First-year 3FiRES Booklet

• Workshop and network updates about • Research on BIPV Photovoltaic Facades for Fire Spread Mechanisms, Structural Failures and Resilience Improvement Methodologies • edited by **Chiara Bedon** & **Yu Wang** •

EUT

[…] There are no doubts that the first-year of scientific activities for the running 3FiRES project represented a powerful opportunity of scientific network and growth for the members of research units on both the Italian and Chinese sides, as well as a unique international experience to share methodologies and discuss new strategies for the analysis of BIPV components and facades in fire […]
Chiara Bedon, Yu Wang

[…] Talking about the optimization of novel prototypes, for example, robust standardized methodologies of experimental investigation are of utmost importance. However, the same consideration can be extended to in-service plants, where efficient diagnostic strategies have a primary role for the analysis of photovoltaic components and systems, both under ordinary and accidental operational conditions. […]
Chiara Bedon, Yu Wang

[…] solar energy has become part of the building fabric as a sustainable alternative, and then it has become obligatory and, today, increasingly indispensable. This is a great opportunity for architectural, urban and landscape design, but let us not forget that when we use and transform this technological device in architecture, solar is synonymous with happiness and beauty […]
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Workshop and network updates about "Research on BIPV Photovoltaic Facades for Fire Spread Mechanisms, Structural Failures and Resilience Improvement Methodologies"

Editors: Chiara Bedon, Yu Wang
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This volume collects some scientific research results from the first year of activities and Workshop contributions (October 7th, 2024, Trieste & online) of the running "Particular Relevance" Italy-China bilateral project 3FiRES - "Research on BIPV Photovoltaic Facades for Fire Spread Mechanisms, Structural Failures and Resilience Improvement Methodologies" (2024-2025). 3FiRES research partners are the University of Trieste, Department of Engineering and Architecture (Principal Investigator Prof. Chiara Bedon) and University of Science and Technology of China, State Key Laboratory of Fire Science (Principal Investigator Prof. Yu Wang). The scientific activities of 3FiRES project are partly financially supported by the Italian Ministry of Foreign Affairs and International Cooperation (grant number CN24GR03) and National Key R&D Program of China (grant number 2023YFE0116700).

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Introduction

Building-integrated photovoltaic (BIPV) systems are rather challenging, innovative, and fascinating solutions, for several reasons. Asu such, their design, implementation, optimization, typically require a multidisciplinary approach and multifunctional analysis.

This is especially complex and challenging under accidental events or unfavorable operational conditions, which may include extreme events (such as fire), complex architectural scenarios, and many other influencing aspects to account.

The multidisciplinary analysis of BIPV solutions and solar architectures in general faces the need of expertise and technical knowledge on the side of engineering and architectural sides, including mechanical and thermo-mechanical aspects, structural mechanics and electrical engineering issues, architectural plans, sound experimental and numerical methods, as well as robust diagnostic strategies, and fire safety engineering knowledge.

The First-year 3FiRES Booklet, in this regard, is an extended collection of research outcomes and advancements from the scientific activities of the running “Particular Relevance” Italy-China bilateral project (2024-2025), which involves the University of Trieste (Principal Investigator Prof. Chiara Bedon) and the University of Science and Technology of China (Principal Investigator Prof. Yu Wang).

The acronym 3FiRES symbolically summarizes the core and goal of the bilateral project, which primarily focuses on “Research on BIPV Photovoltaic Facades for Fire Spread Mechanisms, Structural Failures and Resilience Improvement Methodologies”, but also faces the multidisciplinary nature of the project topic and extended network, as it involves research unit members and international experts that operate in many scientific fields.

Most of research contributions that are collected in this book have been orally presented during the “First-year 3FiRES Workshop”, an international event that took place at the University of Trieste, on October 7th, 2024. It represented a very efficient and constructive networking opportunity for the involved research units on the Italian and Chinese sides, as well as for several international experts and students, with both engineering and architectural background, that had the occasion to present their research studies, interact and scientifically grow. The Workshop was attended by more than 90 participants (65 of them in presence), including a large number of Bachelor, Master and PhD students from very different fields (Civil Engineering, Electrical Engineering, Architecture, Mechanical Engineering, Engineering for the Energy Transition, etc.), and representing many Countries (Italy, China, France, Portugal, Slovenia, Slovak Republic, Iran, Pakistan, etc.). Overall, such a successful experience confirmed the high multidisciplinary innovative and international nature of 3FiRES.

Overall, this first-year booklet represents a strategic chance of networking and scientific growth for all the directly and indirectly involved participants, thanks to the research contributions and the experiences that are shared by members of the extended and highly multidisciplinary 3FiRES network.

In this sense, the booklet first summarizes some achievements, research results and dissemination activities that took place in 2024, according to 3FiRES plans.

The collected research contributions are grouped into three different sections. The first one, “Thermo-mechanical aspects and ongoing investigations for BIPV in fire”, presents six research contributions from the young researchers and early-stage investigators that are active part of 3FiRES units, both on the Italian and Chinese sides. These documents summarize the topic and content of the scientific talks that they presented to the attendants of 3FiRES Workshop. As such, there is a special attention for numerical modelling and experimental strategies for BIPV components in fire, focusing on the need of specific performance indicators to detect failure, as well as of sound modelling strategies to capture realistically the typical resisting and failure mechanisms.

The second section, “Further international experiences on experimental analyses and diagnostics”, includes three additional contributions and presents some ongoing activities from the extended international network of 3FiRES. The presented topics are in line with invited speeches of the Workshop. As a matter of fact, the need of standardized experimental protocols for BIPV systems in fire, but also of extended experimental studies, is essential in the same way of optimal and robust diagnostic approaches, that could be used to capture possible (and different) faults in photovoltaic systems, especially (but not only) in the solar cells.

But photovoltaic systems and BIPV facades are also implicit synonym of architectural design. In this regard, the third section of this book is about “Architecture and solar design”.

The issue of solar architecture raises at least two important questions that need to be addressed, one arising from the fact that the sun is no longer just a technological system and device, useful and necessary for the functioning of the building, but has become an architectural character and, in some cases, a typological element used to create facades, roofs, windows and, in general, enclosures, and the other question is related to the “revolution” that solar architecture is causing in terms of design culture. But are these not the basic materials with which to compose? Aren’t these the elements with which to make the building “speak” and thus, in the end, the syntagmas of a possible new language?

The historical perspective is still short, so it is difficult to speak of a true “new style” of architecture, but certainly all solar-related design approaches that tend towards the integration - not to be confused with camouflage - of solar technologies into the architectural organism tell us that a kind of architectural cultural revolution is underway, centered entirely on this aspect, and not just as a plant extension, but as a new theoretical principle of spatial configuration. And so, when architecture is no longer a “mere support” for solar installations, and we have devices (solar spheres, solar cells, photovoltaic sheets, solar glass, solar organic, etc.) that allow us to go beyond the simple assembly by serial repetition of strings resting on roofs, we realize that we have a new material on our hands, both in technological and spatial-compositional terms. And this allows us to build unprecedented spatial configurations, thanks precisely to the aggregative reasons of these new devices and materials, which among other things carry one of the oldest ideas of life and metaphors of the earth: the sun. Yes..., because thinking of an architecture of the sun means bringing into play the ancient myth of the sun, symbol of life and prosperity for all living things on Earth. So solar architecture is not just an offshoot of plant engineering in an era of eco-sustainability or a new, somewhat bizarre evolution of high-tech style architecture, but perhaps it is a new way of looking at architecture through the sun and, for what it brings us back to, of rethinking the relationship of man with his habitat and of architecture with nature.

The section focused on solar architecture, developed in this publication by Adriano Venudo, Michela Lupieri, Mariacristina D'Oria, Thomas Bisiani and Elisabetta Nascig, reflects on this topic from various points of view, on various planes and with different registers, but fundamentally both as a physical fact (technological and spatial), thus as an "architectural phenomenon", and as a cultural fact, and thus as a critical observation on the birth and development of new languages and new aesthetics of human space.

ARCHITECTURE AND SOLAR DESI

Useful, easy, positive, radiant, beautiful, ... sunny
Let's talk about it!
Adriano Venudo

Figuratively speaking, "sunny" refers to a particularly cheerful, bright and positive person or character. Someone defined as "sunny" conveys cheerfulness, serenity and optimism, just as the sun does with its light. It also indicates an outgoing, friendly personality who is able to bring good humour and harmony to others.
Solar architecture should therefore by definition be an "architecture of happiness", a "positive architecture", which carries beauty as its status and origin. It is "sunny".
The term "solar" describes a work, image or artistic experience that evokes light, warmth, clarity and harmony in relation to aesthetic categories from which architecture and landscape cannot escape or it would be something else. A "solar work" evokes positive and reassuring feelings, often associated with elements such as the sun, nature and vitality. This term can also be associated with a serene and simple beauty, characterized by brightness and an optimistic outlook, as opposed to other aesthetic categories such as the sublime (characterized by grandeur and almost frightening intensity) or the melancholic (associated with deeper, more introspective emotions). When can a style, movement or architectural approach be defined as such?
Solar energy, understood as infrastructure, was born with the idea of making it functional and at the service of the usability and operational use of buildings, in the sense most commonly used in both technical and non-technical circles. Solar energy as an infrastructural facility is equated with a heating or water system. Until now, it has been a technological installation. However, if we take a closer look at the reasoning behind this, we can see that solar energy has become part of the building fabric as a sustainable alternative, and then it has become obligatory and, today, increasingly indispensable. This is a great opportunity for architectural, urban and landscape design, but let us not forget that when

Figure 1. *Crescent Dunes Solar Energy Project*, Las Vegas, US, 2011-2019.

Figure 2. (following pages) *Agua Caliente Solar Project,* Yuma County, Arizona, US, 2014.

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we use and transform this technological device in architecture, solar is synonymous with happiness and beauty. The history of architecture includes many leaps and new paradigms created by introducing technical and functional devices. Think of toilets, lifts, glass windows, etc. This was also the case with the introduction of new materials. Steel and then concrete were revolutionary in terms of formal, spatial and structural developments, and we cannot do without them today.

Will the sun play the same role? Will it undergo the same evolution in architecture?

In the essay We are all children of the sun. A brief history of solar design: how the new solar architecture began, evolved and morphed? by the undersigned author, analyses these jumps in species and the overall evolution of this device into a plant and then, today, into an architectural element, a typological character, an approach to composition and perhaps even a new architectural style, solar design or “solar architecture”.

All the technology and engineering behind, and to some extent in front of, these solar devices are, however, when they become man’s space, carriers of a universal and eternal message, the one linked to the history of man and the earth, namely the sun and the myths and cultures it has always represented and promoted. Michela Lupieri, in Where does the sun set from? asks this very question and shows us, through a series of poetic examples linked to visual art, how the sun has always been the greatest fascination for man and his habitat, for the earth he inhabits and for the universe he observes. Man has always transferred the energies of the cosmos to the earth, with architectures capable of capturing light in its various temporalities, which have paid homage to this luminous sphere in the most diverse forms.
The research and development of building materials have enabled the emergence of new languages and meanings for architecture and the city, and the evolution and transformation of various technological devices into new autonomous architectural elements have broadened the possibilities of

PART 03

characterizing space, inventing new relationships with the environment, and "thus dispelling the idea that technology is cold and complicated", but can be, simple and "solar". The essay Seeking for reinterpretations: re-grounding solar energy by Mariacristina D'Oria observes this general phenomenon of applications and declinations of solar design that affects architecture, but not only, it also reaches fashion and accessories, showing how a possible reinterpretation and re-grounding of the solar energy paradigms can bring the man-nature relationship back into play.

So the challenge is to seek integration between device and space? Between structure and infrastructure? Between technological system and configurational system? If solar design solutions can be integrated into architecture, then the forms of integration must be architecturally appropriate to the project. To test this hypothesis, Thomas Bisiani in Three "dimensions" of solar architectures: design strategies and integration identifies three divergent and alternative cases, comparing the solar design strategies and solutions applied and the consequent architectural effects. Bisiani makes us reflect on compositional strategies related to the different possibilities of integration and exposure of solar technology in relation to different spatial situations.

The hypotheses, reflections and the general point on the potential and criticality of this technique, which is also proposed as an emerging architectural culture of this new "ism" (solarism), are then verified in the last essay, that of Elisabetta Nascig, Ten case studies for an Atlas of the architectural of the sun, which shows, by comparing, ten case studies of experimental buildings that "seem", for the way they use the sun, to open a new road to architecture, positive, beautiful, ... solar.

But if, in the course of the history of architecture, the introduction and invention of new materials have allowed the birth of new languages, can this "new" device today lead to new forms of expression and constructive and configurational possibilities of new spatialities?

With the exception of a few cases, the history of architecture teaches us that technological devices have rarely been used as architectural features or typological elements. They have improved and facilitated species leaps and evolutions, but hardly ever have they opened up real experimentation and paths in terms of language and approach. As we have said, there are few exceptions, and the most notable and well-known is certainly that of High-Tech. High-Tech style began in England in the early 1960s and then became an "international style" that was elaborated and developed, with some local variations, all over the world. High-Tech opened up completely new ways of thinking about human space and architecture. This revolution had different phases and alternated between the "first and second machine ages", as Reyner Banham reminds us, when facades or architectural volumes were marked by the alienating rhythms of ducts and service pipes, external technological units, compressors and refrigerating machines for air exchange and, in general, gears and mechanisms to make the building work and guarantee its internal well-being. These sophisticated devices were the new stylistic features, no longer hidden or integrated in the structure or in the recesses of the building, but highlighted and proudly displayed on the facade to narrate a new architecture, a new space and a new world, all technological, emblematic of a nascent positivist, "machinic culture" where man no longer relates to nature through the "technè", but the latter has assumed the role of "other", replacing, in many cases, the very idea of nature. Those were the years of the totalising hyper-technological experiences of Blade Runner in which man is integrated (overpowered?) by the reason of the machine. It was the time of robots, and architecture was charting new courses, nurturing ideas of techno-society through new aesthetics with a jubilation of artifice over nature. But it was also the death of the dialectic between mimesis and poiesis, an ancient paradigm in which technics had always been contained and never exposed. Then, about a decade later, more or less in the same way, it was the time of the digital, of information technologies where everything was apparently immaterial, dematerialized and virtual, and architecture, once again, exhibited the technic by transfiguring itself into enormous screen-buildings, empty spaces for holograms and virtual elements capable of characterizing, deforming, modifying space at will in a practically infinite cycle, with a simple click. And the image became the "canon" of this architecture, but also the paradigm of a new culture, between the late 1990s and the early 2000s. It was Neri and Zoffoli's "architecture of the immaterial" and Mitchell's "city of bits". Will solar, both design and architecture, now also have this strength and capacity to become an "ism" and even a new culture? Does it exist? What is solar architecture, if it exists?

Where does it fit into the "styles", the "habits", the "movements" of contemporary architecture?

We have to ask ourselves this question because, as we can read in the contributions in the following section (Architetcure and Solar Design), it is no longer just a matter of "installing" panels on roof tiles according to a simple and basic aggregation principle (to say easy: it is integrated!), precisely because, in addition to the thousands of possibilities offered by the evolution of solar devices, we can no longer pretend that solar is only useful and integrated (BIPV), but that it is also "easy, positive, radiant, ... beautiful".

“We are all children of the Sun”. A brief history of solar design: how the new solar architecture began, evolved and morphed?

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Abstract
The essay presents an investigation into the revolutionary role of solar design in architecture. It postulates that solar design can be conceived as a new cultural orientation, as well as an aesthetic language and functional approach that employs solar energy to define living and urban spaces. The evolution of photovoltaics is traced from the earliest scientific discoveries to its architectural integration, with particular attention paid to how current advanced and experimental technologies (e.g. flexible cells, solar fabrics) have transformed photovoltaics into an autonomous spatial and building element. In some cases, this transformation has been so significant that it has led to the birth of a new architectural “movement” (solarism).

The concept of BIPV (Building Integrated Photovoltaics) represents a significant advancement in solar technology, whereby solar energy is integrated into the very fabric of buildings, conferring both energy and spatial value. This article proposes a final reflection on the relationship between humanity, nature and architecture, drawing upon Paolo Soleri’s theories as a foundation for solar design and a sustainable approach to architecture that is in harmony with the environment.

Keywords
Solar design; solar architecture; BIPV; solar machine; organic photovoltaic; Arcosanti.

Figure 1. *BedZED, Beddington Zero Energy Develom-ment*, Hackbridge, (BioRegional, Bill Dunster Archi-tects, Ove Arup) London, 2002-7.

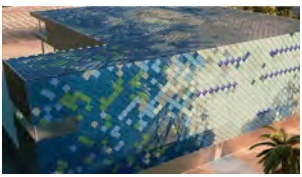
Figure 2. *Solar spheres. Appli-cation example of photovoltaic spheres for energy production*.

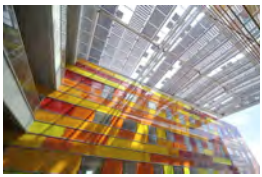
Figures 3-5. *Examples of the application of photovoltaic glass, cells and films for solar facades and roofs integrated into the architec-tural design*.

Introduction. Solarism?

It was a revolution, a turning point not only for architecture, but for civilization as a whole. It opened up unprecedented scenarios for human life and living space, offering almost infinite possibilities for the development and growth [01] of humanity on Earth. Renewable energy sources such as the sun, air and water [02] have played a decisive role in shaping human space in terms of structure, form, technological characteristics and, last but not least, language, so much so that they have marked the birth and development of "specific designs" such as solar design.

We are not talking here about the ways and means of adapting architecture to climatic and more general environmental conditions, such as exposure, radiation, insulation, etc., but about the case of solar design, understood as the result of the paradigmatic application and use of energy to power buildings, parts of cities or mobility networks. This change of perspective is fundamental for reading the new paradigm of solar design. We will therefore confine ourselves to analyzing how solar energy production and all that it entails in terms of space, i.e. the so-called "solar machines", have become true architectures. Unlike





other systems for powering buildings, such as water or gas, solar electricity is the only one in the history of architecture to have had so many and such different applications in buildings as to become the paradigm of a new language (perhaps even "style"?), that of the solar design. We are therefore attempting here to hypothesize the existence of an "ism" (solarism) and the possible emergence of a "solar design movement" (some might say "solar style").

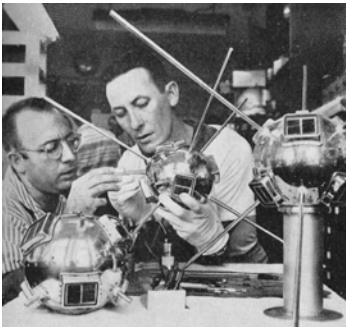
Solar design: a new architectural species?
Origins, development and prospects for evolution
Photovoltaics is both a material and a component capable of significantly modifying spatial models [03], generating new types [04] of (buildings) and inspiring new languages, even to the point of confronting the design of the territorial scale and shaping the landscape [05] (solar mega parks), as was the case with certain materials, first steel and then reinforced concrete, or certain "devices", such as the lift or the water, or certain technological systems, such as sewage system, heating or air conditioning. It should also be remembered that, unlike the slow processes associated with stone [06], brick and wood, solar design has evolved extremely rapidly thanks to the technology applied to silicas, which in just 50 years has gone from bulky and unadaptable photovoltaic panels, to colored solar microcells or flexible solar textiles, to the more recent organic solar, whose applications are practically infinite and almost unlimited (a similar story happened with steel, then reinforced concrete, and today with new metallic alloys).

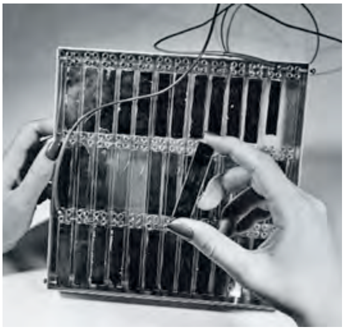
If we look back, the historical perspective is limited. We can see that the development of photovoltaics basically took place in three moments. The first was the scientists who, having discovered the physical phenomenon of the "solar effect", carried out the research and in-depth studies necessary to make the technology practical. After the scientists, it was the turn of the engineers to give shape and consistency to the components used to produce energy with reliable systems that were easy to manufacture and install. Thus, were born the modules, the inverters, the support structures for different applications, the most efficient materials, the assembly kits, the safety devices, the dimensional modularity (rigid, flexible, semi-rigid, etc.), the types of connection, the mono-inverter modules. Then it was the turn of the architects, who are now even required by law and various building and landscape regulations and guide-lines to work on the integration of photovoltaic modules in the building.

Since the ancient Indian populations, and then the Greeks and Romans, the sun's potential to heat rooms and everyday objects has been understood thanks to external "primitive amplifiers" such as glass or metal. However, the first and perhaps most famous case of direct application is certainly that of Archimedes, who used a system of mirrors (burning mirrors) to reflect the sun's rays and set fire to the Roman fleet besieging Syracuse in 212 BC. The Romans used glass mirror systems to direct sunlight into the darkest, dampest and coldest rooms (now called solar chimneys) of the domus, achieving a kind of primitive solar thermal energy. Leonardo Da Vinci also studied solar energy, developing a parabolic mirror to dry clothes and heat rooms in 16th century palaces by radiation. History is full of experiments in the use of solar energy in buildings, exploiting the principle of radiation to serve the spaces of everyday life.

But it is thanks to Alessandro Volta, the inventor of the first electric generator (the battery) from which it all began, and whose accumulator principle (cells and batteries) is still the basis of all photovoltaic technology today. It is also the basis of this research. It is no coincidence that the word "photovoltaic" comes from the combination of "phos – photos", meaning "light" in classical Greek, and the adjective "voltaic", which comes from Volta (Alessandro).

In 1839, the French physicist Alexandre Edmond Becquerel accidentally discovered that the influence of the sun's rays produced slight flows and electrical effects in certain liquids. In 1876, subsequent experiments on solid materials led to the discovery of the so-called "photovoltaic effect", i.e. the generation of an electric current by certain metallic elements exposed to the sun. This was followed by the studies of William G. Adams and Richard Evans, who noticed the sudden change in conductivity (generation of electric flow) of telegraph (silicon) cables when exposed to and illuminated by the sun. In 1879, Charles Fritz, who systematized these early discoveries and inventions, created the world's first rudimentary solar panel (a $30cm^2$ solar cell). It was a sheet of selenium covered with a very thin semi-transparent film of gold, which produced electricity when exposed to the sun. After the photovoltaic effect, the other key discovery in the development of solar technology was the "photoelectric effect". In 1921, the Nobel Prize-winning physicist Albert Einstein theorized the generation of electricity by photovoltaic cells. But for architecture, the real breakthrough was made in 1955, when Gerald Pearson, Daryl Chapin and Calvin Fuller of Bell Laboratories built a silicon photovoltaic cell capable of powering a small transceiver. From then on, everyone concentrated on research and development of photovoltaics for buildings, and in 1958 the Vanguard I satellite was





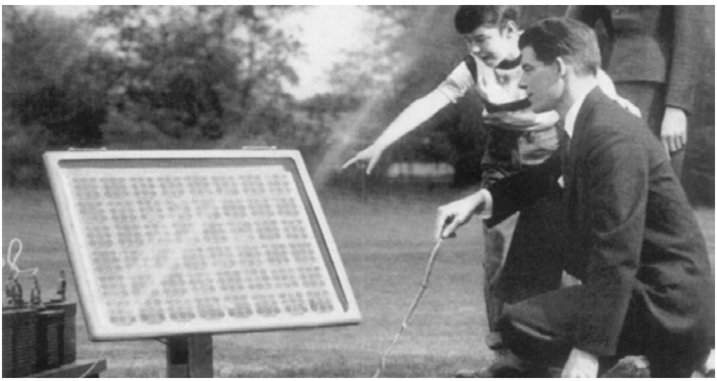


Figure 6. *Charles Fritts made the first selenium photovoltaic panel covered with a very thin film of gold.*

Figure 7. *Scientist Alexandre Edmond Becquerel accidentally discovered the "photovoltaic effect" and the production of electricity through the sun's rays.*

Figure 8. *Study model of Vanguard I, the first orbiting spacecraft powered entirely by photovoltaic cells.*

launched, powered entirely by photovoltaic energy, and remained in orbit until 1964. Since then, photovoltaics has been an integral part of every space project. Let's not forget that all the missions carried out by the Apollo Programme could have been carried out using this technology.

Figures 9-10. *Solar textiles applied to tensile structures for Expo 2015 in Milan*.

Capturing the sun: how solar design is reinventing architecture

The evolution of the components of solar design, from classic photovoltaic panels to the more experimental solar fabrics, or from solar cells to organic photovoltaics, has, over the last 70 years, created the formal matrices of a new formal and spatial lexicon for architectural research, thanks to the evolution of these "basic components": the solar cell, the night photovoltaic cell, printable cells, solar envelopes, solar glass and transparent photovoltaics, solar fabrics, solar spheres, solar inflatables (Tomas Saraceno is experimenting with solar hot air balloons), organic solar, solar paste, solar films, solar liquids and, finally, solar inks. These technological inventions applied to architecture have made it possible to create new spaces, forms and building devices. They have given rise to new architectural elements and features such as photovoltaic tiles, photovoltaic roofs, energy windows, homogeneous solar facades, solar column, solar chimney, solar tower, photovoltaic greenhouses, solar trees and even new types of floating photovoltaic farms.

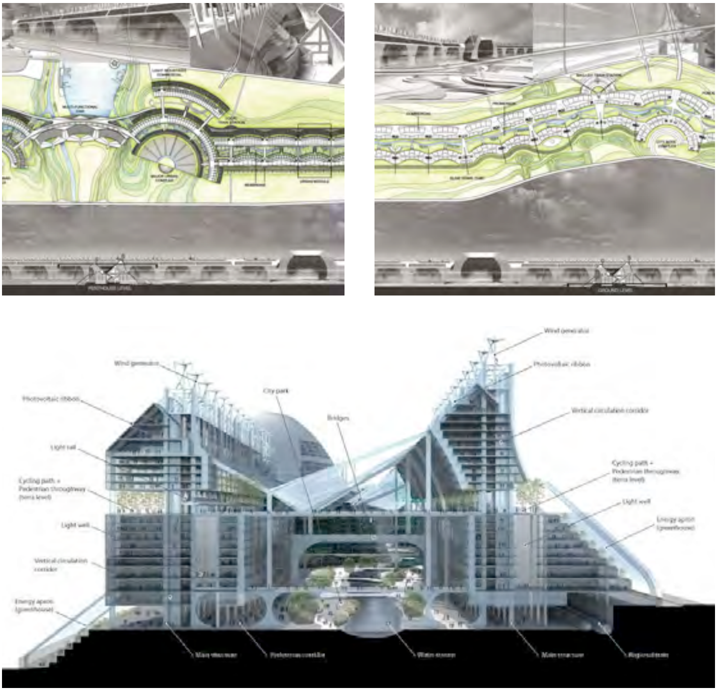
It should be added that the real leap comes when solar design, which until a few years ago was developed according to a modular logic (the basic unit of which is the photovoltaic panel or solar cell), together with lattice frames and supports, has freed itself from this compositional paradigm, freeing itself from the "constructive role" of being merely the envelope or skin of the building organism. Today, thanks to solutions such as organic solar, solar textiles or solar glass, this paradigm can be completely revised, even in terms of structure or as an autonomous spatial element, without prejudice to the requirements of exposure [07]. And even these, thanks to research into "night solar", are beginning to be less binding. The application of solar design is also being explored in the fields of industrial design and fashion. Examples of this include photovoltaic jumpers and jackets, solar necklaces and bags, and photovoltaic shoes.

Figure 11. Tomas Saraceno, *Aerosolar Balloon*, 2020.

Conclusions. Soleri's vision, BIPV's reality: a new era of solar-integrated architecture

In conclusion, the integration of photovoltaic systems into the configuration of space, the building organism, and design accessories and products is becoming increasingly prevalent in the construction of a new architectural vocabulary. It can thus be concluded that solar design has achieved autonomy within the field of architecture when, in addition to its primary energy-related functions, photovoltaic systems also fulfil the conventional roles associated with building elements and features, which contribute to the overall form and structure

Figures 12-14.
Paolo Soleri, *Solar Lean Linear City*, 2005.



of the architectural design. This approach, defined as BIPV (Building Integrated Photovoltaics), can be implemented in two ways: firstly, conventional solar panels can be connected and integrated within the functional surfaces of the traditional building envelope, such as roofs and facades; secondly, multi-purpose integrated systems can be employed, whereby photovoltaics is rethought as an integrated component within a basic building element. Examples of such elements include solar tiles, photovoltaic sheaths and skins, energy windows, and solar facades. These may take the form of a functional building element (e.g. solar roofs, roofs, facades, etc.), a functional building element (e.g. solar panels, roofs, facades, etc.) or a functional building element (e.g. solar panels, roofs, etc.). These may take the form of a functional building element (e.g. roofing sheets, energy windows, photovoltaic greenhouses) or a new building element (e.g. multi-performance facades or roofs, solar towers, solar chimneys, photovoltaic greenhouses).

Figure 15. *Heliodome* is a passive house, one of the most efficient in the world, which exploits the sun's radiant maximisation thanks to its meridian shape, and which follows the sun's trajectory. Eric Wasser, 2013, Cosswiller, France.

The approach proposed by BIPV comprises two aspects that are mutually reinforcing: the multifunctionality of solar energy, understood in constructive and functional terms, and the aspect of architectural design, that is, the quality and characteristics of the system for the linguistic, communicative, symbolic and figurative characterization of the building. At this time, the BIPV strand is the most intriguing and efficacious on the global stage. It situates the issue of architectural design at the core of solar design, no longer merely in terms of efficiency and specifications, but in terms of form, structure, and space, thereby encompassing the full scope of architectural considerations.

"[…] The wind moves the bronze bells, and the sound they make reminds me of the wind in the Arizona desert and the music of Arcosanti. It's a musical fragment that makes me think of how free it is to move in the wind […]"[08].

Following this brief overview of the historical development, evolution and recent applications of solar energy in the construction of new architecture, I would like to recall the words of Paolo Soleri, who was one of the first to consider these topics not only as an exploration, but also as a potential solution to the challenges associated with the built environment, ... as a search for a potential alternative approach to human space, an architectural methodology that begins with the environment, particularly the energy implications of the sun in relation to urban forms of life. “Arcosanti” and “Solar, Lean Linear City” represent two emblematic cases of Soleri’s “energy landscapes”, in which these theories are applied. The necessity for a reevaluation of Paolo Soleri’s theories on energy issues arises not as a technological response to the planetary emergency, but as a preliminary step towards a significant transformation in individual consciousness, modes of thinking, lifestyle and communication patterns in relation to the environment. Solar design can therefore be regarded as a genuinely innovative approach to architecture. And so, it is also important to recall Paolo Soleri’s frequently repeated mantra to all those who came to live or work in Arcosanti: “We are all children of the sun”.

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[01] A. Vico, *Energia. Dal fuoco all’elio. Viaggio nella storia delle fonti fossili e rinnovabili*, Trieste, Editoriale Scienza, 2018.
[02] We refer to historical utilitarian architectures such as windmills or water mills and can go as far as more recent developments such as organic solar or micro-eolic.
[03] Tesla’s Gigafactory is the world’s largest energy self-sufficient production facility. Moreover, it is a true “machine building” that builds itself and repairs itself.
[04] An important case-study are the large “solar canopies” made for Expo 2015 in Milan that covered the large central space between the various pavilions.
[05] We refer to solar parks in the Nevada desert such as Crescent Dunes Solar, or Spanish ones like Plant Solar.
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Figure 16.
Emmanuel Saadi, *Emmaüs solidarité résidence*, Quai de Valmy, Paris, France, 2005.

Short biographies

PART 01.
THERMO-MECHANICAL ASPECTS AND ONGOING INVESTIGATIONS FOR BIPV IN FIRE

Chiara Bedon: Associate Professor at the University of Trieste, Department of Engineering and Architecture (Italy). Presently, she leads the "3FiRES" project on the Italian side, in strong cooperation with Prof. Yu Wang on the Chinese side. With a PhD degree in 2012 in Structural Engineering, on glass related aspects, since 2009 she has been involved in several international projects (JRC-ERNCIP, NATO-SPS, EU-COST). Listed as Top Scientist (2% Worldwide, Stanford) for research impact in Civil Engineering since 2019, Top Italian Scientist (TIS) since 2021 and Top Italian Women Scientist (TIWS) since 2022.

Lorenzo Veronese: (MSc) is 3FiRES research fellow in Structural Engineering at the University of Trieste, Department of Engineering and Architecture. Topic of his fellowship is the development of refined and more simplified Finite Element numerical strategies for BIPVs in fire, including thermo-mechanical failure mechanisms.

Riccardo Del Bello: (MSc) is 3FiRES research fellow in Structural Engineering at the University of Trieste, Department of Engineering and Architecture. His research activities focus on the analysis of BIPVs under ordinary operational conditions or fire, in terms of mechanical characterization and failure mechanisms.

Nicola Cella: PhD Candidate in Structural Engineering at the University of Trieste, Department of Engineering and Architecture. His research project deals on the analysis of glass facades and structural glass systems under extreme design actions, based on refined Finite Element numerical models and analytical approaches.

Yu Wang: Professor at the State Key Laboratory of Fire Science, University of Science and Technology of China (USTC). Yu has published over 50 SCI journal papers, and currently served as an Associate Editor in Fire Technology, Editorial Board Member in Fire Safety Journal, and member of IAFSS Membership Advisory Council. He initiated the English fire course at USTC, Introduction of Fire Dynamics, reported by China News and People's Daily Online. Recently, he has received SFPE Global 5 Under 35 Award, International Partnership Award for Young Scientists of Chinese Academy of Sciences, Young Faculty Career Award (USTCAF), and Best Paper/Presentation/Poster/Image Awards in IAFSS or AOSFST.

Chengming Xiao: PhD candidate at the State Key Laboratory of Fire Science at the University of Science and Technology of China. His research focuses on the performance of PV panels under fire conditions and the interaction between PV panels and compartment fire dynamic.

Yiyang Hu: second-year PhD student at the State Key Laboratory of Fire Science at the University of Science and Technology of China, specializes in the intersection of Structural Engineering, Architecture and Fire Safety Engineering. Her research focuses on the fire safety of BAPV and BIPV systems. She is currently the vice president of the SFPE Hefei Student Chapter.

Haonan Chen: PhD candidate at the State Key Laboratory of Fire Science, University of Science and Technology of China. President of SFPE Hefei Student Chapter. He was a fire captain and a fire investigator in Xuchang City Fire and Rescue Department for 5 years (2019-2024). Haonan has led thousands of firefighting operations especially in the countryside and large outdoor spaces, and experienced more than one hundred fire investigations during that period. Now he majors in the compartment fire dynamics in his PhD study.

Liaoying Zhou: PhD candidate at the State Key Laboratory of Fire Science of the University of Science and Technology of China. Secretary of the Hefei SFPE Student Chapter. Research direction focuses on the thermal breakage behavior and structural response of structural glass under fire conditions.

PART 02.
FURTHER INTERNATIONAL EXPERIENCES ON EXPERIMENTAL ANALYSES AND DIAGNOSTICS

Olaia Aurrekoetxea-Arratibel: Forest Engineer from the Polytechnic University of Madrid (2013). She is currently a PhD student in the field of photovoltaics in the built environment and its risks associated with fire. She is also a member of the Fire Safety Laboratory at TECNALIA and coordinates different studies and R+D+i projects developed in the field of energy generation. She has previously worked as an environmental, forestry or climate change consultant with different consultancy firms in Spain.

Nicola Blasuttigh: received his B.Sc and M.Sc in Electrical Engineering from the University of Trieste in 2015 and 2019, respectively, and a Ph.D. in Industrial and Information Engineering in 2023. Since December 2022, he has been a post-doctoral researcher and Teaching Assistant, focusing on photovoltaic systems diagnosis, energy management, and electric vehicle integration.

Alberto Dolara received his M.S. and Ph.D. in electrical engineering from the Politecnico di Milano in 2005 and 2010. His research areas include power generation from renewable sources, power elecrtronics, electric mobility and traction systems. He is currently an Associate Professor at the Department of Energy at Politecnico di Milano.

Francesco Frontini: graduated in Construction Engineering and Architecture at Politecnico di Milano, earning a PhD with distinction. He worked as a project manager from 2007 to 2010 and has led the Building System Sector and Swiss BIPV Competence Centre at SUPSI since 2011. Appointed director of ISAAC in September 2024, he previously worked with the Solar Facades group at Fraunhofer ISE, Germany. He is active in SIA, CENELEC, and IEC standardization bodies and is Co-manager of the IEA PVPS Task 15.

Andrea Lucherini: holds the position of Senior Researcher at the Slovenian National Building and Civil Engineering Institute (ZAG) and Assistant Professor at the University of Primorska (Slovenia). His field of expertise is construction materials engineering, with a specialization in fire safety science and engineering. His research interests primarily focus on the performance of advanced construction materials and systems during and after a fire, material behaviour at elevated temperatures, advanced experimental fire methodologies, and fire dynamics for performance-based fire safety design.

Alessandro Massi Pavan: is an Associate Professor of Electrical Engineering at the University of Trieste, Italy, focusing on e-mobility, photovoltaics, electrical storage systems, and microgrids. He coordinates the Interdepartmental Centre for Energy, Environment, and Transport and the Summer School on Energy.

Adel Mellit: received his M.Eng. and Ph.D. in electronics from the University of Sciences and Technology (USTHB), Algeria, in 2002 and 2006. He is a Professor of Electronics and Head of the Renewable Energy Laboratory at Jijel University, Algeria. His research focuses on AI applications in photovoltaic systems and micro-grids. He is also an Associate Member at ICTP, Trieste, Italy.

Ainhoa Odriozola-Alberdi: Industrial Engineer, specialized in Materials and Manufacturing Processes from the University of Mondragon since 2022 and Ecotechnologies Engineer in Industrial Processes from University of Mondragon since 2020. Currently, she is a member of the Fire Safety Laboratory at TECNALIA and coordinates different studies and R+D+i projects developed in the fields of energy generation and energy storage.

Emanuele Giovanni Ogliari: received his M.Sc. and Ph.D. in electrical engineering from the Politecnico di Milano in 2016. Since 2010, he has worked on photovoltaic plant design and optimization and, since 2012, on renewable power forecasting using computational intelligence techniques. He is currently an Associate Professor at the Department of Energy, Politecnico di Milano.

Xabier Olano-Azkune: Industrial Engineer from TECNUN (2004). Currently in charge of the Fire Safety Laboratory at TECNALIA (since 2015). Previously, head of Structural Safety at TECNALIA (2010-2019). Member of several entities such as the Technical Board and the specific fire group PT04 EOTA, EGOLF plenary and technical committees, ASEFAVE plenary, CEN/TC 127 Standardisation Committee or IEA Task 15. He has participated in R+D+i projects related to the building envelope and the integration of renewable energies.

Nerea Otano-Aramendi: PhD in materials structure from the University of Centrale Supelec of Paris (2016), Aeronautical Engineer from the Polytechnic University of Madrid. She is currently part of the Fire Safety laboratory at TECNALIA and coordinates different studies and R+D+i projects developed in this laboratory in the field of energy generation. Previously, she has worked as a researcher at IKERLAN and Orona EIC (2016-2020).

Fabio Parolini: graduated in Engineering from Politecnico di Milano and began his career at multinational companies. With extensive experience in renewable energy and fire safety in photovoltaics, he has contributed to designing and implementing numerous energy-efficient buildings. Since 2019, he has been a researcher at SUPSI's DACD/ISAAC within the Innovative Building Envelope Team. He focuses on building envelopes' product development and fire safety, emphasizing applied research and real-world experimental projects.

Giombattista Traina: M.Sc. Eng is the Head of the Reaction to Fire laboratory and a Senior Lead of Research at Instituto Giordano Spa, a Certification and Research company in Italy. He actively participates in several technical committees focused on fire safety matters: CEN/TC 127 WG 4 and WG 5; GNB-SH02; CEI TC 82; EGOLF. He is also a co-author of the new test method to assess the fire behavior of BAPV in Italy, the CEI TS 82-89

PART 03.
ARCHITECTURE
AND SOLAR DESIGN

Adriano Venudo: Architect and Phd, is Associate Professor in Architectural and Urban Design at the University of Trieste, Department of Engineering and Architecture. He has focused his scientific activity over the years on operational research on reuse and redevelopment of disused architectural complexes, solar architecture and green and blue infrastructure. He is currently responsible for the "BluVerdeBlu", "Re.So.LAR" and "The New Friulan Deserts" research units at DIA-UNITS, and is a researcher of "RRR lab" unit research (resp. T. Bisiani). On solar issues, he has several publications and monographs to his credit, including Apollo Zero versus MUSE. Solar Landscapes, EUT, 2020.

Thomas Bisiani: Architect and PhD, currently - as a Researcher in Architectural and Urban Composition of the iNest project - is responsible for the research unit RRR lab at the University of Trieste, Department of Engineering and Architecture, and is a member of the research units "Re.So.LAR" and "The New Friulan Deserts" . He graduated with honours from the IUAV. The Venice Biennale awarded him an honourable mention for the project Ecology of Fear in 2000 and a special prize for the project Alphabetcity in 2008. In 2010 he obtained his PhD in architectural and urban design at the University of Trieste with the thesis Archigrafia, tra architettura e parola.

Michela Lupieri: Adjunct Professor of Contemporary Art History at the Faculty of Architecture, she is currently research fellow in the “Re.So.LAR” and “The New Friulan Deserts” research units at the DIA-UNITS. Her scientific practice, both as a scholar and a curator, focuses on art in public space in relation to architecture and landscape; on the artistic trends of the 1960s and 1970s; and on the practices of post-1945 visual artists.

Mariacristina D’Oria: Architect and Ph.D. (Doctor Europaeus, University of Trieste, Italy, ETSAM, Madrid). She works at the intersection of architecture, landscape and urban practices, detecting the relationship between architecture and transition. She presented her work at international conferences (Ljubljana 2021, Delft 2022 and Bath 2023) and dynamically experimented with the installation medium (Scenes in America Deserta 2019, Apocalypsis cum figuris 2020, Geometries of Time 2021, Time-capsule Transcrypts 2022). Currently research fellow at the University of Trieste, detecting strategies to ”Re-inhabiting the new Friulan deserts.”

Elisabetta Nascig: Ph.D. student in civil-environmental engineering and architecture – curriculum architecture – at the University of Trieste, Department of Engineering and Architecture. Her research activities focus on the new housing models for re-inhabiting the countryside of the lower Friulian plain. She is currently member of the “BluVerdeBlu”, “Re.So.LAR” and “The New Friulan Deserts” research at DIA-UNITS.

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Most of research contributions that are collected in this book have been orally presented during the “First-year 3FiRES Workshop” international event, that took place at the University of Trieste, on October 7th, 2024. It represented a very efficient and constructive networking opportunity, for the involved research units on the Italian and Chinese side, as well as for several international experts and students, with both engineering and architectural background, and this confirms the high multidisciplinary and innovative nature of the project topic.

This first-year booklet also represents a strategic opportunity of networking and scientific growth, thanks to the research contributions and the research experiences that are shared by members of the extended and highly multidisciplinary 3FiRES network.

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