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DEVELOPMENT OF INNOVATIVE AND ECO-FRIENDLY AIRFRAME TECHNOLOGIES TO IMPROVE AIRCRAFT LIFE CYCLE ENVIRONMENTAL FOOTPRINT – LIFE CYCLE ASSESSMENT ACTIVITIES AT ECOTECH / CLEANSKY 2

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Abstract

The activities of ALTRAN as partner in ecoTECH, on the data collection at the flagship demonstration level developed during the consortium are addressed: The following topics will be briefly described at technology and demonstrator level.

- Metallic Fuselage
- Thermoplastic Fuselage Panel
- Thermoset wing/fuselage
- Cabin Interior (Magnesium and Biomaterials)

The data collection process and the life-cycle assessment process will be explained and an example for the achieved results will be given. Furthermore, the challenges in the data acquisition will be addressed and discussed at length.

Keywords: life-cycle analysis, sustainable development, lightweight materials, REACh, environmental impact

1. Motivation [1-6]

Operational and societal considerations are leading to an increasingly high demand for aircraft with lower fuel consumption, lower noise, lower pollutant emissions and lower maintenance costs. From an operational perspective, the materials used for manufacturing aircraft components need to be lighter, less expensive, and more environmentally friendly for disposal. These components include the composite wing, the metal or composite fuselage, and the cockpit structure. From an environmental and societal perspective, it will be necessary to reduce the environmental footprint of aviation through aircraft performance improvements (drag, weight, and versatility) and an environmentally friendly life cycle that comprises a significant increase in recyclability and optimized material flows.

This will be achieved by developing new processes, methods and manufacturing and recycling technologies that will enable Green Manufacturing, Green Maintenance and Green disposal and End of Life (EoL), under affordable conditions by implementing a European logistic network for EoL aviation materials. This also addresses the challenge set by the Advisory Council for Aeronautical Research in Europe (ACARE) for a substantial progress in reducing the environmental impact of the manufacture, maintenance and disposal of aircraft and related products by 2020 and beyond.

To address these challenges, the technical activities in ecoTECH will be aligned in two axes:

- Developing enabling eco-friendly technologies in the field of materials and surface treatments, manufacturing processes, maintenance, and repair, as well as end of life processes. This will be achieved by complementing the technology portfolio addressed in CS1 ECO-DESIGN ITD (Clean Sky 1 eco-design integrated technology demonstrator) and bring the portfolio’s contents to TRL (technology readiness level) 6 and by considering less

mature technologies (TRL 3 to 4) and bringing them to TRL 5 to 6.
- Exploiting the key enabling technologies to design, manufacture, and test appropriate ground demonstrators at representative scale of the airframe component.

The environmental benefit brought by the newly developed technologies can be addressed through Life Cycle Assessment activities. In addition, ecoTECH has been promoting and implementing the Design for Environment (DfE) state of mind throughout the life cycle and end of life of the aircraft structure.

ecoTECH builds on the successful results and lessons learnt from the Clean Sky 1 ECO-DESIGN ITD and will be a natural continuation of these activities in Clean Sky 2. A key strength of the ecoTECH consortium is the participation of the key stakeholders of the ECO-DESIGN ITD which ensures familiarity with the procedures and requirements.

1.1 Life Cycle Analysis activities at ALTRAN

The life cycle assessment is a method according to ISO 14040 used to assess the environmental impacts associated with the various phases of the life cycle of a particular product or material. This fact-based analysis can consider the impacts associated with the extraction, manufacture, distribution, use, and disposal of a product. An assessment only over parts of the life cycle is possible. In this project, the scope was defined to include raw material extraction, product manufacture, use and maintenance.

In a life cycle assessment (LCA), the environmental impacts (especially the CO_2 footprint and energy requirements) of the new technology were assessed. The risk assessment identifies all risks that would jeopardize positive results.

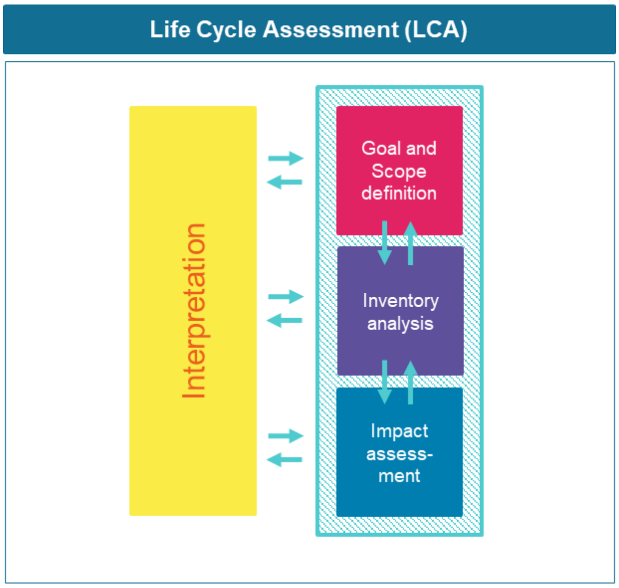

Figure 1 – LCA process

During the last years, ALTRAN has developed its own way of working, by applying the so-called integrative life-cycle analysis approach. In this process, the so-called “hot-spots” i.e., manufacturing steps, materials & processes which contribute negatively to costs or environmental impacts can be identified, thus enabling a prompt and pro-active risk mitigation during design, manufacturing, maintenance & repair, and end-of-life phases of any technological development (e.g. wind turbine, controllable polyelectrolyte membrane fuel cells). Therefore, with the help of the integrative LCA approach, ALTRAN can support industries during the sustainable development & optimization of new technologies by:

1. Assessment of each input for material toxicity, energy demand, global warming potential to target the inputs that have the most environmental impact.
2. Assessment of each input for material cost and availability, thus helping to identify possible

bottlenecks in the material flow.

3. Optimization Potential: New technologies and innovative solutions are considered when making recommendations to address hot spots and incorporate new approaches to eco-design.

The advantages of the integrative LCA are depicted in the Figure 2.

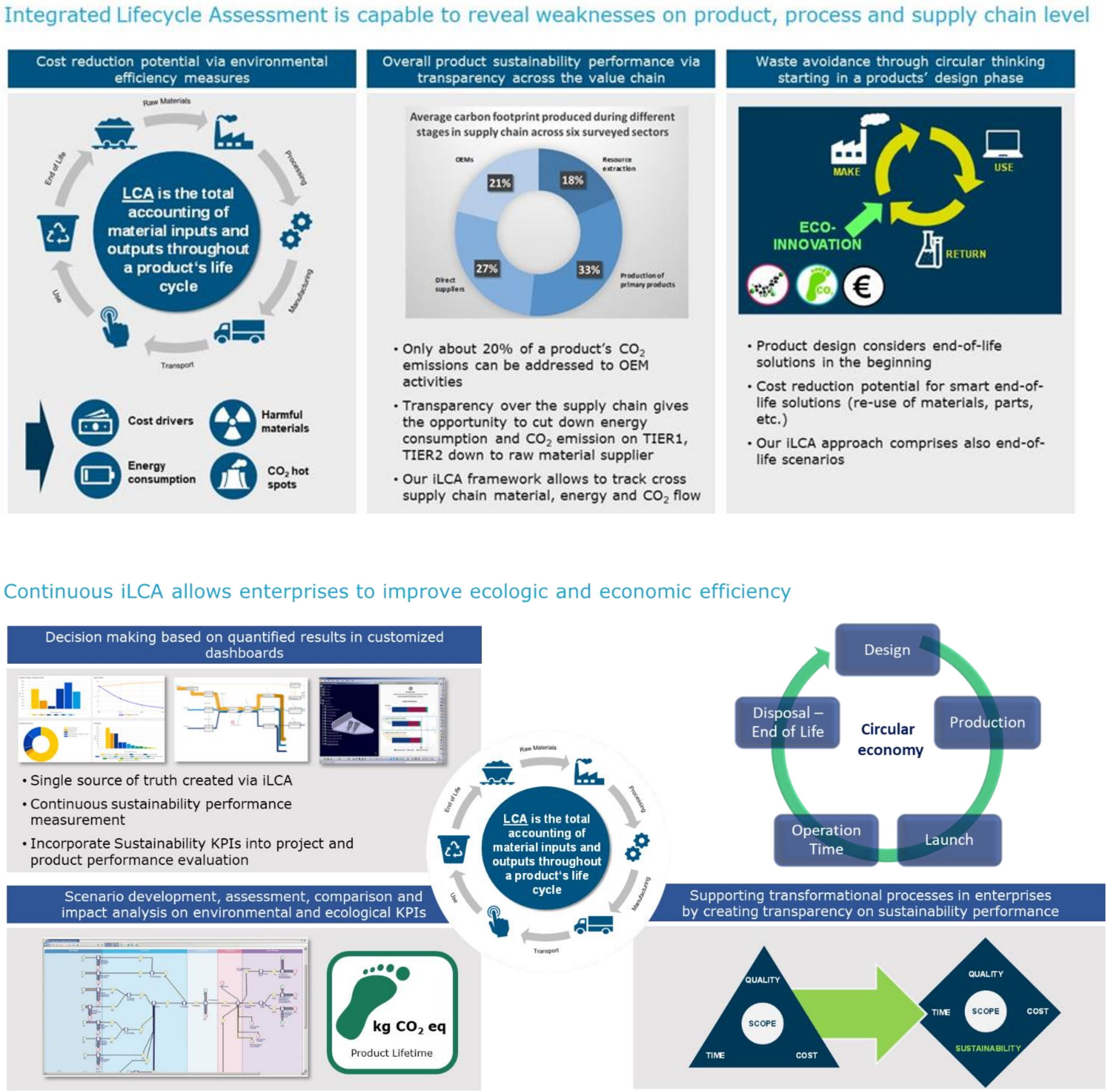

Figure 2 – Overview of the integrative LCA approach and its impact on the ecologic and economic efficiency of the process

1.2 ALTRAN's role in ecoTECH data collection

As part of the Clean Sky (CS) Airframe Integrated Technology Demonstrator Platform, Fraunhofer, Altran and the University of Stuttgart (IABP) have developed life cycle assessments (LCI) of airframe technologies. The CS joint venture is the largest European aeronautics research program and promotes research activities to develop significantly quieter and more environmentally friendly aircraft. To assure the eco-design approach and to guarantee the improvement of the environmental performance of the new materials and technologies under investigation, this group is working on new life cycle analyses of Clean Sky Airframe technologies. The main investigation areas include: Metals and Surface Treatments (innovative chromate-free surface protection systems for metal alloys, new machining processes, use of lighter alloys); Thermosets (new processes for cure monitoring, welding, local self-healing treatment, and selective color deposition); Thermoplastics (new deposition and recycling processes, innovative production techniques using recycled materials); and Biomaterials (new manufacturing systems, new foams with improved fire protection and reduced toxicity). The main objective of this activity is to produce high-quality aviation specific LCI and LCA datasets to evaluate new innovations in the aviation industry. These LCIs are based on robust and accurate data provided directly by industry and leading research partners: Israel Aerospace Industries, Hellenic Aerospace Industry, NLR, AeroMagnesium, AkzoNobel, Lortek, INASCO, Invent, Delft University of Technology (TUD), University of Patras (UPAT), University of Stuttgart (IFB) and Fraunhofer. Currently, more than 80 new technologies are being modeled, mainly gate-to-gate. These LCI data are delivered to the cross-cutting activity Eco-design, led by Fraunhofer, to assess the environmental impact of airframe demonstrators, such as thermoset wings, thermoplastic and metallic fuselage, and cabin interior parts.

Here the so-called integrative LCA approach was not considered.

Table 1 summarizes the technologies developed during the ecoTECH consortium.

Table 1 – List (non-exhaustive) of the technologies and materials investigated during the ecoTECH consortium.

Name of Technology
Aluminium-Lithium alloys
Forming of new Aluminium-Lithium alloys
Environmental friendly machining processes for new Aluminium alloys
New resins
Improved vacuum infusion process using SMART tool with sensors and integral heating
Mould Supervisory System
Manufacture of Chrome-free, corrosion inhibiting primer based on leaching inhibitor technology
Manufacture of Chrome-free, corrosion inhibiting primer based on galvanic protection mechanism
Sol-gels
Thin Film Sulphuric Anodizing
Selective Paint Stripping
Out of autoclave oven prepreg (open mould)
Smart Mould
„One Shot“ moulding and cure process
Thermoplastic welding for repair
Scrapping Thermoplastic materials

Compression molding
Fibre placement using laser
Continuous ultrasonic welding of thermoplastic composite structures
Laser Beam Welding
Friction Stir Welding
Magnesium Alloys (Materials)
Surface protection systems for magnesium Alloys
Die -forging of Magnesium alloys
Press bending of Magnesium sheets
Investments casting of Magnesium alloys
High precision machining of Magnesium solid bar/rolled plate
Bio (Green) foam, bio sandwich microwave cured skins
Local application of self-healing concepts in composite structures
Low energy curing
Advanced Ply placement robotic cell
Ultrasonic Welding
Binder application and activation
Spread Tow Winding
Wire Arc Additive Manufacturing (WAAM)
Casting of new Aluminium alloys
Wire drawing of Aluminium-Lithium alloys
Aluminium Alloys Recycling
Biomaterial End-of-Life

2. ecoTECH technological development at the demonstrator phase [1-5]

The objectives and benefits of ecoTECH include:

- 30% cumulative reduction in CO_2 emission for Airframe ITD (integrated technology demonstrator),
- 33.5% weight reduction for the metals & surface treatments technology stream,

- 10% lower assembly costs for the thermoset materials technology stream,
- 20% lower energy consumption for the thermoset materials technology stream,
- 30% - 50% shorter manufacturing time for the thermoset materials technology stream,
- End-of-Life concepts for recycling and recovering of materials to increase the material circularity.

These technological achievements are met thanks to the synergy of:

- 4 Technology streams (metals & surface treatments, thermoplastic, thermosets, biomaterials),
- 28 Materials & resources technologies (including new light metal alloys, bio-resins, biofibers, bio-composites),
- 23 Manufacturing technologies,
- 2 In-service (repair) technologies (for both metallic and polymer composite substrates),
- 5 End-of-Life technologies,
- 12 Manufacturing demonstrators (which are orchestrated in four major flagship demonstrators, see Figure 4),
- 2 End-of-Life demonstrators.

Figure 3 shows the 4 technology streams of the ecoTECH consortium along with few examples of the parts and/or test coupons manufactured during the technology development level.

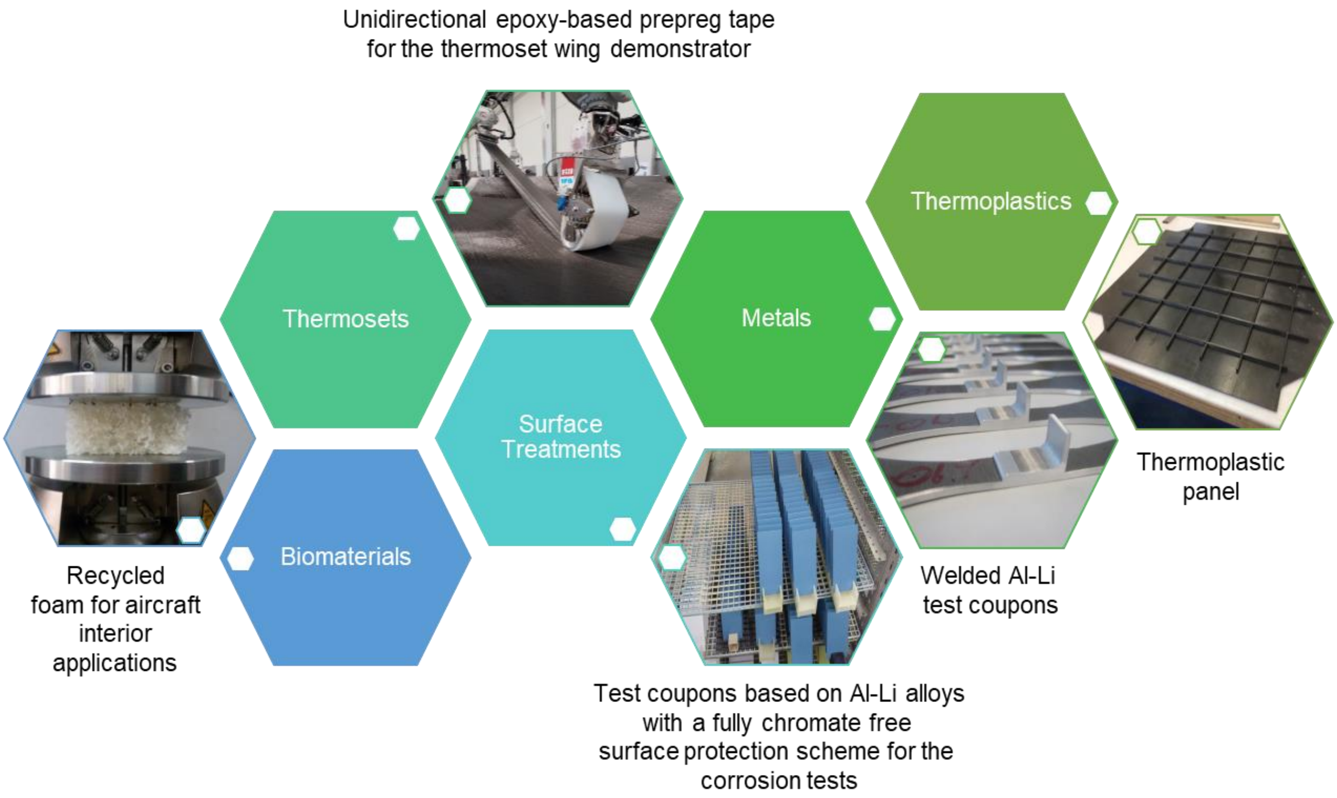

Figure 3 – Technology streams (Metal and Surface Treatments are show separately in this picture) within the ecoTECH consortium.

2.1 ecoTECH Flagship Demonstrators

Figure 4 depicts the so-called flagship demonstrators, developed during the ecoTECH.

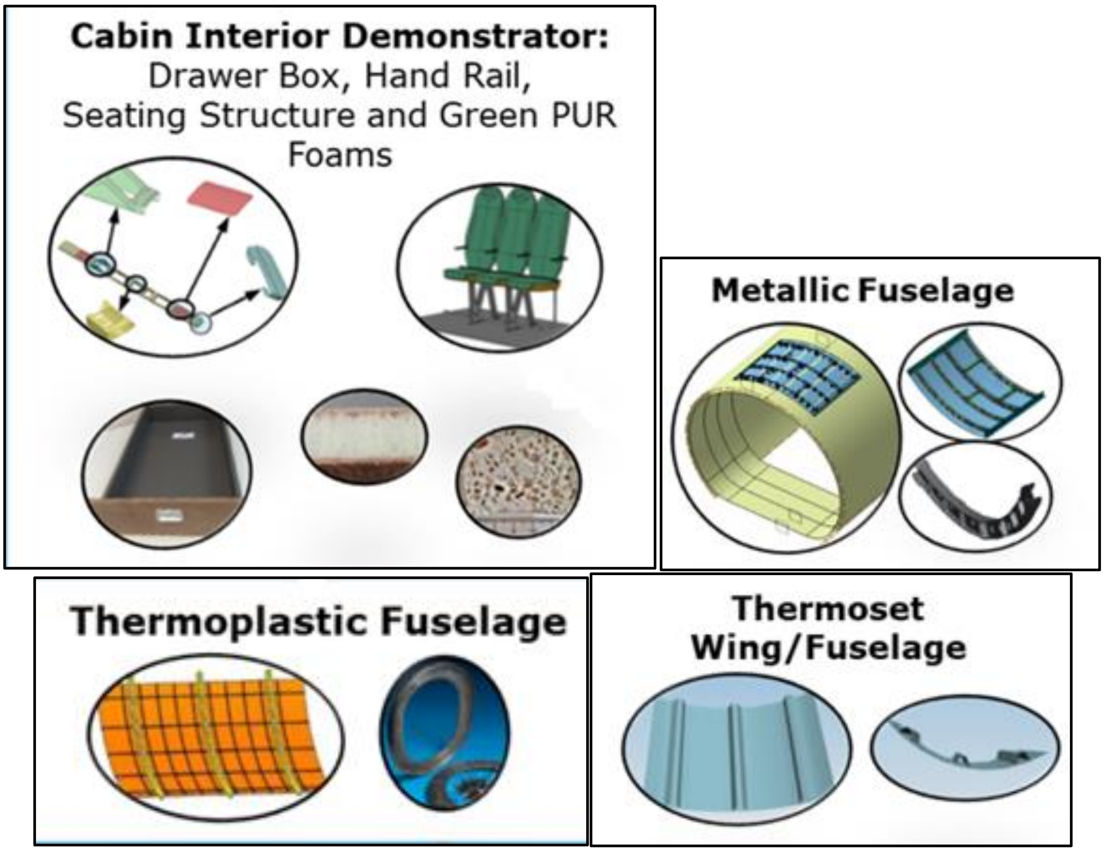

Figure 4 – Flagship demonstrators developed thanks to the technological contribution of ecoTECH.

Various specimen and component level articles are built to assess the different technologies for efficiency and eco-friendliness. The major demonstrators include:

- Thermoplastic Fuselage Panel based on high performance thermoplastic matrices reinforced by carbon-fibers [4,7]
- Metallic Fuselage Panel (see Chapter 3 for details)
- Thermoset Stiffened Wing Panel (based on epoxy resins reinforced with carbon fibers produced by optimized smart curing tools and automized processes) [1]
- Biomaterial Cabin Interior (lightweight Magnesium-Handrail; bio-based green furniture, e.g. drawer)

2.2 From the technology development up to the demonstrator definition phase

The demonstrators in ecoTECH were conceived in the so-called bottom-up concept, meaning that the technologies were initially considered and followed as independent entities and combined during the design phase. The decision criteria and process for the demonstrator development and technology down-selection process are depicted in Figure 5.

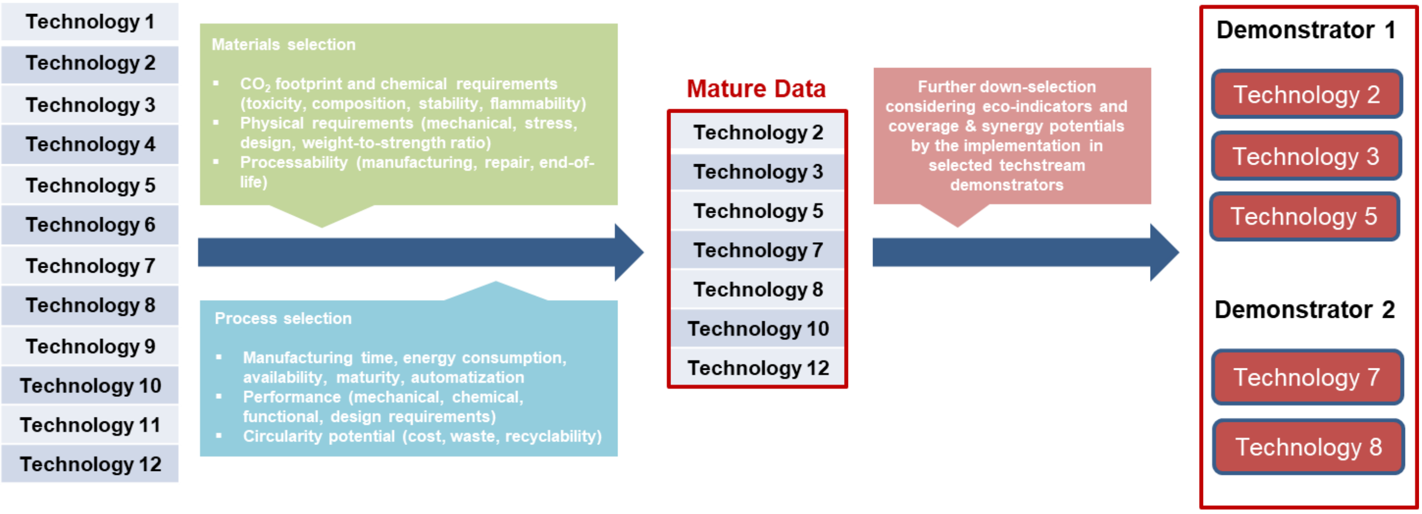

Figure 5 – Technology selection during the demonstration development.

3. Overview on ecoTECH Targets and Achievements – Case Study: Metallic Demonstrator (Surface protection principles)

As the data collection at the demonstrator level has just started, we have few cases for which an evident advantage of the ecoTECH technologies can be reported. Figure 5 summarizes, the achievements in terms of environmental impacts and energy savings of the chromate-free surface protection technologies developed at HAI. The process (thin-film sulfuric acid anodizing) [5] was developed and optimized by HAI for the purpose of fulfilling the REACh (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulations [8]. In the frame of ecoTECH LCA activities, we aim at demonstrating that this technology can offer an alternative manufacturing process with better eco-indicators than the state of the art, corrosion protecting anodizing process (based in chromate-assisted anodizing in acidic media). Details on the performance of these surface treatment processes in welded joints, as well as their metallographic behavior were reported and discussed elsewhere [9].

By comparing the chromate-based reference technology with the technology developed by HAI (ecoTECH technology) we could observe the following benefits:

- 90% reduction of the global warning potential (GWP) when compared to the chromate-based corrosion protection anodizing processes
- 88% reduction of the human toxicity potential (HTP), compared to the chromate-based corrosion protection anodizing processes
- 84% reduction of the marine ecotoxicity potential (MAETP), compared to the state of the art
- 87% reduction of primary energy demand (PAED), compared to the state of the art
- 92% reduction of the water pollution (WP), compared to the state of the art.

Finally, the eco-indicators of the current modelling stage indicate that the replacement of the chromate-based anodized process (which had been used as a surface preparation prior to painting and even bonding of aluminum alloys) by chromate-free technologies has also a positive impact on the water pollution and energy consumption (which are currently targeted costs). Hence, the elimination of chromate-based technology is not only environmentally friendly, but also economically interesting (at least when it comes to the manufacturing steps). More details on the performance of the chromate-free surface protection procedures by HAI can be found in the literature [9].

Apart from the surface protection scheme, other technologies are used for the manufacturing [3,9], in-service activities,[10] and end-of-life (dismantling, alloy recovery) [11] of the metallic demonstrator (as depicted in Figure 6).

Figure 6 – Summary of the achievements of the metallic demonstrator due to the utilization of chromate-free corrosion-protection technologies.

In the frame of ecoTECH, the LCA analysis of the metallic demonstrator will be further modelled at the part level (or at demonstrator level) for the evaluation of the environmental footprint of the whole metallic demonstrator. In this modelling the contribution of all materials & processes; manufacturing technologies and end-of-life strategies will be combined. As a result, the environmental footprint of the whole metallic demonstrator will be obtained. It is important to bear in mind, that the eco-indicators or environmental footprint of the demonstrator need a deeper analysis for a complete understanding of their meaning. For this purpose, a reference part (i.e. an actual flying metallic fuselage part) will be also modelled by LCA. The results will be then compared to evaluate the environmental friendliness of the ecoTECH demonstrator. For getting a complete picture of the potential economic, environmental, and technological potential of the demonstrator, its mechanical performance needs also to be investigated in detail. These activities have been further complemented by mechanical tests, simulations, and endurance tests in the frame of the Call for Proposal (CfP) DEMONSTRATE which will evaluate the mechanical performance and the airworthiness of the developed demonstrator [12]. As these activities are still under completion, this topic shall be the subject of further publications.

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6. Copyright Statement

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