D3.1 – Methodology to test the reliability of subsystem I

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Deliverable Information Sheet

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History of changes

Version	Date	Comments	Main Authors
0.1	01/06/2023	First draft, establishing document structure	M. J. Lægaard (DTI), M. O. Fricke (DTI), S. L. Bertelsen (DTI)
0.2	12/06/2023	First version, incorporating input from all participants	M. J. Lægaard (DTI), M. O. Fricke (DTI), S. L. Bertelsen (DTI)
0.3	22/06/2023	Second version, Expansion of the document structure to the entire RE-SKIN project	G. Paganin (POLIMI), M. Buzzetti (POLIMI)
0.3	28/06/2023	Quality review	Miglioli (ZH), R. Adhikari (POLIMI)
1.0	04/07/2023	Final version addressing all further comments	G. Paganin (POLIMI), F. Leonforte (POLIMI)

List of Figures

Disclaimer

1. Executive summary

The overall goal of this deliverable is the verification and demonstration of the long-term reliability of following three categories of subcomponents:

1. novel façade/roof hybrid components (i.e., multifunctional façade cladding and BIPVT roof system);
2. repurposed components (i.e., EV batteries);
3. refurbished components (i.e., PV modules).

The aim of this deliverable is to establish a framework of scenarios related to external agents with their predictable causes and actions over the useful life of the novel façade/roof hybrid components (i.e., multifunctional façade cladding and BIPVT roof system). This will be continued to define the tests deemed appropriate for performing laboratory tests to verify the reliability of the systems and components on the long-term. The aim of the work is to provide criteria and methods for optimizing component reliability testing.

The first release of the deliverable contains the collection of applicable standards and Product Certificates for the various subcomponents.

An updated version of this report is scheduled for month 24. The next deliverable will implement the methodologies to apply for repurposed components (i.e., EV batteries) and refurbished components (i.e., PV modules).

2. Novel façade/roof hybrid components

The overall goal is to demonstrate the reliability of the envelope subcomponents.
The façade subsystem (described in deliverable D5.1) to major disruptive events: Thereby, the aim is to find out the weaknesses in the assembled system when exposed to extreme weather conditions for a long time, which will be used to continuously evaluate and improve the RE-SKIN façade system to extend the lifetime of the system. To do that some mock-ups / models will be tested.
The weather-conditions can be defined due to:

- *Sun*
- *Rain*
- *Wind*
- *Frost*
- *Hail/windborne sand/flying debris.*

To ensure a repeatability of the tests carried out, European and International standards are used as reference documents wherever possible.

The test-program consist of a cyclic process according to following steps:

- *Determine some physical properties*
- *Do an accelerated ageing of the specimens*
- *Determine the deterioration of the physical properties*
- *Repeat the above steps.*

The mock-ups must contain as many connections and joints as possible and not necessarily be actual parts of a building. For example, a mock-up of a wall must contain numerous panels connected in all possible directions, something that would not be done on a real project.

The mock-ups must also be the worst-case scenario of buildings to renovate. The tightness of the building must be compromised to illustrate this, meaning that the substructure on which the RE-SKIN system is to be mounted, must have penetrations to create a source for a pressure drop.
If the substructure is completely tight, it is not possible to make any observations of penetration of rainwater or sources of air permeability.

The presented methodology to test the reliability of subsystem is not final and can be changed during the process when new insights are learned.

2.1. Methodology

There are numerous tests that can be carried out on a façade. An extensive search has given multiple possibilities, from where the partners in RE-SKIN have made some choices of methodologies to fulfil the goal of the project in the best manner possible. The list is not final one and can be subject to changes during the process.

NOTE: Fire propagation / spreading of fire inside a curtain walling is not part of this first test program but will be taken into consideration later. See EN 1364-4 for testing and EN 13501-2 for classification.

2.1.1. Relevant test standards

Table 1 shows the relevant standards to be used in the investigations of envelope subsystem.

Table 1. Methods relevant for testing the reliability of façade subsystem I.

EN 12153	Curtain walling – Air permeability – Test method
EN 12155	Curtain walling – Watertightness – Laboratory test under static pressure
EN 12179	Curtain walling – Resistance to wind load – Test method
EN 12865	Hygrothermal performance of building components and building elements – Determination of the resistance of external wall systems to driving rain under pulsating air pressure
EN 14019	Curtain walling – Impact resistance – Performance requirements
EN 14509	Self-supporting double skin metal faced insulating panels – Factory made products – Specifications; Annex B: Durability testing method for sandwich panels – B.2: Heat B.3: Humidity
EAD 040914-00-0404	Veture kits – prefabricated units for external wall insulation and their fixing devices; Annex D – Accelerated ageing Annex E – Wind suction and pressure load test Annex K – Resistance to horizontal point load test Annex L – Impact resistance test
EN IEC 61215-2	Terrestrial photovoltaic (PV) modules – Design qualification and type approval – Part 2: Test procedures; Hail test – MQT 17
ISO/PWI 16316 (proposal)	Windows, doors, and curtain walling – Impacted by windborne debris in windstorms – Test method and classification

2.1.1.1. Focus area

When working with curtain walling systems it is always important to consider the drainage system.

Therefore, one additional focus of the test program is to investigate the reliability of the drainage systems. If the drainage stops functioning it can, in worst-case scenario, result in a slow deterioration of the building, but surely it will lead to growth of mould and fungus within the structure in the meantime; moreover, the accumulation of water in the cavity could damage the MIMO remote units that serve the Smart fan coils.

It has been discussed if this is best investigated by testing air permeability and watertightness by static air pressure, or by testing watertightness by driving rain during pulsating air pressure.
Because some tests are done on the same specimens in almost the same setup, it is proposed to test all properties in the first round of tests and then decide the way forward afterwards.

The other properties of the curtain walling system, e.g., wind suction, impact resistance, hail, debris, are very important for the resilience of the system. The exact conditions to expose the system will be specified in collaboration with the risk assessment carried out in WP2 (Task 2.6), when this has been finalised.

2.1.2. Testing procedure

The basic physical properties will be tested according to the relevant standards as listed above in Table 1.

It will involve testing of the complete system for its resistance to weathering according to the plan showed in Figure 1 – Curtain walling.

In addition to illustrated testing procedure, testing for resistance to driving rain during high wind pressure can be added, if it is deemed necessary.

The procedure presented in Figure 1 will be combined with accelerated ageing as described in section 2.1.2.1.

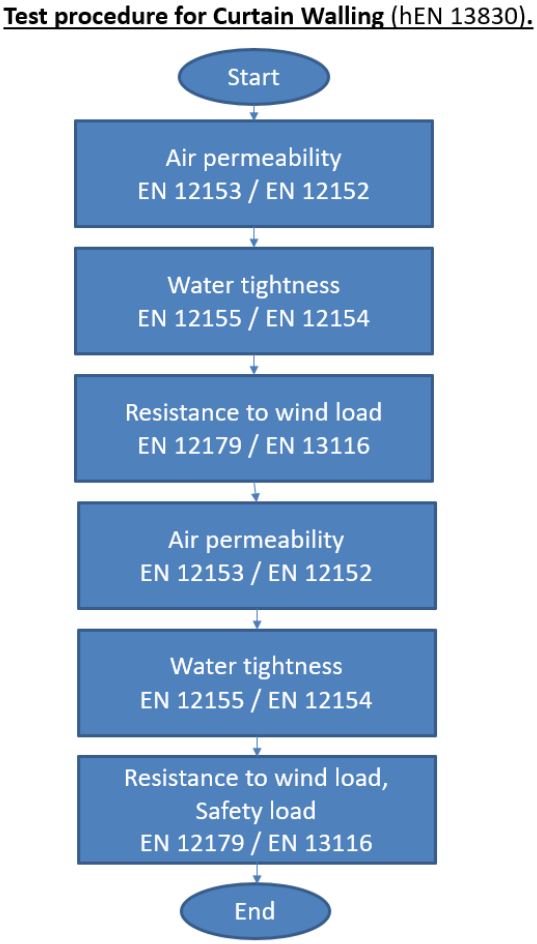

Figure 1: Testing procedure to test the reliability of envelope subsystem.

2.1.2.1. Ageing

Accelerated ageing is not an exact science. It is very difficult to inflict some stress on a system and ensure the stress corresponds to e.g., 10 years of ageing.

DTI has many years of experience with accelerated ageing of different building materials, and this knowledge is used to design a process of stress on the system, that is likely to have the desired impact, e.g., deterioration of the sealings and insulation material, sign of corrosion on the surface of the panels.

Plan and test facility (Fig. 2) for the set-up for stress induced accelerated ageing is described below:

- *Heat – 60 °C*
- *UV – surface temperature 80 °C (black panel)*
- *Water – equivalent to heavy rain*
- *Frost – -15 °C*

- *Imposed cyclic on the specimens;*
- *Three complete cycles pr day;*
- *Done for 90 days.*

- *Inspected daily.*

Figure 2. Ageing chamber (staged)

After ageing, the specimens are tested again as described in section 2.1.2. The ageing and testing are then repeated, adding up to a total of 4 physical tests and 3 times ageing.
The physical properties must not be reduced significantly in comparison with the first time. Levels will be agreed upon later.

2.1.3. Other tests to be considered

Table 2 shows additional test methods applicable to the cladding system and that could be used as references for further tests, if considered useful, in the further stages of the research.

Table 2. Additional testing for possible further investigation.

EAD 040914-00-0404	Veture kits – prefabricated units for external wall insulation and their fixing devices • Annex E – Wind suction and pressure load test • Annex K – Resistance to horizontal point load test • Annex L – Impact resistance test
EN IEC 61215-2	Hail test – Clause MQT 17 in the standard Size and speed of hails to be agreed upon based on risk assessment carried out in Work Package 2, Task 6.
ISO/PWI 16316 (proposal)	Windows, doors, and curtain walling - Impacted by windborne debris in windstorms – Test method and classification. Conditions to be agreed upon based on risk assessment carried out in Work Package 2, Task 6.

2.2. Test specimens

All details regarding the exact build-up of the test specimens have not been decided yet, so this section presents the preliminary thoughts and discussions between the partners. The details are based on the presented system in deliverable D5.1.

The following is a list of test specimens that in this stage are considered useful to cover all aspects of the construction on a building, and which should contain the following features:

- *Wall with many connections between panels, see example in Figure 3;*
- *Wall with a window of 1.0 x 1.5 m;*
- *Wall with a corner, in-ward and out-ward.*

Figure 3 shows a preliminary sketch of one test specimen, illustrating many connections and joints between panels, including a penetration through one insulation panel to see what impact this will have on the performance of the façade system.

Construction of the specimens:

- *A frame is made of at least 4"x 4" timber, measuring 2 x 2 m ± 0.4 m in frame size;*
- *The "building" surface (substructure) is made of 28 mm plywood;*
- *Sketches to be agreed upon before construction.*

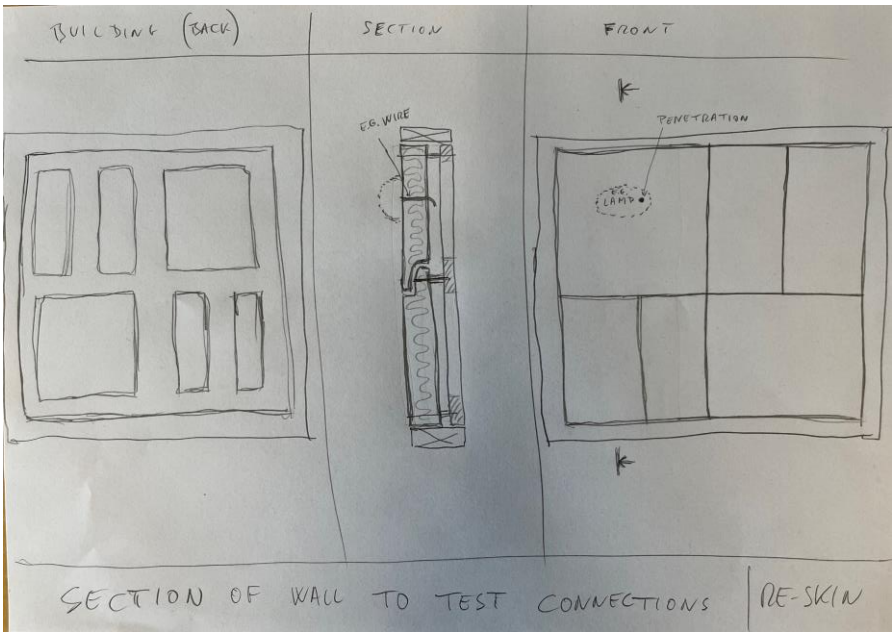

Figure 3: Example of construction of test specimen including several connections, joints and penetrations.

3. Repurposed components

RE-SKIN includes battery repurposing, the re-use of discarded electric vehicle batteries, which no longer have performances suitable for the automotive sector, but are still effective for the construction sector. In such respect, in this section, the test required to obtain the certification for building application will be presented. The methodology to test such component will be defined in the second release of the deliverable.

4. Refurbished components

RE-SKIN includes also refurbished PV panel, that require a set testing procedure.
The baseline to test the electric performances will be IEC 61215-2:2016. The methodology to test such component will be defined in the second release of the deliverable.