Sustainable electronics:

Towards the creation of a European ecosystem and e-waste reduction

GreenDays 2024

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EECONE

Agenda

- EECONE: European Ecosystem for Green Electronics
- Eco-designed Remote Control Unit: From theory to practice
- Global vision: The paths towards eco-innovation

EEECONE:
European Ecosystem for Green Electronics

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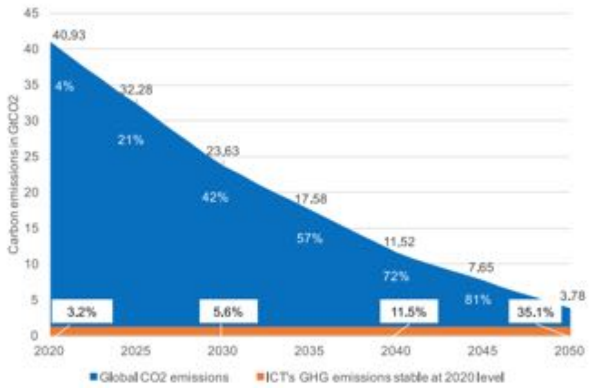
The impact of electronics on the environment

- Many different environmental impacts and benefits arising from electronics
- Double role of electronics in the race towards environmental sustainability
  - Significant environmental impact arising from production and usage
  - Reduce or avoid GHG emissions

Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023

ICT 2020: 2.1-3.9% of global CO2 emissions



Freitag et al., Patterns, 2021

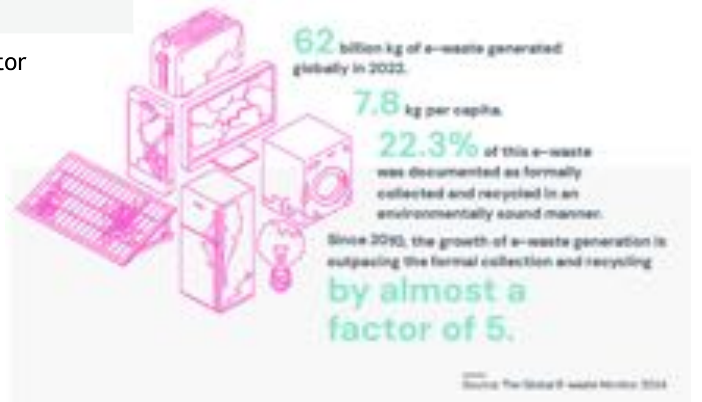
Focus on e-waste

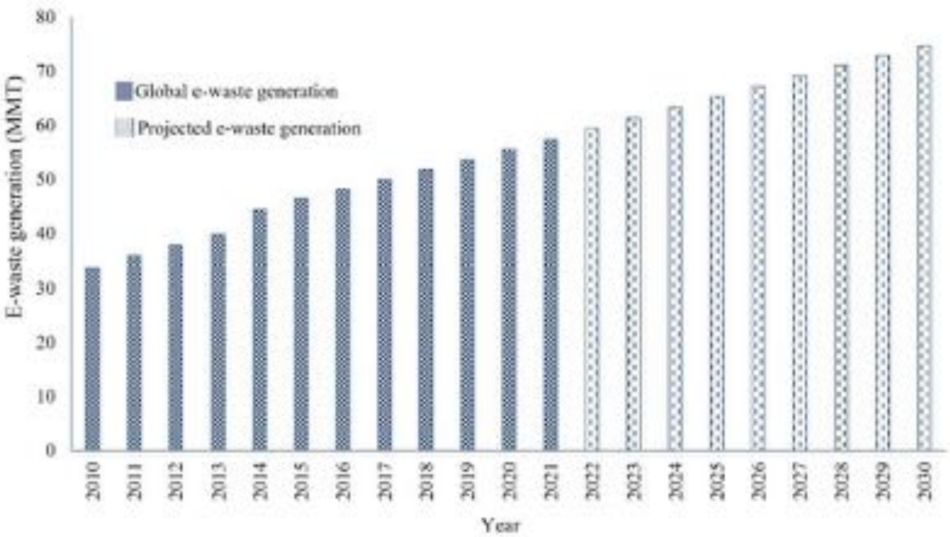
- Many different environmental impacts arising from electronics
- **E-waste**: One of the fastest growing waste streams in EU
  - 5 times faster than e-waste recycling

- Obstacle to EU efforts to reduce its environmental footprint
- Potentially harmful materials polluting the environment
- Many rare materials

- Circular Economy Action Plan priority: E-waste prevention
  - Right to repair
  - Reusability improvement
  - Recycling rewards
- ESPR: Sustainable product design to reduce waste
- WEEE Directive

The Global E-waste Monitor 2020





H. Roy et al., 2022

Electronic waste reduction: How to

- EECONE mission: Electronic waste reduction
- Objective 1: **Define** environmentally sustainable ECS
  - Tools and methods to design ECS for circularity
  - At least 80% of 6R metrics implemented in tools
- Objective 2: **Make** environmentally sustainable ECS
  - Techniques to boost circularity and decrease e-waste in new generation of electronics
  - At least 25% e-waste reduction
- Objective 3: **Showcase** environmentally sustainable ECS
  - Demonstrate solutions along the value chain
  - 10 use cases with dedicated KPIs
- Objective 4: Build consciusness
  - Ecosystem creation
  - At least 100 publications, over 10 recommendations to improve standards and regulations

EC, Waste Framework Directive

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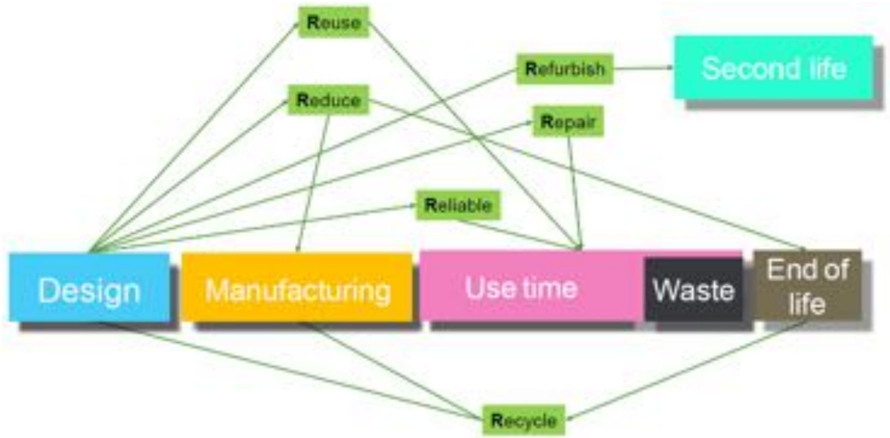
Strategy: The 6R concept

- **Reduce**: Reduction of materials by optimizing the use of resources
- **Repair**: Techniques for repairability facing the barriers
- **Reuse**: Capacity to use parts of a broken product as spare parts for another
- **Refurbish**: Second life, use of a product for another mission
- **Recycle**: Critical pillar of the European e-waste reduction strategy
- ***Reliability***: *Guarantee and maximisation of the lifetime*



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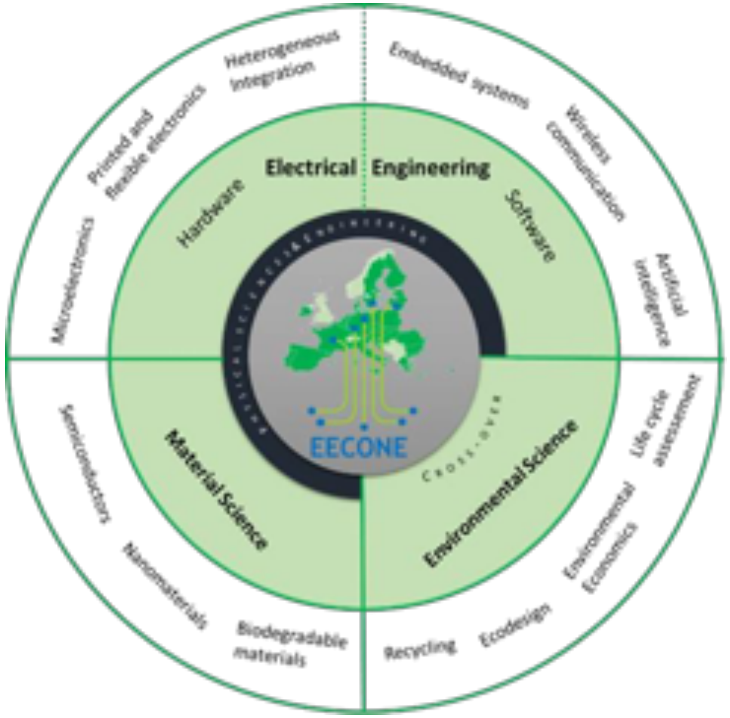
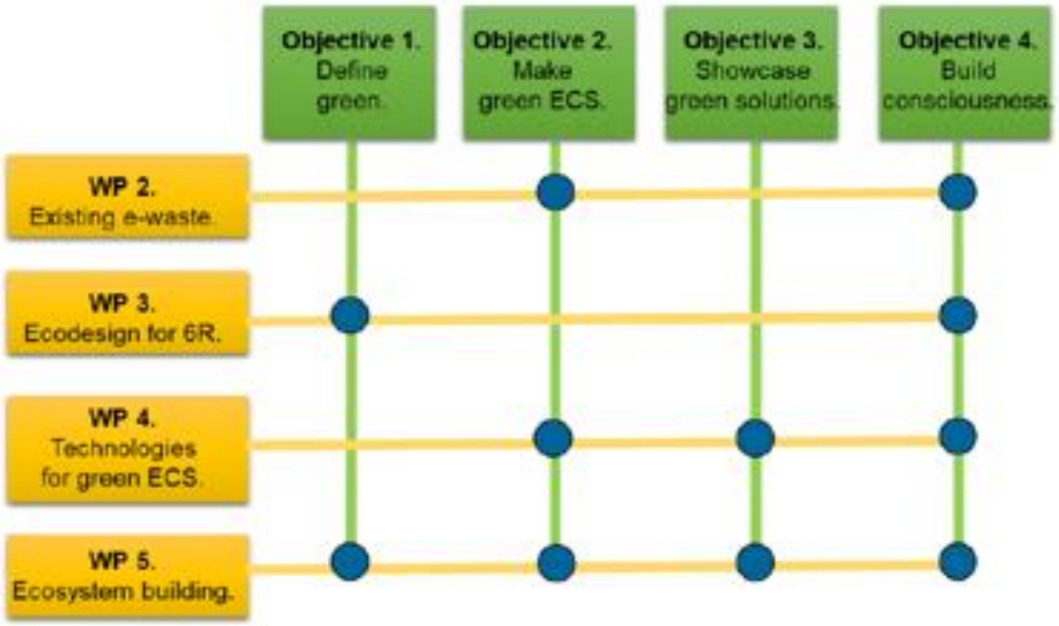
Consortium

- 49 partners from 16 Countries
- Interdisciplinarity to link electronic industry with environmental and material sciences



Work plan

- Management of existing electronic waste
  - Focus on Reuse and Recycle
- Tools and techniques for environmentally sustainable ECS by design
  - Eco-design for 6R at IC, PCB and System levels
- New generation of electronics
  - Technologies for environmental sustainable ECS
- Ecosystem building
  - SWOT of the 6R approach
  - Survey and feedbacks on standards and regulations
  - Education content



Management of existing electronic waste

- Objective: Improve circularity
  - Reuse, waste valorisation, recycling

Gain a view of the raw materials flows and production scraps on a European scale → Identify impacting materials → Develop new recycling technologies and raw materials circular loops

Recyling rate in EU
25%
Minimum Annual EU consumption

- Step 1: Study the raw materials supply
- Step 2: Cross with critical and strategic material list
- Step 3: Create the mapping and define a list of EECONE most impacting raw materials

WEEECycling

Recycling quiz: https://www.eecone.com/eecone/survey/?id=90

European Commission, 2023

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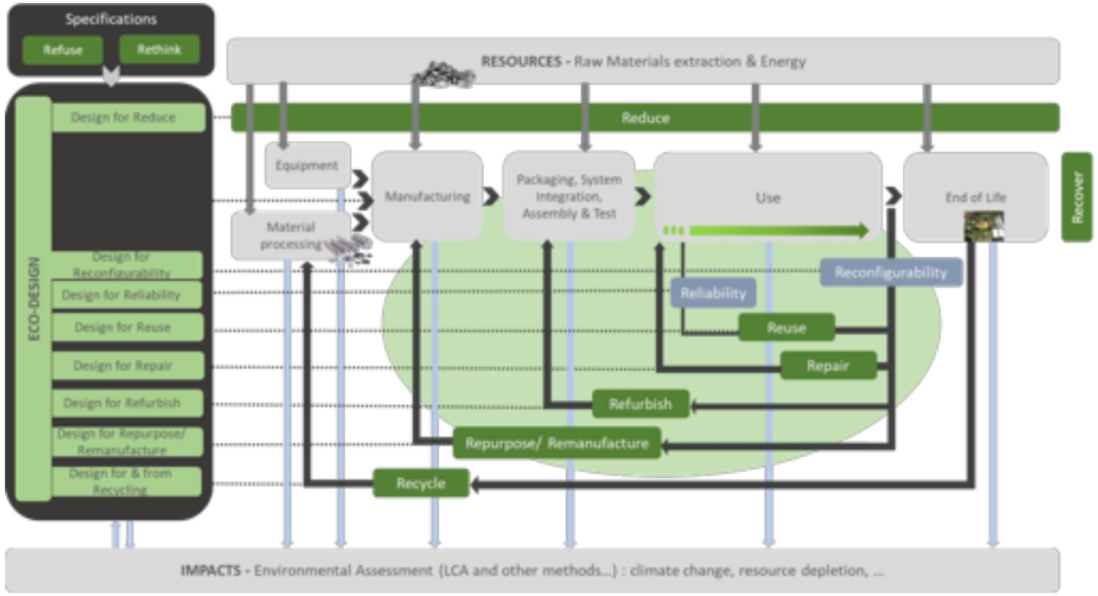
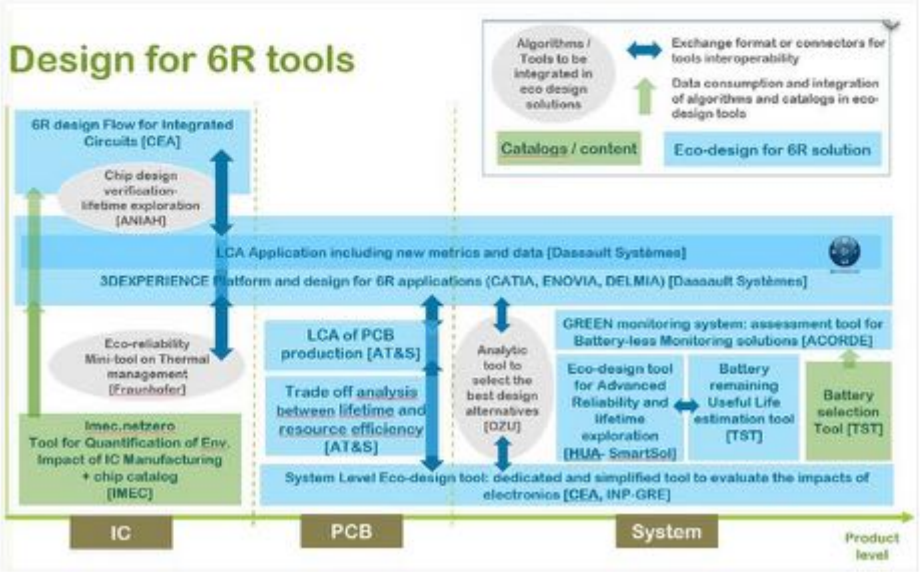
Design of environmentally sustainable ECS

- Objective: **Tools**, **metrics** and **guidelines** to enhance future electronics design based on the 6R

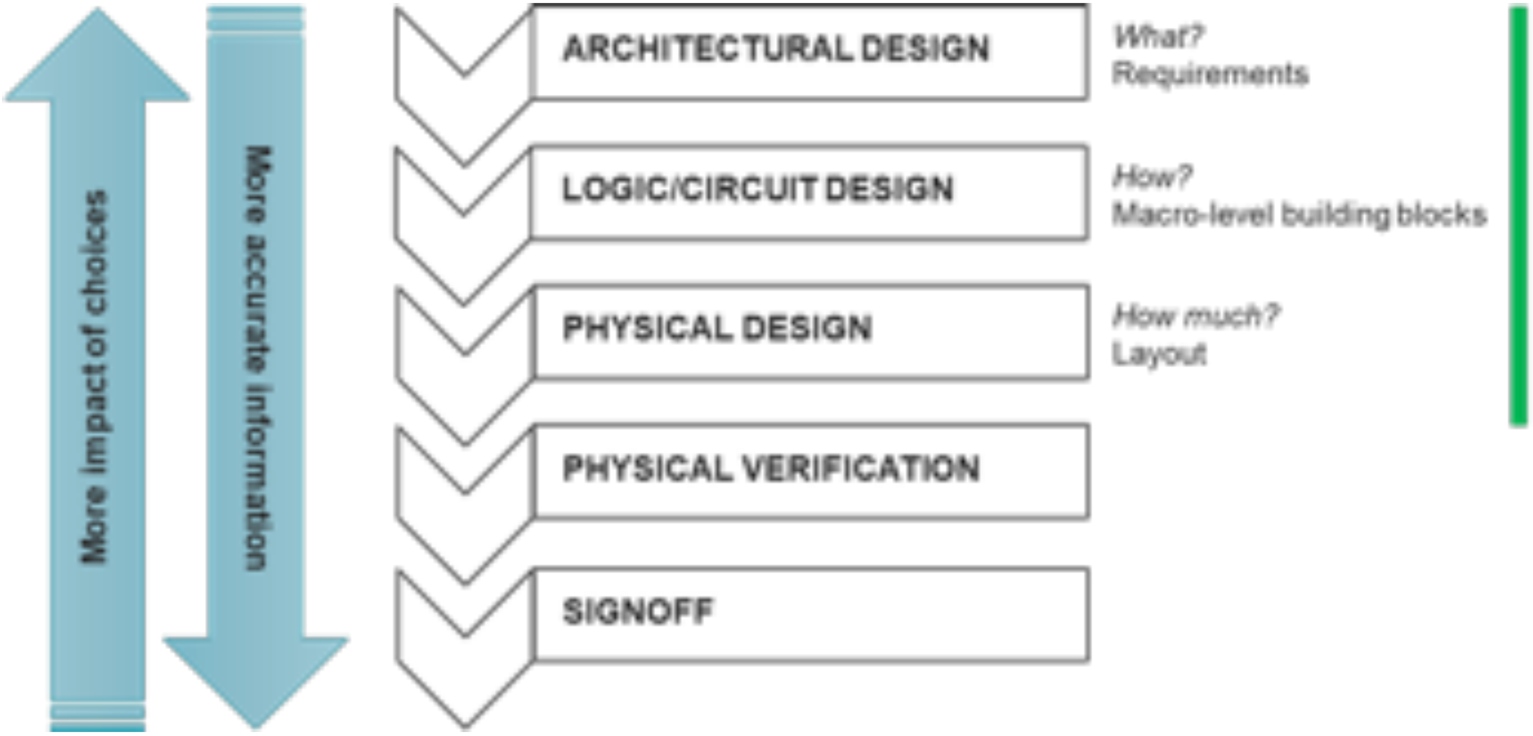


EPoSS, ECS Sustainability and Environmental Footprint,
White paper, July 2023, CEA contribution (B. Robin, C. Sandionigi)



Platform Element example: xR design flow for IC

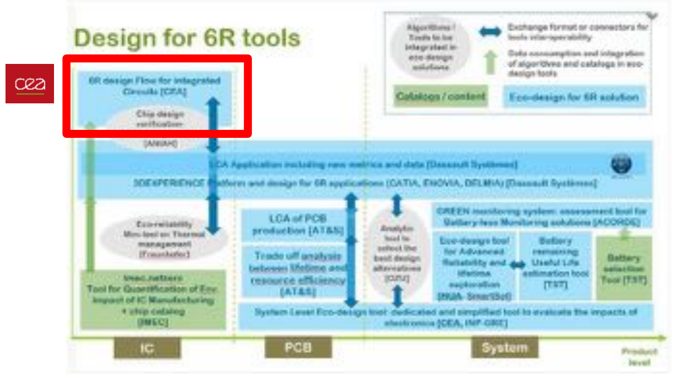
- From traditional design flow to eco-design flow for circularity



EECONE contributions

- Environmental impacts estimation
- Circular economy strategies indicators

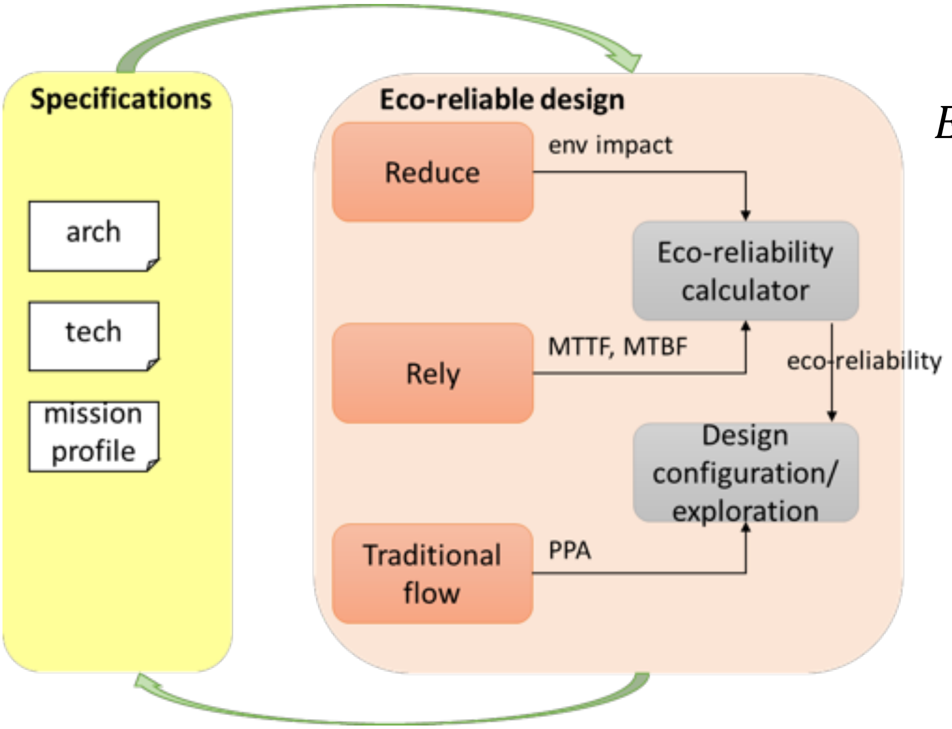
Towards e-waste reduction



Platform Element example: xR design flow for IC (2/2)

- Current status: Eco-reliable design flow

- Eco-reliability: Maximization of the reliability while minimizing the environmental impacts



$$Ecoreliability = \frac{Operating\ time}{System\ Earth\ equivalent\ Time}$$

C. Sandionigi, SusTech 2024, To appear

New generation of electronics

- Objective: Reduction of electronic waste > 25%
  - Introduction of new materials
  - Improved manufacturing technologies to reduce the material usage
  - Modular designs
  - Novel techniques to increase the lifetime of electronics

- Activity example: New IPs to increase lifetime of IC
  - Monitoring of Remaining Useful Lifetime, auto-diagnostic, auto-reparability

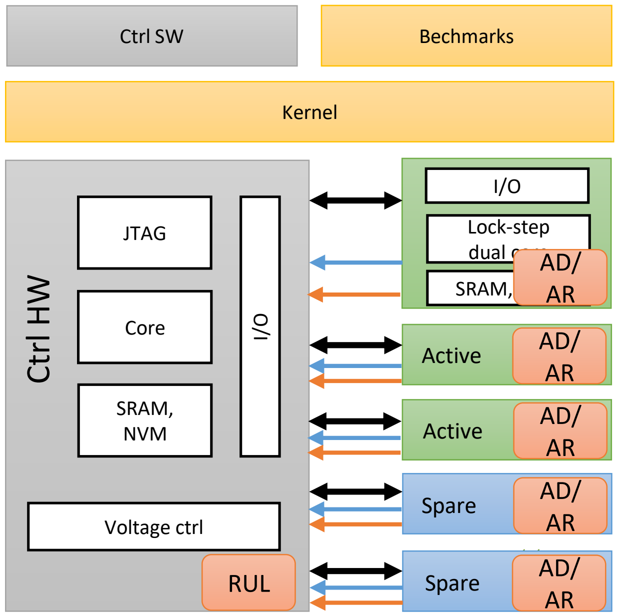
What changes with 6R design flow and lifetime extension IPs?


Knowledge of environmental impacts


Optimized number of active and spare cores


Choice of reliability techniques driven by impacts


Information for reuse



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Ecosystem building

- Have a clear view of ecosystem demands and offers
  - Surveys
    - Map requested needs and available expertise
    - Regularly on eecone.com
  - Standards and regulations
    - State of the art and recommendations

- EECONE contribution for the ecosystem
  - Dissemination
    - Networking events, webinars, publications
  - Education
    - Summer school and MOOC

Showcase environmentally sustainable ECS

		Team	Title	WP-2	WP-3	WP-4
Automotive	UC-01	**BOSCH**, HTV, IZM, AT&S, ORBX, DTI & IFAG	Reducing eWaste from Electrical Control Units for Automotive Industry	✓	✓	✓
Automotive	UC-02	**VITESCO**, SOITEC, SPHEREA, INP-Gr, AT&S, DASSAULT SYSTEM, PREMO & IFAG	Power Electronic Inverter, On-Board Charger and DCDC converters designed for reduced eWaste	✓	✓	✓
Consumer electronics	UC-03	**DTI**, MELSEN, HTV, SYNANO BV	Membrane switches improved via the 6R strategy		✓	✓
Consumer electronics	UC-04	**4MOD**, CEA, DTI, SYNANO BV	Eco-designed remote-control unit		✓	✓
Consumer electronics	UC-05	**ARCELIK**, OzU, WEEECYCLING	Critical Raw Material Value Chain, Traceability Systems and Recycling Strategies in Appliances	✓	✓	
Health	UC-06	**SAL**, HTV, IFAT, PRELONIC, SYNANO BV, CSEM, ORBX	Health monitoring devices employing point-of-care sensors		✓	✓
ICT	UC-07	**RISE**, EcoDC, SVS, UCLouvain, IMEC, INP-Gre, CEA	Reducing data center eWaste via technical LCA-driven refresh and reuse	✓	✓	✓
ICT	UC-08	**UCLouvain**, IMEC, RISE, SPHEREA, Fhg IZM, CEA, THALES DIS	Service life extension of ICT user equipment toward Internet access within planetary boundaries	✓	✓	✓
Aeronautics	UC-09	**LDO**, UniPG, LGE	Sensing electronics for health management system in an aeronautical structural component			✓
Agriculture	UC-10	**TST**, PREMO, ACORDE, SSOL, CSEM, CSIC, DTI, UniPG, LGE	Green Soil Probe – Technologies for green IoT devices for agriculture	✓	✓	✓



Eco-designed Remote Control Unit: From theory to practice

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Rethinking remote controls with Eco-design principles

- While our primary focus is on Remote Control Units, the underlying principles we're developing here have the potential to be applied to a wide range of SMALL ELECTRONIC DEVICES.

Eco-Challenges in Remote Control Design

- Our quest for sustainable remote control design starts with a deep dive. 4MOD LCA expert conducted a comprehensive Life Cycle Assessment (LCA) of our benchmark RCU model.
- This LCA will serve as a crucial starting point, revealing the environmental challenges associated with its entire lifecycle – from material selection and manufacturing to use and end-of-life management.

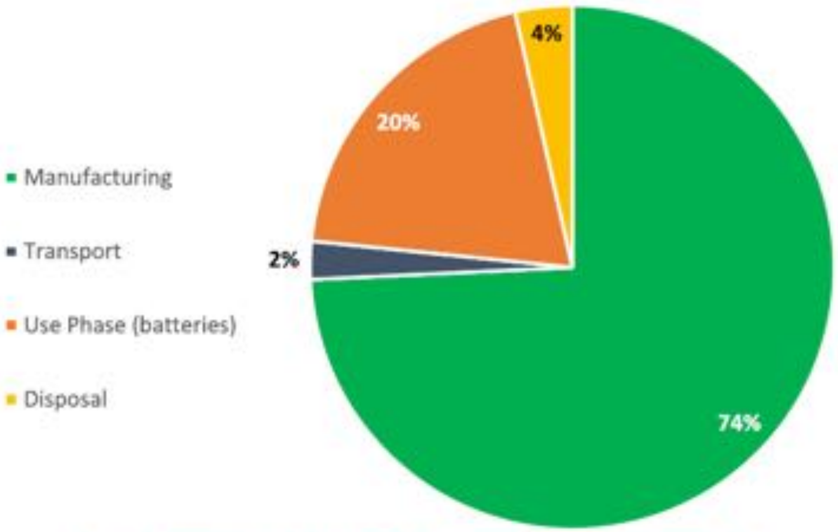

Figure 14: % of weighted score per lifecycle stage (Using the EF 3.1 method weighting factors)

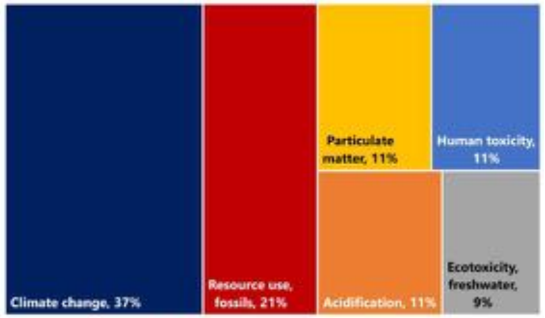

Figure 15: Weight impact categories (Using the EF 3.1 method weighting factors)

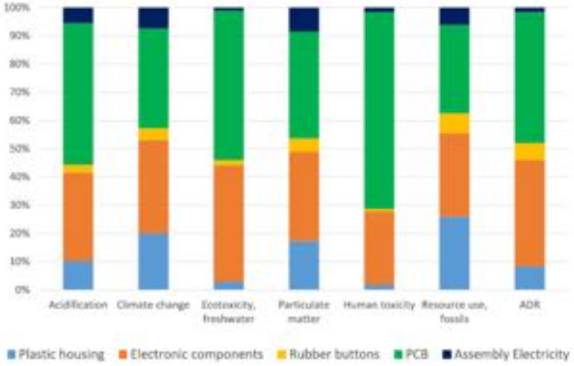

Figure 16: Relative contribution of manufacturing per impact category

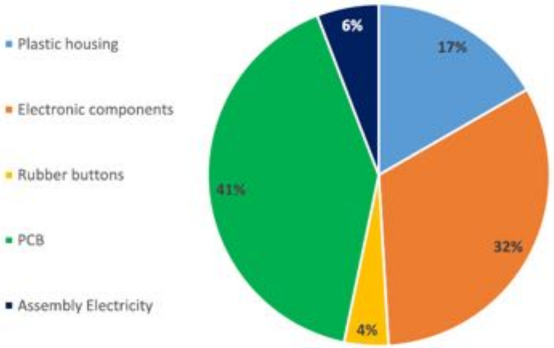

Figure 17: % of weighted score for the manufacturing phase (cradle to gate)

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The Foundation for Our Eco-Design Approach

- Our study will use a recent LCA (July 2023, SimaPro version 9.5) as a starting point to explore new possibilities for more environmentally conscious remote control design. Our LCA is making 2 significant assumptions
  - The RCU will have a lifetime of **8 YEARS**
  - The specific use case of 250 key presses, 120 seconds of voice commands and 8 hours connect to set-up-box

Following the ISO 14040/44 LCA methodology

Utilizing the state-of-the-art ecoinvent database v3.9.1 & custom data

From cradle to grave

Using the Environmental Footprint 3.1 Method developed by the European Commission

ACIDIFICATION
CLIMATE CHANGE
FRESHWATER ECOTOXICITY
PARTICULATE MATTER
RESOURCE USE
WATER USE
TOTAL

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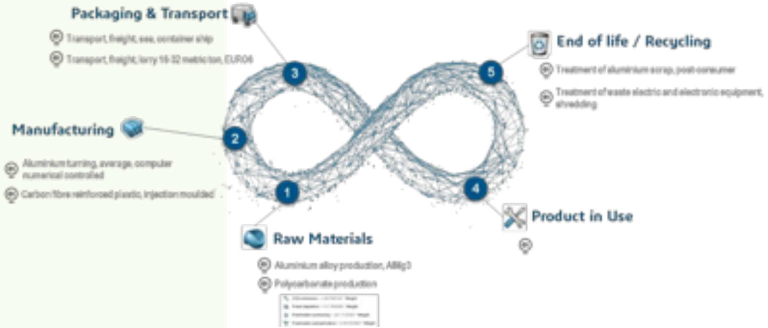
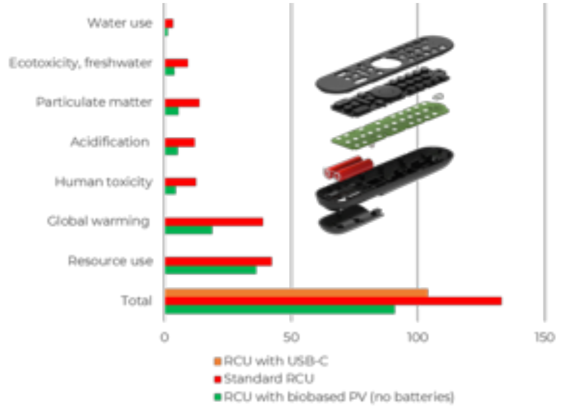
A multifaceted eco-design approach

- Our multifaceted approach leverages the full spectrum of eco-design available tools to create the most environmentally responsible remote controls possible.

Life Cycle Assessment

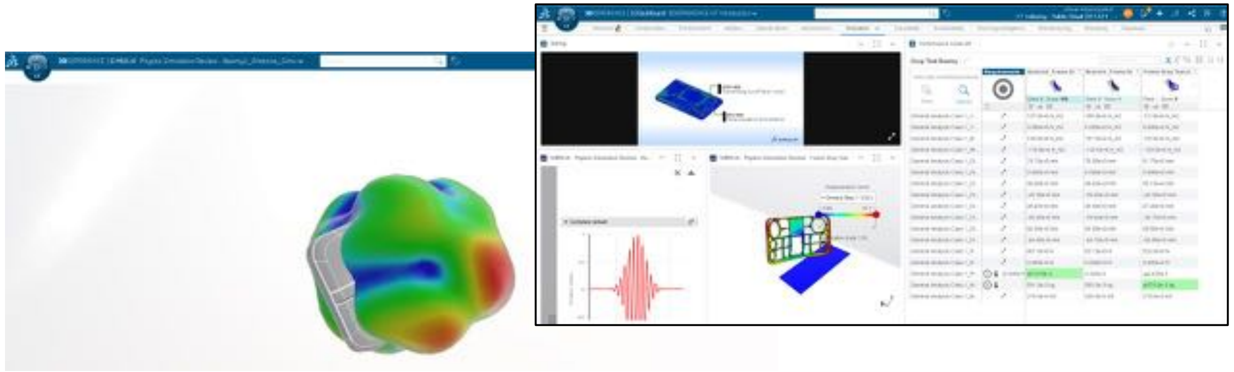




Research & Development

Material	Why this material ?	Limitation	Potential replacement
M-ABS	Esthetics	Oil-based Plastic injection process	**M-ABS bio-based** → would reduce pressure on oil ressources
Silver ink	High conductivity	High ressource use and environmental impact	**Copper ink** → copper is abundant on earth, however it is 8% less conductive than silver and is prone to oxidation
FR4	Fire retardant	Non-recyclable (can't be melted)	**PET** : is recyclable, but has a 1.5% shrink rate which can cause trouble during printing
Silicon	Ergonomics non-slip material	To inquire	Thermoplastic elastomer (TPE) To inquire

Multi-Physics Simulation



A 3-Year Journey Towards an Eco-Friendly Remote Control

- To validate the effectiveness of our multifaceted eco-design approach, we will compare a standard RCU to two optimized versions designed with EECONE 6R principles in mind.

Overall, by avoiding the use of 4 AAA over 8 years and reducing the amount of material used in the PCB.

Our targeted RCU should produce 50% less E-Waste by weight compared to the one we used as our benchmark.

Housing Materials	100% Chemically and Mechanically Recycled plastic. Rubber free keys utilizing an ultra-thin PE layer above the PV cells.
PCB	100% replaced with PCB using low environmental impact flexible substrates, conductive inks and using an additive manufacturing process. Having at least 50% less Environmental impact then traditional PCB.
Use Phase	Ultra-low energy demand Bluetooth chip. The lower power consumption allows the batteries to be replaced with a Biobased photovoltaic cell and a hybrid supper cap.
End Of Life	RCU designed to be easily repairable Refurbished, no glue, PCB can be removed by hand without tools.

Housing Materials	70% Mechanically Recycled plastic
PCB	70-50% of traditional PCB replaced with PCB using low environmental impact flexible substrates, conductive inks and using an additive manufacturing process.
Use Phase	Ultra-low energy demand Bluetooth Chip reducing AAA battery requirements from 8 to 4 over the 8-year use phase.
End Of Life	RCU designed to be easily repairable Refurbishable, no glue, PCB can be removed by hand without tools.

Housing Materials	Fossil fuel-based plastics used for plastic case and synthetic rubber buttons
PCB	traditional FR4 and copper-based 2-layer PCB.
Use Phase	Standard Blue tooth Chip using 8 batteries over 8 years.
End Of Life	Not specifically designed for repair and disassembly

Ensuring Consistency and Measurable Progress

- To ensure a consistent and replicable approach for evaluating the sustainability of each RCU generation, we have identified a defined set of features and criteria for each of the RCU.
- By comparing these features across different RCU generations, we can accurately measure progress towards our eco-design goals.

RCU Features (Beyond the State of the Art)

State-of-the-art technology refers to technology that is currently the best available. This can be a somewhat subjective term, as what is considered state-of-the-art in one field or industry may not be in another. Generally speaking, state-of-the-art technology is **the most advanced technology available in a given field or industry**.

State of the art as of [illegible] (creation of this page)

Antenna

State of the Art	EECONE Innovation
Conventional rigid designs	Flexible organic substrates / conductive inks
Silver ink	Graphene or copper ink

Antenna + PCB Manufacturing

State of the Art	EECONE Innovation
Subtractive methods with hazardous chemicals, waste, bio-incompatibility	Printing-based additive manufacturing, eco-design

Battery

State of the Art	EECONE Innovation
Primary batteries (e-waste)	Use rechargeable batteries
	Use solar-powered technology
	Use radio frequency energy harvesting
	Use ambient light harvesting (sunlight + lamp lighting)
	Recycling models, no primary batteries

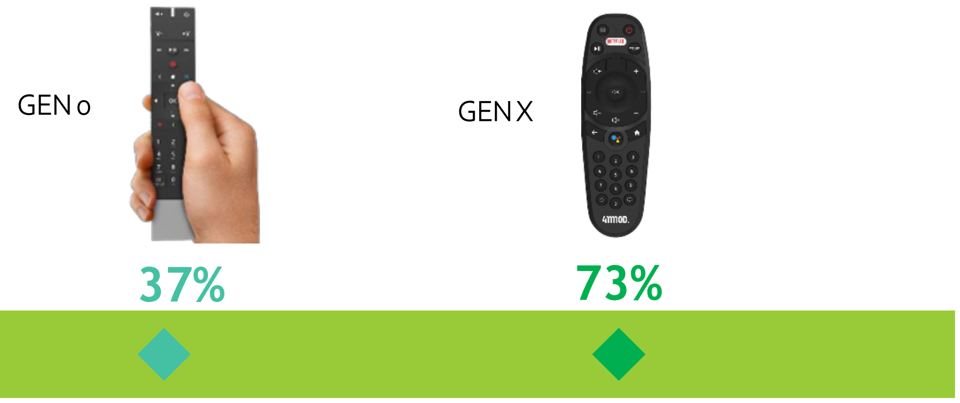
Binding Agent

State of the Art	EECONE Innovation
Use a binding agent that doesn't hinders electrical conductivity	

Non-exhaustive list

PERFORMANCES

Criterion	RCU Value
For the 3 simulation scenarios, test the matching level	dB
For the 3 simulation scenarios, test the realized gain	dBi
For the 3 simulation scenarios, test the resonance frequency	GHz
Operating conditions Humidity Range	20% ~ 75% RH
Operating conditions Storage Temperature	-20° ~ 60° C
Operating conditions Temperature Range	10° ~ 50° C
Use a binding agent that doesn't hinders electrical conductivity	Bi-functional binders (having zwitterion-like structures)
Withstand high humidity test for storage	95% humidity for 48 hours at 40°C
Withstand vibrations	10 ~ 30Hz, Direction: 3 axis (X, Y, Z) 30 minutes each direction



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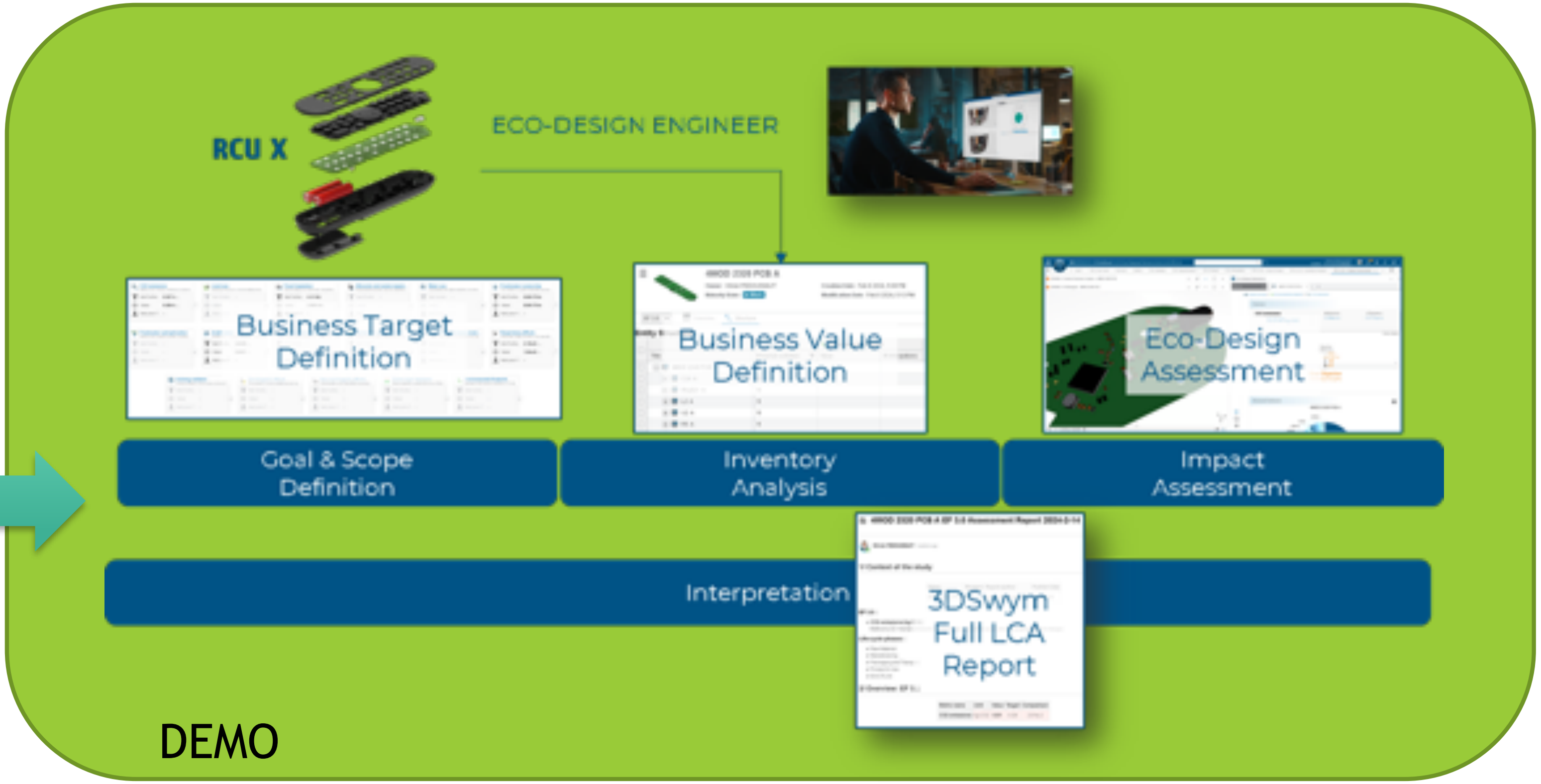
Defining a Common Scenario for Sustainable RCU Design

- To ensure consistent and comparable evaluation of our remote controls across generations, we're developing a common scenario.
- This standardized scenario will replicate a typical usage pattern and environmental context. By applying this scenario to each RCU generation, we can objectively measure progress towards our sustainability goals and identify areas for further improvement.
- This approach ensures a level playing field for comparison and provides a reliable benchmark to track the evolution of our eco-friendly RCU designs.

🎬 ECO-DESIGNED RCU DEMONSTRATOR (Storyboard)

- ☐ Introduction & Objectives
- ☐ Specifications
- ☐ RCU Design Part 1 - MCAD Import
- ☐ RCU Design Part 2 - ECAD Import
- ☐ RCU Design Part 3 - MCAD/ECAD review
- ☐ RCU Simulation - Drop Test
- ☐ RCU Simulation - Vibration Test
- ☐ RCU Simulation - Key test strength
- ☐ RCU Simulation - Electrostatic Discharge
- ☐ RCU Simulation - Antenna
- ☐ RCU LCA (Goal & Scope)
- ☐ RCU LCA (Inventory Analysis)
- ☐ RCU LCA (Impact Assessment Part 1)
- ☐ RCU LCA (Impact Assessment Part 2)
- ☐ RCU LCA Interpretation (report + review)
- ☐ RCU End of Life



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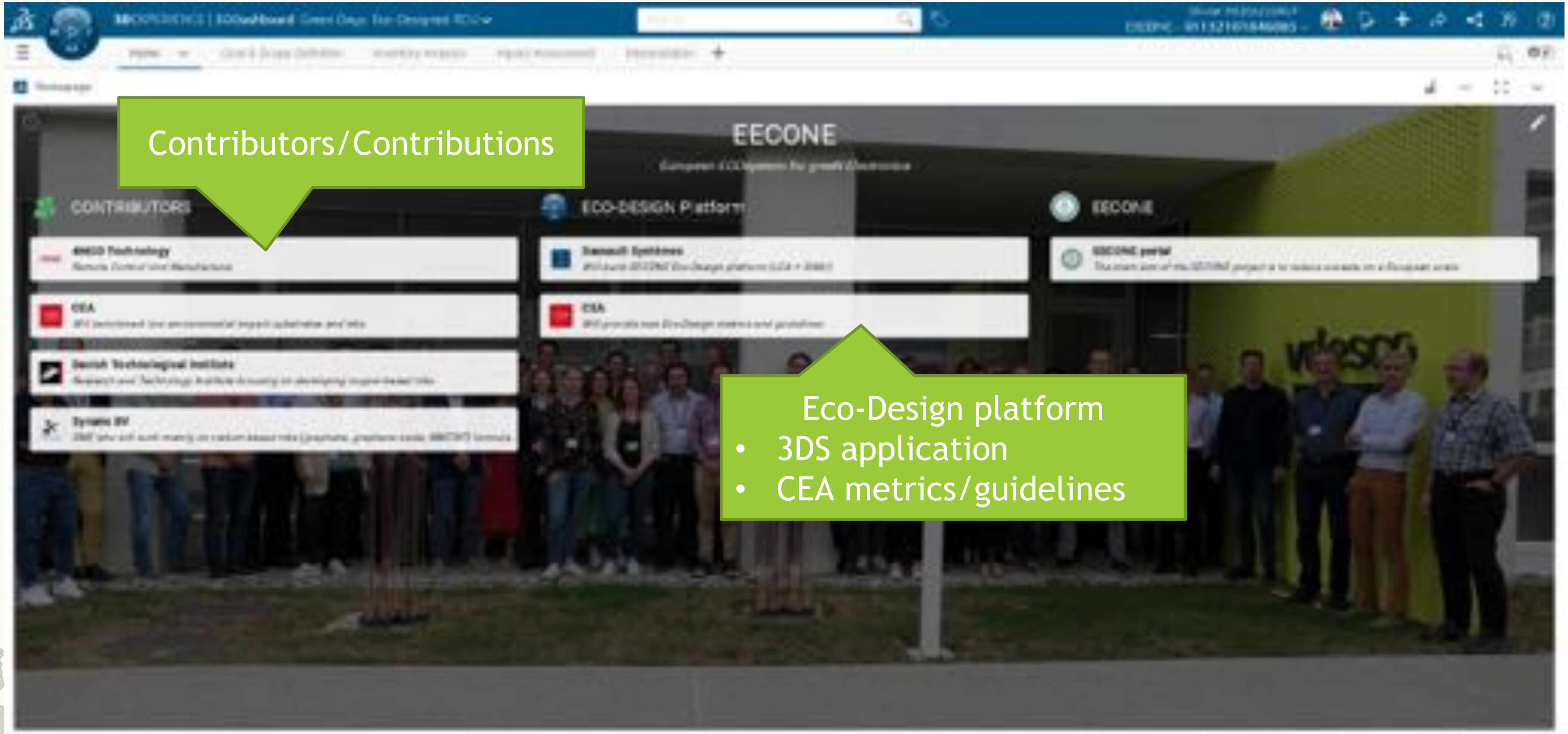
DEMO STEP 0: Intro



DEMO STEP 1: LCA/Define Scope & Target

BOM + 3D directly linked
To LCA

Scope & Target Definition
- 3701 as reference
- REGO improved target = 50%

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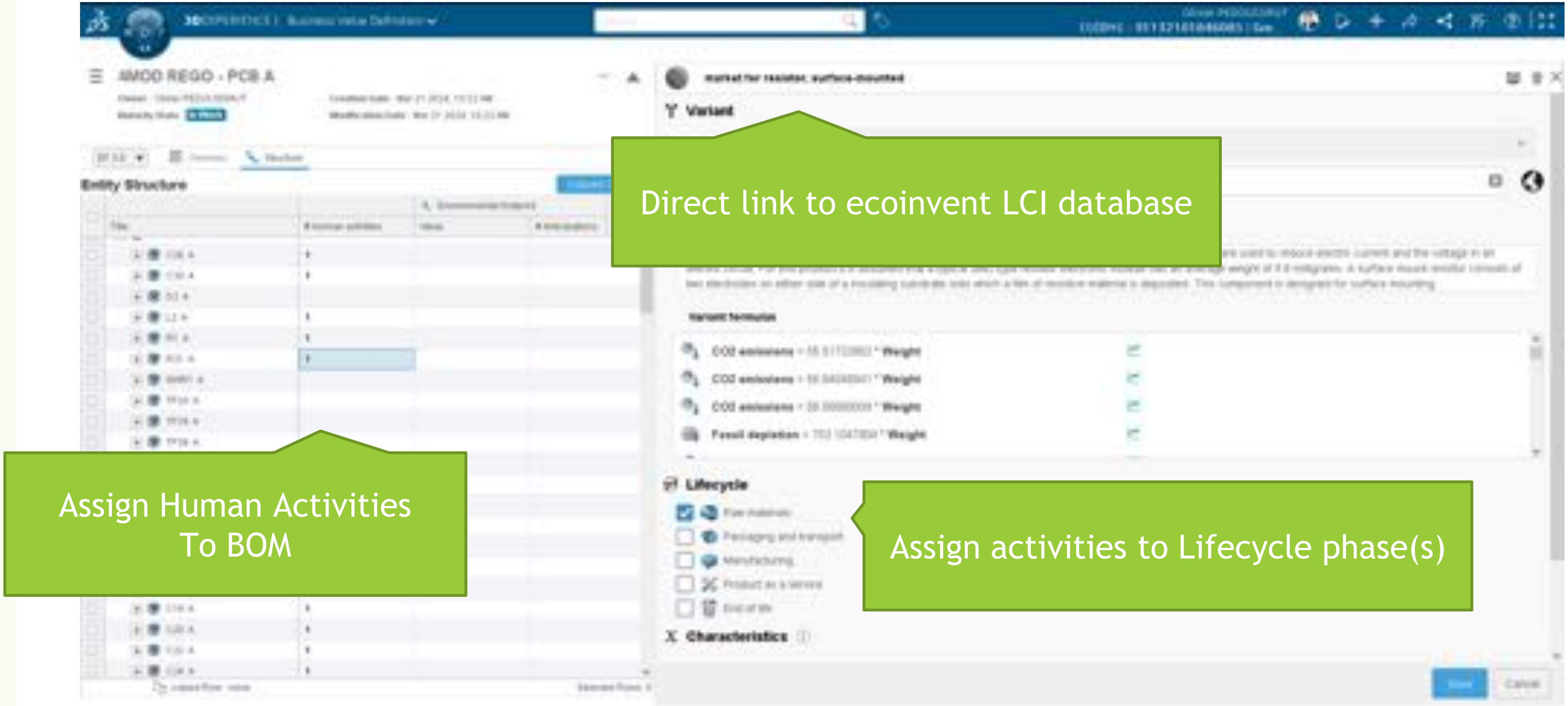
DEMO STEP 2: Inventory Analysis



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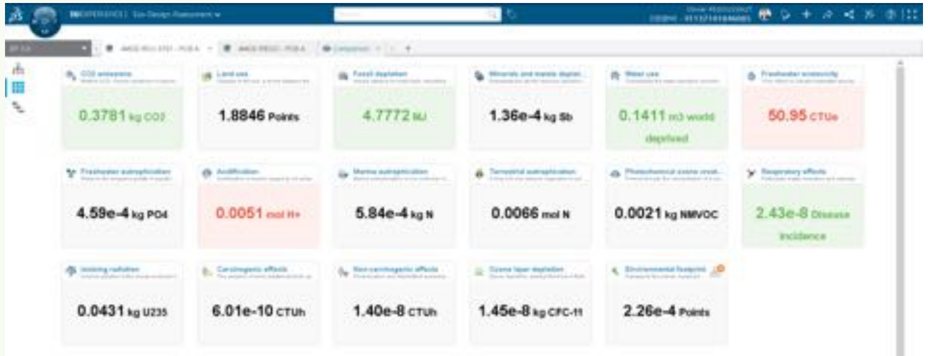
DEMO STEP 3.1: Impact Assessment (Global/Metrics)

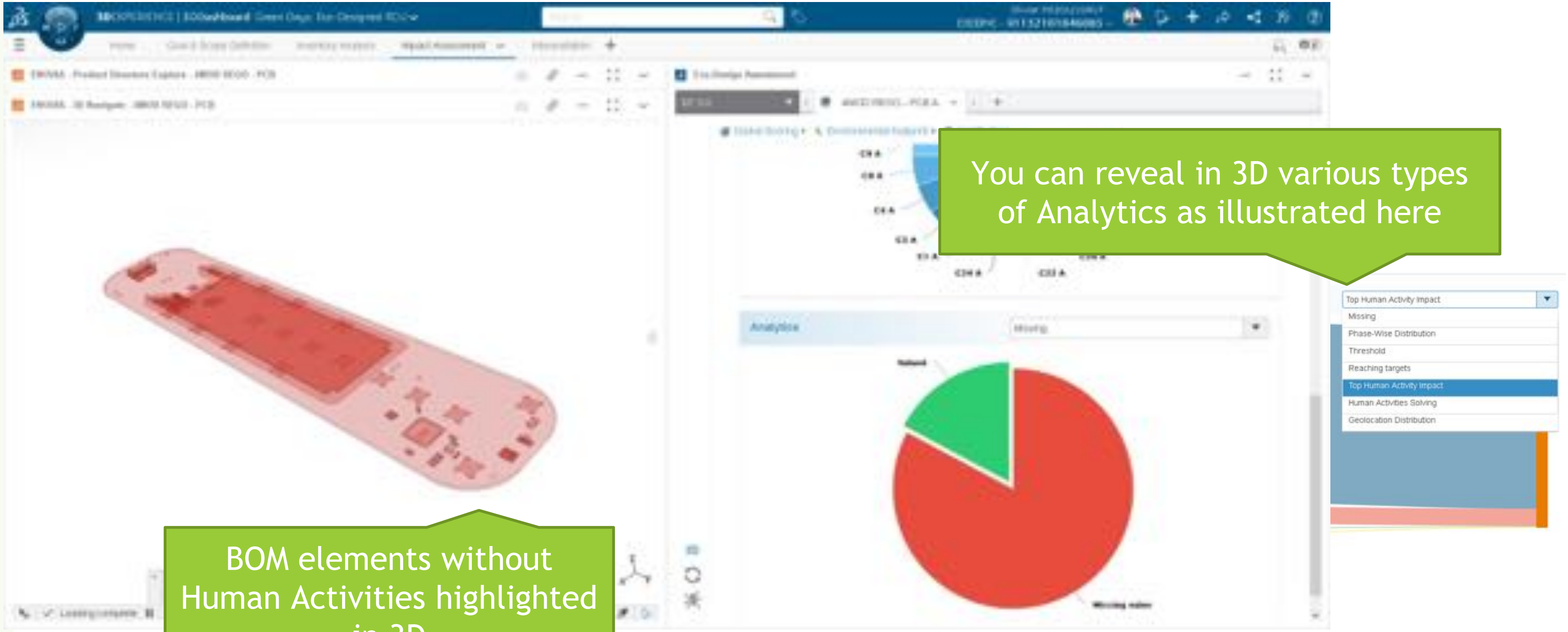


EF3.0 global score
16 metrics score

Detailed view per metric

- Objective
- Top Human Activity Impact
- BOM distribution

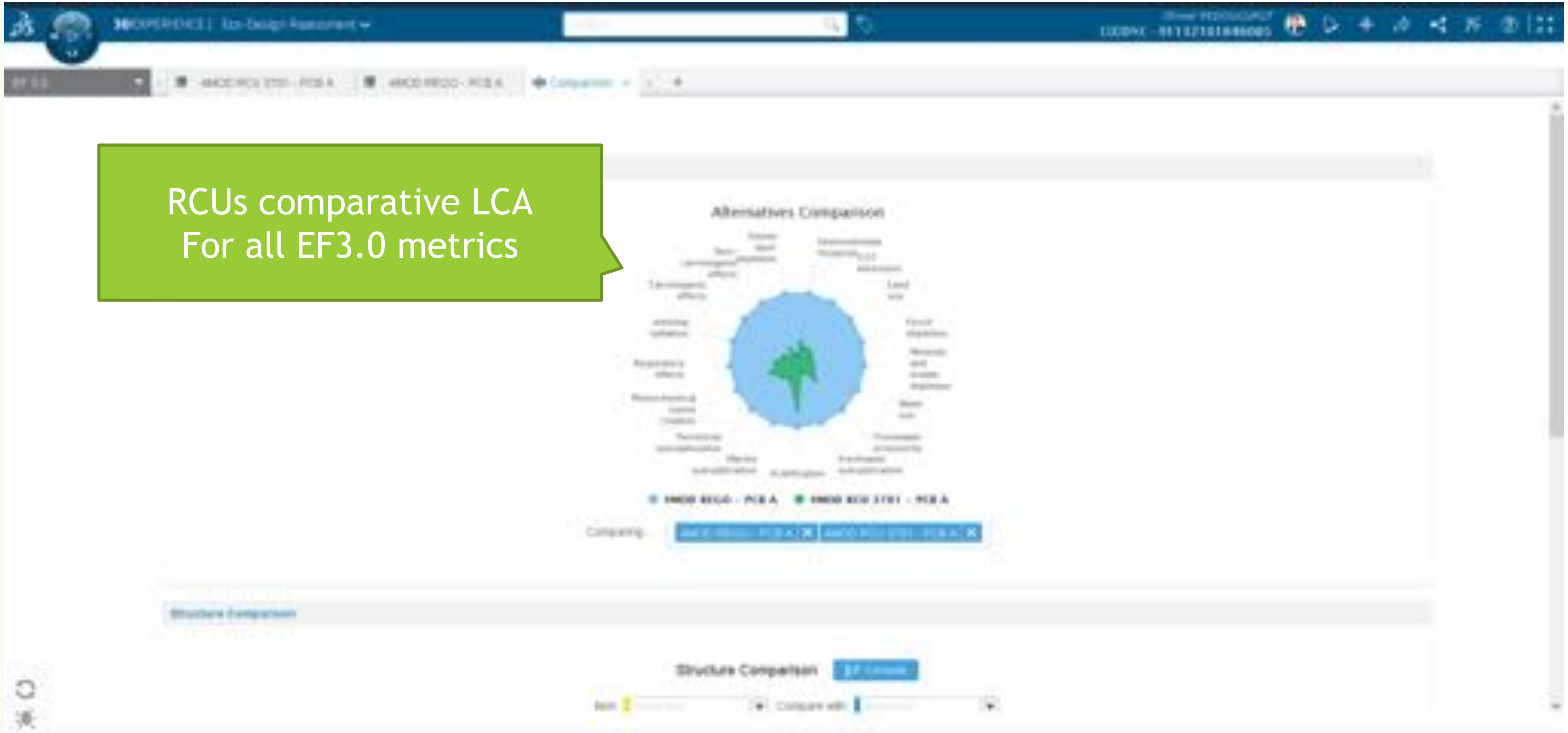
DEMO STEP 3.2: Impact Assessment (Reveal in 3D)



You can reveal in 3D various types of Analytics as illustrated here

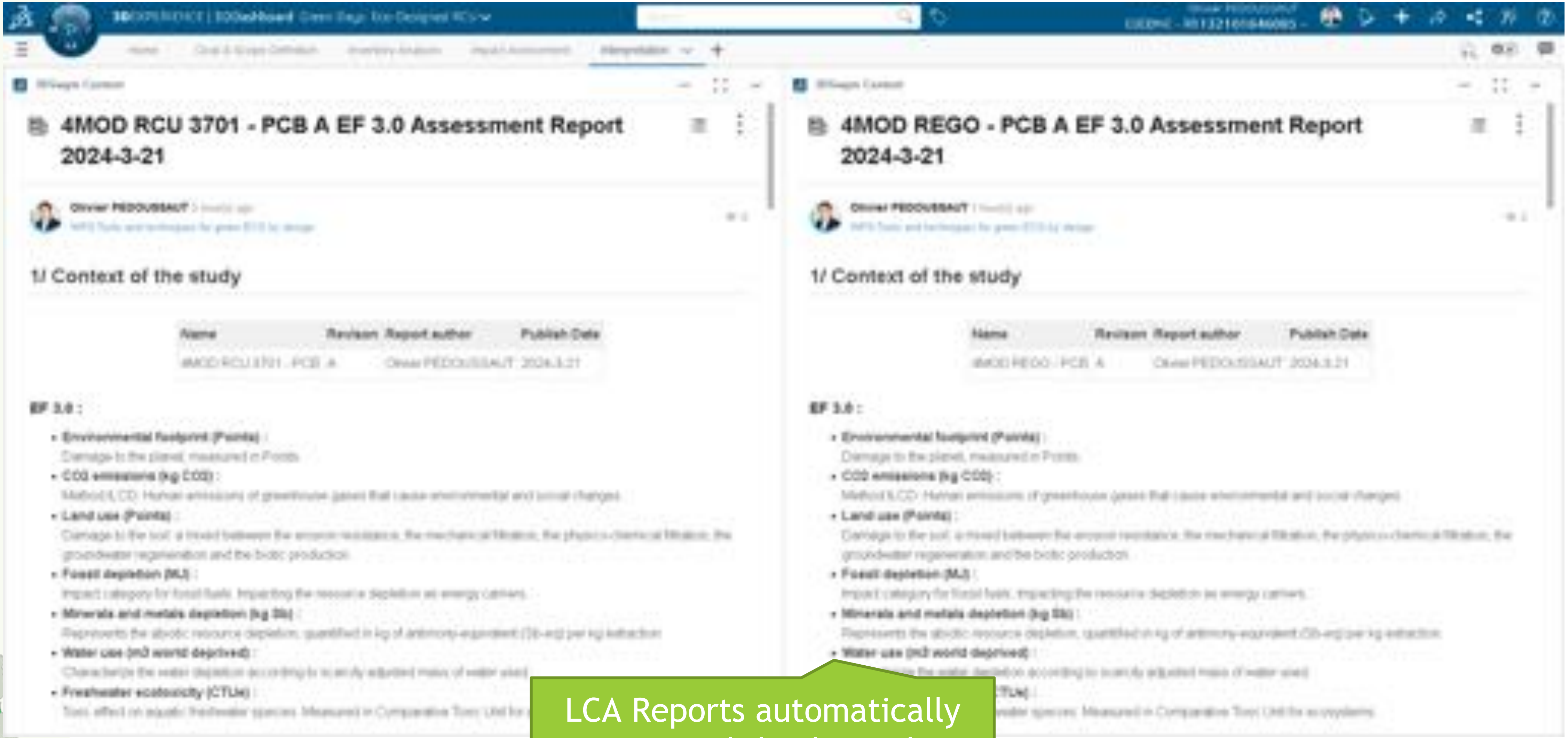
BOM elements without Human Activities highlighted in 3D

DEMO STEP 3.3: Impact Assessment (comparative LCA)



RCUs comparative LCA
For all EF3.0 metrics

DEMO STEP 4: Interpretation



LCA Reports automatically generated thanks to the Impact Assessment results

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Circularity Rating

- In our pursuit of the most eco-friendly remote control design, we're introducing a novel concept: a weighted circularity rating system. It considers a holistic range of parameters crucial for sustainable design:
  - **Environmental impact**: Minimizing the lifecycle footprint of the remote control.
  - **E-waste reduction**: Prioritizing designs that generate less electronic waste.
  - **Performance**: Ensuring the remote control functions effectively and reliably.
  - **Cost**: Balancing affordability with sustainable practices.
  - **User experience**: Creating a remote control that is intuitive and enjoyable to use.

RCU	Circularity Rating	E-Waste Reduction Score (Recycling, Reliability, Reduce)	LCA Score	Performance Score	Cost Score	User Experience
Sustainability Weight		2	2	1,25	1	1,25
Benchmark RCU	C	B	C	B	A	B
ECO DESIGNED GEN 1 RCU	B	B	B	B	B	B
ECO DESIGNED GEN 2 RCU	A	A	A	B	B	A

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Global vision:
The paths towards eco-innovation

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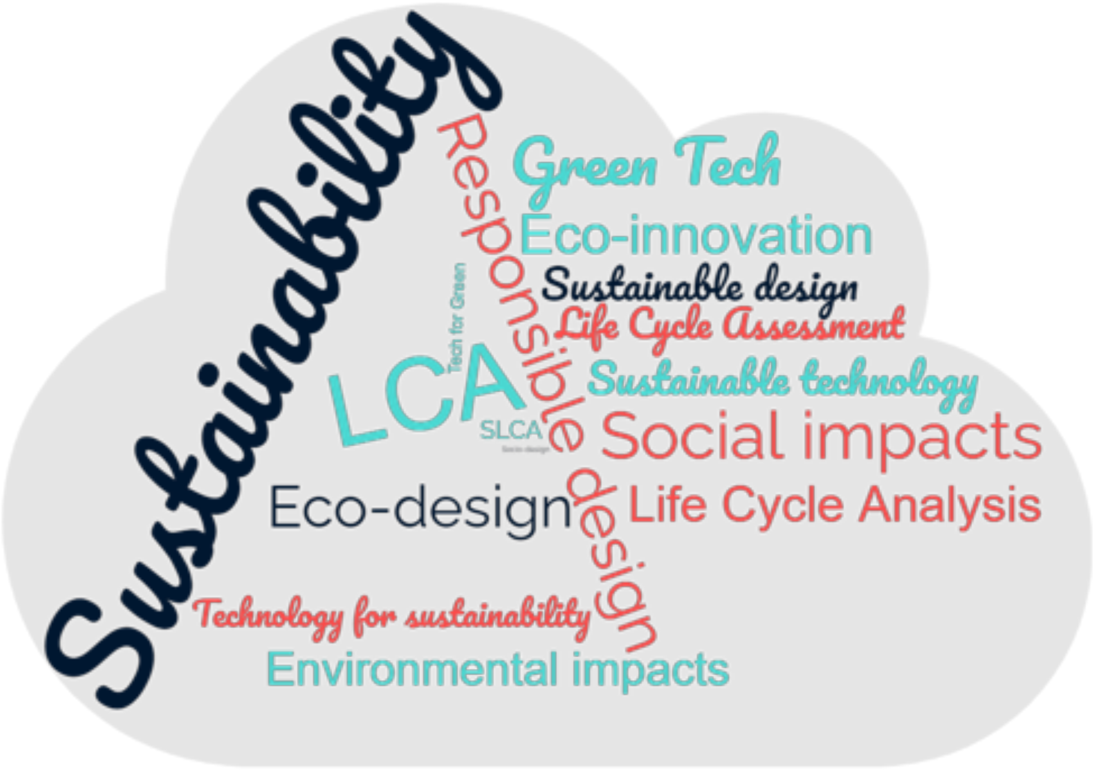
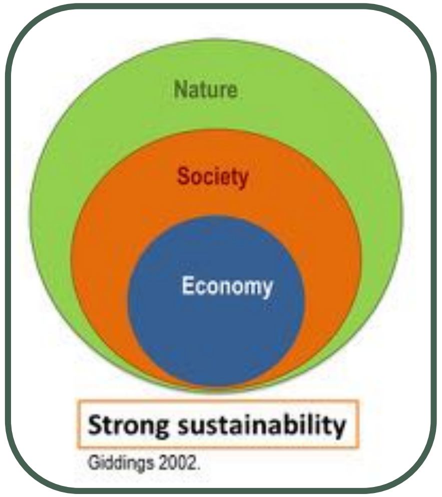
Technology and sustainability: A maze of concepts

- Wide and wild use of various terms to link technology and sustainability
- Risk of collapse of the concepts

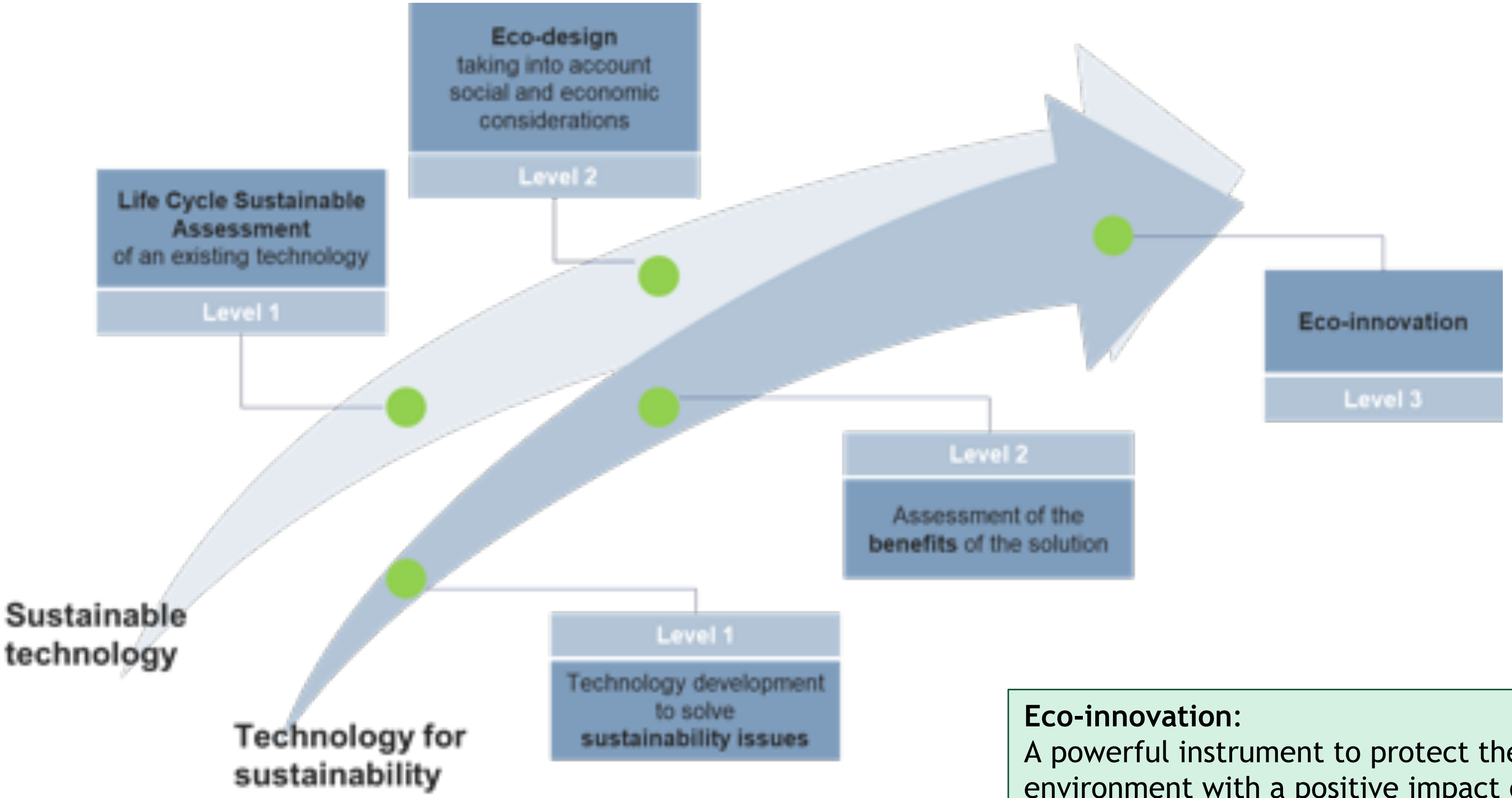
Sustainability:
Ability of meeting the needs of the present without compromising the ability of future generations to meet their own needs

Bruntland report, 1987





Two paths towards eco-innovation



Eco-innovation:
A powerful instrument to protect the environment with a positive impact on the economy and society

C. Sandionigi, J. Berrée, M. Peralta, A. Piel, B. Robin, EGG 2024

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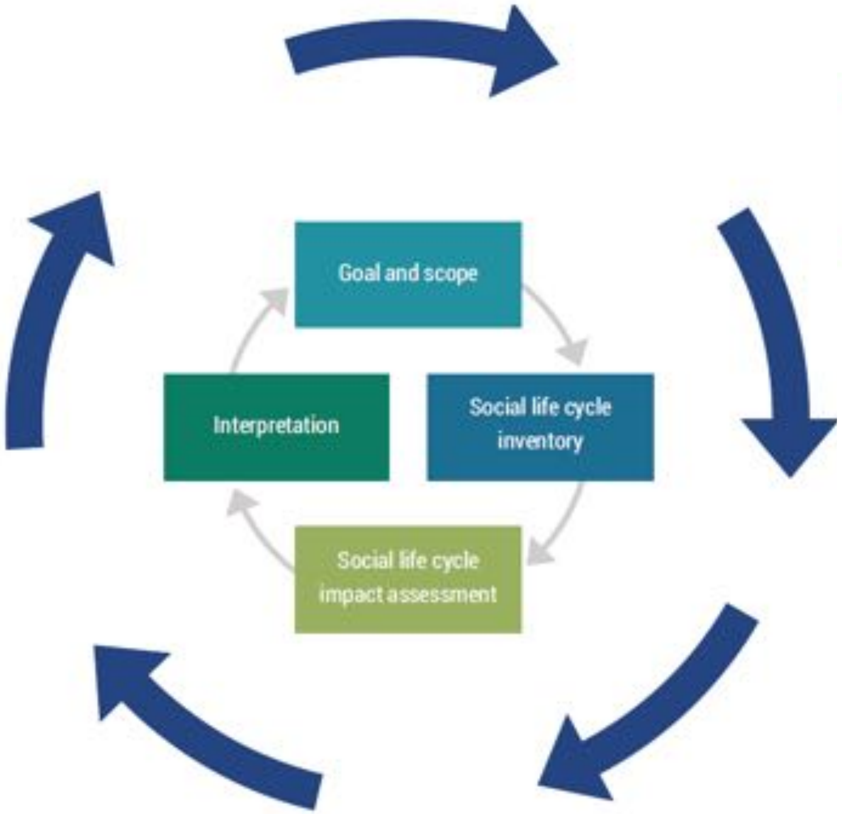
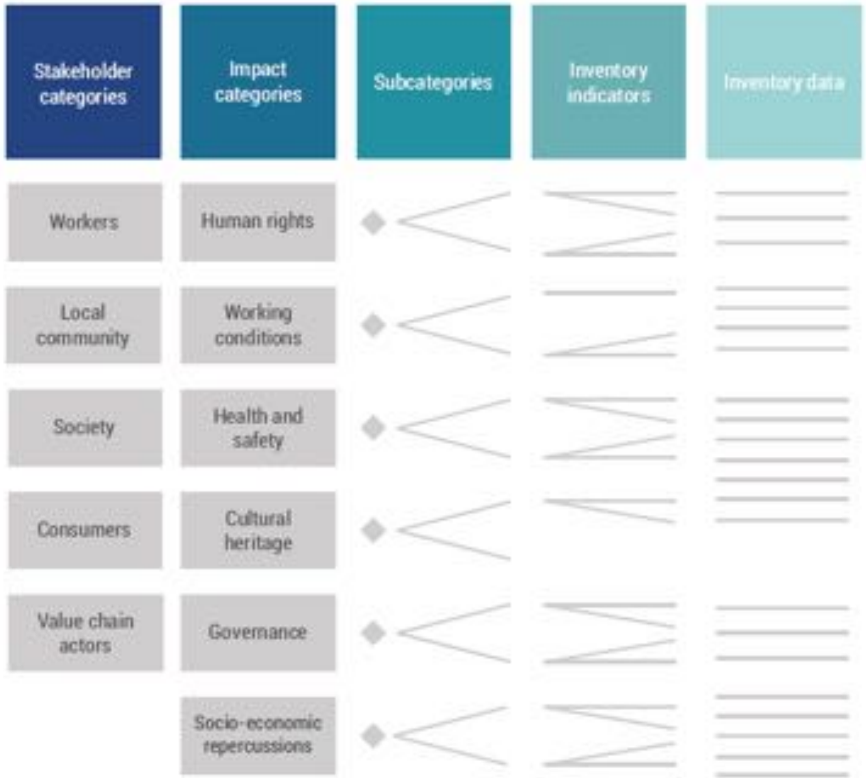
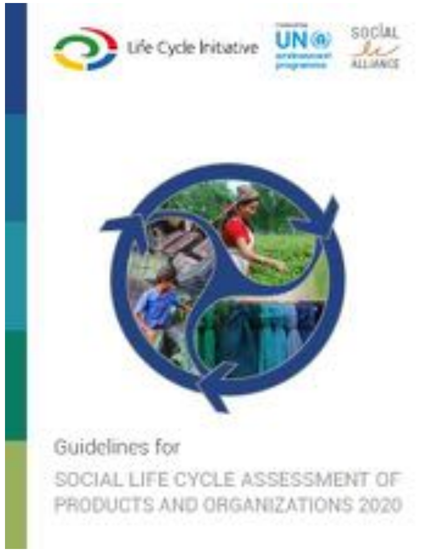
… without neglecting social impacts

- S-LCA: A framework to better understand and address social impacts

ISO 14075







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Recycling quiz: https://www.eecone.com/eecone/survey/?id=90

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