Ryder

Beyond Net Zero
A Holistic Approach to Deep Energy Retrofit

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This document has been designed to be viewed / printed A4 double sided.

Abbreviations

Organisations

IEA (International Energy Agency)
IPCC (Intergovernmental Panel on Climate Change)
PHI (Passive House Institute)

Programmes and software

PHPP (Passive House Planning Package)
IES VE (Integrated Environmental Solutions Virtual Environment)

Building systems

ASHP (Air Source Heat Pump)
BMS (Building Management System)
ERV (Energy Recovery Ventilator) - similar to MVHR
HRV (Heat Recovery Ventilator) - similar to MVHR.
LED (Light Emitting Diode)
MVHR (Mechanical Ventilation with Heat Recovery) - encompasses HRV and ERV
PTHP (Packaged Terminal Heat Pumps)
PV (Photovoltaic)

Reporting metrics

CO_2 (Carbon Dioxide)
COP (Coefficients Of Performance)
EER (Energy Efficiency Ratios)
EUI (Energy Use Intensity)
GHG (Greenhouse Gas)
GHGI (Greenhouse Gas Intensity)
MERV (Minimum Efficiency Reporting Values)
PER (Primary Energy Renewable)
TEDI (Thermal Energy Demand Intensity)
TEUI (Total Energy Use Intensity)

Units

ACH (Air Changes per Hour)
CO_2e (Carbon Dioxide Equivalent)
kgCO_2e/sqm.yr (Kilogram of Carbon Dioxide Equivalent per Square Meter per Year)
kWh/sqm.yr (Kilowatt Hour per Square Meter per Year)
L/s (Liters per Second)
Pa (Pascals)sqm (Square Meter)

Targets

NZC (Net Zero Carbon)
NZE (Net Zero Energy)

Introduction

Preface

For Ryder, retrofit exemplifies our vision of Everything architecture – to improve the world around us and, in doing so, improve people's lives.

By 2050, almost seven billion people are projected to live in urban areas across the world.[1] This is an increase of 2.5 billion from 2021, placing immense pressure on resources and infrastructure.[2] Additionally, in the depths of a climate crisis and the built environment responsible for 39 percent of global emissions[3], it is vital that we retrofit buildings to reduce these emissions and make better use of our existing building stock, and only construct new buildings when absolutely necessary.

There are several definitions for retrofit that are used by different organisations across the industry. Many of these definitions focus solely around reducing operational energy use to cut emissions and mitigate the effects of climate change. However, despite its seriousness, the climate crisis is not the only issue that we currently face. There are several other social, environmental and economic factors that are, in many cases, equally as important and need to be addressed. It would therefore be insufficient to define retrofit solely around energy performance, as this diverts away from these other issues and the myriad of benefits that can result from a successful retrofit.

Our definition for retrofit therefore includes any upgrade to a building that increases its resilience, or the resilience of the community or location. To ensure this addresses the full array of environmental and socioeconomic challenges, we have developed a categorisation system that classifies retrofit across eight different types.

Deep energy – maximising the energy efficiency of a building through comprehensive upgrades to its fabric and systems.

Seismic – strengthening a building to safeguard occupants in the event of an earthquake, limit damage to the building itself and upgrade the structure for additional retrofit loads.

Inclusion and accessibility – adapting a building to maximise equality of access for all users through reconfiguration of the building fabric and systems.

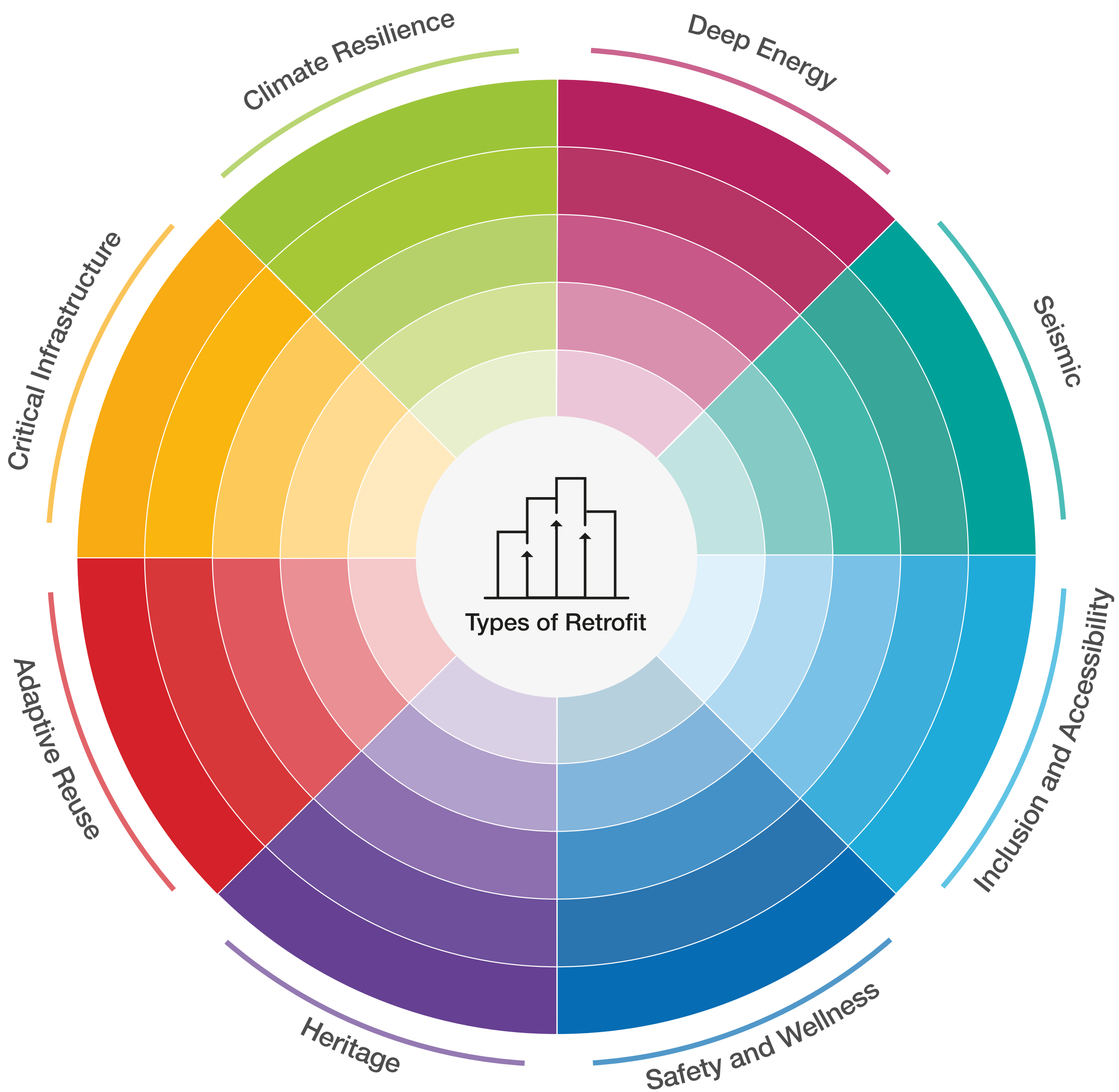
Safety and wellness – alterations to a building to enhance the health, safety and wellbeing of occupants through upgrading to building code compliance, removing hazardous materials and enhancing indoor environment quality.

Heritage – the renovation of a protected or listed building to extend its usefulness whilst preserving and enhancing its historic and cultural value.

Adaptive reuse – the repurposing of an existing structure for an alternative function which results in socioeconomic regeneration

Critical infrastructure – the renovation of healthcare, education, transport or other buildings that are vital to societal functions.

Climate resilience – upgrades to a building that increase its resilience to climate change impacts such as flooding, cyclones, heat waves and wildfires.



Each of these categories is interconnected, and addressing one aspect will often benefit another. For example, reducing emissions via deep energy upgrades can also improve safety and wellness by making indoor spaces more passively comfortable, as well as mitigating fuel poverty through a reduction in energy costs.

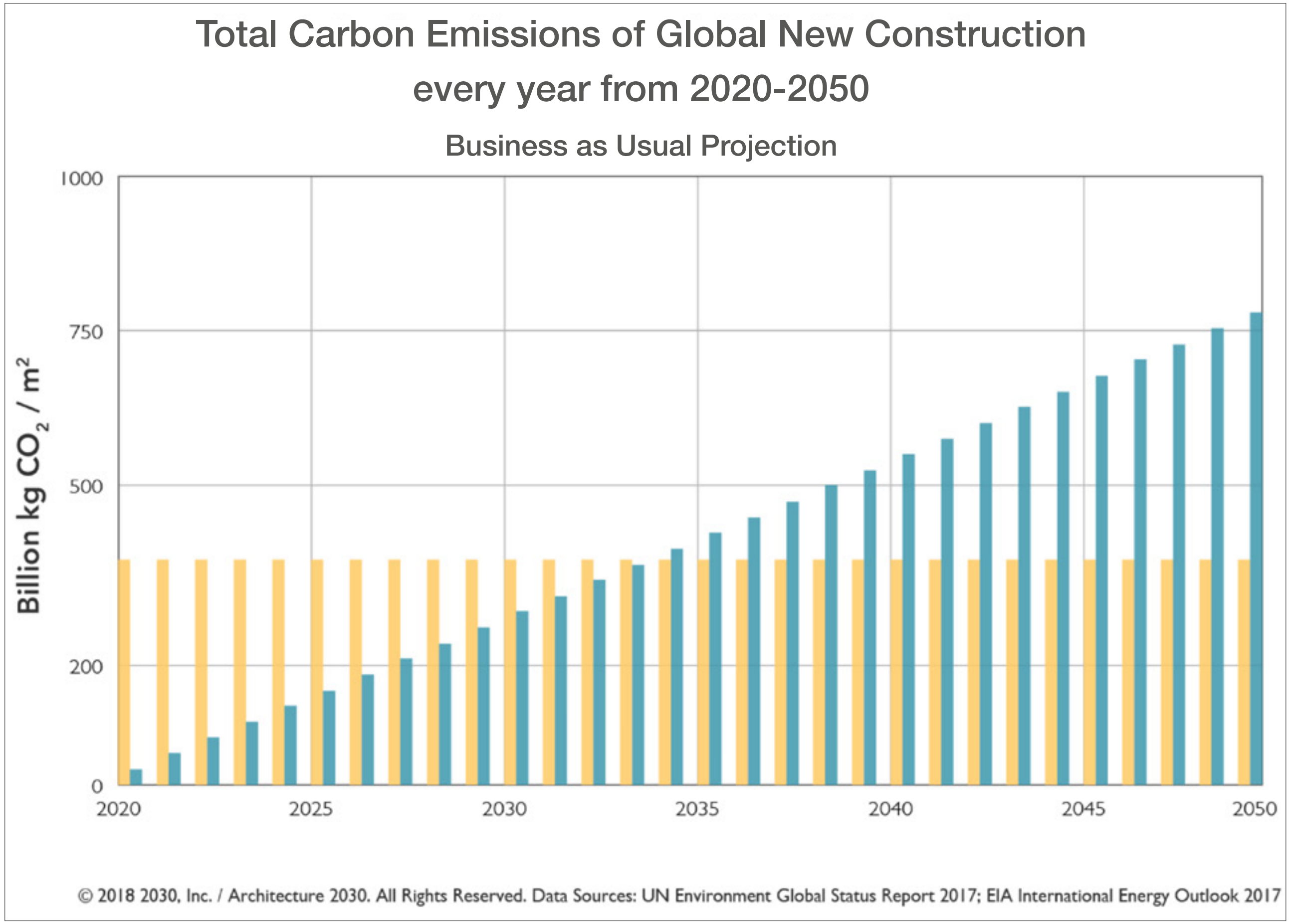
A holistic approach is therefore essential for addressing the various challenges and maximising the resulting benefits. To ensure consistency in this approach and to maintain a reproducible and systematic methodology, we have developed a **Retrofit Analysis Tool** which has been applied to each of the case studies outlined as part of this report.

The use of this tool enables the adoption of a holistic approach to ensure that each of the individual categories and the interrelationship between them is considered throughout.

To provide a better understanding into how fabric and systems upgrades can maximise energy performance, this report focuses specifically on deep energy retrofit, whilst assessing its interaction with the other retrofit types.

Retrofit and the climate

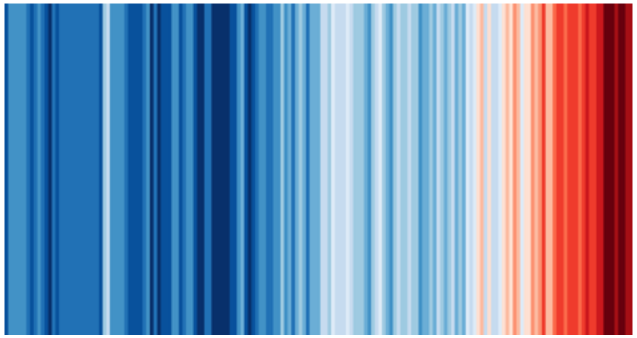
By 2040, approximately two thirds of the global building stock will be buildings that exist today.[4] The majority of these buildings do not meet current codes, are not efficient enough to achieve net zero targets, are not designed for future climate conditions, or the ever changing needs of society. Such buildings will therefore need to undergo some form of retrofit. To further break this down, between 2020 and 2050, it is projected that the embodied carbon of new buildings will account for 49 percent and operational carbon will account for 51 percent of the total carbon emissions from buildings if we proceed with business as usual.[5] The latest climate science says that to avoid the most severe impacts of climate change we must limit global warming to below 1.5 degrees above preindustrial levels. This aligns with the goals of the Paris Agreement, which says that GHG emissions must decline by 45 percent by 2030, followed by the transition to net zero by 2050.[6] Decarbonising the built environment will be key to achieving these targets. It is vital that we reduce the emissions associated with construction by making better use of our existing building stock and only constructing new buildings when absolutely necessary.[7] Today we are at 1.2 degrees and on track to 2.0 degrees.



Total operational carbon shown in blue and total embodied carbon shown in yellow for new buildings starting in 2020

If the construction industry does not change, the embodied carbon of new buildings will account for 74 percent of building carbon emissions between 2020-2030 and will account for 49 percent between 2020-2050.[1]

This would put the world past the tipping point of irreversible harm due to climate change.[8] One of the most successful graphics to represent the accelerated increase in global warming is the Warming Stripes by Ed Hawkins. It is a visual representation of the change in temperature for a year, typically measured in each country, region or city over the past 100+ years. Each stripe represents the change in temperature with colours relative to the average temperature within the graphic.



Warming Stripes by Ed Hawkins representing the global change in temperature from 1850 to 2022.[2]

Ed Hawkins is a climatologist and a professor of climate science at the University of Reading. In addition to greenhouse gas emissions from building operations, there is a significant, global materials shortage and the accelerated rate of raw material extraction will have a negative impact on the climate and the planet.

Additionally, the increase in natural disasters driven by climate change has emphasised issues where building occupants are now dealing with a significant increase in extreme and prolonged heat, wildfire smoke, flooding, heavy winds, ice storms and cold snaps. An increasing number of building owner operators and developers are opting to retrofit rather than new build to mitigate the shortage of raw materials, reduce embodied carbon and minimise the environmental impact of construction on the climate crisis. Throughout the construction of new buildings, valuable materials are thrown into landfills, when they could be saved, reused or repurposed. Markets such as Germany, Netherlands and France[9] have already seen this growth in deep energy retrofit projects where demolishing and constructing new buildings are no longer feasible. Other markets such as New York City[10] and the City of Toronto[11] are ramping up deep energy retrofit efforts with pilot projects, programmes and incentives. However, these places are the exception and not the norm. This report uses latest guidance to define distinct deep energy retrofit tiers. These are then used to compare a series of case studies that showcase a whole building, deep energy approach to retrofit, in order to demonstrate the various associated benefits, as well as sharing knowledge across the industry.

Benefits of retrofit

Defining retrofit solely based on deep energy considerations falls short, as this approach neglects various other concerns and the multitude of advantages that can arise from a comprehensive and successful retrofit project. There is evidence to show that retrofit can make positive contributions on mental and physical health of a building's occupants. Upgrading poor quality housing can also have a positive impact on physical health due to resolving issues such as drafts, stale air, damp, mould, rot or hazardous structures. Recent rises in energy prices have led to several countries entering into a cost of living crisis. As a result, an increasing number of low income households are experiencing fuel poverty and some are being faced with making the desperate choice between heating and eating.[12] Retrofit is an effective, albeit underutilised tool in combating fuel poverty, as it reduces energy demands through an improved building envelope, thereby reducing energy bills. At a larger scale, retrofit can have a positive impact on local areas and wider society by regenerating deprived areas, shaping communities and creating jobs.[13] Retrofit jobs tend to be labour intensive, which creates local employment. This contributes to the 'levelling up' agenda that is forming a focus of government policy globally.

Retrofit Analysis Tool

Deep Energy

To gain a deeper understanding into deep energy retrofit and to provide a more consistent and holistic approach, we have developed a systematic methodology that includes a series of stages, standards and tiers to guide project teams towards successful and high quality deep energy retrofits. There are five key stages to a deep energy retrofit.

Step 1 Assessment – conducting a thorough analysis of the building to identify potential areas for improvement through an energy audit, a site survey and an analysis of the building's energy consumption patterns.

Step 2 Plan – designing and developing an energy retrofit plan, based on the findings from the assessment stage.

Step 3 Implementation – implementing the retrofit measures, based on the construction documentation and phasing from the planning stage.

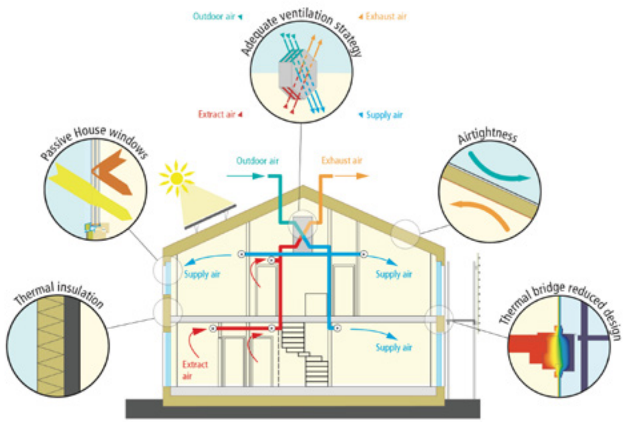
Step 4 Testing and Verification – testing and verification is required to ensure systems and equipment are functioning as designed. This ensures that the building is achieving the energy targets prior to occupancy, such as airtightness testing and ventilation commissioning.

Step 5 Monitoring and Evaluation – monitoring and evaluation of the results, and maintenance of the systems and equipment. This ensures that the building will continue to operate efficiently over time such as monitoring CO_2 levels and an owner's operating and maintenance manual indicating the frequency of filter changes.

To effectively evaluate the potential energy savings and cost effectiveness of a deep energy retrofit project, it is important to use specialised analysis tools. Ryder uses the internationally recognized Passive House standard developed by the Passive House Institute (PHI) in Darmstadt, Germany. PHI tools include designPH, a SketchUp plug in 3D energy model, and the Passive House Planning Package (PHPP), a comprehensive excel spreadsheet energy model.[14] PHI acknowledges that retrofitting existing buildings to meet the Passive House standard, equivalent to the performance of a new building design, can be challenging and expensive. The 'EnerPHit' building standard was therefore developed for existing buildings to address the complexities of retrofit and practical limitations such as unavoidable thermal bridges. EnerPHit uses two methods: the component method determines maximum U values for wall assemblies or the demand method determines the energy consumption target defined by climate zone. The use of Passive House components in EnerPHit certified building retrofits offers nearly all the advantages of a new build Passive House building while at the same time offering optimum cost effectiveness. The EnerPHit design and certification process confirms that optimised thermal protection and energy performance have been implemented for an existing building. It typically includes the insulation of the floors, exterior walls and roofs with Passive House levels of insulation thickness, minimizing thermal bridges, installing Passive House certified windows, reducing air leakage through the envelope of the building, and installing an active building ventilation system with heat recovery to provide reliable fresh air.

Climate zone according to PHPP	Heating	Cooling
	Max. heating demand	Max. cooling + dehumidification demand
	[kWh/(m²a)]	[kWh/(m²a)]
Arctic	35	equal to Passive House requirement[1]
Cold	30	
Cool-temperate	25	
Warm-temperate	20	
Warm	15	
Hot	15	
Very hot	15	

Target EnerPHit classic certification and energy demand method requirements[3]



Five basic Passive House principles[5]

Deep energy retrofits can be complex and require careful analysis to ensure that they are cost effective and provide the desired energy savings. By using specialised analysis tools and resources, it is possible to make informed decisions about the most appropriate retrofit options for a particular building.

As there are other energy standards and tools used globally, different terms and metrics are used which are shown in a comparative chart of similar terms below. Note that separate calculations, conversions or a completely separate energy model are required to have a like for like comparison.

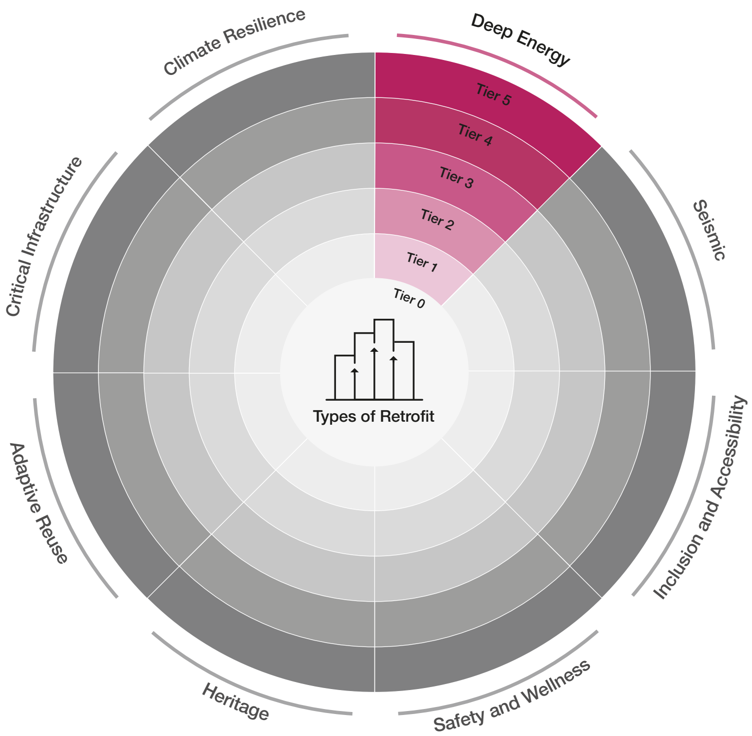
Climate zone according to PHPP	Opaque envelope[1] against...				Windows (including exterior doors)					Ventilation	
	...ground	...ambient air			Overall[4]			Glazing[5]	Solar load[6]		
	Insulation	Exterior insulation	Interior insulation[2]	Exterior paint[3]	Max. heat transfer coefficient ($U_{D/W,installed}$)			Solar heat gain coefficient (g-value)	Max. specific solar load during cooling period	Min. heat recovery rate[7]	Min. humidity recovery rate[8]
	Max. heat transfer coefficient (U-value)			Cool colours							
	[W/(m²K)]			-	[W/(m²K)]			-	[kWh/m²a]	%	
Arctic	Determined in PHPP from project specific heating and cooling degree days against ground.	0.09	0.25	-	0.45	0.50	0.60	$U_g - g^*0.7 \le 0$	100	80%	-
Cold		0.12	0.30	-	0.65	0.70	0.80	$U_g - g^*1.0 \le 0$		80%	-
Cool-temperate		0.15	0.35	-	0.85	1.00	1.10	$U_g - g^*1.6 \le 0$		75%	-
Warm-temperate		0.30	0.50	-	1.05	1.10	1.20	$U_g - g^*3.2 \le -0.6$		75%	-
Warm		0.50	0.75	-	1.25	1.30	1.40	-		-	-
Hot		0.50	0.75	Yes	1.25	1.30	1.40	-		-	60 % (humid climate)
Very hot		0.25	0.45	Yes	1.05	1.10	1.20	-		-	60 % (humid climate)

Target EnerPHit classic certification and component method requirements[4]

Passive House Standard	Other Energy Standards
Heating Demand, Cooling Demand	Thermal Energy Demand Intensity (TEDI)
Primary Energy Renewable (PER)	Total Energy Use Intensity (TEUI), Energy Use Intensity (EUI)
Air Change per Hour at 50 Pascals (ACH at 50 Pa)	Liters per second per square meter of (L/s/sqm at 75 Pa)

Deep Energy Retrofit Tier System

Our research into the deep energy retrofit landscape has led to the creation of a hierarchy of five tiers categorised as follows.



Tier 5 Net Positive Energy

Tier 4 Net Zero Energy

Tier 3 45% Reduction

Tier 2 Improved

Tier 1 Code

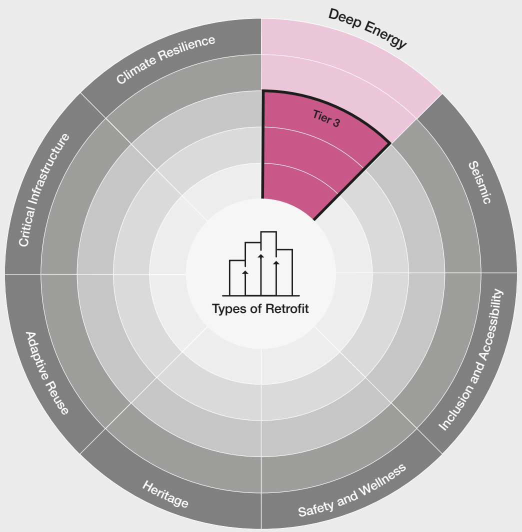
Tier 0 Baseline

Note that the following metrics have been simplified to align with IPCC and EnerPHit metrics, which are internationally understood. Ryder understands that there are other standards that address deep energy retrofits.

Tier 0 represents the project baseline, which is the current operational state of the building before any retrofit intervention has taken place. At this stage the operational energy demand is assessed for later comparison.

Tier 1 refers to code compliance. Typically, a local or regional building code will incentivise or mandate a level of energy efficiency for retrofit projects. A tier 1 project hence retrofits a baseline building to meet a code standard. It is important to note that code is location specific and will change with time.

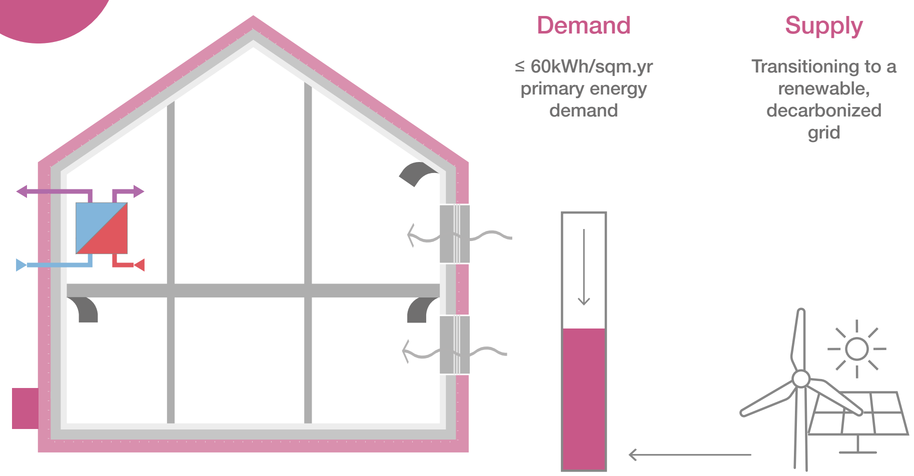
Tier 2 is an improvement from code, reducing the energy use intensity further than code requirements. However, operational energy is not reduced in line with the 2030 minimum target (see Tier 3).



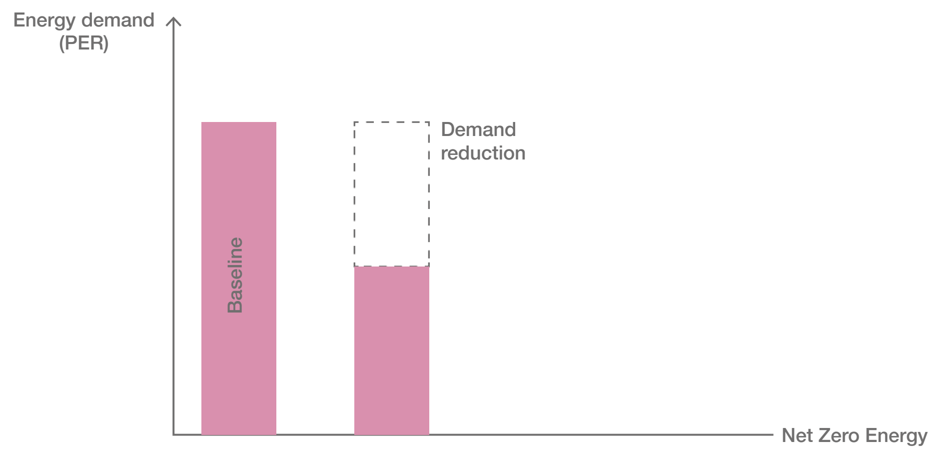
Tier 3 refers to the 2030 minimum target of a 45 percent reduction in operational energy, in line with the trajectory to reach net zero by 2050. This tier is achieved through verifying that the PER demand is below or equal to 60 kWh/sqm.yr. This metric can vary dependant on the building use as housing, commercial, restaurants, offices and schools have different functions and therefore have different energy requirements. As this tier is equivalent to the EnerPHit Classic standard, on site renewable energy generation is not required. However, having a lower carbon grid will reduce the PER.

EnerPHit Certified Retrofit
Passivhaus Institut
| classic | plus | premium |

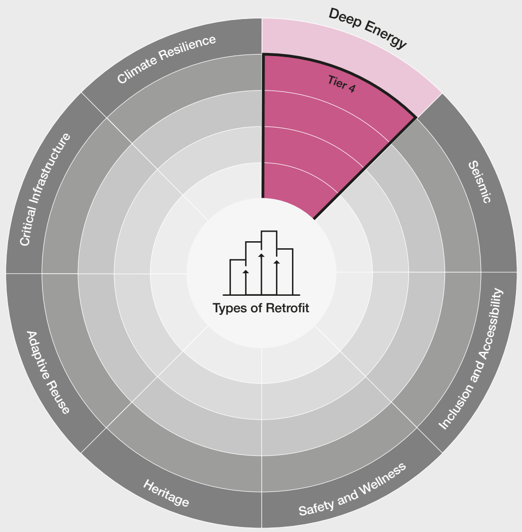
Tier 3



Energy decline by 45 percent

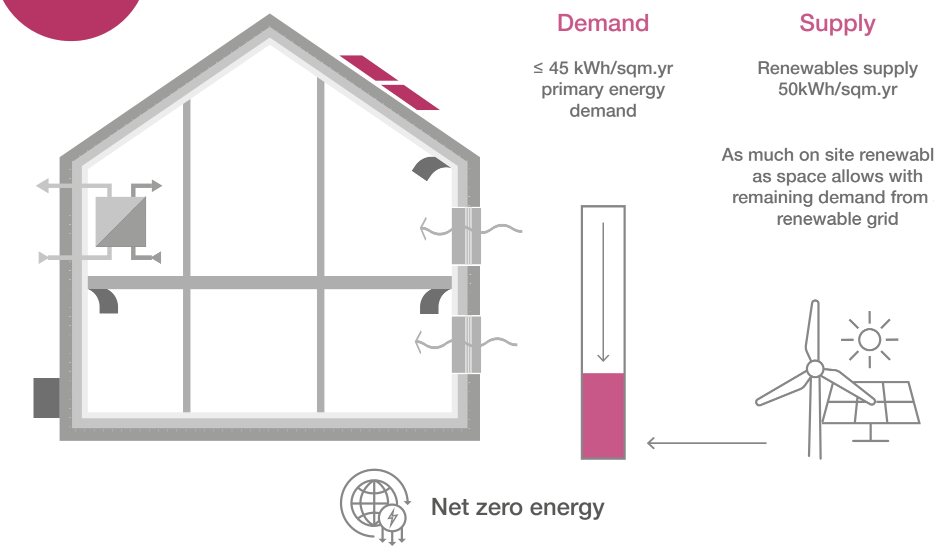


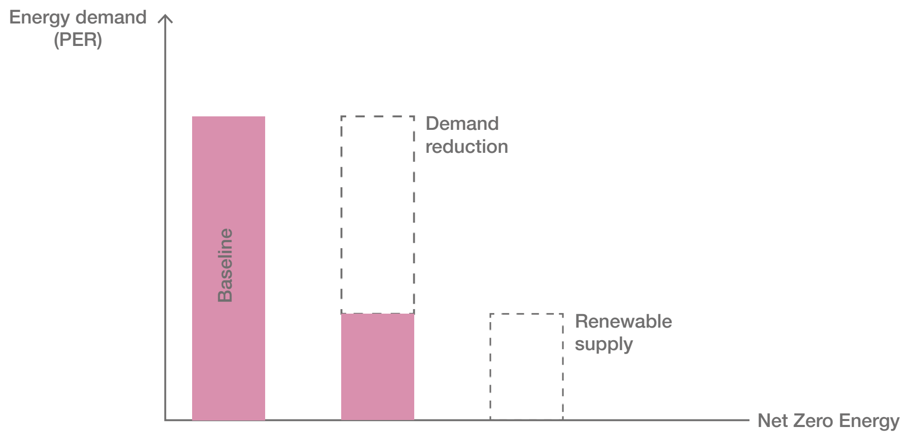
Net Zero Energy



Tier 4 refers to the 2050 minimum target limit of net zero operational energy. This is equivalent to EnerPHit Plus standard, where additional energy is generated, such as from photovoltaics. To achieve this tier, PER demand is typically 45 kWh/sqm.yr, with on site renewable energy generation at 50 kWh/sqm.yr. It should be noted that not all energy generated is useful energy as there can be more supply than demand with little to no storage capacity, but surplus energy can be sold back to the grid.

Tier 4

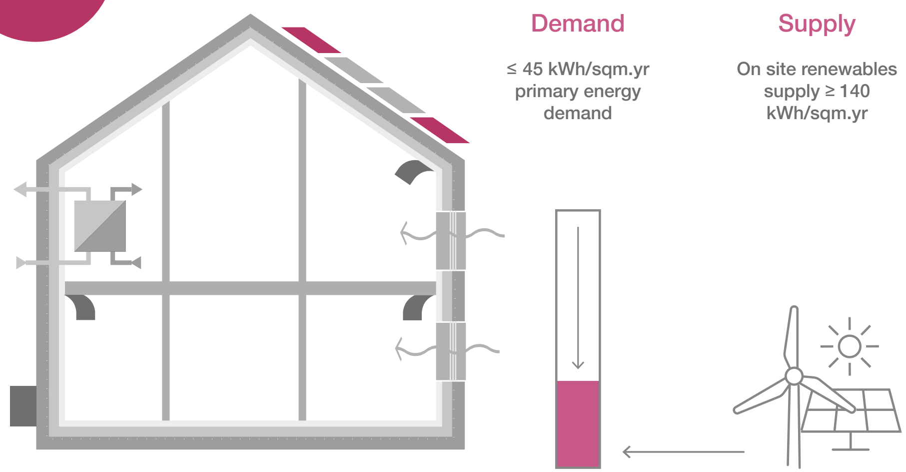




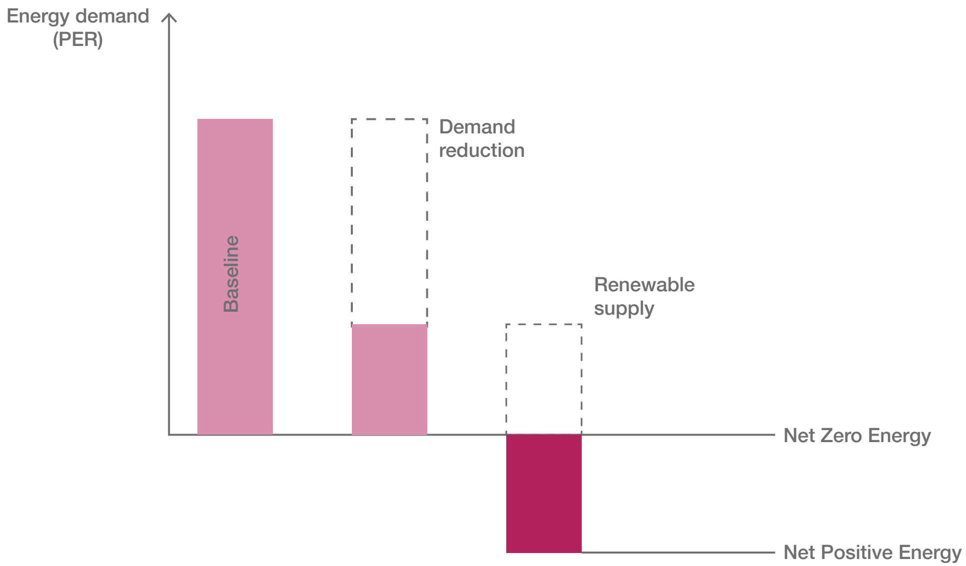
Net Zero Energy

Tier 5 is net positive energy, which means that the building is designed and operated to produce enough energy for the building and supply back to the grid. This is equivalent to the EnerPHit Premium standard, where more energy is produced than consumed over the course of a year. This tier therefore goes beyond economic and ecological considerations already proposed, generating surplus energy that can be supplied back to the grid and contribute to reducing overall energy consumption and emissions. PER demand is below or equal to 45 kWh/sqm.yr, with on site renewable energy generation above or equal to 140 kWh/sqm.yr.

Tier 5



Net positive energy



Funding, Incentives and Programmes

Overview

Through the adoption of building energy codes and minimum performance standards, several countries have begun to make improvements to the energy performance of new developments.

However, improving the energy efficiency of existing buildings can be significantly more difficult, especially at the scale required to achieve net zero minimum targets.

According to the International Energy Agency (IEA), less than one percent of existing global buildings currently qualify as net zero.[15] A large proportion of this existing building stock is old and particularly inefficient.

Upgrading these buildings can be challenging due to the need for significant financial investment and the disruption associated with upgrading buildings that are already in use. As a result, the delivery of high quality, deep energy retrofits the delivery continues to be a challenge. To address this, there are several programmes and incentives promoting the expansion of deep energy retrofit across the globe.

Facade integration of ducts within exterior insulation[6]

Energiesprong[16]

Energiesprong is a Dutch programme that aims to accelerate the large scale implementation of deep energy retrofit in the residential sector. It was launched in the Netherlands in 2013 and has since gained international recognition as a successful model for transforming existing buildings into highly efficient and comfortable homes.

To do this at scale, Energiesprong has adopted several key strategies including the use of prefabricated building components and systems, standardised retrofit solutions, performance guarantees and innovative financing models. By industrialising the retrofit process, Energiesprong aims to drive down costs, ensure quality and efficiency and create a viable market for deep energy retrofit.

outPHit[17]

Another initiative intended to scale up deep energy retrofits is the outPHit programme led by the Passive House Institute. It is funded by the European Union's Horizon 2020 programme in association with ten partners from seven countries across Europe. OutPHit aims to lower the barriers to the uptake of high quality deep retrofits by pairing prefabrication and streamlined processes with the rigour of the EnerPHit standard for renovations according to Passive House principles.

OutPHit intends to scale up serial retrofitting as opposed to the current industry's approach on increasing the efficient implementation of conventional deep energy retrofits. This involves the use of digitised building processes combined with prefabricated wall and roof assemblies, and prefabricated building modules. This brings all the actors and components together from the start which can reduce the time and cost associated with a conventional retrofit. These benefits are more evident when large numbers of similar buildings are retrofit in one go using the same or similar assemblies. Serial retrofitting in this way significantly reduces the disruption to occupants which can be particularly beneficial for housing associations, as many buildings undergo retrofits while residents remain in their homes.

As part of the outPHit programme, 17 model projects have been selected across six European countries. Ten of these projects were successfully complete in 2022. These projects are also being monitored for energy consumption, thermal consumption and air quality prior to and after the retrofit.

First Energiesprong pilot project completed for social housing, row homes in Nottingham, designed by Studo Partington.[7]

Prefabricated, insulated panels being installed on the building's exterior as part of the outPHit approach.[8]

Case Studies

Introduction

The following case studies outline how various retrofit projects meet the various deep energy tiers by reducing the ongoing operational energy use of existing buildings.

To ensure a varied outlook, we chose to focus on three retrofit case studies: a heritage building repurposed to an office, a university building, and a multifamily seniors housing residence. Even with the different building typologies and various deep energy tiers, deep energy retrofit upgrades can fall under seven categories. In addition to the different standards and metrics, there are also different terms used for the same or similar items. These include:

- Draft vs Draughts
- Heat Recovery Ventilator (HRV) vs Mechanical Ventilation Heat Recovery (MVHR)
- Energy Recovery Ventilator (ERV) vs MVHR
- Primary Energy Renewable (PER) vs Energy Use Intensity (EUI)

Envelope and thermal bridges: Adding continuous insulation to the floors, walls and roofs and replacing windows and doors with highly efficient glazing units and frames improve energy efficiency, occupant comfort and building durability.

Airtightness: Adding a continuous air barrier system around the entire thermal enclosure with durable and flexible airtight materials stops drafts, rodents and moisture ingress. In addition, airtightness improves energy efficiency, occupant comfort and building durability. This needs to be completed during or after the ventilation upgrade to prevent stale air accumulating indoors.

Ventilation: Replacing the existing ventilation system with a minimum 75 percent heat recovery efficiency and providing a minimum MERV 13 intake filter provides 24/7, filtered, fresh air, creates healthy indoor air and reduces space heating and cooling demand. Air flows need to be balanced through designing and commissioning to optimize CO_2 levels, heat loss, humidity and energy efficiency. Regular filter changes are required to maintain the volume and quality of air, and minimise the HRV or ERV fan's electrical loads.

Heating and cooling: Replacing the existing system with a smaller, fossil fuel free and energy efficient heating system with integrated cooling capacity improves thermal comfort and operational energy.

Hot water: Replacing the existing system with a smaller, fossil fuel free and energy efficient hot water generator, storage and distribution system reduces operational energy and wait time for hot water and unwanted internal heat gains..

Appliances: Replacing existing components with highly efficient appliances such as kitchen appliances, laundry equipment, LED lights, elevators, server room equipment and other appliances reduces operational energy and unwanted internal heat gains.

Renewables: Adding renewable energy on site generates clean energy, such as solar PhotoVoltaic (PV) panels and wind turbines, and further reduce reliance on the grid.

The report uses various methodologies, with an emphasis on Passive House, designPH and PHPP to create a baseline of the existing building's energy demand and analyses how specific changes to the building envelope, domestic hot water system and heating / cooling systems affect the building performance.

Where specific thermal bridges were analysed, they were modelled using Flixo, a powerful finite element analysis application for assessing thermal bridges according to EN ISO 10211 and EN ISO 10077-2.

Analyses were assessed with planning and timing constraints considered to determine how best to chart a path to meet the deep energy retrofit tier.

This report is limited to a high level building analysis and staging. Specific detailed design should be undertaken before conducting any works. This report may not account for specifics around local building code compliance and further advice should be taken before carrying out works.

King's Daughters Manor, Vancouver BC

Tier 2

Cooper's Studios

This case study focusses on the developed design for the deep energy retrofit of Cooper's Studios, a flexible office space located in Newcastle upon Tyne, UK.

The primary objective was to to effect deliverable measures to maximise carbon reduction in a heritage protected building. This was informed by an energy audit completed by Black and White Engineering using Integrated Environmental Solutions Virtual Environment (IES VE).

Prior to this, an internal, preliminary study was also carried out to assess options for a deep energy retrofit roadmap using the Sefaira modelling software.

Building context

Cooper's Studios is located in Newcastle upon Tyne, United Kingdom and was constructed in 1897. The building was originally a horse and carriage repository with three stories with a steel and brick structure.

Tier 1 retrofit of Cooper's Studios in 2009

In 2009, the building was repurposed and retrofitted for use as Ryder's head office, which it remains to this day.

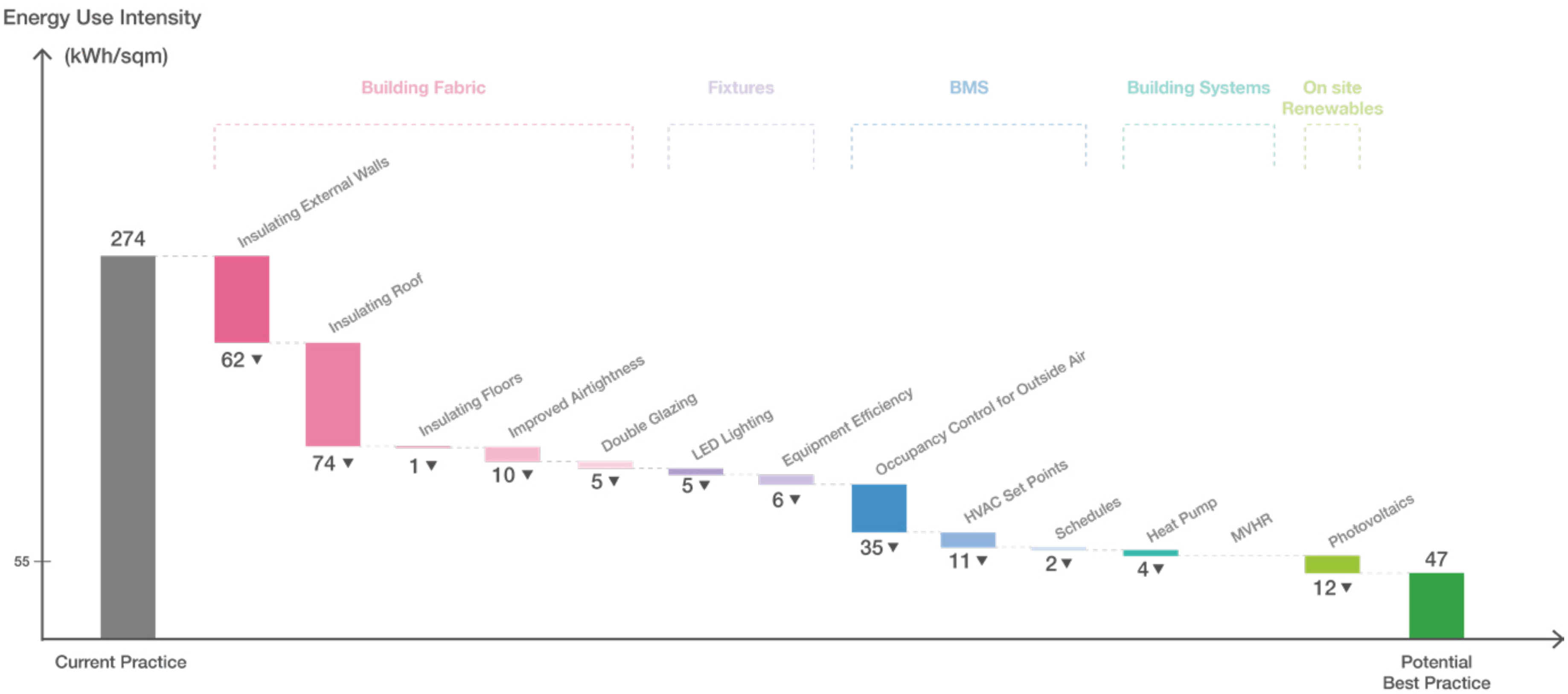
Opportunities

The deep energy retrofit of Cooper's Studios contributes to the corporate Ryder Net Zero target and commitment to improving working conditions. Due to the need to minimise disruption to business operations, a phased approach is proposed.

This involves building on the 2009 Tier 1 retrofit works and upgrading elements of the building and systems to Tier 2 (improved) standard.

	Existing	Tier 2	Tier 4
EUI Balance[a]	274 kWh/sqm.yr	47 kWh/sqm.yr 83 percent reduction	0 kWh/sqm.yr, 100 percent reduction
EUI Balance[b]	314 kWh/sqm.yr	172 kWh/sqm.yr 45 percent reduction	
Operational CO_2e Balance	92.7 kgCO_2e/sqm.yr	67.7 kgCO_2e/sqm.yr 27 percent reduction	

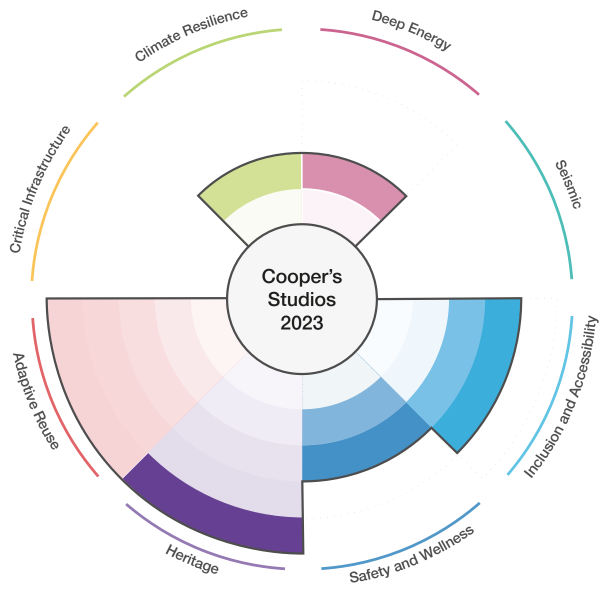
Preliminary Energy Use Intensity (EUI) modelling for theoretical Tier 2 and Tier 4 retrofit options.



Preliminary assessment of options for a deep energy retrofit roadmap using the Sefaira modelling software

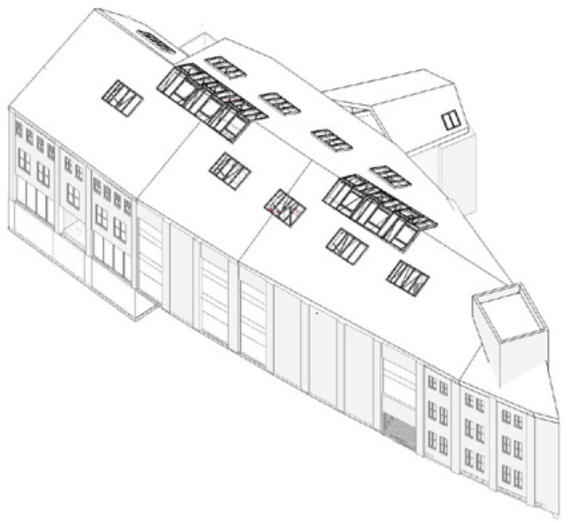
Retrofit analysis tool

This retrofit analysis tool identifies Ryder's response to a holistic retrofit for Cooper's Studio. The initial deep energy retrofit in 2009 brought Cooper's Studios to a Tier 1 deep energy retrofit. In 2023, a Tier 2 deep energy retrofit was planned to contribute to Ryder Net Zero business goals through improvements to Cooper's Studios This also provides incremental improvements to climate resilience, safety and wellness.



Envelope and thermal bridges

Improvements to the fabric were considered, included adding 55mm wall insulation on the interior face of external walls, upgrading the 110mm roof insulation to a less thermally conductive substitute and adding secondary glazing to the existing single glazed windows. Due to heritage conservation constraints, insulation added to the interior face of exterior walls would need to return along the ceiling[18] by 1m to reduce thermal bridging. Following a cost benefit analysis, it was determined that the maximum practical impact would be gained through focus on building systems.



Revit model

Airtightness

Achieving a high level of airtightness is an important aspect of the retrofit plan, especially for heritage buildings. However, historic buildings require a careful approach to increased airtightness, as excess moisture can lead to condensation and mould. Successful examples on historic buildings provided the installation of the primary air barrier with a liquid applied, vapour permeable membrane over a parge coat on the inside face of the brick and continuity to adjacent assemblies.[19, 20] Overall, when designing for a listed heritage brick façade, a hygrothermal analysis should be considered.

Energy model

Ventilation

To address user comfort complaints and reduce energy demand, the mechanical ventilation system will be reviewed, including upgrading the Air Handling Unit (AHU), insulating the ductwork, adjusting the Building Management System (BMS) and its heat recovery capability to match occupancy schedules and actual work hours and replacing sensors to monitor temperature, humidity, noise and CO2.

Heating and cooling

Meeting Ryder's decarbonisation ambitions, the retrofit strategy includes the installation of an Air Source Heat Pump (ASHP) system with High Energy Efficiency Ratios (EER) and Coefficients of Performance (COP), superseding the gas boiler as the heat source. The ventilation improvements ensure effective heating and cooling while minimizing energy consumption and operating costs.

Hot water

The retrofit plan proposes point of use electric water heaters situated at sinks and showers. Compared to the existing Low Temperature Hot Water system, ad hoc water heaters will require no plant room space, reduce energy consumption and heat losses from distribution, and contribute to the electrification of building services.

Appliances

Key upgrades to appliances include switching lights to LED bulbs with improved controls based on the zone and usage, and upgrading to more energy efficient appliances such as refrigerators, server equipment and printers.


Air handling unit from 2009 retrofit


Central hot water gas boiler from 2009 retrofit

Renewables

The retrofit plan includes the integration of on site renewable energy sources such as roof top PV systems. Due to high energy usage from offices, further renewable technologies will be required to meet net zero targets.

This should be determined based on the building's characteristics such as orientation and shading from adjacent buildings.

Phasing

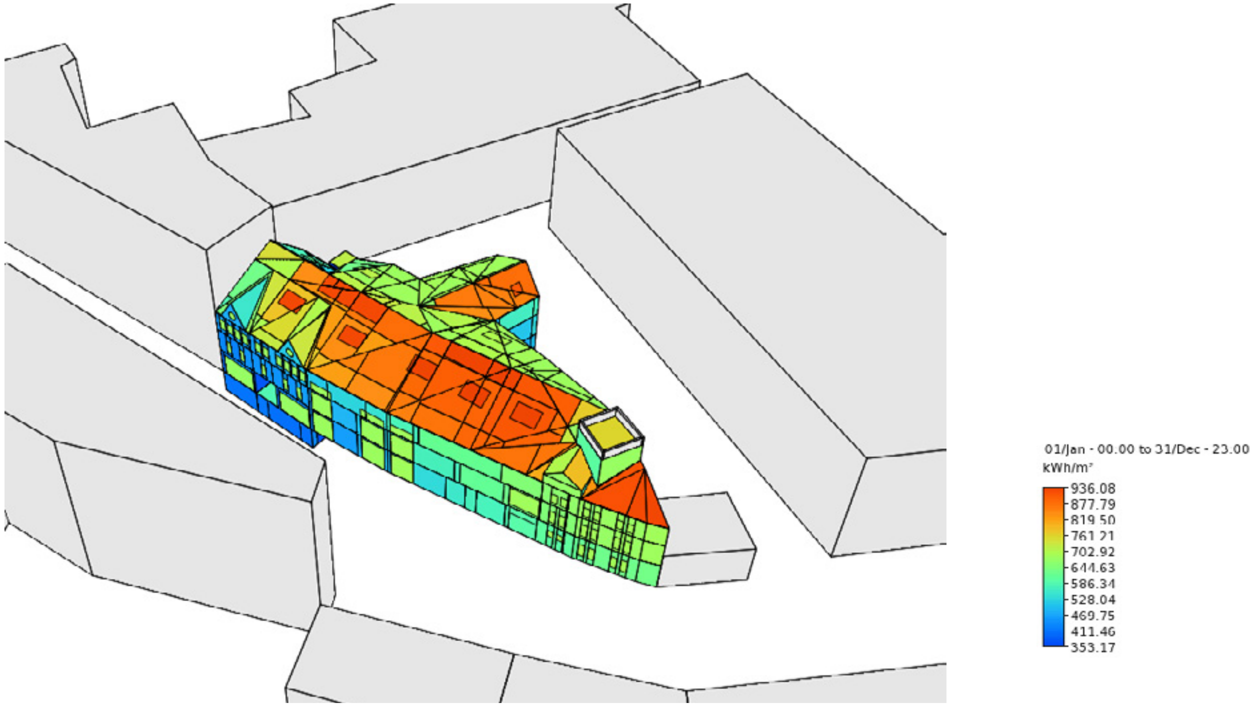
The retrofit is divided into separate areas of the building based on team working stations and common rooms, allowing for gradual upgrades while maintaining the building's functionality.

This phased approach provides flexibility in budget allocation, coordination of construction activities, productivity of teams and ensures that occupants experience improved comfort and energy efficiency throughout the retrofit process.

Conclusion

The retrofit of Cooper's Studios to be NZE presents an opportunity to enhance Ryder's NZC targets as an architectural business. The retrofit plan emphasizes upgrading the building envelope, addressing thermal bridges, improving airtightness, optimizing ventilation, heating, cooling, and hot water systems, integrating renewables, and implementing a phased approach.

Successful implementation of these measures, thoroughly monitored by a reviewed submetering and data logging strategy, will result in reduced energy consumption, improved occupant comfort and productivity, and a significant reduction in carbon emissions.



3D illustration highlighting the solar exposure of the building's exterior surfaces for optimal PV locations.


Cooper's Studios before Tier 1 retrofit 2009


Cooper's Studios after Tier 1 retrofit 2009

Tier 3

Lipman Building

This case study focuses on the schematic design of a deep energy retrofit for the Lipman Building, an educational building at Northumbria University.

The primary objective is to achieve the Tier 3 deep energy retrofit with the EnerPHit Classic standard. This was analysed using the designPH energy modelling tool.

Building context

The Lipman Building is located in Newcastle upon Tyne, United Kingdom and was constructed in the 1960s.

The building is a six and two storey, concrete structure in a L shape with the six storey portion on a linear east west orientation.

It currently houses part of the University's Arts, Design and Social Services departments containing a large lecture theatre, flat teaching, single occupancy academic offices, multi occupancy academic offices, breakout spaces and a large café.

Existing Lipman Building

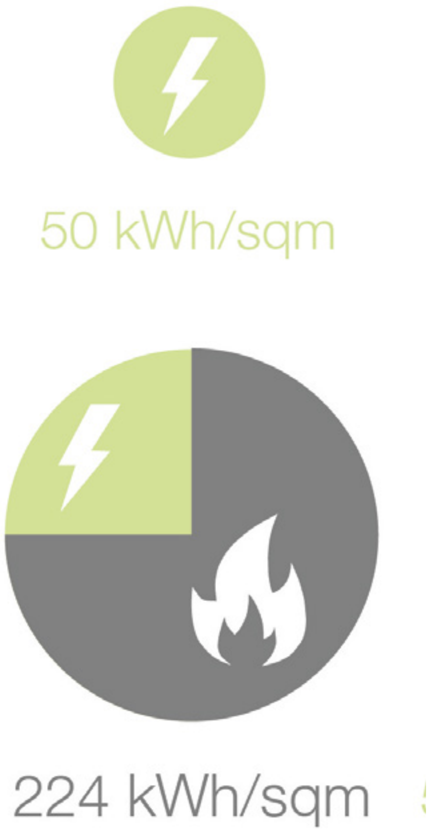
Opportunities

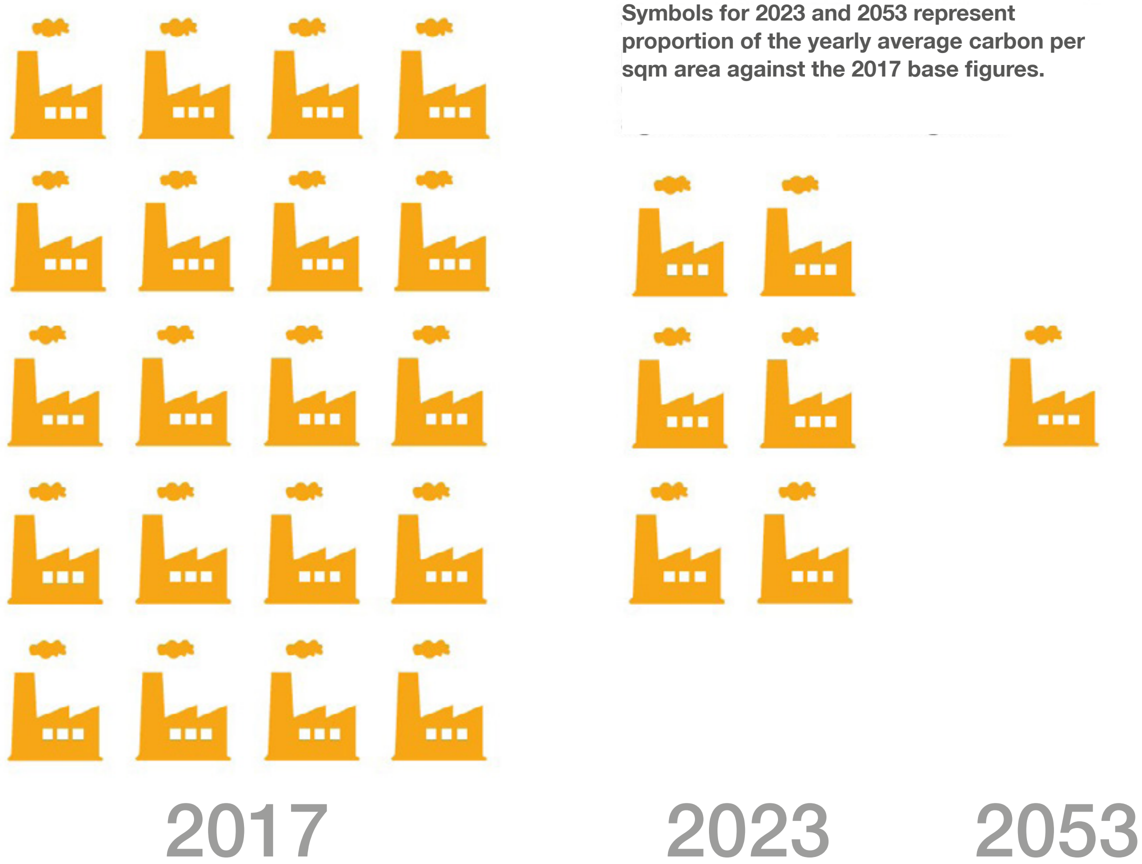
A deep energy retrofit provides significant reductions to the PER, heating demand and operational carbon. A phased approach should be taken to meet the EnerPHit Classic standard with the infrastructure in place for renewable energy generation. Reaching the Tier 4 deep energy retrofit to the EnerPHit Plus standard would be challenging.

This is due to the density of the building, meaning there would not be enough roof area to offset energy demand with on site renewable energy generation. However, Northumbria University has aspirations to minimise energy consumption and carbon emissions to ultra low energy use levels. Considerations have also been given to achieve 'Net Zero Carbon' (as defined by the UK Green Building Council).

	Existing	Tier 3	Tier 3 (with energy generation)
PER Balance	224 kWh/sqm.yr	50 kWh/sqm.yr 77 percent reduction	28 kWh/sqm.yr 89 percent reduction
Heating Demand Balance	170 kWh/sqm.yr	30 kWh/sqm.yr 88 percent reduction	30 kWh/sqm.yr 88 percent reduction
Operational CO_2e Balance	53.6 kgCO_2e/sqm.yr	17.8 kgCO_2e/sqm.yr 67 percent reduction	9.8 kgCO_2e/sqm.yr 82 percent reduction

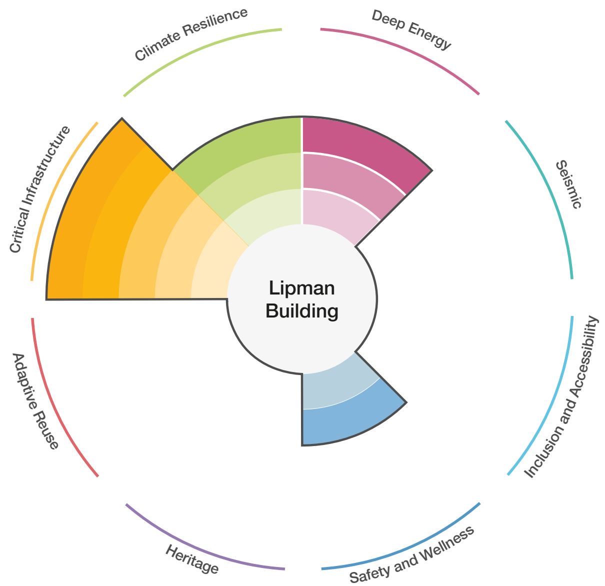
*The operational CO_2e is based on a 2017 natural gas factor of 0.18416 kgCO_2e/kWh and an electricity grid factor of 0.550 kgCO_2e/kWh.[21]





Retrofit analysis tool

This retrofit analysis tool identifies Ryder's response to a holistic retrofit for the Lipman Building. With the focus on a Tier 3 deep energy retrofit using the EnerPHit standard, additional benefits of climate resilience, safety and wellness, and increasing the longevity of a critical educational building are provided.

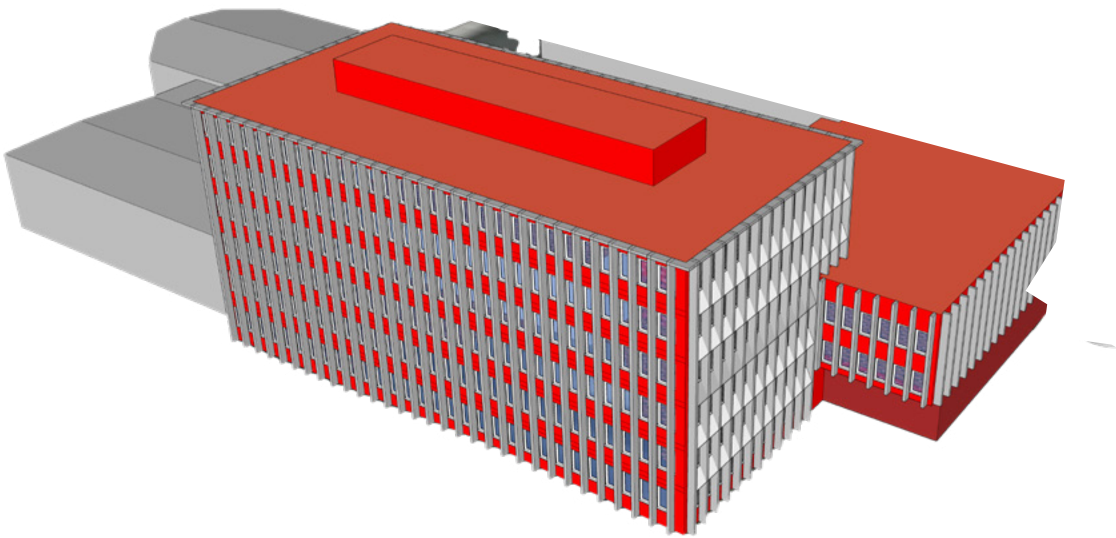


Envelope and thermal bridges

Envelope and thermal bridge upgrades include removal of the entire existing facade system, to be replaced with a full PHI certified rainscreen system including 350mm insulation and triple glazed curtain walling and doors, with integrated ventilation. Roof finishes and insulation will be stripped back to the concrete slab and replaced with 305mm of new insulation. Continuous insulation also addresses thermal bridges furth minimising thermal energy losses and risk of condensation.

Airtightness

The installation of a primary line of airtightness using vapor permeable membranes at the interior side of walls protected by an internal wall liner and on top of the concrete roof structure.



3D illustration of the designPH energy model with the thermal enclosure in red and shading elements in grey.

Ventilation

With a complex building and limited interior space, a centralised HRV system located on the roof should be used. Existing shafts are located adjacent to the building core which can be used for ventilation distribution.

Heating and cooling

A comparison of four options was considered – district heating with existing natural gas fired boilers, district heating with new natural gas fired boilers, direct electric space and hot water heating, and air and sewer source heat pump with direct hot water heating. With aspirations to meet NZC, the heat pump option is preferred.

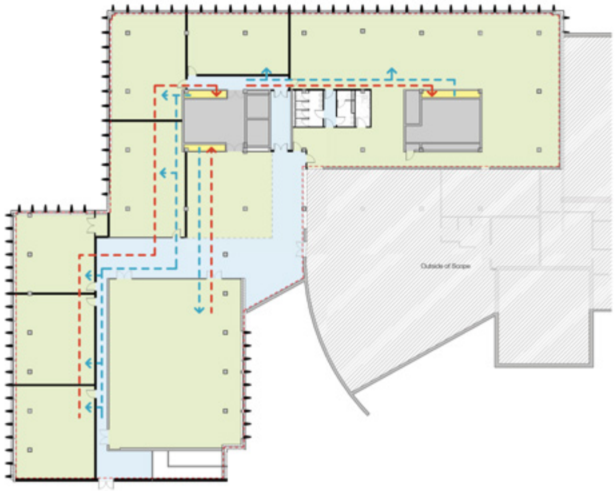
Hot water

Hot water systems were not yet considered at this stage of the design, but the existing hot water is generated by two gas fired water heaters.

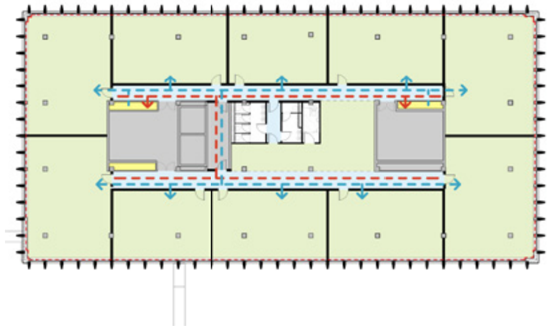
Appliances

Appliances were not yet considered at this stage of the design.

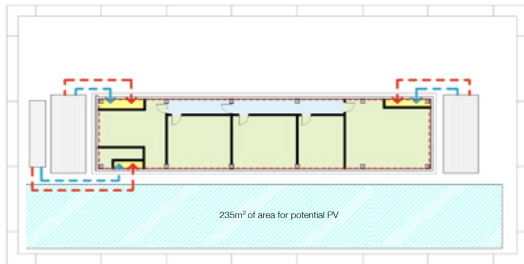
Ground floor



Second floor



Roof



Renewables

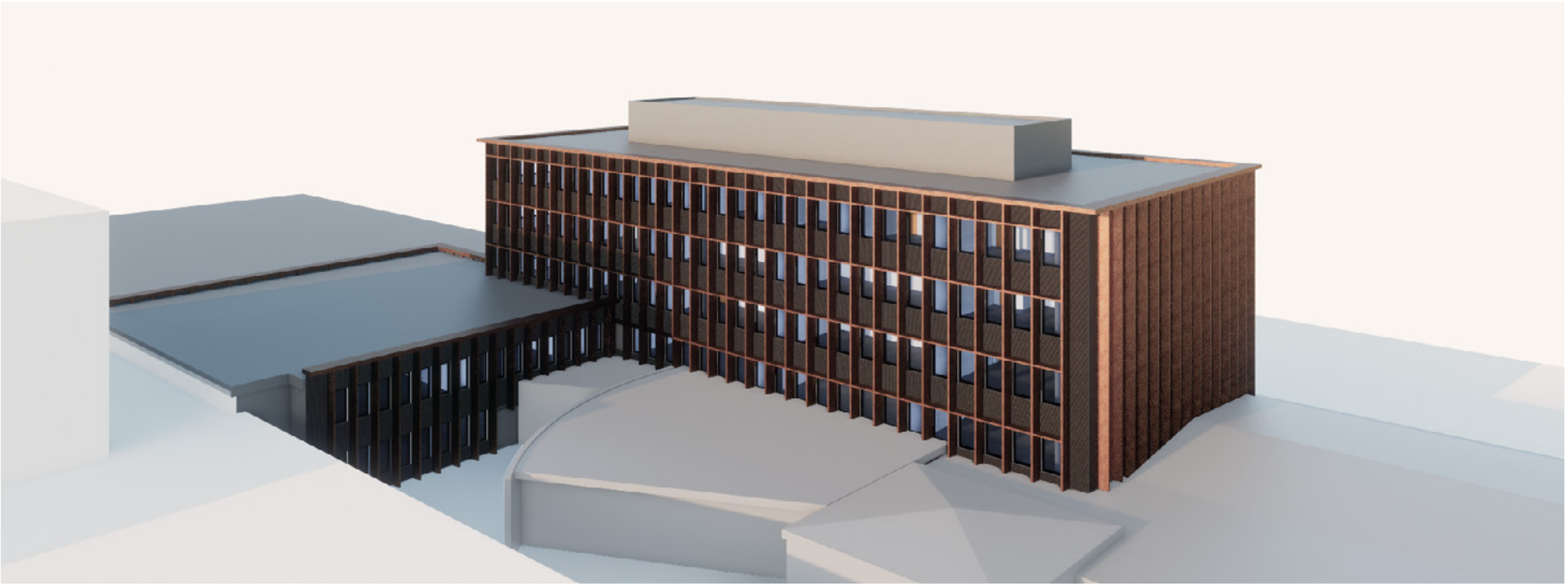
To achieve closer to the Tier 4 deep energy retrofit, the retrofit plan includes the integration of on site renewable energy sources. A roof area of 230sqm can accommodate a 40,000kWh solar PV system, equal to 22kWh/sqm.yr of electricity generation.

Phasing

To prioritise the building fabric first in the retrofit process and with an existing district heating system, a phased approach should be conducted. The retrofit can be divided into two stages, with the second phase switching to a heat pump system to provide the building's reduced heating requirements.

Conclusion

This case study highlights the potential of a deep energy retrofit to the EnerPHit Classic standard for the building. The retrofit plan encompasses upgrading the building envelope, addressing thermal bridges, enhancing airtightness and ventilation, optimizing heating, cooling and hot water systems, and integrating renewables. Successful implementation of these measures will result in a Tier 3 deep energy retrofit.



Tier 4

King's Daughters Manor

This case study focuses on the schematic design of a comprehensive deep energy retrofit for King's Daughters Manor, a residential building owned by Brightside Community Homes Foundation.

The primary objective was to achieve a Tier 3 deep energy retrofit, with EnerPHit Classic as the base standard, making it feasible to reach Tier 4, EnerPHit Plus in the future. This is analysed using the designPH and PHPP energy modelling tools.

Building context

King's Daughters Manor is located in Vancouver, Canada and was constructed in 1972.

The building is a two and a half storey, wood structure on a slab on grade with a linear east to west orientation. Multiple minor upgrades have taken place since 1972, including the replacement of residential windows in 2007 and the replacement of the gas hot water boiler system in 2018.

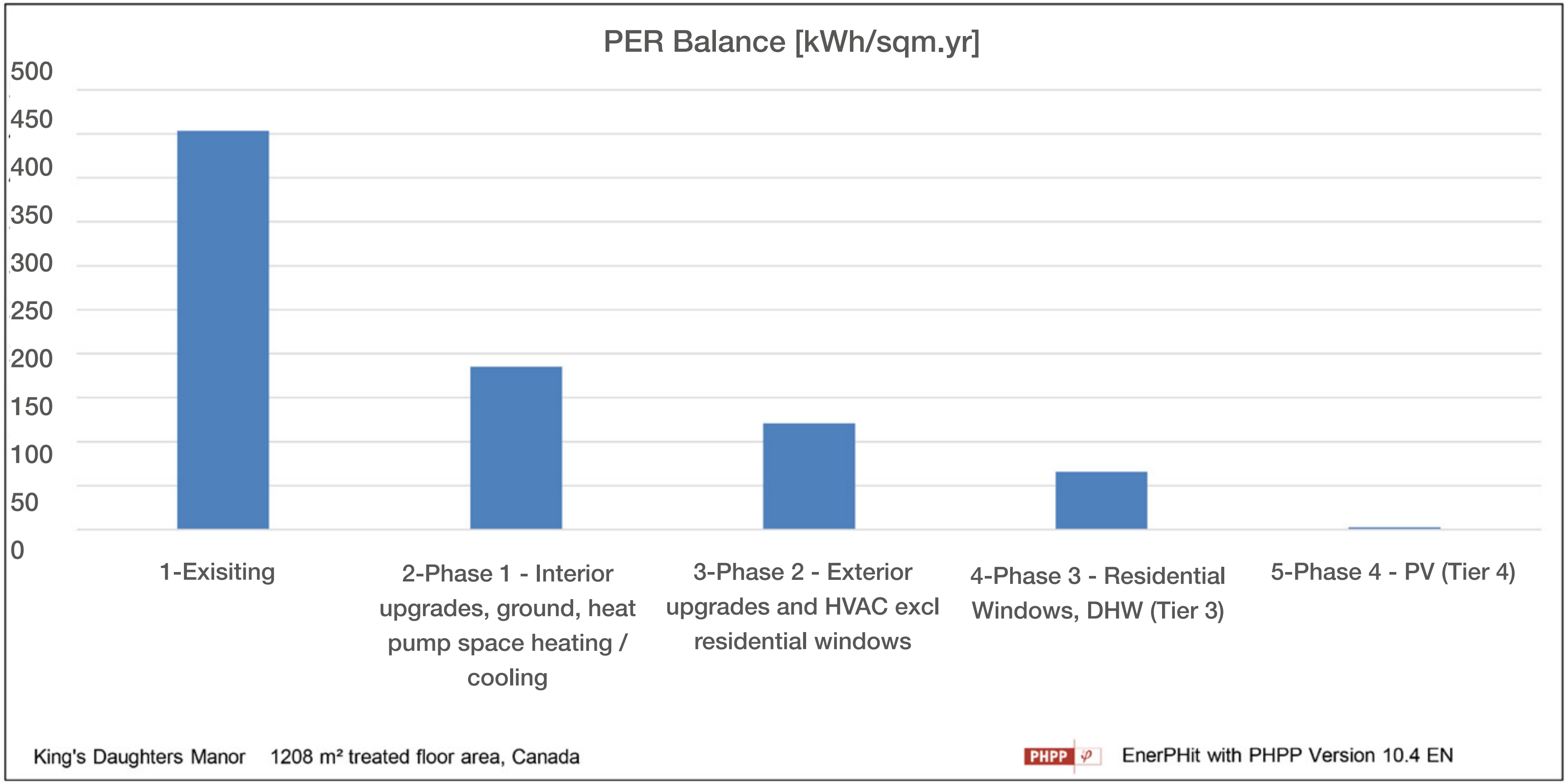
Existing King's Daughters Manor

Opportunities

A deep energy retrofit provides significant reductions to the PER, heating demand and operational carbon. A phased approach should be taken to meet the EnerPHit Classic standard. This responds to recent upgrades to the building and to minimizes tenant disruptions. In addition, the inclusion for renewable energy infrastructure during the Tier 3 retrofit, reaching Tier 4 can be seamlessly completed in the next phase. Reaching Tier 4 can be completed next.

	Existing	Tier 3	Tier 4
PER Balance	453.4kWh/sqm.yr	65.6 kWh/sqm.yr 85 percent reduction	2.72 kWh/sqm.yr 99 percent reduction
Heating Demand Balance	169.6 kWh/sqm.yr	23.7 kWh/sqm.yr 86 percent reduction	23.7 kWh/sqm.yr 86 percent reduction
Operational CO_2e Balance	42.6 kgCO_2e/sqm.yr	0.67 kgCO_2e/sqm.yr 98 percent reduction	0.28 kgCO_2e/sqm.yr 99 percent reduction

*The operational CO_2e is based on a natural gas factor of 0.180 kgCO_2e/kWh and an electricity grid factor of 0.0117 kgCO_2e/kWh.[22]



Retrofit Analysis Tool

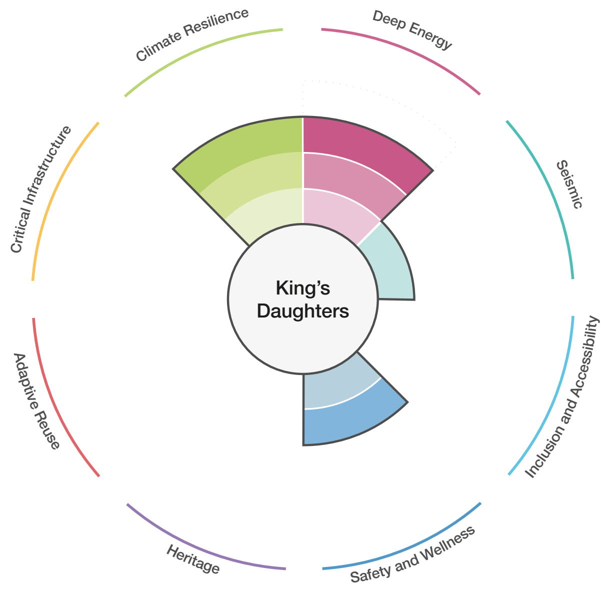
This retrofit analysis tool identifies Ryder's response to a holistic retrofit for King's Daughters Manor. With the focus in deep energy using EnerPHit standard, interconnected benefits of climate resilience, seismic, safety and wellness are also provided.

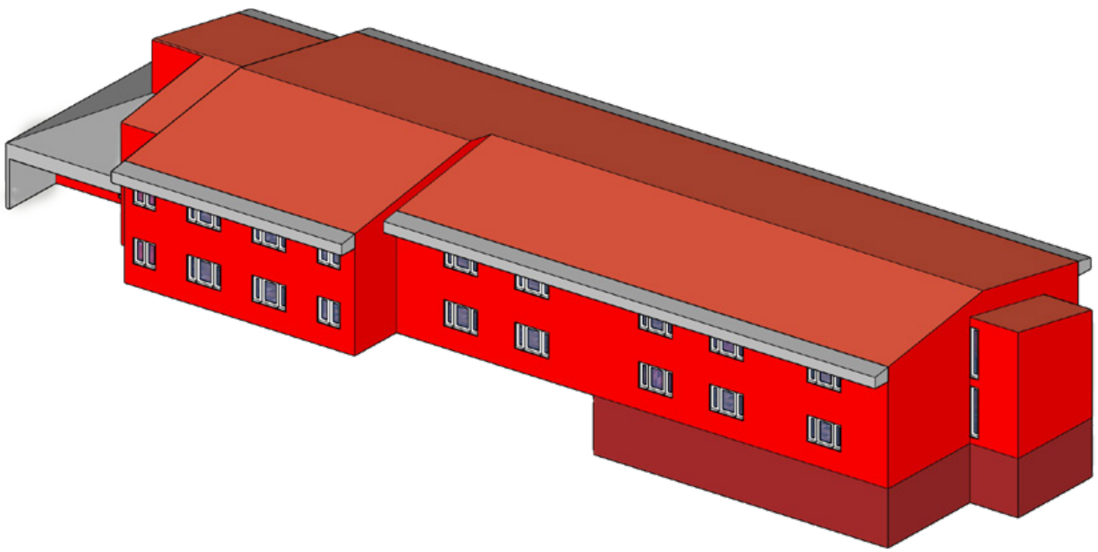
Envelope and thermal bridges

Envelope and thermal bridge improvements include adding 38mm of insulation on top of the basement slab on grade, 200mm of insulation on the exterior of the walls and roofs and replace the windows and doors with PHI certified, triple glazed windows and doors. Continuous insulation also addresses thermal bridges, further minimising thermal energy losses and risk of condensation.

Airtightness

The installation of a primary line of airtightness using self adhered, vapour permeable membranes at the walls and roofs is a common and proven approach for wood framed buildings like King's Daughters Manor. Depending on the substrate, the additional of a plywood layer may be required for a smooth, continuous surface for the membrane.





3D illustration of the designPH energy model with the thermal enclosure in red and shading elements in grey

Ventilation

With some attic space available, continuous exterior insulation and dry winters, a semicentralised ERV system located in the attic should be used. With the increase in wildfires, upgrading to a Minimum Efficiency Reporting Values (MERV) 15 filter between the months of May and September should be provided. A new ventilation distribution network is required as the existing system only serves the bathrooms. Distributing the ductwork to the exterior side of the sheathing and integrating within the exterior insulation would minimise disruption to tenants.

Heating and cooling

Temporary space heating should be provided through Package Terminal Heat Pumps (PTHPs) in each unit. Once the envelope upgrade is completed, space heating can be provided through the semicentral heat pump system integrating with the ventilation system and zoned to each vertical stack and orientation.

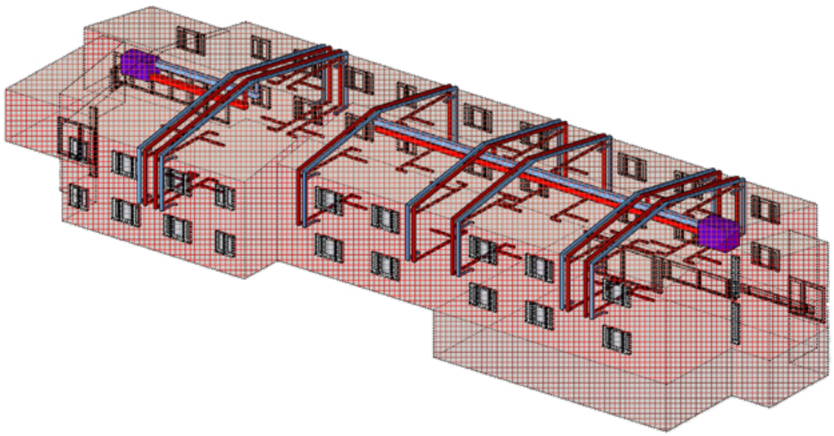
This approach is a balance to maintain comfort and minimize costs on controls. In addition, by using a semicentralized heat pump system, easier maintenance access can be achieved.

Hot water

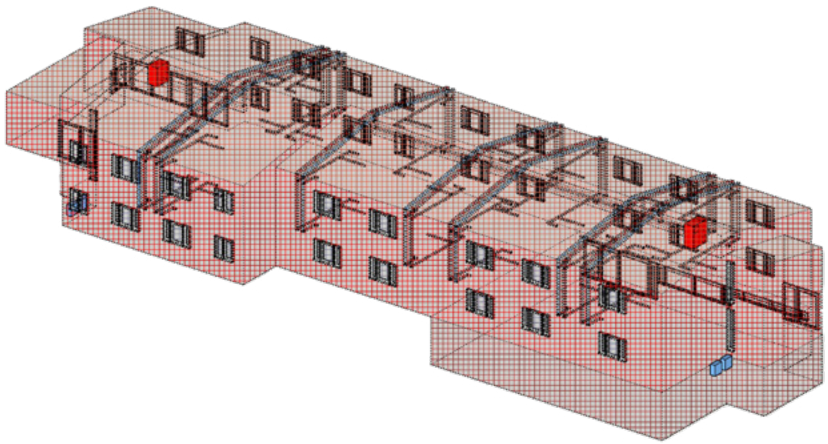
Exploring efficient energy sources for hot water generation is another significant aspect of the retrofit plan. Incorporating CO_2 heat pump systems greatly reduces the reliance on traditional energy sources for hot water supply.

Appliances

Key upgrades to appliances including lighting and kitchen equipment. This includes switching lights to LED bulbs with improved controls based on the zone and usage and upgrading to energy efficient appliances like induction stove tops, ovens, refrigerators and condensing, heat pump dryers.



3D illustration highlighting the ventilation system with the ERV in purple, supply ducts in blue and return ducts in red.



3D illustration highlighting the heating and cooling system with the indoor heat pump units in red, and the outdoor heat pump units in blue.

Renewables

To achieve a Tier 4 deep energy retrofit, the retrofit plan includes the integration of on site renewable energy sources. The specific renewable technologies will be determined based on the building's characteristics and energy requirements. With a large, south facing roof area, PV systems are a viable option to generate renewable energy and further reduce grid energy demand and carbon emissions.

Phasing

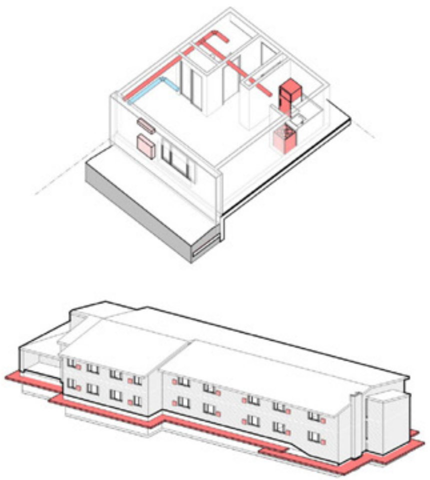
To ensure minimal disruption to occupants and optimise the retrofit process, a phased approach should be conducted. The retrofit can be divided into multiple stages, allowing for gradual upgrades while keeping the building operational throughout the process. This phased approach provides flexibility in budget allocation, coordination of construction activities, and ensures occupants can experience improved comfort and energy efficiency over time.

Conclusion

The case study highlights the potential of a Tier 4 deep energy retrofit (EnerPHit Plus) starting with a Tier 3 (EnerPHit Classic) as the baseline for King's Daughters Manor. The retrofit plan encompasses upgrading the building envelope, addressing thermal bridges, enhancing airtightness and ventilation, optimizing heating, cooling and hot water systems, integrating renewables, and implementing a phased approach. Successful implementation of these measures will result in a net zero energy building.

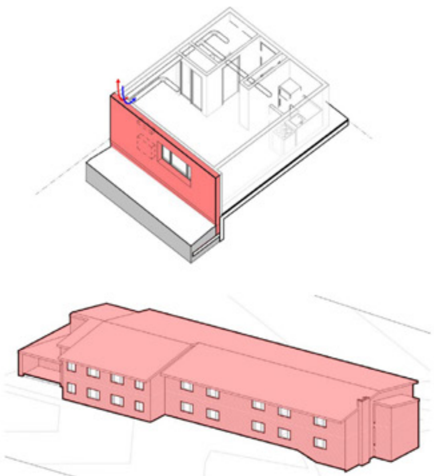
3D illustrations highlighting the phased upgrades in red at the suite and building scales.

Phase 1



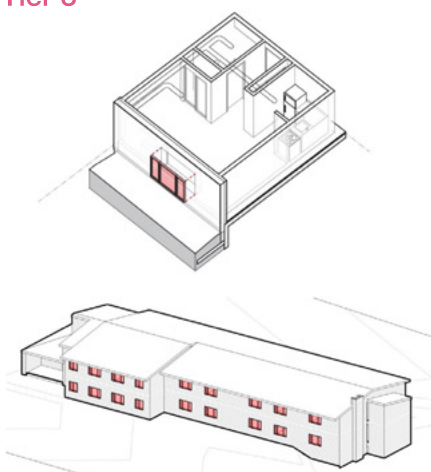
Interior appliances
HVAC rough in
Temporary heat pump
Ground insulation

Phase 2



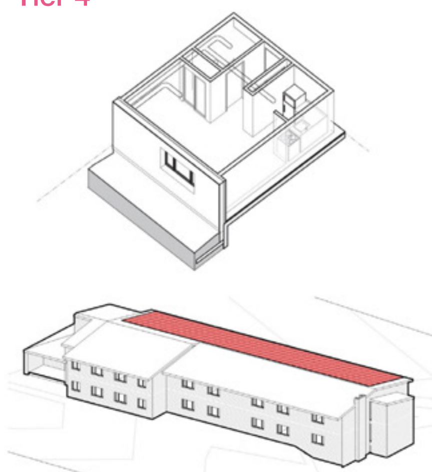
Air barrier, insulation
Cladding
HVAC
Entry window, doors

Phase 3
Tier 3



Residential windows
Heat pump hot water

Phase 4
Tier 4



120 PV panels
Battery storage

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