

MONITORING MOISTURE IN HISTORIC BUILDING: A RETROFIT TO THE AECB SILVER STANDARD



Harry Paticas BA BSc AAdipl

Arboreal Architecture Ltd

St.Margaret's House, 21, Old Ford Road, London, E2 9PL, UK

harry@arborealarchitecture.com

+44 (0)20 8980 5066



PRESENTATION OVERVIEW

1. The existing building
2. Setting an appropriate standard
3. Pre-design investigations
4. Insulation specification
5. Overview of proposal
6. Standard achieved
7. Installation of sensors
8. Results from sensors
9. Trends and observations

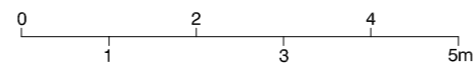
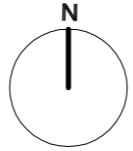
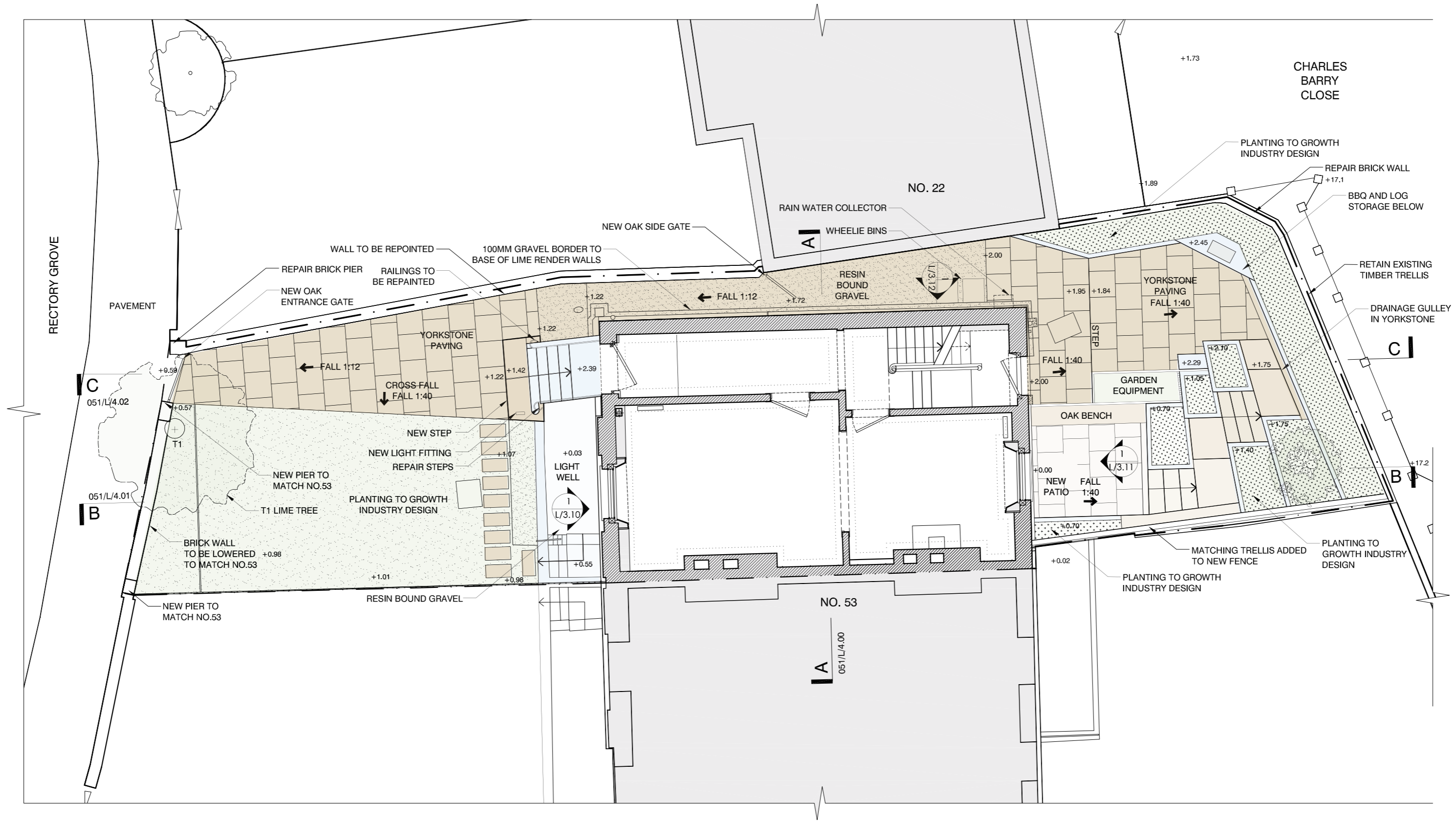
01_THE EXISTING BUILDING_LOCAL CONTEXT



01 THE EXISTING BUILDING LOCAL CONTEXT

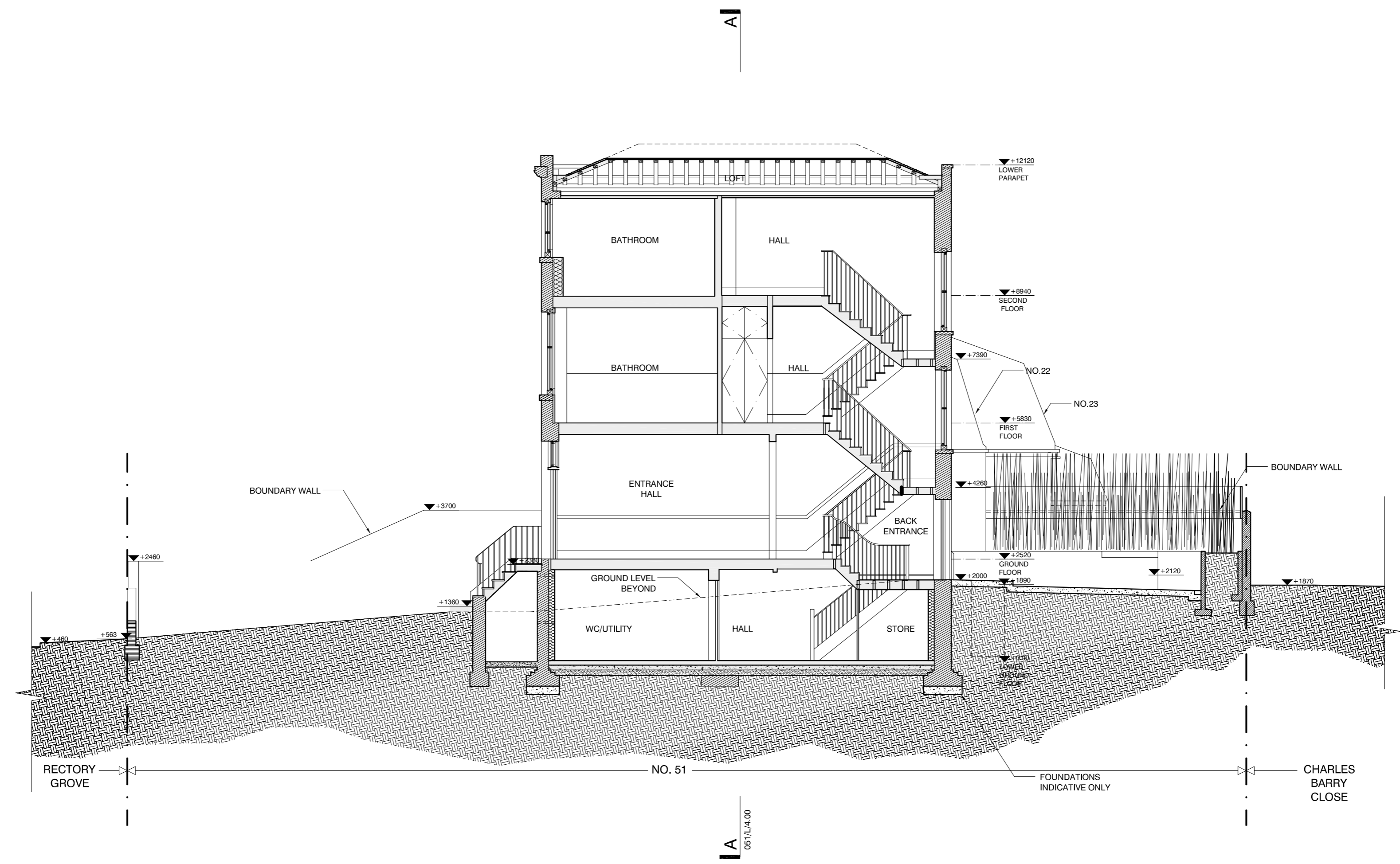


01_THE EXISTING BUILDING_SITE PLAN



PROPOSED CURTILAGE PLAN (GROUND FLOOR) 1
SCALE = 1:100

01_THE EXISTING BUILDING_SITE SECTION



01_THE EXISTING BUILDING_HISTORIC SIGNIFICANCE



1973

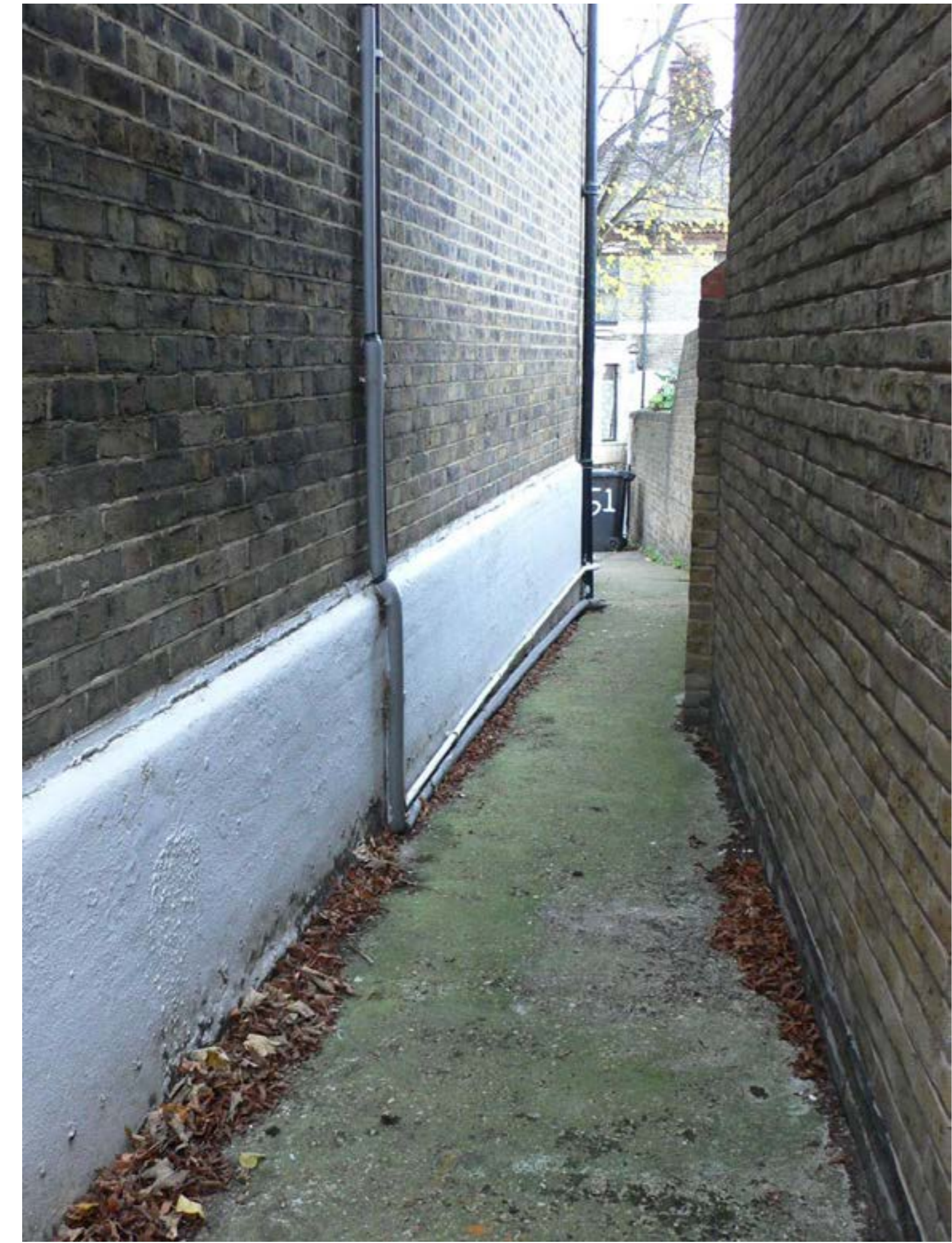
“Early C19 pair, each three stories and basement, two windows. Stock brick with stucco frieze, cornice and blocking course, first floor band and basement with incised lines. Gauged flat brick arches to sash windows with glazing bars in stucco lined reveals. Those on ground floor in segment headed recesses. Five steps, with wrought iron handrails, to doors of five panels in panelled reveals with cornice head and patterned fanlight (No 51 blocked).”

English Heritage Listing 1974

“...Nos. 51-53, a tall late Georgian pair...”

Pevsner's The Buildings of England - London 2

01 THE EXISTING BUILDING EXTERNAL FINISHES



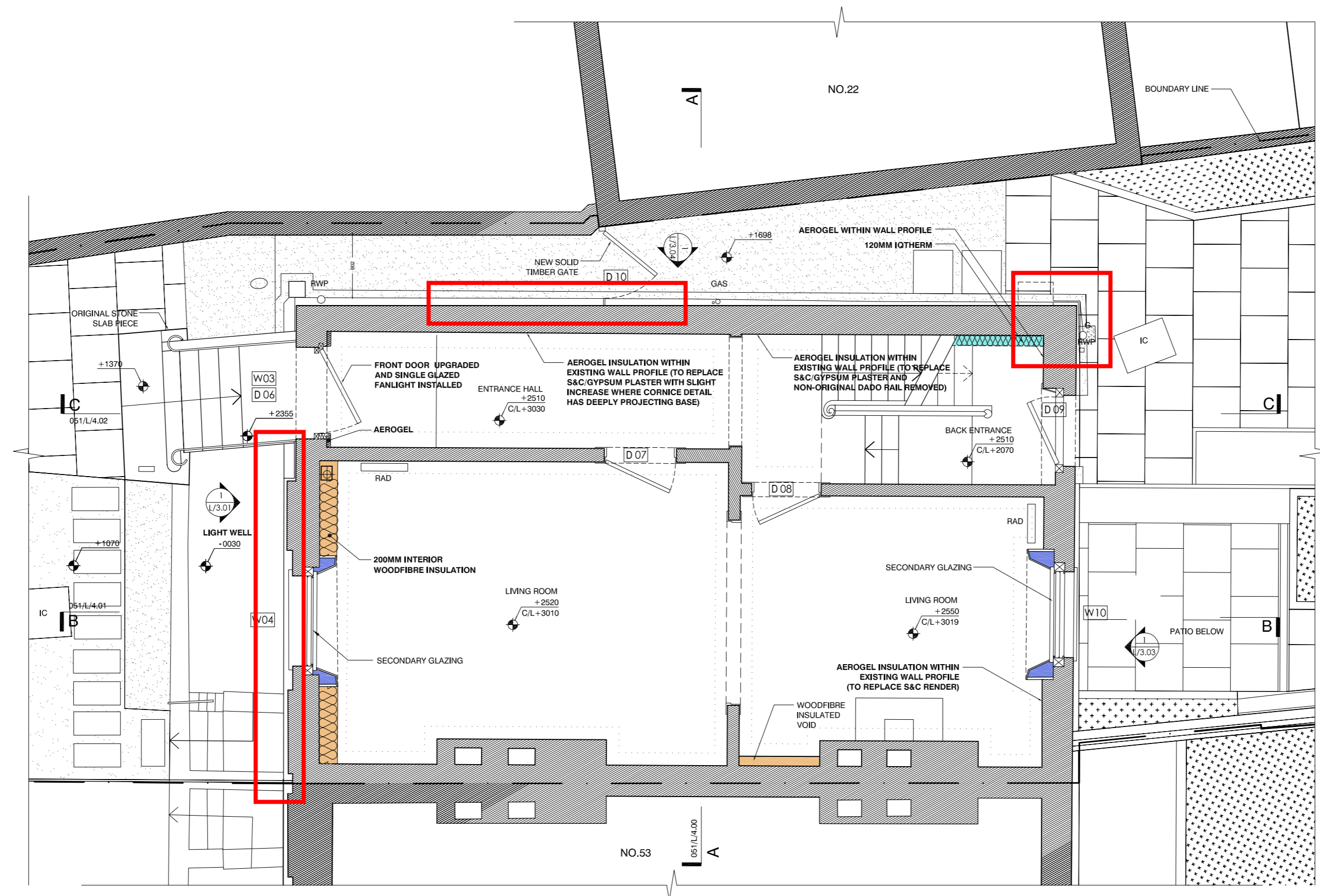
01_THE EXISTING BUILDING_INTERNAL FINISHES



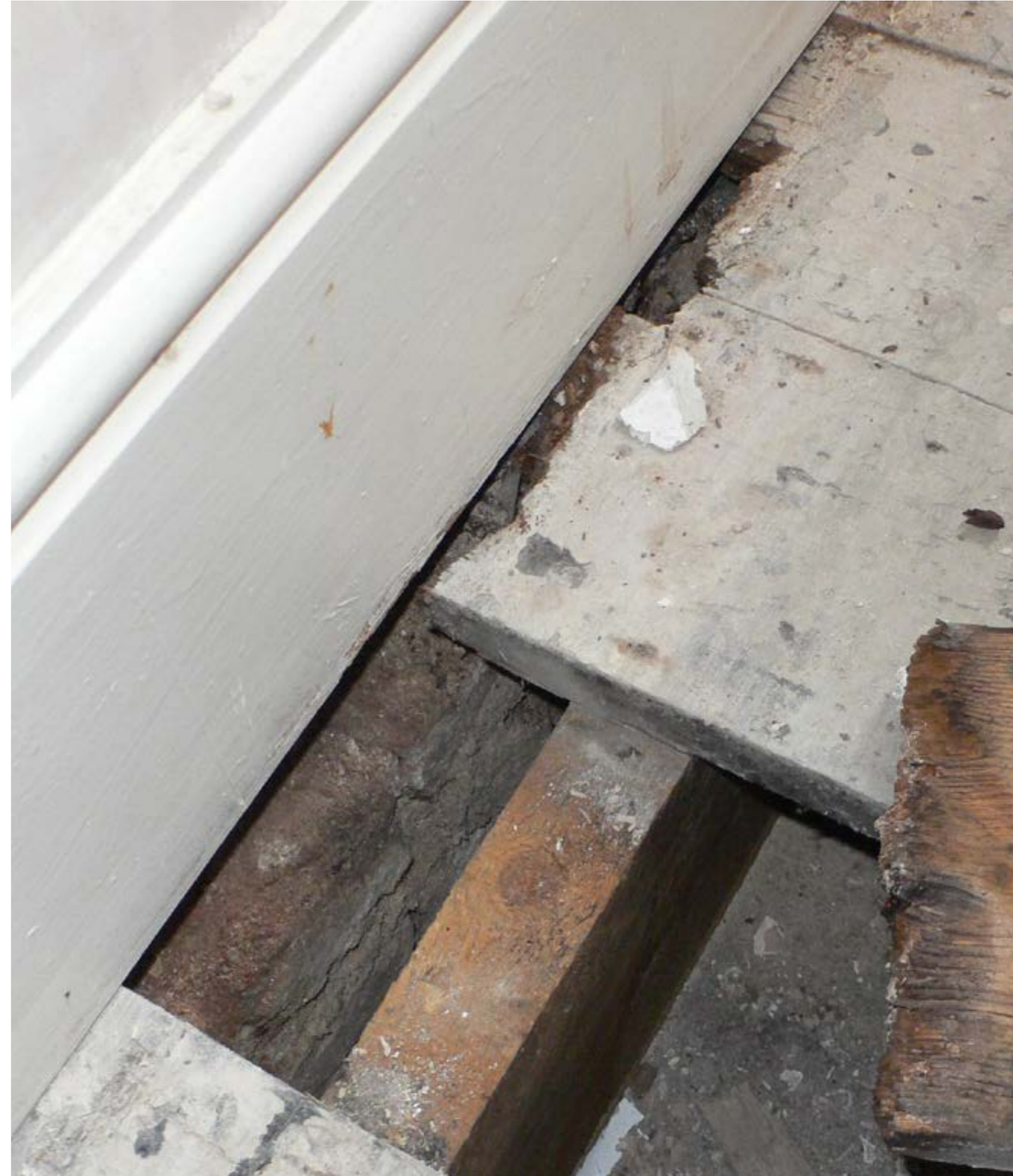
01_THE EXISTING BUILDING_INTERNAL FINISHES

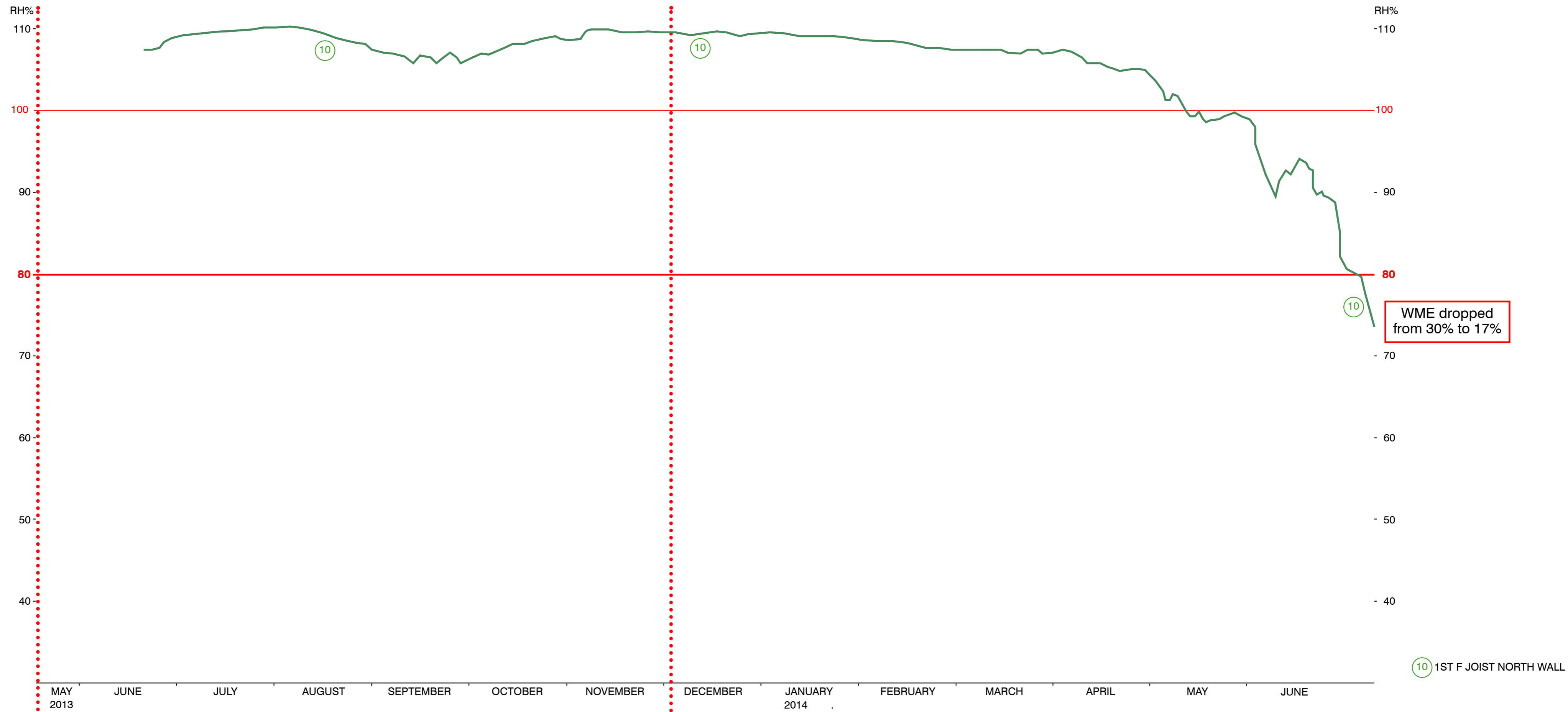


01_THE EXISTING BUILDING_BUILDING DEFECTS & MAINTENANCE



01_THE EXISTING BUILDING_BUILDING DEFECTS





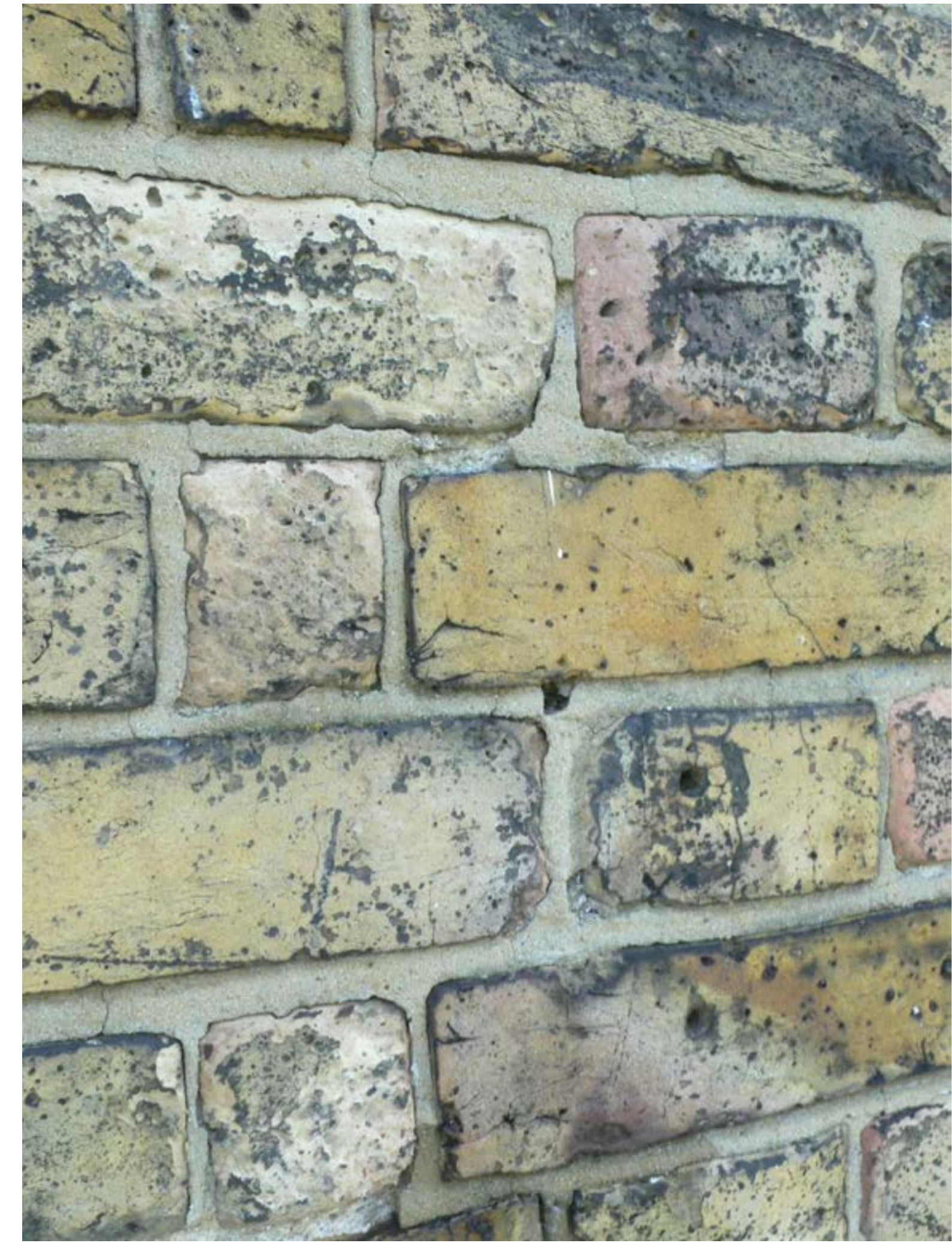
Sensors Installed
22.05.13

Client moved in
14.11.13

WME dropped
from 30% to 17%

10 1ST F JOIST NORTH WALL

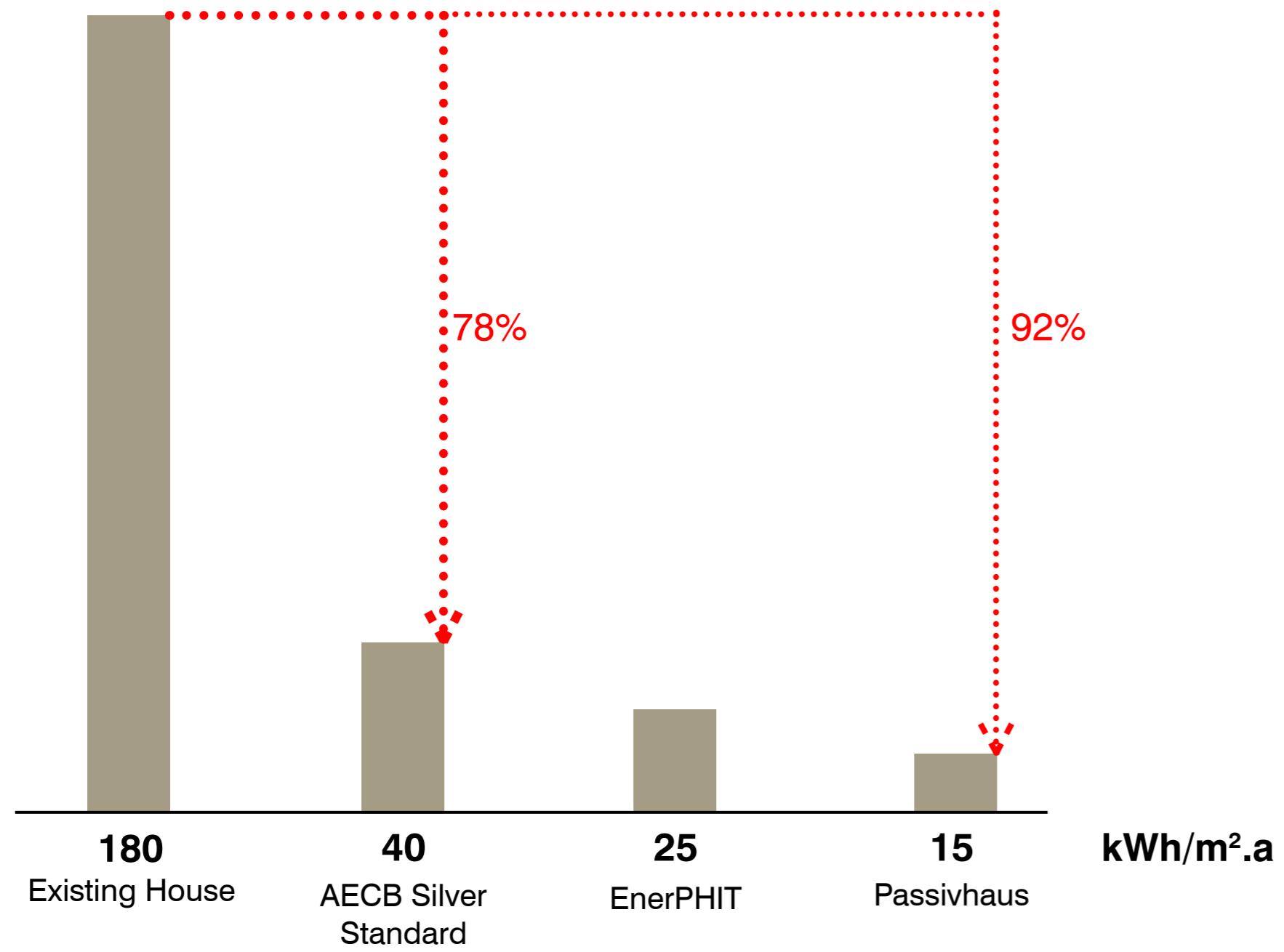
01 THE EXISTING BUILDING REPOINTING BEFORE AND AFTER



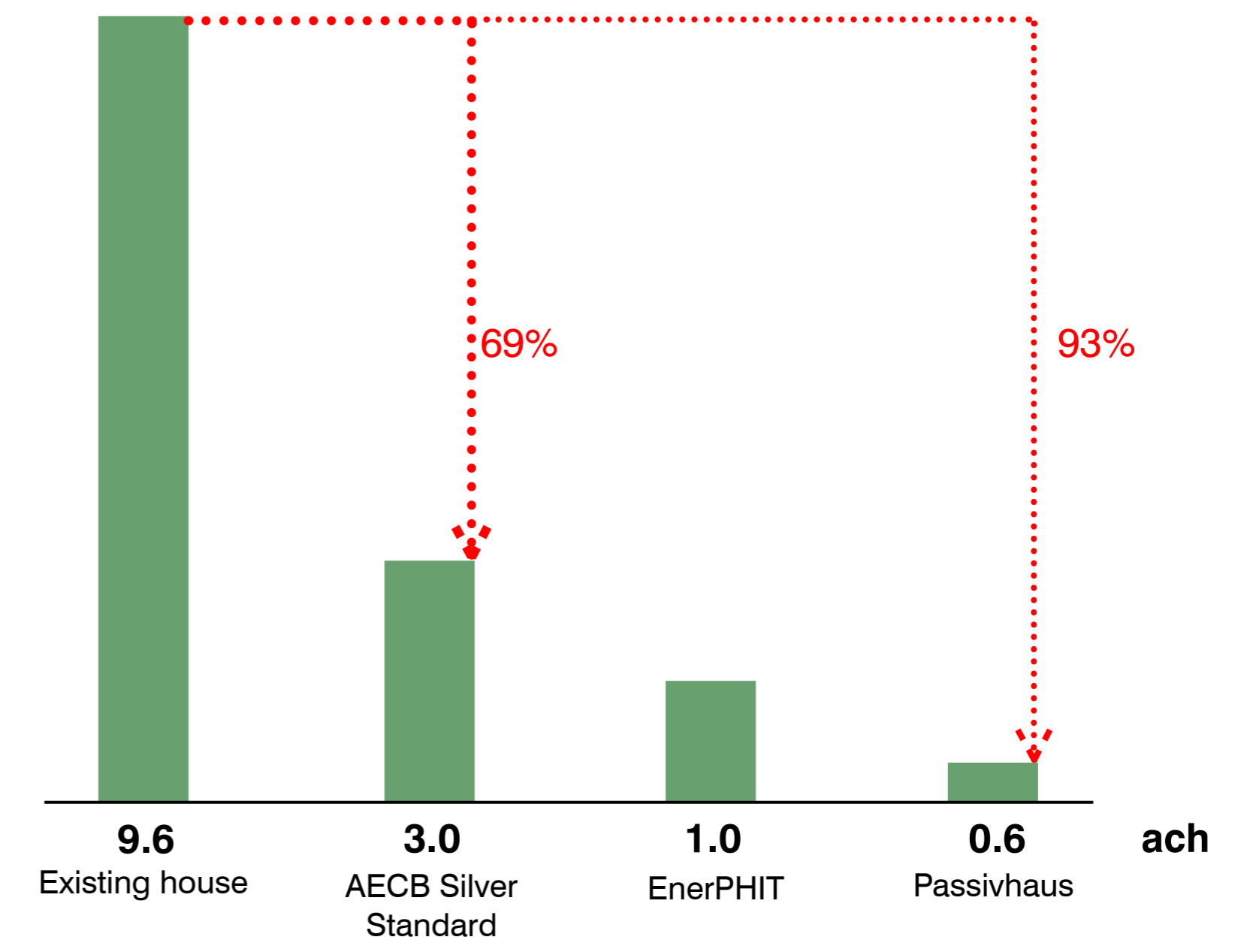
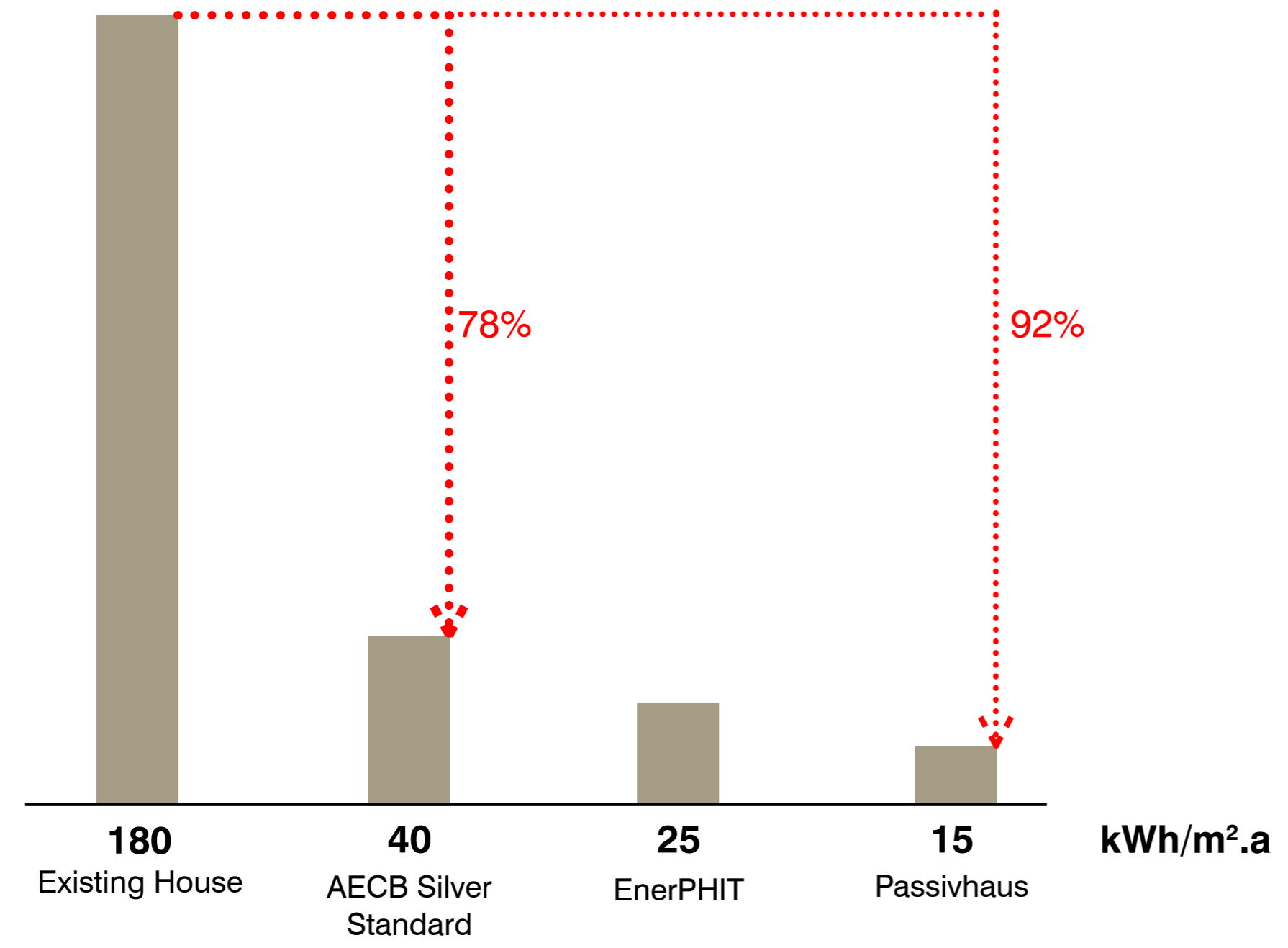
02_SETTING AN APPROPRIATE STANDARD DESIGN AMBITION

- To sensitively restore the house respecting original features
- To upgrade all building services
- To replace non-original kitchen and bathrooms
- To create a liveable house for the 21st century and beyond
- To improve the thermal performance

02_SETTING AN APPROPRIATE STANDARD_SHD



02_SETTING AN APPROPRIATE STANDARD_SHD AND AIRTIGHTNESS



03_PRE-DESIGN INVESTIGATIONS_ARCHIMETRICS



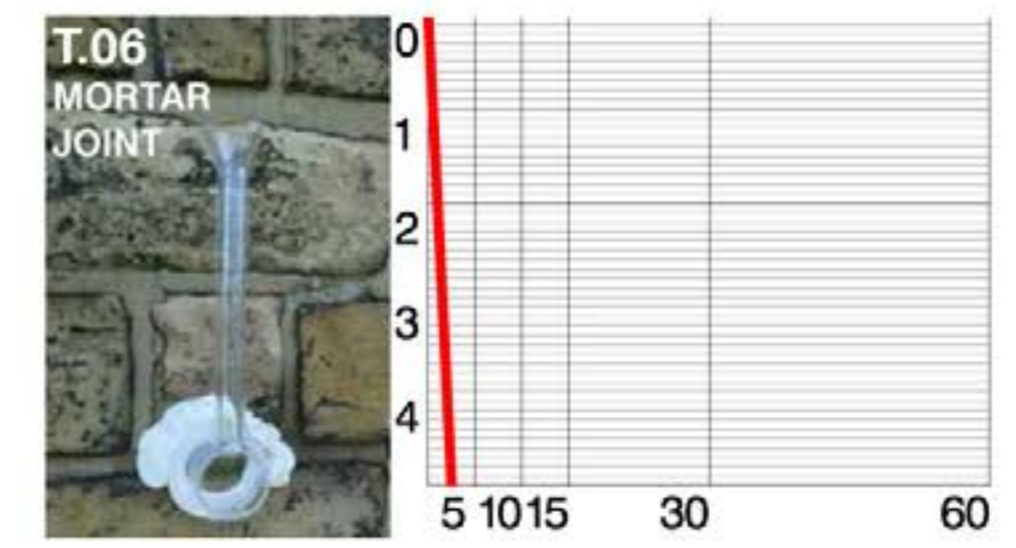
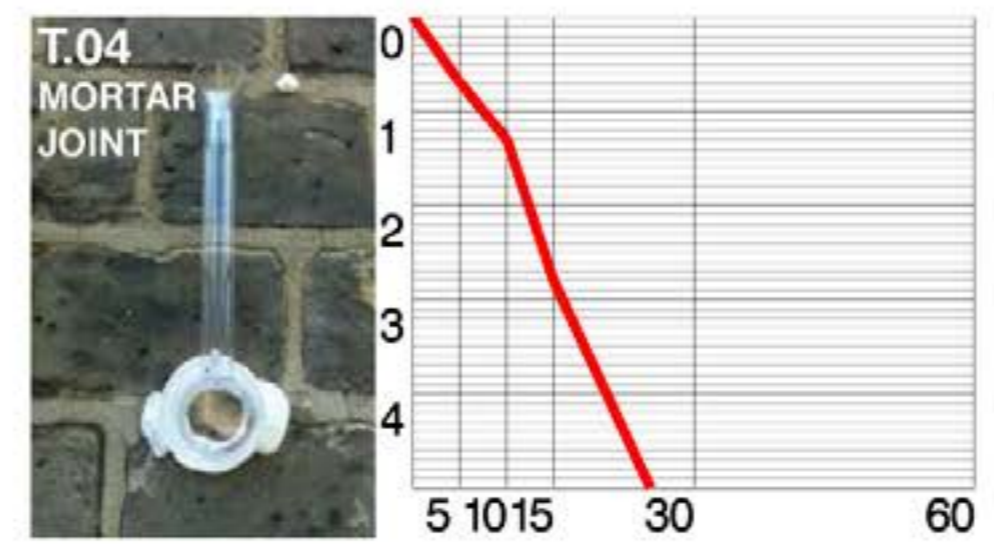
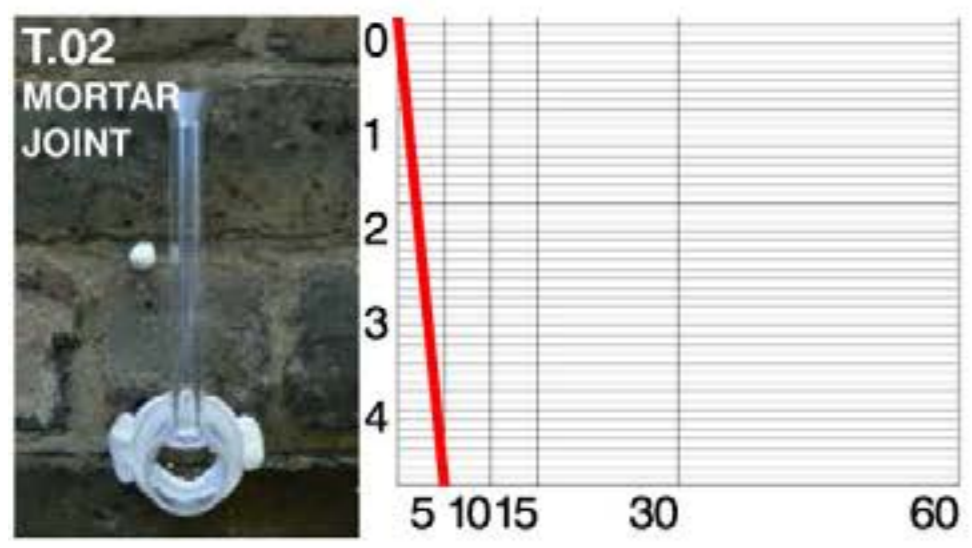
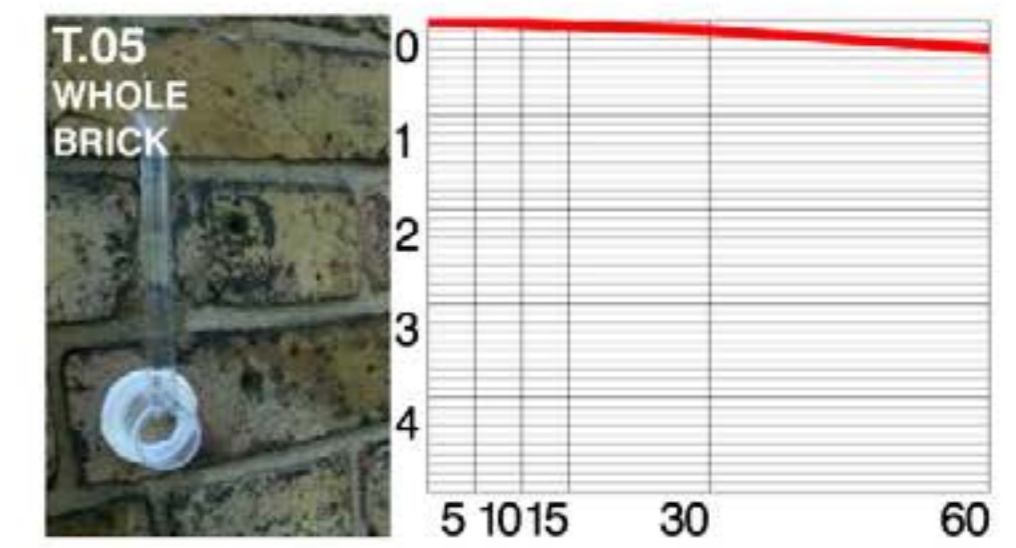
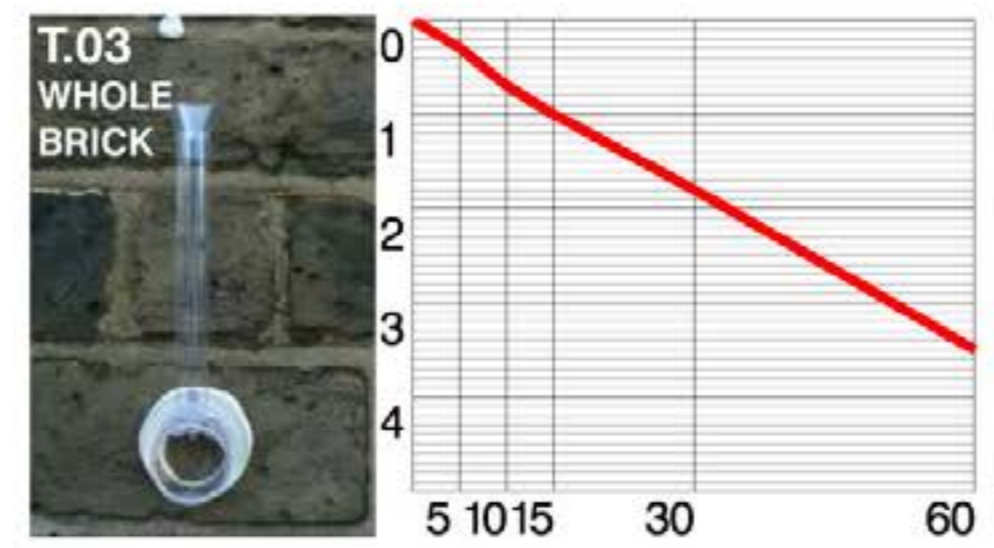
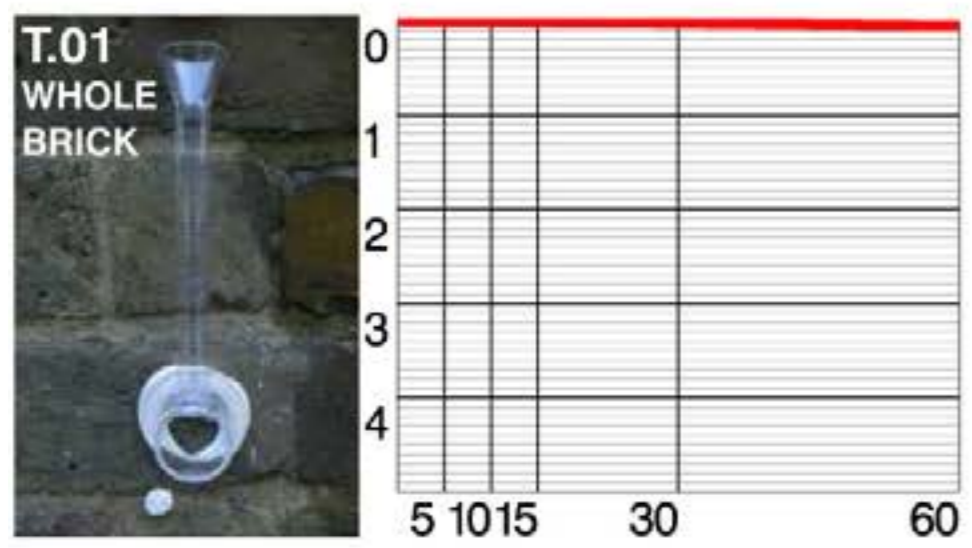
- survey carried out in **February 2012** by Archimetrics
- **u-value monitoring** - based on 2 separate locations the u-value for the brick walls ($0.88 \text{ W/m}^2\text{K}$) was significantly lower than calculated values ($1.14 \text{ W/m}^2\text{K}$).
- **air leakage test** - 9.6 ach (but excluding fixed ventilation points).
- **thermographic survey** - identified weak spots at openings and floor voids.
- **interstitial temperature and moisture gradient monitoring** - identified a reasonable margin of safety between the temperature and dewpoint gradients.

03_PRE-DESIGN INVESTIGATIONS_BRICK PERMEABILITY TESTING



03_PRE-DESIGN INVESTIGATIONS_BRICK PERMEABILITY TESTING

TEST	TYPE	TIME	5MIN	10MIN	15MIN	30MIN	60MIN
T.01	LONDON YELLOW STOCK BRICK	0ML	0ML	0ML	0.01ML	0.025ML	0.05ML
T.02	MORTAR JOINT	0ML	4ML	-	-	-	-
T.03	LONDON YELLOW STOCK BRICK	0ML	0.3ML	0.7ML	1ML	1.8ML	3.5ML
T.04	MORTAR JOINT	0ML	0.7ML	1.3ML	2.8ML	-	-
T.05	LONDON YELLOW STOCK BRICK	0ML	0ML	0ML	0.05ML	0.12ML	0.3ML
T.06	MORTAR JOINT	0ML	4ML	-	-	-	-



03_PRE-DESIGN INVESTIGATIONS_ROOF CONDITION



03_PRE-DESIGN INVESTIGATIONS_ROOF CONDITION



04_INSULATION SPECIFICATION_RANGE OF FACTORS TO CONSIDER

- Hygrothermal condition of existing building fabric
- Historic significance, character and special interest
- Local climate conditions
- Existing wall build up and available thickness for insulation
- Thermal performance (lambda and resultant u-value)
- Vapour permeability
- Hygroscopicity and moisture buffering
- Capillarity
- Buildability, storage and material processes
- Fire rating
- Reversibility
- Cost
- Compatibility with thermal bridging, airtightness and ventilation strategies
- Embodied energy and global warming potential

04_INSULATION SPECIFICATION_MOISTURE RELATED FACTORS

- Existing building fabric - *maintenance and condition*
- Local climate conditions and orientation - *consider driving rain and solar radiation*
- Existing wall build up - *e.g. presence of cementitious materials, thickness of brick, absorptivity*
- Ventilation strategies - *management of internal humidity*
- Thermal performance (lambda and resultant u-value) - *through testing and calculation*
- Vapour permeability (miu and sd values) - *often measured as the resistance to vapour transport*
- Hygroscopicity and moisture buffering - *sorption and desorption of water vapour*
- Capillarity - *sorption and desorption of liquid water*
- Compatibility with thermal bridging - *adjacent uninsulated elements will have higher heat loss*

04_INSULATION SPECIFICATION_MATERIALS RESEARCHED



04_INSULATION SPECIFICATION_MATERIALS RESEARCHED



Name: Foamglas Perinsul
Material: high density foamed glass
Location: door and window sills
Thermal conductivity: 0.058 W/m.K
Vapour diff resistance (μ): ∞



Name: Remmers iQ therm
Material: PIR + capillary active plugs
Location: internal wall insulation
Thermal conductivity: 0.031 W/m.K
Vapour diff resistance (μ): 27



Name: Excel Warmcel 500
Material: blown cellulose
Location: loft floor + shutter boxes
Thermal conductivity: 0.04 W/m.K
Vapour diff resistance (μ): 2



Name: Technopor
Material: foamed glass granulate
Location: external perimeter
Thermal conductivity: 0.08 W/m.K
Vapour diff resistance (μ): low



Name: Silvapor
Material: perlite beads
Location: stair stringer
Thermal conductivity: 0.045 W/m.K
Vapour diff resistance (μ): low



Name: Calsitherm
Material: calcium silicate board
Location: between joists
Thermal conductivity: 0.06 W/m.K
Vapour diff resistance (μ): 6



Name: Gutex Thermoroom
Material: woodfibre
Location: internal wall insulation
Thermal conductivity: 0.04 W/m.K
Vapour diff resistance (μ): 3



Name: Kevothermal VIP
Material: vacuum insulated panel
Location: ground floor below screed
Thermal conductivity: 0.007 W/m.K
Vapour diff resistance (μ): ∞

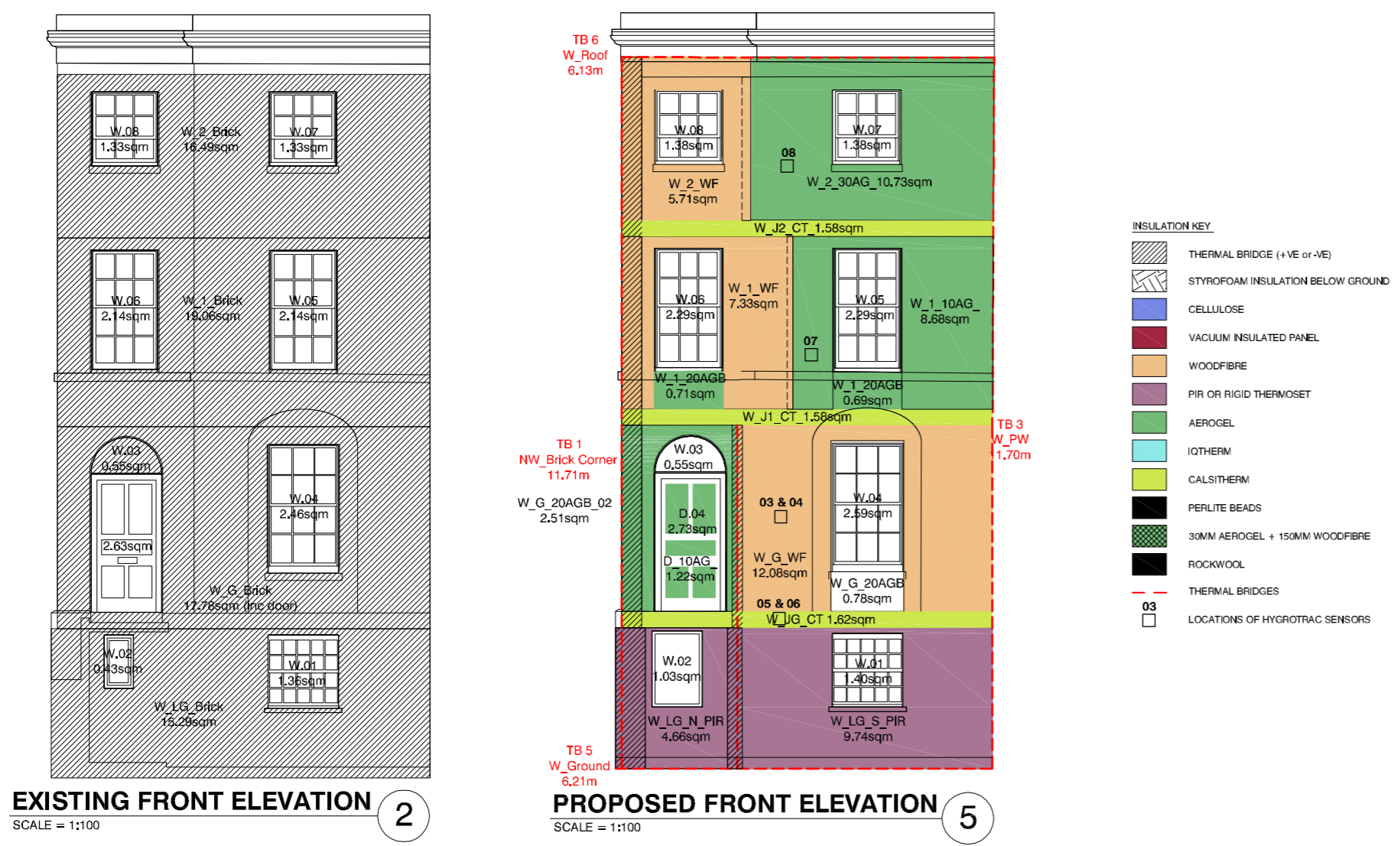


Name: Thermablok SP
Material: aerogel blanket
Location: internal wall insulation
Thermal conductivity: 0.014 W/m.K
Vapour diff resistance (μ): 5.5

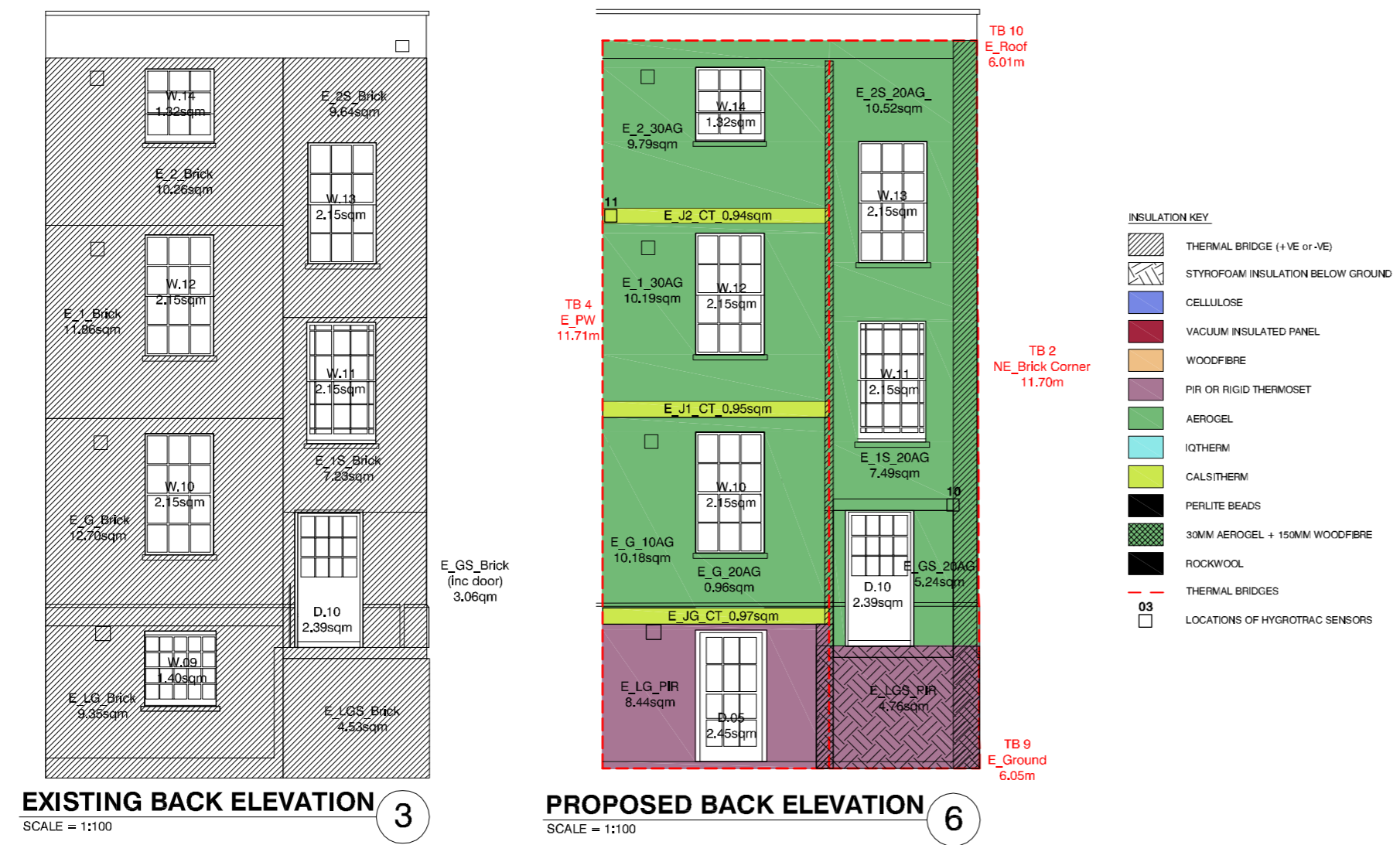


Name: Kingspan Styrozone N300R
Material: extruded polystyrene
Location: below ground external
Thermal conductivity: 0.038 W/m.K
Vapour diff resistance (μ): high

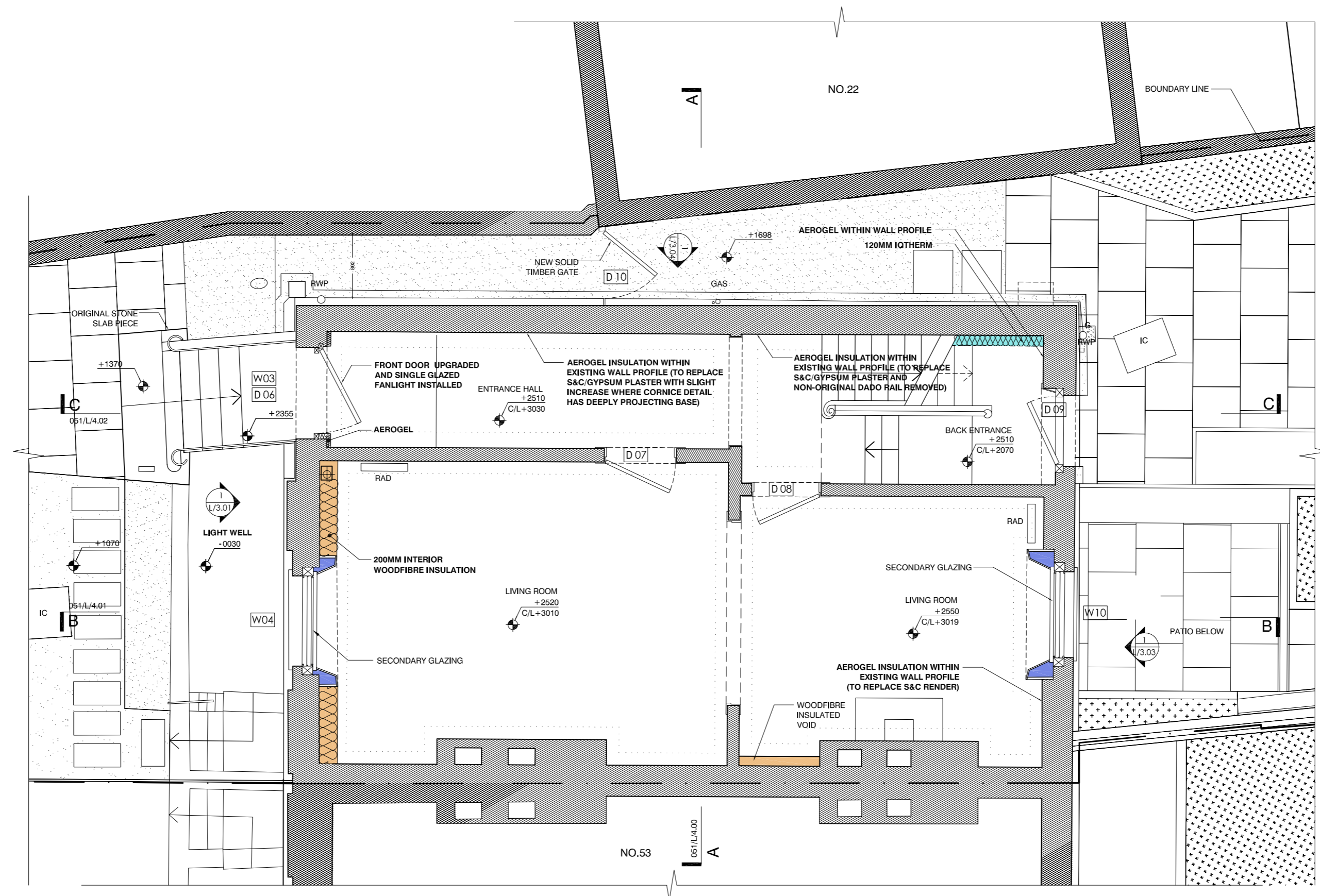
05_OVERVIEW OF PROPOSAL_FRONT ELEVATION



05_OVERVIEW OF PROPOSAL_REAR ELEVATION



05_OVERVIEW OF PROPOSAL_GROUND FLOOR PLAN

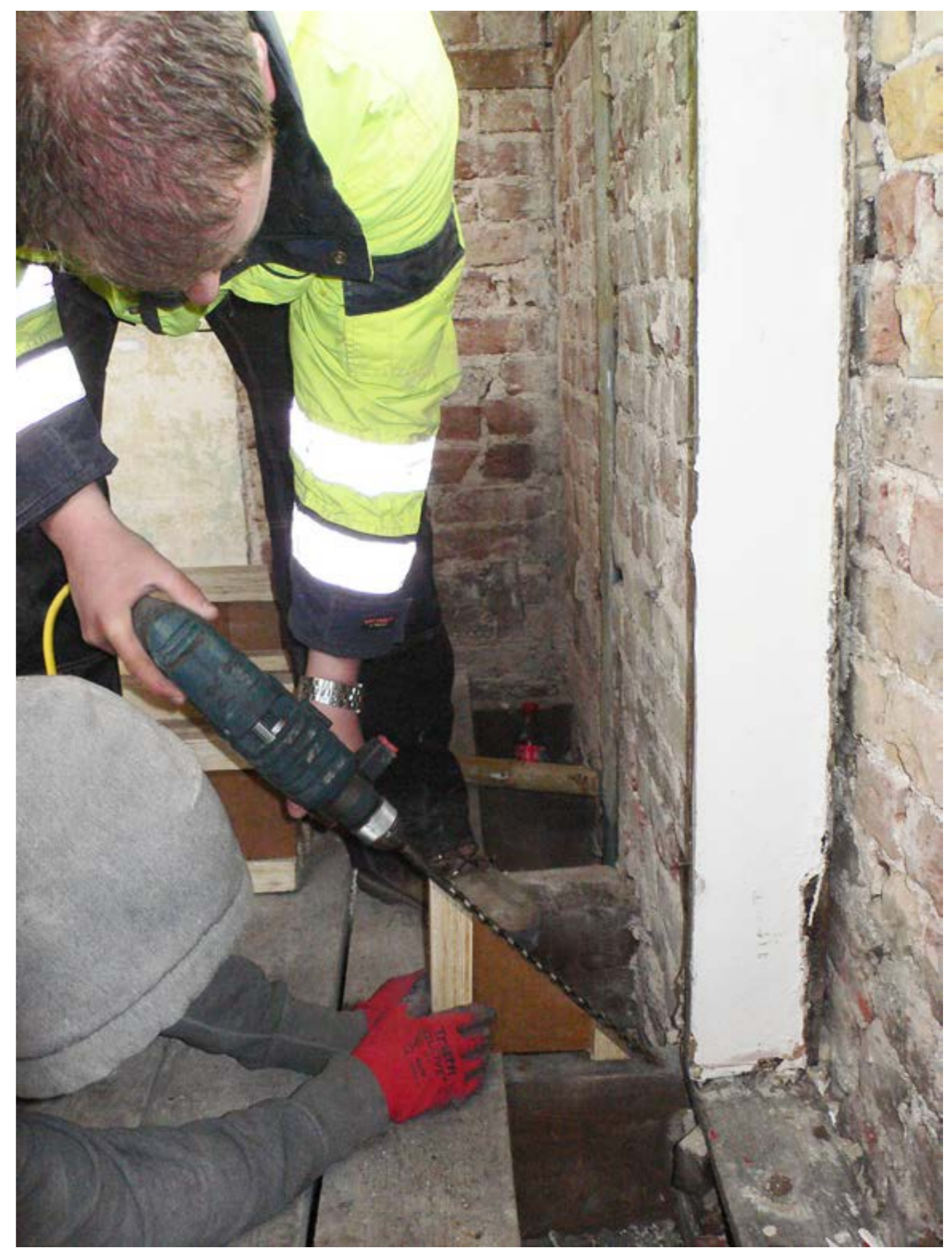
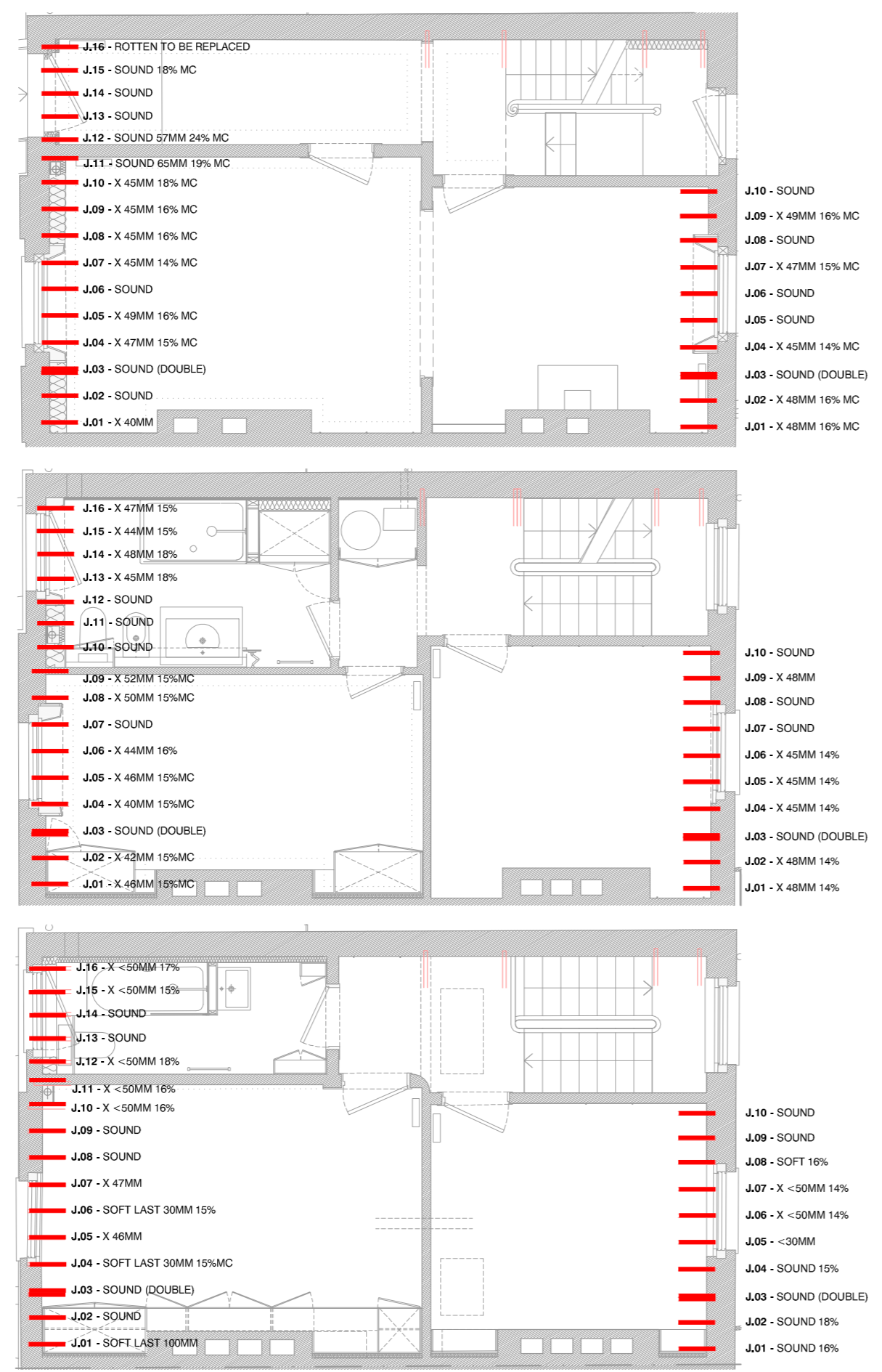


05_OVERVIEW OF PROPOSAL_VENTILATION AND AIRTIGHTNESS



- continuous air barrier formed by lime plaster on all internal masonry walls.
- taped intello plus membrane dressed into all walls with plaster sealing tape.
- joist ends and door/window frames sealed with tapes.
- services penetrations with grommets.
- continuous mechanical extract ventilation system (MEV) installed extracting air from each wet room total 0.4ach.
- air intake through natural leakiness of building.
- warm internal air thus pulled away from building fabric reducing risk of interstitial condensation.

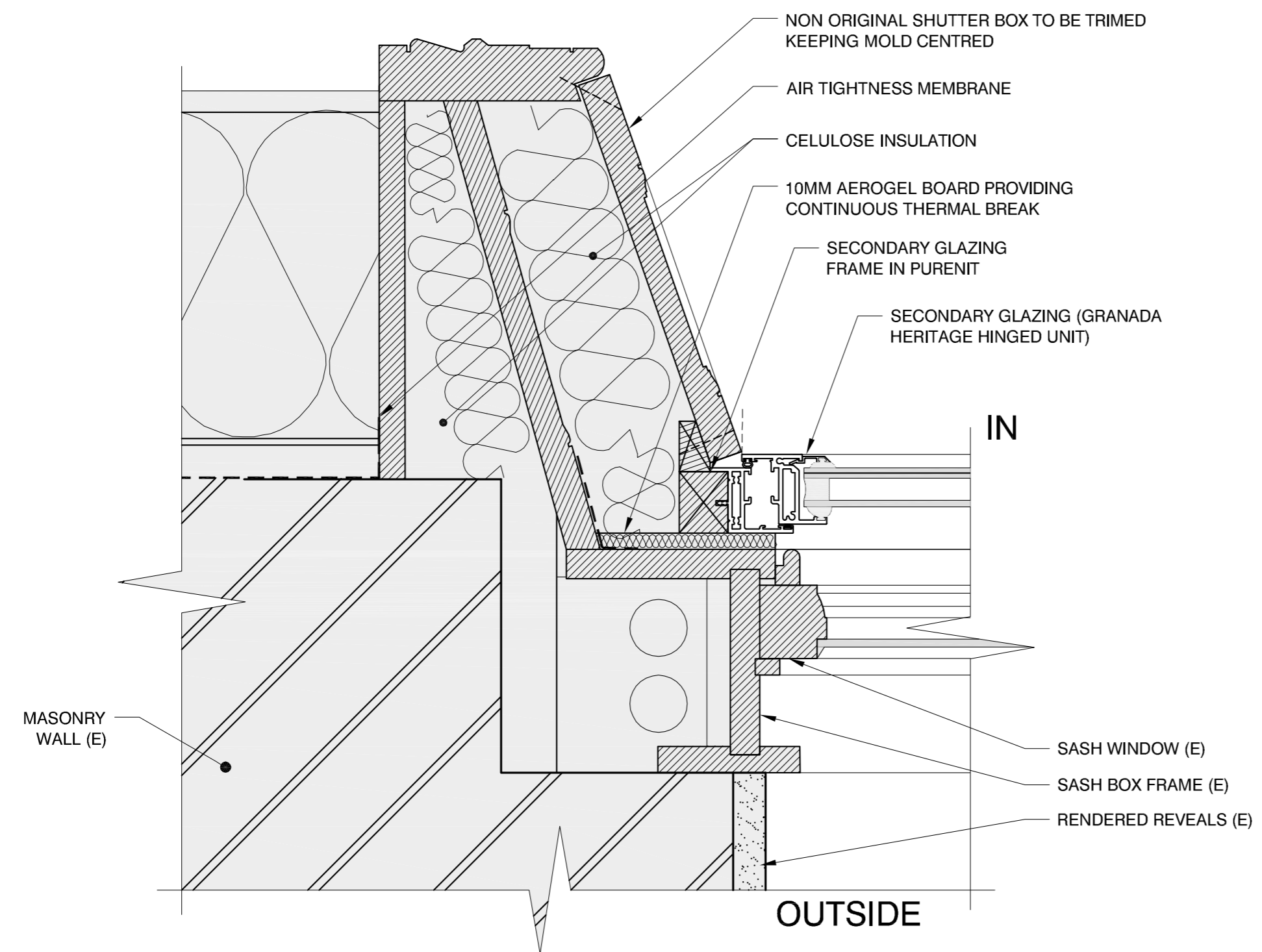
05_OVERVIEW OF PROPOSAL_JOIST SURVEY AND TREATMENT



05_OVERVIEW OF PROPOSAL_PROJECT DRAWINGS



CONSTRUCTION: SECONDARY GLAZING



PLAN @ SECONDARY GLAZING WITH SHUTTER BOXES (W.04) D3
SCALE = 1:5

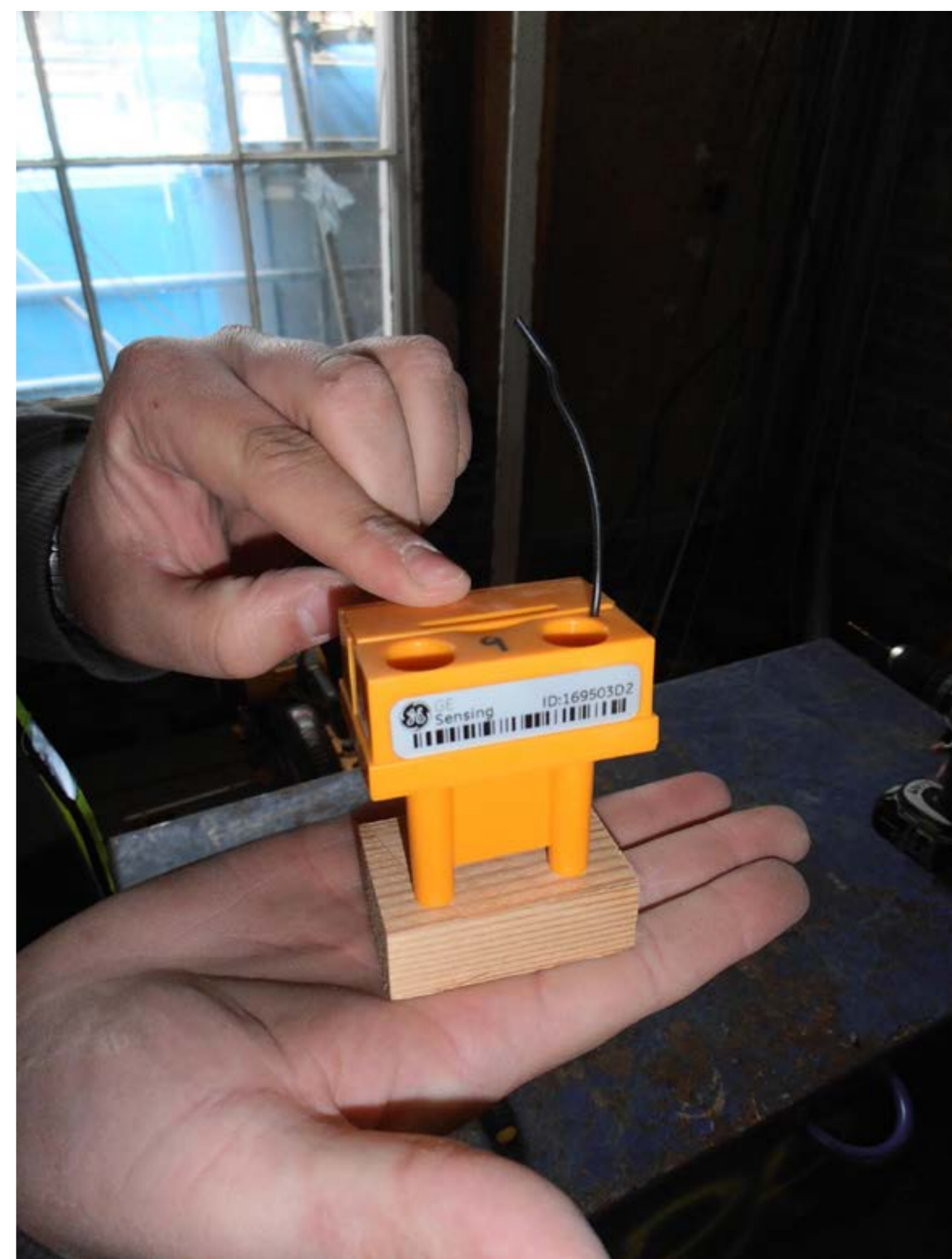


06_STANDARD ACHIEVED_AECB SILVER

- **Space Heat Demand (SHD)**
 - Existing house (PHPP) - 180kWh/m².a
 - Retrofit (PHPP)- 40kWh/m².a (78% reduction in energy for heating)
 - Energy bills are being monitored over time
- **Primary Energy**
 - Retrofit (PHPP) - 114kWh/m².a
- **Airtightness**
 - Existing house - 9.6ach
 - Retrofit - 1.8ach (with co-pressurisation of neighbouring house)
- **Hygrothermal performance**
 - Hygrotrac sensors being constantly monitored
- **Comfort and indoor air quality**
 - Clients have felt comfortable throughout the winter
 - Ambient internal humidity 50-55% and temperature at 20 degrees



07_INSTALLATION OF SENSORS_HYGROTRAC WIRELESS SENSORS



07_INSTALLATION OF SENSORS_HYGROTRAC INTERFACE




Sensors for Arboreal - IWI

Show : All Only Alarming Only Active

Delete Checked Sensors

Sensor Type 1 - T, RH and Wood Moisture										
Sensor Id	Description	Last Activity	Sts	T(°C)	%RH	AH(g/kg)	DP(°C)	%WME	Vbatt(Vdc)	<input checked="" type="checkbox"/>
1695036E	01 - North Wall 2nd Floor +1500 glass shower screen	14-04-20 09:48:56	I							<input checked="" type="checkbox"/>
1695006B	02 - Ground Floor - Interior Ambient	14-04-24 10:41:34	A							<input checked="" type="checkbox"/>
16950077	03 - West Wall - Ground Floor +1200 - cold side brick	14-04-24 10:35:52	A							<input checked="" type="checkbox"/>
16950064	04 - West Wall - Ground Floor +1200 - warm side ins	14-04-24 10:40:02	A							<input checked="" type="checkbox"/>
1695011D	05 - West Wall - Ground Floor - cold side between joists	14-04-24 09:55:00	A							<input checked="" type="checkbox"/>
169503C1	06 - West Wall - Ground Floor - warm side between joists	14-04-24 10:47:08	A							<input checked="" type="checkbox"/>
1695008A	07 - West Wall - 1st Floor +1200 - cold side brick	14-04-24 10:11:12	A							<input checked="" type="checkbox"/>
1695009A	08 - West Wall - 2nd Floor +1200 - cold side brick	14-04-24 10:41:36	A							<input checked="" type="checkbox"/>
169503D2	09 - North Wall - Ground Floor +1200 - cold side brick	14-04-24 10:44:16	A							<input checked="" type="checkbox"/>
16950010	10 - North Wall - 1st Floor landing - cold side joist end	14-04-24 10:41:22	A							<input checked="" type="checkbox"/>
169503BC	11 - East Wall - 2nd Floor - corner joist end	14-04-24 09:56:52	A							<input checked="" type="checkbox"/>
1955024C	12 - West Wall - External Ambient	14-04-24 10:31:20	A							<input checked="" type="checkbox"/>
195500B2	13 - 1st floor south wall - chimney flue	14-04-24 10:06:12	A							<input checked="" type="checkbox"/>
19550068	14 - 2nd floor ceiling - cold side	14-04-24 10:42:04	A							<input checked="" type="checkbox"/>
195503A0	15 - Cold loft - ambient	14-04-24 10:04:58	A							<input checked="" type="checkbox"/>

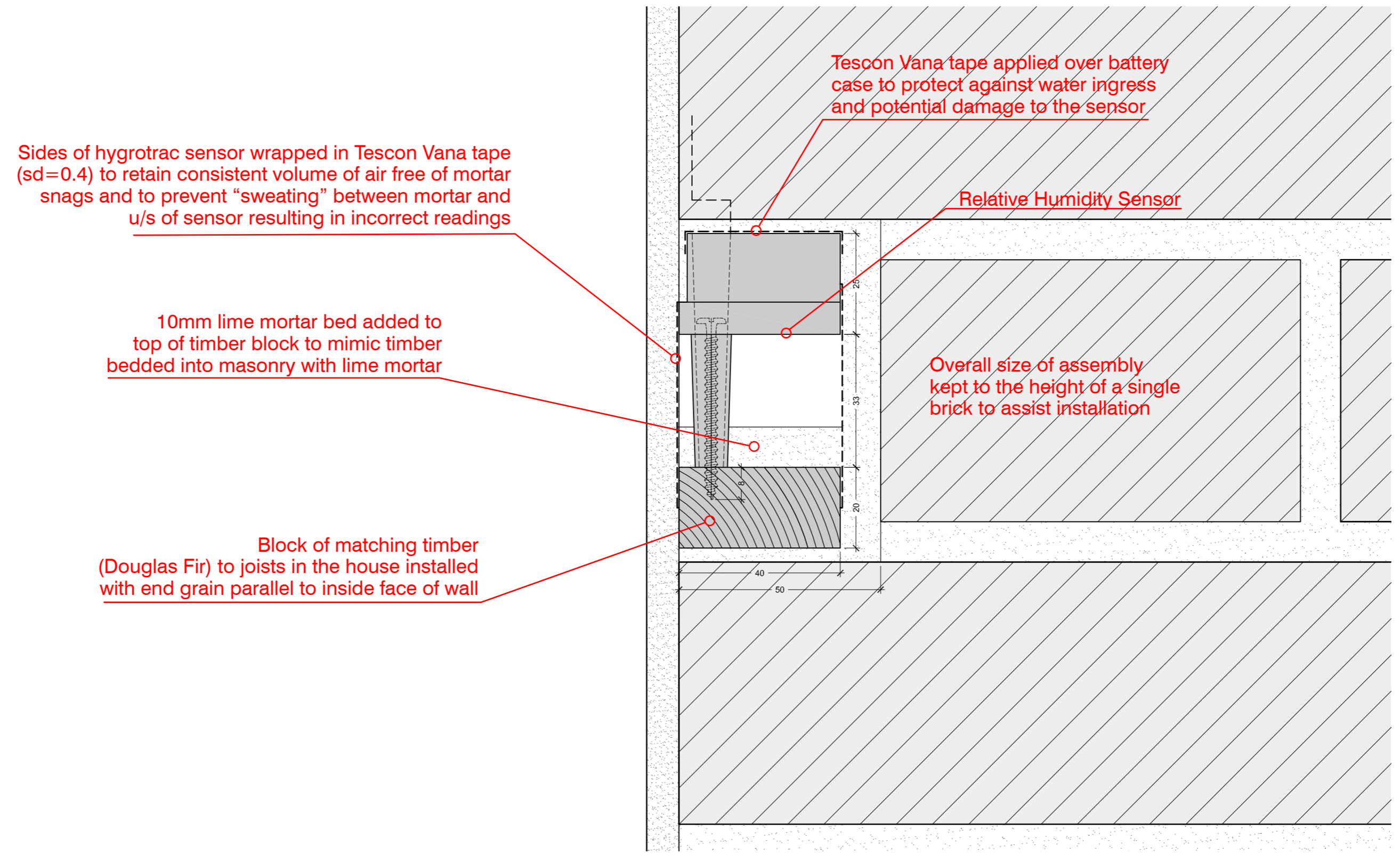
Page Help

- To **View All Sensor Detail and/or Activity** click on a Sensor Id.
- To **Sort On a Column** click on a Column Header.
- To **To Graph a Specific Data Type** click on a Data Value.
- To **Delete** one or more sensors check their delete box then click on **Delete** button.
- To **Edit or Deactivate** a Sensor click on the sensor description.
-  indicates an alarm has been triggered for that sensor. Click on the icon to see the alarm detail for that sensor.

07_INSTALLATION OF SENSORS_HYGROTRAC WIRELESS SENSORS



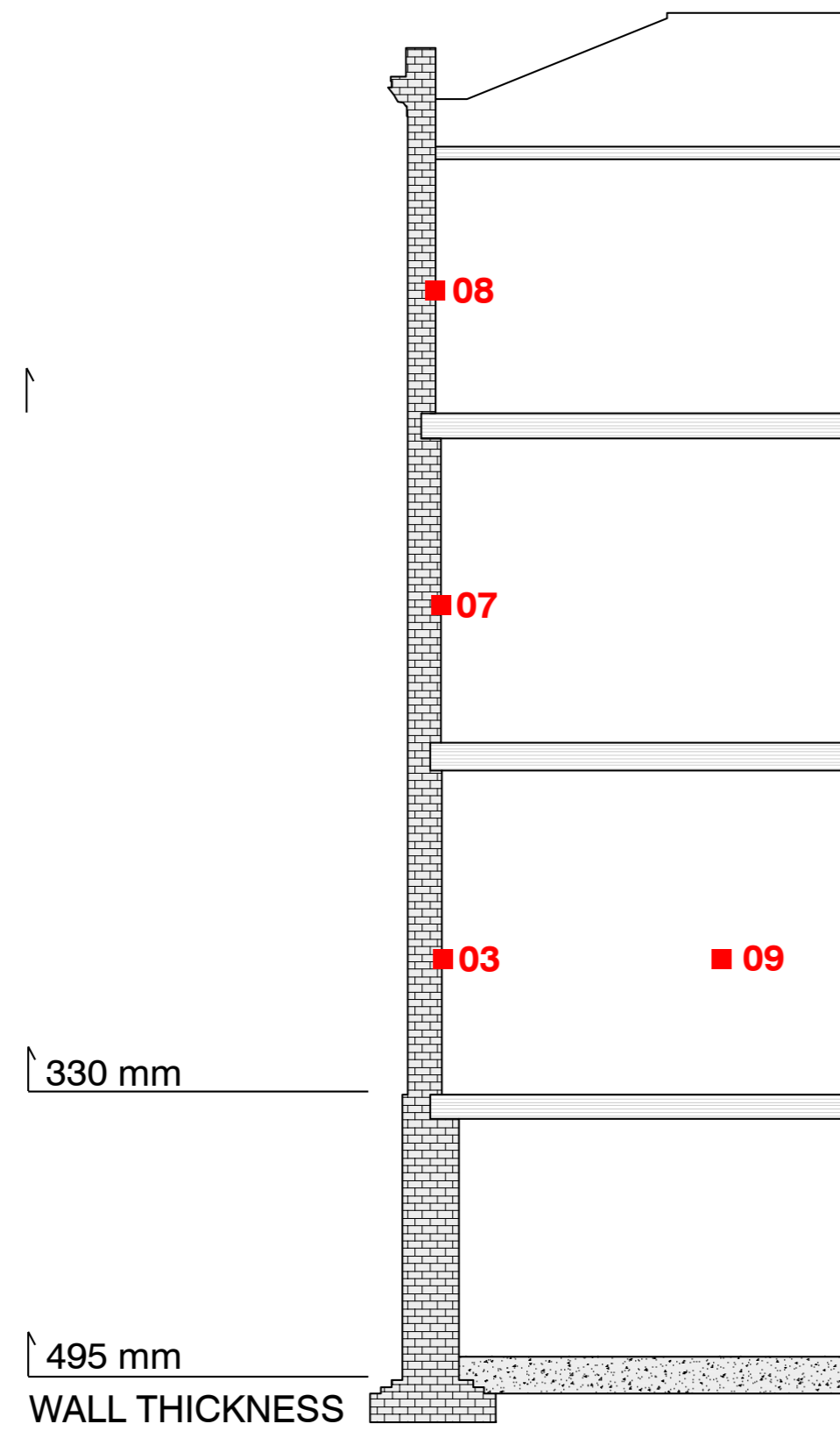
07_INSTALLATION OF SENSORS_HYGROTRAC WIRELESS SENSORS



SECTION @ MASONRY WALL (INSULATION NOT SHOWN)
SCALE = 1:1

D1

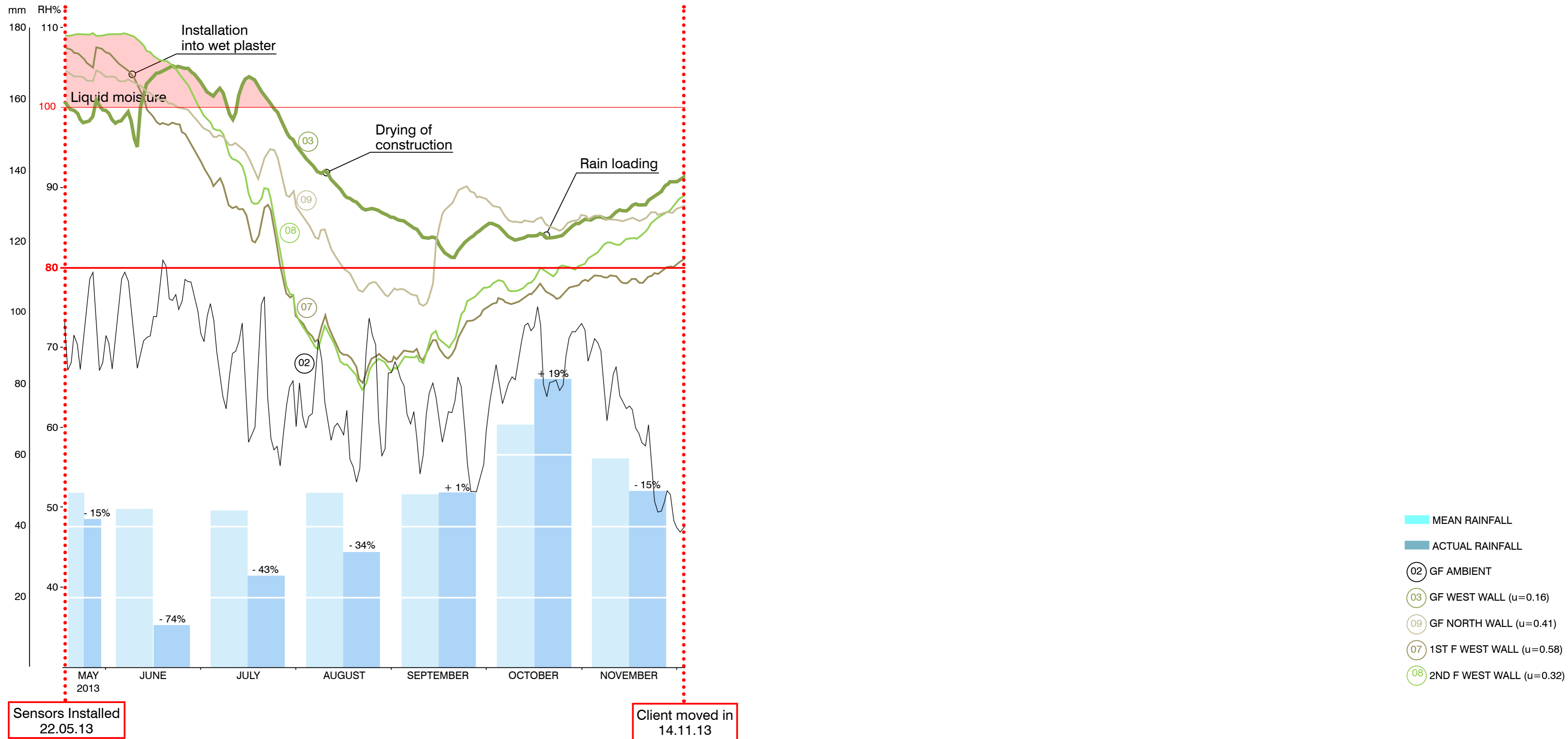
07_INSTALLATION OF SENSORS_HYGROTRAC WIRELESS SENSORS



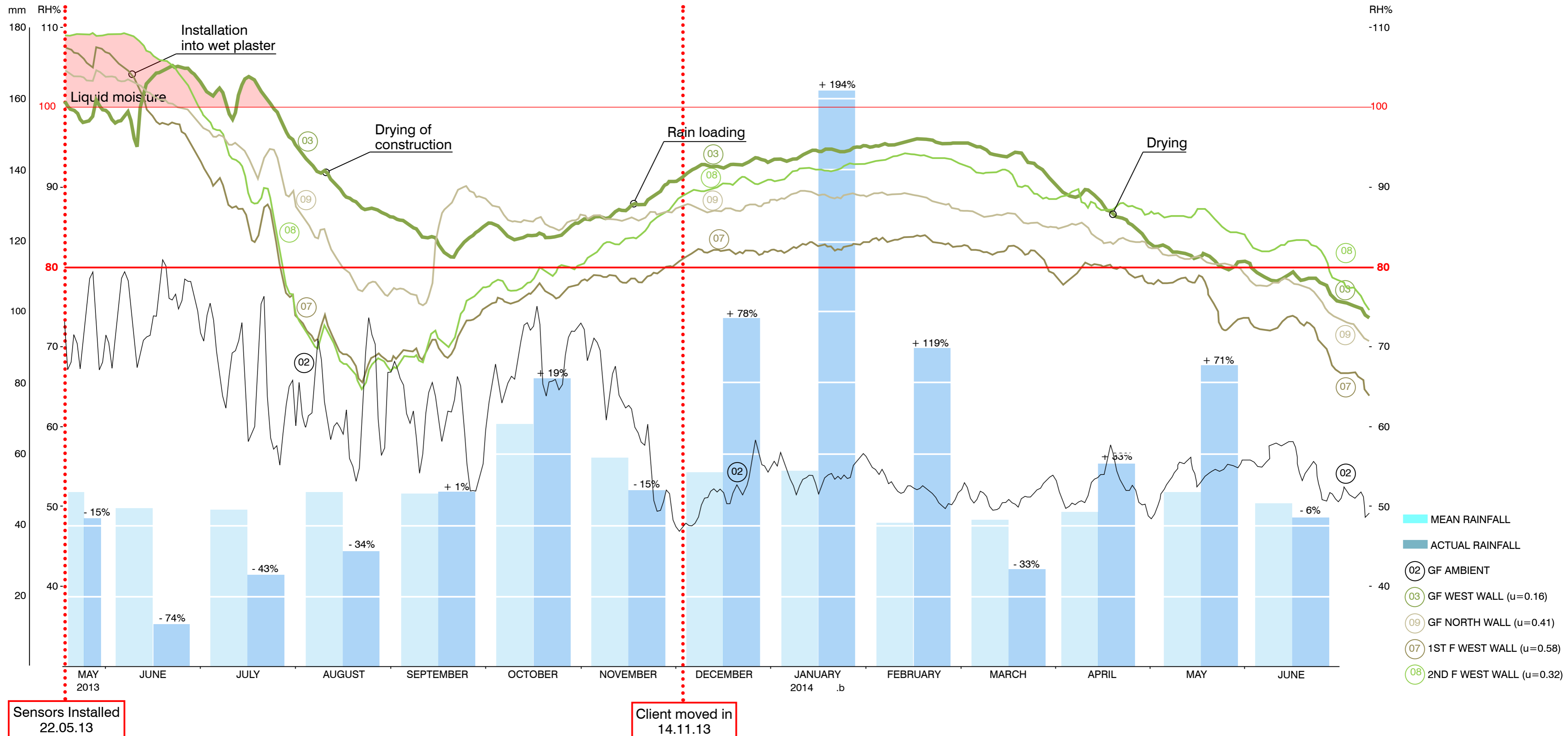
08_RESULTS FROM SENSORS_PRELIMINARY FINDINGS

- Data collected from mid-May 2013 (mid-construction) to July 2014 (on-going)
- Temperature, Relative Humidity and WME data collected
- 15no. sensors installed in a range of locations:
 - Internal and external ambient sensors
 - Uninsulated airtight chimney flues and windtight loft space
 - Early warning sensor installed adjacent to rainwater downpipe
 - Remaining sensors built into fabric of building
- 4 sensors monitoring building fabric have been selected for analysis
 - woodfibre and aerogel insulation with a range of u-values
 - west and north elevations

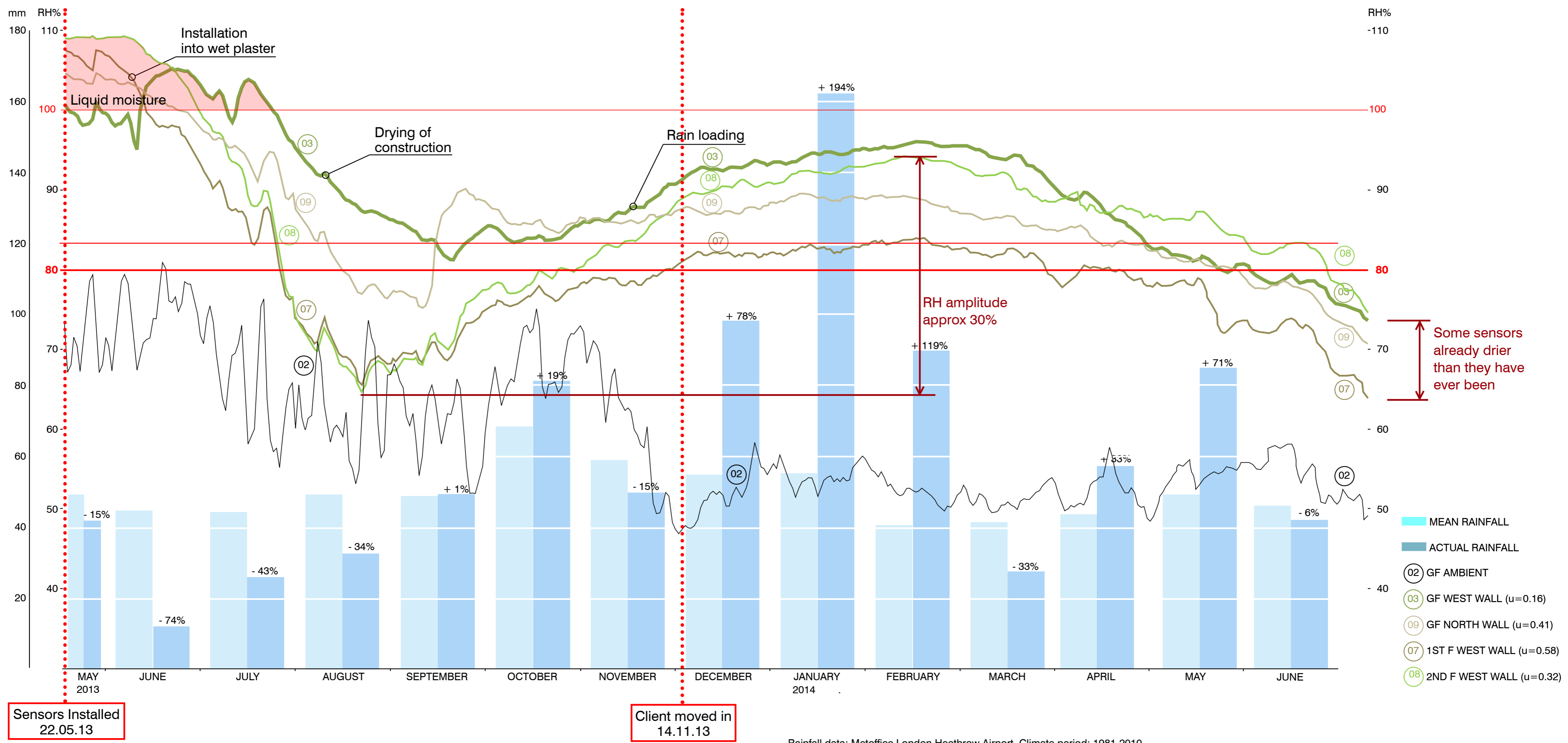
08_RESULTS FROM SENSORS_RELATIVE HUMIDITY



08_RESULTS FROM SENSORS_RELATIVE HUMIDITY



08_RESULTS FROM SENSORS_RELATIVE HUMIDITY

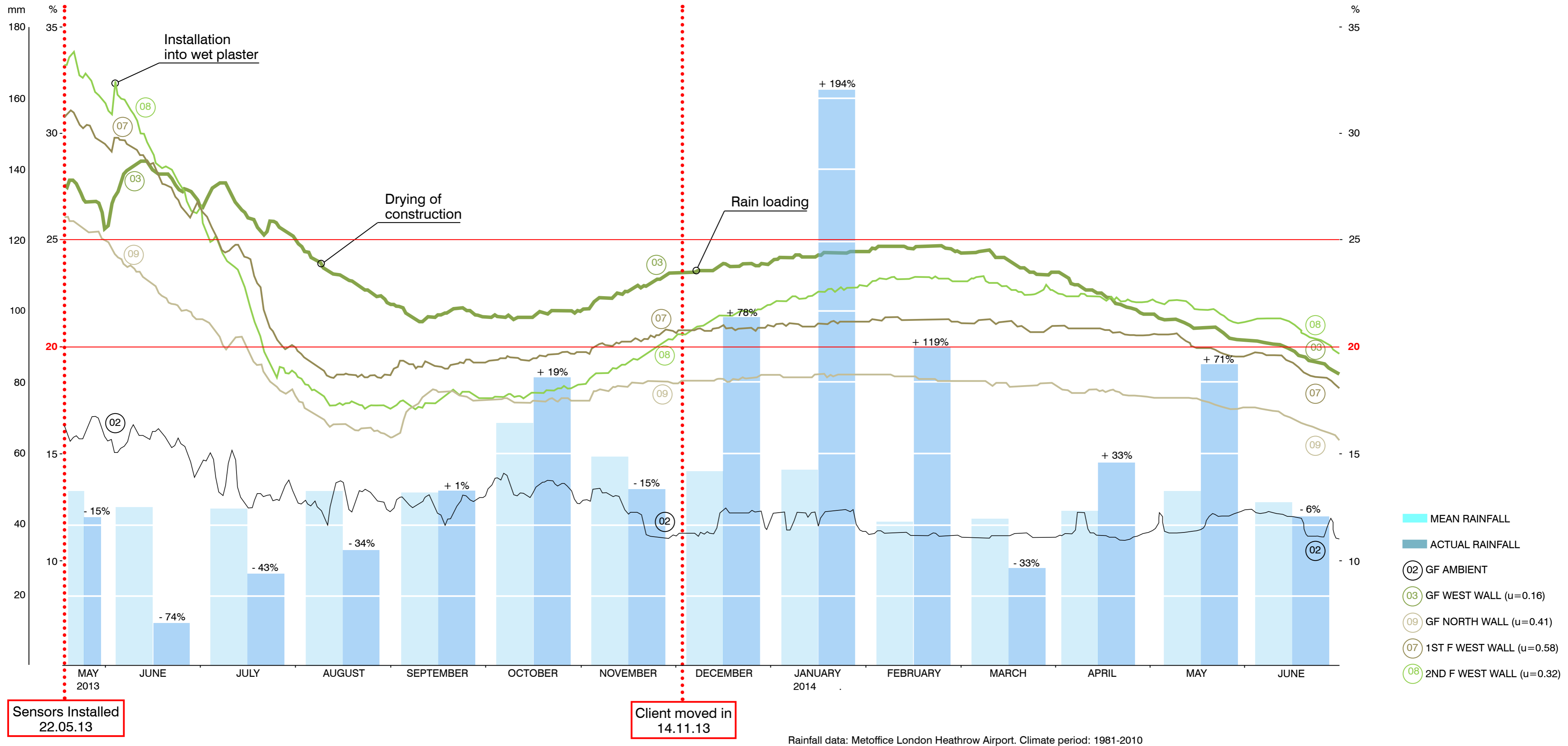


Rainfall data: Metoffice London Heathrow Airport. Climate period: 1981-2010

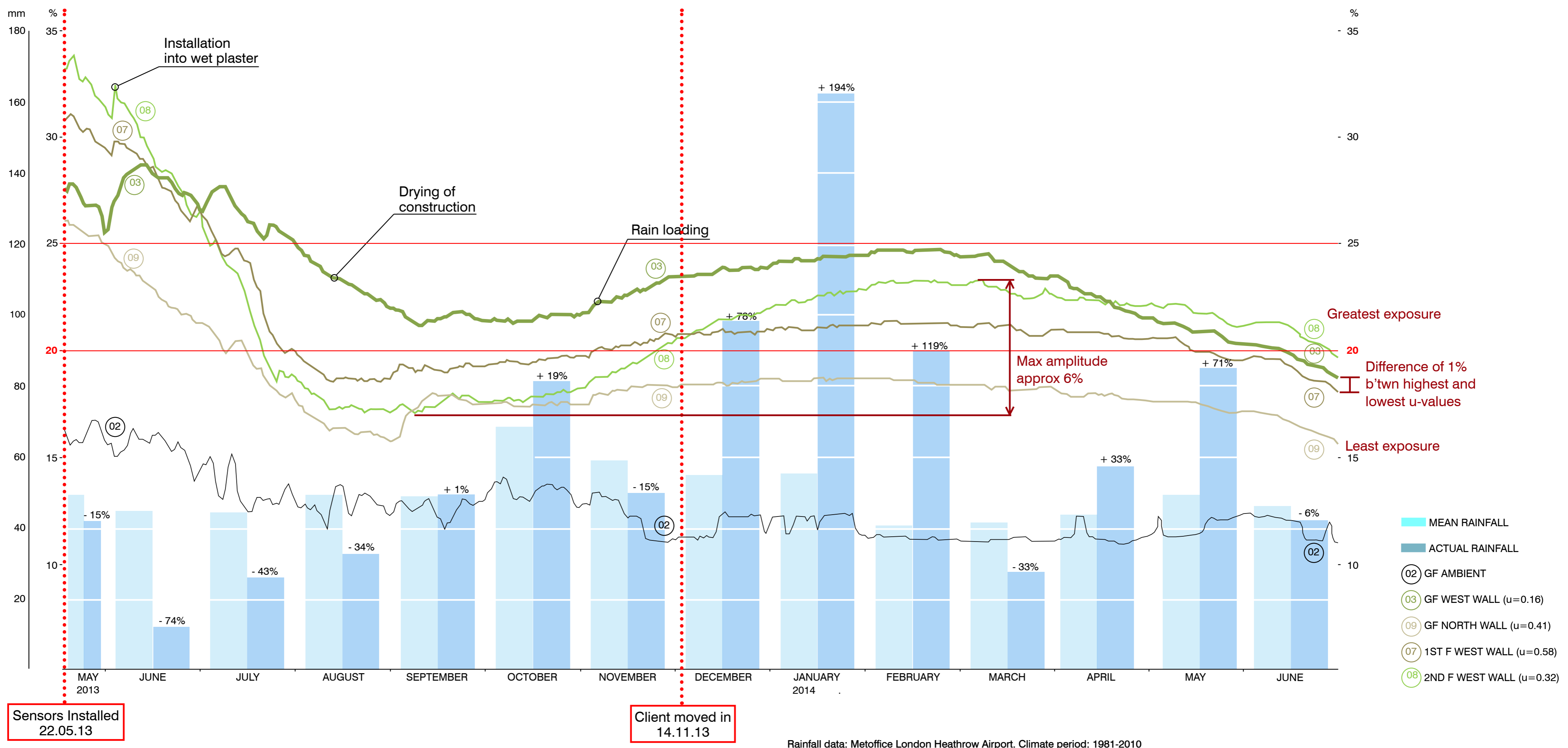
08_RESULTS FROM SENSORS_WME



08_RESULTS FROM SENSORS_WME



08_RESULTS FROM SENSORS_WME



09_TRENDS AND OBSERVATIONS_MOISTURE LEVELS

Safeguards against high RH and WME readings during Winter 2013/14

- High capillarity of woodfibre is likely to be wicking moisture away from the wall and holding moisture within its structure which is diffusing into the room (evidence by sensor on warm side).
- Lime plaster is capillary active and mould-inhibiting due to high pH.
- Where levels of WME higher than 20% have been experienced it is expected that the boron preservative will have activated thus protecting embedded timbers from potential rot.

Key observations

- The highest amplitude in RH occurs in the most exposed wall with a median u-value of $0.32\text{W/m}^2\text{K}$.
- The primary cause of high levels of moisture in the wall appears to be from rain driven moisture.
- Active absorption and desorption of moisture at sensors is proves vapour permeable construction but annual amplitude and maximum values will need to be carefully monitored.
- Sensors are helpful in highlighting problems.

09_TRENDS AND OBSERVATIONS_QUESTIONS

- **How much of the moisture in the walls was “construction” moisture?**
 - Sensor 03 RH didn't get below 80% indicating that a significant proportion of moisture may be yet to dry out from the construction period (this is likely to occur during the summer, weather dependent).
- **Was the wettest winter on record in England the cause of high levels of moisture?**
 - Likely to have had some effect but difficult to assess after only one year's worth of data and time lag.
- **What effects might seasonal variations in weather have on the moisture levels?**
 - How might a warm but wet winter compare to a dry but very cold winter?
- **Should the west elevation (and others) be treated with hydro-phobising cream?**
 - The effect of drying through the summer and subsequent autumn/winter wetting should be observed over at least another two annual cycles before any conclusions can be made.

MONITORING MOISTURE IN HISTORIC BUILDING: A RETROFIT TO THE AECB SILVER STANDARD



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Arboreal Architecture Ltd

St.Margaret's House, 21, Old Ford Road, London, E2 9PL, UK

harry@arborealarchitecture.com

+44 (0)20 8980 5066



10_APPENDIX_EPC BEFORE AND AFTER

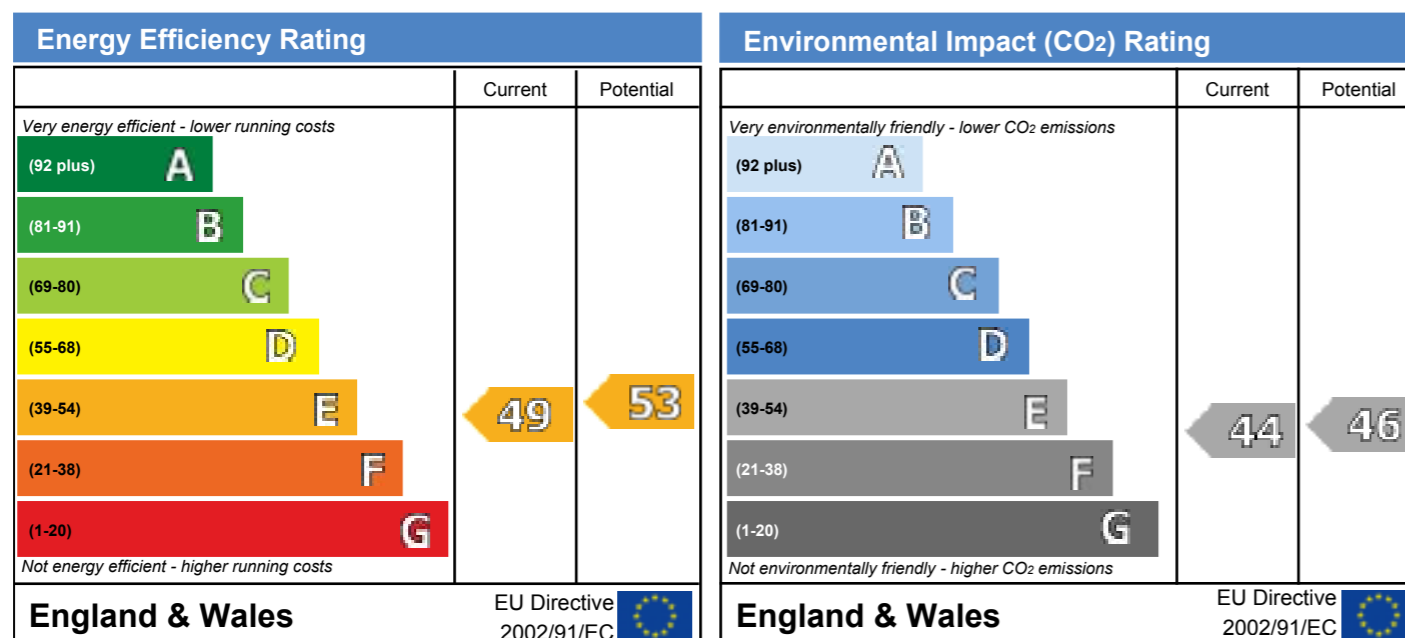
Energy Performance Certificate



51, Rectory Grove,
LONDON,
SW4 0DS

Dwelling type: Semi-detached house
Date of assessment: 31 March 2011
Date of certificate: 31 March 2011
Reference number: 8699-6327-8080-6529-7976
Type of assessment: RdSAP, existing dwelling
Total floor area: 201 m²

This home's performance is rated in terms of the energy use per square metre of floor area, energy efficiency based on fuel costs and environmental impact based on carbon dioxide (CO₂) emissions.



The energy efficiency rating is a measure of the overall efficiency of a home. The higher the rating the more energy efficient the home is and the lower the fuel bills are likely to be.

The environmental impact rating is a measure of this home's impact on the environment in terms of Carbon dioxide (CO₂) emissions. The higher the rating the less impact it has on the environment.

Estimated energy use, carbon dioxide (CO ₂) emissions and fuel costs of this home		
	Current	Potential
Energy use	323 kWh/m ² per year	306 kWh/m ² per year
Carbon dioxide emissions	11 tonnes per year	10 tonnes per year
Lighting	£217 per year	£111 per year
Heating	£1,641 per year	£1,610 per year
Hot water	£195 per year	£195 per year

The figures in the table above have been provided to enable prospective buyers and tenants to compare the fuel costs and carbon emissions of one home with another. To enable this comparison the figures have been calculated using standardised running conditions (heating periods, room temperatures, etc.) that are the same for all homes, consequently they are unlikely to match an occupier's actual fuel bills and carbon emissions in practice. The figures do not include the impacts of the fuels used for cooking or running appliances, such as TV, fridge etc.; nor do they reflect the costs associated with service, maintenance or safety inspections. Always check the certificate date because fuel prices can change over time and energy saving recommendations will evolve.

To see how this home can achieve its potential rating please see the recommended measures.

Energy Performance Certificate



51, Rectory Grove, LONDON, SW4 0DS

Dwelling type: Semi-detached house
Date of assessment: 31 March 2014
Date of certificate: 31 March 2014
Reference number: 0986-2859-6078-9374-5731
Type of assessment: RdSAP, existing dwelling
Total floor area: 196 m²

Use this document to:

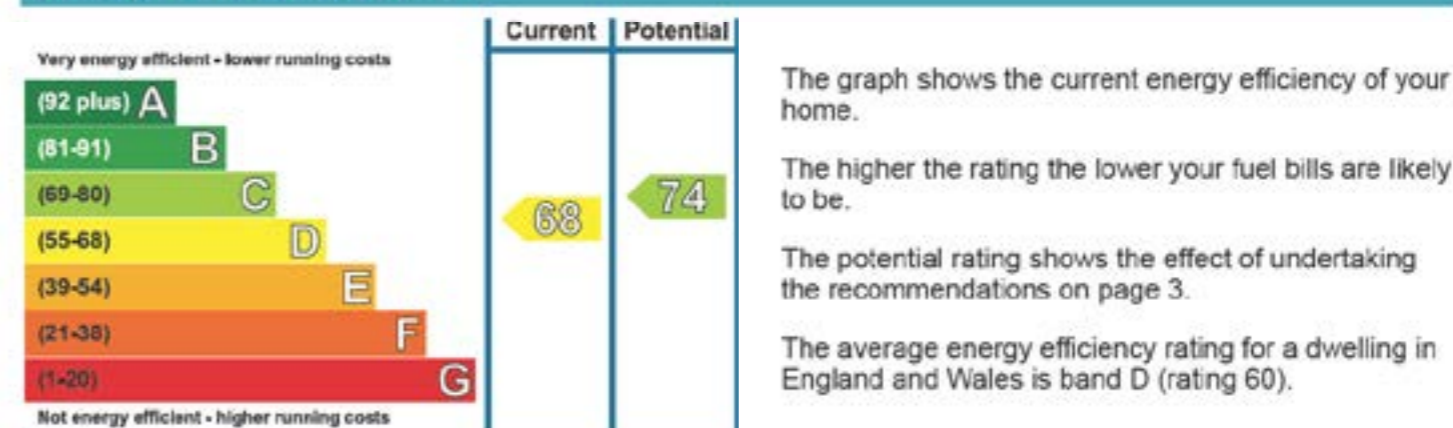
- Compare current ratings of properties to see which properties are more energy efficient
- Find out how you can save energy and money by installing improvement measures

Estimated energy costs of dwelling for 3 years: **£ 4,140**

Estimated energy costs of this home			
	Current costs	Potential costs	Potential future savings
Lighting	£ 261 over 3 years	£ 261 over 3 years	Not applicable
Heating	£ 3,633 over 3 years	£ 3,633 over 3 years	
Hot Water	£ 246 over 3 years	£ 246 over 3 years	
Totals	£ 4,140	£ 4,140	

These figures show how much the average household would spend in this property for heating, lighting and hot water. This excludes energy use for running appliances like TVs, computers and cookers, and any electricity generated by microgeneration.

Energy Efficiency Rating



Top actions you can take to save money and make your home more efficient

Recommended measures	Indicative cost	Typical savings over 3 years	Available with Green Deal
1 Solar photovoltaic panels, 2.5 kWp	£9,000 - £14,000	£ 750	✓

To find out more about the recommended measures and other actions you could take today to save money, visit www.direct.gov.uk/savingenergy or call 0300 123 1234 (standard national rate). The Green Deal may allow you to make your home warmer and cheaper to run at no up-front cost.