Plug-N-Harvest

WP1 – REQUIREMENTS ANALYSIS AND ENGINEERING

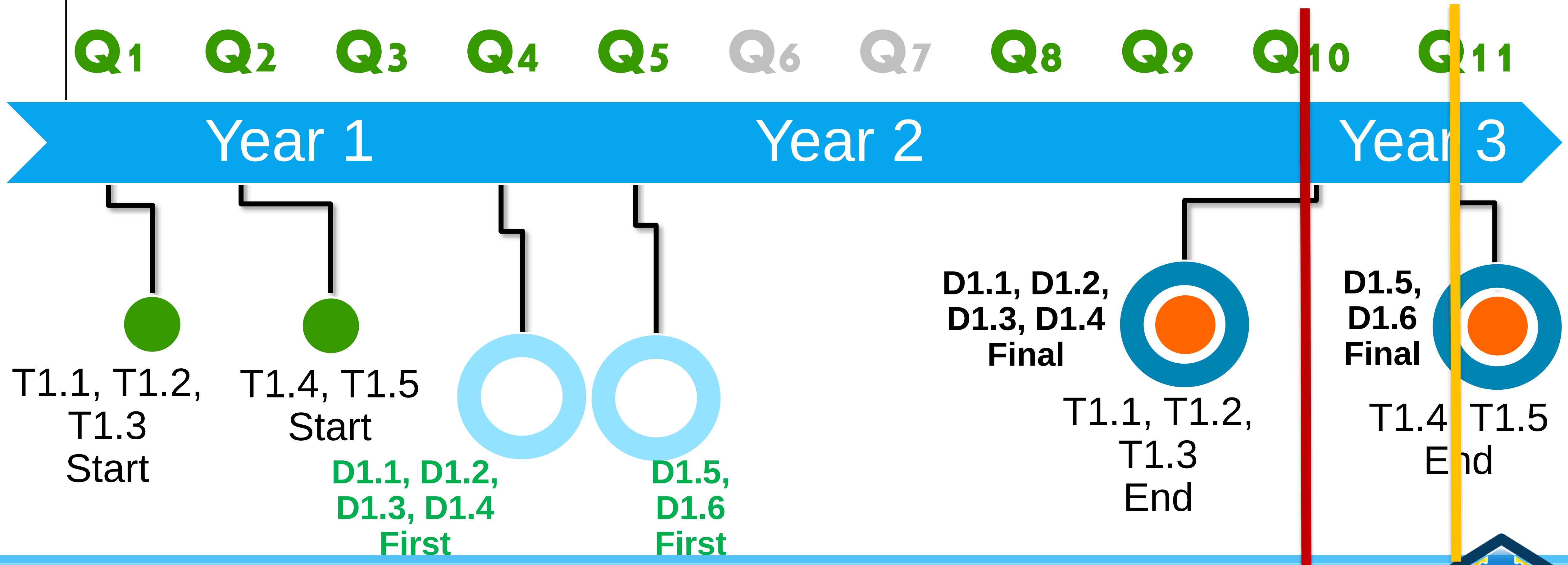
ORGANIZATION: AIGUASOL, CU, RWTH, CERTH
PRESENTER(S): ARNAU GONZÁLEZ (AIGUASOL), HU DU (CU), SEBASTIEN RÉMY (RWTH), NIKOS MARGARITIS (CERTH)

Plug-N-Harvest: Presentation Outline

1. WP1 schedule and progress
2. Overview of WP1 Tasks progress
    1. Task 1.1 – End-Users and Business Requirements
    2. Task 1.2 – Use Cases, Test Scenarios and Evaluation Plans
    3. Task 1.3 – Analysis of building types and Construction Requirements
    4. Task 1.4 – PnH architectural design, functional and technical specifications
    5. Task 1.5 – Active-façade CFD simulation and optimization guidelines

WP1 Schedule and Progress

WP1 Schedule and Progress



WP1 progress

- Task 1.1 delivers second version of D1.1 in February 2020
  - Lists of relevant project indicators: 17 KPIs (key indicators) and 28 DPIs (secondary indicators)
- Task 1.2 delivers second version of D1.2.1 and D1.2.2 in February 2020
  - T1.2.1 – Use case site survey and audit reports
  - T1.2.2 – Evaluation plan layout
- Task 1.3 delivers second version of D1.3 in February 2020
  - Systems engineering requirements definition
- Task 1.4 delivers second version of D1.4 in May 2020
  - Architectural design and technical specs
- Task 1.5 delivers second version of D1.5 in May 2020
  - Active-façade CFD simulations

Overview of WP1 Tasks progress

WP1 – Requirements Analysis and Engineering

T1.1 END-USER AND BUSINESS REQUIREMENTS

TASK RESPONSIBLE: AIGUASOL
PRESENTER(S): ARNAU GONZÁLEZ

MEETING: 7TH PLENARY MEETING, BRUSSELS, 26 FEBRUARY 2020

D1.1 End-User and Business Requirements Report

- Task Leader: AIGUASOL
- Task activities:
  - Definition of End-user and business requirements and related indicators, i.e. Key Performance Indicators (KPIs) of the project
  - Identification of internal and external stakeholders for each project objective
  - External survey to validate project's KPIs
- Deliverables:
  - D1.1a End-User and Business Requirements Report (submitted)
  - D1.1b End-User and Business Requirements Report (submitted February 2020)
- Status of task: completed

D1.1 KPI / DPI

- The main output of D1.1 is the delivery of the **list of project's performance indicators and their calculation methodology** layout:
  - **17 Key Performance Indicators (KPI)** – These are those indicators directly measuring the performance of the project in energy, economic and circularity terms
  - **28 Design Performance Indicators (DPI)** – These are indicators internally required to address the performance of the design of certain systems of the PnH solution (ADBE, IMCS, OEMS, Circularity of the solutions,…) or to calculate some KPIs
- Additional outputs are:
  - Internal and external stakeholders identification for each of the project's Key Objective
  - External validation of the Key Performance Indicators of the project (external survey)
- This is a coral task with almost all partners involved in their respective fields of expertise

D1.1b KPI / DPI

- The obtention of the 17 KPI list comes from a collective iterative process:
  1. “Brainstorming” of indicators using inputs from all partners
  2. Filtering and sorting from Task leader → almost 70 indicators
  3. Following the advise from EC advisor, a fine tuning process was made: some indicators were removed, other not directly related with project outcomes moved to a new cathegory
  4. Final sorting by WP1 Task leaders
- The **second version** of the deliverable incorporates lessons learned from the progress of the project
  - **KPI1 and KPI2 (Primary Energy Consumption and End Energy Bill) have been modified collecting reviewer’s suggestions**
  - **KPI 8 (GHG payback) and KPI 13 (LCC) have been modified changing the time span of the analysis from 20 to 50 years**

WP1 – Requirements Analysis and Engineering

T1.2 USE CASES, TEST SCENARIOS AND EVALUATION PLANS

TASK RESPONSIBLE: CU
PRESENTER(S): HU DU

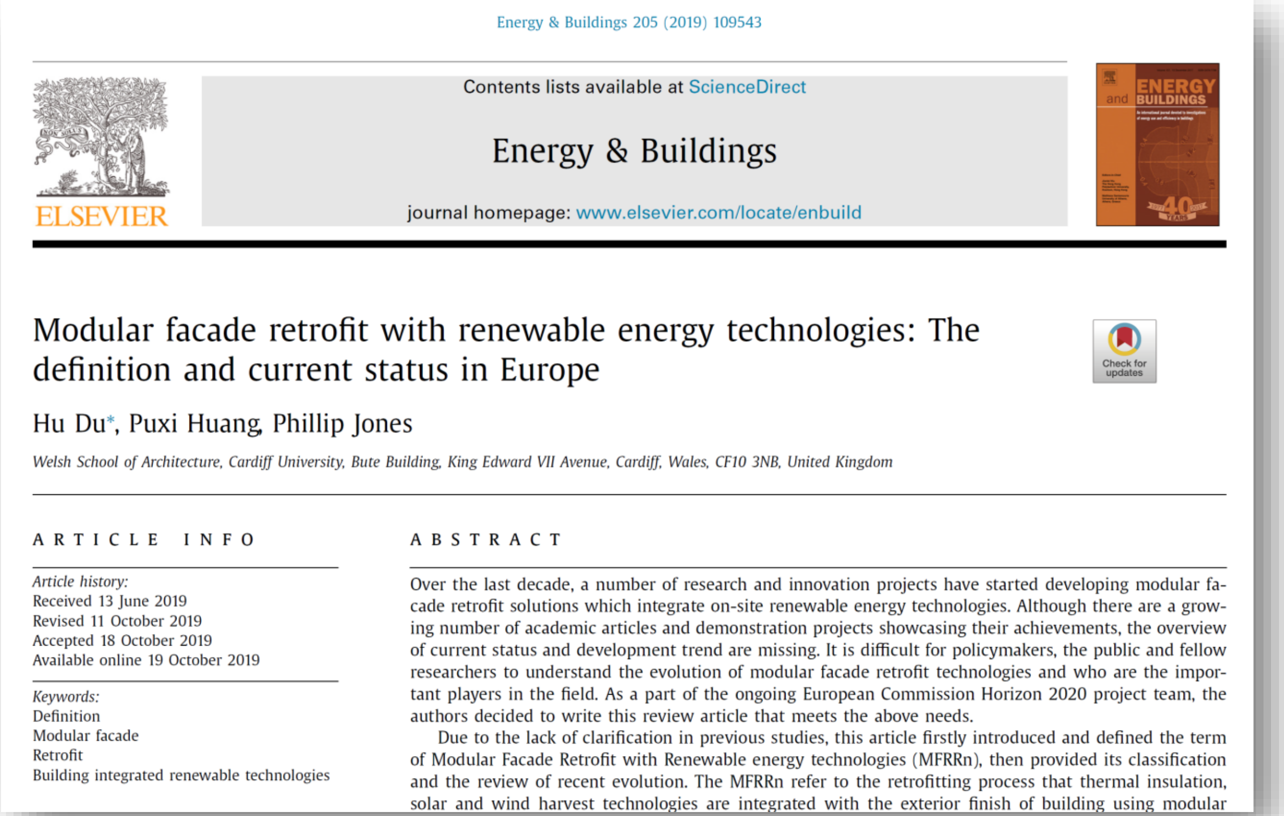
MEETING: 7TH PLENARY MEETING, BRUSSELS, 26 FEBRUARY 2020

Task 1.2 Use Cases, Test Scenarios and Evaluation Plans

- Task Leader: CU
- Task activities:
  - Conduction of a survey of the use cases
  - Creation of a use case audit report
  - Using the outcomes from T1.1 (project's KPIs), develop an evaluation plan
- Deliverables:
  - D1.2.1a Use Case Site Survey and Audit Report (submitted)
  - D1.2.2a Evaluation Plan (submitted)
  - D1.2.1b Use Case Site Survey and Audit Report (submitted February 2020)
  - D1.2.2b Evaluation Plan (submitted February 2020)
- Status of task: completed

D1.2.1b Use Case Site Survey and Audit Report

- The main outputs in D1.2 are:
  - A review of the use case of other EU projects for energy harvesting in façades
  - Site and building information surveys
  - Occupants satisfaction survey
  - Test scenarios
  - **A published journal article on Energy & Buildings**



Energy & Buildings 205 (2019) 109543

Contents lists available at ScienceDirect

Energy & Buildings

journal homepage: www.elsevier.com/locate/enbuild

Modular facade retrofit with renewable energy technologies: The definition and current status in Europe

Hu Du*, Puxi Huang, Phillip Jones

Welsh School of Architecture, Cardiff University, Bute Building, King Edward VII Avenue, Cardiff, Wales, CF10 3NB, United Kingdom

ARTICLE INFO

Article history:
Received 13 June 2019
Revised 11 October 2019
Accepted 18 October 2019
Available online 19 October 2019

Keywords:
Definition
Modular facade
Retrofit
Building integrated renewable technologies

ABSTRACT

Over the last decade, a number of research and innovation projects have started developing modular facade retrofit solutions which integrate on-site renewable energy technologies. Although there are a growing number of academic articles and demonstration projects showcasing their achievements, the overview of current status and development trend are missing. It is difficult for policymakers, the public and fellow researchers to understand the evolution of modular facade retrofit technologies and who are the important players in the field. As a part of the ongoing European Commission Horizon 2020 project team, the authors decided to write this review article that meets the above needs.

Due to the lack of clarification in previous studies, this article firstly introduced and defined the term of Modular Facade Retrofit with Renewable energy technologies (MFRRn), then provided its classification and the review of recent evolution. The MFRRn refer to the retrofitting process that thermal insulation, solar and wind harvest technologies are integrated with the exterior finish of building using modular

https://doi.org/10.1016/j.enbuild.2019.109543

D1.2.2b Evaluation Plan

- The main outputs in D1.3 are:
  - Evaluation design and methodology
  - Historical energy and weather data investigation
  - Review of the existing metering systems
  - Tangible and intangible needs
  - Evaluation scenarios and essential parameters
  - KPIs and monitoring equipment requirement
  - Monitoring system and equipment planning
  - **Evaluation schedule (updated according to Reviewer's comment)**

D1.2.2b Evaluation Plan - Evaluation schedule

	Year 3												Year 4												Year 5		
M	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Month	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	Jul-21	Aug-21	Sep-21	Oct-21	Nov-21

(light green)	Pre-retrofit monitoring (Phase 3)
(yellow)	On-site retrofit construction (Phase 4 & 5)
(green)	Post-retrofit monitoring (Phase 6)
(grey)	Analysis and reporting (Phase 7)

- 7 phases of evaluation
- Performance evaluation will be conducted under Task 4.6
- D4.6 M36 should cover reports from phase 1-3 (pre-retrofit baseline)
- D4.6 M51 should cover reports from phase 4-7 (post-retrofit baseline)

WP1 – Requirements Analysis and Engineering

T1.3 ANALYSIS OF BUILDING TYPES AND CONSTRUCTION REQUIREMENTS

TASK RESPONSIBLE: CU
PRESENTER(S): HU DU

MEETING: 7TH PLENARY MEETING, BRUSSELS, 26 FEBRUARY 2020

Task 1.3 Analysis of Building Types and Construction Requirements

- Task Leader: CU
- Task activities:
  - Understand existing conditions of buildings in the selected demo sites
  - Provide requirements for the ADBE design
- Deliverables:
  - D1.3a Systems Engineering Requirements Definition (submitted)
  - D1.3b Systems Engineering Requirements Definition (submitted February 2020)
- Status of task: completed

D1.3b System Engineering requirements

- The main outputs in D1.4 are:
  - Review of the existing condition of pilot buildings
  - **Construction requirements (updated according to Reviewer’s comment)**
  - Appendix A: Loading requirement of wall cladding in Spain
  - Appendix B: loading requirement of wall cladding in the UK
  - Appendix C: Building information survey
  - Appendix D: Building services system survey
  - Appendix E: Building regulation information

D1.3b System Engineering requirements – Construction requirements

- Fire safety
- Energy conservation
- Waste
- Ventilation
- Structure
- **Seismic codes (added)**
- Acoustic
- Lighting
- Appearance
- Use of toxic and pollutants material
- Battery
- Additional requirements for each pilot

WP1 – Requirements Analysis and Engineering

T1.4 ARCHITECTURAL DESIGN, FUNCTIONAL AND TECHNICAL SPECIFICATIONS

TASK RESPONSIBLE: RWTH
PRESENTER(S): ???

MEETING: 7TH PLENARY MEETING, BRUSSELS, 26 FEBRUARY 2020

Task 1.4 PnH architectural design, functional and technical specifications

- Task Leader: RWTH
- Task activities:
  - General overview of the system design and conceptual architecture design
  - Provision of components functional and technical specifications
  - High-level design of individual components the system
- Deliverables:
  - D1.4a Detailed Architectural Design, Functional & Technical Specification (submitted)
  - D1.4b Systems Engineering Requirements Definition (due May 2020)
- Status of task: 2nd stage ongoing

WP1 – Requirements Analysis and Engineering

T1.5 ACTIVE-FAÇADE CFD SIMULATION AND OPTIMIZATION GUIDELINES

TASK RESPONSIBLE: CERTH
PRESENTER(S): NIKOS MARGARITIS

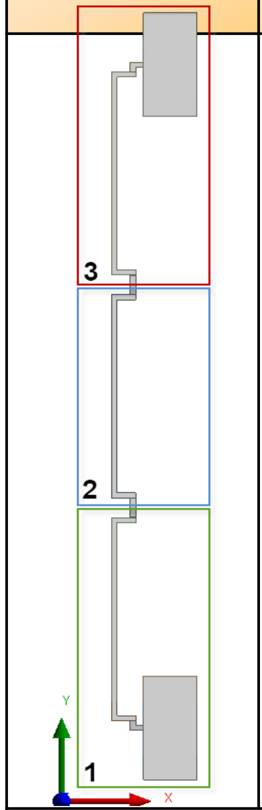
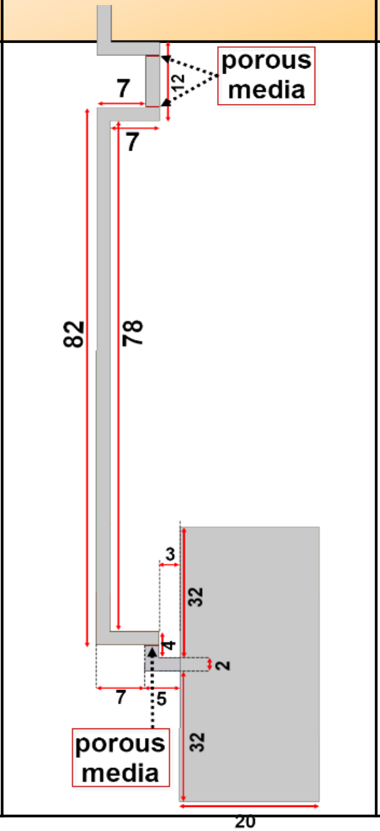
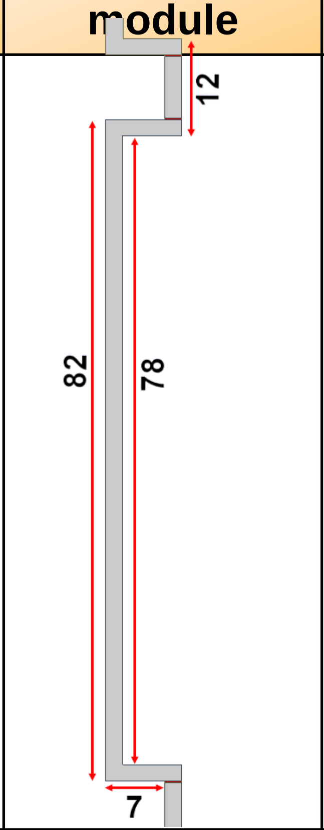
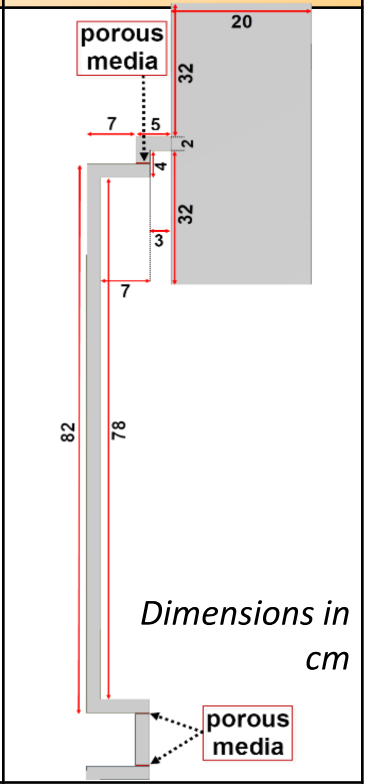
MEETING: 7TH PLENARY MEETING, BRUSSELS, 26 FEBRUARY 2020

Task 1.5 Active-façade CFD simulation and optimization guidelines

- Task Leader: CERTH
- Task activities:
  - Development of a steady-state CFD module to provide inputs and guidelines to the architectural design of the ADBE (carried out in WP2)
- Deliverables:
  - D1.6a Active-façade CFD simulation and optimization guidelines (submitted December 2018)
  - D1.6b Active-façade CFD simulation and optimization guidelines (submitted January 2020)
- Status of task: completed

D1.5b Active-façade CFD simulation and optimization guidelines

Problem Description

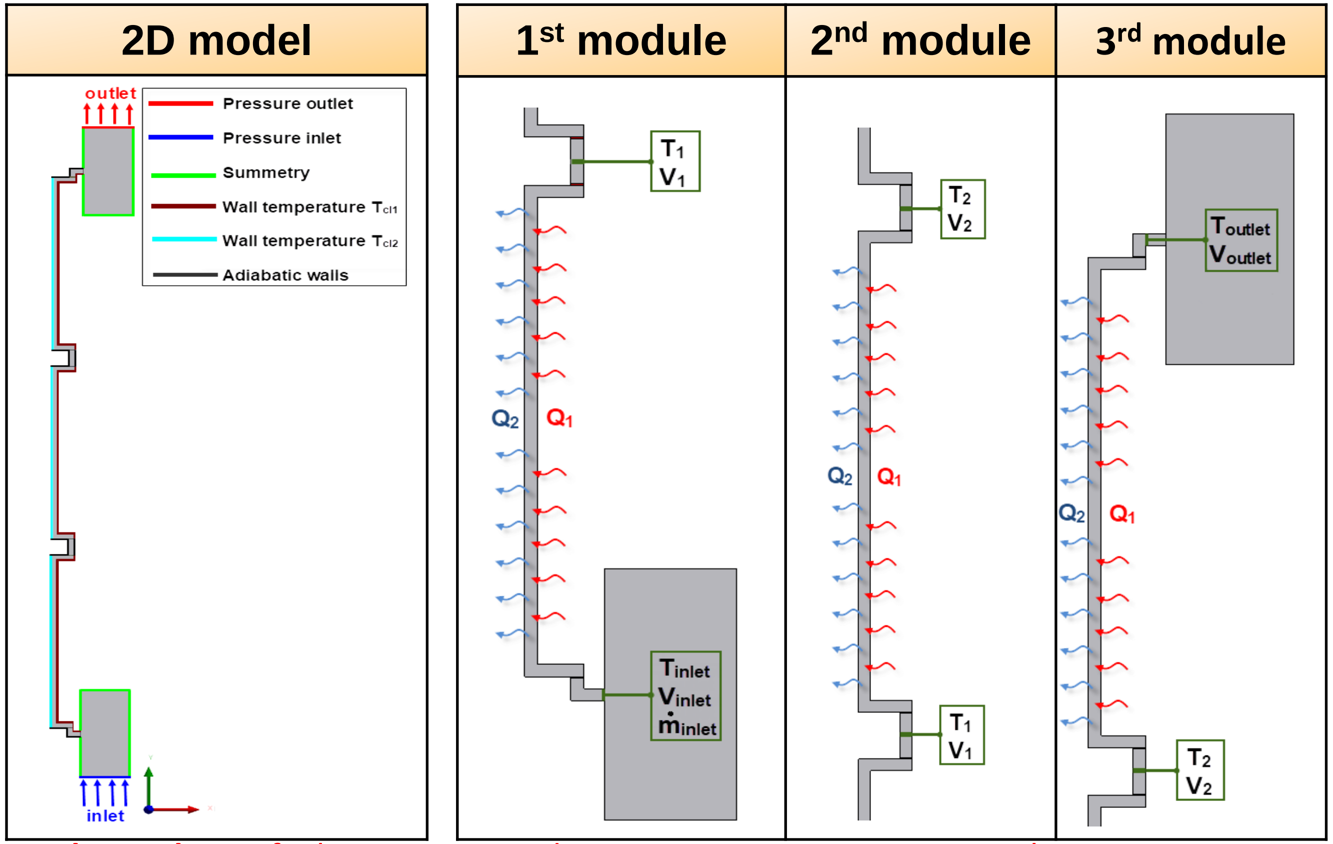
Geometry	First module	Second module	Third module
			

Consideration of worst-case conditions:

- **Three successive modules** installed along the vertical direction
- **No penetration of air** through the gaps between two successive modules

- Simulation of an **active-façade system** installed on a building envelope.
- **Calculation of mass flow rate** and its **thermal effect** for different temperature conditions assuming **natural convection**
- Derivation of fitting curves (correlations) for **Modelica model**

D1.5b Active-façade CFD simulation and optimization guidelines



- The **total number** of the investigated **cases** is 3x3x3=**27** since, the representative temperature values for each parameter have been selected to be three.

Boundary Conditions

Surface heat flux:

- Q_1 from the wall adjacent to the technical room to the air canal
- Q_2 from the air canal to the back wall

Three critical temperatures:

-**Ambient** temperature (**T_{amb}**) {10ºC,20ºC,30ºC}

-**Temperature** on the walls close to the **technical room** of the PV (**T_{cl1}**) {35ºC,45ºC,65ºC}

-**Temperature** on the walls close to the **room** of the building (**T_{cl2}**) {20ºC,25ºC,30ºC}

At the outlet surface: *pressure outlet*

At the inlet surface: *pressure inlet*

At the **bounds** of the domains close to inlet and outlet surfaces: *symmetry*

D1.5b Active-façade CFD simulation and optimization guidelines

Logical Diagram & Heat Flux Results

Step 1

- The results regarding the heat flux values, Q_1 and Q_2, are expressed as a function of the **two non-governing temperatures** based on the fitting of the CFD results
- The function is a **polynomial of degree 2**

Step 2

- **Each parameter** of the quadratic polynomial is expressed as a function of the **governing temperature**

Step 3

- **Comparison** between the CFD results and the values that these functions provide regarding the heat flux of both surfaces for each specific case and temperature combination.

Case (a) → governing temperature T_{cl2}
Case (b) → governing temperature T_{cl1}
Case (c) → governing temperature T_{amb}

Surface 1											
Case (b)– Module 2				Case (b)– Module 2				Case (b)– Module 2			
T_{amb} (°C)	T_{cl2} (°C)	T_{cl1} (°C)	Q_1 (W)	T_{amb} (°C)	T_{cl2} (°C)	T_{cl1} (°C)	Q_1 (W)	T_{amb} (°C)	T_{cl2} (°C)	T_{cl1} (°C)	Q_1 (W)
20	20	35	21.76	20	20	45	40.43	20	20	65	87.70
20	25	35	12.46	20	25	45	30.04	20	25	65	73.33
20	30	35	6.29	20	30	45	21.14	20	30	65	60.56
10	20	35	21.57	10	20	45	39.84	10	20	65	91.82
10	25	35	13.69	10	25	45	30.41	10	25	65	71.23
10	30	35	7.49	10	30	45	22.06	10	30	65	59.97
30	20	35	22.19	30	20	45	37.73	30	20	65	78.37
30	25	35	12.00	30	25	45	30.38	30	25	65	71.07
30	30	35	5.22	30	30	45	21.23	30	30	65	59.61

Surface 2											
Case (b)– Module 2				Case (b)– Module 2				Case (b)– Module 2			
T_{amb} (°C)	T_{cl2} (°C)	T_{cl1} (°C)	Q_2 (W)	T_{amb} (°C)	T_{cl2} (°C)	T_{cl1} (°C)	Q_2 (W)	T_{amb} (°C)	T_{cl2} (°C)	T_{cl1} (°C)	Q_2 (W)
20	20	35	-21.91	20	20	45	-40.48	20	20	65	-83.41
20	25	35	-12.35	20	25	45	-30.29	20	25	65	-72.95
20	30	35	-6.02	20	30	45	-21.05	20	30	65	-59.86
10	20	35	-21.48	10	20	45	-39.21	10	20	65	-85.86
10	25	35	-13.03	10	25	45	-29.68	10	25	65	-69.64
10	30	35	-5.53	10	30	45	-20.15	10	30	65	-57.31
30	20	35	-21.67	30	20	45	-37.72	30	20	65	-78.32
30	25	35	-12.00	30	25	45	-29.74	30	25	65	-65.38
30	30	35	-5.22	30	30	45	-21.48	30	30	65	-60.11

Heat Flux Results for Module (2) and case (b)

D1.5b Active-façade CFD simulation and optimization guidelines

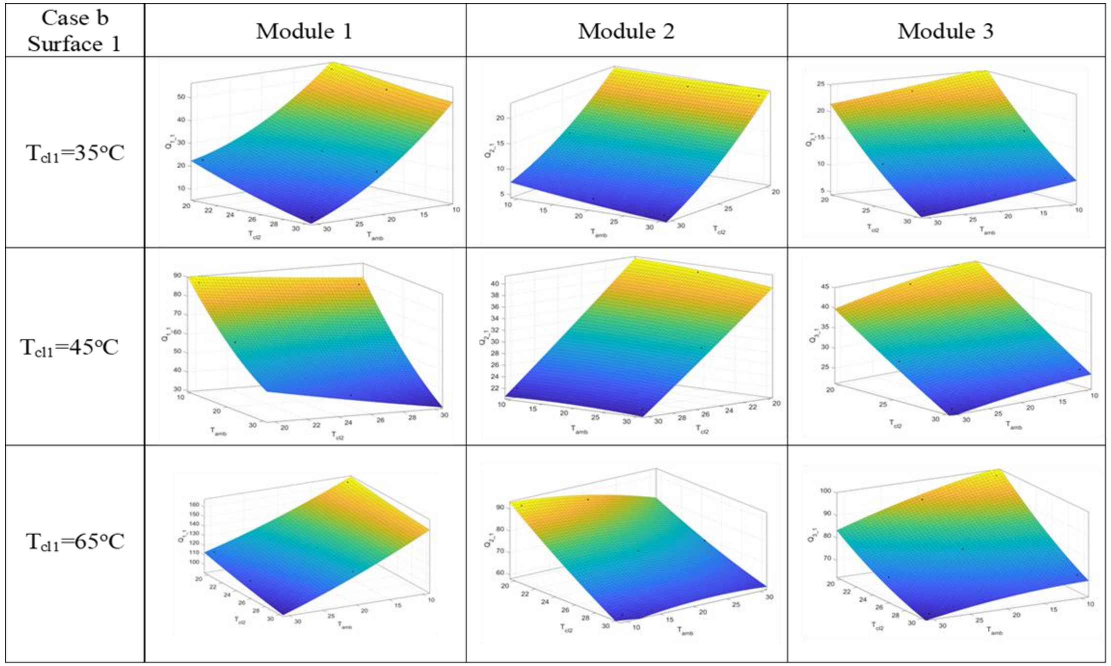
Derivation of Correlations

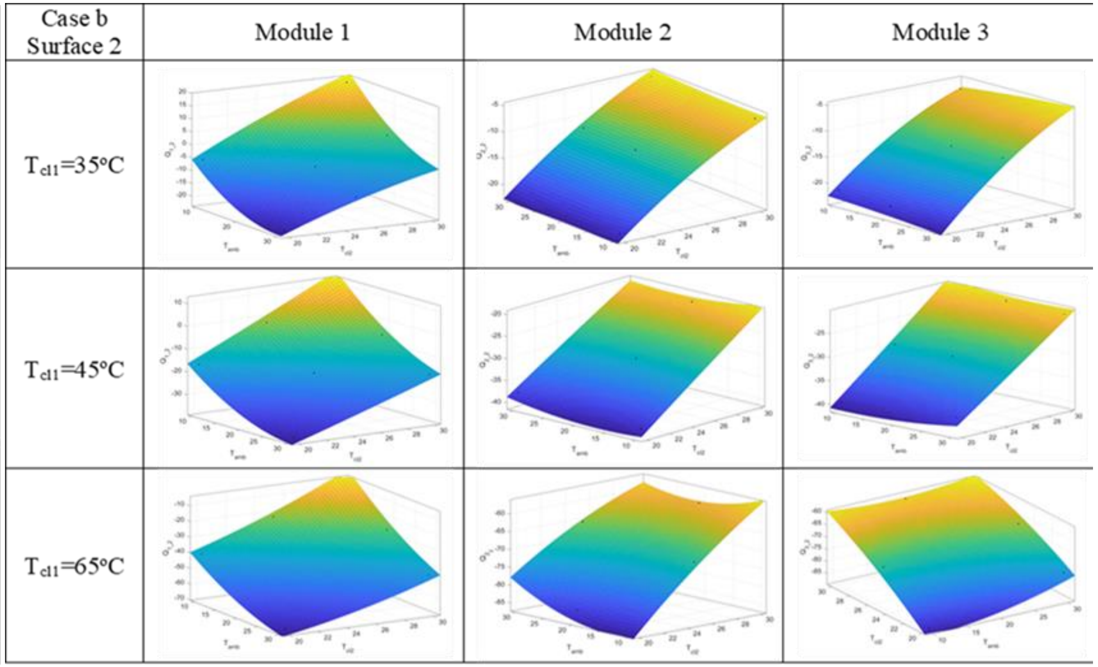
$$Q1(T_{amb},T_{cl2}) = p_0 + p_1*T_{amb} + p_2*T_{cl2} + p_3*T_{amb}^2 + p_4*T_{amb}*T_{cl2} + p_5*T_{cl2}^2$$

$$Q2(T_{amb},T_{cl2}) = p_0' + p_1'*T_{amb} + p_2'*T_{cl2} + p_3'*T_{amb}^2 + p_4'*T_{amb}*T_{cl2} + p_5'*T_{cl2}^2$$

→ *Expression of the heat flux as a function of the non-governing temperatures of case (b)*

The values of the **parameters (p_0, p_1, …, p_5')** are resulted by **fitting the curves** of the heat flux values for each **different governing temperature** value versus the two rest temperature parameters.





The fitting process results in these surfaces for case (b)

Derivation of Correlations

The expressions used as **input** for the **Modelica model** for the **second module**

Second Module

$Q1(T_{amb},T_{cl1},T_{cl2}) = (0.1662*\mathbf{T_{cl2}}^2 - 7.251*\mathbf{T_{cl2}} + 46.76) + (0.0237*\mathbf{T_{cl2}}^2 - 1.3475*\mathbf{T_{cl2}} + 18.951)*\mathbf{T_{amb}} + (-0.0133*\mathbf{T_{cl2}}^2 + 0.6337*\mathbf{T_{cl2}} - 6.6623)*\mathbf{T_{cl1}} + (-1E-04*\mathbf{T_{cl2}}^2 + 0.0061*\mathbf{T_{cl2}} - 0.098)*\mathbf{T_{amb}}^2 + (-0.0005*\mathbf{T_{cl2}}^2 + 0.0282*\mathbf{T_{cl2}} - 0.3846)*\mathbf{T_{amb}}*\mathbf{T_{cl1}} + (0.0002*\mathbf{T_{cl2}}^2 - 0.0122*\mathbf{T_{cl2}} + 0.1701)*\mathbf{T_{cl1}}^2$

$Q2(T_{amb},T_{cl1},T_{cl2}) = (-0.7412*\mathbf{T_{cl2}}^2 + 36.638*\mathbf{T_{cl2}} - 405.29) + (0.0182*\mathbf{T_{cl2}}^2 - 0.8192*\mathbf{T_{cl2}} + 8.1412)*\mathbf{T_{amb}} + (0.0246*\mathbf{T_{cl2}}^2 - 1.1851*\mathbf{T_{cl2}} + 12.978)*\mathbf{T_{cl1}} + (-0.0004*\mathbf{T_{cl2}}^2 + 0.0195*\mathbf{T_{cl2}} - 0.2174)*\mathbf{T_{amb}}^2 + (-8E-05*\mathbf{T_{cl2}}^2 + 0.0023*\mathbf{T_{cl2}} + 0.0006)*\mathbf{T_{amb}}*\mathbf{T_{cl1}} + (-0.0002*\mathbf{T_{cl2}}^2 + 0.0119*\mathbf{T_{cl2}} - 0.1577)*\mathbf{T_{cl1}}^2$

T_{cl2} governing temperature Case (a)

$Q1(T_{amb},T_{cl2},T_{cl1}) = (0.1872*\mathbf{T_{cl1}}^2 - 14.855*\mathbf{T_{cl1}} + 370.92) + (-0.0128*\mathbf{T_{cl1}}^2 + 1.2033*\mathbf{T_{cl1}} - 30.498)*\mathbf{T_{amb}}\ (-0.0006*\mathbf{T_{cl1}}^2 + 0.0138*\mathbf{T_{cl1}} + 0.4697)*\mathbf{T_{cl2}} + (0.0002*\mathbf{T_{cl1}}^2 - 0.0235*\mathbf{T_{cl1}} + 0.5944)*\mathbf{T_{amb}}^2 + (3E-05*\mathbf{T_{cl1}}^2 - 0.0002*\mathbf{T_{cl1}} - 0.0419)*\mathbf{T_{amb}}*\mathbf{T_{cl2}} + (-1E-05*\mathbf{T_{cl1}}^2 + 0.0005*\mathbf{T_{cl1}} - 0.0003)*\mathbf{T_{cl2}}^2$

$Q2(T_{amb},T_{cl2},T_{cl1}) = (-0.1654*\mathbf{T_{cl1}}^2 + 13.05*\mathbf{T_{cl1}} - 334.47) + (0.012*\mathbf{T_{cl1}}^2 - 1.1181*\mathbf{T_{cl1}} + 28.357)*\mathbf{T_{amb}} + (0.0003*\mathbf{T_{cl1}}^2 - 0.0076*\mathbf{T_{cl1}} - 0.2005)*\mathbf{T_{cl2}} + (-0.0002*\mathbf{T_{cl1}}^2 + 0.023*\mathbf{T_{cl1}} - 0.565)*\mathbf{T_{amb}}^2 + (-7E-06*\mathbf{T_{cl1}}^2 - 0.0011*\mathbf{T_{cl1}} + 0.0491)*\mathbf{T_{amb}}*\mathbf{T_{cl2}} + (6E-06*\mathbf{T_{cl1}}^2 + 0.0002*\mathbf{T_{cl1}} - 0.0116)*\mathbf{T_{cl2}}^2$

T_{cl1} governing temperature Case (b)

$Q1(T_{cl1},T_{cl2},T_{amb}) = (-0.0299*\mathbf{T_{amb}}^2 + 0.425*\mathbf{T_{amb}} + 11.437) + (-0.0008*\mathbf{T_{amb}}^2 - 0.0076*\mathbf{T_{amb}} + 1.9283)*\mathbf{T_{cl1}} + (0.0037*\mathbf{T_{amb}}^2 - 0.0148*\mathbf{T_{amb}} - 3.4338)*\mathbf{T_{cl2}} + (-1E-05*\mathbf{T_{amb}}^2 + 0.0001*\mathbf{T_{amb}} + 0.0174)*\mathbf{T_{cl1}}^2 + (5E-05*\mathbf{T_{amb}}^2 + 0.0006*\mathbf{T_{amb}} - 0.0723)*\mathbf{T_{cl1}}*\mathbf{T_{cl2}} + (-1E-04*\mathbf{T_{amb}}^2 - 0.001*\mathbf{T_{amb}} + 0.1001)*\mathbf{T_{cl2}}^2$

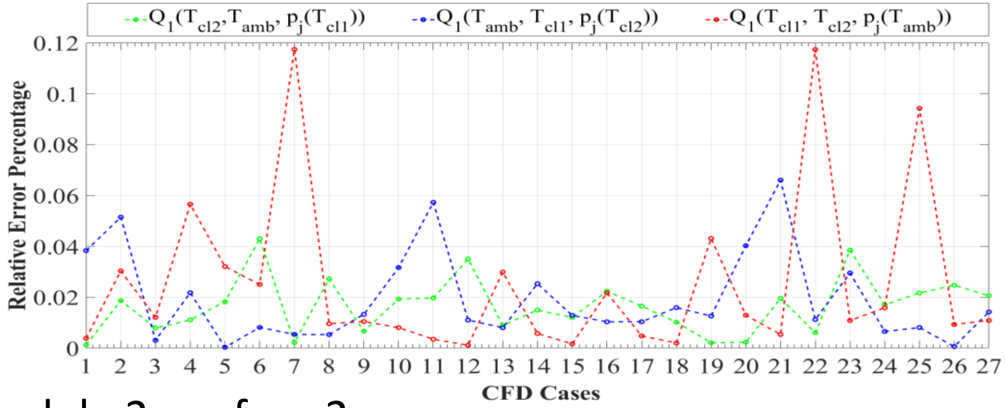
$Q2(T_{cl1},T_{cl2},T_{amb}) = (-0.244*\mathbf{T_{amb}}^2 + 7.5505*\mathbf{T_{amb}} - 50.737) + (0.0003*\mathbf{T_{amb}}^2 + 0.0088*\mathbf{T_{amb}} - 1.671)*\mathbf{T_{cl1}} + (0.0196*\mathbf{T_{amb}}^2 - 0.6254*\mathbf{T_{amb}} + 5.961)*\mathbf{T_{cl2}} + (6E-06*\mathbf{T_{amb}}^2 + 7E-05*\mathbf{T_{amb}} - 0.0156)*\mathbf{T_{cl1}}^2 + (-2E-06*\mathbf{T_{amb}}^2 - 0.0017*\mathbf{T_{amb}} + 0.0603)*\mathbf{T_{cl1}}*\mathbf{T_{cl2}} + (-0.0004*\mathbf{T_{amb}}^2 + 0.0142*\mathbf{T_{amb}} - 0.1343)*\mathbf{T_{cl2}}^2$

T_{amb} governing temperature Case (c)

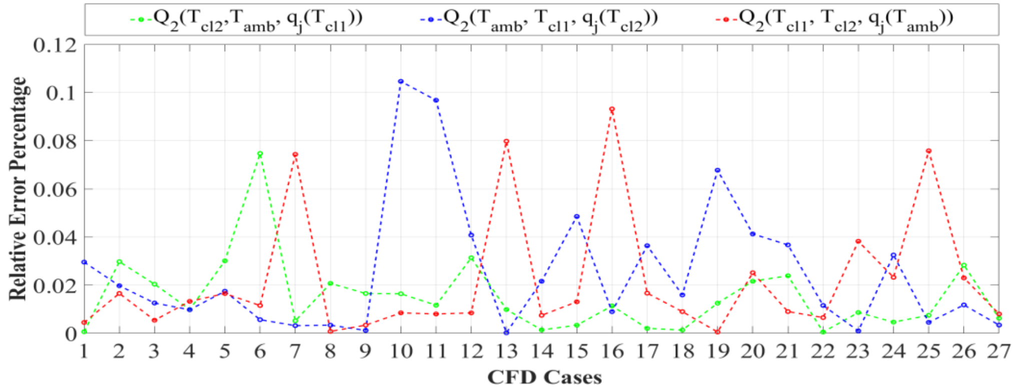
D1.5b Active-façade CFD simulation and optimization guidelines

Derivation of Correlations and Conclusions

Module 2, surface 1



Module 2, surface 2



- The empirical correlations of **case (b)** show the **best** approximation to the CFD results, since the **standard deviation** is the **lowest** among the cases.

- More specifically, it is 0.018 in case (a), 0.011 in case (b) and 0.035 in case (c) for surface 1, while it is 0.028 in case (a), 0.015 in case (b) and 0.028 for surface 2.

- So, it can be concluded that the empirical correlations that use $\mathbf{T_{cl1}}$ as governing temperature, case (b), and refer to **Module 2** provide good approximation to the CFD results.

THANK YOU