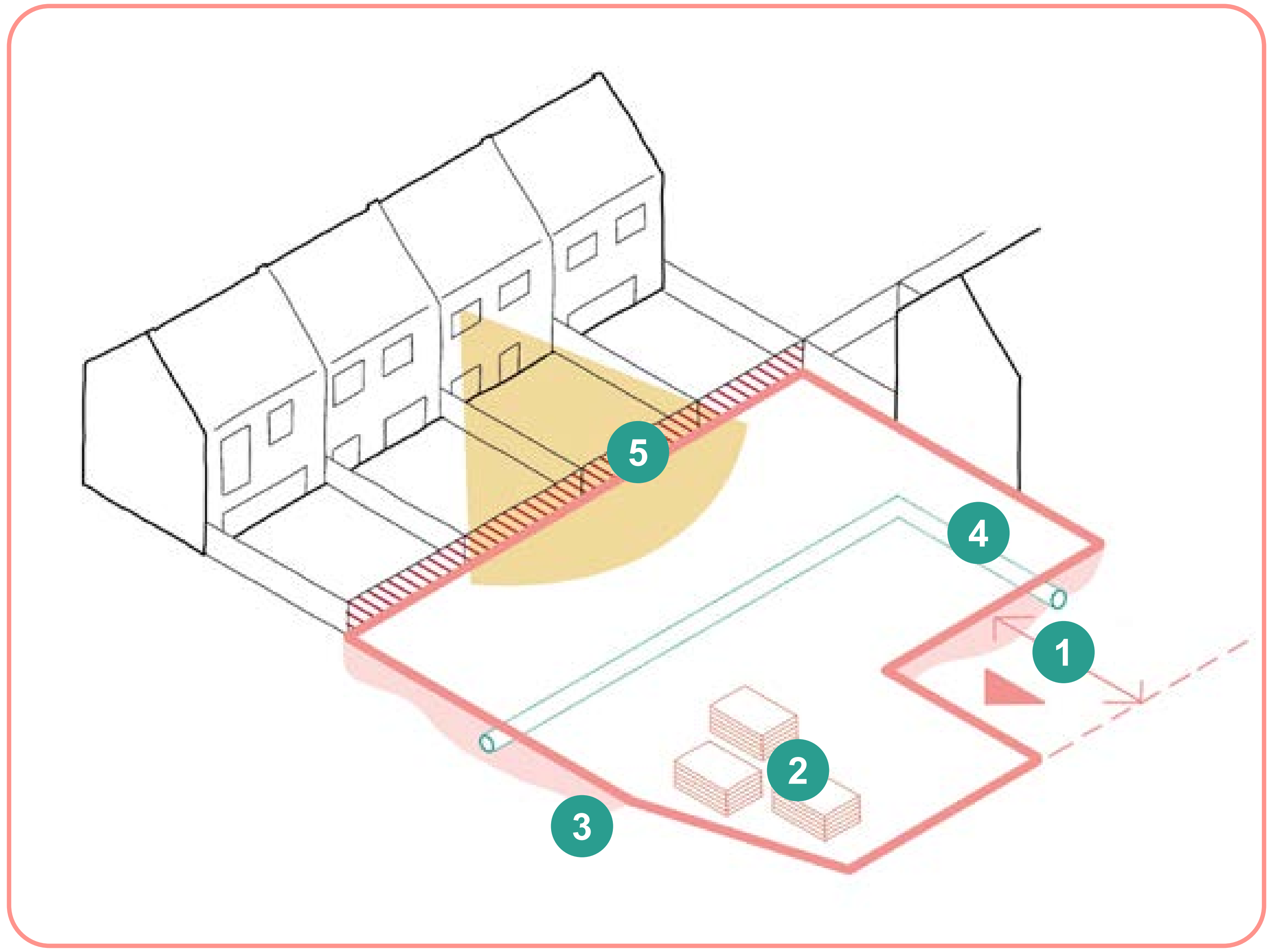
6.1 Buildability

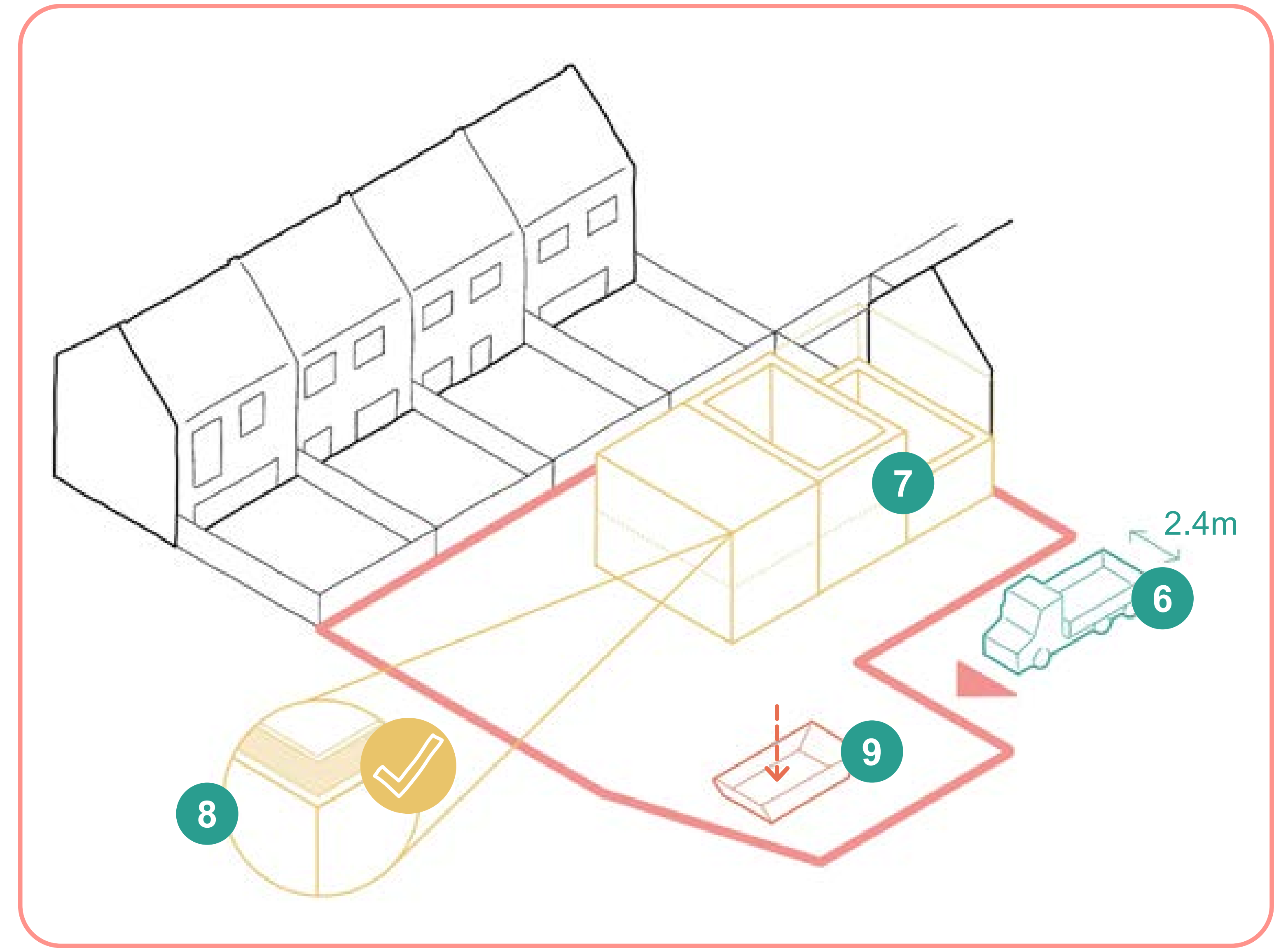
Site constraints:

1. Restricted Access: some sites may have limited access for large construction vehicles and machinery (cranes).
2. Storage Space: Limited space on-site for storing materials
3. Irregular Site: some sites may be irregular in shape and have existing structures and building in close proximity.
4. Foundations and utilities: sites may have existing foundations and utilities. Preparing the site for modular buildings will need to be set-up with precision.
5. Boundaries: Designs will need to consider overlooking from neighbouring properties and possibly obtain party wall agreements.

Opportunities and considerations:

6. Module Sizes: the Patternbook has been designed to modules of 2.4m, meaning materials can be transported and delivered using a standard goods vehicle.
7. Speed of Construction: Reduced construction time and less weather dependant due to off-site manufacturing.
8. Quality Control: MMC offers higher quality, consistency, and precision, reducing defects.
9. Reduced Waste: MMC systems efficiently use materials, and there is less on-site waste generated.

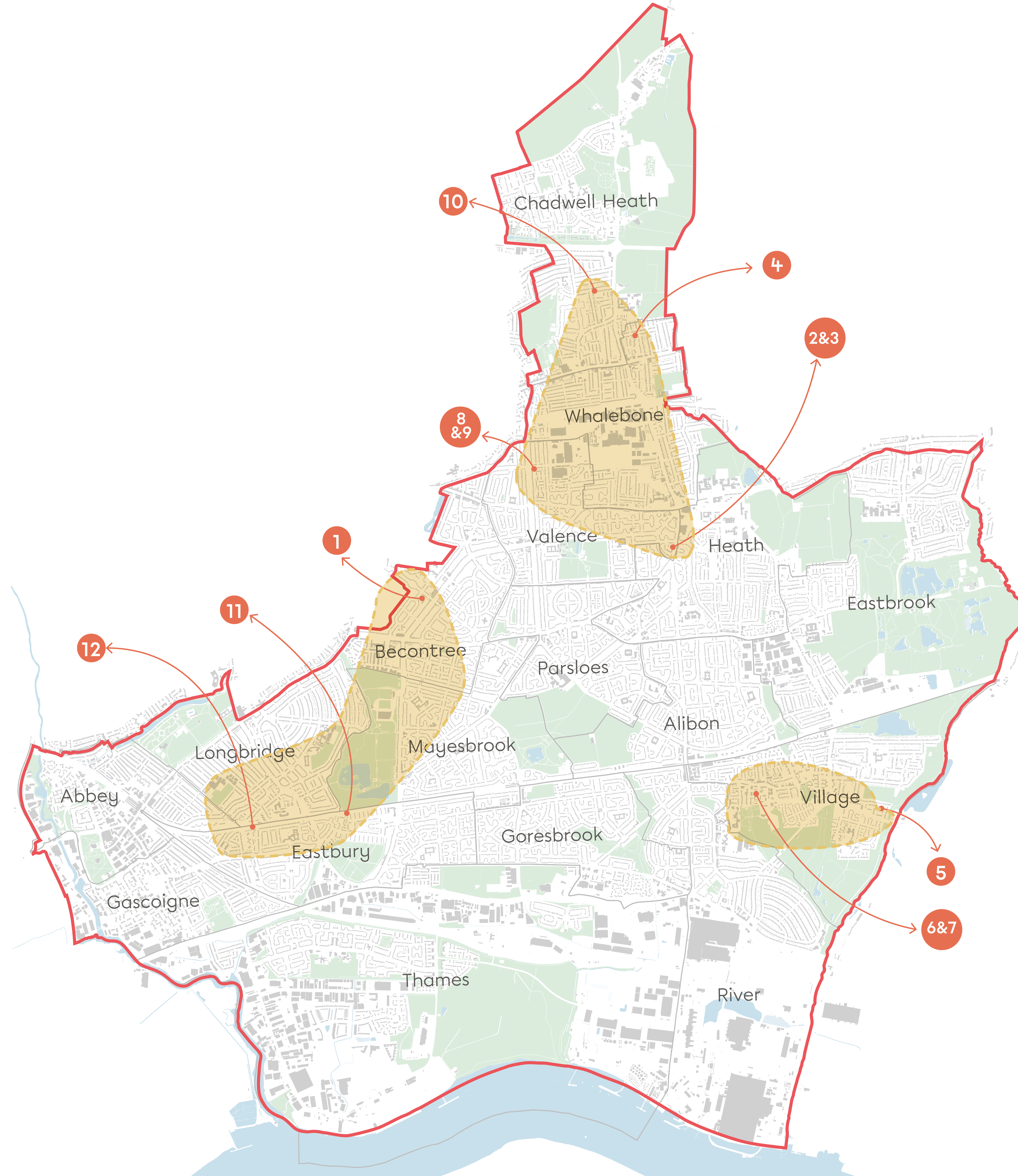




6.2 DfMA Opportunities

Site Clusters:
To assist with deliverability and buildability across multiple small, constrained sites, it is suggested that sites situated closer together are grouped into clusters for programming and delivery. This allows for more efficient transport of materials to and from site, and where possible can offer an opportunity for an off-site storage or factory facility.

To maximise opportunities for PMV across a project, flying factories in the vicinity of multiple sites should be explored.



Key:

1. Vicars Walk
2. Stone Close West
3. Stone Close East
4. Forsters Road
5. Beamway
6. Hollidge Way North
7. Hollidge Way South
8. Claridge Road West
9. Claridge Road East
10. Lansbury Avenue
11. Margaret Bondfield Avenue
12. John Burns Drive

Potential site cluster

Opposite: Location of small sites in LBBD

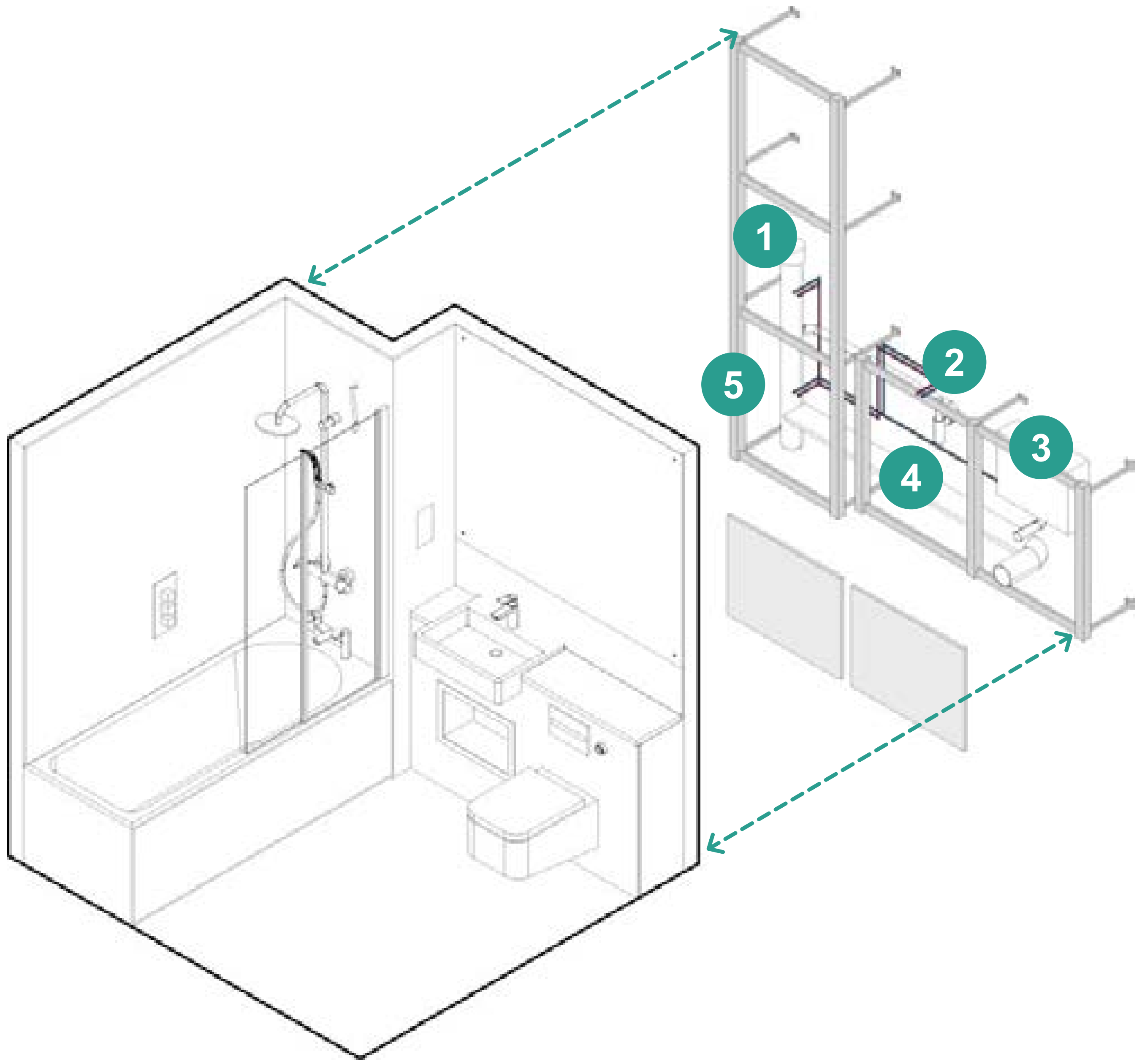
6.3 Assemblies 1

Serviced walls:
The sizes of each of the bathroom types (bathroom, ensuite, and cloakroom WC) align with building regulations Part M space requirements.

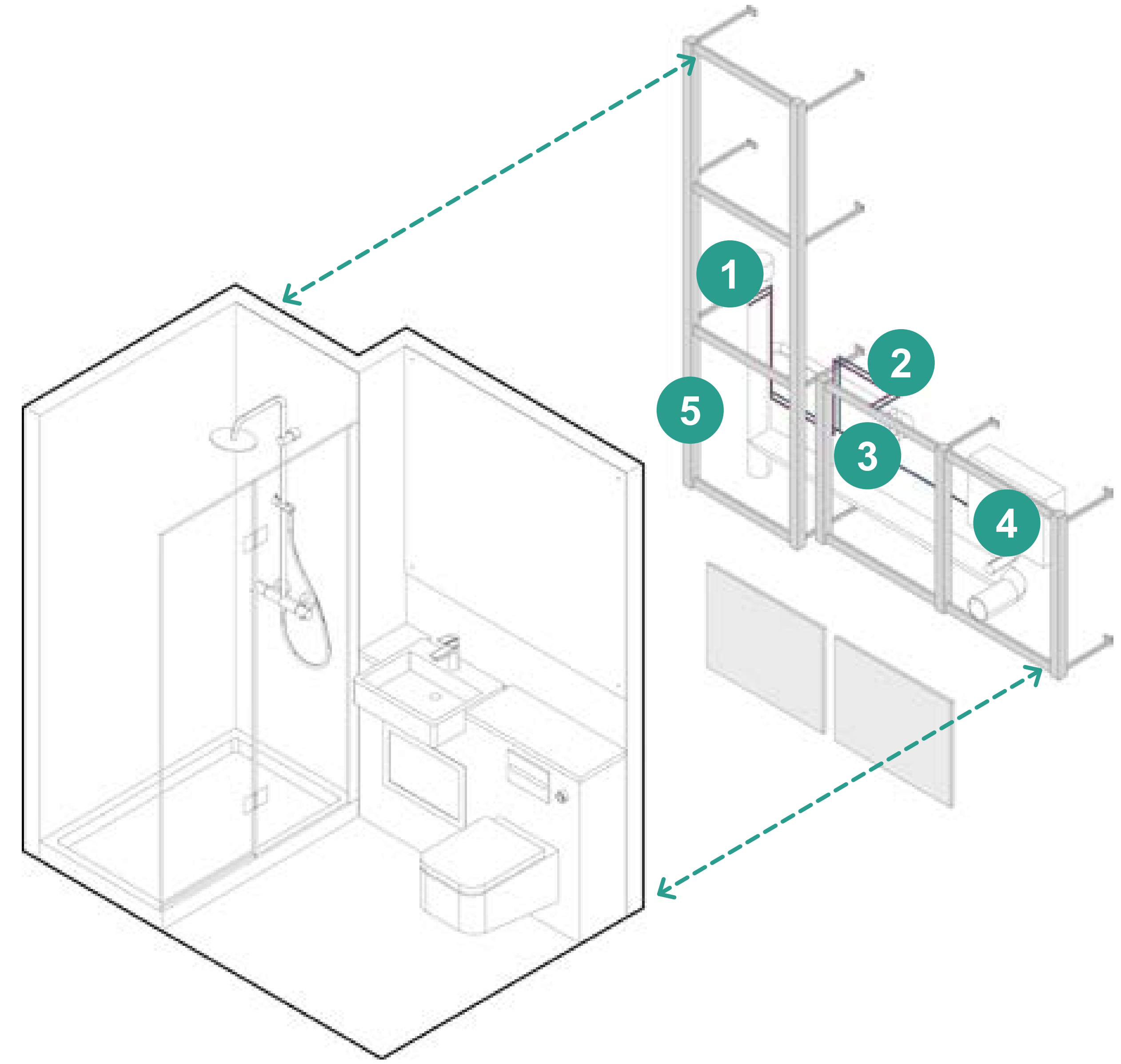
Purchasing pre-fabricated bathroom pods on a small scale may not be feasible, so Integrated Plumbing Systems (IPS) are encouraged. For the family bathroom and ensuite, this system can accommodate all required water and waste connections for the shower, toilet, and sink.

Due to restricted space within the cloakroom WC, the IPS should be used for the toilet only, with the boxing for the sink being constructed on site. If however a house type provides a room width of 1450mm, then the sink and toilet can be located on the same wall, and the IPS system may service both items. Air Admittance Valves (AAVs) should be used instead of venting soil stacks through the roof. Manifold and mircrobore distribution from utility cupboard should be considered to minimise heat losses.

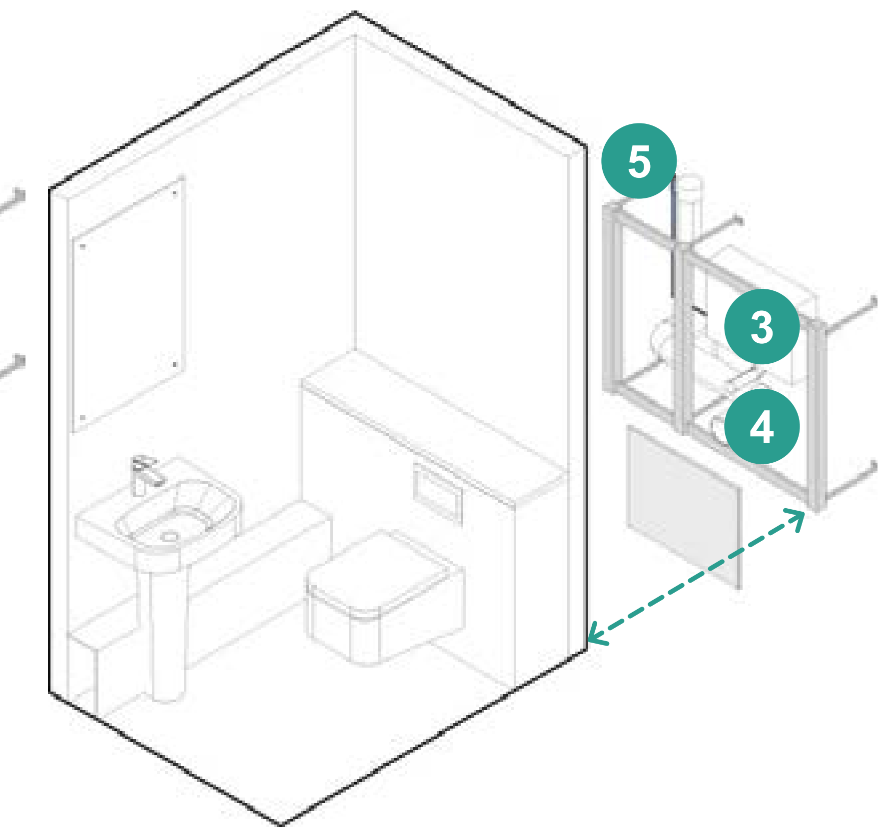
1. Soil discharge pipe (with AAV)
2. Hot and Cold Water
3. Cistern (incl. water connection)
4. Waste
5. Pre-fabricated framework



Bathroom
2100 x 2200mm



Ensuite
2100 x 1500mm



Cloakroom WC
1550 x 1150mm

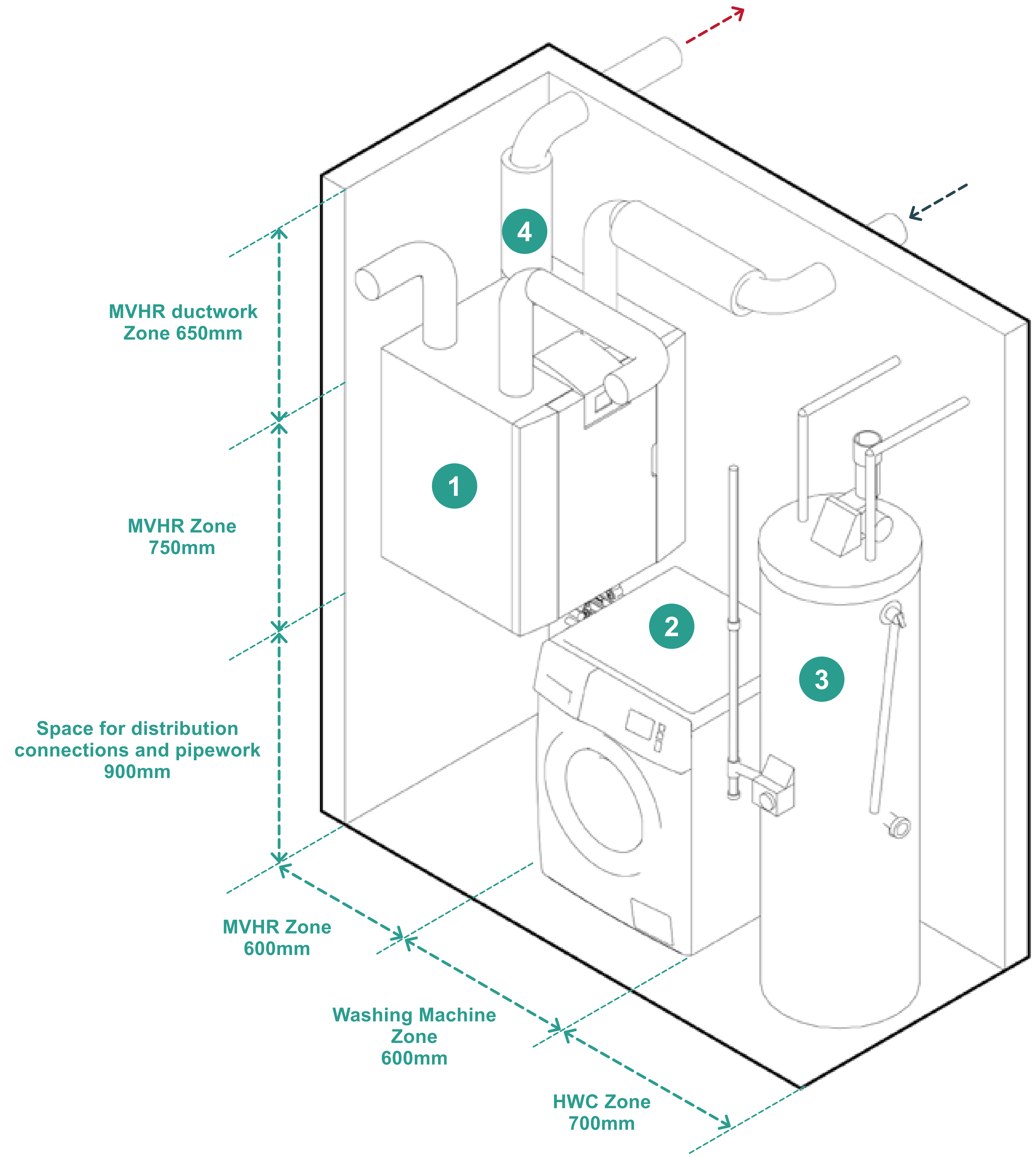
6.4 Assemblies 2

Utility Cupboard:
The utility cupboard houses the Mechanical Heat Recovery Unit (MVHR), washing machine (WM) and hot water cylinder and pressurisation unit (HWC).

The zones identified on the drawing opposite ensures the required equipment can be installed in the identified location, whilst considering access requirements (e.g. changing filters). The cupboard size also accounts for an expansion vessel, pump, and hot and cold-water manifolds.

If the building is designed to have Photovoltaic panels (PVs), the battery should be located in a fire rated cupboard, and all other required equipment can

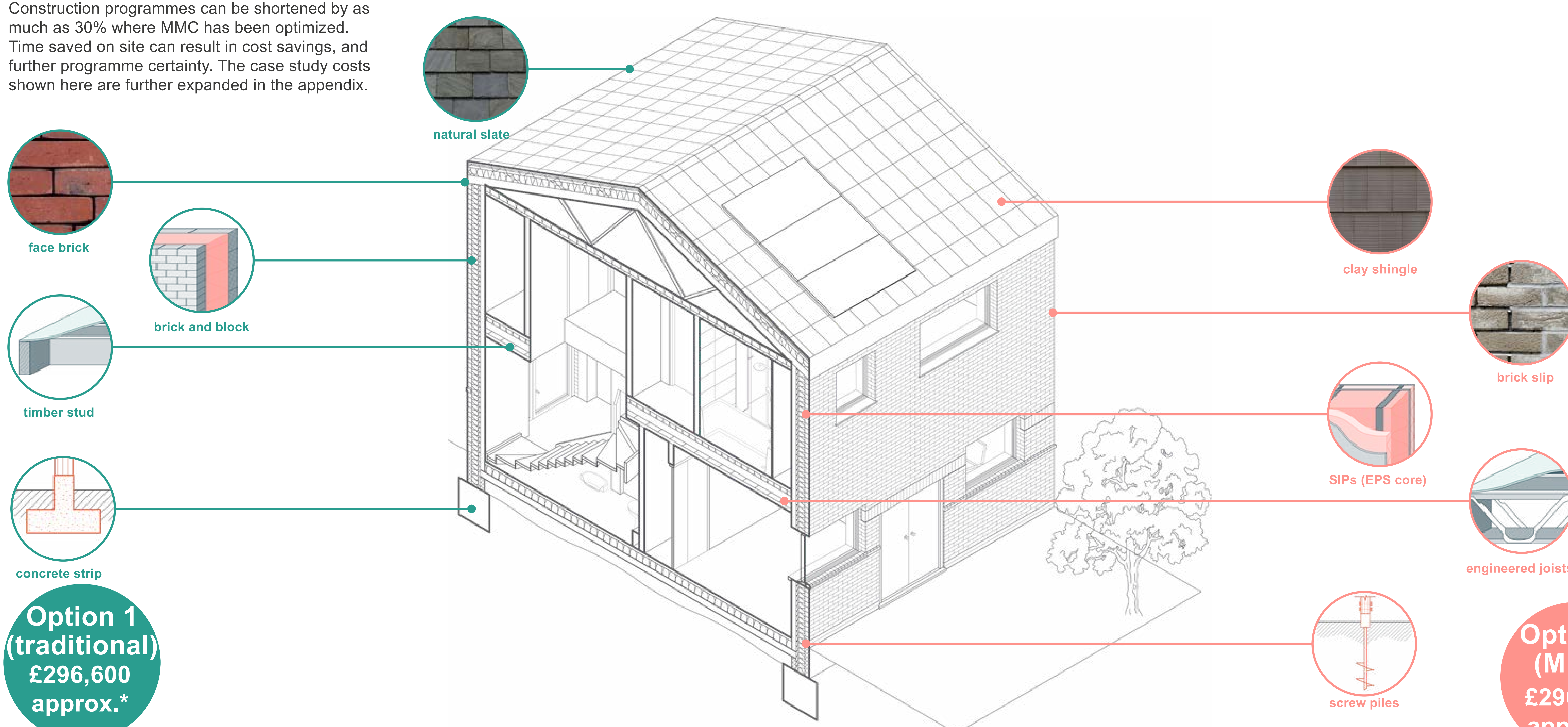
1 MVHR
2 WM
3 HWC
4 Distribution pipework



Utility Cupboard
1900 x 850mm
(clear dimensions)

6.5 Case Study

Cost:
Construction programmes can be shortened by as much as 30% where MMC has been optimized. Time saved on site can result in cost savings, and further programme certainty. The case study costs shown here are further expanded in the appendix.



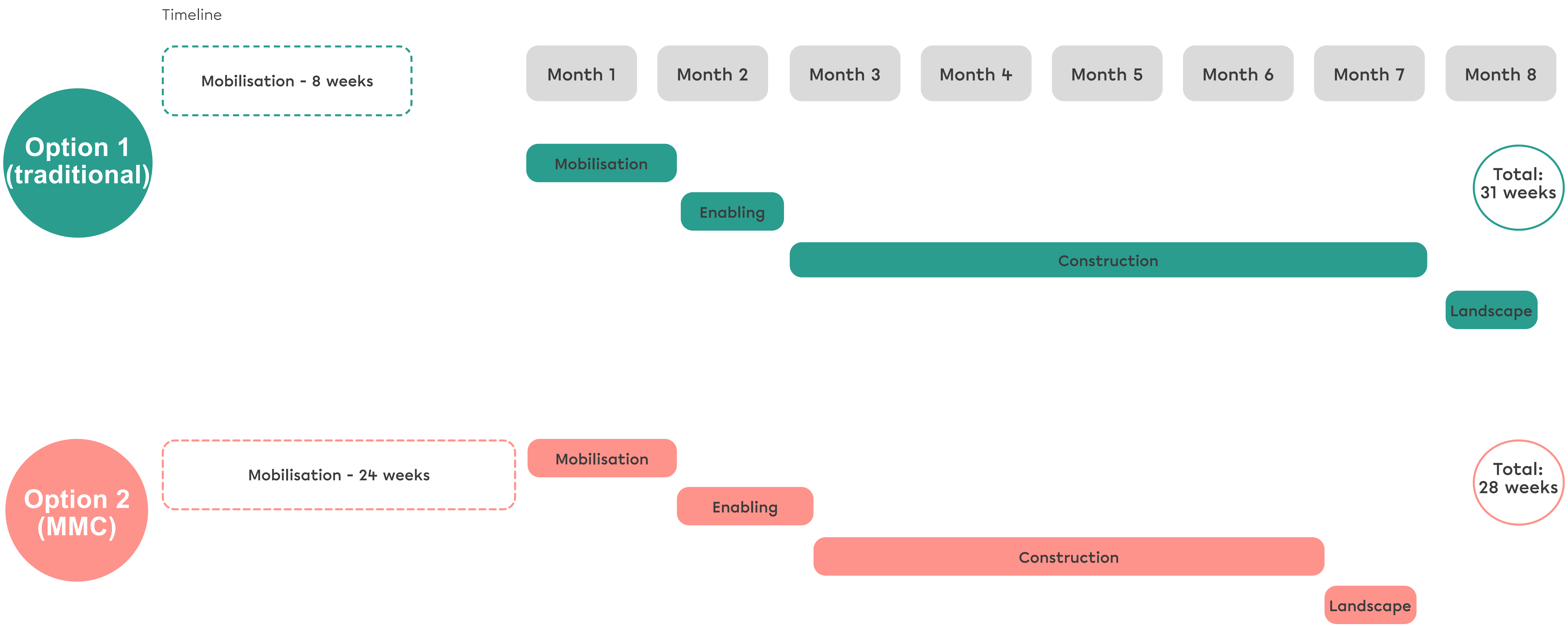
Option 1 (traditional) £296,600 approx.*

Option 2 (MMC) £296,400 approx*.

* figures correct at time of publication, for more information please refer to cost plan

6.6 Programme

Cost & Programme:
Cconstruction programmes can be shortened by as much as 30% where MMC has been optimized. Time saved on site can result in cost savings, and further programme certainty. The case study costs shown here are further expanded in the appendix.



6.7 Embodied Carbon

Comparison of the embodied carbon of the two case study options shows a timber structural system would have a significant reduction in embodied carbon compared to traditional masonry.

		Option 1 Baseline Embodied CO2 kgCO2e/m2, GIA								Option 2 SIPs and Engineered Floors Embodied CO2 kgCO2e/m2, GIA							
	Building element category	A1-A3 Manufac	A1-A3 Sequestered	A4 Transp to site	A5 Construc	B1, B2, B3	B4, B5	C1-4	D	A1-A3 Manufac	A1-A3 Sequestered	A4 Transp to site	A5 Construc	B1, B2, B3	B4, B5	C1-4	D
Facilitating works	Toxic Material Treatment							0	0							0	0
	Major Demolition Works							0	0							0	0
	Temporary Enabling Works	0	0	0	Estimated using RICS as a total only (C1 is also given as a total, so is in the 3 totals but not the table)	0	0	0	0	0	0	0	Estimated using RICS as a total only (C1 is also given as a total, so is in the 3 totals but not the table)	0	0	0	0
	Specialist Ground works	0	0	0		0	0	0	0	0	0	0		0	0	0	0
Substruc	Substructure	28	-24	9		0	0	24	-9	28	-14	1		0	0	15	0
Superstructure	Frame	0	0	0		0	0	0	0	0	0	0		0	0	0	0
	Upper floors incl. balconies	1	-4	0		0	0	4	0	1	-1	0		0	0	1	0
	Roof **and Built-in PV**	0	0	0		0	0	0	0	21	-20	1		0	0	20	-1
	Stairs and ramps	0	0	0		0	0	0	0	0	0	0		0	0	0	0
	External Walls	132	-7	30		-8	5	8	-8	67	-48	6		0	0	50	-2
	Windows and External Doors	16	0	0		5	21	0	0	16	0	0		5	21	0	0
	Internal Walls and Partitions	6	-7	1		0	0	8	-5	6	-7	1		0	0	8	-5
	Internal Doors	0	0	0		0	0	0	0	0	0	0		0	0	0	0
Finishes	Wall Finishes	0	0	0		0	0	0	0	0	0	0		0	0	0	0
	Floor Finishes	0	0	0		0	0	0	0	0	0	0		0	0	0	0
	Ceiling Finishes	0	0	0		0	0	0	0	0	0	0		0	0	0	0
FF&E	FF&E (fixed)	12	0	0		2	14	0	0	12	0	0		2	14	0	0
	FF&E (non-fixed)	0	0	0		0	0	0	0	0	0	0		0	0	0	0
Building Services	Building services	13	0	0		1	35	0	0	13	0	0		1	35	0	0
	Refrigerant Leakage	0	0	0		0	0	0	0	0	0	0		0	0	0	0
	Renewable Electricity Generation	20	0	0		0	40	0	0	20	0	0		0	40	0	0
Prefab	Prefab Building Units	0	0	0		0	0	0	0	0	0	0		0	0	0	0
Existing	Minor Demolition and Alterations	0	0	0		0	0	0	0	0	0	0		0	0	0	0
External	External Works	0	0	0		0	0	0	0	0	0	0		0	0	0	0
	LETI Total for Option 1	208	-41	41	53	0	75	47	-22	163	-91	10	53	8	70	97	-8
	RIBA Total for Option 1	227	-41	41	53	0	115	47	-22	183	-91	10	53	8	110	97	-8
	All: Option 1	227	-41	41	53	0	115	47	-22	183	-91	10	53	8	110	97	-8

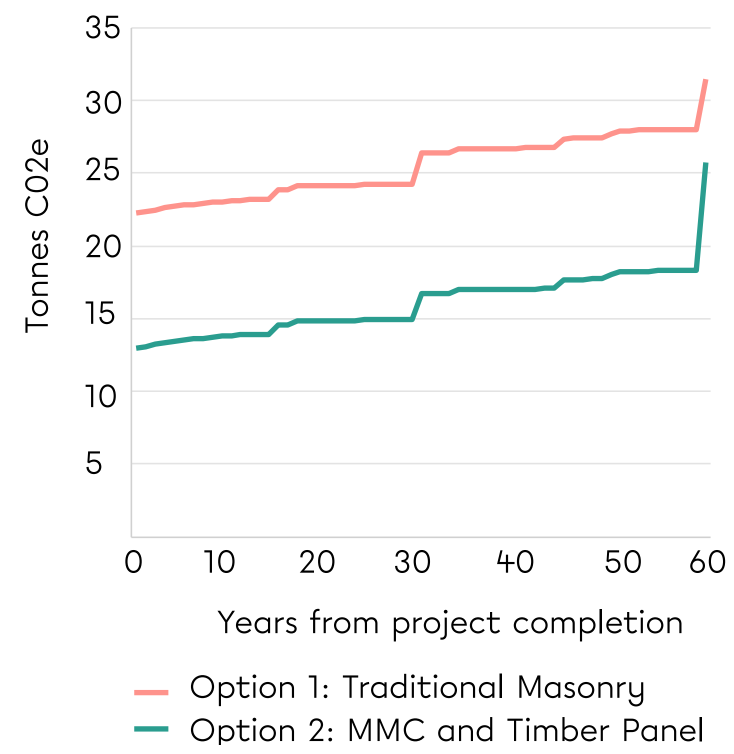
RIBA/RIAI CHALLENGE

	Building Type: Domestic	Building Type: Domestic
Operational Energy	30.0 kWh/m².a GIA	29.7 kWh/m².a GIA
RIBA level met	2030 Target	2030 Target
RIAI level met	2030 Target	2030 Target
Embodied Carbon	442 kg CO₂e/m² GIA	370 kg CO₂e/m² GIA

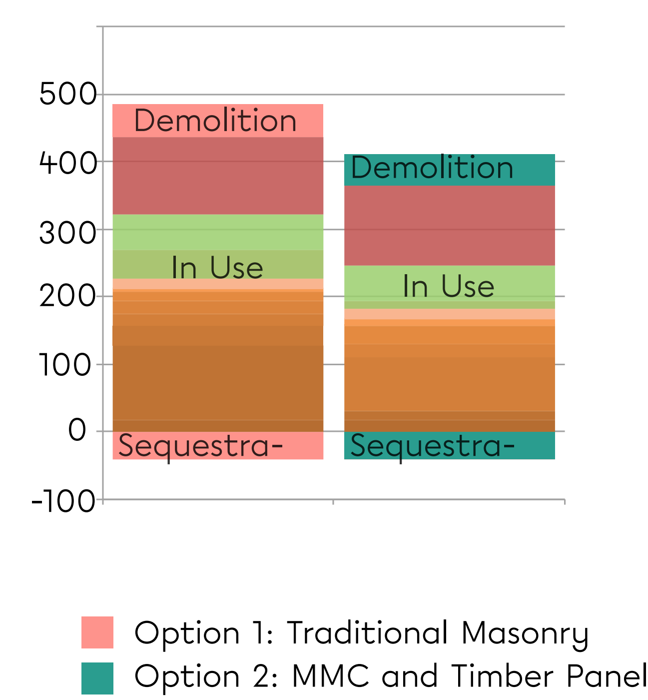
LETI

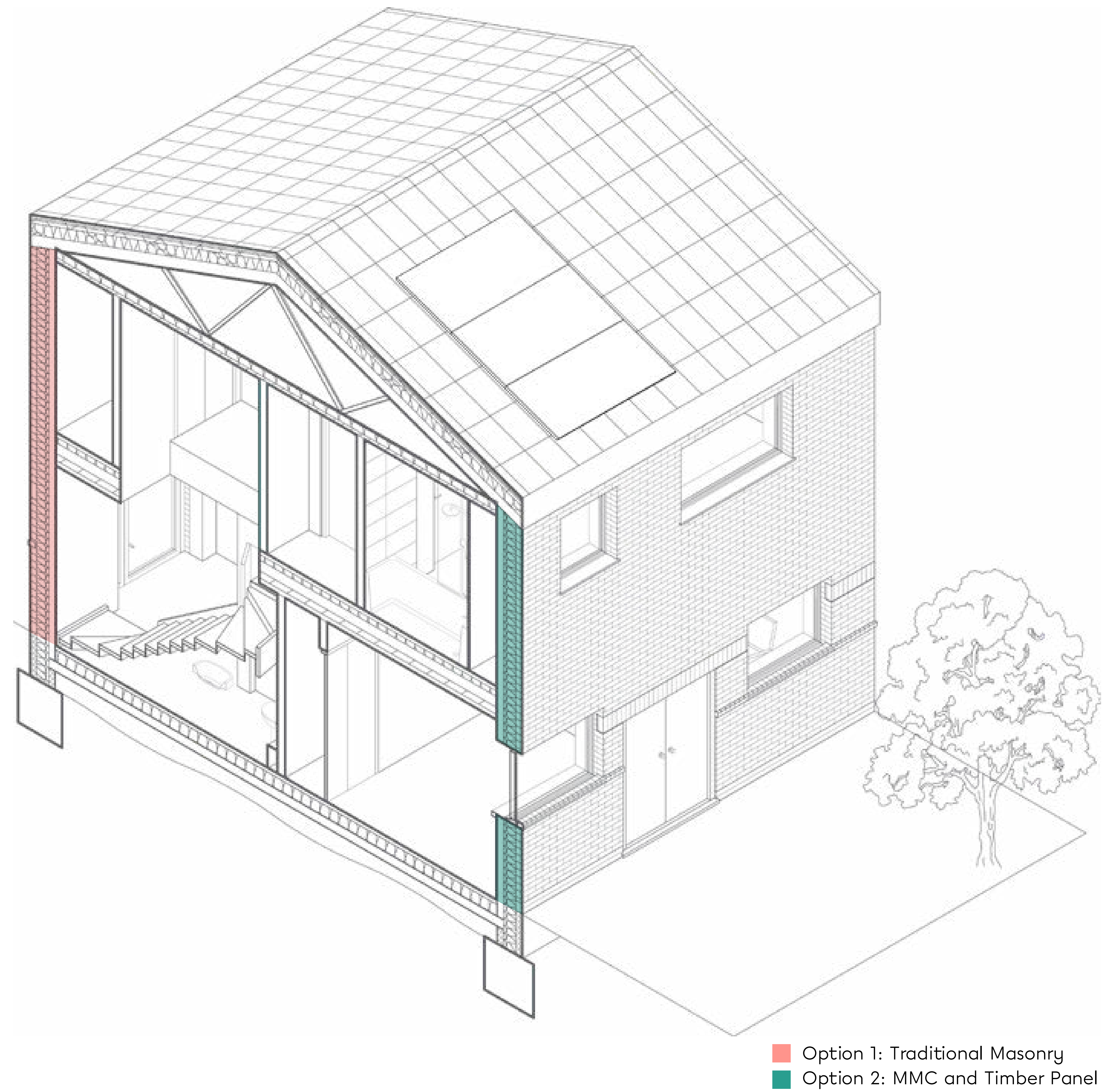
Upfront Carbon A1-5 excl Sequestration	301 kg CO_2e/m_2 GIA	226 kg CO2e/m2 GIA
Embodied Carbon A1-5, B1-5, C1-4	382 kg CO_2e/m_2 GIA	310 kg CO2e/m2 GIA
Sequestered Carbon	41 kg CO_2e/m_2 GIA	91 kg CO2e/m2 GIA
Module D	-22 kg CO_2e/m_2 GIA	-8 kg CO2e/m2 GIA

Module D -22 kg CO_2e/m_2 GIA



-8 kg CO2e/m2 GIA





APPENDIX A

Illustrative Blocks and Layouts

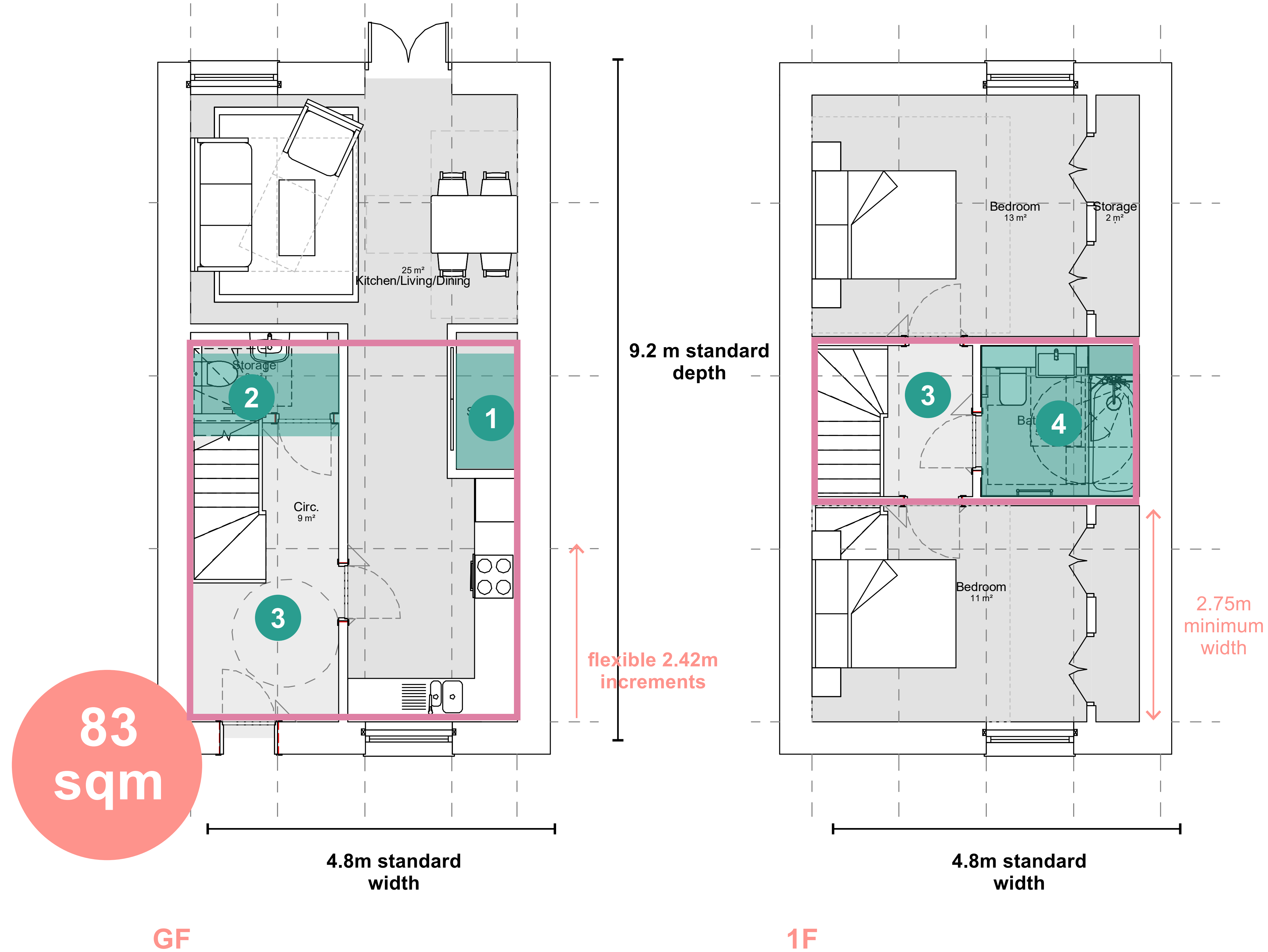
A2. Standard Layout Type A

10.5 sqm circ

Two bedrooms over 2 stories, with active frontage and bedrooms on both sides.

Fixed Parameters

1. Utility Cupboard 1900 mm x 850mm
2. Cloakroom WC 1550mm x 1150mm
3. Corridor 1050mm (minimum width)
4. Standard Bathroom 2100mm x 2200mm



Typical 2B4P Unit Layout Type A

Key

- Serviced area
- Potential lowered service ceiling

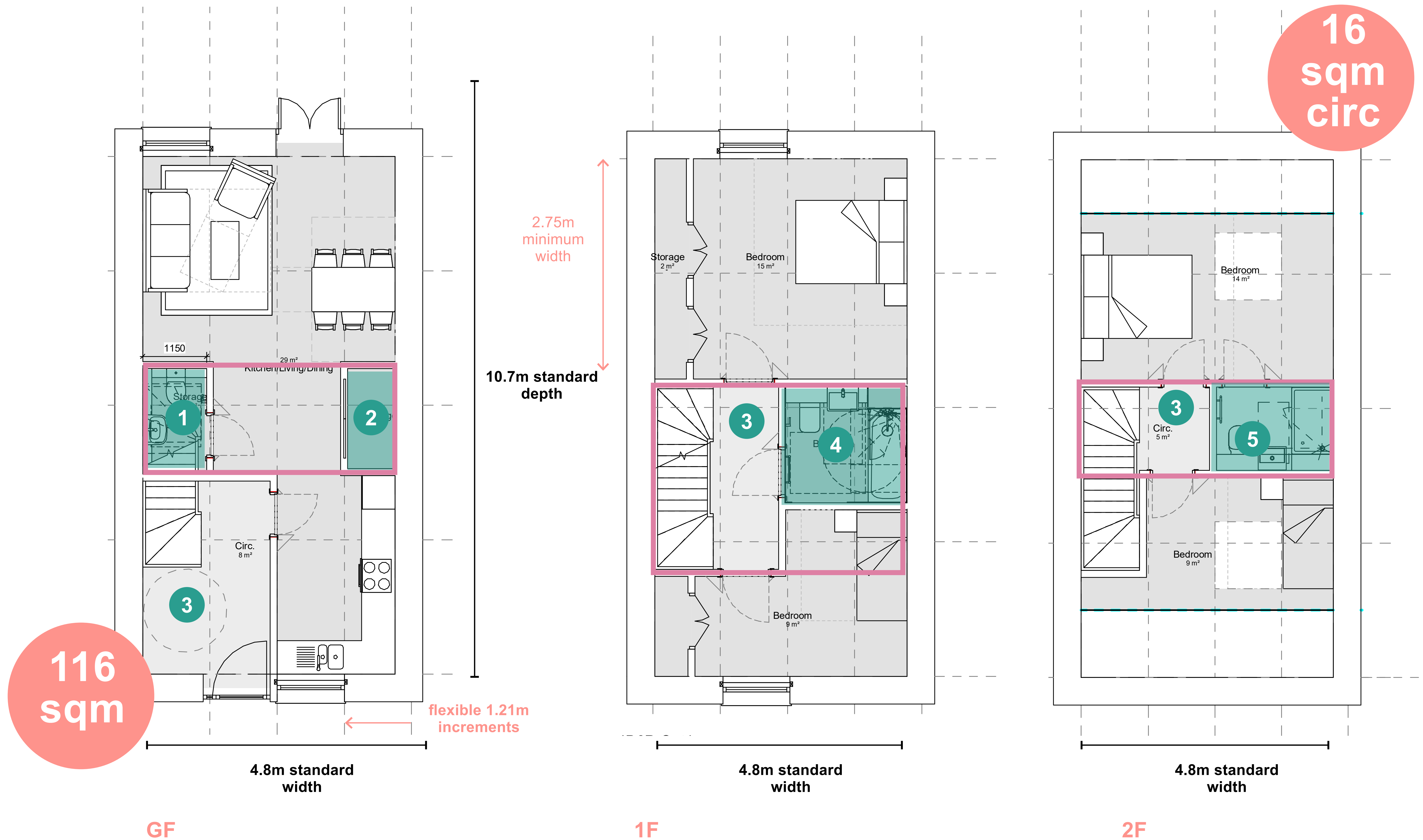
Opposite: Typical Floor Layouts

A2. Standard Layout Type B

Four bedrooms over 3 stories, with active frontage and bedrooms on both sides.

Fixed Parameters

1. Utility Cupboard 1900 mm x 850mm
2. Cloakroom WC 1550mm x 1150mm
3. Corridor 1050mm (minimum width)
4. Standard Bathroom 2100mm x 2200mm
5. En-Suite Pod 2100 x 1550mm



Key

Serviced area

Potential lowered service ceiling

Typical 4B6P Unit Layout Type B

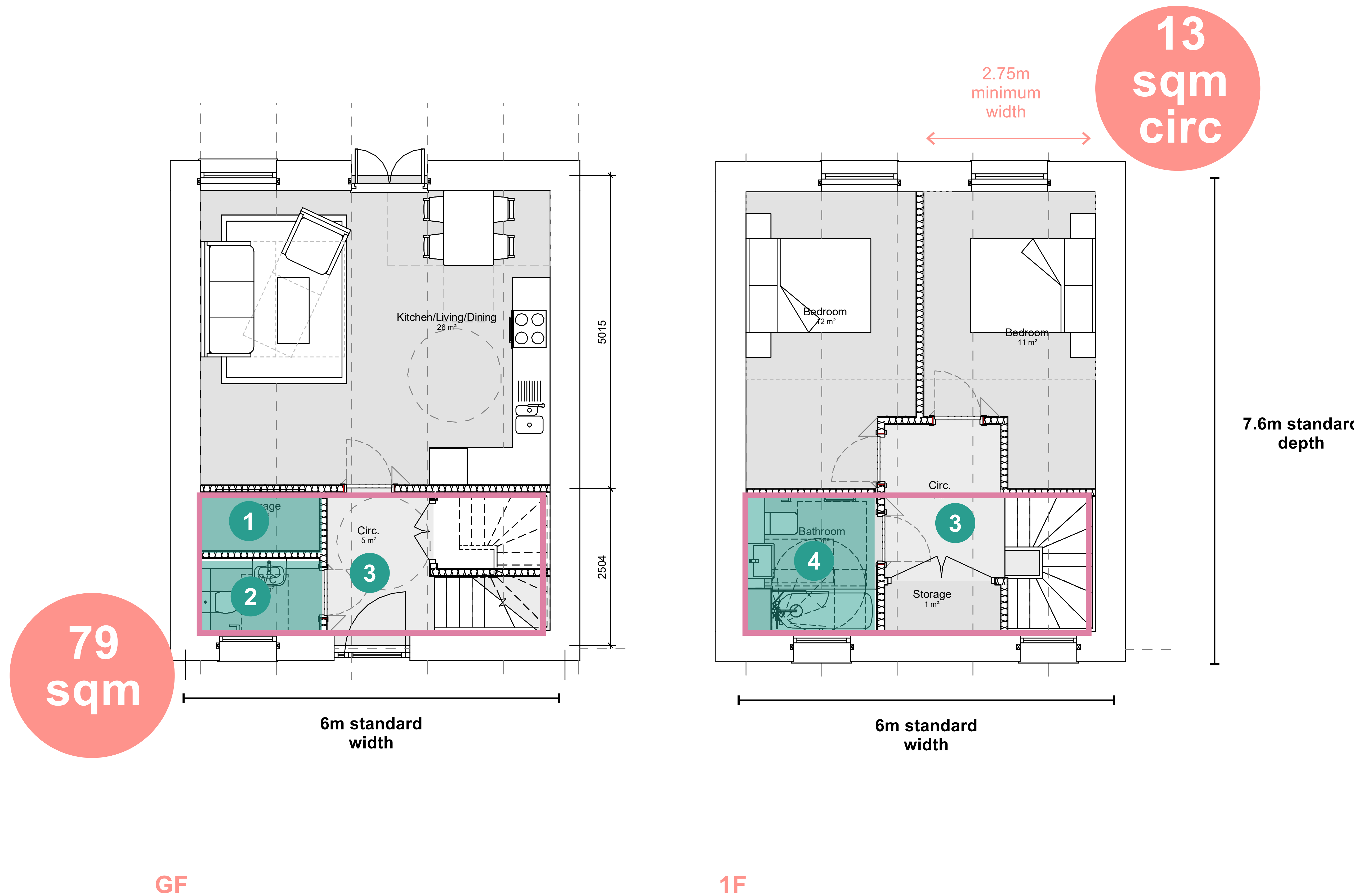
Opposite: Typical Floor Layouts

A2. Standard Layout Type C

Two bedrooms over 2 stories, with servicing at ground floor frontage and bedrooms on at rear

Fixed Parameters

1. Utility Cupboard 1900 mm x 850mm
2. Cloakroom WC 1550mm x 1150mm
3. Corridor 1050mm (minimum width)
4. Standard Bathroom 2100mm x 2200mm



Key

Serviced area

Potential lowered service ceiling

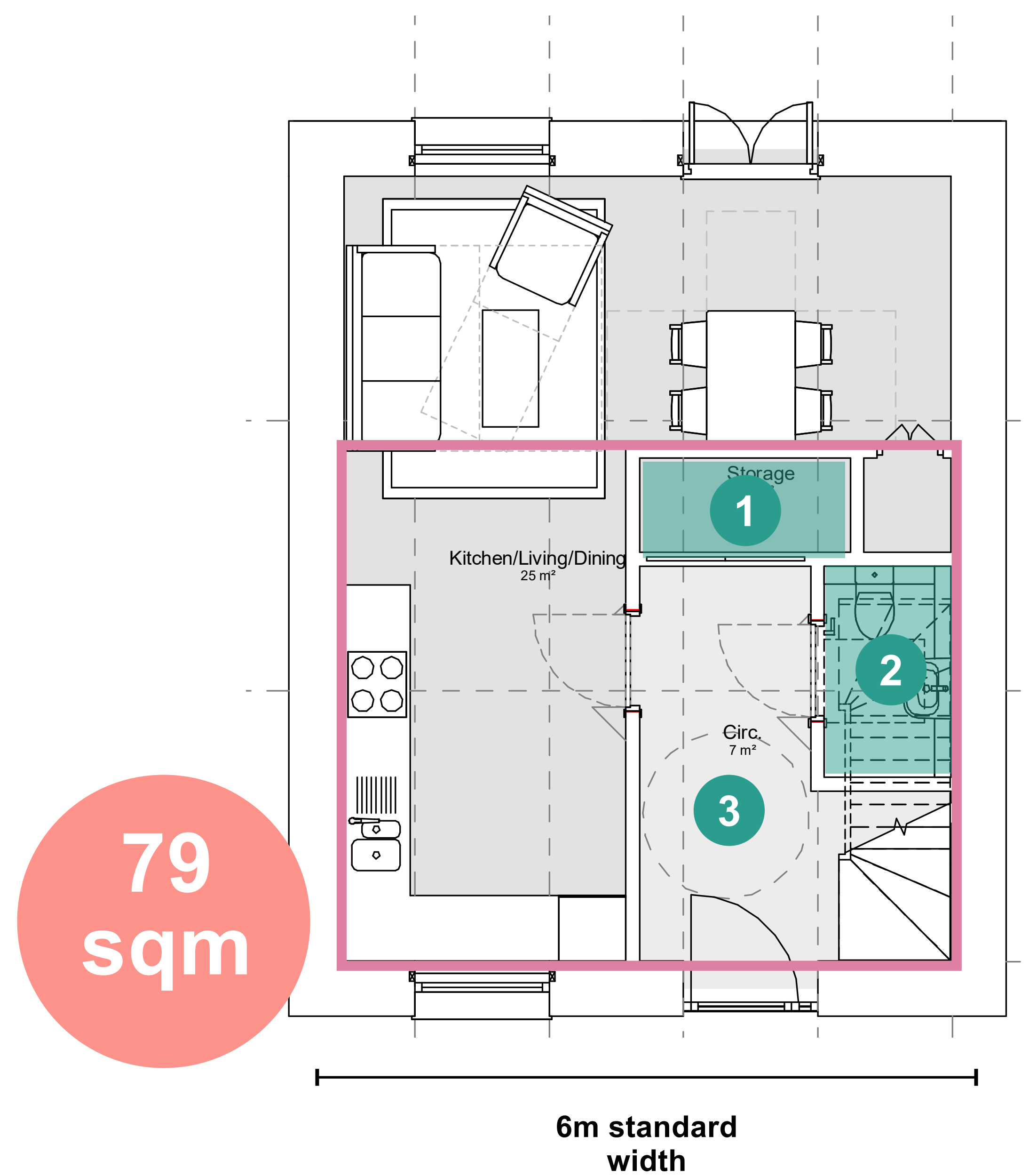
Typical 2B4P Unit Layout Opt 3

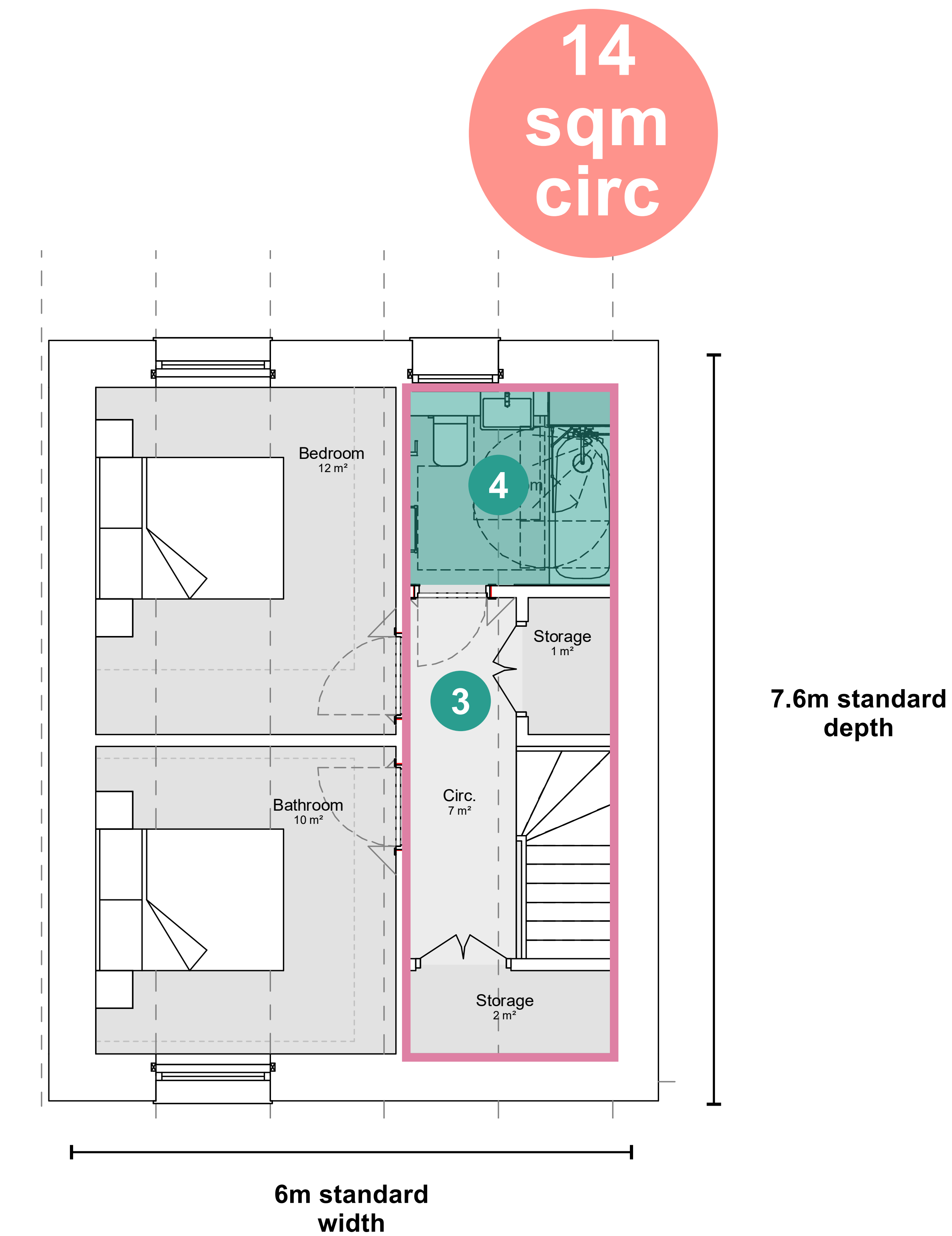
A2. Standard Layout Type D

Two bedrooms over 2 stories, with active frontage and bedrooms on both sides.

Fixed Parameters

1. Utility Cupboard 1900 mm x 850mm
2. Cloakroom WC 1550mm x 1150mm
3. Corridor 1050mm (minimum width)
4. Standard Bathroom 2100mm x 2200mm





Typical 2B4P Unit Layout Opt 2

Key

Serviced area

Potential lowered service ceiling

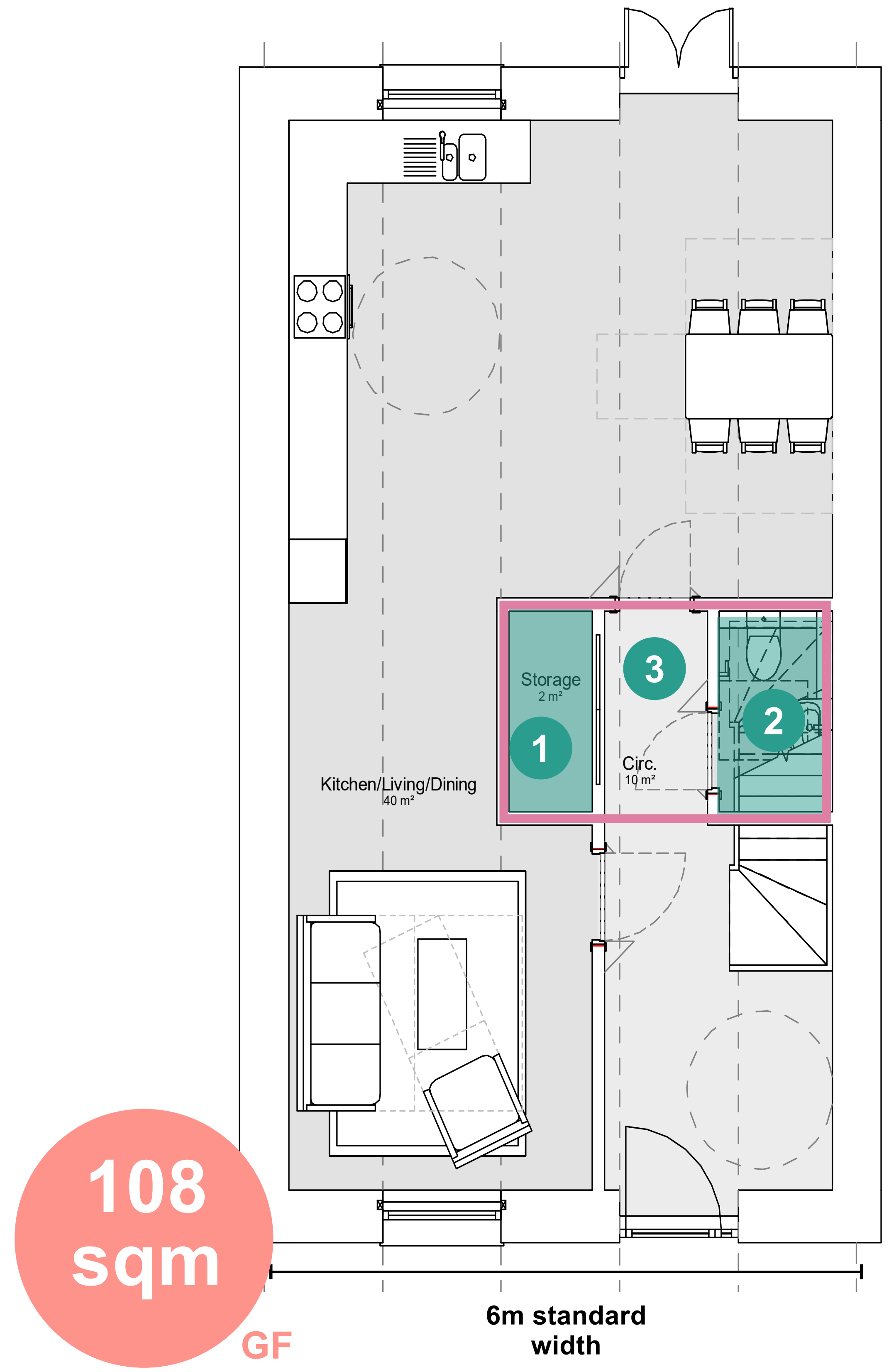
Opposite: Typical Floor Layouts

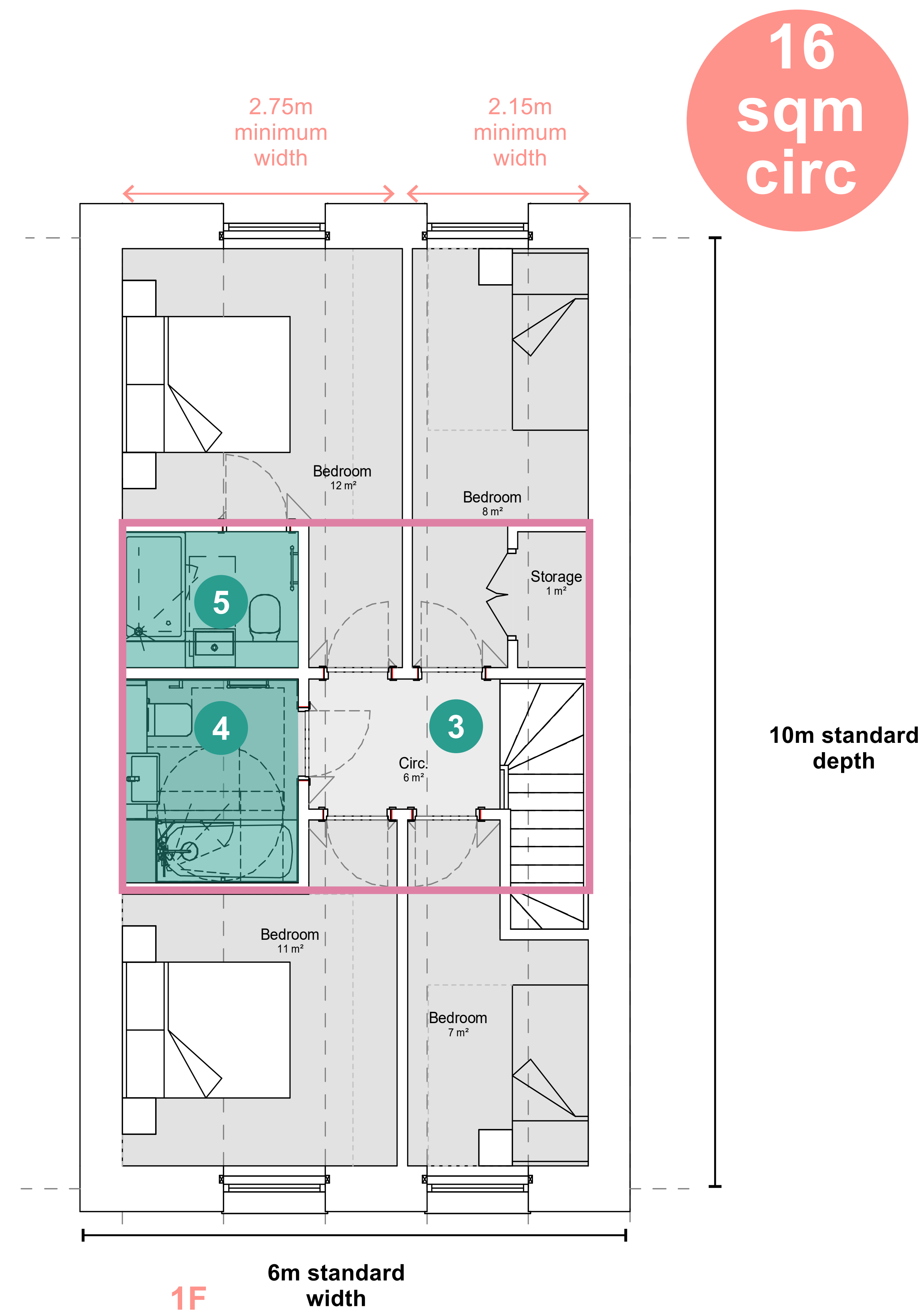
A2. Standard Layout Type E

Four bedrooms over 2 stories with active frontage and bedrooms on both sides.

Fixed Parameters

1. Utility Cupboard 1900 mm x 850mm
2. Cloakroom WC 1550mm x 1150mm
3. Corridor 1050mm (minimum width)
4. Standard Bathroom 2100mm x 2200mm
5. En-Suite Pod 2100 x 1550mm





Typical 4B6P Unit Layout Type E

Key

- Serviced area
- Potential lowered service ceiling

Opposite: Typical Floor Layouts

APPENDIX B

Structural Systems Matrices

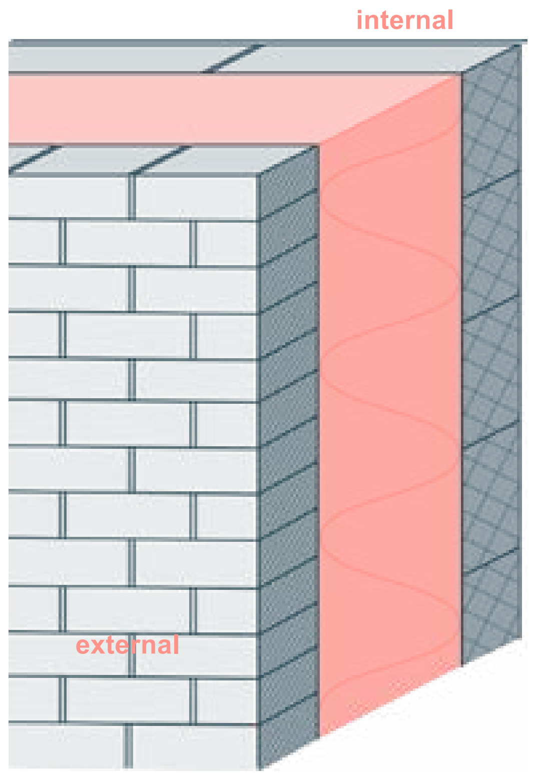
B1. Structural Systems

System Comparison - Overview

Notes:

* Correct at the time of writing. Following formal classification as a combustible material timber has been excluded from use on projects funded by the GLA Affordable Homes Programme 2021 - 2026.

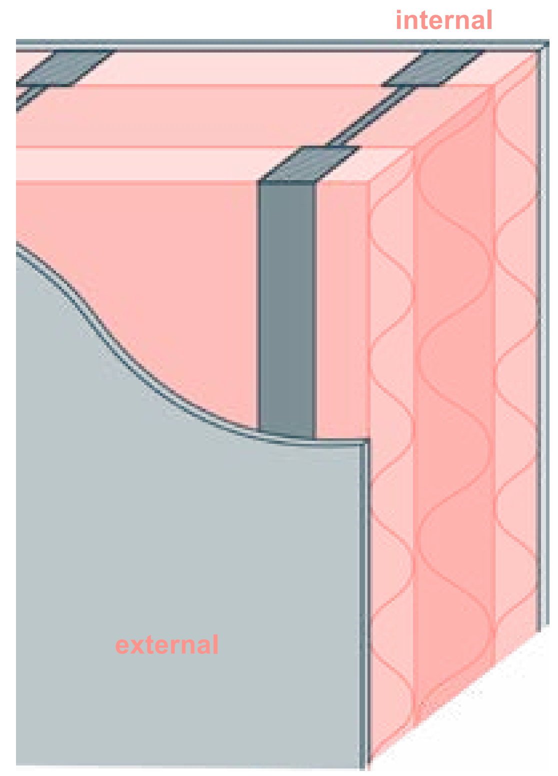
Cavity Wall (Brick & Block)



+ Common construction type, high availability of labour
+ Carbon could be reduced with reused brickwork
+ Highly compatible system
+ Structural depth includes external finish
+ Supports systems with high span ranges

- Traditional system, not MMC
- Labour intensive and slow construction method
- Heaviest option so requires the most intrusive foundation
- High embodied carbon
- Re-use options may increase costs associated with labour and salvage time

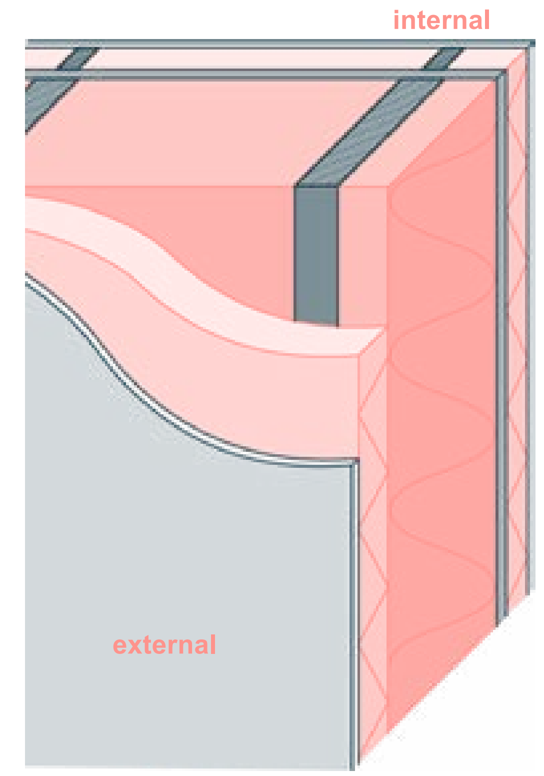
I-Joist / Truss Timber & Woodfibre Panels



+ Low embodied carbon
+ Known construction method - easily procured with contractors
+ Lightweight solution reducing load to foundations
+ Large typical span range

- Stick frame construction - more time than SIPs consuming on site, unless prefabricated as cassettes
- Typically only compatible with timber joist floor construction
- Excluded from use on GLA Affordable Housing Programme projects*

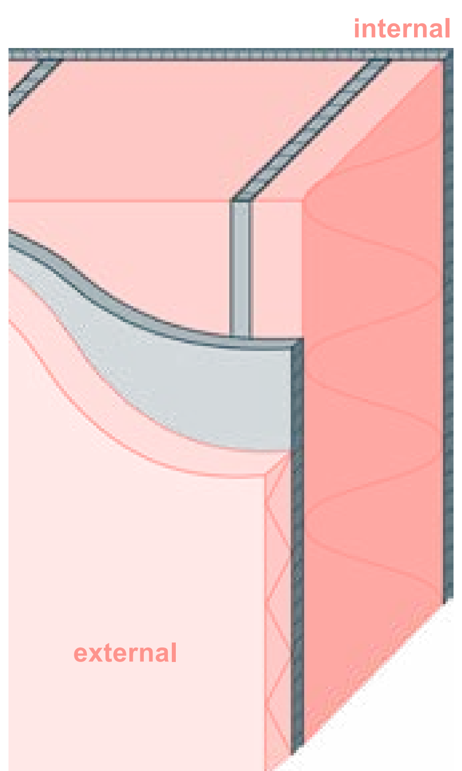
SIPs (EPS and PUR Core)



+ Quick construction on-site
+ Simple logistics
+ Good air tightness possible due to interlocking panel joints
+ Lightweight option compared to traditional masonry
+ Embodied carbon can be low (system dependent)

- Most expensive material (potential for economy of scale)
- Prefabricated panels require specialist contractor
- Embodied carbon can be high (system dependent)
- Low compatibility (typically other timber systems only)
- Short typical span range
- Excluded from use on GLA Affordable Housing Programme projects*

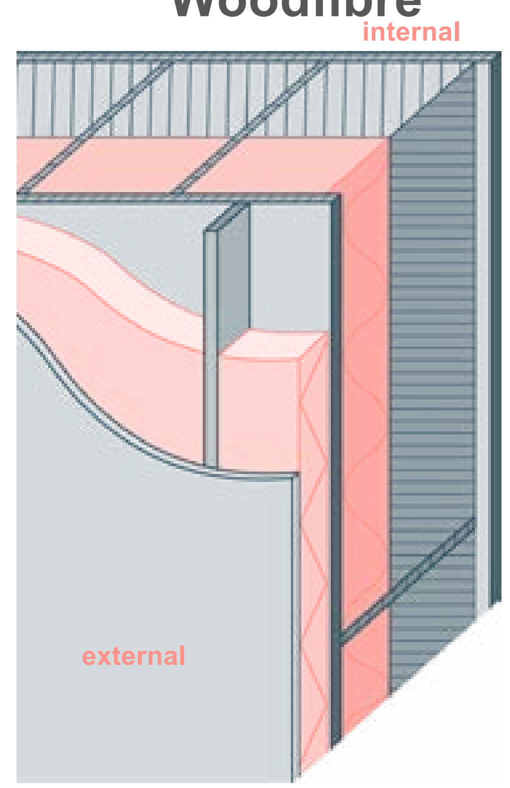
Plywood Cassettes & Wool / Woodfibre



+ Quick construction on-site
+ Simple logistics
+ Lowest sequestered embodied carbon - Insulation options offered are sheeps wool / wood fiber from British farmers
+ Demountable design with adaptable structure
+ Good typical span range
+ Finished internal face

- Highest cost option
- Prefabricated panels require specialist contractor
- Low compatibility
- High structural depth before application of external cladding
- Excluded from use on GLA Affordable Housing Programme projects*

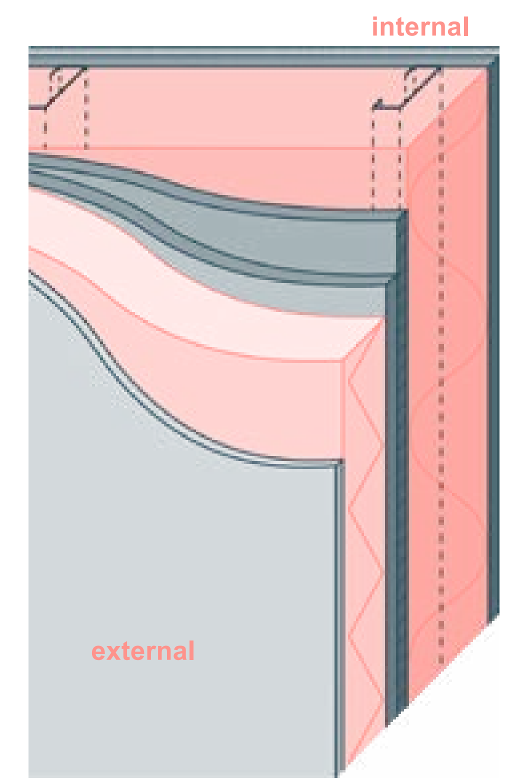
Plywood Cassettes, Hempcrete & Woodfibre



+ High availability of CNC timber systems on the market
+ Quick construction on-site
+ Simple logistics
+ Demountable design with adaptable structure
+ Low embodied carbon

- More costly than traditional systems
- Prefabricated panels require specialist contractor
- Low compatibility
- Low typical span range
- High structural depth before application of external cladding
- Excluded from use on GLA Affordable Housing Programme projects*

Cold-formed Steel (SFS)



+ Common construction type, high availability of labour
+ Can be load-bearing up to four storeys, or non-structural infill
+ Can be recycled at end of life

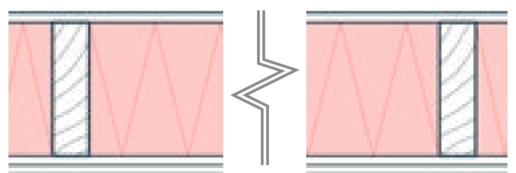
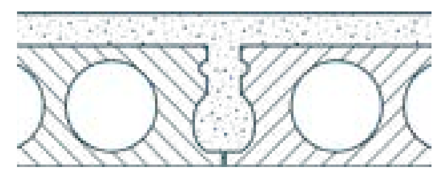
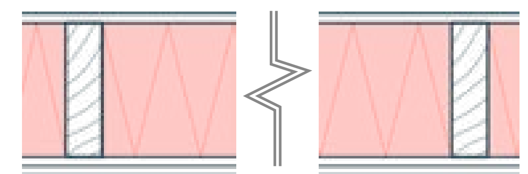
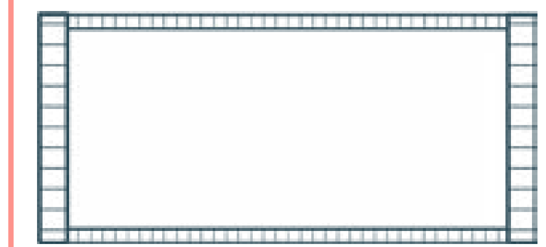
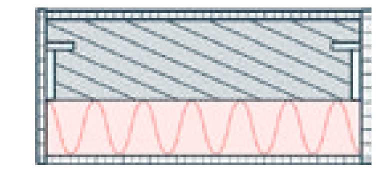
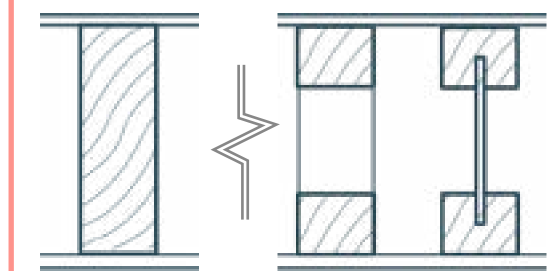
- Additional acoustic treatment and finishing required
- Typically higher embodied CO2 than timber-based alternatives
- Low compatibility (typically SFS systems only)
- Low typical span range

B2. Horizontal Elements

Structural Floor Systems

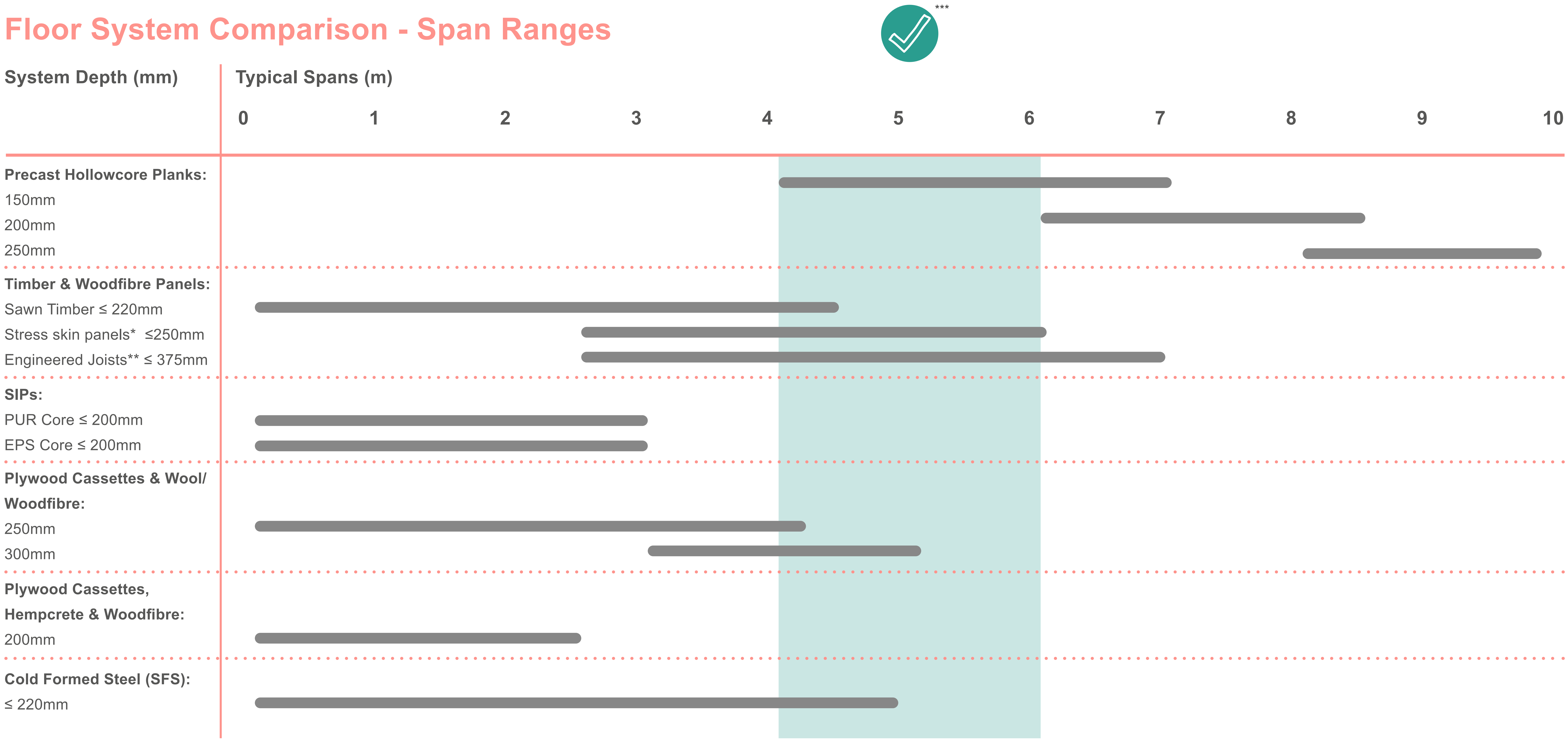
Notes:

An additional allowance for deflections and construction tolerances should be allowed for in addition to structural depth - typically L/250 for deflection and +/-15mm for tolerances, but tolerances may be less in precision-manufactured systems. * Typical structural depths have been shown as an approximate range available the structural systems considered. Systems may vary in size, performance and embodied carbon. Structural depth to achieve span only. Doesn't include floor finish and/or any additional substrate, insulation included where pre-formed as part of a cassette/panel only.

Typical System	SIPs PUR Core	Cold-formed Steel (SFS)	Precast Hollowcore Planks	SIPs EPS Core	Plywood Cassettes & Wool / Woodfibre	Plywood Cassettes, Hempcrete & Woodfibre	I-Joist / Truss Timber & Woodfibre Panels
							
DfMA Benefits	Panelised system Interlocking panels increase air tightness Supply chain availability No wet trades required Fast assembly	Panel / modular system Supply chain availability No wet trades required Fast assembly Can be recycled at end of life	Supply chain availability Simple logistics Rapid assembly	Panelised system Interlocking panels increase air tightness Supply chain availability No wet trades required Fast assembly	Panel / cassette system No wet trades required Fast assembly Demountable design allows for adaptability + good circular economy practise	Panel / cassette system No wet trades required Fast assembly Demountable design allows for adaptability + good circular economy practise	Supply chain availability of individual components to form panel / cassette system and labour No wet trades required Fast assembly
Cost £/m	●	●	●	●	●	●	●
Embodied Carbon sequestered	●	●	●	●	●	●	●
Build Up*	●	n/a	n/a	●	●	●	●
150mm			✓				
200mm	✓	✓ 220mm includes studs and plywood	✓ 150mm plank + 50mm screed	✓		✓	✓ 220mm I-Joist to achieve span of 4.5m
250mm			✓		✓		✓ Timber Stress Skin panels to achieve span of 4.5m
300mm					✓		
350mm+							✓ Engineered Joists to achieve span from 2.5m-7m

B2. Horizontal Elements

Floor System Comparison - Span Ranges



Notes:
Typical span ranges have been shown as an approximate range for the structural systems considered. Longer spans may be achievable with particular systems, or particular design criteria e.g. lightweight finishes

* Timber joists with structural ply skins top and bottom.
**Posi / Easi / Eco-Joist / JJI Joist etc.
*** Span range required to achieve in a single span (without intermediate supports) the grid sizes outlined in Section 3.

Key

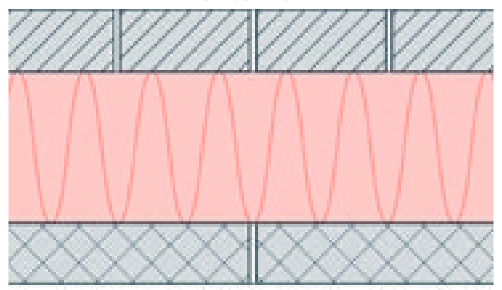
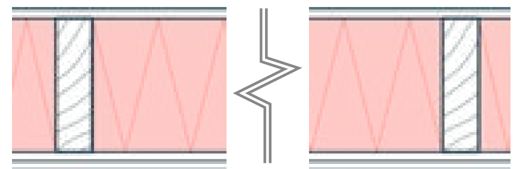
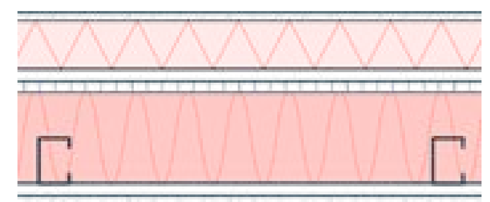
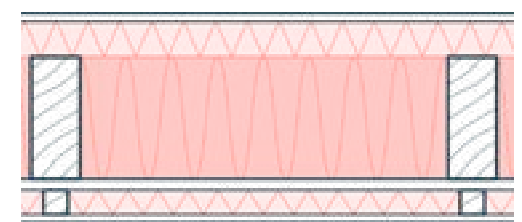
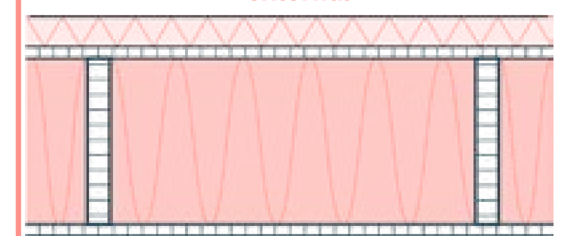
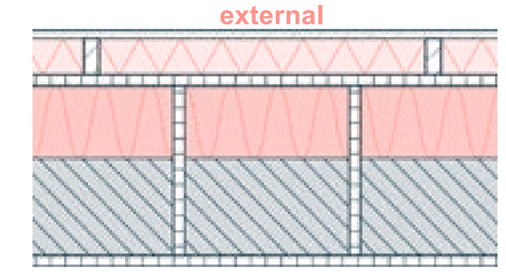
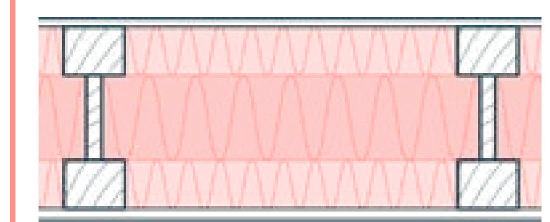
Most suitable for this application

B3. Vertical Elements

Structural Wall Systems

Notes:

* Typical ranges of wall thicknesses are shown approximately, based on an assumed two-to-three storey building. Thinner structural walls may be achievable with particular systems, or particular design criteria e.g. lightweight finishes, shorter supported spans etc. See illustration for typical build up to achieve U-Values between approximately 0.137 W/(m²K) - 0.153W/(m²K). Build up exclusive of external facade system, a typical ventilated cladding system has been assumed in u-value calculations.

Typical System	Cavity Wall (Brick & Block) external 	SIPs PUR Core external 	Cold-formed Steel (SFS) external 	SIPs EPS Core external 	Plywood Cassettes & Wool / Woodfibre external 	Plywood Cassettes, Hempcrete & Woodfibre external 	I-Joist / Truss Timber & Woodfibre Panels external 
MMC Benefits	Not MMC ready included for comparative purposes On-site only Requires finishing internally	Panelised system Supply chain availability No wet trades required Fast assembly Gypsum internal finish	Panel / modular system Supply chain availability No wet trades required Fast assembly Boarded internal finish	Panelised system Supply chain availability No wet trades required Fast assembly Gypsum internal finish	Panel / cassette system No wet trades required Fast assembly Plywood internal finish	Panel / cassette system No wet trades required Fast assembly Plywood internal finish	Supply chain availability of individual components to form panel / cassette system No wet trades required Fast assembly
Cost £/m	●	●	●	●	●	●	●
Embodied Carbon	●	●	●	●	●	●	●
Build Up*	sequestered n/a	●	n/a	●	●	●	●
250mm - 300mm		✓					
301mm - 350mm			✓	✓	✓		✓
351mm - 400mm						✓	
401mm - 450mm							
451mm - 500mm	✓						

B4. Compatibility

Wall and Floor Structural Compatibility

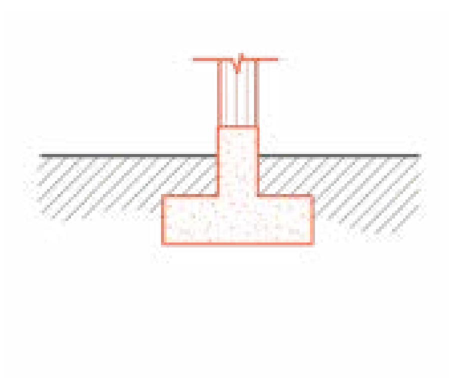
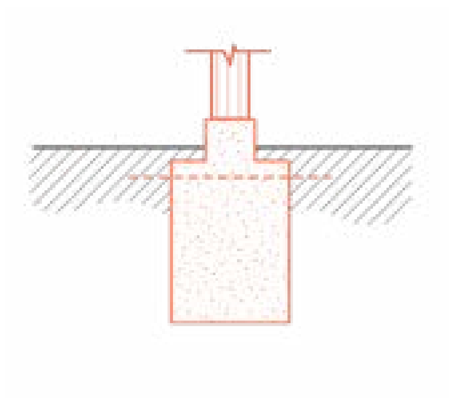
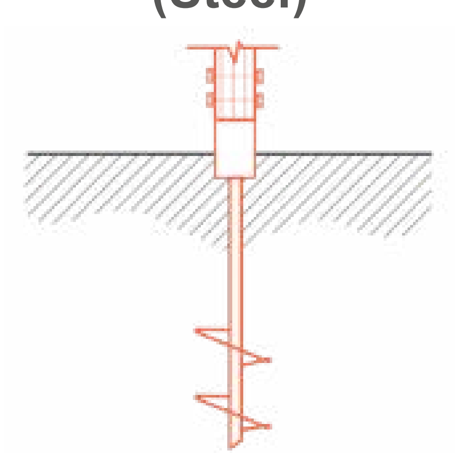
Wall / Floor	Cavity Wall* (Brick & Block)	I-Joist / Truss Timber & Woodfibre Panels	SIPs (EPS & PUR Core)	Plywood Cassettes & Wool / Woodfibre	Plywood Cassettes, Hempcrete & Woodfibre	SFS Prefabricated Panels
Precast Hollowcore Planks	✓	✗	✗	✗	✗	✗
I-Joist / Truss Timber & Woodfibre Panels	✓	✓	✓	?	?	✗
SIPs (EPS & PUR Core)	✓	✗	✓	✗	✗	✗
Plywood Cassettes & Wool / Woodfibre	✗	✗	✗	✓	✗	✗
Plywood Cassettes, Hempcrete & Woodfibre	✗	✗	✗	✗	✓	✗
SFS Prefabricated Panels	✓	✗	✗	✗	✗	✓

Notes:

Compatibilities of wall and floor systems have been shown based on typical practice.
* Not MMC included for comparative purposes.

B5. Substructure

Foundation Systems

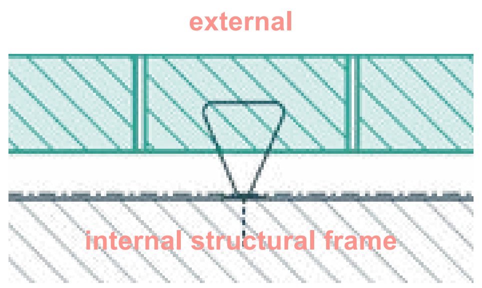
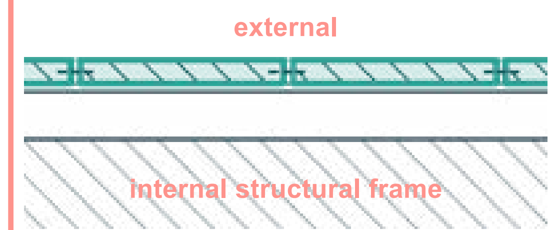
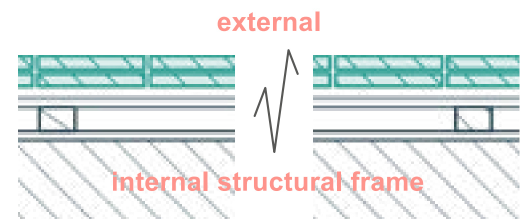
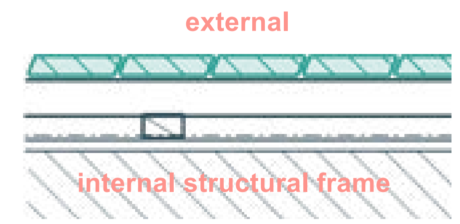
Typical System	Embodied Carbon	Excavation Required	Specialist Contractor Required	Suitable for Clay soil / presence of Trees	Raised Deck Required**	Cost £/m	DfMA Benefits
Shallow Concrete Strip 	🔴	✓	✗	✗	✓	🟢	Simple construction Compatible with precast concrete beam and block floor or timber cassettes
Trench Concrete 	🔴	✓	✗	✗ ✓ *	✓	🟠	Simple construction Compatible with precast concrete beam and block floor or timber cassettes
Screw Piles (Steel) 	🟠	✗	✓	✓	✓	🔴	Fast construction Most prefabricated option dependent on build up Compatible with precast concrete beam and block floor or timber cassettes Removable at end of life, higher circular economy potential

Notes:

* Suitable for clay soil dependent on depth, protected tree root zones may impact viability.
** Ventilation void required for suspended floor systems. Timber floors typically required to be raised above the external ground level according to Approved Document C.

B6. Facade

Fabric

	Face Brick	Brick Slips	Clay Shingles	Timber Board (FR)
Typical System				
MMC Benefits	Supply chain availability	Panelised system Off-site manufacture Supply chain availability Fast assembly	Available as an off-site manufacture system solution No wet trades required Fast assembly	Opportunity for panelised off-site manufacture Supply chain availability No wet trades required Fast assembly
Cost £/m				
Embodied Carbon				
sequestered	n/a	n/a	n/a	
Build Up*				
75mm - 100mm		✓	✓	✓
101mm - 125mm				✓ build up dependent on desired board profile
126mm - 150mm				
151mm - 175mm	✓			
176mm - 200mm				

Notes:

Assumptions have been made to create parity between systems. Cost includes timber batten fixings for Clay Shingle and Timber Board options. A metal bracket / fixing system has been assumed for Brick Slips and Metal Rainscreen cladding options. 25mm - 50mm ventilated cavity assumed for all systems.

B7. Facade

Compatibility with Structural Wall Systems

Facade System \ Wall System	Cavity Wall* (Brick & Block)	I-Joist / Truss Timber & Woodfibre Panels	SIPs (EPS & PUR Core)	Plywood Cassettes & Wool / Woodfibre	Plywood Cassettes, Hempcrete & Woodfibre	SFS Prefabricated Panels
Face Brick**	✓	✓	✗	?	?	✓
Brick Slips	n/a	✓	✓	✓	✓	✓
Clay Shingles	n/a	✓	✓	✓	✓	✓
Timber Board (FR)	n/a	✓	✓	✓	✓	✓

Notes:

* Not MMC included for comparative purposes. For Brick & Block the structural system includes external brick leaf.
** Not directly compatible requires building off it's own foundations.

APPENDIX C

Case Study Cost Plan

C1. Case Study Costs

Type A1: Traditional Masonry

Building Works - Build Up		QTY		RATES £	£	TOTALS £
0.0	**Facilitating Works**					
0.2	Site clearance					
	Allowance for site clearance	1	item	2,500	2,500	
	Total					**2,500**
1.0	**Substructure**					
1.1	**Foundations** *					
	Foundations and Floor Slab					
	Strip foundation incl insulation	39	m2	£280.00	10,920	
	Beam and block floor	39	m2	£160.00	6,240	
	Total					**17,160**
2.0	**Superstructure**					
2.1	**Frame**					
	N/A					
	Total					**0**
2.2	**Upper Floors**					
	Timber joists and chipboard boarding	39	m2	135	5,265	
	Total					**5,265**
2.3	**Roof**					
	Timber trussed roof	39	m2	£110.00	4,290	
	Slate roof tiles, incl. insulation	39	m2	£225.00	8,775	
	Rainwater goods; aluminium (GIFA)	39	m2	£25.00	975	
	Total					**14,040**
2.4	**Stairs and Ramps**					
	Timber stairs					
	Softwood stairs and balustrades; 2.80m rise; straight	1	nr	1,700	1,700	
	Total					**1,700**
	External Walls					
2.5	Brickwork					
	Brickwork (PC Sum £700/1000) including internal leaf blockwork, insulation, wall ties, cavity trays etc	170	m2	350	59,500	
	Total					**59,500**
2.6	**Windows and External Doors**					
	Aluminium Composite Windows					
	Window - triple glazed	7	m2	£800.00	5,600	
	External Doors					
	External Entrance Door - Aluminium composite	1	nr	£3,000.00	3,000	
	Double Door - Curtain Wall Glass (Garden)	1	nr	£8,000.00	8,000	
	Total					**16,600**
2.7	**Internal Walls and Partitions**					
	Plasterboard partitions; 102mm wide dry line finish; emulsion both sides	68	m2	90	6,120	
	Total					**6,120**
2.8	**Internal Doors**					
	Single doors	3	nr	1,500	4,500	
	Riser/Storage doors - double	4	nr	1,500	6,000	
	Toilet doors	2	nr	750	1,500	
	Total					**12,000**
3.0	**Internal Finishes**					
3.1	**Wall Finishes**					
	Skim coat plaster and paint - to internal face of external walls	123	m2	45	5,535	
	Tiling to WCs and kitchens	1	item	1,300	1,300	
	Total					**6,835**
3.2	**Floor Finishes**					
	Cement and sand screed; 75mm thick incl	39	m2	30	1,170	
	Carpet	22	m2	50	1,100	
	Tarkett Safetred Wood	39	m2	55	2,145	
	Skirtings	121	m	25	3,020	
	Floor tiles - toilet/bathroom	7	m2	45	315	
	Vinyl	4.5	m2	40	180	
	Total					**7,930**
3.3	**Ceiling Finishes**					
	Plasterboard and paint	78	m2	55	4,290	
	Total					**4,290**
4.0	**Fixtures and Settings**					
4.1	**Kitchens and bathrooms** **					
	Kitchen unit	1	nr	5,500	5,500	
	Toilet area fittings: mirrors, WC roll holder, sanitary bins, towel rails etc.	2	nr	500	1,000	
	Washer/dryer	1	nr	500	500	
	Total					**7,000**
4.2	**General Fitting, Furnishings & Equipment**					
	Allowance for post-boxes	1	nr	150	150	
	Allowance for signage	1	item	250	250	
	Total					**400**
5.0	**Services**					
5.1	**Sanitary Fittings**					
	Basic Spec					
	WCs and cisterns	2	nr	400	800	
	Wash basins with taps	2	nr	400	800	
	Baths with mixer tap, shower over, screen, panel	1	nr	1,300	1,300	
	Total					**2,900**
5.2	**Services Equipment**					
	Total					**0**
5.3	**Disposal Installations**					
	Sanitary plumbing - residential					
	Soil pipes; casing and insulation	78	m2	55	4,290	
	Total					**4,290**
5.4	**Water Installations**					
	Hot and cold water installations (residential)	78	m2	40	3,120	
	Total					**3,120**
5.5	**Heat Source**					
	Air Source Heat Pump (ASHP)	1	item	8,000	8,000	
	Total					**8,000**
5.6	**Space Heating and Air Conditioning**					
	HIU	1	nr	3,500	3,500	
	LTHW radiators	78	m2	50	3,900	
	Total					**7,400**
5.7	**Ventilation**					
	MVHR	1	nr	4,000	4,000	
	Total					**4,000**
5.8	**Electrical Installations**					
	Electrical installations	78	m2	100	7,800	
	Total					**7,800**
5.9	**Fuel Installations**					
						0
5.10	**Lift and Conveyor Installations**					
	Total					**0**
5.11	**Fire and Lighting Protection**					
	Fire alarm	78	m2	10	780	
	Smoke detection	1	item	500	500	
	Total					**1,280**
5.12	**Communications, Security and Control Systems**					
	Dwellings					
	Communication, security and control systems to	78	m2	5	390	
	Telephone installations in dwellings	1	nr	200	200	
	Television installations	1	nr	500	500	
	Video door entry systems	1	nr	700	700	
	Total					**1,790**
5.13	**Special Installations**					
	Photovoltaics panels;	1	item	5,000	5,000	
	Total					**5,000**
5.14	**Builder's Work in Connection with Services**					
	Builders' work in connection with services	78	m2	12	936	
	Testing and commissioning	1	Item	1,000	1,000	
	Total					**1,936**
8.0	**External Works**					
8.1	Provisional Allowance for External works- soft and hard landscaping, fencing.	39	m2	£300.00	11,700	
	Total					**11,700**
						220,556

Notes:

* Assumptions of no abnormal foundation requirements
** Based on Be First Employers Requirements

C2. Case Study Costs

Type A1: MMC & Timber panel

Building Works - Build Up		QTY		RATES £	£	TOTALS £
0.0	**Facilitating Works**					
0.2	Site clearance					
	Allowance for site clearance	1	item	2,500	2,500	
Total						**2,500**
1.0	**Substructure**					
1.1	**Foundations ***					
	Foundations					
	Screw piling: 1.5m centres, grid system	26	nr	£480.00	12,480	
	Beam and block floor	39	m2	£160.00	6,240	
Total						**18,720**
2.0	**Superstructure**					
2.1	**Frame**					
	See External Wall					
Total						**0**
2.2	**Upper Floors**					
	I-Joist systems	39	m2	140	5,460	
Total						**5,460**
2.3	**Roof**					
	Timber trussed roof	39	m2	£110.00	4,290	
	200mm insulation to roof joists	39	m2	£12.00	468	
	Clay shingles	39	m2	£115.00	4,485	
	Rainwater goods; aluminium (GIFA)	78	m2	£25.00	1,950	
Total						**11,193**
2.4	**Stairs and Ramps**					
	Timber stairs					
	Softwood stairs and balustrades; 2.80m rise; straight	1	nr	1,700	1,700	
Total						**1,700**
	External Walls					
2.5	Frame					
	Healthy SIPs	170	m2	145	24,650	
	Internal face of external wall - plasterboard, emulsion.	170	m2	45	7,650	
	Façade					
	Brick Slip	170	m2	165	28,050	
Total						**60,350**
2.6	**Windows and External Doors**					
	Aluminium Composite Windows					
	Window - triple glazed	7	m2	£800.00	5,600	
	External Doors					
	External Entrance Door - Aluminium composite	1	nr	£3,000.00	3,000	
	Double Door - Curtain Wall Glass (Garden)	1	nr	£8,000.00	8,000	
Total						**16,600**
2.7	**Internal Walls and Partitions**					
	Plasterboard partitions; 102 wide dry line finish; emulsion both sides	68	m2	90	6,120	
Total						**6,120**
Total						**6,120**
2.8	**Internal Doors**					
	Single doors	3	nr	1,500	4,500	
	Riser/Storage doors - double	4	nr	1,500	6,000	
	Toilet doors	2	nr	750	1,500	
Total						**12,000**
3.0	**Internal Finishes**					
3.1	**Wall Finishes**					
	Skim coat plaster and paint	123	m2	45	5,535	
	Tiling to WCs and kitchens	1	item	1,300	1,300	
Total						**6,835**
3.2	**Floor Finishes**					
	Cement and sand screed; 75mm thick incl	39	m2	30	1,170	
	Carpet	22	m2	50	1,100	
	Tarkett Safetred Wood	39	m2	55	2,145	
	Skirtings	121	m	25	3,020	
	Floor tiles	7	m2	45	315	
	Vinyl	4.5	m2	40	180	
Total						**7,930**
3.3	**Ceiling Finishes**					
	Plasterboard and paint	78	m2	55	4,290	
Total						**4,290**
4.0	**Fixtures and Settings**					
4.1	**Kitchens and bathrooms ****					
	Kitchen unit	1	nr	5,500	5,500	
	Toilet area fittings: mirrors, WC roll holder, sanitary bins, towel rails etc.	2	nr	500	1,000	
	Washer/dryer	1	nr	500	500	
Total						**7,000**
4.2	**General Fitting, Furnishings & Equipment**					
	Allowance for post-boxes	1	nr	150	150	
	Allowance for signage	1	prov	250	250	
Total						**400**
5.0	**Services**					
5.1	**Sanitary Fittings**					
	Basic Spec					
	WCs and cisterns	2	nr	400	800	
	Wash basins with taps	2	nr	400	800	
	Baths with mixer tap, shower over, screen,	1	nr	1,300	1,300	
Total						**2,900**
5.2	**Services Equipment**					
Total						**0**
5.3	**Disposal Installations**					
	Sanitary plumbing - residential					
	Soil pipes; casing and insulation	78	m2	55	4,290	
Total						**4,290**
5.4	**Water Installations**					
	Hot and cold water installations	78	m2	40	3,120	
Total						**3,120**
Total						**3,120**
5.5	**Heat Source**					
	Air Source Heat Pump (ASHP)	1	Prov	8,000	8,000	
Total						**8,000**
5.6	**Space Heating and Air Conditioning**					
	HIU	1	nr	3,500	3,500	
	LTHW radiators	78	m2	50	3,900	
Total						**7,400**
5.7	**Ventilation**					
	MVHR	1	nr	4,000	4,000	
Total						**4,000**
5.8	**Electrical Installations**					
	Electrical installations	78	m2	100	7,800	
Total						**7,800**
5.9	**Fuel Installations**					
						0
5.10	**Lift and Conveyor Installations**					
Total						**0**
5.11	**Fire and Lighting Protection**					
	Fire alarm	78	m2	10	780	
	Smoke detection	1	item	500	500	
Total						**1,280**
5.12	**Communications, Security and Control Systems**					
	Dwellings					
	Communication, security and control systems	78	m2	5	390	
	Telephone installations in dwellings	1	nr	200	200	
	Television installations	1	nr	500	500	
	Video door entry systems	1	nr	700	700	
Total						**1,790**
5.13	**Special Installations**					
	Photovoltaics panels;	1	item	5,000	5,000	
Total						**5,000**
5.14	**Builder's Work in Connection with Services**					
	Builders' work in connection with services	78	m2	12	936	
	Testing and commissioning	1	Item	1,000	1,000	
Total						**1,936**
8.0	**External Works**					
8.1						
	Provisional Allowance for External works- soft and hard landscaping, fencing.	39	m2	£300.00	11,700	
Total						**11,700**
						220,314

Notes:

* Assumptions of no abnormal foundation requirements
** Based on Be First Employers Requirements