9 Conclusions

This dissertation aimed to explore the possibilities and constraints for the façade integration of solar cooling systems, in order to support the design of climate responsive architectural products for office buildings as an alternative to conventional AC systems. This final chapter summarises and discusses the main outcomes of the dissertation. Firstly, responses to the research questions are showcased, starting with the sub-questions and their particular findings, leading to a comprehensive answer to the main research question driving the research project. Then, general conclusions are drafted, outlining the scientific contribution and limitations of the study to finalise with recommendations for further developments in the field.

§ 9.1 Introduction

This thesis aimed to explore the possibilities and constraints for the façade integration of solar cooling systems, in order to support the design of climate responsive architectural products for office buildings as an alternative to conventional AC systems. The exploration was conducted through diverse qualitative and quantitative assessments, in order to provide a comprehensive answer to the main research question, and the sub-questions that build up to it. Following the discussion of these answers, this chapter finalises with general conclusions, highlighting the scientific contribution and limitations of the study, besides outlining recommendations for further development and final remarks.

§ 9.2 Answers to the research questions

The responses to the sub-questions are presented first, as partial outcomes that lead to a comprehensive response to the main research question, featured directly after. The sub-questions outline the thesis chapters, hence the conclusions summarise the main findings of each chapter.

§ 9.2.1 Sub-questions

What is the available knowledge on façade related cooling strategies for office buildings? (Chapter 2)

This first sub-question aimed to present a panorama of cooling research in office buildings as a start point for the thesis, identifying relevant research trends and current knowledge gaps to expand the background of the research project. This panorama of the available knowledge in the field was the outcome of systematic data gathering, categorisation of reported research experiences, and the detailed review and discussion of relevant findings. Peer reviewed scientific articles published from 1990 to 2014 were the source of the study, generating a journal article database for referential purposes of the thesis. Chapter 2 showed an initial exploration of this database, conducted at the beginning of the research project (2014). Nonetheless, the database kept growing during the course of the study, adding new experiences and state-of-the-art developments.

The initial exploration conducted in 2014 showed that cooling research follows an increasing trend over time, which remains true for different climates (temperate, hot-arid, hot-humid) and cooling sources (passive, active, solar). Interestingly, solar cooling research related to building applications has experienced steady growth from 2008 onwards. This trend has been maintained until today with current explorations of integrated façade concepts, thermoelectric based prototypes in particular, published in the last three years. This evidences increasing interest and current relevance of the topics studied in this dissertation. Regarding research content, most experiences deal with passive cooling, and especially heat prevention strategies. Simulations are the preferred evaluation tool by far, although there is an increasing amount of on-site monitoring studies and prototype testing of new technologies, as validation of previous simulations. Moreover, further tests under real conditions are encouraged when possible. Besides this clear knowledge gap, other identified gaps are the need for more research on heat dissipation cooling principles, such as ground , evaporative, and solar cooling; and the exploration of the architectural integration of active/hybrid low-energy cooling equipment and systems, a challenge that defined the focus of this research project.

What are the conceptual issues and state-of-the-art components and systems to consider for solar cooling façade integration? (Chapter 3)

This question sought to define the concept of solar cooling integrated facades, and the components and technical possibilities comprised by it. Firstly, they are defined as façade systems that consider all necessary equipment to self-sufficiently provide solar driven cooling to a particular indoor environment. From an architectural point of view, the façade integration of building services is regarded as a second step in the design of climate responsive or adaptive façades. Hence, this definition acknowledges a necessary first step of design optimisation through passive strategies or supplementary measures to take care of regulatory façade functions. Moreover, from a constructive standpoint, building services integration can follow either an integral or a modular approach, with different impacts on façade design possibilities and construction and assembly processes.

Discussing solar cooling technological possibilities, a first important distinction to make is between solar electric and solar thermal processes, which will have a great impact on the external appearance of the façade unit. The former rely on photovoltaic panels (PV) and batteries, while the latter deal with solar thermal collectors (STC) and heat storage units. Various cooling principles derive from this major distinction: thermoelectric, sorption, desiccant and thermomechanical cooling, along with sub-principles and systems within them. Nonetheless, self-sufficient decentralised cooling modules need to consider all necessary equipment to remove heat from indoor spaces and release it outdoors. Therefore, all these components are categorised in three main groups, charting the most common possibilities for cooling generation, distribution, and delivery. Although talking in terms of 'cooling generation' or 'delivery' are not physically correct, these categories were preferred for their simplicity.

Cooling generation comprises solar cooling principles, and their corresponding energy conversion technologies (PV or STC). Cooling distribution discusses general technology based on different heat transfer mediums (air, water or mass); while finally, under cooling delivery, several systems for heat exchange with the indoor air are showcased. The integration of technological components from all three groups is regarded as a condition for the development of self-sufficient cooling façade modules. Furthermore, while distribution and delivery basically cover all general possibilities; new alternative cooling processes could be added in the 'generation' tab, further expanding the proposed framework for design and development of self-sufficient cooling facades.

What are the main perceived problems for building services integration in facades at different stages of the façade design process? (Chapter 4)

The answers to questions 3 and 4 are derived from the analysis of the results from the questionnaire exhibited as Appendix A. In general, barriers related to the overall process are perceived as more pressing issues to solve than issues about the end product itself, to allow for widespread façade integration of building services. In particular, problems related to the coordination among professionals from different areas are perceived as the most relevant ones, which holds true in all three defined stages of façade development (design, production and assembly). Discussing other highly mentioned process related problems, lack of technical knowledge seems to be especially relevant during design and assembly stages. The fact that this did not appear as a major problem during the production stage, is regarded as evidence of the experience and maturity of façade building companies, at least in the European context, where most responses came from. Nonetheless, several logistical issues were pointed out in production and assembly stages, focusing on the lack of flexibility within the production chain; together with economic barriers during production for the construction of high quality components, aggravated by usual underestimation of cost projections during design phases. Finally, other mentioned problems, of minor compared reference, refer to undefined responsibilities and warranties throughout the overall process.

In terms of product related problems, the physical integration of components seems to be the most relevant issue during both production and assembly stages. Additionally, the inaccuracy of long term performance estimations and operational limitations of currently available systems were stated as relevant problems in the design stage. Furthermore, other identified product related barriers, albeit with lower mentions in all stages, are the technical feasibility of integrated concepts; durability and maintenance; and aesthetics and lack of variety of available building services for integration. Even though these problems do not seem to have the same importance than process related aspects, they represent basic requirements and relevant challenges to overcome in the path for the development of components and systems for façade integration.

What are the main perceived barriers for façade integration of solar collection technologies? (Chapter 5)

Regarding the particular integration of solar collection technologies in facades, economic issues were declared as the most pressing barrier to overcome. The cost of current systems, energy prices, and the lack of economic incentives were mentioned among key aspects within this barrier. Secondly, grouped product related issues were perceived as a highly relevant barrier, based on the total amount of mentions.

On a side note, the classification of responses from this section of the questionnaire followed slightly different categories compared to the assessed barriers for building services integration. In that case, the barriers were identified solely based on the provided responses, while in the case of solar technologies it was decided to use pre-defined categories already validated in the literature, allowing for the comparison and discussion of the findings against previous experiences in the topic.

A further exploration of product related barriers was conducted, based on the gathered responses, in order to freely identify key aspects to draft recommendations for future developments. Hence, detailed product related barriers refer to performance, technical complexity of the systems, aesthetics, durability, and product availability; which unsurprisingly closely match the identified key product related aspects for building services integration. In this case though, performance and aesthetics are the main perceived issues to overcome, which makes sense considering the strong impact of solar collectors and PV panels on the outer finishing of the façade and thus, the external appearance of buildings.

What is the potential impact of the application of passive cooling strategies on the cooling demands of office buildings in different warm climates? (Chapter 6)

To answer this question, an assessment of the effectiveness of selected passive strategies was conducted, based on a statistical analysis of published data from previous research experiences, and additional cooling demand simulations under a controlled setup. The assessment focused on the most common heat prevention and heat dissipation strategies applied on buildings, avoiding hybrid systems of more complexity, to provide referential performance ranges for early design stages. Thus, the effectiveness of solar control (shading, glazing type, window-to-wall ratio) and ventilation strategies (when external conditions allow) was assessed in several locations from warm-dry (Riyadh, Athens, Lisbon) and warm-humid (Singapore, Hong Kong, Trieste) climates of different severity.

In general terms, the results showed that the potential impact of these strategies is quite relevant in all climates, affirming the importance of a climate responsive design approach for buildings. As expected, this impact is larger in warm dry climates than in warm humid ones. Maximum cooling savings obtained from the application of combined strategies on a worst case scenario, reach up to 80% in Lisbon and 70% in Riyadh and Athens; compared to 40% and 65% in Singapore / Hong Kong and Trieste, respectively. Nevertheless, it was found that the mere inclusion of passive strategies is not enough to guarantee these savings. Hence, they need to be carefully considered within a conscious design process to not only optimise their effectiveness, but even more importantly, to avoid counterproductive effects.

Regarding particular strategies, lower window-to-wall ratio (down to 25%) was found to be a highly effective strategy in all events and every climate zone. Similarly, natural ventilation is an important complement to solar control, leading to relevant extra savings in all locations except Hong Kong and Singapore, where its use increased cooling demands due to the high humidity (latent loads) of incoming air. Finally, the use of external shading devices or reflective glazing showed potentially good results as standalone strategies, but counterproductive effects when used in combination, due to their redundant action. Therefore, the choice between one or the other should follow local particularities of the climate context, users' preferences, and other architectural considerations.

What are the current possibilities and technical barriers for the architectural integration of solar cooling technologies in façade systems? (Chapter 7)

This question was answered through the qualitative assessment of the current façade integration potential of main solar cooling technologies, based on an exhaustive state-of-the-art review. Hence, thermoelectric, sorption, and desiccant technologies were assessed in terms of the main product related barriers for façade integration of building services, identified in Chapter 4. This showed what is currently possible for each assessed technology, while identifying bottlenecks and technical barriers to overcome. Furthermore, different paths for the development of distinct façade integrated products were recommended, based on the strengths and shortcomings of each technology.

First of all, no technology currently meet all criteria in all required aspects for the development of self-sufficient integrated façade products; so further research and development is needed, targeting specific aspects. The detailed assessment is showcased in Chapter 7. Nevertheless, in summary, thermoelectric modules are regarded as a promising technology for the development of integral building components, and absorption based compact units present interesting prospects for modular plug & play systems for façade integration. Important performance barriers remain in the former, while further exploration of alternative working materials and testing of compact modular units are the main challenges for the latter. Liquid desiccant systems are potentially promising, but the overall technology is less mature compared to the others. Finally, a partial integration approach is recommended for further explorations on compact adsorption and solid desiccant cooling systems, acknowledging certain technical barriers while promoting the alternative development of products for semi-decentral application and cooling distribution to areas far from the façade.

What is the potential for the application of self-sufficient solar cooling façades in different warm climate contexts, and what is the impact of the climate conditions on façade design possibilities? (Chapter 8)

Results from numerical calculations show that the application of self-sufficient façade concepts could be feasible on virtually all orientations from every assessed location. Even though these outcomes follow a theoretical approach, based on several assumptions and referential values; this fact is regarded as evidence that the application of self-sufficient solar cooling façades is not a far-fetched concept, and could indeed be promoted following further technical developments to overcome previously identified barriers for façade integration.

Nevertheless, the self-sufficiency of these concepts is conditioned by important restrictions for façade design in most cases, seeking to optimise the solar input throughout the dimensions of the solar array, and panel tilt. These design constraints are more pressing in south and north facades, making east and west orientations more generally suited for solar cooling applications. Regarding climatic application potential of the assessed technologies, there are clear research and development paths. Although solar electric processes present clear advantages for façade integration, as discussed in Chapter 7, their overall performance is an important barrier, allowing for application at most in temperate dry climates, under medium to strong design constraints. Solar thermal offers more possibilities, recommending further research for the application of sorption based concepts in temperate and hot-arid contexts with minor to medium constraints, depending on orientation and climate severity. Finally, desiccant based units are recommended for warm-humid environments, both due to higher efficiencies associated with the technology, and particular general suitability to handle larger latent loads. On Hong Kong and Singapore, west, east and north applications are theoretically feasible with medium design constraints, but south applications are heavily hindered.

The discussed design constraints refer to requirements for the optimisation of the solar array. However, basic design constraints remain for the application of all concepts, based on the collection technology needed to achieve the reference efficiencies used in the calculations. Presently, BIST and BIPV products such as coloured thermal collectors or transparent PV cells, especially designed to appeal to architects, have lower efficiencies than state-of-the-art basic systems with no 'aesthetical considerations'. Hence, further development of these technologies are needed to expand the general range of façade design possibilities. Furthermore, the self-sufficiency of integrated concepts is conditioned to the use of passive strategies to lower cooling demands to a manageable amount. If these concepts are theoretically possible under important design constraints, their feasibility is downright impossible without being embedded within a climate responsive approach to façade design.

§ 9.2.2 Main research question

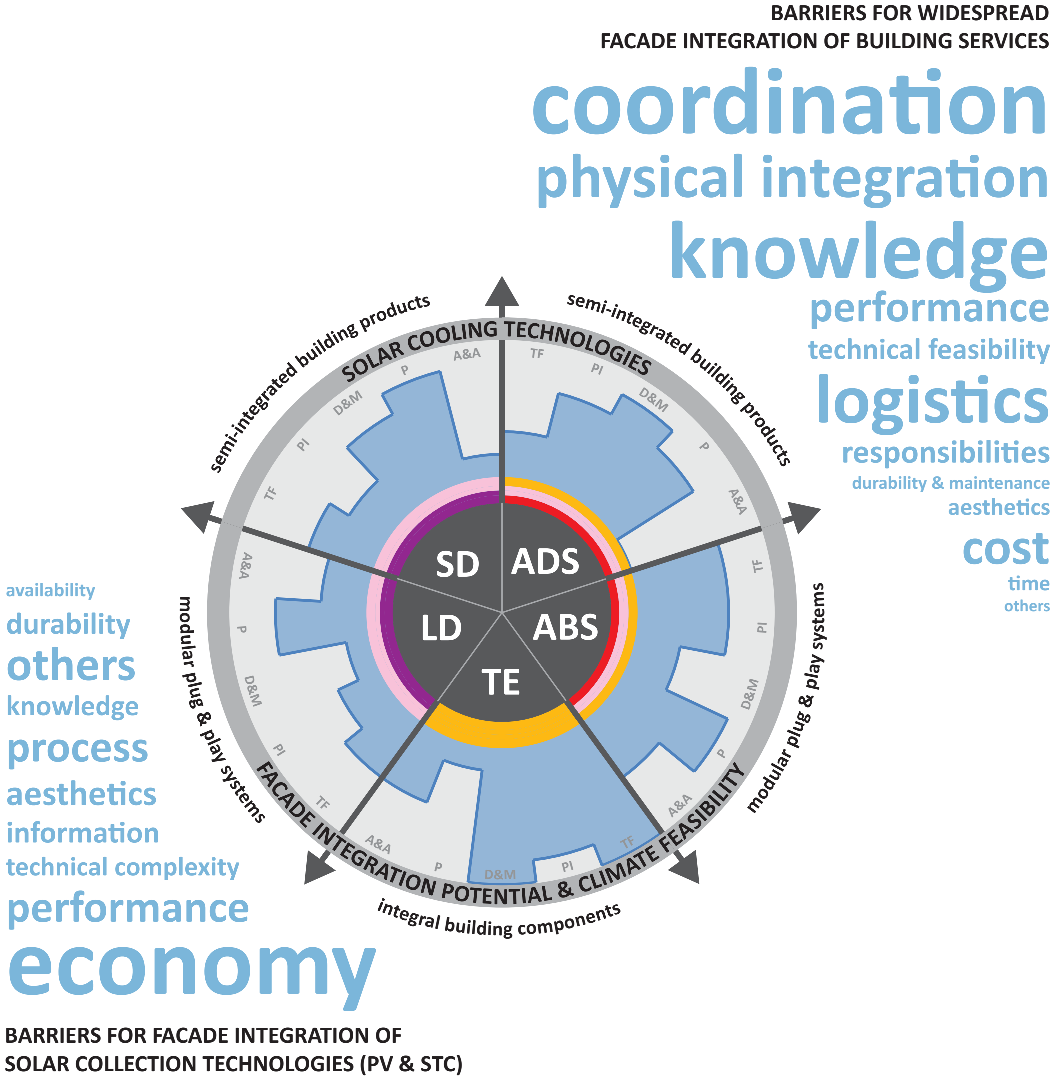
To what extent can solar cooling technologies be integrated into the building envelope, in order to meet local thermal requirements through climate responsive integrated façade units, as an alternative to conventional centralised mechanical cooling in office buildings?

The driving force of the research project was the intention to test the limits of solar cooling integration in façades, showcasing current possibilities while identifying technical constrains and barriers to overcome for the widespread application of integrated façade concepts. A short and simple answer to the main research question is that self-sufficient integrated façade concepts based on solar cooling technologies are still far from widespread application, based on current possibilities. Although interesting prospects were identified in this dissertation, important technical constraints need to be solved to conceive a façade component fail-tested for application in buildings. Furthermore, several barriers related to the façade design and development process would need to be tackled in order to introduce architectural products such as these into the building market.

In spite of this, there is potential for further development, aiming to overcome the constraints and barriers identified throughout the research project. This brings us to a second, lengthier version of the answer provided above, in order to fully address the extents of current possibilities for façade integration. Seeking an answer to the main research question proved to be a complex task, due to several requirements of diverse nature. The answers to the sub-questions discussed above, address the different types of requirements to meet, focusing on specific aspects of the main research problem. However, they present a fragmented panorama of current possibilities for façade integration. Therefore, an effort to summarise all findings was conducted, in the form of the chart showed in Figure 9.1. This chart is regarded as a collated representation of the main outcomes of this dissertation, acting as graphical answer to the main research question, and a compass to guide further explorations in the topic.

The chart comprises several types of barriers acting at different levels, around a core composed of the solar cooling technologies assessed throughout the research project. The widespread application of integrated solar cooling façades will depend then, on successfully overcoming each particular set of barriers. The ring around the core of solar cooling technologies consists of the threshold for façade integration of these systems, under self-sufficient operation. This is regarded as the main focus of the dissertation, exploring the suitability of solar driven cooling generation technology, for the development of self-sufficient integrated cooling façade units. Therefore, this ring shows the outcomes from the evaluation conducted in Chapters 7 and 8, showcasing the potential for façade integration of each technology [Chapter 7] based on their response to several product related barriers for integration of building services [Chapter 4]; and the climate contexts where their self-sufficient application is theoretically feasible [Chapter 8], within a climate responsive design approach [Chapter 6].

Outside of the ring, there are barriers that do not respond to a specific technology, but are essential for the application of integrated products nonetheless. The list on the left down side showcases the main identified barriers for the integration of solar collection technologies in façades, namely PV & STC [Chapter 5]. The application of these technologies in façades is conditioned in particular by economic barriers and performance issues that require further explorations. Finally, the list on the upper right corner showcases perceived problems for façade integration of building services in general, related both to the façade design and development process, and the façade products themselves [Chapter 4]. Even if the assessed technologies meet all the technical requirements for façade integration, coordination is greatly needed to make this a reality. Moreover, the involved professionals need to understand the intricacies behind these systems; while the building industry ultimately needs to turn these concepts into architectural products, for different potential applications following the strengths and shortcomings of each solar cooling technology.



SOLAR COOLING TECHNOLOGIES	CLIMATE CONTEXTS	PRODUCT INTEGRATION BARRIERS
TE: Themoelectric cooling	HOT-ARID (desertic)	TF: Technical feasibility
ABS: Absorption cooling	HOT-HUMID (tropical)	PI: Physical integration
ADS: Adsorption cooling	TEMPERATE-DRY (mediterranean)	D&M: Durability & maintenance
SD: Solid desiccant + evap cooling	TEMPERATE-HUMID (sub-tropical)	P: Performance
LD: Liquid desiccant + evap cooling		A&A: Aesthetics & availability

FIGURE 9.1 Chart of current possibilities and identified barriers for the development of solar cooling integrated facades.

§ 9.3 General conclusions

§ 9.3.1 Scientific contribution

Besides specific outcomes from each chapter, aiming at particular knowledge gaps; the main scientific contribution of this dissertation is the identification of the main barriers and constraints to overcome for the development of solar cooling integrated facades, based on current possibilities. The aforementioned chart, or compass, aims to serve as a graphical representation of a guide for further research and development, based on a comprehensive assessment of technical possibilities related to each evaluated technology, and state-of-the-art research in the field. Furthermore, the systematic approach developed in order to assess the façade integration potential of solar cooling technologies, could be further expanded to explore façade integration potential of new technologies in general, promoting the development of high-performance architectural products under a climate responsive façade design approach.

§ 9.3.2 Limitations of the research

The interpretation of the outcomes presented throughout this dissertation follows the focus and aim defined in the introductory chapter. Hence, while the results provide comprehensive answers to the research questions, certain limitations of the study need to be discussed in order to define their validity on a wider sense, as issues to be addressed to allow for replicability. Three main limitations are identified throughout the study, discussed as follows.

Firstly, the study consciously focused on commonly reported solar cooling technologies, for their environmental benefits in contrast to the use of harmful refrigerants in current air-conditioning systems. Therefore, widespread vapour compression systems were out of the scope of the study, to give room for the exploration of alternative cooling processes. Nonetheless, the main problem associated with current systems lies with the refrigerants used as working materials, rather than vapour compression technology itself. This technology is greatly mature, so it could potentially be a more promising choice for integrated concepts, if (and only if), environmentally friendly refrigerants are developed throughout research in chemical and material sciences, fields far from the scope of the present study, established within the boundaries of architectural engineering and climate design. In any case, if progress is indeed achieved on those areas, vapour compression technologies could be added into the proposed framework, coupled to PV panels as a solar electric process. Although for sure there would be specific technical issues to solve, the general barriers for façade integration and identified design possibilities will remain valid.

Secondly, the assessment of cooling demands was based on scenarios that considered a typical office room in an abstract building and site, without accounting for the potential impact of climate responsive design strategies at building level. While this followed a focus on the building envelope, façade design should not be isolated from the particularities of the building and the microclimate surrounding it. A conscious design approach should comprehend strategies at different scales to optimise the operation of buildings, and lower their energy consumption as much as possible. Furthermore, this also applies to the use and operation of buildings, and perceived comfort by users. Even though these aspects fall out of the scope of this dissertation, their correct assessment could help decrease cooling demands even further than the results showcased in this study.

Finally, economic aspects related to the potential cost of solar cooling integrated facades could not be directly assessed, due to the development level of current examples. Integrated façade concepts are still in early development stages; and small-scale solar cooling systems, designed for integration purposes are not yet market-ready. This is a highly relevant aspect, that could impede introduction to the market and widespread application. The potential for cost-effectiveness was indirectly addressed in the assessment in terms of the performance, technical complexity of the cooling process and required components for each technology, but specialised studies will be required in the future. All technologies assessed need to be further developed, and production chains need to be optimised in order to promote the application of competitive integrated concepts.

§ 9.3.3 Recommendations for further development

The main recommendations for further research and development in the field follow the different rings depicted in the chart from Figure 9.1, containing different barriers and thus, specific challenges for diverse disciplines.

First of all, there is need for further research on small-scale solar cooling systems and components, aiming to increase current efficiencies and simplify their operation. Fundamental research on new working materials and alternative cooling processes derived by the main addressed principles would enhance the potential for application at a base technological level. Furthermore, experimental and applied research on system level is encouraged for all cooling technologies, in order to develop integrated building components, or modular compact plug & play units for façade integration purposes. Fundamental research needs to be carried out by specialists, but the development of systems conceived for architectural integration would greatly benefit from a multidisciplinary approach, to tackle technology-specific challenges identified in Chapter 7.

Similarly, the integration of solar collection technologies in façades needs to be further promoted. The technical optimisation of these systems is currently well on track, steadily achieving performance goals set by different technological roadmaps; whilst there is an increasing number of products conceived with 'aesthetical considerations' in mind. Nonetheless, important economic restrictions remain in order to promote widespread application. Recommended actions to mitigate this, include further manufacturing of cost-effective products for integration by system developers; technical improvements on electricity and heat storage technologies; and the exploration of new business models and subsidy schemes to incentivise their application. Moreover, the introduction of new players in the market, such as Tesla's solar venture, may increase market competition, lowering costs and promoting innovative solutions.

Finally, further parallel actions are needed to push for the integration of building services and new technologies for high-performing façades in general. Building technologies should be a central part of façade design education, striving for a basic understanding of technical aspects of building systems and façade requirements under an integrated design approach. Moreover, the façade manufacturing industry should take the lead in the exploration of new production processes, simplifying logistical and coordination issues derived by the integration of several systems, under an integrated supply chain. Furthermore, research on innovative business models for the management of façade systems could change the current value chain, generating new incentives for the development and application of high-performing façades.

§ 9.3.4 Final remarks

This dissertation explored the potential for façade integration and widespread application of solar cooling technologies as a response to rising cooling demands and the widespread use of environmentally harmful refrigerants in the built environment. However, this is regarded as a potential alternative to cope with the situation and not a definitive solution to the problem. Furthermore, the climate feasibility assessment conducted as part of the study, showed that, technical issues aside, the application of self-sufficient integrated façade concepts is heavily conditioned by achieving an important reduction of cooling demands throughout the use of passive design strategies. Therefore, the need to decrease cooling demands at base level remains to be the most logical starting point for a responsible design of sustainable buildings and cities.

A responsible approach to architectural design then, implies that all low-tech and passive options should be exhausted, considering the climate design of buildings, and operational measures involving buildings' users, before considering the integration of complex technologies into the building and particularly the façade. Most probably, if this were to be strongly enforced and taken to the limit, there would be no need for integrated systems for cooling in several temperate contexts. Although this may seem to hinder some prospects for application identified in this dissertation, this final remark aims to deliver a clear message for the understanding of the outcomes from this study. Technological developments will not solve current environmental challenges by themselves. They will merely provide an increasing array of possibilities, whose application needs to be carefully assessed during the development of sustainable buildings, under an overall environmentally conscious and responsible design approach.

Appendix Questionnaire: requirements for facade integration of building services

The purpose of this questionnaire is to gather information about **design and construction requirements for the architectural integration of building services in facades**, as a way to promote the development of new cost-effective multifunctional façade products for office buildings. The questionnaire is addressed to professionals with practical experience in the development of façade systems for office buildings, situated at any stage of the design and construction process. Hence, architects, façade consultants, system and building services suppliers and façade builders are welcome to participate.

This questionnaire is part of the ongoing PhD research project titled *COOLFACADE: Architectural integration of solar cooling technologies in the building envelope*, developed within the Architectural Façades & Products Research Group (AF&P) of Delft University of Technology (TU Delft).

All information will be treated as confidential and will be used only for research and dissemination purposes, in activities related with the development of the PhD project.

Questionnaire

Introduction

This questionnaire is divided in three main sections: (I) Basic Information, (II) Design process of building services integrated facades, and (III) Integration of solar technologies in the building façade. Filling this form takes about 10 minutes. Please provide only one answer for multiple choice questions unless specifically stated otherwise.

I. BASIC INFORMATION

1. Which alternative represents your background more closely?

- A) Architecture
- B) Engineering
- C) Material Science
- D) Other: _______________________________________

2. Which alternative represents the role that you have mostly taken within façade development processes?

- A) Architect / Façade Consultant (Designer)
- B) Façade builder
- C) System supplier
- D) Other: _______________________________________

3. How many years of experience do you have in the field?

- A) Less than 5 years
- B) Between 5 to 20
- C) More than 20

4. Where are your projects mostly located? (name up to three countries)

____________________ | ____________________ | ____________________

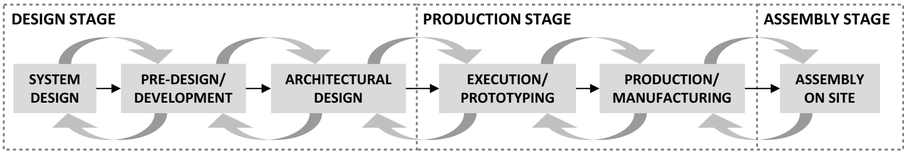
5. Have you been part of a project involving the integration of building services in the façade? (heating, cooling or ventilation systems)

- A) YES
- B) NO

II. DESIGN PROCESS OF BUILDING SERVICES INTEGRATED FACADES

NOTE: To answer the following questions, please refer to the scheme below, which contains the stages of design and construction process for façade products (based on scheme in Klein, T. 2013):

TOC



Stages of development process for façade products (based on scheme in Klein, T. 2013).

6. In your experience, what is the importance of the following variables when discussing the possibilities for building services integration in facades during the design stage (pre-design and architectural concept) of the development process? (Please mark with an "X" the corresponding level of importance)

VARIABLES	NOT RELEVANT	RELEVANT	HIGHLY RELEVANT
AESTHETICS	-	-	-
PERFORMANCE	-	-	-
COST	-	-	-
TECHNICAL FEASIBILITY	-	-	-
USER CONTROL & INTERACTION	-	-	-
OTHER:	-	-	-

7. What are in your opinion the main problems associated with building services integration in facades encountered during the **DESIGN STAGE**? (mention up to three problems starting from the most relevant)

1st ____

2nd ____

3rd ____

8. What are in your opinion the main problems associated with building services integration in facades encountered during the **PRODUCTION STAGE**? (mention up to three problems starting from the most relevant)

1st ____

2nd ____

3rd ____

9. What are in your opinion the main problems associated with building services integration in facades encountered during the **ASSEMBLY STAGE**? (mention up to three problems starting from the most relevant)

1st ____

2nd ____

3rd ____

III. INTEGRATION OF SOLAR TECHNOLOGIES IN THE BUILDING FAÇADE

10. Have you had practical experience integrating any of the following solar technologies in façade systems? (you may check more than one alternative)

- A) YES, I have worked with integrated solar thermal collectors in façade systems
- B) YES, I have worked with integrated Photovoltaic cells (PV) in façade systems
- C) YES, I have worked with integrated solar cooling technologies in façade systems
- D) NO, I haven't worked with solar technologies.

11. Do you see potential for developing architecturally integrated façade products considering solar technologies?

- A) YES
- B) NO
- C) NOT SURE / If so, why not? ____

12. In your opinion, is there market currently for commercial application of solar integrated architectural products?

- A) YES
- B) NO
- Please specify ____

13. In your opinion, what would be the most important constraints to overcome in order to promote widespread integration of solar technologies into the façade? (mention up to three constraints starting from the most relevant)

1st ____

2nd ____

3rd ____

14. Would you be open to discuss your answers in more detail by means of an in-depth interview? If so, please write your full name, affiliation and contact information. If not, you may skip this question (all information will be treated as confidential and will be used only for research and dissemination purposes)

NAME: _
AFFILIATION: _
E-MAIL: _

THANK YOU!