Plastics Circularity Multiplier

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Online Conference

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Implementing Product Design for Recycling through Additive Manufacturing – 3D Printing Technologies

Prof. Costas Charitidis[1]

[1]*Research Unit of Advanced, Composite, Nanomaterials and Nanotechnology (R-NanoLab), National Technical University of Athens, Greece*

R-NANO

Repair 3D

SmartFAN

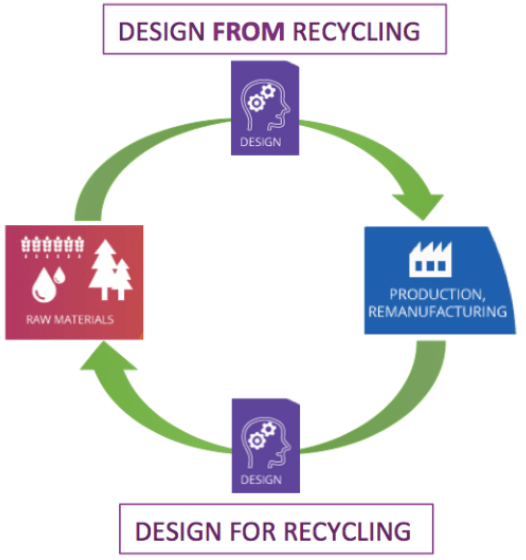
OUTLINE

- Introduction : **Design for Recycling** (DfR) and Design for Circularity
- Repair3D project overview
- Product D_fR in Repair3D
- SmartFAN project overview & Recycling strategies
- Impact Highlights

Introduction: **Design for Recycling** (DfR) and Design for Circularity

- Problems of plastic waste generation are now being taken into consideration at the **design stage of product** development, having a ***large impact on both their recyclability*** (EoL) and the ***degree*** to which they can ***incorporate recycled materials***.
- **Additionally, COVID-19** has strengthened the tendency to create ***more plastic waste*** (increased demand for face shields, gloves, packaged food packaging and wrapping for online shopping) and has intensified the price war between recycled and new plastic.
- **D_fR** is **product development strategy** - new products are developed so that they can be recycled at their EoL → promoted by *Eco-design Directive* and *A European Strategy for Plastics in a Circular Economy*.
- **D_fR** and **Design from Recycling ($D_{from}R$**)are complementary strategies → material full circle.

adapted from EU-Parliament (2015)



Design for Recycling (D_fR) Rules

5 fundamental D_fR rules have been derivated related to material interactions, recovery and losses addressing entire recycling system from design to manufacturing:

01 **Product and recycling system specific:** Every product has a **unique recyclability profile** due to its functional and unique mix of materials.

02 **D_fR demands a tool** - **process simulation models** to pinpoint D_fR issues of importance (**recycling rate, toxicity, scarce material recovery/losses, environmental impact**, etc.)

03 **Design data** - to be accessible and available in a consistent format, compatible with the **detail** required to optimise and quantify recycling performance of products for all materials and compounds present.

04 Existence of economically viable technology **infrastructure and tools**, based on a robust physical **separation/sorting infrastructure** and **maximum recovery of "critical" materials.**

05 **CAD, Process and System Design** tools - **linked** to recycling system to realise D_fR, including **Design for ease of maintenance & repair.**

https://alexklootwijk.nl/

M. Reuter, A. Schaik, 10 Design for recycling rules, product centric recycling & urban/landfill mining

Design for Recycling (D_fR) Guidelines

- Applying D_fR rules & principles → **D_fR guidelines** have been derived per product as a function of material mix, (BAT) recycling systems and product functionality.
- **Products designed with recyclability in mind** must be designed/redesigned and manufactured to:

06

Identify, select and reduce the quantities materials

- **product material composition** - quantify, identify and localize the **commodity /critical/disturbing materials.**
- Contain the **maximum amount of materials** that are **recyclable**.
- Reduce materials **variety** – ↑recyclability, ↓ decrease manufacturing energy
- **Reduce raw materials** – use recycled materials and/or components.
- Select **less impacting materials** - **free of hazardous** (not recyclable or impede the recycling process)

07

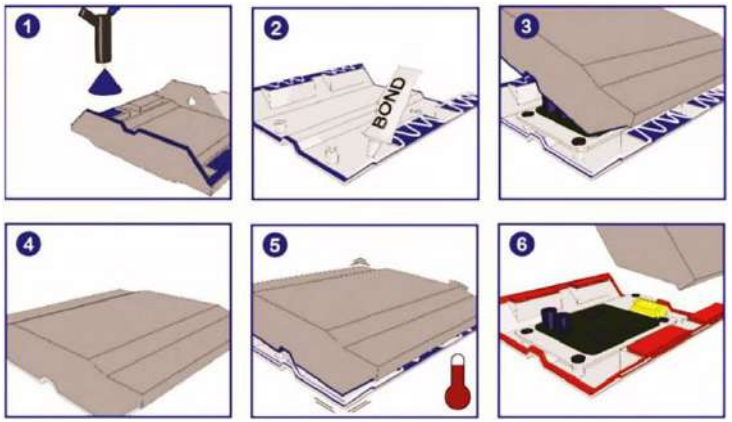
Identify components/clusters in a product, which will cause problems and losses in recycling due to **combined and applied materials**.

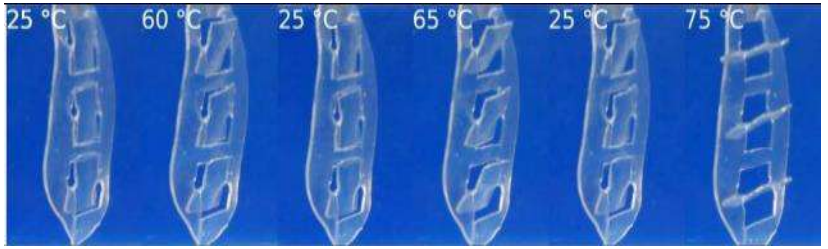
Design for Recycling (D_fR) Rules & Guidelines

08

Design for Disassembly (D_fD): product (clusters or sub-units) to be disassembled for easier maintenance, repair, recovery and reuse of components /materials

- **Disassembly embedded design** - mechanism triggered to initiate the disassembly process using a thermal, electrical, mechanical or an electromagnetic stimuli
- **Active disassembly** - separation using smart materials or structures in the product that can be activated using a single or more external stimuli

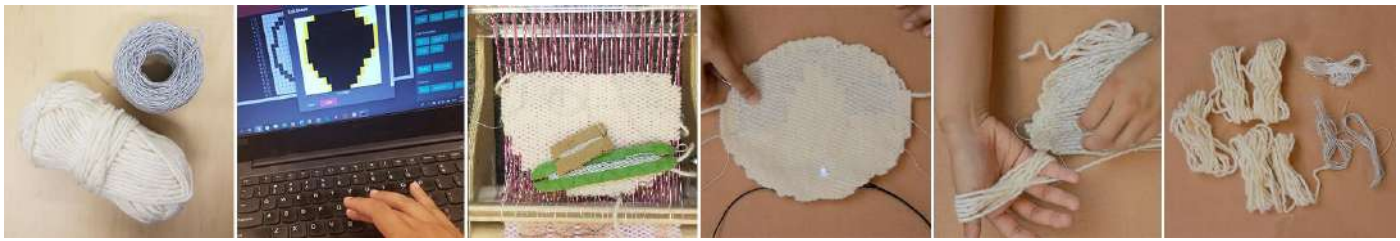




Disassembly at specific temperature (SMP)

H. Abuzied et al. / Engineering Science and Technology, 23 (2020) 618–624

Upon heating or vibration, the interstitial layer degrades allowing clean separation at EOL.



Unfabricate: Designing Smart Textiles for Disassembly, S. Wu, L. Devendorf

Design for Recycling (DfR) Rules & Guidelines

09 **Labelling of products/components based on recovery and/or incompatibility**

- Easily identified from recyclates and waste streams (Design Waste stream sorting)
- Smart additives and the new laser marking techniques

Fluorescent markers printed on labels/sleeves. PRISM (PET, PP bottles), Edward Kosior | 2020

Radio Frequency Identification (RFID) tags

10 **Design for Liberation (of materials) -** Be mindful of **liberation** of materials in design (Design for Liberation).

Introduction to the **Repair3D project**

01 **26 Mt of post-consumer plastic** were discarded within 2016 in the EU, **only 31.1% of was recycled**, **27.3% ending as landfill waste and 41.6% being burnt** for Energy Recovery.

02 **Carbon Fiber Reinforced Polymers (CFRPs)** with a global market demand estimated to 155 kt by 2020, are **not adept to recycling due to their** composite nature, making separation and recycling a hard task.

1 **Product design, digitalization, production**

2 **Competitive multi-life products**

3 **EoL product reuse in new second life product**

03 The global **3D Printing market** size was $8.6 Bn in 2018 and it is expected to reach $76.9 Bn by the end of 2025, with a **CAGR of 31.4% during 2019-2025**.

04 **Thermoplastic (TP) filaments** represent the **second largest segment** in the AM materials market, increasing from 260M$ in 2018 to **1.6 B$ by 2025, CAGR of 25.8%**.

Design for Recycling
Design from Recycling
Circular by design

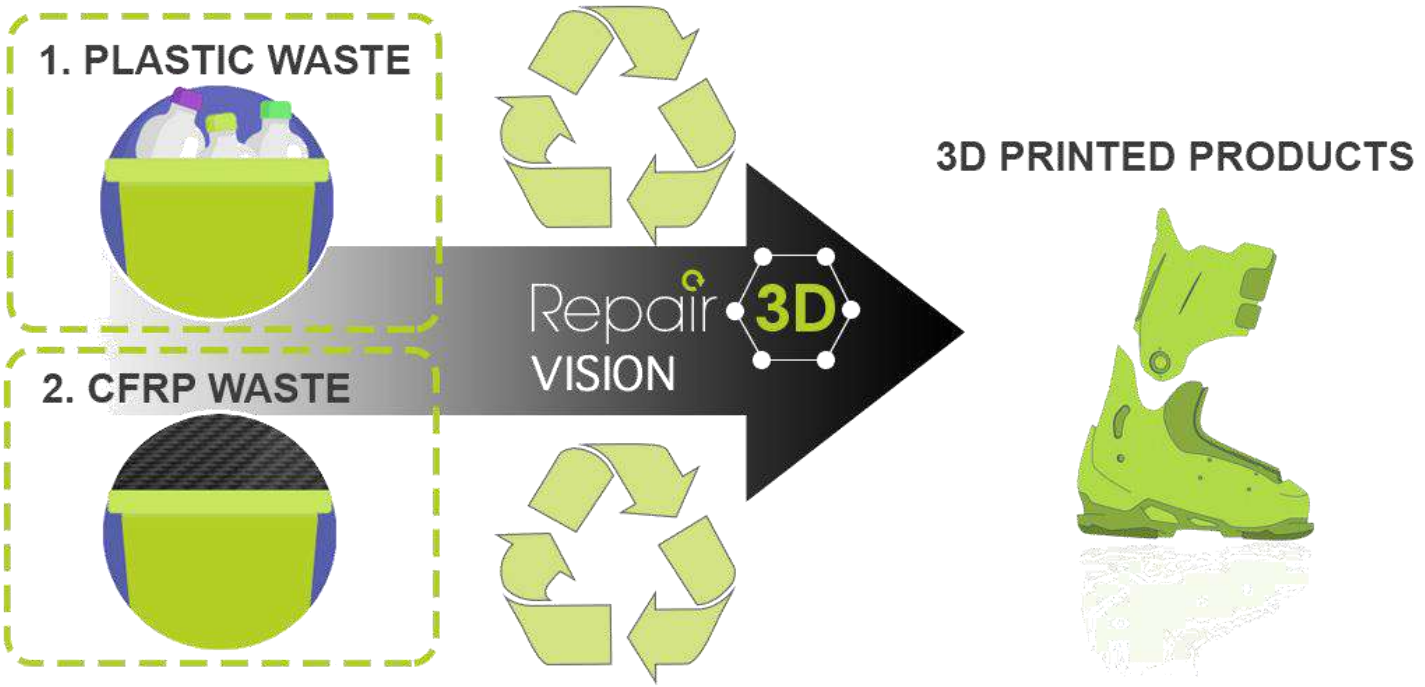
"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814588".

Project ID

Sustainable recycling and repurposing of thermoplastics and CFRPs towards 3D printing

…to address all aspects and stages of TP and CFTP 3D printing material:

- development from recycled resources by selection of suitable waste streams
- strategies for material repair, compatibilization and upgrade
- comparative assessment of various AM TP processing technologies
- closed-loop material optimisation in terms of processability and performance.



"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814588".

Project ID:

Call identifier: H2020-NMBP-ST-IND-2018

Topic: CE-NMBP-26-2018

Duration: 49M (Jan 1, 2019)

Number of partners: 18

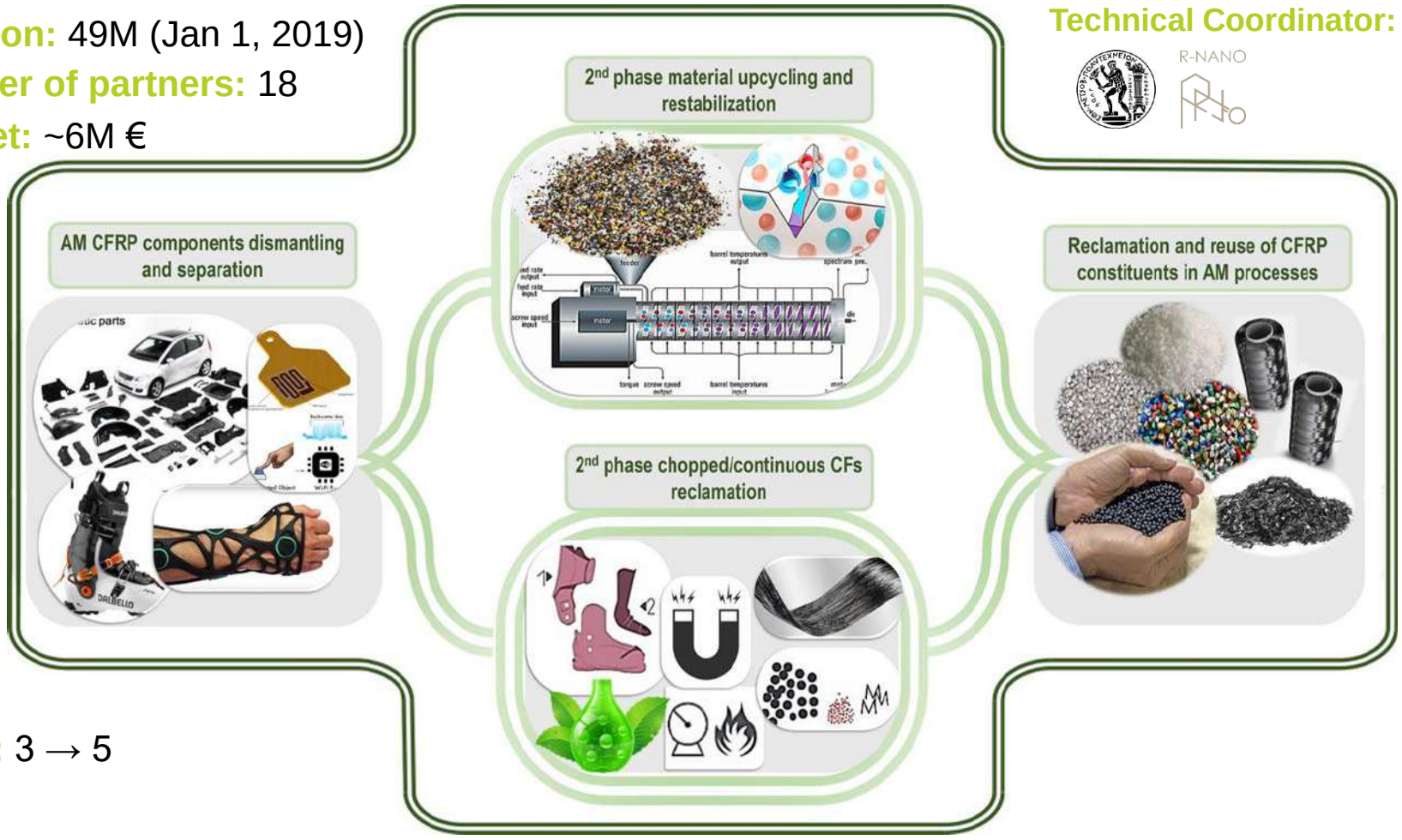
Budget: ~6M €

Project Coordinator:

Warrant Hub
TINEXTA GROUP

Technical Coordinator:

R-NANO



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TRL: 3 → 5

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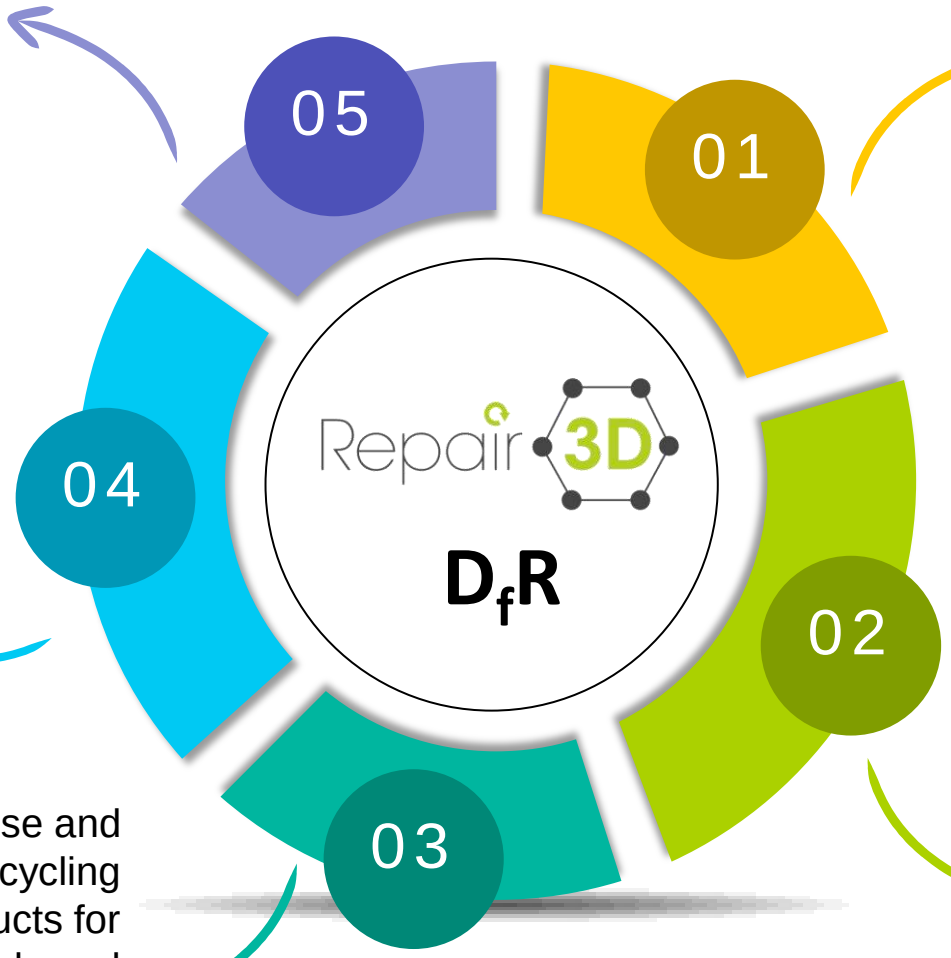
Application of R_fD Rules

Process and System Design tools: General design, Design for AM, Topological optimization

Intrinsic features for **disassembling**, **dismantling** and reclamation process at the EOL.

Targets to optimise and quantify recycling performance of products for all materials and compounds



Product oriented D_fR, five different industrial applications

Improved design on resource efficiency.

Development of **competitive, highly customisable industrial demonstrators** with improved functionalities and **eco-design**

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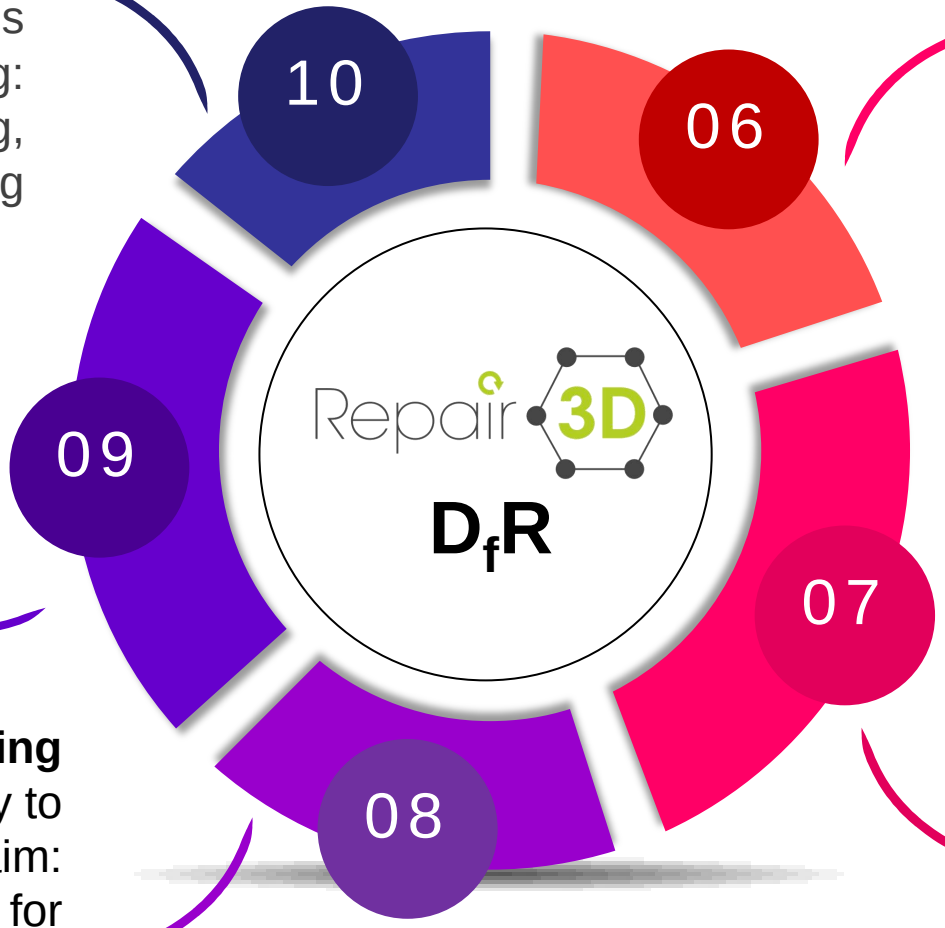
Application of R_fD Guidelines

Simple compositions and connections Emissions monitoring: Shredding, mechanical recycling



Post-industrial waste, automotive components and the rigid packaging sector

RFID tags – for tracking and EOL smart waste management

Restabilisation strategies identified for different types of TP materials.

Intrinsic recycling properties - easy to disassemble and reclaim: functionalized CFs for tunable interfacial adhesion to TP matrices.

TP blends, CF from various CFRPs waste

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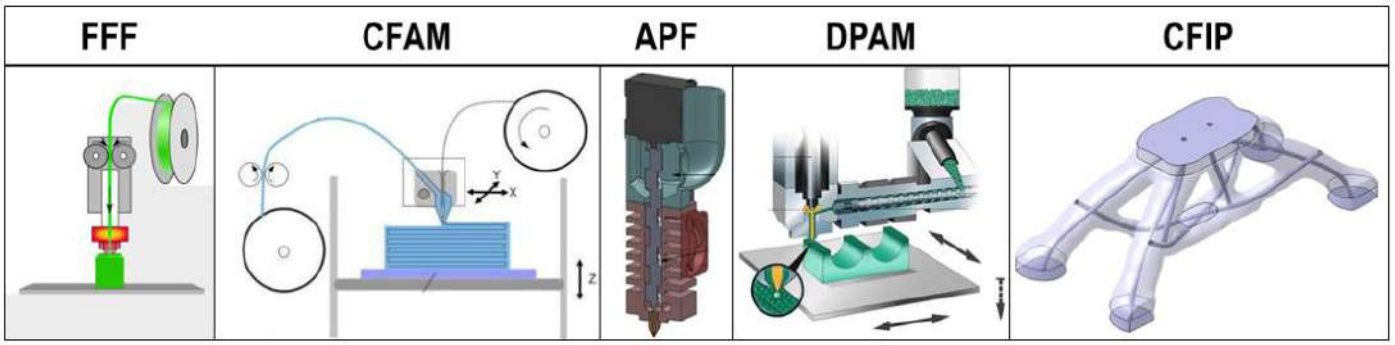
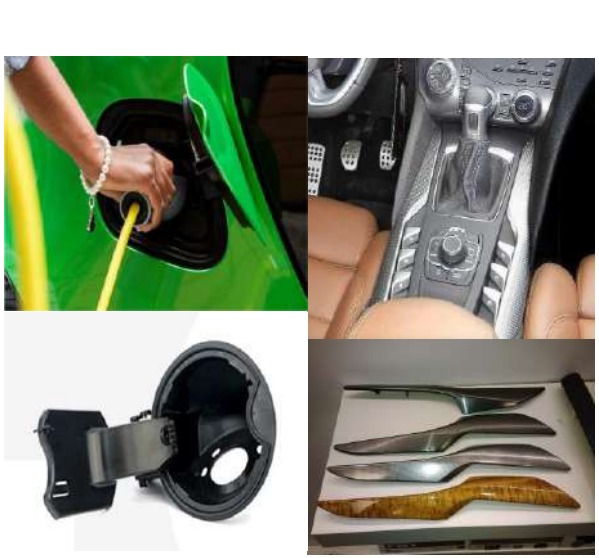
Demonstration



To use generative design, Design for Additive Manufacturing (D_fAM) and Design for Recycling (D_fR) in order to take advantage of the selected AM processes



"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814588".

Project ID:

Full title: Smart by Design and Intelligent by Architecture for turbine blade fan and structural components systems

Call identifier: H2020-NMBP-04-2017

Topic: Architectured / Advanced material concepts for intelligent bulk material structures

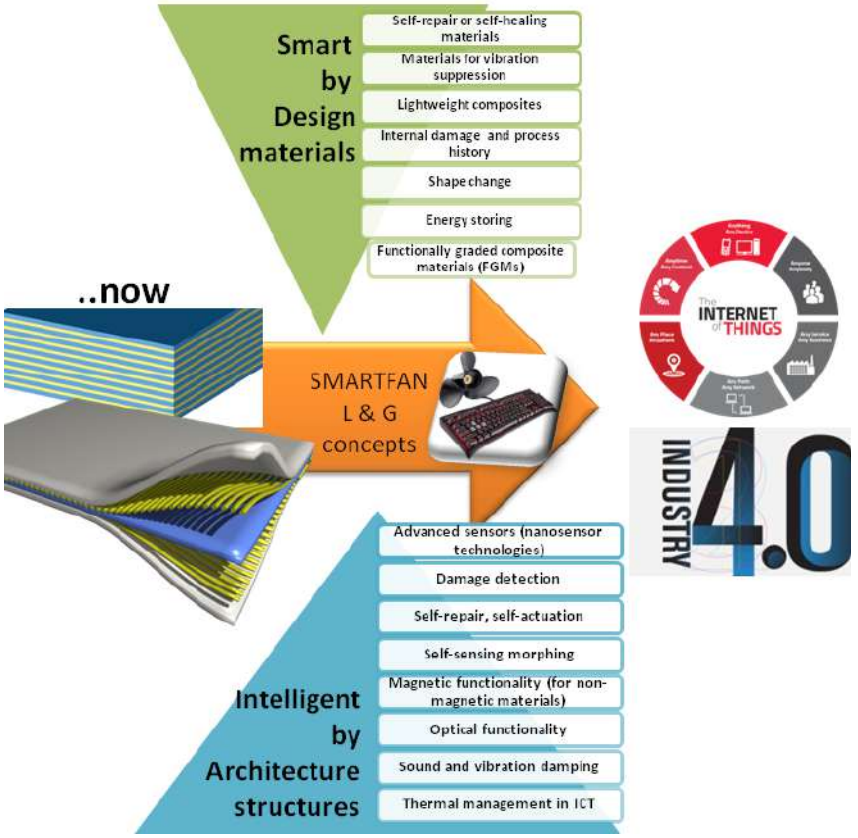
Duration: 48M (Jan 1, 2018)

Number of partners: 18

Budget: ~8M €

Project Coordinator:

TRL: 4 → 6

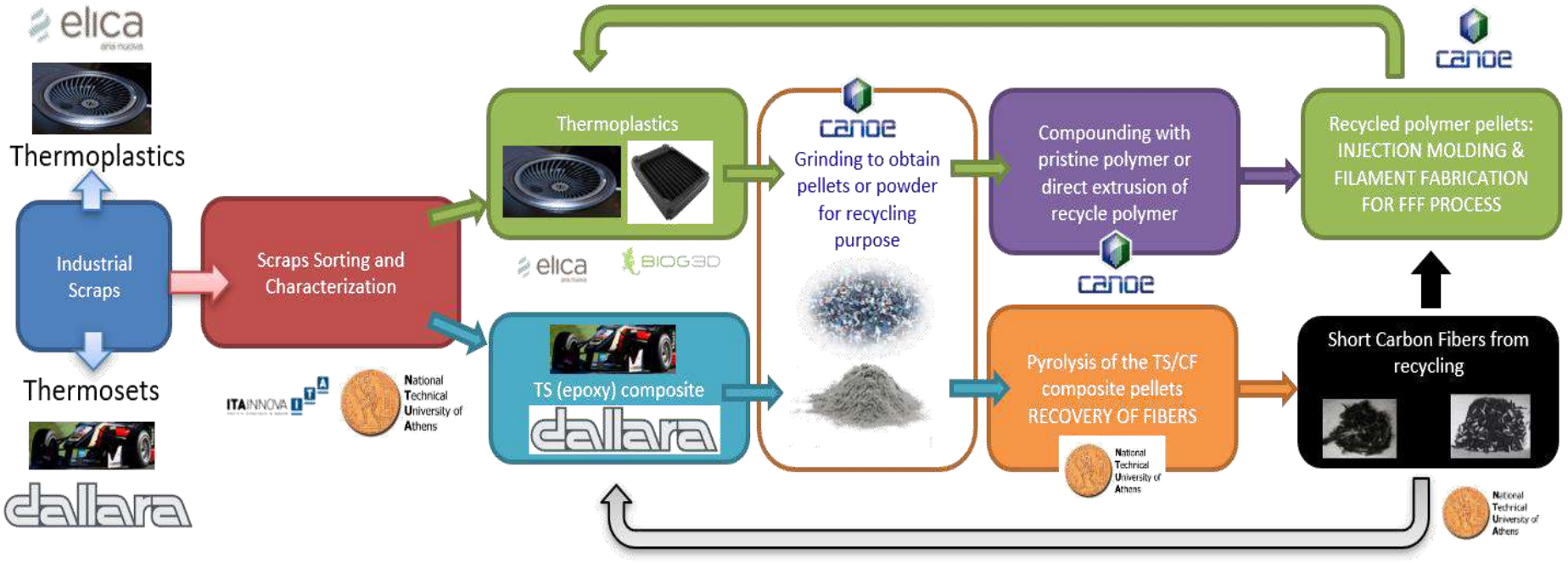


SMARTFAN proposes the development of **"smart" material and product architectures with integrated functionalities**, that will interact with their environment and **react to stimuli.**

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 760779".

Guideline routes for scrap reuse and recycling

...within SMARTFAN consortium



D4.2 – Scrap material re-use guidelines (NTUA, BIOG3D, M23) → Public deliverable (available soon)

D_fR, $D_{from}R$, D_fAM

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No760779".

Impact

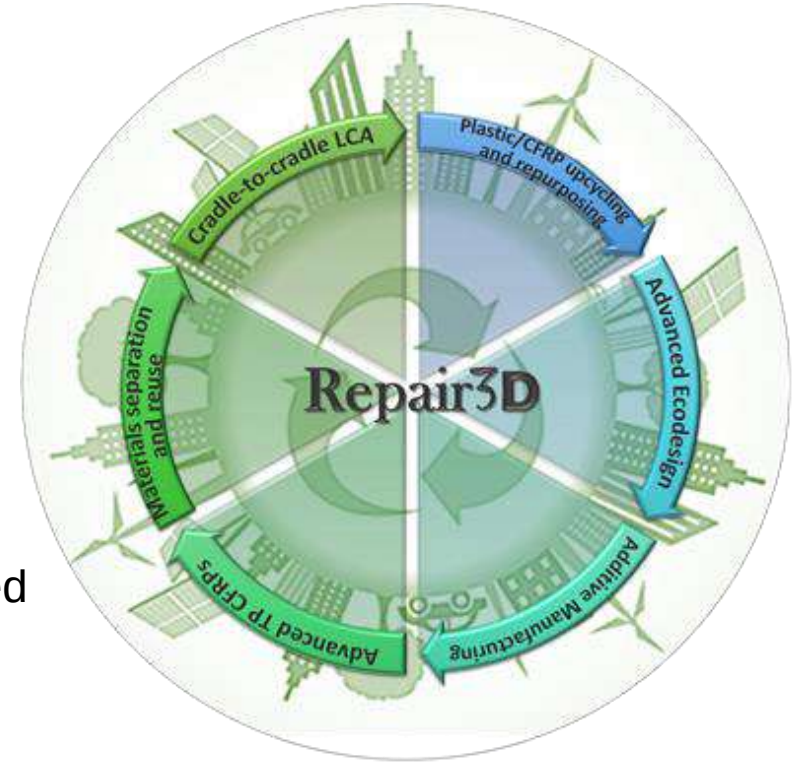
- **New pathways for recycling** of TP polymers and CFRPs for multiple processing life cycles.

- Development of **competitive, highly customisable industrial demonstrators** with improved functionalities and **eco-design - disassembling, dismantling and reclamation** process improved at the EOL by application of **Design for Recycling (DfR).**

- Increase maximum reprocessing cycles by development of **upcycling strategies** specialized for each TP category.

- **Industrial symbiosis** of **AM** and **recycling industry** - a new paradigm of a flexible, distributed recycling process, complementary to distributed manufacturing networks & existing recycling units.

- **Landfill waste reduce:** circular use of materials by recycling and re-use of the industrial case studies.



"These project s have received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 760779" and No 814588".

Impact

All **D_fR rules/guidelines** are subject to a mindful consideration of **product/component functionality** and should not impair these.

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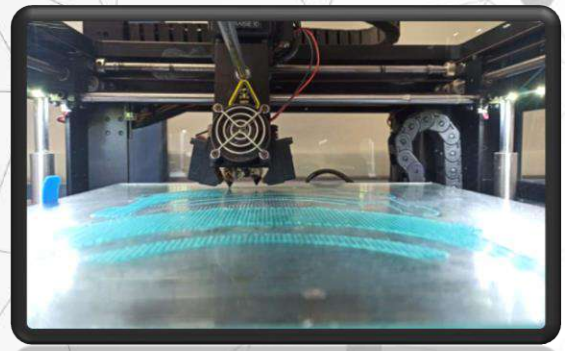
#Tackling coronavirus together



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3D Printing and Recycling of protective face shields: From design and manufacturing to end-of-life management

Special thanks to my colleagues:
Tanja Kosanovic, Kate Trompeta, Elias Koumoulos , Athanasios Morozinis
and all partners involved in both projects

Thank you for your attention

charitidis@chemeng.ntua.gr

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