Evaluation of the construction technology for the allocated construction element

Rainscreen cladding of a commercial wall

Contents

1 Literature Review

What are the standard and sustainable forms of construction for a rainscreen clad wall of a commercial building?

The aim of the research question is to examine the standard form of a rainscreen clad wall which includes the main components of the rainscreen cladding system and the standards/regulations the mechanisms must comply with. A green façade has been selected as the most visibly appealing and tangible expression of a sustainable walling. The rationality of this optimum form of sustainable walling will be explored in the impacts section of this review.

1.1 Standard form of a Rainscreen Clad wall

Rainscreen cladding is a type of external cladding that can be used on commercial buildings to it protect the load bearing wall of the structure from water damage caused by penetrating water (please see figure 4 in section 3.2, the author is scoping it to this form of rainscreen cladding). The panel of a rainscreen clad wall is a water proof material that resists wind-blown rain often made out of aluminium, zinc, copper and stainless steel. A rainscreen clad panel typically comes in sizes 1250mm width, by 3200mm in length and 4mm in thickness (Valcan , 2018). The main material used to produce a rainscreen cladding panel should be a 'material of limited combustibility' as described in Table A7 of Approved Documents B (Vol2), or in accordance with BS EN 13501-1. The main difference from a standard cladding wall to a rainscreen clad wall is that the rainscreen panels have a 'ventilation cavity of at least 25mm' (Boothmuirie, 2016) which allows ventilation and water to drain to the exterior of the building. The airflow within the ventilation cavity allows precipitation that reaches the load bearing wall structure is able to evaporate at a quicker rate and reduce effect on the materials of the wall. The other main type of rainscreen cladding prevents rain from penetrating into the system and from being drawn up through the joints by equalising the pressure within the air gap. The cladding panels must comply with the criteria of Approved Documents B paragraph 12.5 to 12.9 or must meet the performance requirements within BS 8414 Fire performance of external cladding systems and BR 135 Fire Performance of external thermal insulation for walls of multi-storey buildings. The cladding panels also require supporting rails which attaches the cladding panels to the backing wall to hold the element into place and provide a gap between the panels and external wall. The fixings for the panels will need to comply with Approved document A section 3 which describes states that the cladding must be 'securely fixed to and supported by the structure of the building' (HM Government , 2010). The rainscreen system requires a backing wall that the railings will transfer the load of the rainscreen system across to which therefore provides structure and stability to the system. The standard material for the backing wall has been taken as a concrete block wall for a commercial building; the concrete must conform to the European standard for concrete BS EN 206 and its UK standard BS 8500. A vapour control should be

attached to the element on the warm side of the wall insulation to conform to British Standard 5250 (Code of practice for the control of condensation in buildings).

1.2 Sustainable form and its impacts

Sustainability is defined by the Brundtland Commission as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland Commission, 1987). Rainscreen cladding can be a variety of different materials therefore its environmental impact can be wide ranging. A green façade is a method improving sustainability of a rainscreen clad wall and is defined by the Growing Green Guide as 'growing climbing plants up and across the façade of a building, either from plants grown in garden beds at its base, or by container plating installed at different levels across the building' (see figure 1 for an image of a Green façade). There is a variety of different species of plants that can be used for this type of façade although there are certain properties of the plant to consider choosing the most appropriate plant. Factors that affect the chosen plant include:

- Climate conditions
- How much natural or artificial light the plant will be exposed to
- Type of roots (shallow or fibrous)
- Level of watering requirements
- Growing environments

Figure 1 A example of a green façade on a commercial building (cable-supported green façade, Switzerland)

A green façade can be used in replace of a rainscreen panel as it provides protection to the main structural external wall of the building. A green façade has insulating qualities when the environment is cooler on the exterior of the building. When temperatures are higher it provides protection against solar radiation through passive cooling (shading and evapotranspiration), keeping the building cooler thus reducing the need for energy for air conditioning and heating to the building, K.Perini states that green facades ‘reduces the energy demand for air-conditioning up to 60% in Mediterranean climate’. Green façade reduce the rate of surface water runoff caused by rainfall which increases in built up areas where there is a large amount of impermeable surfaces. A slower rate of surface water runoff decreases the risk of flooding. The main types of green façade include traditional, modular, absorbent foam, structural, tubular and alternative piping green facades (F.Amorim, 2017). The type of green façade needs to be considered by the architect and the design team to establish the most appropriate method as maintenance is required through the lifecycle of a green façade. Maintenance includes the type of irrigation system (natural or drip) and whether the plants require pruning or replacement, this requires 'skilled labour and consequently more costs to the building' (F.Amorim, 2017). Compared to the lightweight rainscreen panels, a green façade can be heavier and

increase in weight as water and nutrients are added to the system causing more loading on the structure. The density of the façade can be suited to the function of the façade. The is no guarantee that the façade is uniform because due to the nature of growth of plants it can vary between plants this may result in a variety of colour and size of plants which needs to be considered with the clients requirements.

For this element to comply with Part L2A of the building regulations thermal bridging contributes towards achieving this. Thermal bridging is 'an area of a building construction which has a significantly higher heat transfer than the surrounding materials.' (BRE) Usually a board of insulating material is used in a rainscreen cladding system however mineral wool quilts would provide better insulation to the wall because they can be cut to fit tightly around the wall brackets thus reducing the risk of thermal bridging (C.Stirling, 1999) and increasing the energy efficiency of the element as this reduces energy consumption of the building. Mineral wool is relatively easy to install as it is manufactured into roll that can be easily laid down. Although this does reduce energy consumption, it requires fossil fuels to heat the raw material to melt into a usable material in the manufacturing process; this is embodied energy that will contribute to CO2 production.

In the production of plasterboard, the material gypsum requires a process that uses fossil fuels to produce the form of gypsum that can be used in plasterboard, it also requires mining to extract the natural gypsum from the bedrock and more energy is used to transport and dispose of the material causing it to have high volumes of embodied energy. To reduce the use of fossil fuels the plasterboard layer that is used to form the rainscreen cladding can be formed out of recycled plasterboard, this could be specified by the client in the design proposals, plasterboard can be recycled an infinite number of times as the process of removing the water from the natural gypsum is reversible. The use of recycled plasterboard reduces the volume of waste plasterboard sent to landfill; it also reduces the cost of the plasterboard significantly compared to using virgin raw material. However plasterboard cannot be entirely produced using only recycled material. Using recycled material will show awareness of sustainability and can improve the profile of the business, as this is assisting the UK government to working towards annual targets set out in the Ashdown Agreement (British Gypsum). From a contractors perspective they can reduce waste by not over ordering.

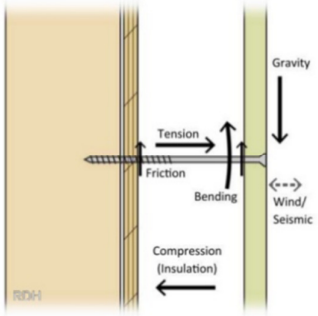
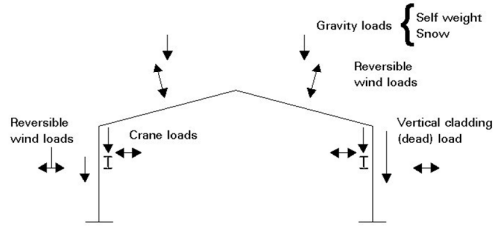
2. Technical Notes

2.1 Structures

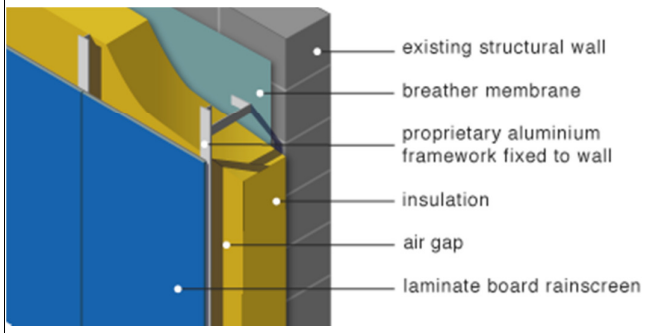
This section evaluates the structural performance of a rainscreen clad wall on a commercial building within the table below, the components of the system is based on a standard form of a rainscreen cladding system (please see figure 4 for the standard form used in these sections).

Components	Unit Weight	Units	Length (m)	Width (m)	Depth or Height (m)	Quantity Type (& Units)	Quantity	Load (kN) = Unit wgt & quant	Notes
Breather membrane	0.00063	kN/m^2	20	50	n/a	A	1000	0.63	Lowest loading (Housewrap, 2018) – High density
Supporting rails (steel channel)	17.9	kN/m	20	n/a	n/a	L	20	358	
Insulation (Celotex)	0.028	kN/m^2	20	50	n/a	A	1000	28	(Celotex, 2018)
Rainscreen (Aluminum Composite Panel)	0.088	kN/m^2	20	50	n/a	A	1000	88	
Plasterboard	0.081	kN/m^2	20	50	n/a	A	1000	81	(Metric handbook Ch6, 2015)
Concrete Block Wall	0.566	kN/m^2	20	50	n/a	A	1000	566	Highest loading (Metric handbook Ch6, 2015)
							Total	1121.63	

From the data shown in the table, the concrete block wall is accounts for the most significant load of the whole element with a load of 566kN. The breather membrane is a very light material and therefore has the least significant load of 0.63kN. The supporting rails appear to be an anomaly because it has a high weight however does not have the most significant load; this is because the rails run linear around the building however do not cover the whole surface of the wall.

Types of loads	Connection Details	Load paths
• The primary structure will resist a dead load (self-weight) of 1122kN/m from all the components of the rainscreen clad wall. The transfer of load from cladding through supporting rails is linear. • External elements are affected by wind as a live load which is mostly horizontal. Changes in wind speed cause pressure to increase and decrease which could cause structural failure. The load bearing wall and cladding should withstand the effects of the weather without 'risk of failure or loss of function' (Authority, 2014). The code of practice for wind loading in the UK is BS EN 1991-1-4. • Live include snow loads as there are horizontal surfaces that snow can settle on to creating a load from the force of gravity on the snow. • Depending on the location of the commercial building, there is potential for dynamic loading caused by traffic on a roads in close proximity or heavy machinery being used on site close • Seismic waves caused by earthquakes can result in loading on to the components of a clad wall and will result in deformation.	• All fixings must transfer loads back to the backing wall. The panels are often a lightweight material therefore applies minimal load to the existing structure of the wall (Sharpfibre, 2014). • The rain screen cladding is held to the surface by the supporting rails, the supporting rails are connected to both the primary structure and the rainscreen cladding, and this connection is a fixed connection which applies a V and H load. • Insulation and the breather membrane will need to be fixed to the backing wall also; this is done through a self-drilling to the structure which allows both vertical and horizontal load.  *Figure 2* (L.Ricketts, 2017) – diagram to show the loads through a screwed connection between the insulation and backing wall	• The dead load of the components of the cladding will be transferred horizontally through the supporting rails to the backing wall. • The backing wall will then transfer the load vertically downwards through the external wall to the ground.  Figure 3 In-plane frame loads *Figure 3* (14) – diagram showing the load paths applied on to a cladded building wall

2.2 Strengthening

1. Element illustration:	**2. Potential strengthening reasons:**
 *Figure 4* - (GreenSpec, 2018)Diagram of a standard rainscreen clad wall	**-** Moisture and temperature variations can form in the concrete structural walls. Cracks may also form due to mistakes in design, overloading or accidental loads which may have been unforeseen. Untreated cracks can increase in size over time which will cause the wall to become weak and eventually may fail. - Corrosion of the steel brackets and rails due to moisture as the steel reacts with water and oxygen.

Components	**Strengthening Comment**
Breather Membrane	Strengthening not applicable
Supporting Rails	Steel can be strengthened, if the corrosion is too serve then the steel will have to be replaced
Insulation	Strengthening not applicable
Rainscreen	Strengthening not applicable but making the material more durable
Plasterboard	If there is significant damage it would be replaced

Description of technique	Advantages / Benefits	Disadvantages / Challenges
Steel rails and brackets can be strengthened by - increasing section width or thickness by: - Bonding FRPs around rails - steel plates welded/bolted underneath rails which are supporting the cladding	Light weight, high strength, durable, non-corrosive, non-conductive, versatile, flexible Makes the section bigger, high strength	High initial cost, requires skilled labour Corrosive, might not be viable if the rails are small/thin, not lightweight
Concrete Block wall can be strengthened by - FRP/Fabric bonding around the wall - Stitching for cracking - Encase in concrete, possibly with additional reinforcement -Bed joint reinforcement -Denser blocks	Light weight, high strength, durable, non-corrosive, non-conductive, versatile, changes the behaviour the concrete, quick application, can hold heavier cladding if required Cheap, fast Increased strength and section, gives similar aesthetic look, durable Improves walls' strength	High initial cost, requires skilled labour Will not work unless the cause of the crack has been addressed, not aesthetically pleasing Might only be able to be done on the internal side of the wall Will need to be done as the wall is being built not after
Plasterboard can be strengthened by - increasing the width of the plasterboard by adding another board to the back/front	Increased section will increase strength	Unlikely to be done in practice

2.3 Modern Methods of Construction

Prefabricated façade wall  *Figure 5* - (DesigningBuildingWiki, 2017) An image showing a prefabricated façade wall being craned into place on a building	A prefabricated façade can incorporate the many different elements of rainscreen cladding into a whole system such as the rainscreen cladding panels, insulation, interior wall finish and brackets. The different components can be manufactured and assembled together in one place. The prefabricated rainscreen cladding system could incorporate more than one panel, creating larger units of the walling. Once completed these structures are transported to site, where they are installed onto the building. The panels are often craned into place using a small crew to direct the modular unit in to place as seen in Figure 5. It is then fastened to the structured wall/beams of the building.

Advantages	Disadvantages
• Made in a factory gives a controlled environment which allows better quality control as there's less external factors from the environment affecting the quality of the materials. • The elements are assembled off site therefore can be delivered as one resulting in fewer lorry movements on site for materials if they were separate. This reduces workforce needed onsite as different trades can carry out all work within the factory. Reduced risk of potential delays due to waiting for other elements of construction. • Pre-assembled panels means that this reduces the time spent on site for assembling the components thus speeding up construction time, therefore achieving a faster build programme. • It is '15 times safer than traditional method' (Baker Triangle Prefab, 2018), as protective equipment can be close at hand, reduces the amount of people potentially working at height, it is a more controlled environment and less risks from other construction activities that are carried out on site. • Easier to create different designs in a factory environment giving the client and architect more design options (BRE, 2018). • As the units are lifted into place this reduces the need for scaffolding which minimises cost, time and safety hazards • Smaller installation crew would be needed to fit the units, reduces the amount of labour needed on site thus reducing cost, time	• More expensive as it is a higher quality product. • Future adaptation is more difficult as components are fixed together before fixing to the building. • Early design lock-down reduces the chances for adaption. From a client's prospective they can be a problem due to the inadaptability to make variations to design. • This method is relatively new to the industry therefore there could be unknown potential risks • If the design hasn't been decided on then they cannot be assembled till they are all complete, this could cause delays to manufacturer and getting the units to site. • The client will have to have trust in the manufacturer to produce what they have asked for, plus to have inspections before they leave the factory so that when they get to site they can be installed and will not cause delays if any aren't correct. • There is a potential risk of parts getting damaged while they're being transported to site which would be costly for money and time. • Lead times need to consider so that the units are produced and ready to be installed when they are required at site, this may be tricky to organise. • Some sites might have restrictions of space to be able to lift the prefabricated systems into place.

3. Summary Matrix

The quality of a source is scored on a scale from 1 to 5 on the reliability of the source. For example if a course is given a rating of 5 the source would be from a website of a well-known company/organisation and has unbiased information. Whereas if a source has a quality rating of 1 then the source is deemed could for example be out of date or has unknown authors.

APA Reference:	Quality of source	What used	Where used it
Bailey Total Building Envelope (2017), What Are The Elements Of An Effective Rainscreen Cladding System? Retrieved from https://www.bailey-uk.com/face-value/technical/elements-of-a-rainscreen-cladding-system/	2	Finding the various components of a rainscreen clad wall	loads of elements and connection details
Baker Triangle Prefab, (2018), Prefabricated exterior wall panels, Retrieved from: http://www.bakerprefab.com/prefabricated-exterior-wall-panels/	3	The pros for using their wall panels	Used the information for how prefabricated wall
BoothMuirie. (July 2016). Architectural Cladding Systems. Retrieved from http://www.euroclad.com/media/3546/booth-muirie-architectural-cladding-systems_web.pdf	3	Principles of rainscreen cladding	Cold Bridging in Rainscreen cladding
Bre, (2018), Technik Wall Case Study, Retrieved from: https://www.bre.co.uk/page.jsp?id=3079	2	The core benefits of the façade	Used in the advantages of using a prefabricated cladded wall
BRE. The importance of thermal bridging. Retrieved from https://www.bre.co.uk/certifiedthermalproducts/page.jsp?id=3073	5	Definition of thermal bridging	Use of mineral wool instead of board
BREEAM UK. (2016). Ene 1 Reduction of energy use and carbon	5	BREEAM information	Element evaluation

emissions. Retrieved from http://www.breeam.com/BREEAMUK2014SchemeDocument/#06_energy/ene01_nc.htm%3FTocPath%3D6.0%2520Energy%7C_____1		on Energy	
BREEAM UK. (2016). LE 4 Enhancing site ecology. Retrieved from http://www.breeam.com/BREEAMUK2014SchemeDocument/#11_landuse/le04.htm%3FTocPath%3D11.0%2520Land%2520Use%2520and%2520Ecology%7C_____4	5	BREEAM information on land use and ecology	Element evaluation
BREEAM UK. (2016). Man 2 Life cycle cost and service life planning. Retrieved from http://www.breeam.com/BREEAMUK2014SchemeDocument/#04_management/man02.htm%3FTocPath%3D4.0%2520Management%7C_____2	5	BREEAM information on Management	Element evaluation
BREEAM, UK. (2016). Mat 1 Life Cycle Impacts retrieved from http://www.breeam.com/BREEAMUK2014SchemeDocument/#09_material/mat01_nc.htm%3FTocPath%3D9.0%2520Materials%7C_____1	5	BREEAM information on Management	Element evaluation
BREEAM UK. (2016). Pol 3 Surface water run-off. Retrieved from http://www.breeam.com/BREEAMUK2014SchemeDocument/#12_pollution/pol03_nc.htm%3FTocPath%3D12.0%2520Pollution%7C_____3	5	BREEAM information on Pollution	Green façade evaluation
BREEAM UK. (2016). Wst 01 Construction waste management. Retrieved from http://www.breeam.com/BREEAMUK2014SchemeDocument/#10_waste/wst01_nc.htm#Wst_01_Construction_waste_management%3FTocPath%3D10.0%2520Waste%7C_____1	5	Details of Waste 01: Construction Waste Management	To review the issue of a BREEAM section in depth
British Gypsum. (2018). Ashdown Agreement. Retrieved from	4	Ashdown agreement	Plasterboard

https://www.british-gypsum.com/about-us/csr/environmental-challenges/plasterboard-recycling/ashdown-agreement			sustainability
C.Stirling. (1999). Good Building Guide, Insulated external cladding systems. BRE Publishing	5	Insulation details	Airtightness for a rainscreen clad wall
Designing buildings wiki Ltd (2017), Precast Concrete Cladding, Retrieved from: https://www.designingbuildings.co.uk/wiki/Precast_concrete_cladding	3	Image of precast concrete cladding installation	Use of an image to show how the units are installation once at site
Designig Buildings Wiki. (2018). ACM cladding. Retrieved from https://www.designingbuildings.co.uk/wiki/ACM_cladding#Building_regulations	4	Building regulations	Standard form of a rainscreen clad wall
ESDEP WG 14. Structural Systems: Buildings. Retrieved from http://fgg-web.fgg.uni-lj.si/~/pmoze/esdep/master/wg14/l0110.htm	3	Figure 3 – In-plane frame loads	Diagram to show load paths
European Commission. (2018). Eco-Management and Audit Scheme. Retrieved from http://ec.europa.eu/environment/emas/index_en.htm			
G.Milne. (2013). YourHome: Embodied Energy. Retrieved from http://www.yourhome.gov.au/materials/embodied-energy	2	Definition of embodied energy	Sustainability of a product
GreenSpec (2017), Housing Retrofit: Insulation: Rainscreen cladding, Retrieved from http://www.greenspec.co.uk/images/web/refurb/rainscreen/boardpanel80.png	3	Diagram of rainscreen cladding	To show an illustration of the different elements of rainscreen cladding
GreenSpec (2018). Gypsum Plasterboard: Manufacture & Additives. Retrieved from http://www.greenspec.co.uk/building-design/plasterboard-drylining-partition/	5	How plasterboard is manufactured	How a rainscreen clad wall can be made more sustainable

Growing Green Guide. (2018). Green Façade Definition. Retrieved from http://www.growinggreenguide.org/technical-guide/introduction-to-roofs-walls-and-facades/green-facade-definition/	3	Definition of green façade	Green cladding technology
G.Hobbs. (2009). Plasterboard: Sustainability Impacts and Initiatives. Retrieved from https://www.plasterboardpartnership.org/pdfs/Plasterboard_Final_11-9-09.pdf	3	Environmental impacts of plasterboard	Explaining how the process of manufacturing plasterboard causes environmental impacts
Gyproc (2018). Providing Solutions for Sustainable Habitat, Environmental Brochure. Retrieved from https://www.gyproc.co.za/sites/gypsum.eeap.za/files/content/files/gypsum_environmental_brochure.pdf	3	Types of embodied energy plasterboard manufacture contains	How plasterboard is unsustainable
HM Government. (2010). The Building Regulations: Approved Document A: Structure. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/429060/BR_PDF_AD_A_2013.pdf	5	Regulations	Standard form of cladding
Jaggs.M, scivyer.C (2011). Airtightness in commerciAl And public buildings. 3rd edition. Retrieved from http://www.ihsti.com.lcproxy.shu.ac.uk/tempimg/49A0BF2-CIS888614800297293.pdf	4	Infiltration Paths	Discuss where airtightness is an issue with rainscreen cladding
K.Perini, P.Rosasco. (2013). Cost-benefit analysis for green façade and living wall systems. Retrieved from https://www.researchgate.net/publication/270997871_Cost-benefit_analysis_for_green_facades_and_living_wall_systems	3	Pros and cons of a green façade	Green technology of rainscreen cladding
Tensile Design & Construct.(2018). Plant Selection for Green Facades –	3	Green façade plant	Pros and cons of green

the types of plants that can be used. Retrieved from https://www.tensile.com.au/plant-selection-for-green-facades-the-types-of-plants-that-can-be-used/		selection	façade
The Balance (2017), Fiberglass Reinforced Panels- FRP Panels, Retrieved from https://www.thebalance.com/fiberglass-reinforced-panels-frp-panels-844834	2	Different types of advantages of FRP	To explain the advantages of using FRP to strength the steel rails
The Building Envelope Authority. (Nov 2014). Guidance for wind loadings on roof and wall cladding. Retrieved from http://www.mcrma.co.uk/pdf/Wind_guidance_document_final.pdf	4	Wind loading paths	Wind loads on a rainscreen panels
J.Anderson, D.Shiers, K.Steele. (2007). Fourth Edition. The green Guide to Specification. Blackwell Publishing.	5	Standards for rainscreen clad wall	Energy performance of the wall
Tyvek Housewrap (2017), Control Moisture With a Breathable Membrane for Walls, Retrieved from http://www.dupont.co.uk/products-and-services/construction-materials/tyvek-building-envelope/brands/tyvek-breather-membrane/products/tyvek-housewrap-breathable-membrane-for-walls.html	2	Unit weight of the breather membrane	Used the unit weight of the breather membrane to calculate the load component
Bailey Total Building Envelope (2017), What Are The Elements Of An Effective Rainscreen Cladding System? Retrieved from https://www.bailey-uk.com/face-value/technical/elements-of-a-rainscreen-cladding-system/	3	Lit Rev	Lit Rev
Baker Triangle Prefab, (2018), Prefabricated exterior wall panels, Retrieved from: http://www.bakerprefab.com/prefabricated-exterior-wall-panels/	3	Lit Rev	Lit Rev

BoothMuirie. (July 2016). Architectural Cladding Systems. Retrieved from http://www.euroclad.com/media/3546/booth-muirie-architectural-cladding-systems_web.pdf	3	Lit Rev	Lit Rev
BRE. The importance of thermal bridging. Retrieved from https://www.bre.co.uk/certifiedthermalproducts/page.jsp?id=3073	5	Lit Rev	Lit Rev
BRE (2018), Technik Wall Case Study, Retrieved from: https://www.bre.co.uk/page.jsp?id=3079	4	Lit Rev	Lit Rev
European Commission. (2018). Eco-Management and Audit Scheme. Retrieved from http://ec.europa.eu/environment/emas/index_en.htm	4	Lit Rev	Lit Rev
G.Milne. (2013). YourHome: Embodied Energy. Retrieved from http://www.yourhome.gov.au/materials/embodied-energy	3	Lit Rev	Lit Rev
GreenSpec (2017), Housing Retrofit: Insulation: Rainscreen cladding, Retrieved from http://www.greenspec.co.uk/images/web/refurb/rainscreen/boardpanel80.png	3	Lit Rev	Lit Rev
GreenSpec (2018). Gypsum Plasterboard: Manufacture & Additives. Retrieved from http://www.greenspec.co.uk/building-design/plasterboard-drylining-partition/	3	Lit Rev	Lit Rev
Growing Green Guide. (2018). Green Façade Definition. Retrieved from http://www.growinggreenguide.org/technical-guide/introduction-to-roofs-walls-and-facades/green-facade-definition/ G.Hobbs. (2009). Plasterboard: Sustainability Impacts and Initiatives.	3	Lit Rev	Lit Rev