KYKLOS 4.0

An Advanced Circular and Agile Manufacturing Ecosystem based on rapid reconfigurable manufacturing process and individualized consumer preferences

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Annex 1.1:
Technical information on KYKLOS4.0 services, technological components and KPIs

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1. Overview

The objective of the KYKLOS 4.0 - Open Call #2 is to fund SMEs and manufacturing companies to carry out manufacturing experiments using the services and technologies from the KYKLOS 4.0 project.

The purpose of this complementary annex is to provide applicants with an overview of what the KYKLOS 4.0 services are, as well as the technological components that support such services.

Applicants are reminded that a maximum number of proposals addressing each service will funded (see section 4.1.1 of Annex 1).

Applicants are also required to identify, select, and describe in their technical proposal (see Annex 2.1) one or more Circular Economy related KPIs, as presented below in Section 5.

2. KYKLOS 4.0 services

The services provided by the KYKLOS 4.0 Circular Manufacturing Framework are divided into two main categories, namely: (1) ***smart design*** services and (2) ***production optimisation*** services.

The services that belong to each category focus either on the manufacturing design or the production phase, as the corresponding category name indicates. Nevertheless, the services leverage functionalities related to product lifecycle management in each of the stages of the manufacturing process. Moreover, each category is divided into multiple sub-categories, which are described below.

1. **Smart design services**

   - ***Personalised product specification*** related services.

     The services included in this sub-category support both the customer and the product designer. The service helps the customer provide the specific requirements of an individual fully customized product. On the other hand, the product designer can convert the requirements defined by the customer into individualized product specifications and complete a customer-oriented design for additive manufacturing product by using KYKLOS 4.0 service. In this way, the design process runs efficiently and smoothly, which represents savings in time and cost.

   - ***Optimisation of Additive Manufacturing design related services.***

     The services included in this sub-category support the product designer on the decision-making about the additive manufacturing design of a specific product in terms of best materials selection, best specification sizes and orientation or simulation of the final product. As a result, the manufacturing process is improved by accelerating and enhancing the quality of the design process and consequently, the KYKLOS 4.0 service provides enhanced operational effectiveness in terms of cost and time too.

2. Production optimization services

- ***Maintenance optimization*** related services.

  The services included in this sub-category support the maintenance team (i.e., Maintenance manager, maintenance supervisor, maintenance engineer, maintenance operator) which is responsible of the equipment part of the production line. The KYKLOS 4.0 service guides the maintenance team on the optimal management of the maintenance tasks, resources, and materials. The service includes Artificial Intelligence techniques for advanced data analytics to provide predictions concerning maintenance operations.

- ***Advanced support for production*** related services.

  The services included in this sub-category support the manufacturing operator during the production phase, including preparation of the production, the production phase itself, post-production, and assembly. KYKLOS 4.0 services offer innovative technologies such as Augmented Reality (AR) and AI techniques for improving the guidance and support of the process to the operators.

- ***Resource use monitoring and optimization*** related services.

  The services included in this sub-category support the production manager or plant manager by monitoring in real-time the production as well as providing simulation of the process in case some of the inputs change. KYKLOS 4.0 components also provide a decision support system based on the indicators calculated during the production phase to enhance both the production and the circular indicators. KYKLOS also allows to orchestrate multiple services involved into the manufacturing process of a product line so all of them are synchronized and efficiently managed.

The KYKLOS 4.0 services also provide product life cycle management support by Life Cycle Assessment (LCA) service (providing circular and sustainability related KPIs monitoring) or Refurbishment service (performing a trustworthy tracking of the different parts of the final product to ensure that all parts comply with the user requirements).

Section 3 lists the various specific services (17) associated to the five main service sub-categories. Furthermore, the table lists the KYKLOS 4.0 technological components associated to each of the 17 KYKLOS 4.0 services.

In Section 4, further information is provided on each of these technological components.

3. List of services and components

SERVICE CATEGORY	SUB-CATEGORY	KYKLOS4.0 SERVICE [ID]	TECHNICAL COMPONENT
SMART DESIGN	Personalised product specification	Personalised product specification [**KS1.1**]	Front end
			New Product Order (flow)
			Web 3D Modeller Component
			LCA Simulations Engine
		Personalised product re-specification & refurbishment [**KS1.2**]	Front end
			Product Refurbishment (flow)
			Web 3D Modeller Component
			Product Refurbishment Certification
			LCA Simulations Engine
	Optimization of Additive Manufacturing design	Optimization of Additive Manufacturing design (optional Marketplace) [**KS2.1**]	Front end
			Rapid Prototyping Module
			LCA Simulations Engine
			Marketplace (opt)

SERVICE CATEGORY	SUB-CATEGORY	KYKLOS4.0 SERVICE [ID]	TECHNICAL COMPONENT
		Optimization of Additive Manufacturing design with automated task planner (optional Marketplace) [**KS2.2**]	Front end
			Rapid Prototyping Module
			Automated task planner
			LCA Simulations Engine
			Marketplace (opt)
PRODUCTION OPTIMISATION	Maintenance optimisation	Predictive maintenance [**KS3.1**]	Front end
			Maintenance scheduler (Cognitive toolkit)
		Predictive maintenance with auditing [**KS3.2**]	Front end
			Maintenance scheduler (Cognitive toolkit)
			Auditing mechanisms
		Predictive maintenance with AR based guidance [**KS3.3.1**][1]	Front end
			Maintenance scheduler (Cognitive toolkit)
			AR based content editor
		Predictive maintenance with AR based	Front end

[1] Uses the **PLM** component as the data repository, with the **Cognitive Toolkit** being the technical component running in the background.

SERVICE CATEGORY	SUB-CATEGORY	KYKLOS4.0 SERVICE [ID]	TECHNICAL COMPONENT
		guidance [**KS3.3.2**][2]	Maintenance scheduler (Cognitive toolkit)
			AR based content editor
		Preventive maintenance with AR based guidance [**KS3.4**]	Front end
			Maintenance scheduler (Cognitive toolkit)
			AR based content editor
		Reactive maintenance with AR based guidance [**KS3.5**]	Front end
			Maintenance scheduler
			AR based content editor
		Preventive maintenance with auditing and refurbishment [**KS3.6**]	Front end
			Maintenance scheduler
			Auditing mechanisms
			Product Refurbishment Certification
	Advanced support for production	AR-based guidance for production [**KS4.1**]	Front end
			AR based content editor

[2] Uses the **Backend** component as the data repository, with the **Cognitive Toolkit** being the technical component running in the background.

SERVICE CATEGORY	SUB-CATEGORY	KYKLOS4.0 SERVICE [ID]	TECHNICAL COMPONENT
			Maintenance scheduler (to upload AR resources in PLM)
		AR-based guidance and monitoring for production [**KS4.2.1**][3]	Front end
			AR based content editor
			AR based re-configurator tool
			Maintenance scheduler (to upload AR resources in PLM)
			LCA Simulations Engine
		AR-based guidance and monitoring for production [**KS4.2.2**][4]	Front end
			AR based content editor
			AR based re-configurator tool
			Maintenance scheduler (to upload AR resources in PLM)
			LCA Simulations Engine
	Resource use monitoring and optimization	Real-time monitoring and resource optimization with Decision Support	Front end
			LCA Simulations Engine

[3] Uses the **Backend** component as the data repository, with the **SP cognitive accelerator** being the technical component running in the background.

[4] Uses the **PLM** component as the data repository.

SERVICE CATEGORY	SUB-CATEGORY	KYKLOS4.0 SERVICE [ID]	TECHNICAL COMPONENT
		[**KS5.1**]	Decision Support System
		Monitoring and resource optimization with Decision Support [**KS5.2**]	Front end
			LCA Simulations Engine
			Decision Support System
			Data Manager
		Real-time monitoring and resource optimization with Virtual Production Line Orchestrator (VPLO) [**KS5.3**]	Front end
			VPLO
			LCA Simulations Engine
			Cognitive ToolKit/Maintenance Scheduler

4. Services and components information

TECHNICAL COMPONENT	COMPONENT OWNER	NOTES
TC3.1.1 KYKLOS 4.0 Shop Floor Cognitive Accelerator Hardware	UPM	Video
TC3.1.2 Shop Floor Cognitive Accelerator Platform Software	UPM	*N/A*
TC3.2.1 Data Reduction Techniques & Fault Dependency Model	UC	*N/A*
TC3.3.1 Semantic Knowledge Base (SKB)	CERTH	Video
TC3.3.2 Semantic Knowledge Base Service (SKBS)	CERTH	Video
TC3.4.1 Inference Engine	UC	*N/A*
TC3.5.1 Production Equipment Clustering (PEC)	CERTH	Video
TC3.6.1 KYKLOS Maintenance Scheduler	SIMAVI	Video
TC4.1.1 Deep Learning Toolkit	FOKUS	Video
TC4.2.1 Augmented reality-based re-configurator tool	TECNALIA	Video
TC4.2.2 Automated Task Planner Toolkit	PDMFC	Video
TC4.3.1 Rapid Prototyping Module (RPM)	TWI	Video
TC4.4.1 LCA Simulations Engine	EFB	Video
TC4.5.1 PLM Module	JOTNE	Video
TC4.6.1 Manufacturing Management Component	SIMAVI	Video
TC5.1.1 Blockchain-based Auditing Platform	TECNALIA	Video
TC5.4.1 Data Manager	KT	Video
TC6.1.1 Parametric Design Methodology	CETMA	Video
TC6.2.1 Recommendation Engine	MAGG	Video
TC6.3.1 Advanced Additive Manufacturing Component	CIRTES	*N/A*
TC6.4.1 Web 3D Modelling Component	TWI	*N/A*
TC6.5.1 Augmented reality-based content editor	TECNALIA	Video
TC7.1.1 Virtual Production Line Orchestrator	MAGG	Video
TC7.2.1 KYKLOS 4.0 Marketplace	PDMFC	Video

TECHNICAL COMPONENT	COMPONENT OWNER	NOTES
TC7.3.1 Brokering and Matchmaking	PDMFC	*N/A*
TC7.4.1 KYKLOS 4.0 Front End	ALGOSYSTEMS	*N/A*
TC7.5.1 KYKLOS 4.0 Back-End Infrastructure - A Collaborative Private Cloud Platform	ADSYS	*N/A*
TC8.1.1 DSS Decision Support System	KT	Video
TC9.1.1 KYKLOS Interoperability layer	ADSYS	Video
TC9.3.1 Open SPHINX	GFT	*N/A*
TC9.5.1 KYKLOS Product Refurbishment Certification	PDMFC	Video

5. Circular Economy KPIs

Circular Economy Objectives	Indicator	Description
RI: Reducing inputs and the use of natural resources	Feedstock intensity	Feedstock intensity (FI) estimates the fraction of mass of primary feedstock needed in production ($M_{primary.mat}$) in relation to the total mass of products (M_{prod}) and useful co-products ($M_{co.prod}$). The formula for the indicator is: $$Feedstock\ Intensity\ (\%) = \frac{M_{primary.mat}}{M_{prod} + M_{co.prod}}$$ *Ref: [Lokesh et al, 2020]*
	Circularity Transition Indicators (CTI) - water Circularity	Water circularity estimates the circularity of the water through the % circular water inflow and % circular water outflow, with the purpose of lower the freshwater demand. The formula for the indicator is: $$Water\ Circularity\ (\%) = \frac{\%\ \text{circular water inflow}\ + \%\ \text{circular water outflow}}{2}$$ Where $$\%\ circular\ water\ inflow = \frac{Q\ total\ circular\ water\ withdrawal}{Q\ total\ water\ withdrawal}\ \text{x}\ 100$$ $$\%\ circular\ water\ outflow\ (discharge) = \frac{Q\ total\ circular\ water\ discharge}{Q\ total\ water\ withdrawal}\ \text{x}\ 100$$ *Ref: [WBCSD, 2020]*
RR: Increasing the share of renewable and recyclable resources	Circularity Transition Indicators (CTI) - renewable energy	The renewable energy estimates the renewable energy consumption per total energy consumption in plant. The formula for the indicator is: $$\text{Renewable energy}\ \ (\%) = \frac{\text{Renewable energy (annual consumption)}}{\text{Total energy (annual consumption)}}\ x\ 100$$ *Ref: [WBCSD, 2020]*
	Circularity Transition Indicators (CTI) - % Circular inflow	% circular inflow is determined by the % non-virgin content and % renewable content.

Circular Economy Objectives	Indicator	Description
		$\%\ Circular\ inflow = \frac{M_{non-vrgin\ material}}{M_{tot.}}\ x100 + \frac{M_{Renewable\ material}}{Mtotal}\ x100$ *Ref: [WBCSD, 2020]*
RL: Reducing valuable materials and energy losses	% to upcycling	The % upcycling estimates the percentage of material collected for upcycled over the total mass of the product. The formula for the indicator is: $\%\ to\ upcycling = \frac{M_{Upcycled}}{M_{total}}\ x\ 100$
	Disassembly time	Disassembly time estimates the total time to disassembly the product. The formula for the indicator is: $Disassembly\ time = \sum time\ for\ each\ disasembly\ operation$ *Adapted from - Ref: [Kanellou et al, 2021]*
	Reusability/ Recyclability/ Recoverability rate	Reusability/Recyclability/Recoverability (RRR) rate estimates the fraction of the product that is potentially reusable/recyclable/recoverable at the end of life. The formula for the indicator is: $RRR\ Rates\ (\%) = \sum_{i-1}^{p} \frac{m_i * x_{RRR,i}}{m}\ x\ 100$ Where: m_i = mass of the component i, part of the product. $x_{RRR,i}$ = the rate of the component which is potentially reusable/recyclable/recoverable (X_{reuse} X_{recyc}; and X_{recov} respectively) (%) m = total product's mass (kg) Reusable is considered when is possible to separate a component from the product without compromising its functional integrity, and there must be a commercial reuse and refurbishment system established. Recyclable does not include material that enters the recycling flow during the production phase. Recovered is considered when is potentially energy recoverable. *Ref: [Ardente and Mathieux, 2014]*

Circular Economy Objectives	Indicator	Description
DU: Increasing the value durability of products."	Longevity	The longevity indicator considers the time a material resource is maintained in a product system and is expressed in units of time. It quantifies the initial lifetime (L^A), the lifetime contributions of remanufacturing (L^B), and recycling (L^C). The formula for the indicator is: $$Longevity\ (time) = L^A + L^B + L^C$$ *Ref: [Figge et al, 2018]*
	Use Phase Circularity Indicator	Use phase CI estimates the expect lifespan of the utilized products, compared to the average life span of status-quo products in the same application. The formula for the indicator is: $$Use\ phase\ CI(years) = \frac{L}{L_{av}}$$ L is the potential functional lifespan of a product in years. L_{av} is the industry average lifespan this product is applied in. *Ref: [Heisel and Rau-Oberhuber, 2020]*
RE: Reducing emissions levels	Ecoefficiency	Use phase CI estimates the expect lifespan of the utilized products, compared to the average life span of status-quo products in the same application. The formula for the indicator is: $$Use\ phase\ CI(years) = \frac{L}{L_{av}}$$ L is the potential functional lifespan of a product in years. L_{av} is the industry average lifespan this product is applied in. *Adapted from - Ref: [Huysman et al, 2015]*