

Fiber-Reinforced Composite Materials for the Circular Economy: Challenges and Opportunities

RECREATE MOOC

Gianmarco Griffini

23/04/2026, Brussels



MOOC description

The MOOC is available on **POK – Polimi Open Knowledge**, the MOOC platform of Politecnico di Milano:
<https://www.pok.polimi.it/course/view.php?id=191>

This course provides a comprehensive overview of:

- end-of-life challenges (technical, logistic, legislative);
- reuse, repair, demanufacturing, remanufacturing, and recycling technologies;
- design strategies for recyclability (modular design, reversible materials).

The course also covers:

- circular economy principles;
- innovation management and business models;
- environmental and socio-economic sustainability assessment.



MOOC structure

Weeks	Main topic	Learning Resources
Week 1	Supply Chain	Video lectures, PDFs, activities and quizzes
Week 2	De-manufacturing and Re-manufacturing of Composite Parts and Structures	Video lectures, PDFs, activities and quizzes + Digital Twin
Week 3	Next Generation Recyclable-by-Design Composites	Video lectures, PDFs, activities and quizzes
Week 4	Circular Economy and Sustainability	Video lectures, PDFs, activities and quizzes
Week 5	Gamification platform	Link to a game-based assessment

MOOC structure: presentation on the platform

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POK Open Knowledge

Overview Course content Certificate Fees and access Faculty

Fiber-Reinforced Composite Materials for the Circular Economy: Challenges and Opportunities

How advanced technologies and systemic solutions can promote the transition from a linear to a circular economy of fiber-reinforced composite materials.

Course description

Carbon-fiber and glass-fiber reinforced composites are widely used in a variety of industrial sectors because of their excellent thermo-mechanical response, their lightweight, and their inherent resistance to corrosion. Important market segments where such complex materials are commonly employed include areas as diverse as aerospace, automotive, wind energy, construction and sport equipment. The global composites market is expanding rapidly, driven by a constantly growing demand for high-performance and lightweight parts and products. However, their increasing use poses critical challenges related to their end-of-life, as traditional disposal methods (landfilling, incineration) for these materials are both economically and environmentally unsustainable and non-viable. In addition, recycling rates remain low due to technical and economic barriers, making circular economy strategies essential. Within this framework, this MOOC will provide a comprehensive overview of sustainable strategies for the end-of-life management of fiber-reinforced composites. After introducing the technical, logistic, and legislative challenges associated with the end-of-life of composite parts and products, the course will explore different reuse, repair, demanufacturing, remanufacturing and recycling technologies to boost the circularity of composite materials. These will be complemented by innovative design strategies for recyclability, including the implementation of modular design concepts and the adoption of reversible materials. The course will also integrate circular economy principles, innovation management, and circular business models, alongside environmental and socio-economic sustainability assessment practices. This MOOC was developed in the context of the RECREATE project (REcycling technologies for Circular REuse and remanufacturing of fiber-reinforced composite mATerials, g.a. 101058756), a Horizon-Europe-funded collaborative research and innovation initiative aiming to develop a set of innovative technologies turning end-of-life complex composite waste into feedstock for high-value parts and materials for the manufacturing industry. Students attending this course will be equipped with the tools to drive sustainable innovation in the field of fiber-reinforced composite materials, in line with the principles of the circular economy.

Total workload of the course: 28 hours
This MOOC is provided by Politecnico di Milano.

Completed 0% 21 / 64

Week 1 - Supply Chain

- Geographical and sectorial mapping and distribution of end-of-life (EoL) composite waste
- What do you know...
- Composites the di...
- Design a typical c...
- Quiz 1 - Module 1
- Typical composition and technical features (e.g. typical sizes, parts etc.)
- The European co...
- Composites as ke...
- Composites stock...
- Assess the compo...
- Assess the compo...
- Issues related to dismantling, transportation and logistics
- Dismantling of lar...
- Sorting of compo...
- Business Inquiries

This MOOC is one of the outputs of the RECREATE project, funded by the European Union's Horizon Europe research and innovation programme under grant agreement (No.101058756).

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Funded by
the European Union

MOOC structure: videos on POK

Example of one video from Week 1

The European composites market in a nutshell: sectors and products



It is possible to watch videos on the platform, from YouTube, and download the transcripts.



Example of graphics included in the videos: images, schemes, keywords and illustrations



Example of one video from Week 4

Fundamental Concepts in the Circular Economy



It is possible to watch videos on the platform, from YouTube, and download the transcripts.



Example of graphics included in the videos: images, schemes, keywords and illustrations

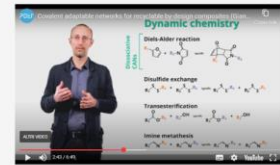


Example of one video from Week 3

Covalent adaptable networks for recyclable-by-design composites



It is possible to watch videos on the platform, from YouTube, and download the transcripts.



Example of graphics included in the videos: images, schemes, keywords and illustrations



Example of one video from Week 2

Temperature-assisted reshaping of composite parts



It is possible to watch videos on the platform, from YouTube, and download the transcripts.

Material	Mat 100	Mat 200	Mat 400	Mat 400 (SM2)	Mat 400 (SM4)	Mat 500	Mat 500 (S12)
Polyester (Hexamethylene)	1	2	3	4	5	6	7
Polyester (Dodecyl)	1	2	3	4	5	6	7

Example of graphics included in the videos: images, schemes, keywords and illustrations



MOOC structure: videos on youtube

RECREATE
di Polimi OpenKnowledge
Playlist · Non in elenco · 15 video · 7 visualizzazioni

Riproduci t...

- The European composites market in a nutshell: sectors and products (Luca Gentilini)**
Polimi OpenKnowledge · 3 visualizzazioni · 7 giorni fa
- Composites as key material for innovation: the automotive market example (K. Lange, M. Haumann)**
Polimi OpenKnowledge · 1 visualizzazione · 7 giorni fa
- Dismantling of large EoL composite infrastructures (Luca Gentilini)**
Polimi OpenKnowledge · 2 visualizzazioni · 7 giorni fa
- Sorting of composite components from complex assemblies (Luca Gentilini)**
Polimi OpenKnowledge · 1 visualizzazione · 7 giorni fa
- Landfilling, transportation of aftermarket and waste, and other legislative structures (Gentilini)**
Polimi OpenKnowledge · 1 visualizzazione · 7 giorni fa
- Temperature-assisted reshaping of composite parts (Le Gal La Salle, Preisner, Jawad Berro)**
Polimi OpenKnowledge · 1 visualizzazione · 7 giorni fa
- Geometrical stability of reshaped composite parts (Le Gal La Salle, Preisner, Jawad Berro)**

Youtube playlist:

The videos are also accessible directly from a YouTube playlist, so they can be watched without enrolling in the course on POK.

<https://www.youtube.com/playlist?list=PLmKUwJ0KJQnUu3yueEiXAZqIpbeTVO2WD>



MOOC structure: PDFs

This is how the PDF looks like inside the platform: Title, abstract and the button to download the full paper.

Role of Digital Technologies

View

Role of Digital Technologies

This lesson delves into the transformative role of digital technologies in advancing the circular economy within the context of the Fourth Industrial Revolution. It highlights how tools like IoT, big data analytics, and AI are reshaping the industrial landscape by enhancing resource efficiency, extending product lifespans, and reducing waste. By enabling precise tracking, optimizing usage, and facilitating efficient recycling, these technologies help close material loops and support more sustainable business models. The lesson also underscores the importance of integrating digital systems into resource management, promoting smarter decision-making and more sustainable practices. Additionally, it addresses the critical role of stakeholders—including governments, companies, and international institutions—in driving the adoption of these technologies to create a more sustainable and circular industrial ecosystem. The interconnection of digital innovation and sustainability is essential for successfully implementing circular economy principles.



Read the full text "Role of Digital Technologies" to explore more about this topic.

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The relationship between Industry 4.0 and circularity is both unidirectional and bidirectional, meaning Industry 4.0 drives circularity while both concepts mutually benefit each other. Key areas where CE intersects with Industry 4.0 include recycling, reusing strategies in smart production, and sustainable supply chains [8]. Organizations are encouraged to explore emerging digital technologies to enhance sustainability efforts and to leverage data throughout the product lifecycle [9]. The rise of digital technologies such as the Internet of Things (IoT), big data analytics (BDA), and artificial intelligence (AI), as detailed in Fig. 1 [10], is transforming manufacturing and consumption landscapes [11].

Figure 1: Main emerging digital technologies of Industry 4.0

In the stage phase, digital tools, particularly the Internet of Things (IoT), transform products into "smart" entities that enhance resource efficiency and extend their lifespans by monitoring and optimizing usage. At the end-of-life stage, these tools facilitate loop closure through efficient recycling and reuse-life solutions, highlighting the interconnectedness of design, end-of-life activities, and decision-making processes. The integration of digital technologies into product creation and usage is increasingly recognized as a critical enabler for transitioning to a circular economy, helping to address the challenges inherent in this shift [12-14].

These digital tools are pivotal in overcoming barriers, promoting resource-efficient smart factories, enhancing workforce productivity, and enabling closed-loop manufacturing processes [15]. They support the creation of knowledge, improved user experiences, resource accessibility, sustainability.

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Full text

The integration of advanced technologies into the industrial landscape exemplifies the core elements of the Fourth Industrial Revolution: digitalization, automation, human-machine collaboration, value-added services and businesses, and the seamless exchange and communication of data. This interconnectedness between various systems and assets offers significant advantages over traditional circular economy models. Key benefits include enhanced efficiency in resource utilization, minimized waste through improved traceability and optimized waste management, and prolonged lifespans for products and equipment, all of which contribute to more sustainable circular economy practices. The shift towards digitalized circular business models enables managers to align their objectives with circular economy principles and effectively leverage Industry 4.0 technologies to support their strategies [1].

Nonetheless, realizing the sustainable benefits of digitalization necessitates the development of innovative business models, particularly those based on advanced service paradigms [2]. Furthermore, Information and Communication Technology (ICT) solutions play a critical role in facilitating the transition to a circular economy. Certain ICT tools, such as cloud manufacturing and big data, have been identified as especially vital in upholding the principles of circularity [3].

The integration of digital systems into resource accounting is poised to be a critical factor in realizing a circular economy. Such systems enable continuous monitoring of resources, data-driven decision-making throughout their life cycle, and waste reduction through informed choices. Although waste management is essential, a circular economy extends beyond simple recycling. Increasingly, waste management companies are moving upstream in business markets to prevent resources from becoming waste in the first place [4].

Lastly, concepts such as Material Passports have emerged, enabling the digital registration of data sets that describe an object's characteristics, location, history, and ownership. These passports, often managed through digital platforms, facilitate data management and support circular economy practices [5].

Digitalization holds significant potential to accelerate the transition towards a sustainable circular economy [6]. It enables precise tracking of product availability, location, and condition, which aids in closing material loops. Additionally, digital processes within companies help reduce waste, extend product lifespans and lower transaction costs. This digital support enhances circular business models by facilitating loop closure, slowing material cycles, and enhancing resource efficiency [7].

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and data-driven decision-making, all of which are essential for advancing circular entrepreneurship [16]. Moreover, digital technologies play a crucial role in implementing advanced Circular Economy and Industrial Systems solutions by enabling efficient monitoring of resource and energy flows and supporting human decision-making [17].

Incorporating responsive design techniques and digital tools can make the design process more efficient and aligned with circular principles. Digital technologies optimize design decisions, facilitate circular concepts like disassembly, and enable efficient manufacturing, thus reducing waste [18]. However, it is essential to assess technology implementation approaches, considering factors like ease of implementation, cost, localization, data privacy, and the ethical use of AI on public data [19].

Ultimately, the successful implementation of circular economy principles hinges on the active engagement of various stakeholders, including governments, international institutions, and companies, in transitioning toward more sustainable and digitalized supply chains [20].

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MOOC structure: quizzes

POLI Home Dashboard All courses Target Topics VB Edit mode

Completed 0% 21 / 64

- Selection of EoL composite parts in relation to their second life use (e.g. selection criteria, definition of key performance indicators etc.)
- Are composites r...
- State-of-the-art te...
- Landfilling, transp...
- Extended Waste ...
- Final Quiz - Wee...**
- Week 2 - De-manufacturing and Re-manufacturing of Composite Parts and Structures
 - Advanced material identification and characterization methods (e.g. non-destructive techniques, decision-support systems based on artificial intelligence, etc.)
 - Advanced repair, reuse and remanufacturing

Final Quiz - Week 1

[Back](#)

Question 1

Tries remaining: 3 | Marked out of 1.00

The main groups of resins used for composites are:

- Epoxy, polyester, vinylester
- Thermosets, thermoplastics
- Thermosets, thermoplastics, elastomers
- Polypropylene, polyamide, polyurethane

[Check](#)

Question 2

Tries remaining: 3 | Marked out of 1.00

The current European stock of end-of-life boats not dismantled by the owners for inconvenience has an estimated volume of:

- 10-50 kton

Final Quiz - Week 1

[Back](#)

Question 1

Correct | Mark 1.00 out of 1.00

[Flag question](#) [Edit question](#)

The main groups of resins used for composites are:

- Epoxy, polyester, vinylester
- Thermosets, thermoplastics
- Thermosets, thermoplastics, elastomers
- Polypropylene, polyamide, polyurethane

😊 Your answer is correct.
The use of different matrix materials/plastics is possible. A distinction is made between three main groups: Thermosets, thermoplastics and elastomers. As a rule, however, only thermosets and thermoplastics are used for composites. The major difference between these two systems lies in their chemical composition.

MOOC structure: Open Badge

The user can obtain the Open Badge by achieving 60% or more correct answers.



Fiber-Reinforced Composite Materials for the Circular Economy: Challenges and Opportunities

Disponibile dal: 2026-01-12

Tipo Badge: Attestato di partecipazione

Emesso da: Politecnico di Milano

Tags

CHEMICAL ENGINEERING

COMPOSITE MATERIALS

CIRCULAR ECONOMY

Emessi

22

Fiber-Reinforced Composite Materials for the Circular Economy: Challenges and Opportunities.

How advanced technologies and systemic solutions can promote the transition from a linear to a circular economy of fiber-reinforced composite materials.

Learning outcomes

Through this MOOC, the participant has developed a solid understanding of the challenges and opportunities related to the end-of-life management of fiber-reinforced composite materials within a circular economy framework. The badge certifies his/her ability to understand and evaluate sustainable strategies such as reuse, repair, remanufacturing, and recycling, as well as innovative design approaches aimed at improving the circularity of composite products. By earning this badge, the participant has demonstrated their knowledge of advanced technologies, circular

MOOC structure: link to the gamification platform

Explore the “Game- based assessment tool”

You will reach the gamification platform aimed at providing a comprehensive assessment of knowledge and understanding about the specific topic of Circular Economy and Sustainability. This assessment is the last step in this MOOC.

No login is required. On accessing the platform, you will find in the homepage an interactive Map that serves as the central assessment hub.



In the interactive map there are three mission hotspots, each corresponding to a step in the assessment:

1. **Module 1 the Green Archive:** a questionnaire to test knowledge about Circular Economy and Sustainability;
2. **Module 2 Tech match:** a mini-game, where players see cards with problems and must combine each problem with the potential solution;
3. **Module 3 Manufacturing district:** a strategic simulation game that engages students in managing the activities of a hypothetical manufacturing company with the aim of improving its circularity performance through appropriate decisions on investments and business initiatives.

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**Scan this Qrcode
and explore the MOOC!**



Thank you for your kind attention

Contacts:

Prof. Gianmarco Griffini

Department of Chemistry, Materials and Chemical Engineering "Giulio Natta"

Politecnico di Milano - Italy

gianmarco.griffini@polimi.it



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