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A Co-Creation Workshop on Designing and Developing Solar Cooling Integrated Facades

A Summary Report on Workshop Outcomes

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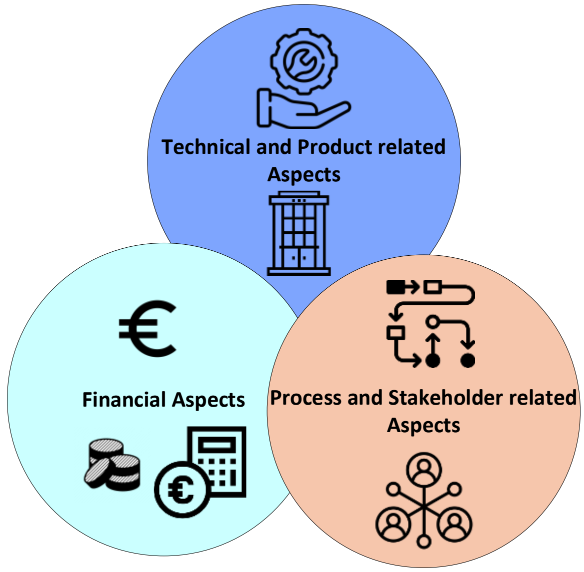
1. Study Summary

Given the global challenges arising from climate change, relevant, promising methods to expedite the energy transition are essential (Enteria and Sawachi, 2020; Sahin and Ayyildiz, 2020; Santamouris, 2016). The integration of solar cooling technologies into façades represents an important option, especially given the expected increase in cooling demand within the built environment population (Prieto et al., 2017). This is due to the fact that building façades can have a huge amount of surfaces exposed to solar radiation, which can be used to harvest solar energy to drive cooling equipment. Although there have been developments in the technological level of solar cooling systems, their integration into facades in real projects has been limited due to various challenges. These challenges include lack of knowledge, as well as design-supporting tools in early design stages that facilitate the integration of various key aspects affecting product applicability (Hamida et al., 2022). On the other hand, encouraging multidisciplinary collaboration and streamlining the dissemination of product information have been recognized as crucial factors in facilitating product development (Hamida et al., 2023). Hence, this study aims to support the design team and stakeholders involved at design and development stages with a framework that supports developing solar cooling integrated façades. The framework is intended to integrated key aspects affecting the widespread application of solar cooling integrated façades (Figure 1) (Hamida et al., 2022). The framework is created through conducting a desk research and a pre-workshop survey completed by relevant stakeholders. Subsequently, the framework is evaluated with stakeholders in a co-creation workshop. Finally, it is refined based on the workshop outcomes.

This report presents the key outcomes of the facilitated workshop, which are used to refine the created framework. The workshop outcomes revealed the following:

- The identification of key decision-making factors centers on three primary categories: demand-related factors, architectural integration, and practical considerations and system characteristics.
- The design team emphasizes that designers, owners, and contractors have differing perspectives on façade solutions, with cost being a primary concern for clients. Clients frequently assess façades based on cost per square meter, making it challenging to justify innovative solutions.
- The integration of active systems into prefabricated façades necessitates substantial design modifications to address structural and functional requirements.
- Prefabricated or plug-and-play solutions can reduce on-site construction time and simplify installation. However, these solutions must be incorporated during the design phase; otherwise, implementation becomes challenging.
- The findings emphasize the importance of distinguishing between building design and product design, particularly in the context of modular solar cooling systems. Additionally, they highlight the necessity of adopting a hybrid approach.
- The integration of passive design strategies, active energy systems, and building services requires a non-conventional, holistic approach. A potential solution involves enhanced collaboration among suppliers, designers, and consultants or the emergence of an innovative supplier/façade builders that bridges the gap between building and installation components..



Finger 1: Key aspects to be considered for supporting the application of solar cooling integrated façades

2. Product Design and Development Framework

Considering the key aspects (Figure 1), the framework aims to cover the following key point:

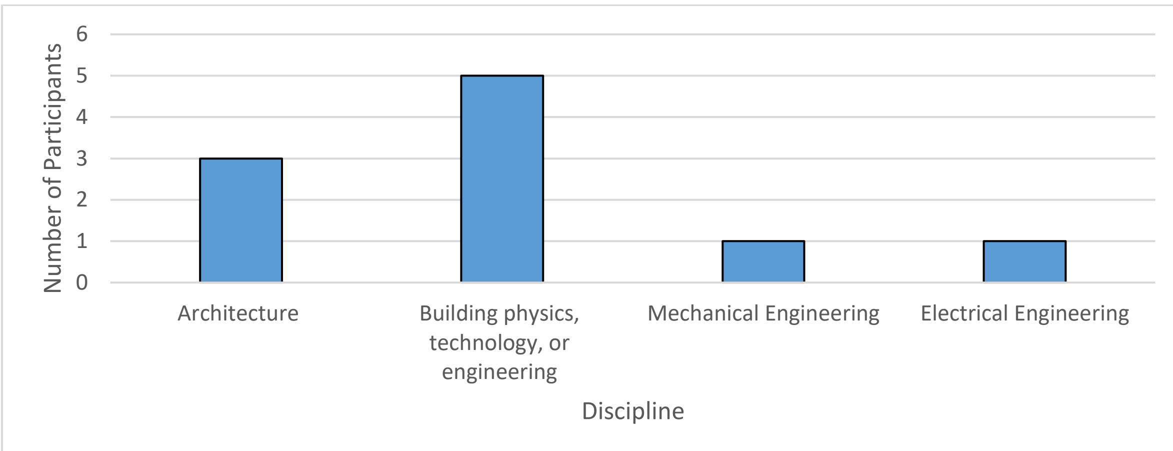
- Main stages related to the design and development of solar cooling integrated façades.
- Main roles and tasks within the main stages
- Key decisions to be made with the design and development stages
- Required information to be processed in order to make decisions and carry out tasks
- Main stakeholders involved and playing a role in the stage
- Tools and means to carry out tasks

To cover the aforementioned key points mentioned, the creation of the framework required various methods and sources of data, including desk research, pre-workshop survey, and co-creation workshop. The desk research is conducted over relevant topics as a first step. The topics included design and construction processes, key stakeholders involved in the façade design and construction stages, and design approaches of solar cooling integrated façades (Hamida et al., 2025; Klein, 2013; Oliveira and Melhado, 2011; Prieto et al., 2023; RIBA, 2020). To facilitate the creation of the framework, the study considered the five stages, namely, conception and strategic definition, preparation and briefing, façade technological selection, façade integration design, and execution. Moving into the determination of the main stakeholders involved at design and development stages and their roles and responsibilities, this study involved the following categorization of the main stakeholders involved in design and development stages:

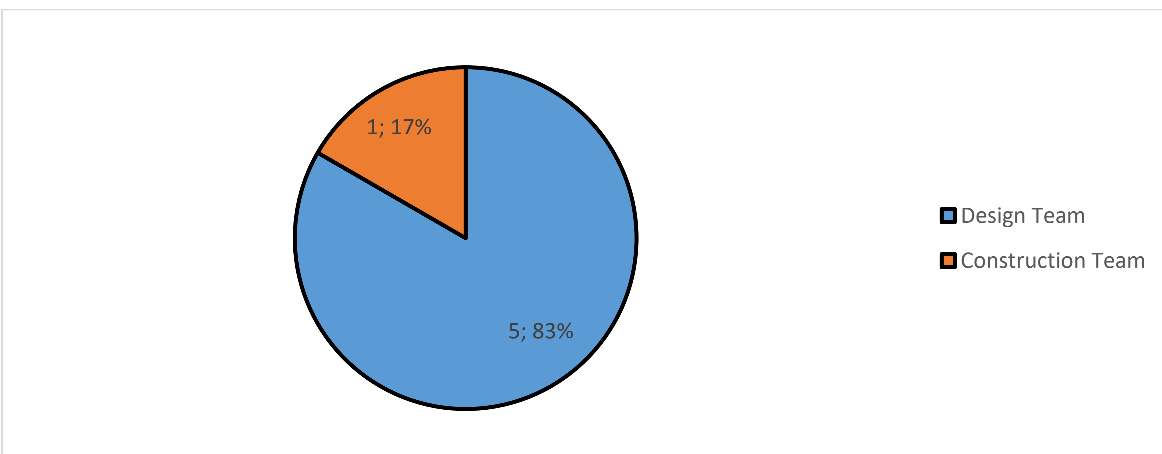
- Client Team: Owner, investor, and/or real estate/property developer.
- Design Team: Design coordinator, architectural designer, façade designer, and/or consultant (Mechanical, Electrical and Plumbing (MEP), building physics, or facade consulting).

- Construction Team: Contractor, subcontractor, supplier/manufacturer, and/or façade builder/assembler.

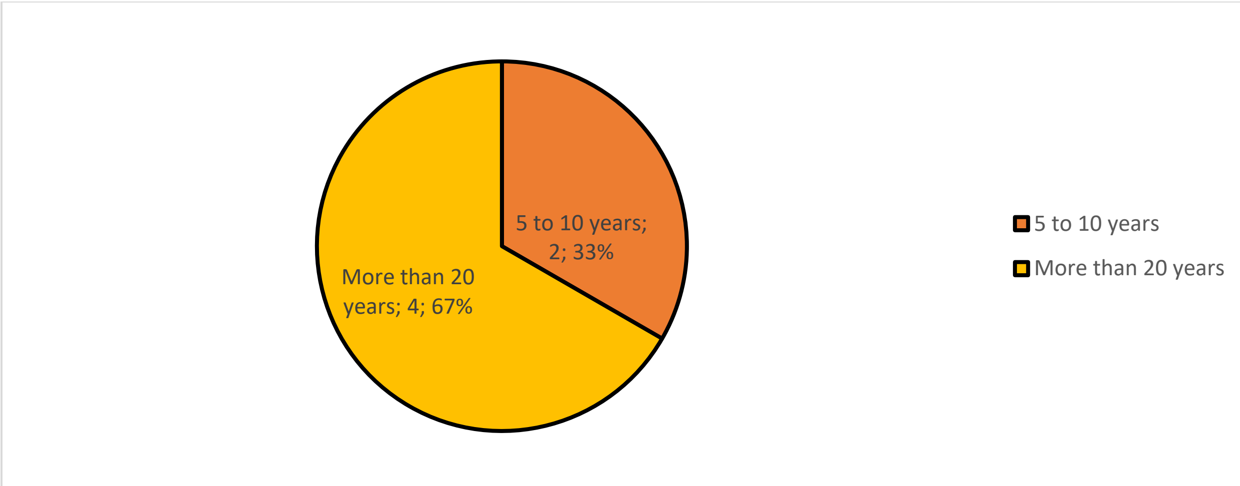
Based on the determined aforementioned groups of stakeholders as well as the main stages for framework creation, a pre-workshop survey was distributed over invited participants representing relevant stakeholders in the European context. Based on an invitation sent to more than fifteen professionals to be invited to the workshop, a total of six professionals accepted the invitation and filled the pre-workshop online survey. Figures 2 to 10 show participants' profile in terms of their educational and technical background, professional experiences in the building industry, and professional years of experience.



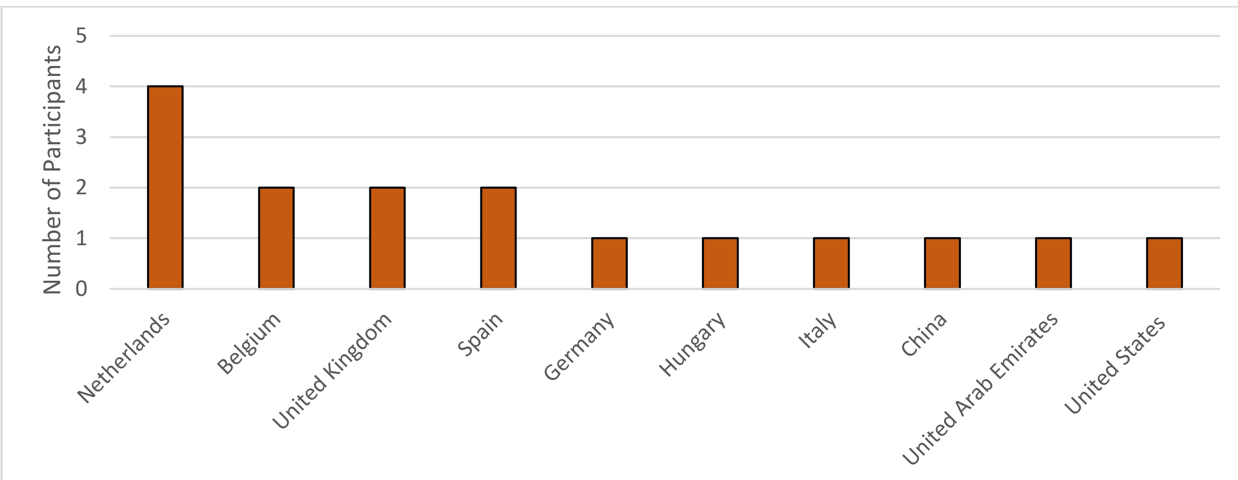
Finger 2: Main educational and technical background



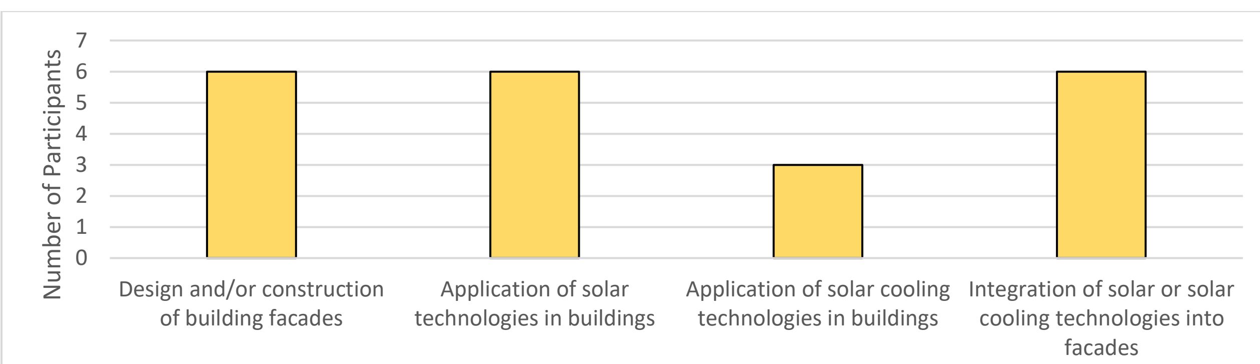
Finger 3: Field of professional experiences in the building industry



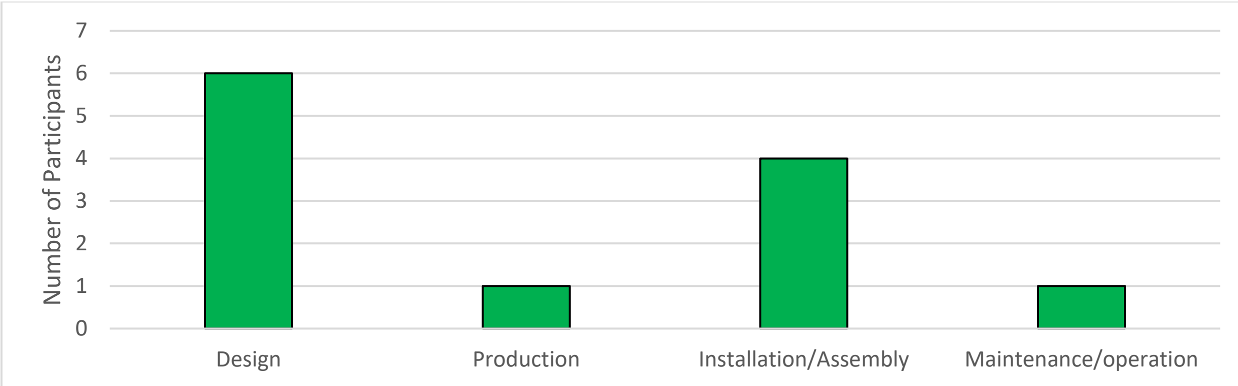
Finger 4: Professional years of experience



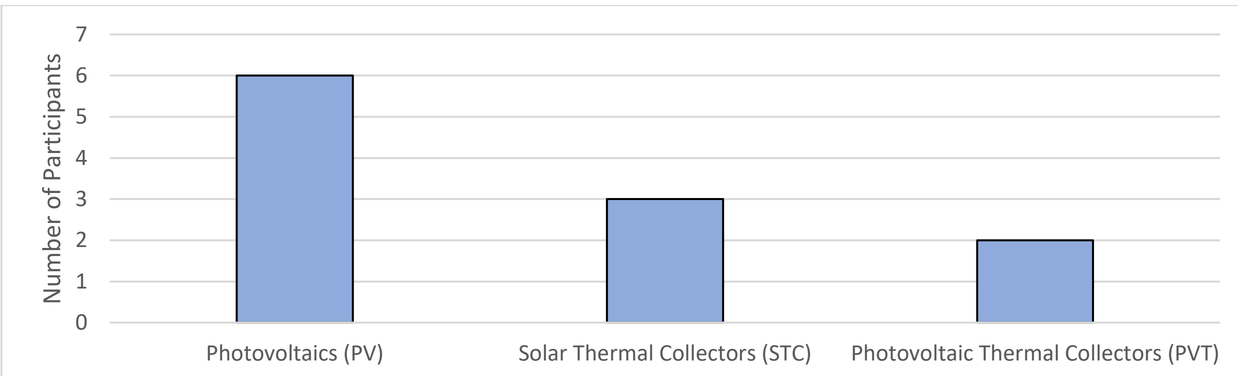
Finger 5: Countries where most of the project participants have worked



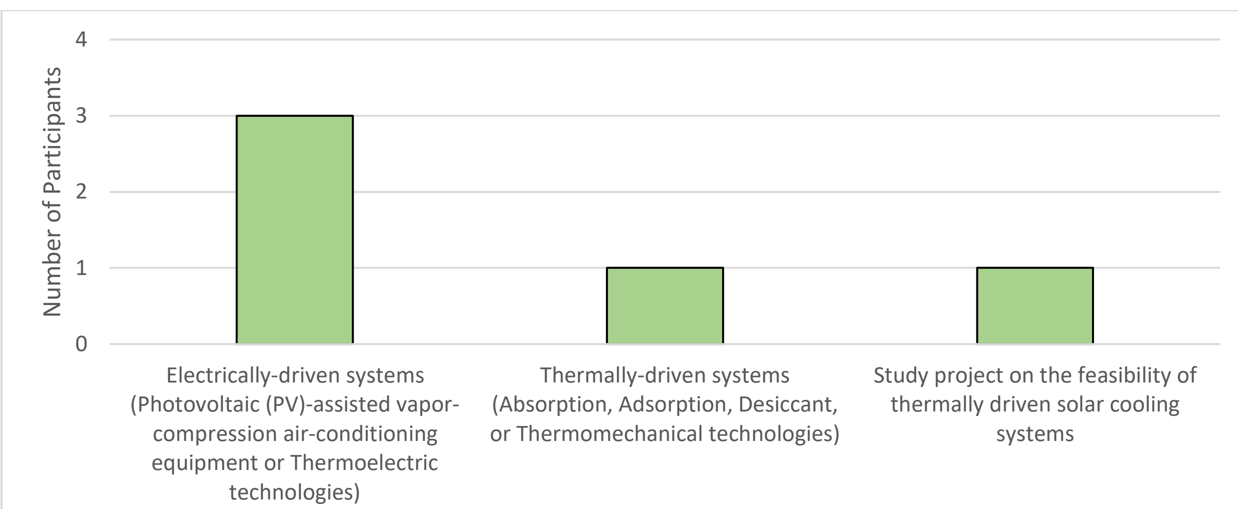
Finger 6: Involvement of participants in different types of projects



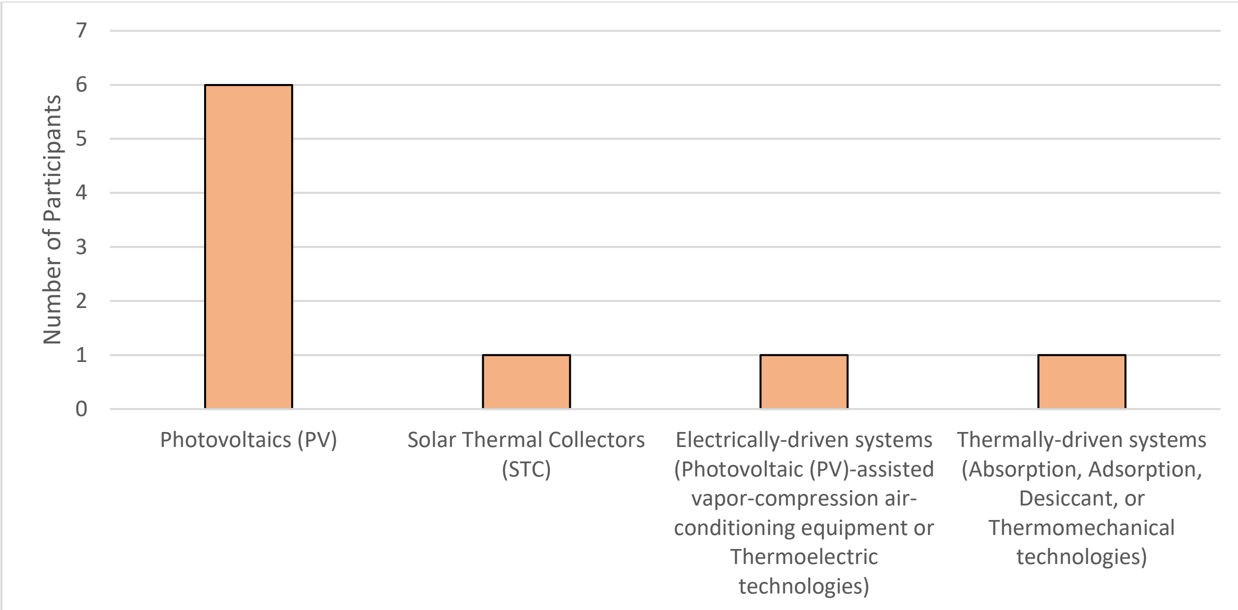
Finger 7: Phases in which participants have been involved during the design or construction of building façades



Finger 8: Technologies used in projects that applied solar technologies in which participants have been involved



Finger 9: Technologies used in projects that applied solar cooling technologies in which participants have been involved



Finger 10: Technologies used in projects that integrated solar or solar cooling technologies into façades, in which participants have been involved

3. Framework Evaluation and Workshop Outcomes

To evaluate the created framework, a virtual workshop guide was developed. The workshop protocol covered the four main parts, namely the welcome and introduction round, research background, interactive session and activities, reflection and closing. The evaluation of the framework was carried out in the interactive session as well as reflection parts through the following:

1. Participants in the interactive session were given a hypothetical office building case, where they were asked to think and plan together and perform the following tasks:
    a) Identify key design-decisions
    b) Organize and prioritize the decisions
    c) Determine required information to process the decisions
    d) Identify stakeholders playing a role in making decisions
2. Participants in the reflection part were asked to answer and discuss the following questions and aspects, respectively:
    a) Are there any key aspects that have not been covered?
    b) Were there any parts related to the created framework that were not addressed?
    c) Which parts did participants find difficult to decide on, and why?
    d) To what extent do the integrated decisions, information and stakeholders support the design and development of solar cooling integrated façades? (Consider both drivers and concerns.)

Accordingly, a two-hour workshop was organized on February 28, 2025, using Microsoft Teams and Whiteboard, as indicated in the appendix. Of the six participants who completed the pre-workshop survey, four attended the workshop. Three represented the design team, while one represented the construction team. The following sections discuss the main outcomes of the workshop.

3.1. Main Outcomes

The identification of decisions revolves around key aspects that can be categorized into demand-related factors, architectural integration, practical considerations and system characteristics, as summarized below:

- Energy Demand and Optimization:
  - Designing buildings to reduce energy demand
  - Focusing on passive design strategies, particularly for cooling
  - Integrating the system with passive measures to optimize efficiency
  - Understanding overall cooling demand and how it affects system feasibility
- Architectural and Building Typology Considerations:
  - Understanding how the system integrates with building typology
  - Identifying architectural elements like daylight, orientation, and overall façade design
  - Considering the importance of façade design in combining functionality with aesthetic and performance goals
- Practical Considerations and System Characteristics:
  - Taking into account access to maintenance and maintenance requirements
  - Considering the ease of installation: Plug and play, prefabricated or industrialized solutions
  - Understanding life expectancy and durability: Clients can be hesitant to invest in unproven technologies as they seek reliability and proven solutions for large investments.
  - Involving factors related to weather resistance
  - Determining the type of technology used and components of the system (e.g., storage, evaporation)
  - Practical aspects such as size, weight, and fire safety

These key aspects were linked to different stages, as shown in Table 1. Consequently, based on the organized decisions, the necessary information for decision-making and the stakeholders involved in the process were identified, as shown in Table 1.

Table 1: Summary of Main Outcomes

Item	Stage				
	Conception and Strategic Definition	**Preparation and Briefing**	**Façade Technological Selection**	**Façade Integration Design**	**Execution**
Purpose and Main Outcomes	Identify possibilities for building integration	Assess the feasibility of the generated possibilities	Select the relevant architectural façade technology	Present the detailed design of integrating the selected technology	Design for installing façade components
Decision Aspects Linked to the Stage	• Assessing and reducing building preliminary energy consumption in relation to energy demand • Determining the potentials of having modular, industrialized, or plug and play solutions • Analysing the sequence of construction activities • Considering building orientation, architectural elements, and available envelope possibilities to integrate the technology • Identifying life expectancy and replacement requirements of components • Amortization (payback period/cost-effectiveness)	• Assessing the feasibility in terms of demand and cost: Assess whether the system makes sense based on energy demand and financial feasibility. • Determining component weight and Structural Impact: Heavy components may require structural reinforcements, increasing costs. • Ensuring fire safety of materials	• Prefabrication types of system components (storage, evaporation, electrical driven heat pump) • Sizes of components for façade integration and checking how much space is available in the façade • Maintenance accessibility requirements	• Ease of installation considering the potentials of having a prefabricated and plug and play solution • Maintenance accessibility requirements	• Analysing installation process considering auxiliary elements avoiding conflicts with other activities • A company proving guarantees and having sufficient expertise to maintain the installation

Table 1: Summary of Main Outcomes (cont.)

Item	Stage				
	Conception and Strategic Definition	**Preparation and Briefing**	**Façade Technological Selection**	**Façade Integration Design**	**Execution**
Determined Required Information to Process Decisions	• Technical design criteria and performance requirements • Working materials of technologies • Performances and efficiencies of technologies • Cost of technologies • Maintenance requirements	• Technical design criteria and performance requirements • Working materials of technologies	• Regulatory requirements • Safety, fire resistance, thermal performance • CE marking for existing products. Architectural elements • Detailed cost calculation data	• Information on the components, size, way of connection etc. How it can be connects	• Warranties • Order of construction activities not to damage the active systems • Information about installation
Identified stakeholders playing a role in making decisions	• Owner, investor, and/or real estate/property developer • Façade suppliers/manufacturers • Architectural designer (As responsible for the design)	• HVAC suppliers/manufacturers • Consultants (Mechanical, Electrical and Plumbing (MEP), building physics, or facade consulting) • Architectural designer (As responsible for the design)	• Architectural designer • Consultants (Mechanical, Electrical and Plumbing (MEP), building physics, or facade consulting) • Suppliers/manufacturers	• Façade designer • Suppliers/manufacturers	• Contractors • Suppliers/manufacturers

3.2. Additional Outcomes

3.2.1. Consideration of Installation Aspects from the Early Design Phase

The construction team, primarily the contractor, emphasizes the necessity of planning the installation process from the beginning. Considerations should extend beyond cost to include auxiliary elements and required labour. Construction companies can typically work with a client's pre-existing building design. This can include the considerations of prefabricated or plug-and-play solutions, which can reduce on-site construction time and simplify installation. Hence, the decision to implement prefabrication depends entirely on client approval. However, if prefabrication is introduced, the building design often requires substantial modifications. Consequently, late-stage design changes can significantly impact production and feasibility. This is due to the fact that integrating active systems into prefabricated façades necessitates considerable design adjustments to accommodate both structural and functional requirements. In addition to that, prefabricated and industrialized solutions tend to operate differently from conventional construction methods.

3.2.2. The Relationship between Building Design and Product Design .

The outcomes revealed the importance of considering the relationship between building design and product design. Building design tends to follow a sequential process, beginning with large-scale considerations prior to selecting specific components. Product design adopts a different methodology, wherein standardized systems are developed and subsequently adapted to various buildings. Taking into account the considerations of prefabrication and standardization (Section 3.2.1), it was pointed out that developing a product tailored to a single building is not commercially viable. Accordingly, a successful modular solar cooling façade system should be adaptable across various building types to ensure market feasibility. Hence, prefabricated components should incorporate a degree of standardization while maintaining flexibility for different applications. Consequently, building design tends to follow product design, as it integrates available, standardized systems that have already been developed.

3.2.3. Client Influence

The design team emphasizes that designers, owners, and constructors have differing perspectives on façade solutions, with cost being a primary concern for designers. Clients often assess façades based on cost per square meter, which can make it challenging to justify innovative solutions. Furthermore, clients can generally fall into two categories: investors, who prioritize cost per square meter and are less inclined to adopt new technologies, and owners, who retain the building and are more open to innovation due to long-term payback considerations. When the owner and investor are the same entity, there is greater flexibility to implement energy-efficient systems. To secure client approval, factors such as life cycle cost analysis, payback periods, and maintenance requirements should be considered from the project's outset. The early integration of innovative solutions increases the likelihood of adoption, reducing the risk of their exclusion due to cost concerns. Ultimately, the process requires balancing costs and benefits across different project phases.

3.2.4. Collaboration.

The conventional construction process involves clients setting a budget, designers proposing solutions, and contractors bidding for the lowest cost. Such cost-driven approach can be challenging when it comes to the adoption of innovative façade technologies. Hence, it was pointed out that a more effective alternative can involve a collaborative approach in which the client, designer, and builder engage from the outset, optimizing processes despite potential increases in initial costs. Successful implementation requires collaboration among an innovative client, architect, and supplier. Without such coordination, projects risk failure due to unclear responsibilities and disjointed workflows.

3.2.5. Responsibility

The lack of clear responsibility among stakeholders represents a major challenge in adopting innovative façade systems. While client support is essential, conflicts can often arise when suppliers do not assume responsibility for installation. For instance, architects in some countries are required to sign off on projects and are held accountable for design decisions, making their involvement crucial. However, architects may lack the technical expertise needed for integrating and installing innovative solutions. Hence, having a clearly accountable party represents an essential factor for the successful integration of innovative façade systems. It was therefore pointed out that a potential solution could include involving suppliers in supervising installation to ensure expertise is maintained throughout the process.

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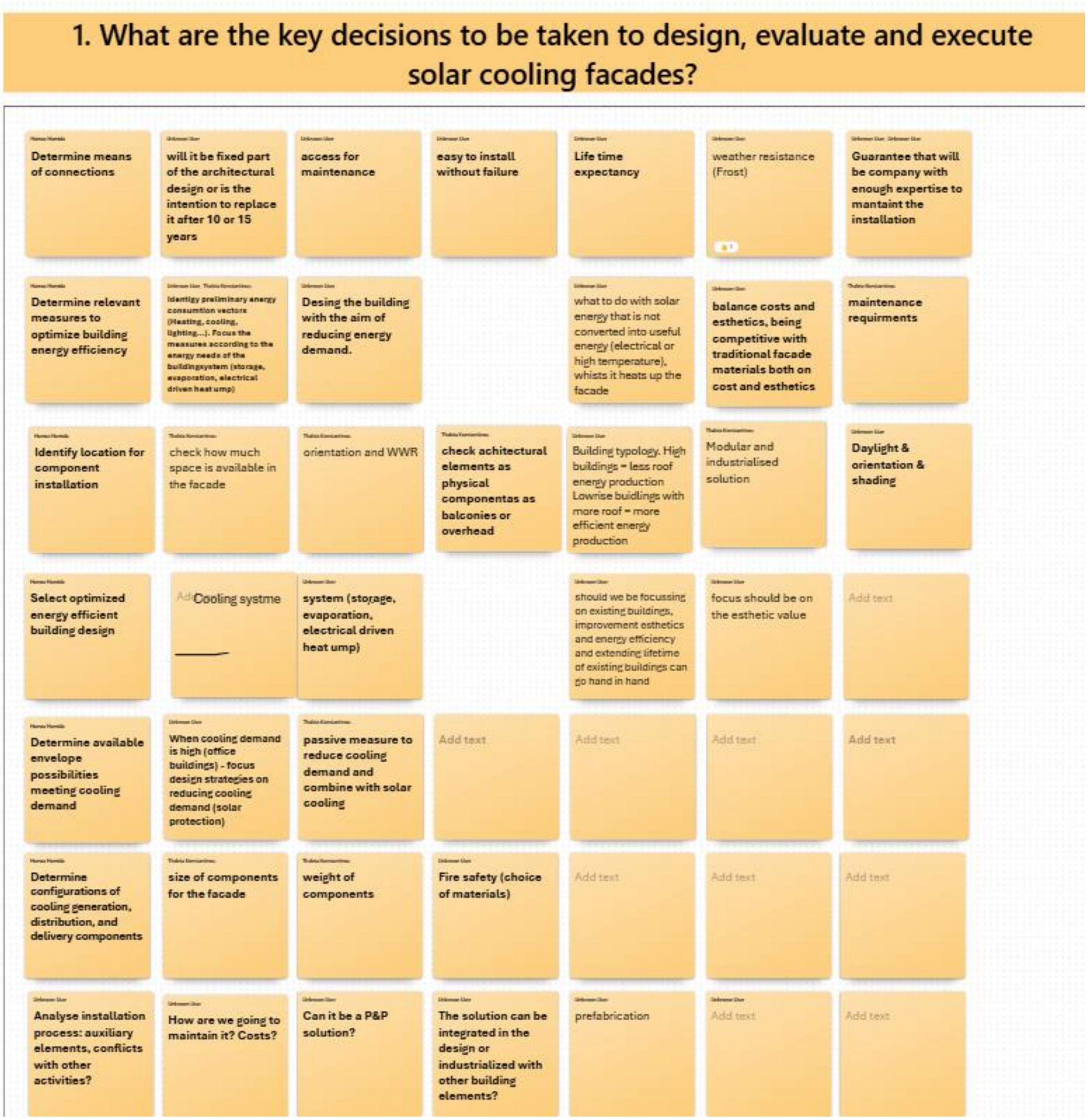
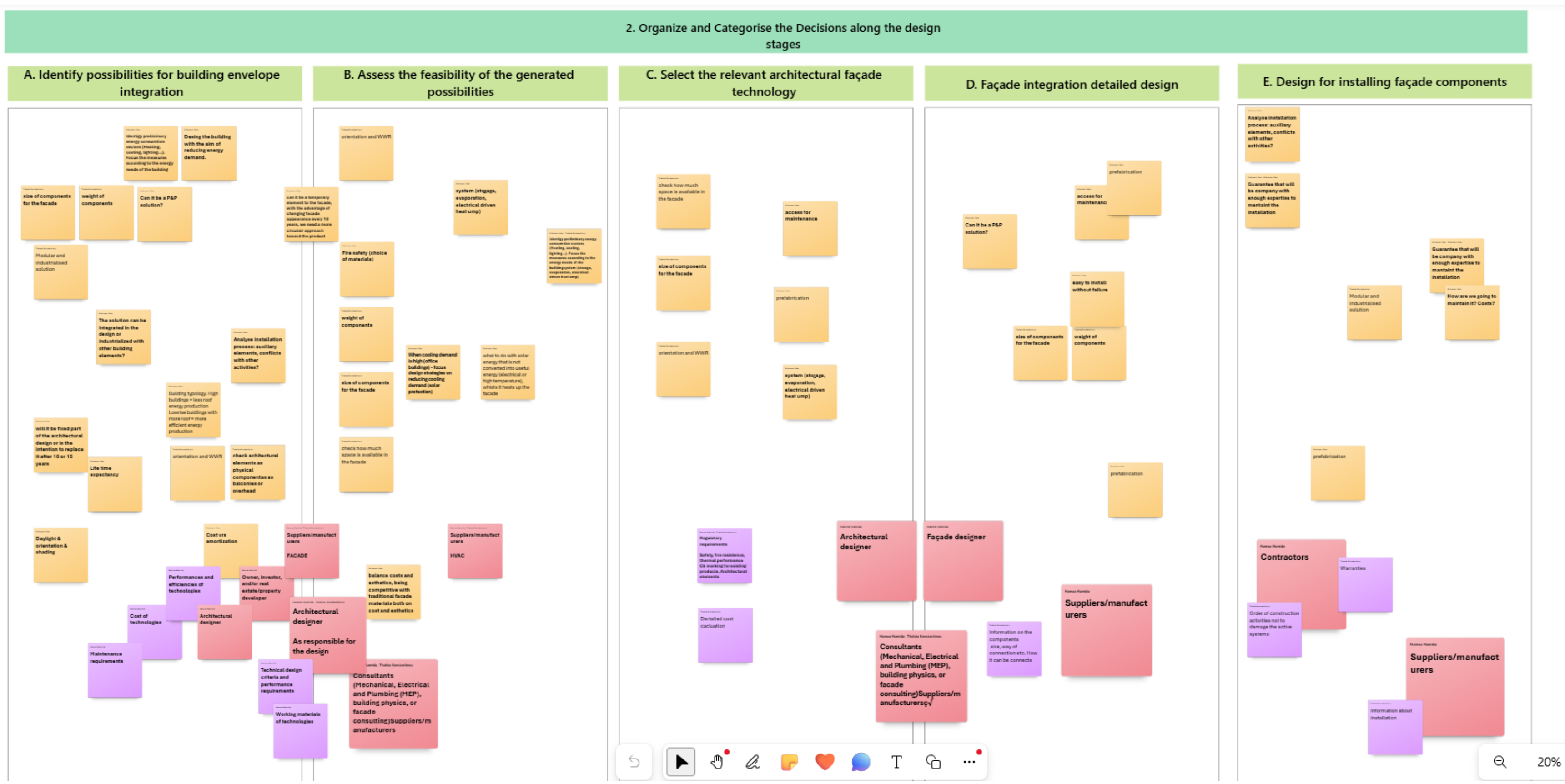
APPENDIX: WORKSHOP ACTIVITIES




2. Organize and Categorise the Decisions along the design stages
A. Identify possibilities for building envelope integration
B. Assess the feasibility of the generated possibilities
C. Select the relevant architectural façade technology
D. Façade integration detailed design
E. Design for installing façade components
Architectural designer
Façade designer
Suppliers/manufacturers
Contractors
20%