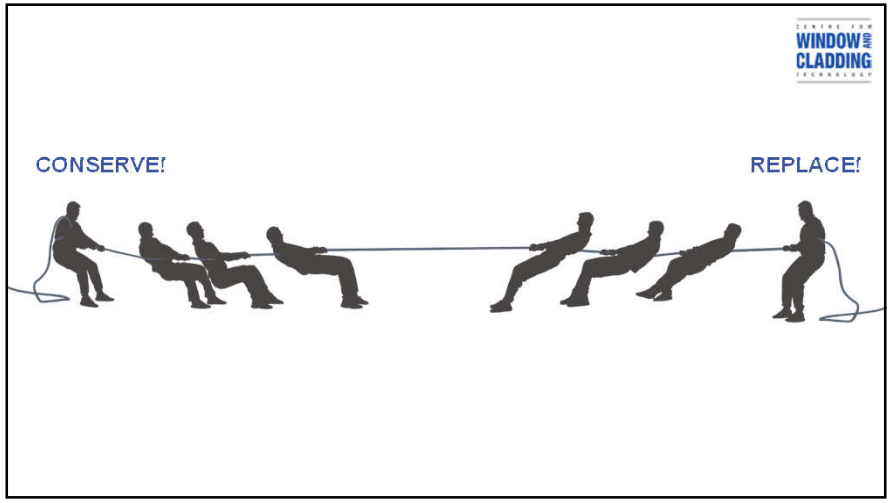
1

The Team

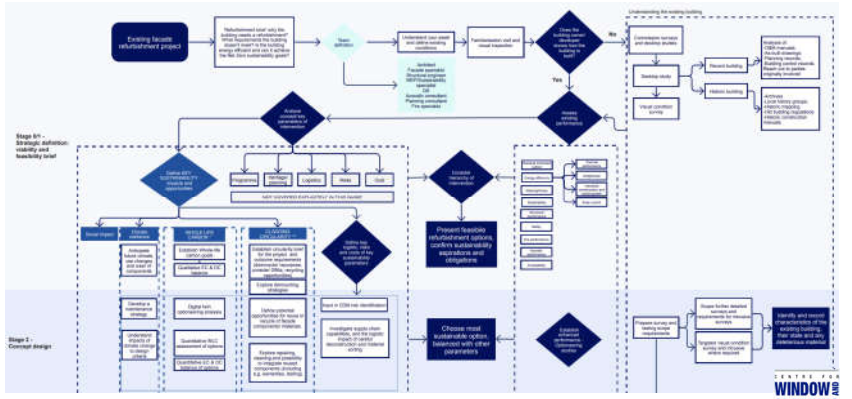
Name	Discipline	Organisation
Hugh McGilveray	Facade Engineer	EOC
Mark Elliot	Facade Engineer	CWCT
Teni Ladipo	Facade Engineer	Buro Happold
Gurprit Bassi	Facade Engineer	Wintech
Ana Araujo	Facade Engineer	Buro Happold
Francesca Rossi	Facade Engineer	EOC
Greta Invernizzi	Facade Engineer	EOC
Ian Hagan	Specialist Contractor (refurb - glazing / cladding)	Clearline
Robert Greer	Specialist Contractor (stone / masonry)	Paye
Phil Sedge / Alex Bodo	Main Contractor	Mace
Anusha Badrinarayana	Sustainability Engineer	Lendlease
Mark Skelly	M&E Engineer / Sustainability	Skelly & Couch
Andrew Morris	Main Contractor / Client	Lendlease
Daniel Gruesser	Quantity Surveyor	Alinea

2



3

Putting down a process



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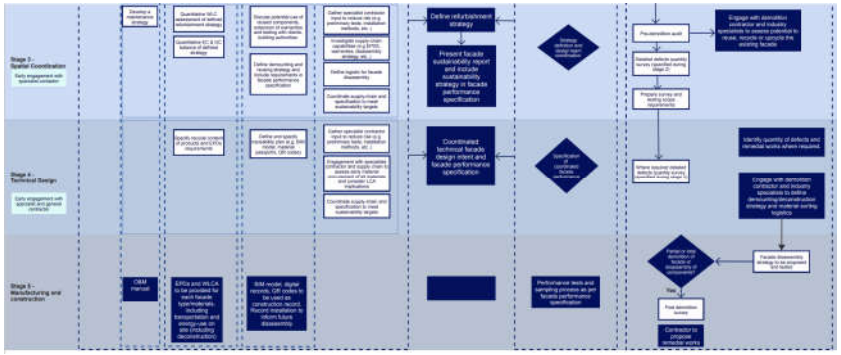

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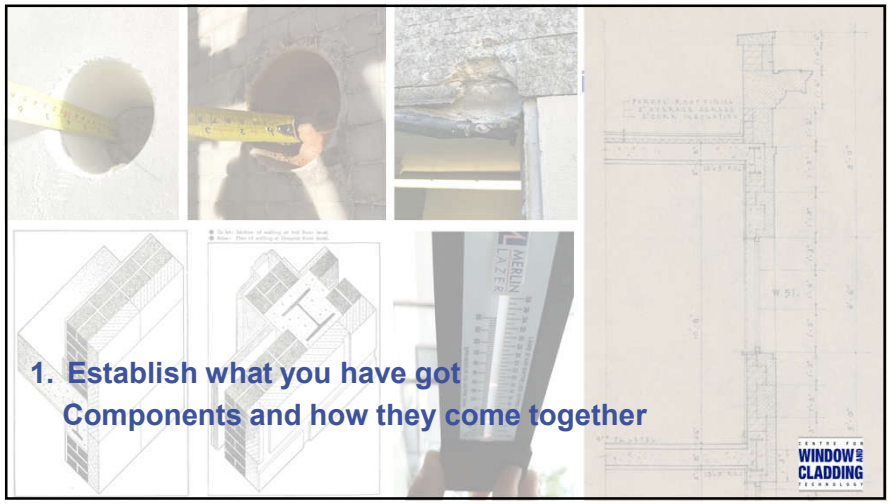


6

Surveys

Survey 'level'	RIBA Stage	Key discipline	Description
1 – Building Survey	0	Building surveyor	High level facade survey, assessing general condition from visual inspection and review of available As Built and maintenance history information
2a – Specialist scoping visual survey	0/1	Facade specialist	Facade specific survey, informed by (1) above and including independent review of available information, to get 'up close' to the facade and visually inspect a representative proportion of the different systems and hone in on potential issues. Used to establish defect typologies, categorise them and determine a strategy for remediation. Also used to scope further detailed surveys
2b – Intrusive survey (if required)	1/2	Facade specialist	Scoped by (2) if deemed necessary to understand defects properly.
		Structural Engineer	The structural Engineer involved in the project should carry out investigation surveys to provide information on the residual capabilities of the existing structural elements of the facade and whether a replacement or refurbishment should be considered to withstand the current or increased facade loads. A soft-strip area should be accessed to validate the current structure and desktop study. This is to be carried out along with a dimensional survey to allow for structural and facade coordination.
		Others specialists	Various survey requirements should be coordinated by the lead consultant. (e.g. fire-led, services survey.)
3 – Pre-demolition audit	3	Facade specialist	Auditing the existing facade, engage with industry specialists to assess the potential for disassembly to reuse, recycle, or upcycle facade systems, components, products or materials.
4 – Detailed defects quantity survey	3/4	Depending on procurement preference and strategy determined in (2)…	
		Facade specialist	Scoped by (2) and (2b) (if required), a detailed survey to establish a detailed 'BOQ' of defects and repair requirements to communicate and get final costs from one or various remedial works contractors as appropriate. Roughly equivalent to 'traditional' procurement
		OR	
		Specialist contractors	Scoped in (2) and tendered to contractors (or groups of contractors) to establish the quantities of defects and remedial works required. Contractors would then do the work they have recommended, perhaps with warrantees . Roughly equivalent to 'design and build' procurement
5 - Post-demolition survey	5	Specialist contractors	Following partial or total demolition of the facade or disassembly of components, to establish any damages to the retained parts of the facade. Contractors would then propose remedial works specifically for these areas where the previous assessment (3) cannot be applied anymore to achieve the design intent.

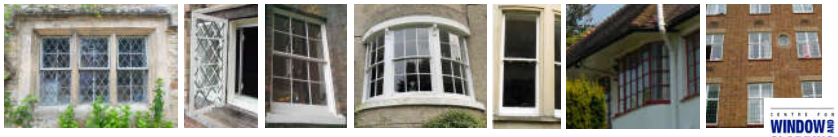
7

Example:
Windows

8

Window types

Window frame technology timeline	1200s	1300s	1400s	1500s	1600s	1700s	1800s	1850	1860	1870	1880	1890	1900s	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000s	2000	2010	2020
Stone, large scale (e.g. cathederals)																										
Wrought iron																										
Timber frame	Single glazed casements Single glazed horizontal (Yorkshire) sliders Double hung, vertical sliders. Made of smaller glazing, usually 6 units of 6 units Double hung, vertical sliders. Single large pane. Usually incorpating 'sash horns' Timber frames, general Composite timber																									
Steel	Rolled steel Crittall 'Universal Suite' and subsequent hot rolled suites Cold rolled, tubular steel Thermally broken profiles																									
Aluminium	non-thermally broken extrusions - primarily curtain walling More common use as windows Thermally broken profiles																									
Other materials	uPVC Fibreglass																									



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Glass types

Glass technology timeline	1200s	1300s	1400s	1500s	1600s	1700s	1800s	1800	1850	1860	1870	1880	1890	1900s	1905	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000s	2000	2010	2020
Raw glass processing: Broad glass																												
Raw glass processing: Crown glass								1674																				
Raw glass processing: Cylinder glass									1845																			
Raw glass processing: Hand drawn glass										1860s																		
Raw glass processing: Machine drawn glass																1915												
Raw glass processing: Float glass																						1959						
Glass treatment: Wired glass												#																
Glass treatment: Laminated glass															1905	PVB												
Glass treatment: Tempered glass																1930s												
Glass treatment: Chemically tempered glass																					1960s							
Glass treatment: Heat strengthened glass																								1990s				
Insulated glass: Insulated glass																				USA adoption			1970s in UK				
Insulated glass: Triple glazing																								1990s				
Insulated glass: Warm edge spacers																									2000s			
Insulated glass: Vacuum glass units																												
Glass coatings: Low-e coatings																								1990s				
Glass coatings: Solar control (double silver)																								1990s				
Glass coatings: High performance coatings																									2000s			
Glass coatings: Solar control (triple silver)																												
Typical DGU performance (U-value W/m2K)							5.8															2.8		1.4-1.6	1.1-1.4	1.0-1.1		

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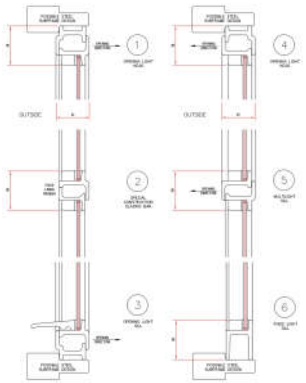
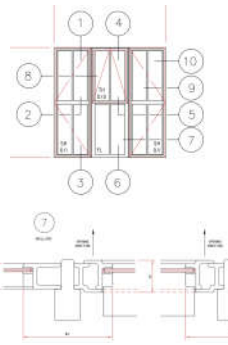
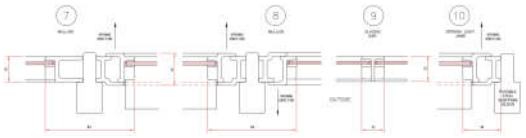
Heritage steel windows







Single Glazed
Not thermally broken
Poor air-tightness
Poor acoustics

BUT

Beautiful
Very slim sightlines
Have intrinsic value

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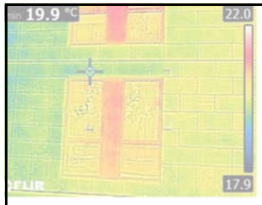

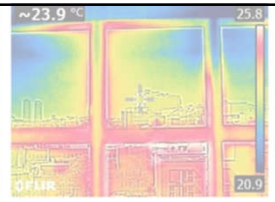

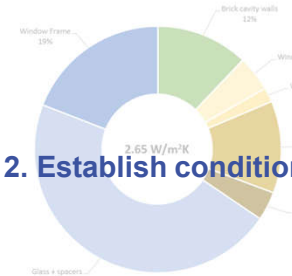

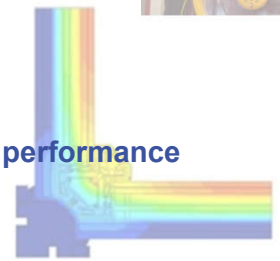

2. Establish condition and performance

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Defects

- **Leaks**
- **Condensation / mould growth**
- **Local comfort** issues
- **Hazerdous materials** e.g. lead paint, asbestos, anthrax etc.
- Compliance with modern **safety** codes (e.g. Part K)
- **Solar control / overheating** issues
- **Interstitial** condensation
- Poor **ventilation**
- **Inappropriate materials** (e.g. cement mortar rather than lime)

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Rationalising Defects

	Warranty period / early design life	Mid design life	End of design life
Workmanship issue	Often repairable under warranties. Many workmanship issues present at this time	Less common to present at this time, if they are present they likely perform adequately for typical conditions but may present during an unusual event.	Potentially uncovered during refurbishment or replacement.
Design issue	Design defects at this stage indicate inadequate design	Less common to present at this time, if they are present they likely perform adequately for typical conditions but may present during an unusual event.	Potentially uncovered during refurbishment or replacement.
Material/system deterioration	Uncommon. Some localised defects or unusual conditions may present early	Could indicate localised defect not observed earlier or accelerated deterioration	Anticipated end of life and therefore increase in issues presenting themselves likely.

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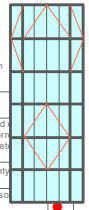
Layout existing performance and condition clearly

Performance evaluation key: ● Defect ● Below current performance standards ● Likely meets current performance standards ● Unknown performance * Potential future problem



Key parameter	Existing Windows	
Thermal insulation and comfort	Single glazed and non-thermally broken steel framing Very poor performance resulting in high energy demand and local discomfort near glazing **U-Value ~ 5.8 W/m²K** (varies slightly depending on glazing ratio)	●
Solar control	Some solar film observed within laminated single glazing but not sufficient to manage peak solar gains on South / West elevations	●
Daylighting	Relatively high LT% on glazing promotes good daylight where glazing ratio is appropriate, although whether there is sufficient glazing configures into the overall building is subject to analysis by the daylighting consultant	●
Water tightness / resistance	Fixed glazing generally putty sealed so good watertightness performance and minimal leaks observed. Operable elements have no weather stripping so likely to suffer from leaks	●
Condensation resistance	Poor performance due to metal thermal bridges through framing and single glazing	●
Air tightness	Not quantified but no weather stripping on operable elements will result in very poor air-tightness. Fixed glazing may be ok due to putty / bead sealing and painting in	●
Fire and smoke safety	The materials used in the glazing systems appear to be non-combustible. Further work with the fire engineer is required to understand whether there should be any passive fire rating performance or fire escape operability provided by any of the systems	●
Impact resistance	Glazing in critical locations (as defined in Part K)	●
Acoustics	Single glazing is limited in it's capacity to resist sound, but the presence of some laminated glass would help in mitigating noise ingress. Measured results from Sandy Brown very poor (~15dB)	●

Key parameter	Existing Windows	
Durability / service life	The systems age would suggest they are coming to the end of useful service life. Furter investigation into the extent of corr under the paintwork etc. would need to be undertaken to det whether additional service could be achieved	
Warranty	The systems are 65-85 years old so have no active warranty them	
Material safety	There may be some asbestos present in the glazing putty so should be checked Painting to frames is likely to contain lead so this should be checked	●
Safety performance	Glass looks to be laminated or to include a safety film in many places so glass falling from height is not a concern. Glazing in critical locations (as defined in Part K)	●
Accommodation of loadings, movements and tolerances	There doesn't appear to be any issues regarding movements in the facade adversely affecting the windows	●
Ventilation	Operable windows are in varied state of repair; high level windows operated using spindles etc. are typically stuck / very difficult to operate.	●
Environmental impact	Considering when the building was constructed, the systems part of the main facade's thermal, water, air, and vapour control lines do not meet current performance standards which include stricter regulations for facade systems regarding energy performance and carbon emissions. These deficiencies negatively impact the building's consumption of energy and associated operational carbon emissions which has a detrimental impact on the environment.	●

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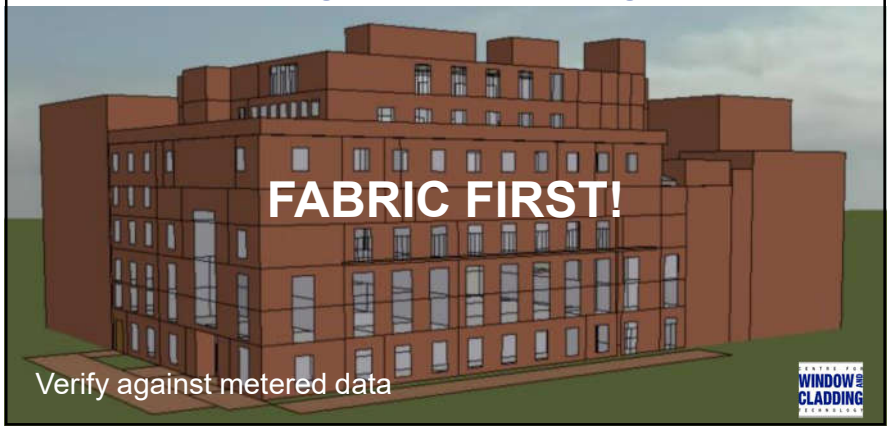
3. Coordinate existing performance with digital twin



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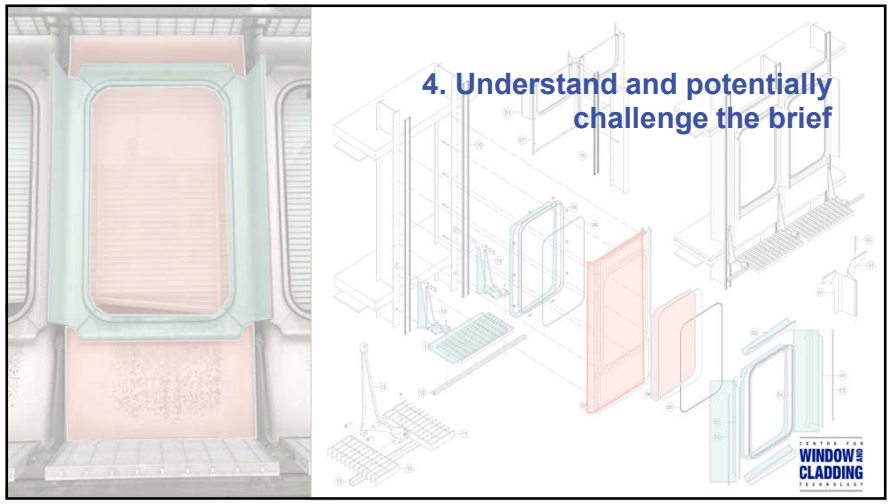
4. Understand and potentially challenge the brief

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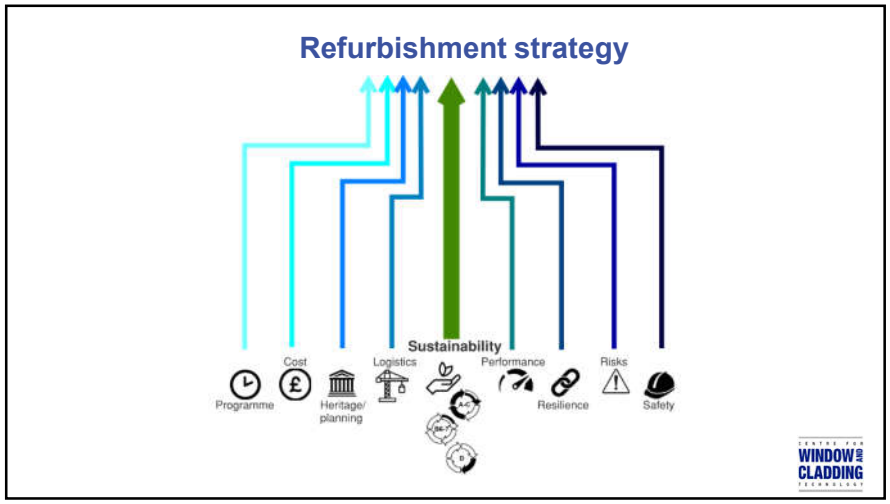
Refurbishment strategy
Sustainability
Programme
Cost
Heritage/ planning
Logistics
Performance
Resilience
Risks
Safety

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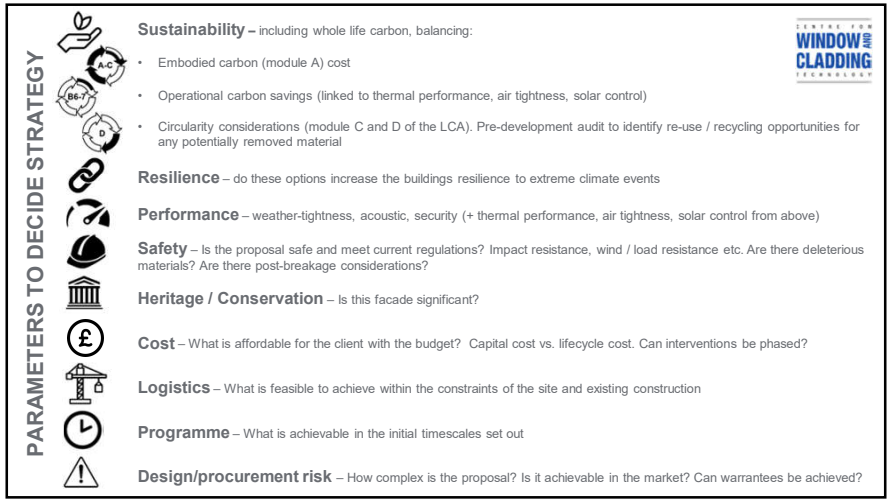
PARAMETERS TO DECIDE STRATEGY
Sustainability – including whole life carbon, balancing:
• Embodied carbon (module A) cost
• Operational carbon savings (linked to thermal performance, air tightness, solar control)
• Circularity considerations (module C and D of the LCA). Pre-development audit to identify re-use / recycling opportunities for any potentially removed material
Resilience – do these options increase the buildings resilience to extreme climate events
Performance – weather-tightness, acoustic, security (+ thermal performance, air tightness, solar control from above)
Safety – Is the proposal safe and meet current regulations? Impact resistance, wind / load resistance etc. Are there deleterious materials? Are there post-breakage considerations?
Heritage / Conservation – Is this facade significant?
Cost – What is affordable for the client with the budget? Capital cost vs. lifecycle cost. Can interventions be phased?
Logistics – What is feasible to achieve within the constraints of the site and existing construction
Programme – What is achievable in the initial timescales set out
Design/procurement risk – How complex is the proposal? Is it achievable in the market? Can warrantees be achieved?

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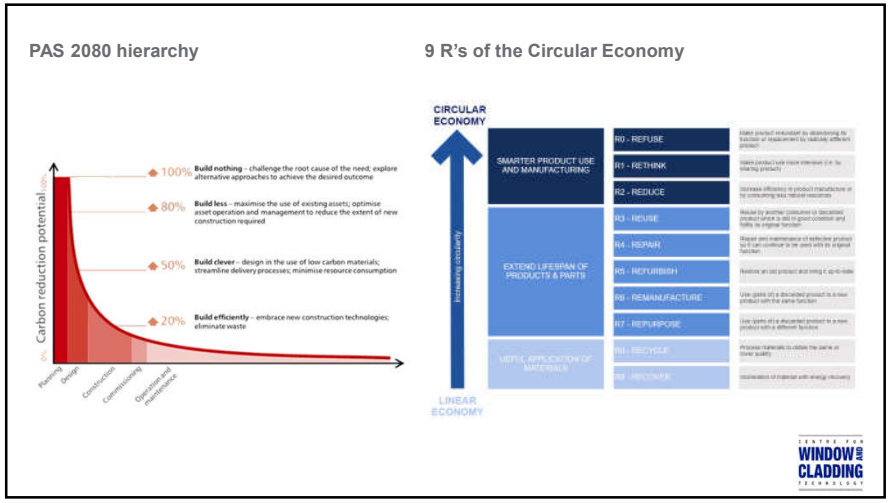
PAS 2080 hierarchy
9 R's of the Circular Economy
Carbon reduction potential
100%
80%
50%
20%
Build nothing – challenge the root cause of the need; explore alternative approaches to achieve the desired outcome
Build less – maximise the use of existing assets; optimise asset operation and management to reduce the extent of new construction required
Build clever – design in the use of low carbon materials; streamline delivery processes; minimise resource consumption
Build efficiently – embrace new construction technologies; eliminate waste
Planning
Design
Construction
Commissioning
Operation and maintenance
CIRCULAR ECONOMY
LINEAR ECONOMY
Increasing circularity
SMARTER PRODUCT USE AND MANUFACTURING
EXTEND LIFESPAN OF PRODUCTS & PARTS
USEFUL APPLICATION OF MATERIALS
R0 - REFUSE
R1 - RETHINK
R2 - REDUCE
R3 - REUSE
R4 - REPAIR
R5 - REFURBISH
R6 - REMANUFACTURE
R7 - REPURPOSE
R8 - RECYCLE
R9 - RECOVER

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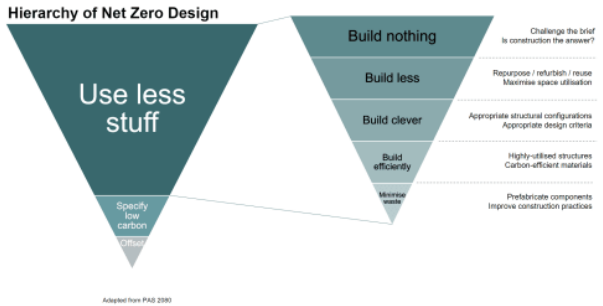
Hierarchy of Net Zero



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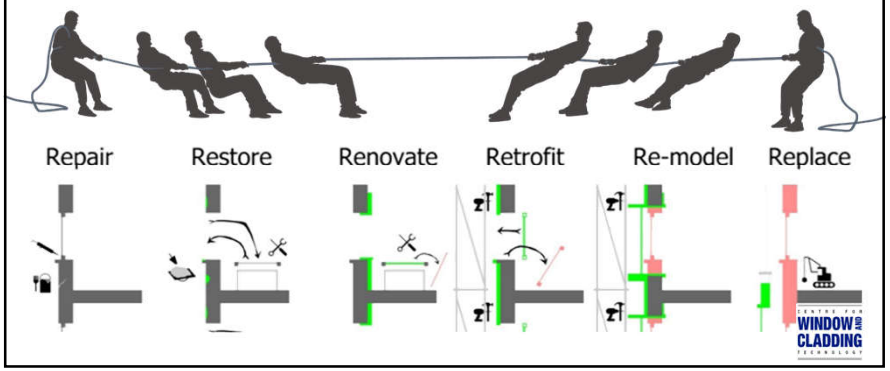
4. Establish a "Hierarchy of Intervention" for the facades



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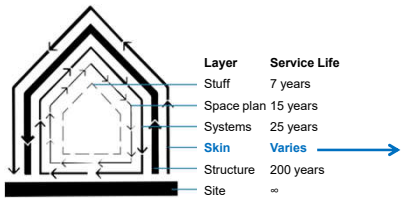
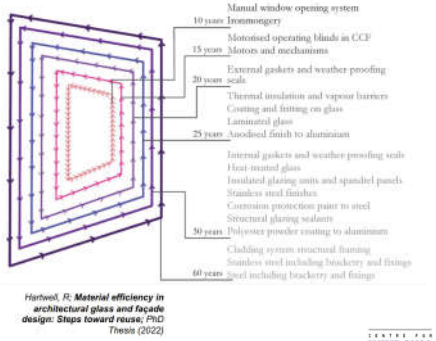
Component / system-based assessments



Layer	Service Life
Stuff	7 years
Space plan	15 years
Systems	25 years
Skin	Varies
Structure	200 years
Site	∞



*Hartwell, R: **Material efficiency in architectural glass and façade design: Steps toward reuse;** PhD Thesis (2022)*

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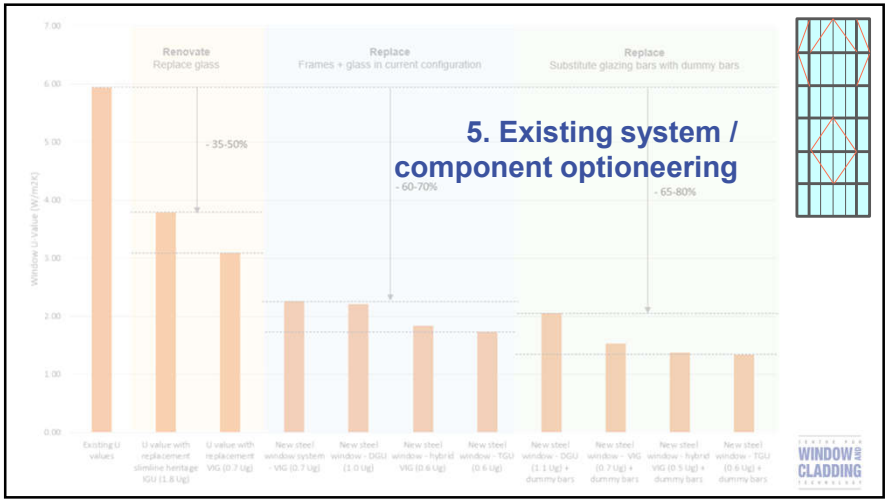

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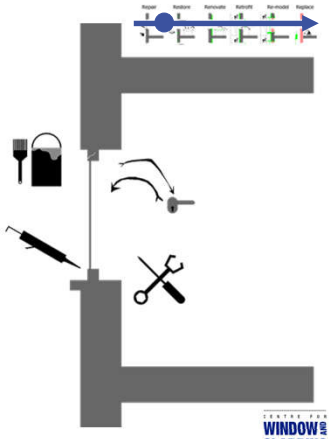
Repair / Restore

Strategy: A full restoration to bring the existing window back to its original condition (or as close to it as possible). E.g. resealing small joints, reputting glass, replacing broken panes etc

Notes:

- This will typically have little thermal benefit so U-values would remain **~5 – 6 W/m²K**
- Re-seal fixed joints which would **improve airtightness performance slightly**, although retrofitting weatherstripping to opening elements needs careful consideration and detailing
- Windows are still likely to **need replacement in 10 years** for safety reasons (corrosion etc)



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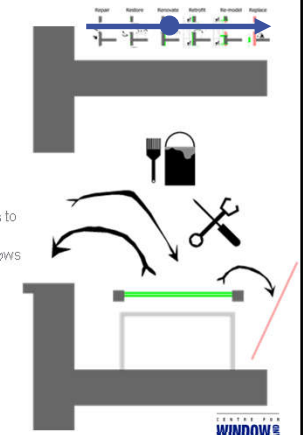
Renovate

Strategy: Upgrading the existing system via:

- stripping paint and repainting
- add additional weatherstripping (to improve airtightness) if possible
- replace/refurbish ironmongery / actuation etc.
- replace glass units (with adapted bead profile where required) as such:

Notes:

- Likely would need to remove window; feasibility of doing so without damage needs to be investigated
- Glass upgrade typically yields a **~30-50% thermal improvement** in heritage windows
- **Good improved airtightness**
- Window life could be extended by (say) **30 years** until replacement



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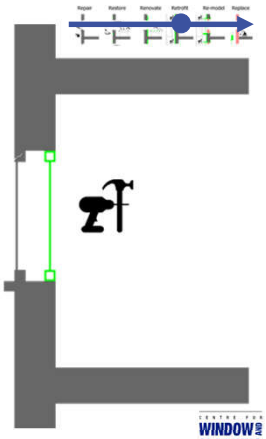
Retrofit

Strategy: the addition of additional systems to compensate for the poor performance, E.g. Secondary glazing.

Performance Notes:

- Can **significantly reduce U-values**
- Need for **ventilation** makes secondary glazing difficult
- Cold bridging and **colder window frames / detailing** alongside potential for **trapped moisture** can lead to accelerated deterioration of existing windows
- Large windows can be difficult to secondary glaze sensitively



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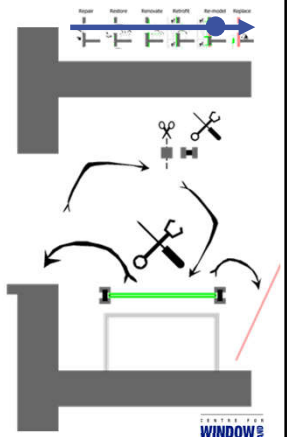
Re-model

Strategy: consider removing window and look at options to improve / adapt the frame and glass.

E.g. Retrofit seals / thermal breaks to existing frames.

Notes:

- Much more relevant to timber windows which are more adaptable
- Very difficult in metal windows



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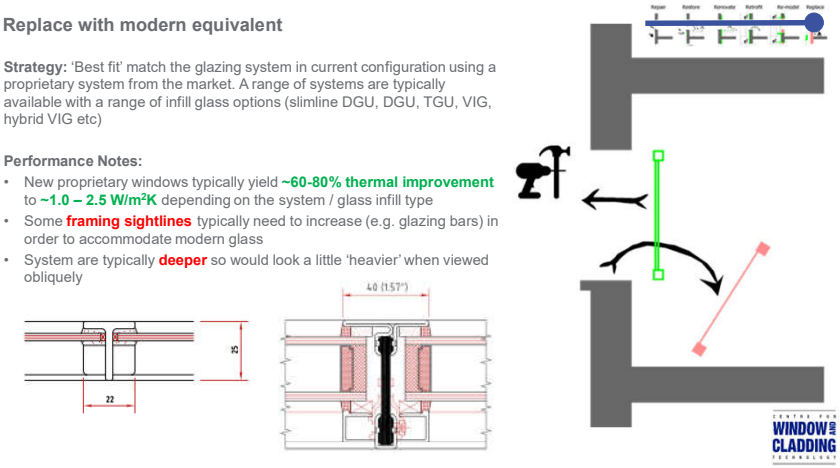
Replace with modern equivalent

Strategy: 'Best fit' match the glazing system in current configuration using a proprietary system from the market. A range of systems are typically available with a range of infill glass options (slimline DGU, DGU, TGU, VIG, hybrid VIG etc)

Performance Notes:

- New proprietary windows typically yield **~60-80% thermal improvement** to **~1.0 – 2.5 W/m²K** depending on the system / glass infill type
- Some **framing sightlines** typically need to increase (e.g. glazing bars) in order to accommodate modern glass
- System are typically **deeper** so would look a little 'heavier' when viewed obliquely



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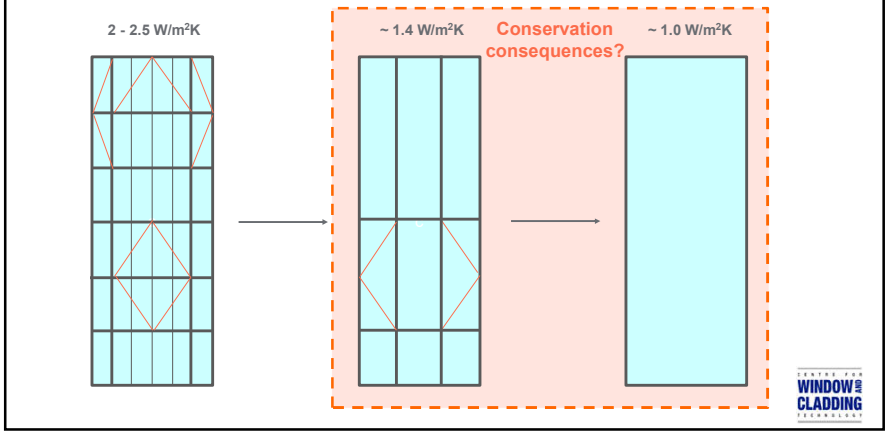
Consider options to increase performance



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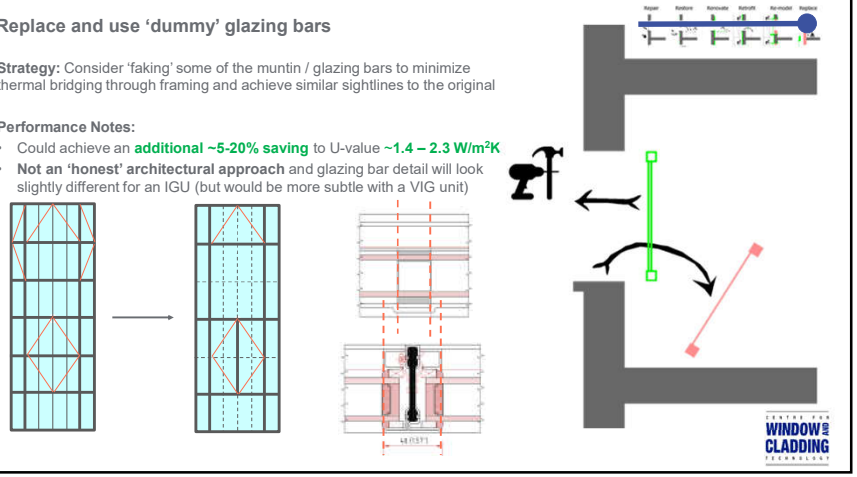
Replace and use 'dummy' glazing bars

Strategy: Consider 'faking' some of the muntin / glazing bars to minimize thermal bridging through framing and achieve similar sightlines to the original

Performance Notes:

- Could achieve an **additional ~5-20% saving** to U-value **~1.4 – 2.3 W/m²K**
- **Not an 'honest' architectural approach** and glazing bar detail will look slightly different for an IGU (but would be more subtle with a VIG unit)



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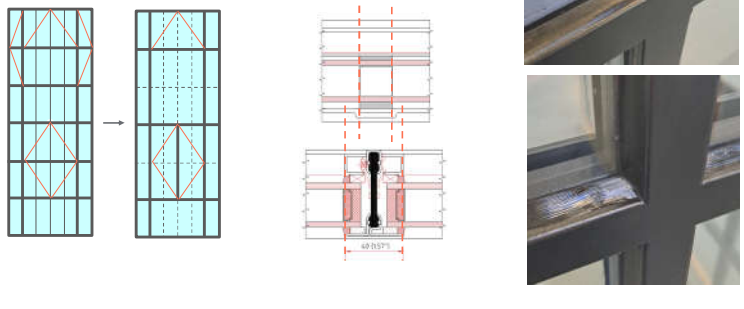
'Dummy' bars

Offer performance benefit but are not 'authentic' and are sometimes controversial with architects / planners

Likely to be much less noticeable in a VIG with no thermal loss



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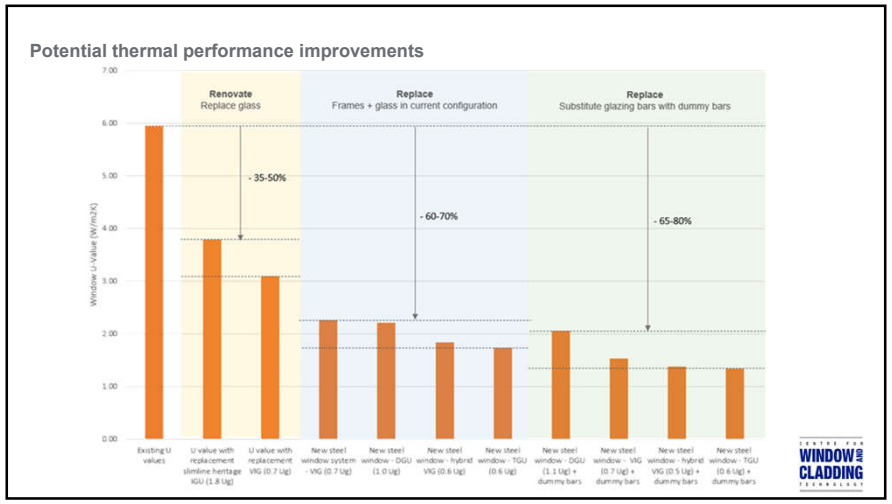

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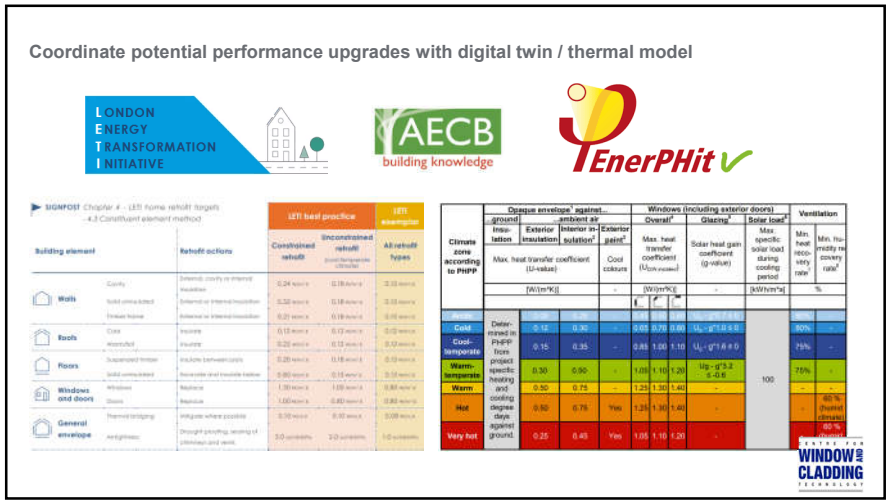

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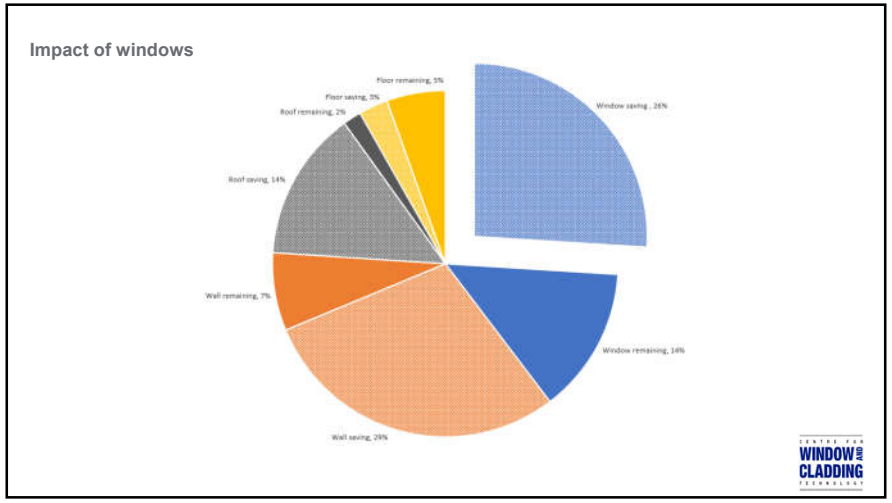

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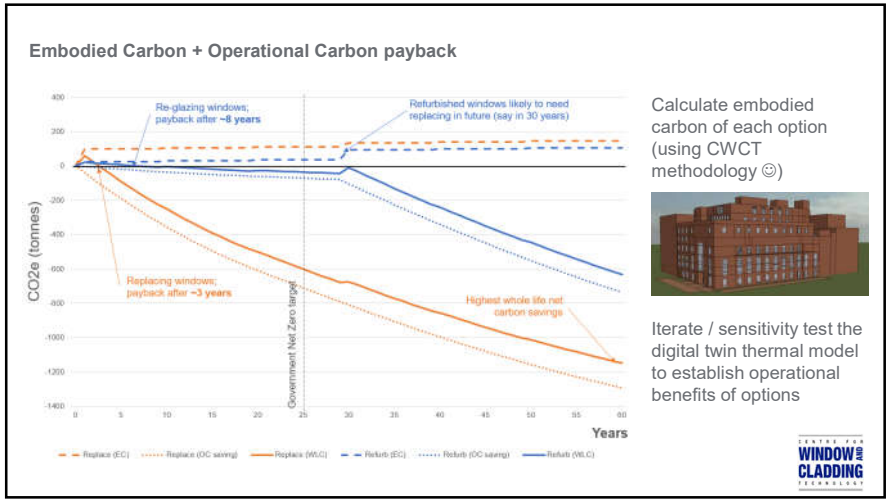

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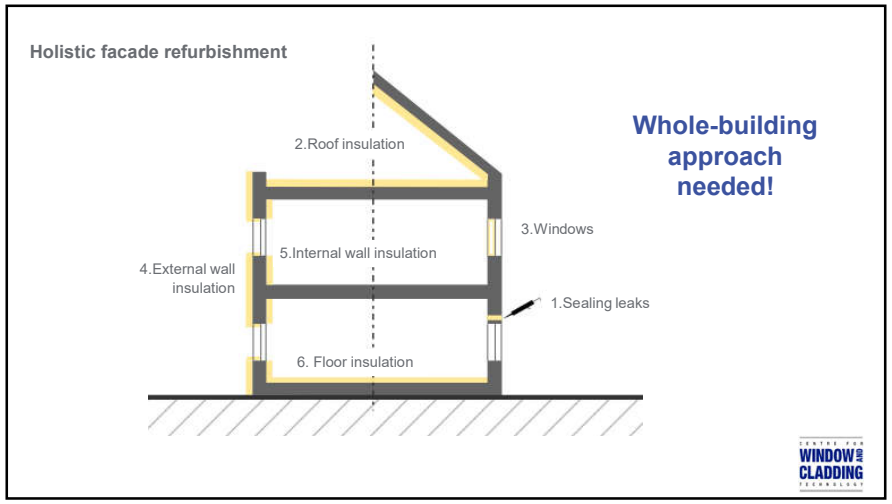
Holistic facade refurbishment
2.Roof insulation
3.Windows
5.Internal wall insulation
4.External wall insulation
1.Sealing leaks
6. Floor insulation
Whole-building approach needed!

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Thank you

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