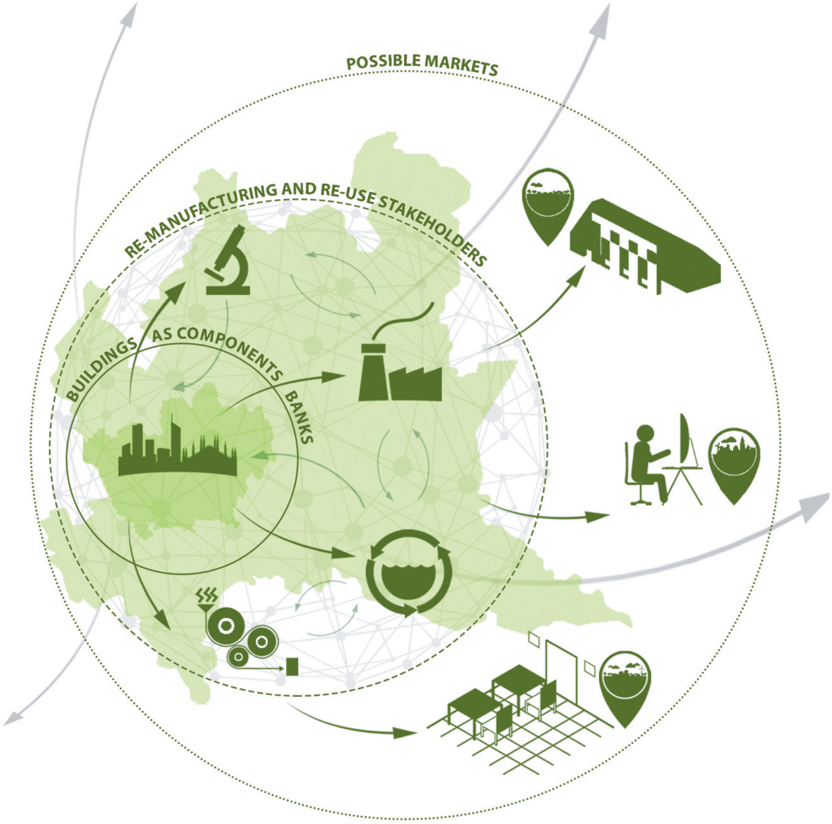
Re-manufacturing networks for tertiary architectures

Innovative organizational models towards circularity

edited by Cinzia Maria Luisa Talamo



Ricerche di tecnologia dell'architettura

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RICERCHE DI TECNOLOGIA DELL’ARCHITETTURA

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The book presents the results of the project "*Re-NetTA (Re-manufacturing Networks for Tertiary Architectures). New organizational models and tools for re-manufacturing and re-using short life components coming from tertiary buildings renewal*", developed at Politecnico di Milano (2018-2021) and supported by Fondazione Cariplo, grant n° 2018-0991 (Call "Circular Economy for a sustainable future 2018").

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Introduction

This book deals with re-manufacturing, recondition, reuse and repurpose considered as winning strategies for boosting regenerative circular economy in the building sector.

The book presents many of the outcomes of the research "Re-NetTA (Re-manufacturing Networks for Tertiary Architectures). New organisational models and tools for re-manufacturing and re-using short life components coming from tertiary buildings renewal". The research was funded in Italy by Fondazione Cariplo for the period 2019-2021 and developed by a multidisciplinary group composed of all the authors present in this publication.

The field of interest of the book is the building sector, focusing on various categories of tertiary buildings, characterized by short-term cycles of use.

The building sector is a fundamental lever for the activation of circular economy. European Commission identifies the construction sector as a "Priority area" involved in specific challenges in the context of circular economy: according to the Eurostat statistical data in EU-28 the main field that produces waste is construction sector, contributing to 33.5% of the total waste generated by all economic activities and households in 2014. Besides, the construction sector is an important driver for circular economy as it provides, according to European Commission data, 18 million direct jobs and contributes to about 9% of the EU GDP. The application of new circular economy strategies can create new jobs, social benefit, energy and resource efficiency and a sustainable environment.

Currently, the circular strategy more promoted in the built environment is recycling. Most of European Projects (e.g. HISER PROJECT, Resource Efficient Use of Mixed Waste, DEMOCLES, ENCORT) and particularly Life Project investigate on recycling (inter-sectoral or within the construc-

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tion sector) of construction and demolition waste and deal with specific recycling topics (e.g. LIFE-PSLOOP Polystyrene Loop; CDW recycling Innovative solution for the separation of construction and demolition waste). Often recycling implies the downcycling and requests complex and energy-consuming processes. On the contrary, if well-organized, re-manufacturing and reuse require very simple and low-impacting processes, reduce the generation of waste and maintain over time the value of the resources embodied in manufactured products – once they are removed from the buildings – by extending their useful life and their usability with the lowest possible consumption of other materials and energy and with the maximum containment of emissions in the environment.

In the perspective of circular economy, the focus of this book on tertiary buildings derives from some considerations:

- cities all over the world are characterized by high quantities of tertiary buildings with various destinations (public and private offices, accommodation facilities, retail, exhibition facilities, temporary shops, etc.);
- there is an increasing stock of unused, often obsolete, tertiary buildings, especially after the pandemic;
- tertiary buildings are more and more characterized by quick cycles of renewal and reconfiguration of interior spaces following a series of phenomena that determine a fast functional obsolescence and frequent reshaping such as: recent approaches that shift attention to the use of buildings in terms of service (such as hoteling, leasing, co-working, smart working and various declinations of sharing) determining a high degree of temporary use; shortening of leases; transformations in the Real Estate market; transformations in the models of commerce;
- this kind of buildings generate significant quantities of disused elements and systems that become waste if not reused or remanufactured. These products (in particular interiors, services, equipment and furnishings) have usually a high degree of residual performances and are characterized by being dry assembled (therefore easy to disassemble), composed of high-value raw materials, generally equipped with manufacturer technical datasheets (therefore easily traceable) and, besides, by having a high added value.

This book investigates the most promising strategies and organisational models to maintain over time the value of the environmental and economic resources integrated into manufactured products, once they have been removed from buildings. Some novel concepts for the construction sector should be introduced:

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- the integrated "re-actions" (re-manufacturing, re-condition, re-purpose, reuse, repair) as strategies for keeping building products and their embodied materials in use for longer time with significant decrease of waste, energy and water use and emissions through the reduction of manufacturing activities;
- the building as "components bank". The building is no longer meant as the last destination of industrial products, but as a node within circular processes;
- "planned obsolescence" as a proactive strategy for addressing and optimizing the "re-actions";
- decommissioned building products meant not as waste but as "bought and sell" items available for purchase from catalogues or other sources;
- "reverse supply chains" that is the delivery of goods (decommissioned elements) from the owners to the reuse or remanufacture operators.

These new concepts are connected with various possible approaches, innovative for the construction sector:

- from product to service, i.e. overcoming the purchase of building elements towards "pay per use" approaches which assume the presence of an operator who supplies products for defined periods and uses and who withdraws them and re-introduces them into the use network, possibly after re-manufacturing, repair, etc.;
- "disown ownership", possibly with forms of peer to peer market, which assume the presence of networks that facilitate the sharing, renting or leasing and exchanging of products that can be remanufactured and repaired over time;
- lengthening of the life cycle of products through services, with low or zero consumption of materials and energy, based on the scheduled monitoring and updating (re-manufacturing, recondition, repair). These services may be integrated within FM (Facility Management) services related to space and maintenance management;
- assessing the reduction of impacts and the consumption of resources from the point of view of environmental (LCA), economic (LCC) and social (SLCA) sustainability in order to evaluate the effectiveness of circular economy strategies based on re-manufacturing and reuse processes.

By assuming these concepts and approaches the book introduces some challenges to the existing paradigms:

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– from the design of products, meant as "black boxes", to the design of systems that can be divided into items, identified for the different durations and for the possibility of being disassembled, remanufactured, traced and reused once isolated;
– from the sale of a product (the building element) to the supply of a service, enhancing the "extended producer responsibility" and "shared responsibility" along the supply chain through the introduction of new re-manufacturing operators;
– from the ownership of an asset to the delivery of a service (for example renting and leasing models).

Also thanks to the hints that emerged from the intense dialogues and many roundtables involving various categories of stakeholders, conducted during the *Re-NetTA* research, the book intends to identify and analyse the most important berries to the development of effective re-manufacturing practices and the possible strategies to overcome them.

The book is articulated into three parts and 15 chapters.

Part I BACKGROUND introduces the current theoretical background and identifies key strategies about circular economy and re-manufacturing processes within the construction sector, focusing on tertiary architectures. It is divided into three chapters.

Chapter 1 deals with the relationships between circular economy and building sector, proposing tertiary architectures as promising testing ground for assessing circular strategies.

Chapter 2 introduces and discusses a hierarchy of the possible "re-actions" for circularity, each of one characterized by the return of a used product, trying to highlight the fundamentals and the basic conditions for propagating re-manufacturing, recondition, reuse and repurpose.

Chapter 3 provides an overview of the most existing consolidated practices of re-manufacturing within different industries and highlights possible strategies and approaches to transfer to the building sector.

Part II PROMISING MODELS outlines, according to a proposed framework (Ch. 4), a set of promising circular organizational models to facilitate re-manufacturing practices and their application to the different categories of the tertiary sector: exhibition, office and retail. This part also reports the results of active dialogues and round-tables with several categories of operators, adopting a stakeholder perspective. The chapters 5,6,7 describe each of the three models and share the same structure: the description of the organizational model, cases and views from the

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perspective of some key stakeholders in the field-sectors, the enabling and hindering elements.

Chapter 4 proposes three promising circular organizational models and discusses some key features useful for deepening them: *rent contract as a support for re-manufacturing*; a*ll-inclusive solution to support re-manufacturing; alternative/secondary markets for re-manufactured products.*

Chapter 5 introduces the rent contract, focusing on value chain key factors that enable circular practices. Representative case studies for the tertiary sectors are discussed.

Chapter 6 presents the characteristics of an innovative organizational model proposed for the tertiary architecture based on the integration of all-inclusive services with the goal of promoting re-manufacturing practices. The investigation is developed considering the exhibition, office and retail sectors.

Chapter 7 The chapter presents the characteristics of an innovative organizational model aimed at promoting circular dynamics through the setting of a supply chain that identifies alternative/secondary markets as potential destinations for reused, re-manufactured and repurposed products.

Part III INSIGHTS provides some insights on the issue of re-manufacturing, analyzed from different perspectives with the aim of outlining a comprehensive overview of challenges and opportunities for the application of virtuous circular processes within building sector. In particular, Part III is organized in four key topics: A) Design for re-manufacturing; B) Digital Transformation; C) Environmental Sustainability; D) Stakeholder Management, regulations & policies.

Topic A "Design for Re-manufacturing" investigates the relevance of original product design in the specific context of re-manufacturing in tertiary architecture, with a focus on design strategies and guidelines.

Chapter 8 focuses on the topic of design for re-manufacturing (DfRem), presenting a set of guidelines that can facilitate product re-manufacturing processes toward more circular and sustainable organizational models in specific contexts, with particular attention on the tertiary sector.

Chapter 9 deepens the subject of design for re-manufacturing and circular processes applied to the field of textile architectures.

Topic B "Digital Transformation" explores the possibility to apply digital technologies to re-manufacturing practices, highlighting possible solutions to streamline current activities and to exploit the novel availability of real-time information and advanced data management capabilities offered by Information and Communication Technologies (ICTs).

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Chapter 10 investigates how digital technologies can support the transition to circular economy of tertiary building through the digital simulation of the disassembly and remanufacturing stages.

Chapter 11 discusses how some barriers to the spreading of re-manufacturing practices may be handle more effectively by means of the Information and Communication Technologies (ICTs), especially Internet of Things (IoT), highlighting the key role of information platforms towards stakeholder collaboration and co-operation.

Topic C "Environmental Sustainability" focuses on the environmental benefit of re-manufacturing practices, emphasizing the application of life cycle tools to support the sustainability assessment of circular practices, encouraging the materials flow monitoring and information exchange among stakeholders.

Chapter 12 focuses on the assessment of the environmental sustainability of building products derived by re-manufacturing organizational models, in order to support eco-innovative approaches for the development of long-term value and green products. In this context, the material flows associated with re-manufacturing process are mapped and analyzed in depth, providing a framework for the application of LCA to re-manufacturing processes and re-manufactured products.

Chapter 13 deals with the traceability tools (e.g. materials passports, pre-demolition audit, etc.) useful to keep information related to building components in their entire life cycle (from material extraction to the disassembly after use and the end of life).

Topic D "Stakeholder Management, Regulations & Policies" deals with the definition of regulations supporting the relationships between the stakeholders and of approaches to the management of the re-manufacturing supply chain, providing also value chain insights to foster circular processes in the building industry.

Chapter 14 introduces the Sustainable Product-Service Systems (S.PSS) discussing to which extent they can enable value chain opportunities for re-manufacturing practices in the context of tertiary architectures and focusing on the application of product-service based models attached to re-manufacturing activities in the tertiary architectures context.

Chapter 15 aims to provide an overview of the main aspects on novelty introduced by reuse and remanufacturing practices assuming as a sample the Italian regulatory framework of the building sector, in particular focusing on aspects related to negotiation (sale, donation and leasing), safety, environmental and waste management.

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9. *Design for Re-manufacturing (DfRem) of short chains from design-to-construction: the case of textile-based tertiary architecture*

by *Carol Monticelli, Alessandra Zanelli*

9.1 The peculiarities of Textile-based Tertiary Architecture (TTA)

This chapter focuses on the peculiarities of the typical design-to-construction process of textile building systems, that today have been mainly used in tertiary architecture.

The so-called textile architecture or membrane architecture is a niche of construction where durable materials are mostly applied for temporary uses.

The time-span of textile architecture may widely vary wether the textile artefacts are designed for interiors or for outdoor installations.

On one hand, textile-based architectural products shall include ceilings, movable partitions, curtains and even more innovative self-standing detachable and modular walling systems. Their application in tertiary architecture sees very short cycle of installation and renewal. Typically, the first service life of textile products in interior architecture is ranging from one to five years.

The latter open-air application shows even wider time-span, from few days (ephemeral uses), or few months (seasonal purposes) up to 10 years (long temporary functions). The main uses are ephemeral mobile pavilions, seasonal sport halls, as well as tensile membrane structures for public events and coverings for exhibitions or fairs.

The Design for Re-manufacturing (DfRem) approach is always intrinsically inherent to the textile-based building artefacts. Independently by the functionality, textile architecture foresees dry and reversible installation methods, that are the basic approach for any further transformability of building artefacts.

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Despite of the shortage of their use, the durability of membrane products (fabrics and foils) is ranging from 25 to 30 years. Considering the typical long-lasting, petrol-based, composite nature of current architectural membranes, it's worth to promote their reuse, renewal and re-manufacture in further installations, after their first temporary service.

Short-time architectural functionality and long-time durability of materials are added values for the re-manufacturing of tertiary architecture. Textile-based products have a widespread use in tertiary architecture, thanks to their lightweight, easy handling in the installation phase and a general design-to disassembly potential. Nevertheless, their DfRem attitude and their real re-manufacturing practice need to become more effective and wide-spread, after the first service life.

9.2 Fundamentals of Design for Re-manufacturing (DfRem) in TTA

The designers of the so-called tent-architecture (Drew, 2008) have always adopted a design approach aimed at disassembling, with the final goal of easily replacing components during the service life, as well as their repurposing in further installations and artefacts (Otto, 2004; Knippers, and Speck, 2012; Fabricius, 2016). In other words, since ancient time, designers specialised in tent-like constructions have been following the fundamental rules of the Design for Re-manufacturing (DfRem) approach:

a) the minimisation of the number of parts to be installed and their easy replacement by means of reversible, visible fixing systems;
b) the minimisation of the interface surfaces and the types of materials used, usually summarised as: primary structure (wood, steel, rarely aluminium), membrane in a single sheet and single material, tensioning kit (aluminium profiles, steel cables, ropes);
c) the optimisation of the membrane to be pre-assembled in the industrial manufacturing phase, aimed at minimising fabric waste and simplifying the sewing and welding operations (cutting pattern and fitting phase);
d) the preparation of a rigorous plan for packing and unfolding the textile membrane aimed at reducing the days of installation at height but above all to avoid the installation of fixed cranes on site;
e) the coincidence of operations and responsibilities relating to industrial manufacturing, installation and often also of the general contractor of the entire work;

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f) the delivery of the work-report to the end user, consisting of a series of recommendations for the use of the textile structure, the declaration of the duration of the construction system, its maintenance, the repair of the parts at the foot of the work, and the its final uninstall (EN 13782:2015).

9.3 Fundamentals of Design for Reducing (DfRed) in TTA

In the niche of the best temporary textile-based constructions, even before the Design for Re-manufacturing approach, a combined use of the imperatives of Reducing and Re-thinking is effectively adopted. This occurs during the "form-finding" process, in the early-stage design phase, when designers work on an iterative process of both refinement and reduction of each structural element, on one hand, and of the whole structural and architectural shape, on the other hand. The general Design Reducing (DfRed) strategy deals with the design principle of "doing more with less", for thus achieving the lightest weight of the whole systems, through a refinement of the structural concept.

The lightness paradigm in textile architecture is inevitably meaningful in a double level: highest efficiency of the shape (tensile membrane) on one side, and highest efficiency of the matter (pre-stressed membranes, fabrics or foils) on the other one. Appropriate combination of both aspects is the best feasible outcome of an innovative design process. Furthermore, the reversible perspective of the construction process might have a greater influence to the environmental contest (Beukers and Van Hinte, 2005; Drew, 2008).

Why nowadays can DfRed principles be seen as an advantage in general terms for any type of construction, not just textile-based ones? Four good reasons to extend the DfRed and lightweight principles today to a wider range of mass-building systems follow:

1. An optimised DfRed building system might be transportable: a lightweight system allows a simplified and faster installation process.
2. An optimised DfRed building system might be transformable along its service life; it meets the ever-changing needs as it is the output of an "error friendly" design thinking (Manzini, 2012).
3. A constructive system with less embedded materials might be more efficient in terms of hand-ability and usability; this principle is well known by nomadic users of tent-architecture.
4. A DfRed lightweight system might be designed with the natural sense of limit (Knippers and Speck, 2012): it is a constructive system for

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which the designer will be forced to develop more creative strategies, and to figure out a solution "of necessity"; it is one of the greatest understanding by the study of natural artefacts.

The attitude of continuously reducing the weight of the textile architecture has been a long process of refinement of the construction systems' efficiency, that it would be desirable to concern today also the architecture in general, i.e. not only tensile structures, not only temporary constructions, but also other more durable or massive ones. The optimisation of the building components' weight is not enough considered by architectural designers, while it is an essential requirement of other kind of lightweight construction, i.e. aero-spatial, nautical and automotive sectors. Looking for a lighter – optimised DfRed – architecture means to enlarge the research into flexible and advanced materials (Cost Action CA17107, 2019), reducing the thickness of components, optimising the sections of the construction. If in the past materials suggested their own most appropriate use, today designers mould and create materials to cater to the project's requirements, no longer with any limits. Thus, the main aspects to be assessed during this optimised DfRed phase become more and more:

a) the embodied energy of components and the whole building system;
b) the reusability /recyclability of each material embedded in the whole construction;
c) the expected lifespan of building, which is closely linked with the way of managing connection details for installation, maintenance and final dismantle.

The above-mentioned topics can be conceived as strategies for the membrane structures' eco-efficient design (Cost Action TU1303, 2017; Monticelli and Zanelli, 2016 and 2020). Nevertheless, most of those design guidelines might be hopefully transferred to other building technologies widely applied today, as well as to more sustainable technological approaches of renewing the built environment.

9.4 Focus on durability and environmental informations of textile-based building products applicable in TTA

Nowadays, the main peculiarities of TTA, as the optimised lightweight system and the flexibility of fabrics, need a further development, in the light of the updated sustainability issues.

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The design criteria of material and energy saving are still mandatory but not enough, while consumers, stakeholders, customers and designers are more and more demanding information about the environmental implications of construction activities.

Environmental information about technical textiles and transparent laminated foils for tensile membrane structures is still very limited.

The transferring new materials, especially plastics (Motro, 2013) in architecture has been meant the extension of the durability of textile-based products as well. Nowadays, a membrane product shall have an expected life time of 15-30 years. A polymeric coated/woven fabric like pvc-coated/polyester fabric has typically a durability of 15 years, while ptfe-coated/glass woven fabric shall achieve a durability of 25 year; eventually flour-polymeric membranes as e-ptfe tenara fabric or etfe foils shall extend the life time of a textile building product up to 30 years.

Foams, films, sheeting, coatings, chemical additives: very few studies are available to deeply knowing the impact to produce them, to replace them after their life cycle and the impact to recycling them (Hegger, *et al.*, 2005; Knippers *et al.*, 2011). The responsibility of producers of human-made yarns and polymeric membranes in this field is crucial. The ecological information at the product level allows the producer's deep understanding on how to reduce energy consumption, material consumption, waste production, and last but not least economic cost (Monticelli and Zanelli, 2016; Zanelli *et al.*, 2020). Unfortunately, a comprehensive description of environmental performance of each material can't be managed by a designer, throughout the routine of work practice. The typical results of a life cycle assessment can be interpreted only by specialists. A simplistic way of compressing them into a readable score, or an ecolabel, which essentially says "good" or "bad" product, is not applicable at neither the simplest, one-day-use, architectural object, due to the complexity of the environmental issued that a choice of a single building product implies over the entire design-production-construction-service-dismantle process.

It is thus clear that the environmental data on the building products has to be considered as technical information, as a performance profile, leading the designers' decision. Furthermore, the environmental data used for assessing the building's life cycle has to be consistent, without gaps, and then possibly audited by an independent third party.

In the field of TTA, a starting point for collecting environmental data is to supporting a program of development of environmental product declaration (EPD), defining data quality requirements into a Product Category Rules (PCR) documents for textile-based membranes (Monticelli

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et al., 2021). Currently, regarding membranes there are no PCR, with the exception of the Waterproofing membranes. Since 2019, the TensiNet Working Group Sustainability and Comfort has been working with 24 members (membranes' producers, manufactures, builders, as well as designers, testing labs and academic experts) to deepen how the association may support, at the European Level, the definition of the Architectural membrane PCRs, considering that two main families of products (textiles and foils) exist on the global market. The interest is focus on harmonising the PCRs for this specific sector and defining common rules such as the LCA system boundaries to be considered, the end of life scenarios, the functional unit as a basic rule to allow the comparison of the EPD data at the end of the process.

The main issues of debate by the producers of raw materials in the textile construction sector – technical fabrics on the one hand, polymers and fluoropolymers on the other – concern the raising of the performance level of building systems, in the face of the increased demand for systems of longer duration even if temporary. This demand certainly makes it even more important to find levers for the future re-manufacturing of materials of increased commercial value and long life.

In recent decades, membrane manufacturers have improved the performance of basic polymers, synthetic fibers and composite membranes. The warranty of architectural membranes is constantly increasing: from an average of 10 years to 15 years for the most basic and cost-effective membranes; form an average of 20 year to 30 years for the most advanced, performative and expensive products. Thus, membranes play a new role in the field of structural materials. The harmonisation of design standards is a further step in the direction of being able to consider membranes as the lightest building material. If the mechanical performance is no longer in doubt, now the attention of the developers is on the transition to more sustainable and less impactful industrial processing methods and procedures on the environment. Almost all of the technical textiles used in the textile architecture sector today are of chemical synthesis and petroleum origin. It therefore becomes urgent to evaluate alternative strategies to create new polymers, of biological origin and, at the same time, to evaluate the possibility of recovering waste internal to the supply chain and/or even external to it, in a circular economy approach (Zanelli *et al.*, 2020).

The TensiNet association has seen in recent years an intense activity of the WG Sustainability and Comfort working group which wants to lay the foundations for a more sustainable development of the entire production sector, sharing evaluation methods based on the LCA approach of membrane building components and working on the progressive efficiency

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and reduction of the environmental impacts of textile building systems along the entire life cycle, from industrial production to their disposal. In terms of understanding the environmental impact produced by the range of textile materials currently in use in textile architecture – recent studies (Monticelli *et al.*, 2021) show how the minimum quantities involved per unit of surface area (per sm) see the field of textile constructions winning over other building technologies, certainly at least in terms of carbon footprint, while more in-depth studies are underway on the comparison of the impacts along the entire life cycle of the textile building.

9.5 Re-actions in TTA field

This part of the chapter includes re-actions' experiences concerning the current Textile-based Tertiary Architecture. From these experiences, ideas are gathered for transferable eco-design principles and re-manufacturing approaches that seem appropriate and applicable to wider ranges building products.

9.5.1 Reuse of membranes, towards their Re-manufacturing

When structural membranes are used for a shorter time than the certified durability of the material (as indicated in the manufacturer's technical sheet), undamaged membrane materials, after a simple cleaning process, can be re-used. The possibility of whether or not to reuse the materials is closely linked to the material properties and other variables, e.g. cutting patterns, storage conditions of the material when not in use and assembly/disassembly methods. For example, some materials such as glass-fibre-reinforced-polymers or extruded foils are sensitive to folding and therefore may not be suitable for repeated use (Mazzola, 2020).

Sometimes the reuse may find some difficulty due to the specificity of each project (e.g. size and required performance) and to the necessary verification of the actual conditions and performances of the recovered materials (e.g. aesthetic, mechanical resistance, water-proofing). When temporary membrane-based buildings cannot be entirely re-used, membranes can be reused – and thus at least partially re-manufactured- as building components in the form of portions cut from the original panels, or for other purposes. This option is reliable and feasible in the special sector of textile membrane structures as the fabric materials – whether of not of first of second hand – needs to be specifically tested for its mechan-

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ical performances, before its application as a building product. This is why this textile-based buildings are not fully covered by the common rules of harmonized standards of the building products covered by the communitarian regulation n. 305 (EU Regulation, 2011), while technical committees ad the European level (CEN/TC 250/WG 5 and CEN/TC 248) are working hardly to finalise common rules for the whole process of design – production – testing – packaging – installation and dismantle of a new generation of structural membranes and textiles-based buildings (Mollaert *et al.*, 2016).

9.5.2 Recycling current textile-based composites, towards re-thinking and re-processing future textile membranes

In the last ten years, the recyclability is a quite advanced achievement in the market of membrane products used in textile architecture. Beside the most commons composite membranes (pvc coated/polyester and ptfe coated/glass) there are new mono-component membranes, i.e. fluoro-polymeric foils (ETFE, THV, ECTFE) that are produced by means of extrusion processes that allow the production of highly performing foils characterised and, the recyclability of 95% of both production's by-products and post-dismantling wasted products (Campioli and Zanelli, 2009).

A virtuous example of recyclability of composite architectural membranes has been recorded, since 2000, by Solvay, a company that developed and patented a process called "Texyloop" (Motro, 2013), a selective recycling system for PES/PVC coated fabric that separate PVC fibers and polyester resin through the selective chemical dissolving of the coating. Through the application of this process, the French company Sérge Ferrari has been recycled several post-dismantle pvc-coated/polyester fabrics at the Vinyloop industrial plant in Ferrara, Italy, from 2008 to 2018 (Fournier, 2013). Starting from 2020, a new business model has been lauched by Polyloop, Smart Factory 4.0 start-up. The new compony is going to supply to the end-manufacturers of the textile architecture field a medium-size rig for re-cycling their own by-products and the dismantled membranes straightly into their warehouse, as those companies are responsible for the installation the repairing and any further maintenaince actions of every textile-based construction they have buit (Faysse, 2020).

The further steps on the way of eco-efficiency might be, on one hand, the re-thinking of production processes towards new families of mono-component coated-fabrics, where both woven yarns and protection coating

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are made of the same recyclable raw components, and, on the other hand, the introduction of novel bio-based textile products and the enhancement of their performances along the time.

9.5.3 Reusing temporary textile-based architectures, towards movable systems

There are many emblematic cases of itinerant or seasonal textile pavilions that have been well designed by archistars to be easily disassembled, washed and maintained and then properly stored for months, to be reused and installed in the new season or in a new location. This is the case of the Tea House by architect Kengo Kuma, but also of the stage for the Oslo Jazz Festival by architects Snoetta. At the end of their temporary life cycle of less than 5 years, none of these artifacts have actually been reused.

One wonders if it is really reasonable to tear apart an architectural artifact and propose building components for sale through online building materials platforms, in the name of a sustainable re-manufacturing action. Would we do the same with the components of Richard Buckminster Fuller's fly's Eye Dome or with Renzo Piano's IBM pavilion?

Undoubtedly, the reuse of the System is to be promoted more than the reuse of single parts.

9.5.4 Re-manufacturing textiles within circular economy: first trials of closing the loops between apparel and architecture sectors

Finally, a higher level strategic approach can aim to reduce the impacts of the textile-clothing industrial chain by introducing in the field of temporary textile architecture a range of materials with certainly more limited and less durable performances, but adequate for the short cycle of use., for example for ephemeral installations of days or up to 3 months.

There are two cases that go in this direction.

9.5.5 Re-m 01: from sport-ware to tertiary architecture. The Re-manufacturing of Speedo swimsuits for a textile-based Pavilion, London Architecture Festival

After having produced the LZR Raced line, Speedo, the manufacturer of swimsuits, he has seen them rejected because they are considered technological doping. Speedo decides to sell 600 unusable swimsuits

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to Chelsea for free Collage of Art & Design. The project was directed by Cyril Shing, professor of Interior Spatial Design, together with the students, which were challenged to explore how to transform the swimsuits into an architectural pavilion for the London Festival of Architecture.

9.5.6 Re-m 02: from fashion wastes to shading system. The re-manufacturing of Humana post-consumers T-shirts for a shading system, T-Shade project, Leonardo Campus, Politecnico di Milano, 2020

An ultra-lightweight shading system made of 500 post-consumer fabrics, such as reusable t-shirts, with the support of HUMANA people to people onlus, was installed at Polimi Campus, the 30th June 2021. It was a demonstrative temporary artefact to show how reversible connections may facility the installation of reused fabrics. The mechanical behaviours of the post-consumer T-shirts was preliminary testes and the output of the testing investigation oriented the form-finding process and the design optimization of the new T-shade membrane.

All over the world, lifestyles are increasingly bringing out the need for flexibility, speed and dematerialization and these changes, though in a slower way, also involve the construction sector. Membrane tensile structures as ultra-light constructions (Sobek, 2016; Zanelli *et al.*, 2022), in recent decades are playing a key role whenever the first objective is the compression of time from the conception of the project to the inauguration of the work (international expo, temporary events) but also when the speed of installation and the manageability of the system are added values. Despite the stimulating continuous technological advancement, it is indeed important that the sector of light structures does not forget the precious lesson of the past.

The ancient uses of fabrics in different cultures have been oriented and guided by the concepts of saving and efficiency of materials, which today can be read as inspiring concepts of intrinsic environmental sustainability for the textile architecture of tomorrow. Indeed, a lightweight system should always continue to be designed with a natural sense of limit; to say so, a lightweight membrane construction system will have to continue to be designed as a "necessity" construction kit where nothing is superfluous, and each is an essential part of an integrated system in the environment.

Almost seventy years after the start of the membrane tensile construction industry, a significant result of the joint work of all the professionals

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that revolve around the design, industrial production and construction and maintenance of membrane structures, has certainly been the creation of a technical table for the drafting of a specific Eurocode on the design of membrane structures. In 2016, under the supervision of the JRC of the European Commission, the first SaP Report concerning the guidelines for the structural design of membrane tensile systems was published (Mollaert *et al.*, eds, 2016) While the works of CEN/TC250 are in the final phase Structural Eurocodes related to membrane structures. Furthermore, since 2019 Europe through the EN 17117 standard has also normalized the procedures for verifying the quality of coated textile materials, introducing the need to standardize the procedures for performing biaxial mechanical tests on all textile and polymeric products that can be used in construction at membrane. Through these important standardized design tools it will be increasingly possible to operate with an approach of material minimization and intelligent structural conception, sought together by architects and engineers, as the first key step for future dismantling and effective recoverability of the parts of the building system.

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This book deals with re-manufacturing, recondition, reuse and repurpose considered as winning strategies for boosting regenerative circular economy in the building sector. It presents many of the outcomes of the research *Re-NetTA (Re-manufacturing Networks for Tertiary Architectures). New organisational models and tools for re-manufacturing and re-using short life components coming from tertiary buildings renewal*, funded in Italy by Fondazione Cariplo for the period 2019-2021.

The field of interest of the book is the building sector, focusing on various categories of tertiary buildings, characterized by short-term cycles of use.

The book investigates the most promising strategies and organizational models to maintain over time the value of the environmental and economic resources integrated into manufactured products, once they have been removed from buildings, by extending their useful life and their usability with the lower possible consumption of other materials and energy and with the maximum containment of emissions into the environment.

The text is articulated into three sections.

Part I BACKGROUND introduces the current theoretical background and identifies key strategies about circular economy and re-manufacturing processes within the building sector, focusing on tertiary architectures. It is divided into three chapters.

Part II PROMISING MODELS outlines, according to a proposed framework, a set of promising circular organizational models to facilitate re-manufacturing practices and their application to the different categories of the tertiary sectors: exhibition, office and retail. This part also reports the results of active dialogues and roundtables with several categories of operators, adopting a stakeholder perspective.

Part III INSIGHTS provides some insights on the issue of re-manufacturing, analyzed from different perspectives with the aim of outlining a comprehensive overview of challenges and opportunities for the application of virtuous circular processes within building sector. Part III is organized in four key topics: A) Design for Re-manufacturing; B) Digital Transformation; C) Environmental Sustainability; D) Stakeholder Management, Regulations & Policies.

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