ECOSISTER
ECOSYSTEM FOR SUSTAINABLE TRANSITION IN EMILIA-ROMAGNA

PNRR M4C2 1.5 "ECOSISTEMI TERRITORIALI D'INNOVAZIONE"

SPOKE3 - Green manufacturing for a sustainable economy

WP1 (D3.1.3 – D3.1.9)
WP3 (D3.3.5/D3.3.10 – D3.3.11/D3.3.15)

Activities performed by: ENEA Bologna Lab. TERIN ICER-CROSS ProtoLab

WP1 - Development of zero-pollution products, processes and production systems that minimize the energy demand and the use of hazardous and of non-renewable materials (ENEA, UNIMORE, CENTRO CERAMICO, BIREX)

D3.1.3 (08/24) Release of the demonstrator of an innovative production process in the ceramic and fashion sectors.	D3.1.9 (09/25) Development of a tool on a 3D web platform for geometric and topological optimization using Interactive Generative Modeling aimed at minimizing the use of materials and energy.
T.3.1.6	T3.1.7
Configuration of the Interactive Generative Modeling tool for 3 different industrial sectors of fashion in Emilia-Romagna: - Generative Modeling tool for 3 sectors (fashion accessories, textiles, footwear)	Involvement of fashion companies in the different industrial sectors identified: - at least 6 fashion companies in the 3 different industrial sectors

M4 WP1 D.3.1.3. Roadmap

Release of the demonstrator of an innovative production process in the ceramic and fashion sectors (08/24)

Literature Review
CD (IGM) + AM in fashion + Continuous Mass Customization
Tools and methodologies
Report of 42 projects

Mapping SOTA
- CD (IGM) + AM in fashion + CMC
- Visualize and identify involvment of 3Dp
- Technology x Sectors Matrix

Algorithms Development
- Tools identification
- Augmenting SMEs/CCI
- Identify IGM + AM solutions for fashion products

Case Studies
- Scounting process
- 3 industrial fashion partners
- 3 case studies

M4 WP1 D.3.1.3. Roadmap

Release of the demonstrator of an innovative production process in the ceramic and fashion sectors (08/24)

Current activities:

The previous activities were done by analyzing 43 case studies selected by the following criteria:

1. Process innovation through the introduction of AM (**Additive Manufacturing)** technologies

2. Possibility to customize a product and also follow made-to-order policies to apply the CMC (**Continuous Mass Customization**) concept

3. Recycled, sustainable or optimized materials

The common characteristics of each example are the manufacturability only with AM technologies and the complexity of the 3D model.

From the point of view of 3D modelling, starting from the cases studies, we have analyzed and developed the algorithms that allow the creation of CAD files using Grasshopper (GH), a visual programming language and algorithmic modelling tool:

1. Implement the **Generative Design** (GD) flexible and customizable

2. Helps designers explore a wide range of 3D solutions impossible to create with conventional CAD features

3. Provide high performance and efficiency from the point of view of materials utilized
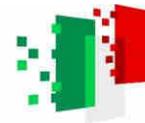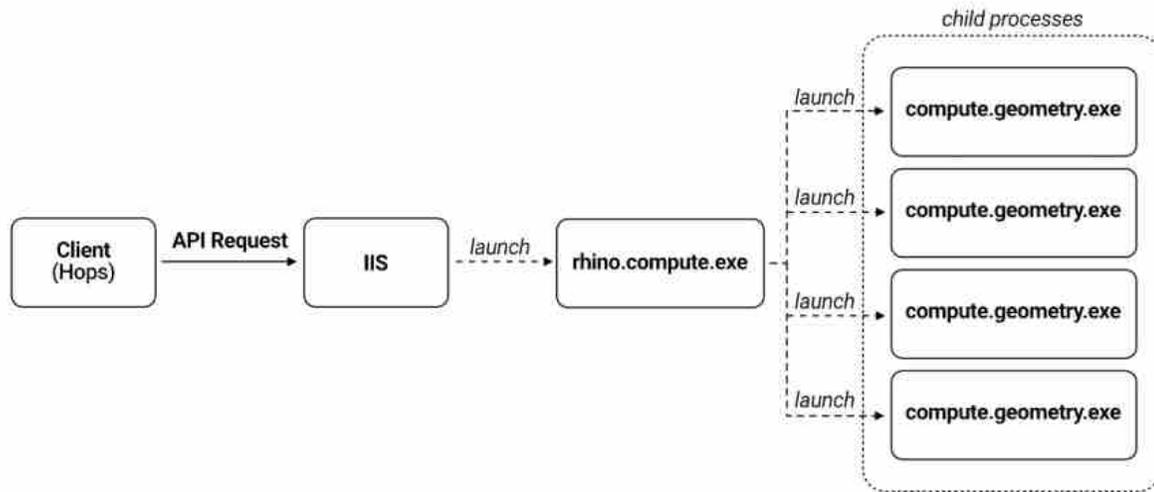
WP1 D.3.1.9. Roadmap

Development of a tool on a 3D web platform for geometric and topological optimization using Interactive Generative Modeling aimed at minimizing the use of materials and energy (09/25).

Literature Review
Cloud Manufacturing
Current state on IGM interactive platforms
3D intective platform proposition

Fashion Sector
- Search of SMEs/CCIs (partnership)
- Identify 6 fashion companies
- 3 sectors

3D IGM Platform
- Development of a 3D IGM platform
- Application of IGM for cloud manufacturing
- 6 case studies (2 for each sector)

Optimization Integration
- Integration of generative processing strategies for TO+LS on 3D IGM Platform
- Identify optimization opportunity in fashion products
- Interactive and explorative tool to promote sustainability by end user

WP1 D.3.1.9. Roadmap

Development of a tool on a 3D web platform for geometric and topological optimization using Interactive Generative Modeling aimed at minimizing the use of materials and energy (09/25).

Platform for IGM (Interactive Generative Modeling)

Rhino.Compute → is an open-source web server that can perform geometry calculations using Rhino's 3D geometry library

1. Local Server → Local intranet on shared PC

WP1 D.3.1.9. Roadmap

Development of a tool on a 3D web platform for geometric and topological optimization using Interactive Generative Modeling aimed at minimizing the use of materials and energy (09/25).

2. RhinoCompute → VM on dedicated server

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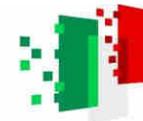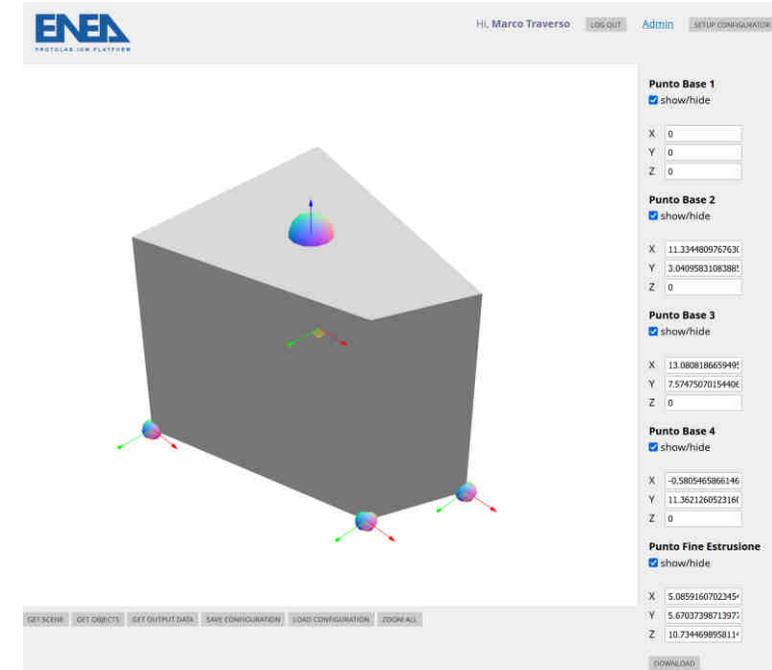
WP3 - Life Cycle and Sustainability Assessment of materials, products and processes (ENEA, UNIPR, UNIMORE, CNR)

| D3.3.5 (09/23) - D3.3.10 (09/24) 1. Development of generative processing strategies for the breakdown of product characteristics and possible redesign and recovery actions.	D3.3.11 (09/24) - D3.3.15 (09/25) 2. Development of a model for the re-manufacturing of product components with the use of 3D printing systems.
T.3.3.5	T3.3.7
Identification of types of representative products on which to attend with recovery actions: - at least 5 types of representative products	Development of processing strategies relating to the intervention sectors aimed at the recovery and redesign of the product: - 3 processing strategies

Consumer Goods report cards

- The criteria for case studies selection was based on declared features like:

I. adaptation of DfAM methodologies (TO, LS, part consolidation, print-in-place);

II. RE for spare parts or EoL services;

III. customization (also with RE) with CD;

IV. recycled, sustainable or optimized materials.

- A total of 42 projects were examined in the Consumer Goods sector was subdivided in 6 areas: *Sports Equipment; Footwear; Eyewear; Electronics and Wearables; Music Instruments; Packaging*.

- For each project was developed a simple card reporting: brand; technology, materials, year of production and its sector in the Consumer area.

		Sports Equipment	Footwear	Eyewear	Electronics and Wearables	Music Instrument	Packaging	References*	Industry**
POLYMER	FDM	x			x	x	x	Isaac & Duddeck (2022) Prajapati et al. (2022) Ryan-Johnson et al. (2021) Arefin et al. (2021) Pan et al. (2020) Saritha (2020) Liu et al. (2018) Tang et al. (2018)	wove Superstrada Vector Finesse Aenrual Syos Kupol Stratasys+Pavlovich Loop3D+Körner
	SLA/DLS	x	x	x	x	x	x	Li et al. (2023) Isaac & Duddeck (2022) Arefin et al. (2021) Pan et al. (2020) Saritha (2020) Liu et al. (2018)	CCM+Carbon ADIDAS 4DFWD JINS+Carbon iF.r.a Incase+Carbon Rawlings 3dVarius Wilson Minerva Hearing Senneheiser Guardlab MAMEHA F1 fragrances
	PJ		x					Isaac & Duddeck (2022) Arefin et al. (2021) Liu et al. (2018)	Quant-U
	MJF	x	x		x	x		Isaac & Duddeck (2022) Arefin et al. (2021)	OECHSLER COBRA GOLF HP Dior Tailored-Fits Syng Odiselmusic
	SLS	x	x	x		x		Isaac & Duddeck (2022) Pan et al. (2020) Liu et al. (2018) Helou et al. (2016)	Hoet Nike YOU MAWO Wilson Stratasys+Pavlovich 3DMusicInstruments ODDGuitar (PA)
METAL / CERAMIC / OTHERs	M_FDM							Gandhi & Minak (2022)	
	SLM/DMLS	x		x		x		Isaac & Duddeck (2022) Guo et al. (2022) Zhu et al. (2021) Yang et al. (2021) Wang et al. (2021) Pan et al. (2020) Saritha (2020) Meng et al. (2020) Maconachie et al. (2019) Liu et al. (2018) Donofrio (2016) Helou et al. (2016) Zeleny & Cadek (2015) Dagres (2007)	Bastion Cycles Hoet Sandvik Nick Huber Guitar
	M_BJ	x			x	x		Segonds & Zamariola (2020) Donofrio (2016) Tang et al. (2016)	ODDGuitar (wood) COBRA GOLF Holthinrichs Götz+Sandhelden

Technology X Sector Matrix

- The involvement of redesign and remanufacturing in consumer goods sectors: compilation of all data and notable references from the literature review into a single matrix, to visualize of the current state of redesign and remanufacturing involvement in consumer goods sectors.

- Identifying 5 products for recovery actions:

1. Music Instrument = chin rest for violin
2. Footwear = high-heeled shoe
3. Packaging = necklaces jewelry display
4. Eyewear = pair of sunglasses
5. Sports Equipment = riser for archery

Legend: FDM = Fused Deposition Modeling; D2T = Direct To Textile (FDM); SLA = Stereolithography; DLS = Digital Light Sintering (SLA); PJ = Polyjet (by Stratasys); 3DFashion = Polyjet (PJ by Stratasys's Techstyle); MJF = Multi Jet Fusion (BJ); SLS = Select Laser Sintering (L-PBF); M_FDM = Metal Fused Deposition Modeling (FDM); SLM = Selective Laser Melting (L-PBF); DMLS = Direct Metal Laser Sintering (L-PBF); M_BJ = Metal Binder Jetting (BJ); L-PBF = Laser Powder Bed Fusion; BJ = Binder Jetting.
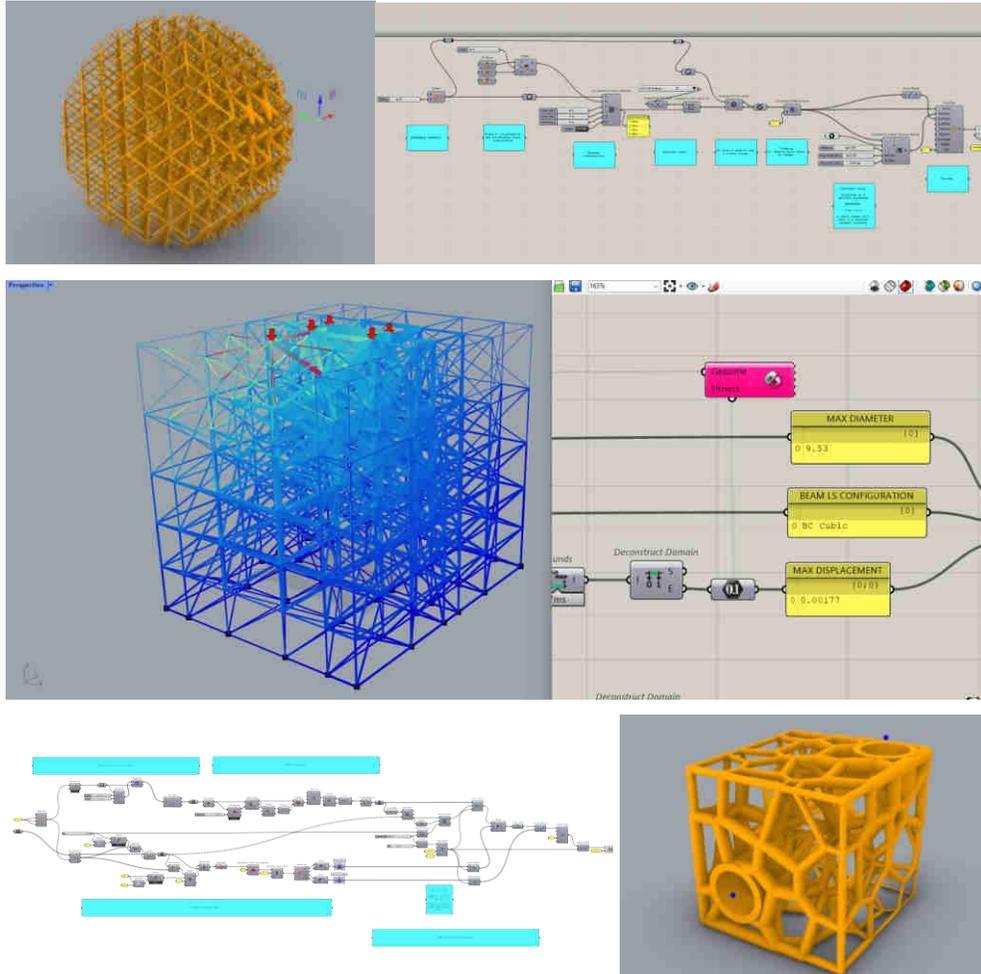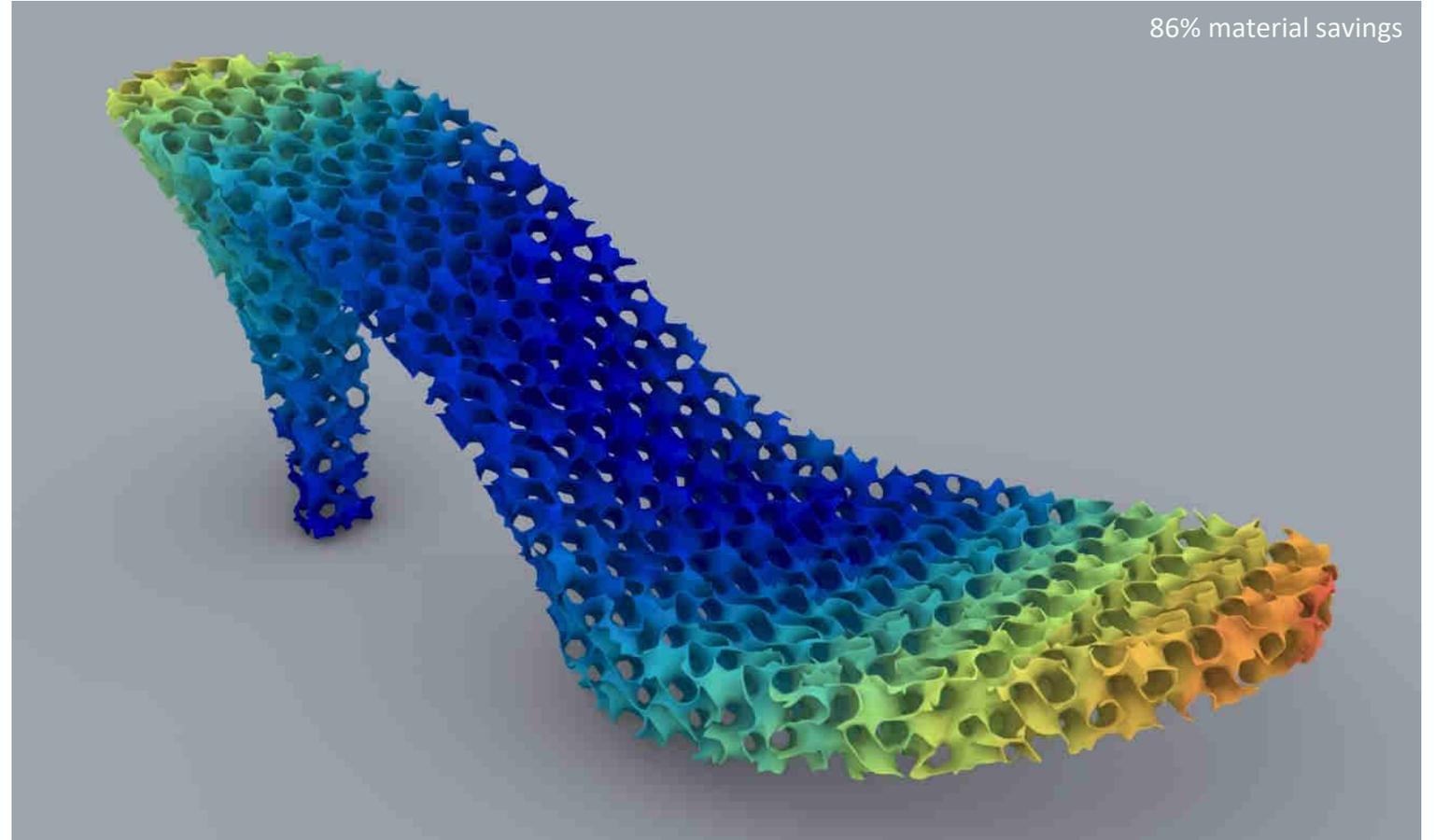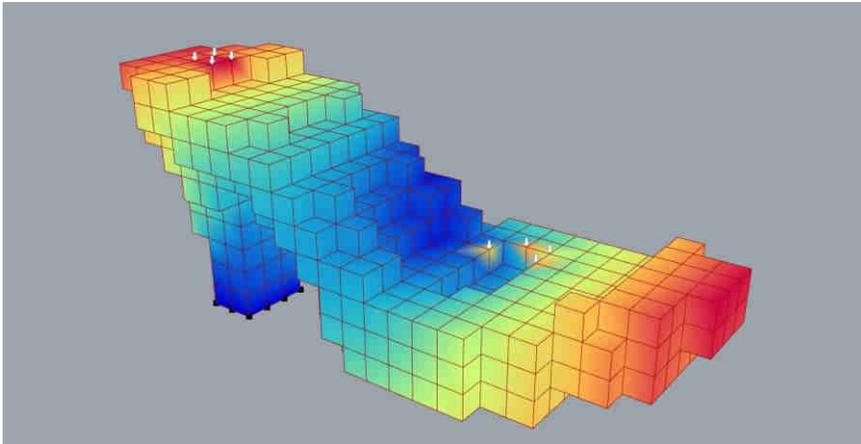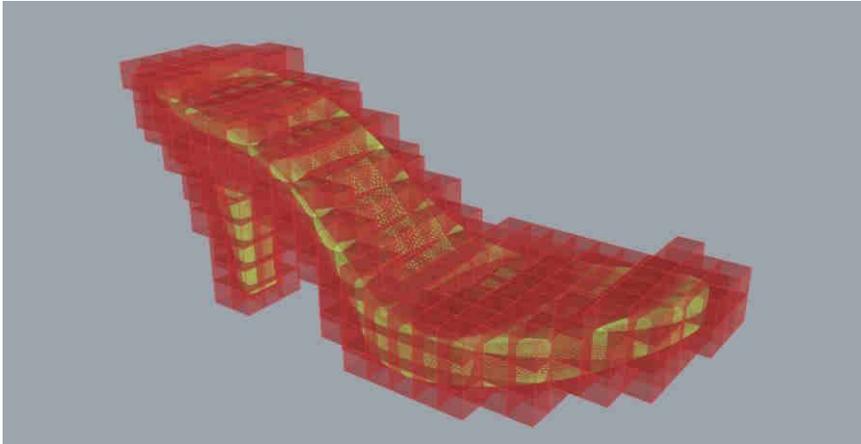
15 Tutorials/Templates

- 15 tutorials/templates have been developed to address various situations individually and provide solutions for each. These tutorials explore different TO and LS workflows, highlighting their advantages and making them valuable for specialized courses, mostly oriented towards SMEs and CCIs.

- Each tutorial can also be categorized according to which product characteristics is to breakdown using three key criteria:

I. Weight-Critical

II. Structural Complexity

III. Adaptive Performance

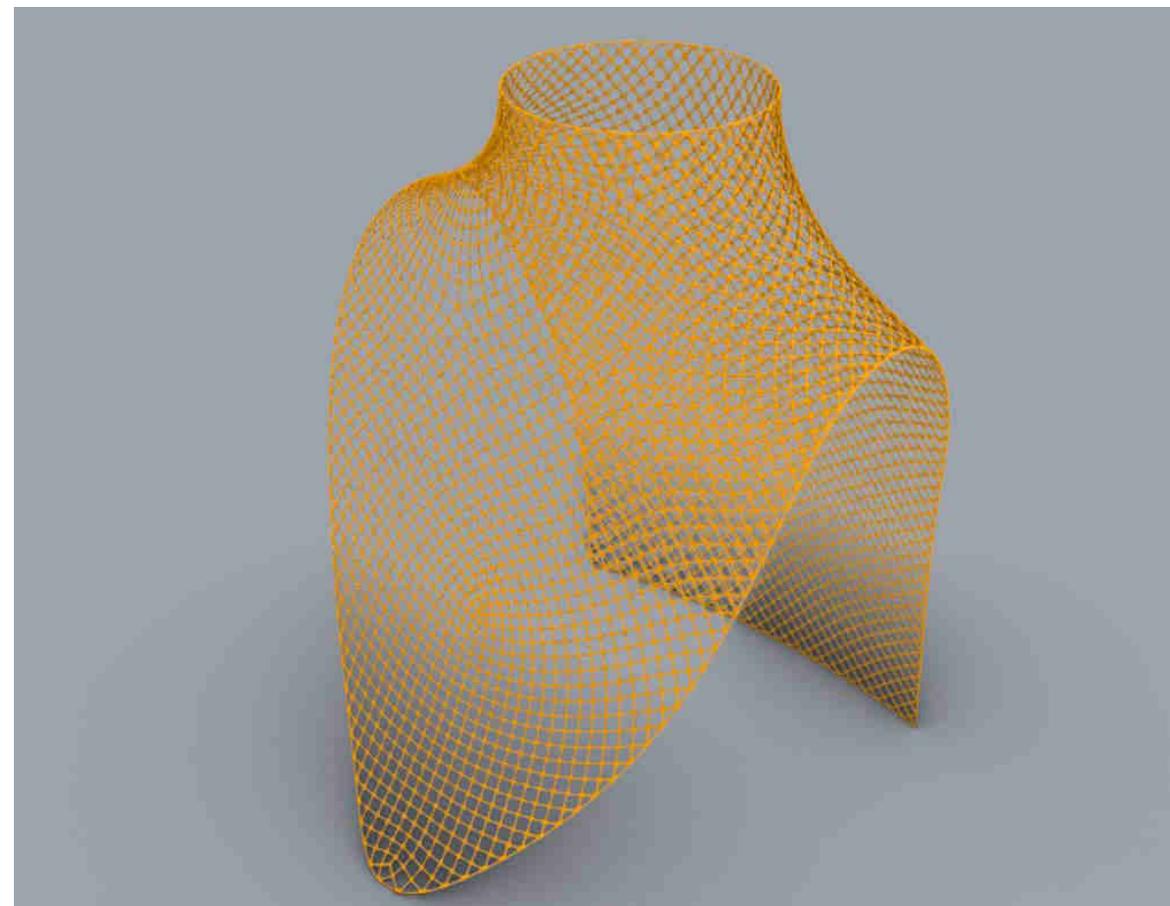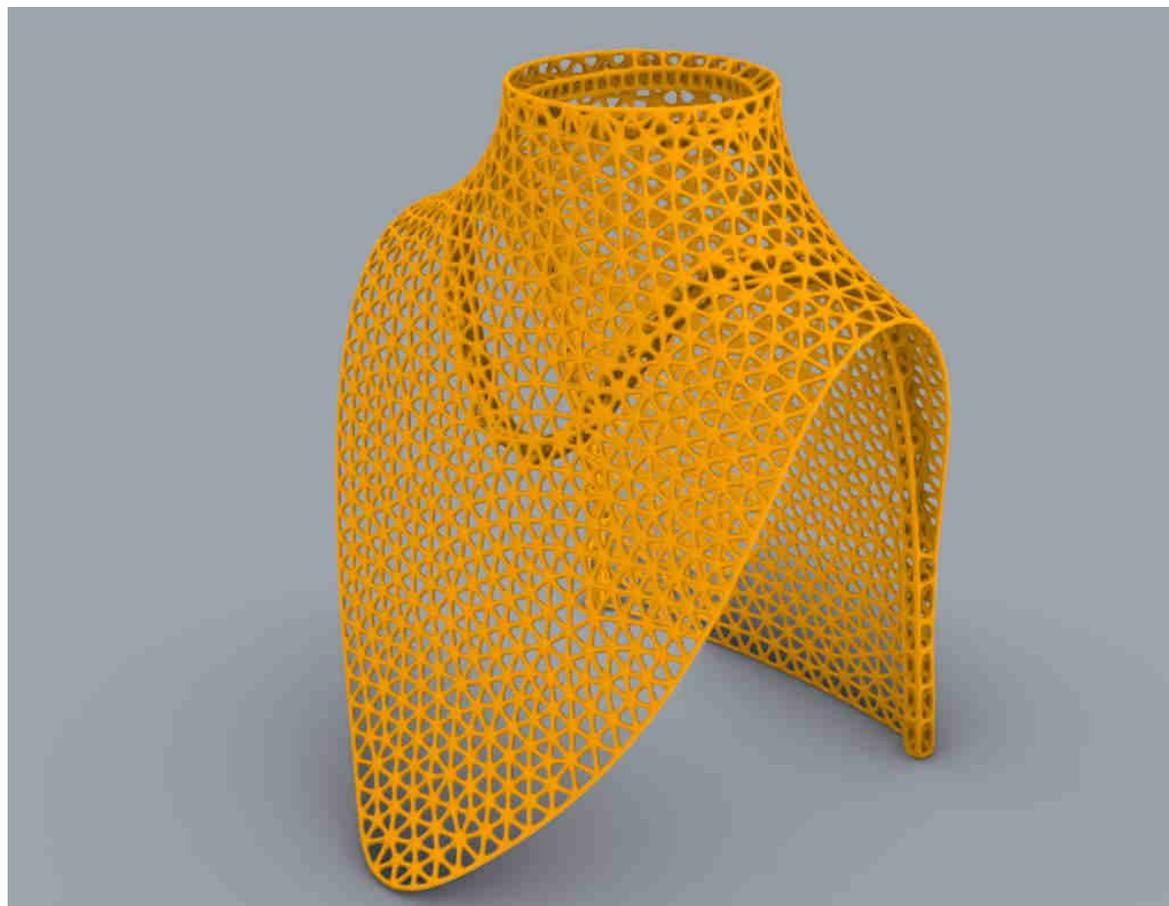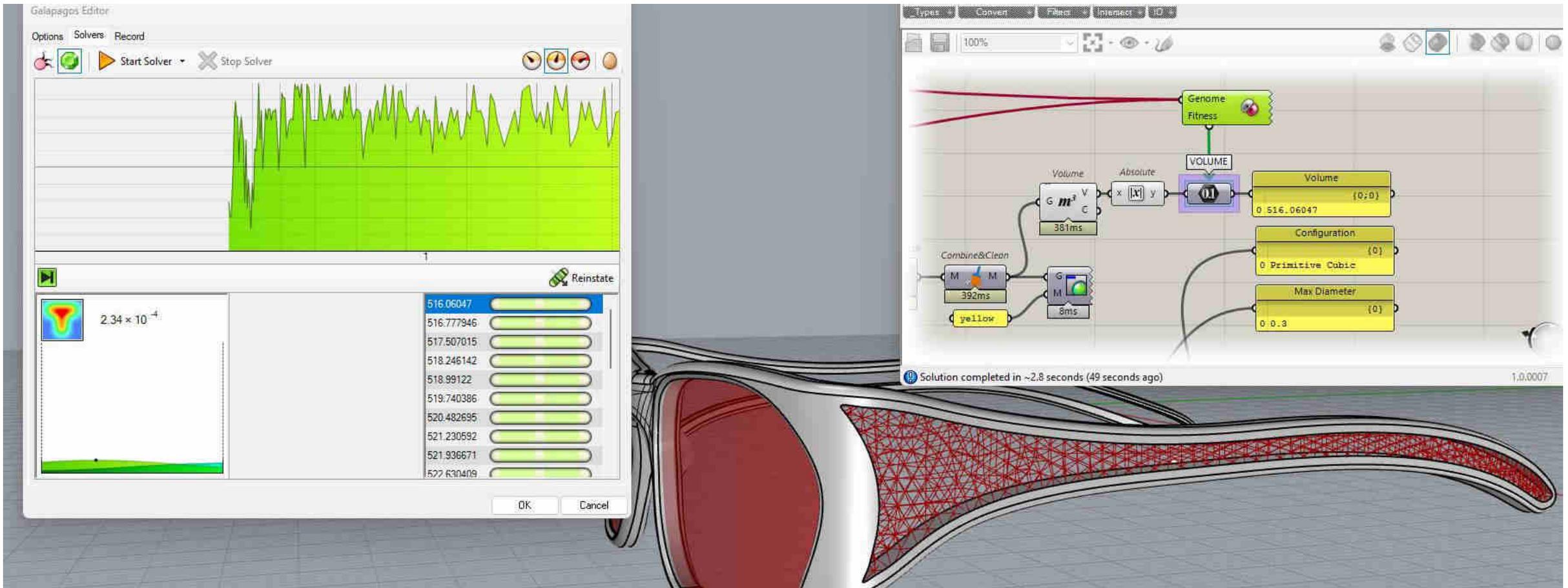- To gather feedbacks and possible improvements, all the templates were posted on a popular online repository (Github) at https://github.com/ENEA-ProtoLab.

Violin's chin rest: Weight-Critical

60% material savings
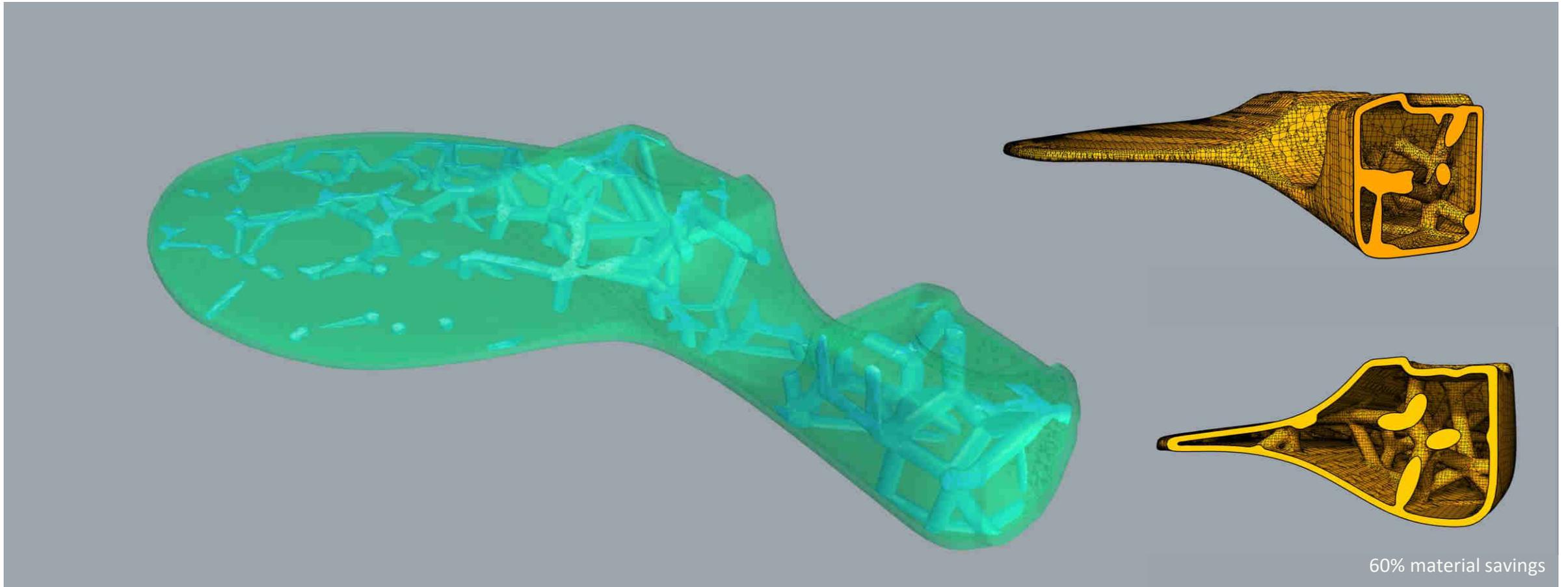
High-heeled shoe: Structural Complexity

86% material savings

Necklaces's display: Adaptive Performance

Sunglasses: Adaptive Performance

Riser: Weight-Critical + Structural Complexity

80% material savings
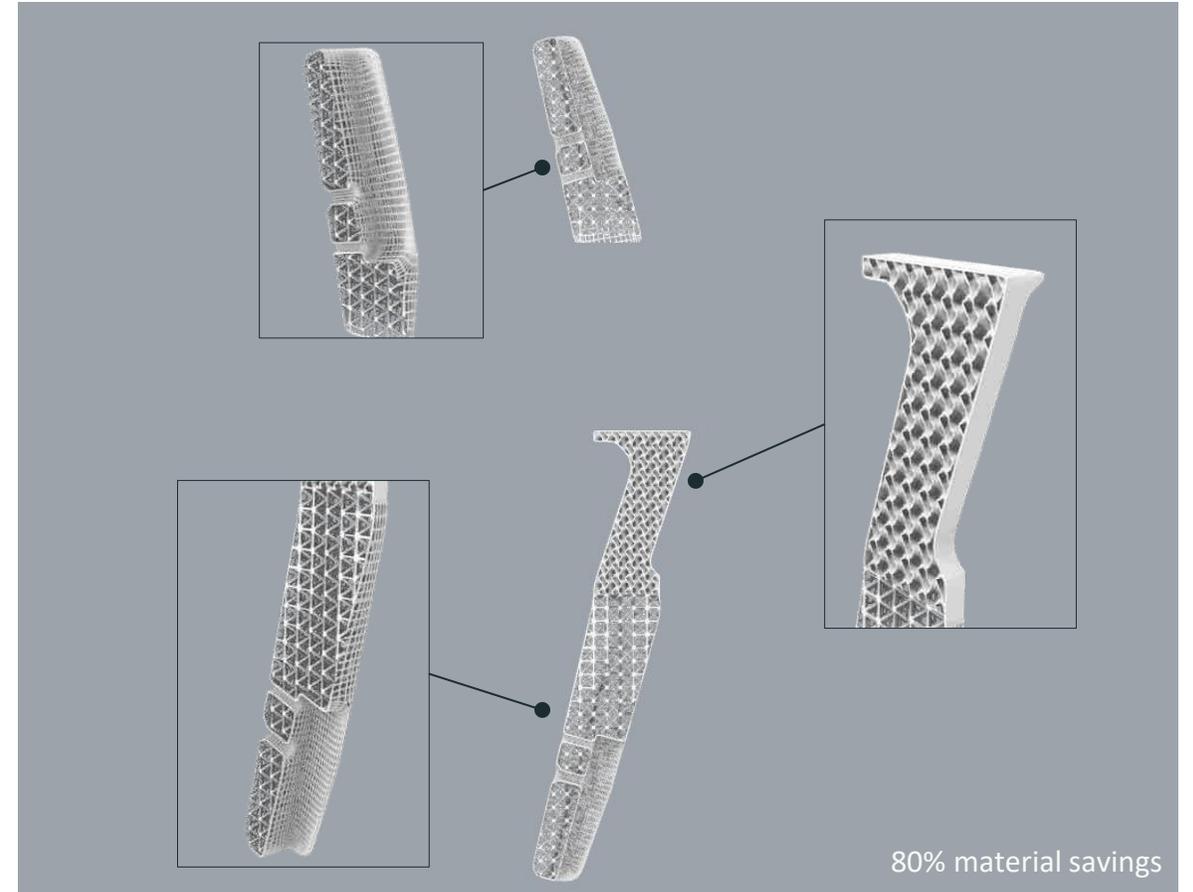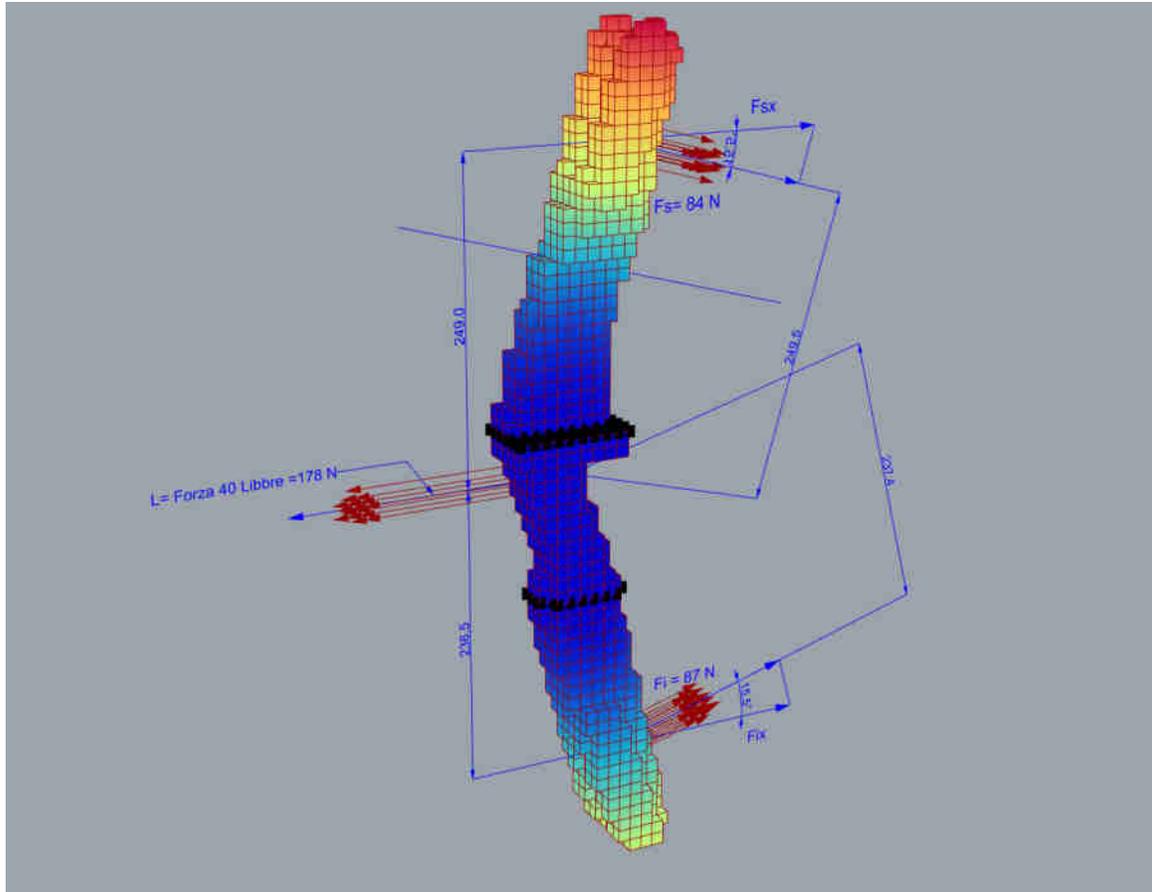
M4 WP3 D.3.3.10 Roadmap

1. Development of generative processing strategies for the breakdown of product characteristics and possible redesign and recovery actions (09/24).

ENEA
Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

ecosister

D3.3.5

University
Wp3 partecipants
Trade Associations
…

D3.3.5 (Algorithms
Development)

Reverse Engineering
TO+LS
ReMeshing
…

Seminar/Workshops
- Templates disseminations and testing
- Courses for SMEs/CCIs and Univ.
- Flexibility evaluation

Strenght Tests
- Reproposing load condition on 3dp parts
- Identify best solutions
- Real case evaluation

Identify 3 strategies
- Recovery and redesign of products
- Algorithm development of 3 strategies
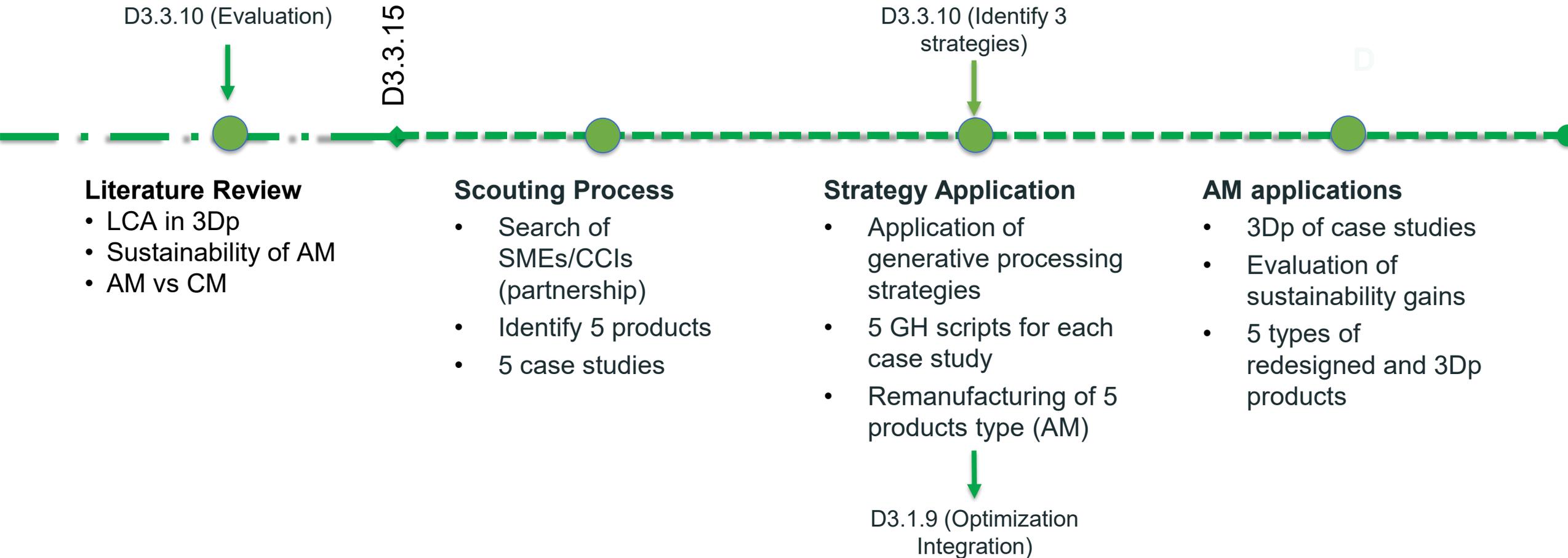- 3 responsive generative process strategies

Evaluation
- CNC vs AM
- Evaluation of recovery actions
- Energy savings; Material savings; Process time.
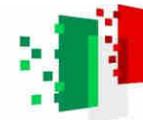
M4 WP3 D.3.3.11+ D3.3.15 Roadmap

2. Development of a model for the re-manufacturing of product components with the use of 3D printing systems (09/24- 09/25).

D3.3.10 (Evaluation)

D3.3.15

D3.3.10 (Identify 3 strategies)

D

Literature Review
- LCA in 3Dp
- Sustainability of AM
- AM vs CM

Scouting Process
- Search of SMEs/CCIs (partnership)
- Identify 5 products
- 5 case studies

Strategy Application
- Application of generative processing strategies
- 5 GH scripts for each case study
- Remanufacturing of 5 products type (AM)

D3.1.9 (Optimization Integration)

AM applications
- 3Dp of case studies
- Evaluation of sustainability gains
- 5 types of redesigned and 3Dp products

Riferimenti:

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https://www.cross-tec.enea.it/
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