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Technological Imagination in the Green and Digital Transition

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Foreword by Antonella Polimeni

Good afternoon to all participants, ladies and gentlemen, and welcome to Rome.

On behalf of the Community of Sapienza University of Rome, it is a real pleasure to welcome all of you to the first edition of the International Conference "Technological imagination in the green and digital transition". I am also pleased to give my best welcome to Dr Antonio Parenti, Head of the European Commission Representation in Italy, and to Prof. Mario Losasso, President of the Italian Society of Architectural Technology, as well as to all guests, students and colleagues.

The conference that we are about to open, organised by the Department of Architecture and Design and directed by Prof. Alessandra Capuano in cooperation with Sapienza Foundation, is to be a moment of methodological debate about built environments and the rise of contemporary urban challenges, so engaging for public and private institutions at national and international level.

The proposed key points of this conference—namely Innovation, Technology, Environment, Climate Changes and Health—are all interconnected priorities that cannot be further postponed, representing in the meantime strategic research and education activities for our University, perfectly aligned with the Italian National Recovery and Resilience plan, to be implemented in Italy as well as European member States, in order to overcome the present financial and social challenges.

I truly believe that Universities are, by definition, places of imagination, where planning the future is intended as an unavoidable "existential condition" as well as an essential moment of collective participation for an accomplished society.

Thank you for your attention, and I wish you a fruitful continuation of the conference.

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Foreword by Eugenio Gaudio

My warmest greetings to Dr. Antonio Parenti, Head of the European Commission Representation in Italy, to the President of the Italian Society of Architectural Technology Mario Losasso, to the Director Alessandra Capuano, and to Pietro Montani who will open with a Philosophical Lecture the Conference "Technological imagination in the green and digital transition".

A special greeting to Prof. Anna Maria Giovenale, my dear colleague and friend, who invited me to be here today. Thank you Anna Maria.

Let me also greet all other speakers as well other participant that will follow this Conference organized by the Department of Architecture and Design, together with the Fondazione Roma Sapienza.

From the very beginning, as President of the Fondazione Roma Sapienza, I supported the initiative of an international Conference on the theme of "Technological Imagination" having clear in mind that human imagination is inseparable from the "technical practice" with which it is entangled from the earliest origins of mankind, as Pietro Montani states in his book, *Technological destinies of the imagination.*

When the contents of the Conference were increasingly defined and focused around the areas of the green and digital transition, I realized that the very core of the Conference was becoming an attempt to respond to the contemporary challenges of the National Recovery and Resilience Plan, in their key role of revitalization for Research and University.

In this sense, the potential of technological culture is reaffirming its role of strategic tool for the conceiving, design and validation of future scenarios.

The sessions into which the Conference is structured, namely: Innovation, Technology, Environment, Climate Changes and Health, identified in order to outline the evolutionary scenarios of architectures and cities, allowing us to reflect at different levels on innovative models of building and management process, as well as design and products.

The goals of promoting digital transformation, supporting innovation in the production system, improving sustainability and ensuring an equitable environmental transition, find their clarification in the elaborations and experimentation presented through the contributions in the different sessions.

Modern technological innovation allowing multiple possibilities in all areas: nowadays digital technologies are enabling us to interact with people and things, all over the world.

There are astonishing, yet untapped potentials, suggesting that digitization, rather than a strict sense adaptive development, should be seen as an important evolutionary phenomenon and in the meantime a great opportunity.

Innovations connected with new technologies can provide to civil society a better quality of life, both at indoor and urban scale settings, addressing scientific development toward an effective culture of sustainability, reuse and security.

The employment of new technologies, a careful approach to the containment of land consumption as well as a careful consideration towards soil coverage modality and urban density, the recycling strategies and technological and typological redevelopment of degraded areas and buildings applying an energetic and eco-systemic approach, are the key elements for the conception of healthy and resilient urban habitats, able to adapt to the present global changes, as well as promoting prosperity, inclusiveness and social equity.

Last but not least, "health" issues, that need to be conceived at the very core of the potential determined by 'technological innovation and processes of ecological and digital transition.

The structure of the Conference is rooted on all these interrelated themes, and on that same basis also research needs to be reoriented.

I am confident that this first edition of the Technological imagination conference will contribute to pave the way of an innovative and interdisciplinary scientific approach to technology and policies for built environments, considered the real human challenge of the twenty-first century.

Thank you so much for your attention and enjoy the Conference.

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Foreword by Antonio Parenti

New European Bauhaus

Good morning,

Magnificent Rector of Sapienza University of Rome Professor Antonella Polimeni
President Fondazione Roma Sapienza Professor Eugenio Gaudio,
Director Department of Architecture and Design Professor Alessandra Capuano
and others.
Ladies and Gentlemen,

It is my pleasure to address you today and to open this International Conference "Technological Imagination in the digital and green transition" organized by Sapienza University of Rome.

Let me say that the title, the contents, and the proposals envisaged by the Conference match perfectly with the main pillars of the flagship initiative shaped by the President Ursula von der Leyen and launched in September 2021: the New European Bauhaus.

The New European Bauhaus is by nature transdisciplinary: it invites architects, designers, artists, scientists, engineers, artisans and citizens to share their expertise in preparing for the future.

With the New European Bauhaus, we want to make the European Green Deal tangible and "palpable".

We want to add a cultural dimension to the economic and technological transformation. This is essential to achieve our overarching goal: making Europe the first climate neutral continent by 2050. And thus reconciling our way of life with nature.

To get there, we need both: a real transformation of our economy and society, and a debate about how we can live in respect of nature and our planet.

The historical Bauhaus was founded in Weimar and Dessau. It turned into a worldwide movement. This did not happen by chance. Some ingredients of what made the historical Bauhaus a success can also be an inspiration for the New European Bauhaus.

Let me mention three.

The first ingredient: The historical Bauhaus was created in a time of **profound transformation**. People were facing the challenges of industrialisation. Gropius and the founders wanted to respond to the emerging needs of a new era. They aimed for solutions that were functional, affordable, but also beautiful. With this principle in mind, they shaped buildings, fabrics and furniture. They always aimed higher than just innovative design. The New European Bauhaus is also striving for this mix of aesthetics and affordability. But we want to add another element: sustainability. Because the New European Bauhaus wants to match sustainability with style.

Now, the second ingredient: **The historical Bauhaus boldly promoted new materials like steel and cement**. Today, we also need to look into new building materials. But this time, it is about sustainability. It is about materials that need less CO_2 in their production process. The New European Bauhaus wants to accelerate the transition of the built environment. It wants to scale up nature-based materials, to support circular design and architecture. Buildings are responsible for 40% of our energy consumption. And if we manage to change this, we have a chance to keep global warming below 1.5 degrees.

The third important element from the historical Bauhaus is **interdisciplinarity**. We want to convene people from different backgrounds and with different competences to share and grow their ideas and visions. We can create a better tomorrow, if culture and technology, innovation and design go hand in hand.

For our New European Bauhaus, the European Commission needs scientists, activists, artists, designers, architects and entrepreneurs. We want to include the ideas and perspectives of all ages and all backgrounds.

Today, at this conference we can contribute to this evolving New European Bauhaus network.

This project is a project of hope. It is a project of change and of economic transformation.

So I hope that this conference can contribute further to making the transformation happen and to connecting more and more people who want to make it happen.

Thank you very much and have a great conference.

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Foreword by Mario Losasso

Presentation of CONF.ITECH 2022

The green and digital transition represent in the contemporary research field the two new challenges for the evolution of technology within the themes of sociotechnical innovation. Consequently, technology and innovation in contemporary world must adapt to this general objective. Innovation in its hard and digital components once again becomes a central factor in the experimental propulsion that the project is assuming within a processuality and technologies that enable its conception and implementation.

Today, research is increasingly characterised by the need to focus on specialisms that lead to and contribute to the advancement of knowledge and the predictive value of what is studied in the disciplinary fields. However, with respect to the evolving complexity of phenomena, research requires continuous disciplinary interactions to be developed because we understand that one disciplinary field cannot alone address the most important challenges of contemporary society.

New forms of coexistence must be organized in a vision of interdependence and connection, while the green transition requires the definition of the limits of design action and the characteristics of the transformation processes. The new perspective of co-evolution will have to express a design attitude that allows to repair and, where necessary, rebuild the lost links between man, technology and nature.

The green and digital transition represent the two new challenges for the evolution of technology within the themes of social innovation. The Italian society of architectural technology SITdA has been working for a long time on the topics of the relationship between technology and urban and building development within a process-oriented and eco-systemic approach. In the field of technological design of architecture, the scientific society of the technology of architecture has activated research and training sensitivities on the themes of design experimentation framed within process and ecosystem dynamics, aimed at optimising the efficiency of products and processes by reducing inefficiencies and waste.

The SITdA supports research and spin-off outcome on territories through the activities of its scientific clusters. The Scientific Society SITdA has granted its patronage to the CONF.ITECH 2022 Conference, sharing its importance and topicality in view of the new challenges identified in the urban construction and environmental fields by the Next Generation EU Programme and the implementation programmes in the various nations of the European Union.

The topics that will be addressed during the three-day conference are fascinating and challenging, linking innovation, technology, environment, climate change and health.

These topics are strongly interrelated themes in which we are realising that it is impossible to deal with them separately, arriving in the most recent reflections at considering a single health for human beings and for the entire environment which is their living environment.

I would like to remind that the topic of digital culture, nature and technology was the central topic of the SITdA Naples 2020 Conference held last July with a delay due to pandemic difficulties, while the 2022 Conference of the Scientific Society is focused on the topic of the centrality of processes. As we can see, the work carried out in the Departments of Architecture and by the Scientific Societies in the area of architecture is an activity that has picked up significantly, foreshadowing new approaches, new fields of enquiry and new paradigms necessary for the new complexities that constitute the reference scenario of the future.

The experience of this Conference can provide a significant contribution to the sustainable and environmental evolution of the design area in its trans-scalar, multidisciplinary and challenging dimension, overcoming technocratic responses to a demand that requires the integration of the humanistic and technical-scientific dimensions.

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Foreword by Orazio Carpenzano

Welcoming Address from the Dean

On behalf of the Faculty, I wish to thank the organisers for asking me to give this opening address, while congratulating them on their efforts to bring together, in an international encounter, various perspectives on topics of such decisive importance for the future of our respective territories, as well as their people, living organisms and architecture.

My thanks go to Anna Maria Giovenale, Fabrizio Cumo, Eugenio Arbizzani, Carola Clemente, Eliana Cangelli and Francesca Giofrè, who will be giving talks on technological innovation, the environment, climate change and public health.

Thinking of energy in terms of how it relates to architecture during the green and digital transition means cultivating a *technological imagination*, a topic which leads to the broader question of the man–nature relationship and the possibility that architecture, by applying innovative ideas and concepts while promoting a growing social and emotional intelligence of its own, can contribute to inventing of new types of habitat for mankind on the planet earth, under a new pact for survival that allows all elements, both artificial and natural, to coexist in a sustainable balance which can serve as a preventive measure against the intrinsic destructive force of the Cosmos, an especially pressing problem where mankind has neglected certain methods for dissipating the energy of calamitous events made available by both ancient wisdom and scientific advances.

The 2021 Architecture Biennial, entitled "How Will We Live Together?", implicitly drew the attention of visitors to the need for a new approach to the man–nature relationship, following a thorough review of its historical and ethical premises. Hashim Sarkis, the curator of the exposition's seventeenth edition, passed on the following message: "In a scenario of exasperated political divisions and growing economic inequality, we call upon architects to imagine spaces in which we can all live in fruitful fellowship".

The man–nature relationship has always been a distinctive feature of humanistic and artistic thought on things technical, expressed in the construction of the *civitas*, the physical and political synthesis of civilisation. Medieval mysticism viewed nature as a foreboding wilderness, while the Renaissance redeemed the sense of *technè*, and the Romantic Period, with its high-strung, emotive outlook, led to the elaboration of the concept of the sublime.

Controlling and putting to use the energy generated by nature through sources of heat and movement (wind, sun, water), first through manual effort and then using the tools and machines produced by human ingenuity, was also a topic and challenge that led architecture to express, during the Modern Movement, boundless enthusiasm for the theories of Taylorism, which Corbusier summed up by interpreting human dwellings as machines of habitation.

But it is from the time of Vitruvius that architecture, engaged more or less explicitly with the triad of *utilitas-firmitas-venustas*, has addressed the problem of dissipating heat (or thermal inertia), as well as kinetic and elastic energy (in the case of earthquakes), at various latitudes of the globe, drawing on the available resources and raw materials. Historic Italian buildings, for example, built with walls roughly a metre thick and a structural layout measuring 4 × 4 or 5 × 5 m, have offered excellent thermo-hygrometric performance (in terms of energy consumption), as well as structural dependability (against seismic risk). In both cases the objective is to "mitigate", a term used by many modern-day scholars, the dissipation of different types of energy.

The history of architecture is filled with archetypes that need to be updated and reinvented. Think of the ingenuity it took to build Venice atop a giant underwater forest, or the aesthetic quality of the Tu'rat walls constructed by Southern Italian peasants, the windmills of Northern Europe and countless other magnificent examples of *swarm intelligence* collected by Bernard Rudofsky in his well-known book *Architecture without Architects: a short introduction to non-pedigreed architecture*, published by Doubleday & Company Inc., Garden City, (in 1964), following an exhibition at New York's Museum of Modern Art. Though, in truth, Roberto Pane and Gino Capponi had already touched on the topic in articles on the architecture of Ischia published in "Architettura e Arti decorative" in 1927, as did Giuseppe Pagano at the Milan Triennial "Rural Italian Architecture", published in the Notebooks of the Milan Triennial by Hoepli in 1936.

Looking beyond the confines of architecture, a recent reconsideration of the topic of Cinema and Energy can provide potentially useful points of affinity with architecture, especially in the collection of essays found in issues 7 and 8 of the periodical Imago, under the title *Cinema & Energy. Interdisciplinary Outlooks Combining Science, Aesthetics and Technology*, edited by Marco Maria Gazzano and Enrico Carocci (and published by Bulzoni in 2013). In an essay entitled *Dissipation and Aesthetic Experience*, the physicist Giuseppe Vitiello, in commenting on the film Transeurope Hotel by Luigi Cinque, writes: "The brain [which leads me to think of *swarm intelligence*] is described as an open system engaged in continuous exchanges with its surrounding environment. In both models and films, antinomies such as information/knowledge, feeling/knowing, blend with each other in the aesthetic experience, the favourable connection between ‘me and the object’ that characterises our existential dimension.”

Dissipation, therefore, should be seen as part of the evolution of our ecosystem, of our contemporary habitat. It gauges the possibilities for losing and exchanging, through a rekindling of collective emotional intelligence and technical and intellectual micro-revolutions. It is a risk that we must continue to face, as otherwise architecture will die, depriving man of an indispensable tool for managing the complexity of the physical habitat through creativity, in order to transfigure energy in a way that, at times, can prove so unreal, and yet so effective and indispensable, that it leads to the construction of new values and sublime beauty.

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Chapter 66
Building Façade Retrofit: A Comparison Between Current Methodologies and Innovative Membranes Strategies for Overcoming the Existing Retrofit Constraints

Giulia Procaccini and Carol Monticelli

Abstract The constant expansion of the cities outside their borders, together with the rapid growth of new technologies and the environmental impact of the building sector, make existing buildings quickly obsolete, both in terms of their functions and their performances. Achieving the goal for greenhouse gas reduction by 2030 implies the necessity to improve the energy performances of the building stock and, for doing so, to overcome the existing constraints that very often prevent builders, tenants and residents from undergoing a renovation process. Given also that the building renovation contributes in the up-cycle strategy of the building stock, avoiding the production of unnecessary waste caused by demolition processes, innovative fast and average costly solutions must be shaped in order to encourage building façade renovation processes at different scales of interventions. Considering that membranes present some inherent properties (such as lightness, thinness, fast assembly, etc.) that make them suitable for both temporary and permanent façade renovations and valuable for overcoming current retrofit constraints, their investigation is of primary interest in order to promote and achieve an extensive building façade renovation. Starting by the investigation of Textile-based Façade Retrofit Solutions (TFRS), this analysis aims at comparing current methodologies with innovative membranes retrofit strategies, in order to evaluate the effectiveness and advantages of textile-based products in overcoming existing constraints to façade retrofit. The main goal of the analysis is to present innovative membrane existing solutions for making building façades resilient and adaptable to the several requirements expected from time to time. The research highlights future developments for TFRS with regard to both temporary and permanent solutions through their employment over existing façades.

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66.1 Introduction

Cities have always accommodated humans' needs and their necessity of permanent dwellings. Actively facing new challenges over time, they have always reflected either the stability of the society or the changes of time.

Nowadays, cities are asked to be resilient more than ever: given that 'resilience' means the ability of an entity to be able to deal and to overcome a traumatic event or a period of difficulty, cities are called to accommodate and to react to extreme conditions such as the COVID-19 pandemic, the climate change and the severe globalization.

Consequently, with the current fast times, temporary constructions are re-gaining popularity as a practical solution for accommodating the recurring changes dictated by the time. The accelerated speed, due and thanks to which the global society is nowadays moving faster and further, is contributing in making cities quickly obsolete.

Additionally, the continuous birth of new technologies is a double-edged sword, affecting on one hand the progress of the society and their cities but intensifying, on the other hand, the process and the speed of the changes, with a consequent mutual impact on climate change, contributing in parallel to its acceleration and to its slowdown.

Cities and buildings obsolescence is reflected by their need to be more resilient and open to changes, both in terms of aesthetic appearance and technical performances.

The climate change has led to the necessity to diminish the greenhouse gas emissions of the building stock, which is responsible for approximately 40% of the energy consumptions, representing the largest energy consumer and one of the most significant CO_2 emission sources in Europe, with a share higher than a third of the total EU emissions (European Commission 2021).

The strategy of the renovation has been continuously spreading in the last years, and new incentives have been launched with the exact purpose of increasing this good practice that contributes in the up-cycle of the building stock and avoids the production of unnecessary waste caused by demolition processes. With the aim to look for fast and average costly solutions in order to encourage building façade renovation processes at different scales of interventions, this paper analyzes innovative solutions on the market for making building façades resilient and adaptable through the application of membranes over façades.

Among the spectrum of lightweight materials, membranes present some inherent properties [such as thinness, easy transportability, fast assembly, etc. (Chilton 2010; Pohl and Pohl 2010)] that make them suitable for both temporary and permanent façade renovations and valuable for overcoming current retrofit constraints. Consequently, taking advantage of membranes potentialities, this analysis aims at comparing current methodologies with innovative membranes retrofit strategies, in order to evaluate the effectiveness and advantages of textile-based products in overcoming existing constraints to façade retrofit and achieving extensive building façade renovations.

66.2 Methodology

Starting from the assumption that architectural textiles present some inherent properties suitable for retrofit applications, the study focuses on a comparative analysis between current Façade Retrofit Measures (FRMs) and Innovative Membrane Strategies for identifying the current façade retrofit constraints that could be overcome by the application of textile-based solutions.

In order to do so, a qualitative and comparative analysis based on the data acquired through the state of the art has been carried out. The methodology applied for the study consists of two parallel analyses and a sequential investigation aimed at comparing the acquired data: The attention has been drawn, on one hand, on current façade retrofit methodologies and their constraints and, on the other hand, on the analysis of textile potentialities for façade retrofit applications. Successively, the investigation of some textile-based façade retrofit best practices and innovative research contributes in supporting the discussion about the advantages of TFRS.

66.3 Review of the Current Retrofit Methodologies and Their Constraints

The retrofit practice is globally increasing its popularity due to the necessity to diminish building energy consumptions and to adapt existing buildings to enhanced performances. Aesthetic and functional reasons usually drive the renovation of a building, due to the aging of the components and the lowering of the performances.

Building façade retrofit is an effective measure to reduce global energy consumptions, considering that only façades account for 20–30% of the total (Dall'O' et al. 2012), being characterized by large thermal transmittance. Therefore, the aim of building façades retrofit is to reduce the use of air-conditioning and heating systems in existing buildings.

The extensive review of Façade Retrofit Measures (FRMs) provided by Sarihi et al. (2021) divides them between Energy Conservation Measures (ECMs), Energy Modulation Measures (EMMs) and Combined Measures (CoMs) (Fig. 66.1), analyzing their effectiveness in different climatic conditions.

The most common FRMs are insulation and shading, respectively, representing the most effective solutions in Heating and Cooling Dominated climates. The main difference between ECMs and EMMs consists in the extension of the measure over

Façade Retrofit Measures (FRMs)		
Energy Conservation Measures (ECMs)	Energy Modulation Measures (EMMs)	Combination of Measures (CoMs)
• **Insulation** - Exterior Insulation - Interior Insulation • **Window Improvement** • **Airtightness** • **Window to Wall Ratio**	• **Double Skin Glazed Façade** • **Opaque Ventilated Façade** • **Façade Finish Coating** • **Shading** • **Green Façade** • **Phase Change Material (PCM) Façade**	• **ECMs + EMMs**

Fig. 66.1 FRMs classification according to Sarihi et al. (2021)

time: While ECMs are permanently applied to building façades, EMMs measures modulate energy consumptions only in specific periods.

Given that the thermal transmittance of the building envelope represents the main cause of the high energy consumptions, ECMs are being extensively applied in order to stabilize the internal temperature both in summer and winter, minimizing the use of technological appliances for improving interior thermal conditions. The EMMs instead aim at controlling the solar properties by the application of solar thermal-driven heating and cooling technologies. The combination of ECMs and EMMs aims to fully exploit their benefits for reducing the heating and cooling energy demand.

However, each of these strategies implies not only advantages but also various disadvantages (Corrêa et al. 2020) that often prevent tenants and builders from undergoing building renovation processes. The main constraints limiting the extensively application of the practice have been summarized in Fig. 66.2, associating FRMs with each related constraint.

	Insulation ETI (ExternalThermal Insulation)	Insulation | ITI (Internal Thermal Insulation)	Insulation | CTI (Cavity Thermal Insulation)	Window Properties	Window to Wall Ratio	Double Skin Glazed Façade	Opaque Ventilated Façade	Green Façade	Finish Coating	Phase Change Material (PCM)	Shading Device
Durability issues related to system coating	•••	•	•	•		••••	•	•	•••	••	••
Finishing execution complexity due to architectural constraints	•••		••	••	••	••	••	•••	••	••	•
Vulnerability to mechanical stresses	•••	••	•	••	•••	••	••	•••	•••	•••	•••
Additional weights to the structure	•	•	•	•	•••	•••	••	•••	•	••	•••
Exposed execution to weather conditions	•••			•••	•••	•••	•••	•••	•••	•••	•••
Leak of protection of the façade from outside actions		•••	•••								••
Poor reduction of thermal inertia		••	••		••						•••
Increase of moisture-related problems		•••	••		••			••			
Presence of thermal bridges		•••	••		••		•				
Fire spreading risk			•••			•••	•				
High skilled labour required			•••	••	•	•		•••		••	
Aesthetical modification of the building appearance	•••			•	•••	•••	•	•••	•••	••	•••
High cost investment	••	•	•••	•••	•••	•••	••	•••	•••	•••	••
Disturbance for the occupants during the execution	••	•••	••	••	•••	••	••	••	••	••	••

Fig. 66.2 FRMs and related constraints

On top of the detailed analysis of each single practice, it should be clarified that most presumably there are some parameters, such as (i) the disturbance for the occupants during the execution of the process, (ii) the high-cost investment requested for the retrofit practice and (iii) the limited durability of the strategy in an optic of LCA, that limit the spread of this practice, representing the crucial barrier that must be overcome for increasing the number and possibilities of application of FRMs.

66.4 Membranes for Façade Retrofit Strategies

Starting from the most diffused constraints, it follows the clear necessity to exceed them in order to enhance the building façade retrofit practice.

Textile materials are nowadays re-gaining popularity in architecture thanks to their intrinsic characteristics (Chilton 2010; Pohl and Pohl 2010) and the renovated awareness about environmental and sustainability topics (Mendonça 2010; Monticelli and Zanelli 2021; Sandin and Peters 2018). As highlighted by Monticelli (2015a):

> the success keys for the textile envelopes in architecture are (1) the reduction of weight and stiff parts of the building elements coupled with ensuring high performances […] and (2) the minimisation of the time of installation and maintenance though allowing an easy replacement of the building elements […].

Indeed, with high performance textiles available on the market, new functions and different architectural applications arise. Membrane applications in façades are mainly recorded as cladding systems for commercial buildings or, sometimes, as the second layer of a double skin (existing) façade. Lately, a new diversified range of products has entered the construction market for being applied either in retrofitting practices of existing buildings, either as sunscreens, or backlit surfaces (Monticelli 2015a).

The main characteristics that make textiles attractive as envelope materials are their lightness, thinness and flexibility, together with the light transportability and the increased durability. Additionally, they present pleasant aesthetic qualities and visual properties given by their translucency and the possibility of sun and light control. They can also comply with the mechanical and thermal requirements of a building façade, being able to face daily and seasonally temperature differences (Mendonça 2010; Paech 2016). Given that textile structures have the advantage to be easy dismantled, it is therefore possible to foresee a second (and even a third) life for these type of structures (Monticelli and Zanelli 2021; Sandin and Peters 2018). The efficient use of the materials and the reduced environmental impact contribute to the diffusion of membranes and their spread especially for temporary structures, taking advantage of the minimization time of installation and maintenance. Starting from the most common characteristics that define and differentiate these materials, it is possible to foresee an extensive use of textiles in the retrofit practice with different applications.

66.4.1 Membranes in Façade Retrofit Applications

Although nowadays the use of membranes in façade retrofit practice is still limited and it is majorly employed for the purpose of an aesthetic retrofit with the aim to give a new iconic appearance to a building, there are few cases in which it has been used as a sun-shading device or with the aim to improve the energetic efficiency of the building envelope (Mendonça 2010).

The application of textiles and membranes for the purpose of the façade retrofit lays its ground in the exploitation of the intrinsic properties of the materials and the great freedom they leave: Being very lightweight, their application can be taken in consideration even in a second moment, without interfering on the existing structure with additional and excessive weights.

As testified by the Case Studies in Fig. 66.3, the transparency or translucency given by the material used allows for the control of the natural light penetrating inside the building without obstructing the inside-out view. The creation of a textile second-skin has the aim to protect the building components from the atmospheric aging and, defining a buffer zone, allows for natural ventilation. Textiles and membranes can also be employed as exterior sun-shading devices, modulating the sunlight penetration inside the building (Fig. 66.4a) or obstructing it partially or completely through textile curtains, representing at the same time a useful and decorative element of the façade (Fig. 66.4b). A more common application of the material can be detected in Fig. 66.5, where textiles have, respectively, been used as a cladding system for giving a new appearance to the building or as an additional envelope with the aim to define an iconic façade.

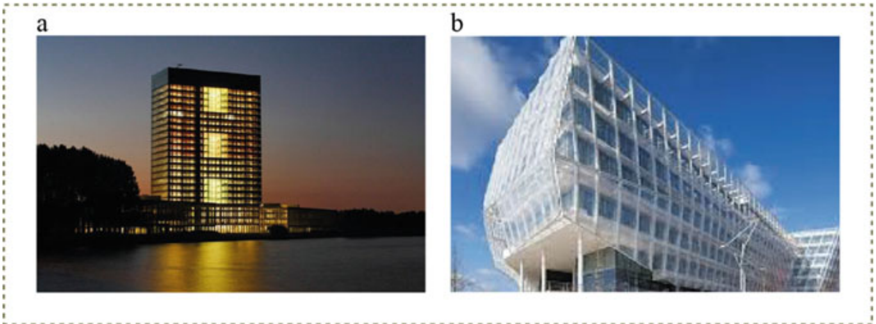

Fig. 66.3 **a** Westraven Office Complex—Utrecht, Netherlands (Credit: Cepezed - picture: Joannes Linders); **b** ETFE Façade Unilever Building—Hamburg, Germany (Credit: Vector Foiltec)

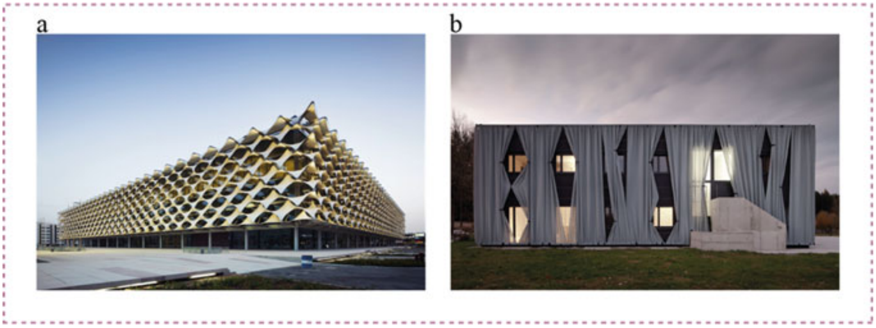

Fig. 66.4 **a** King Fahad National Library—Riyadh, Saudi Arabia (Credit: Gerber Architekten - picture: Christian Richters); **b** Aichinger House—Kronstorf, Austria (Credit: Hertl Architekten - picture: Kurt Hörbst)

Fig. 66.5 **a** McDonald's – Legnano, Italy (Credit: Canobbio Textile Engineering); **b** Gotha Cosmetics Headquarter - Lallio, Italy (Credit: iarchitects - picture: Claudia Calegari)

66.5 Discussion

The use of textiles in façades for the purpose of the retrofit is increasing its popularity thanks to the different FRMs it matches, especially the ones referring to the EMMs (Fig. 66.6). Some recent studies have been conducted for simulating the application of a textile solution onto an existing façade for improving its energy performances.

The tensile second-skin simulation refurbishment (Ciampi et al. 2021) highlighted a yearly heating and cooling energy demand reduction of about 9.8%, while the semi-opaque ventilated façade solution (Cortiços 2020) testified around 23% in heating and 39% in cooling savings in inland areas, with a reduction of 6.45% of CO_2 emissions and around €13.5/m^2 on the heating and €23.5/m^2 on the cooling spending.

Within the spectrum of EMMs, these last two research testify a potential application of TFRS with respect to the first and second strategies. Although there are no studies investigating the energetic behavior of textile sun-shading systems, the

TEXTILE FAÇADE RETROFIT MEASURES (TFRMs)		
ENERGY CONSERVATION MEASURES (ECMs)	ENERGY MODULATION MEASURES (EMMs)	COMBINATION OF MEASURES (CoMs)
• Insulation - Exterior Insulation - Interior Insulation • Window Improvement • Airtightness • Window to Wall Ratio	• Double Skin Glazed Façade • Opaque Ventilated Façade • Façade Finish Coating • Shading • Green Façade • Phase Change Material (PCM) Façade	• ECMs + EMMs

Fig. 66.6 TFRMs (in green) within the more general spectrum of FRMs edited by Sarihi et al. (2021)

numerous applications that can be found and the spread of the practice serve for valuing this measure too.

Given that the analysis of the current FRMs led to the understanding of three main constrains that limit the practice of the retrofit, it is presumable that the application of TFRS could overcome them thanks to their intrinsic characteristics:

- In terms of disturbance for the occupants, it is possible to claim that a TFRS could diminish it given the reduced amount of time for the installation of the system (Paech 2016; Gezer and Aksu 2021);
- The cost investment could be lowered by the use of a minor amount of material (Cortiços 2020; Beccarelli and Chilton 2013);
- The advantage in terms of estimated duration of the practice can be foreseen in an optic of LCA: The use of TFRS could be conceived both for permanent and temporary applications, therefore unveiling new temporary retrofit strategies able to comply with the specific requirements of the time without implying the use of excessive materials, whereas forecasting the re-use of the system (Sandin and Peters 2018; Monticelli and Zanelli 2018).

66.6 Conclusion

Currently, innovative Façade Retrofit Strategies are being investigated with the aim to disclose easier, faster and lower-cost solutions. TFRS perfectly fit in this scenario, envisaging both permanent and temporary solutions.

The paper has presented some TFRS already accomplished, analyzing their applications and advantages in comparison with current methodologies and the main façade retrofit constraints that limit the spread of the practice. The qualitative analysis has been based on the data acquired through the Literature Review and the investigation of some Best Practices. The outcome highlighted the potentialities of TFRS in overcoming some of the current retrofit constraints, such as the disturbance for the occupants and the cost investment, consequently framing new textile-based products development lines.

Further LCA, Life Cost Analysis and Energy Simulations will be run in order to quantitatively value the thesis. Nevertheless, it is already possible to envisage a wider spread of TFRS by taking advantage of textile intrinsic properties for overcoming current retrofit constraints.

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