H2020 Innovation Action - This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 760792

WP8 – EXPLOITATION

Task 8.1 – Exploitation routes

Person responsible / Author:	Bernd Kopacek (SAT), Paolo Rosa (POLIMI), Sergio Terzi (POLIMI)
Deliverable No.:	8.1
Work Package No.:	WP8
Date:	28.06.2019
Project No.:	760792
Classification:	Confidential
File name:	FENIX D8.1 Report final
Number of pages:	62

ABSTRACT

The main aim of the FENIX project is developing new business models and industrial strategies for three novel supply chains, in order to enable value-added product-services. Through a set of success stories coming from the application of circular economy principles in different industrial sectors, FENIX wants to demonstrate in practice the real benefits coming from its adoption. In addition, Key Enabling Technologies (KETs) will be integrated within the selected processes to improve the efficient recovery of secondary resources. Deliverable 8.1 focuses on different exploitation routes using, as a baseline, the draft exploitation plan presented in this proposal. To this aim, tangible and intangible results will be assessed in terms of: i) early definition of the FENIX exploitation strategy and ii) identification of the FENIX exploitable results and partners (or clusters of them) responsible for them.

Table of Contents

Figures

Tables

1. INTRODUCTION

This document describes the initial Exploitation Plan customized for the FENIX project, funded by the European Union's (EU) Horizon 2020 programme under the Grant Agreement (GA) No. 760792.

This is only a draft version of the Exploitation Plan. This document will be updated periodically throughout the course of the project. The Final -Official- version of this document will be available to the consortium by M36.

According to the article 28.1 of the Grant Agreement, all involved partners are obligated to take necessary measures to ensure proper exploitation of the projects' results for up four years after the end of the project (M36).

FENIX Exploitation Plan aims to cover the most important topics concerning the identification of the project results as well as the methods of exploitations (including all relevant information)

The current -draft- version of the Exploitation Plan includes a list of the exploitable results that have been identified in the GA, with relevant updates and revisions as of M18.

2. INNOVATION OBJECTIVES OF FENIX AND THEIR MANAGEMENT

2.1. Innovation objectives

The main objective of the FENIX project is developing new business models and industrial strategies for three novel supply chains, in order to enable value-added product-services. Through a set of success stories coming from the application of circular economy principles in different industrial sectors, FENIX wants to demonstrate in practice the real benefits coming from its adoption. In addition, Key Enabling Technologies (KETs) will be integrated within the selected processes to improve the efficient recovery of secondary resources. To achieve the goals of the project, 9 Key Exploitable Results (KERs) have been identified (see Table 1).

No.	KER Name	Lead partner	Participants
1	Semi-automated robotic assembly-disassembly cell	POLIMI	n/a
2	CEPA methodology	POLIMI	n/a
3	Innovative technology for WPCBs treatment	UNIVAQ	n/a
4	Process engineering /Turnkey plant for the recovery of precious and critical metals from waste	UNIVAQ	n/a
5	BAL.LCPA software tool	BAL	n/a
6	High Energy high capacity mills for powders production	MBN	-
7	3D printing	FCIM	n/a
8	3D scanning of human faces	I3DU	3DHUB
9	FENIX integrated platform	SINGULAR	n/a

Table 1: List of FENIX Key Exploitable Results

2.2. Exploitation management

The management of the exploitation and the detailed elaboration of the exploitation strategy will be handled by SAT. As stated in the GA, SAT will be responsible for preparing, monitoring and updating the project's key exploitable results. In addition, POLIMI will support SAT in IPR management activities, for increasing the awareness about IP protection and ownership rights/implementation during the project. To this aim, two IPR management meetings have taken place: 1st) June 2018 and 2nd) November 2018 (as part of M6 and M12 general meetings). The results of the IPR management meetings have been shared with the entire consortium. The third IPR management meeting will be conducted during the next general meeting at M18.

3. EXPLOITATION PLAN STRUCTURE

This chapter will set out the general structure of the FENIX Exploitation Plan. The segments listed below will be elaborated and discussed into detail during the project. The information required for the completion of the Exploitation Plan will be collected via questionnaires, workshops or conference call(s) with individual partners.

3.1. Exploitable innovations and ambitions

This section will provide a description of innovations generated by FENIX, state of the art, as well as their advantages and disadvantages compared to similar existing products, technologies and services.

3.1.1. Technical description

This section will include the technical description of the innovation or services.

3.1.2. Innovation properties and benefits

This section will include a brief description of the value proposition (including added-value).

3.1.3. Limitations

The potential limitation of the innovation (if any) will be discussed in this section.

3.2. Exploitation strategy

An exploitation strategy shall shed light on the paths how the innovations of FENIX can be exploited and delivered to the market. This includes the necessary steps during the lifetime of the project, as well as the four years after the end of the project.

3.2.1. Exploitation routes and guidelines

The exploitation routes and the timeline of the execution during the project.

3.3. IPR strategy

Issues related to the protection of intellectual property (before, during and after the project), will be discussed in this section.

3.3.1. Background IP access and ownership

Description of the background IP, developed by partners prior to the start of the FENIX project, will be provided in this section. This section will also include an overview of limitation and conditions of utilizing the background IP for future exploitation.

3.3.2. Foreground IP

A description of the foreground IP and the method of protection will be provided in this section.

3.3.2.1. IP strategy

A detailed IP strategy will be developed for each KER for the final version of the Deliverable (M36).

3.3.2.2. Analysis of filed patents

A description and a brief analysis of the filed patents will be provided in this section. It is important to note that currently there are no foreseen issues with patents or patent applications for the FENIX project.

3.4. Exploitation risk management

This section will provide a description of the exploitation risks, as it might impact the successful exploitation of the project results. The risks will be identified based on internal and external sources (via Risk Matrix) and will be monitored and updated during the project (see Figure 1).

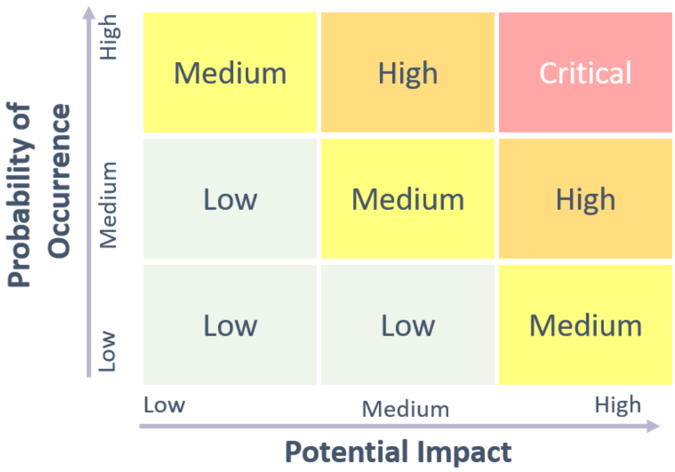


Figure 1: Risk matrix

4. EXPLOITATION PLAN: KER #1

No.	KER Name	Lead partner	Participants
1	Semi-automated robotic assembly-disassembly cell	POLIMI	n/a

Table 2: FENIX KER #1 details

4.1. Exploitable innovations and ambitions

KER#1 will provide an innovative assembly-disassembly cell to operators involved in WEEE management systems. Key innovations that the semi-automated cell offers include:

- Cobot-assisted disassembly process, where cobots and operators can work together by sharing the same workplace.
- Real-time control of disassembly process performances through a Digital Twin specifically developed.
- Integration of Industry 4.0-based technologies in WEEE management systems.

4.1.1. Technical description

KER #1 integrates a commercial cobot with an industrial drier. The system, once defined the right trajectory, can repeat a sequence of movements and assist the operator during the disassembly process. Moreover, the Digital Twin developed both for the cobot and for the entire disassembly line allows to control in real-time the behaviour of the process. This way, exploiting digital technologies and advanced manufacturing systems (e.g. CPS/IoT, Human Machine Interface and Machine-to-Machine communication protocols), it is possible to manage and optimize in a more efficient way the disassembly process and its resource consumption.

KER#1 is currently at TRL 7 and is expected to maintain it till the end of the project.

4.1.2. Innovation properties and benefits

Optimization of the PCB disassembly process, leading to new forms of semi-automated disassembly processes, with better performances (for both EEE and other sectors). This innovation could be used in the following forms: process, product and service.

4.1.3. Limitations

n.d.

4.2. Exploitation strategy

The full exploitation strategy is not yet defined.

4.2.1. Exploitation routes and guidelines

The exploitation routes have not yet been defined. However, it may include use for further research as well as use for future standardisation activities.

4.3. IPR strategy

The IPR strategy is not yet defined.

4.3.1. Background IP access and ownership

Currently, no issues related to background IP and ownership are foreseen.

4.3.2. Foreground IP

Currently, no forms of protection are foreseen. This may evolve/change during the project.

4.3.2.1. IP strategy

A detailed IP strategy will be developed for the final version of the Deliverable (M36).

4.3.2.2. Analysis of filed patents

n.d.

4.4. Exploitation risk management

Currently no exploitation risk is foreseen.

5. EXPLOITATION PLAN: KER #2

No.	KER Name	Lead partner	Participants
2	CEPA methodology	POLIMI	n/a

Table 3: FENIX KER #2 details

5.1. Exploitable innovations and ambitions

KER#2 will provide an innovative Circular Economy Performance Assessment (CEPA) methodology to companies, research centres, universities and end users. The CEPA methodology is composed by three different sub-methodologies that are related to three different fields of analysis to assess CE benefits: (i) the Circular Product Assessment (CPA), (ii) the Circular Cost Assessment (CCA) and (iii) the Circular Environmental Assessment (CEA). The first (CPA), allows to calculate the circular share of resource flows used during the product life cycle, in order to obtain an exhaustive final index (KPI) about the circular percentage share of the product compared to total resources used (Circularity Product Indicator, CPI). This methodology has its strength in the product system Eco-Effectiveness evaluation through CPI calculation. Then, starting from the system circularity calculation and KPIs system carried out in the first methodology, through CCA is possible to analyse and quantify the economic benefits related to CE, always referring to a well-defined product system. Its application is used to calculate the cost savings generated by the triggering of materials and other resources circularity and to evaluate the economic savings related to energy circularity. Finally, with CEA it is possible to evaluate the environmental benefits resulting from the use of a circular business model. The objective is therefore to quantify the emissions and other forms of pollution avoided by triggering the resources flows circularity present throughout the entire life cycle. This methodology consists in the association of a "weight" to all the environmental impacts that characterizes each circular resource flow, in order to be able to calculate the difference with the environmental impacts of the corresponding linear system. Key innovations that the methodology offers include:

- A set of specific KPIs regarding resources circularity degree present within the product life cycle and the quantification of those that are the economic and environmental benefits of the Circular Economy;
- A metric for the creation of a product certification system related to the circularity of resource flows;
- It represents a methodology to design new products considering the circularity as a decision criterion (Design for Circular Economy);
- The methodology indicators allow the comparison between different versions of the product ("what if" analysis) based on their degree of circularity and the benefits they can bring; this applies both to new products and to developments and improvements linked to existing products;
- Internal reporting and benchmarking. Companies would be able to compare different products based on their circularity and on the benefit they can achieve.

Wrapping up, this methodology can support the analysis of a certain system on different levels:

- Being applicable to different dimensions of the system (micro, meso and macro),

- Focusing on different phases of its lifecycle (BoI, MoL, EoL or entire lifecycle),
- Considering at the same time single or multiple variables belonging to it,
- Taking either an economic, environmental or resource efficiency perspective.

This flexibility represents of course the main strength of the methodology proposed, also helping users in balancing the effort needed to adopt it, that has not to be neglected, and the degree of focus of the analysis.

5.1.1. Technical description

KER#2 is currently at TRL 2 and is expected to reach TRL 4 by the end of the project.

5.1.2. Innovation properties and benefits

Circularity performance assessment of the PCB disassembly process, leading to new forms of CE performance assessment methods (for both EEE and other sectors). This innovation could be used in the following forms: software, service and policy recommendations.

5.1.3. Limitations

n.d.

5.2. Exploitation strategy

The full exploitation strategy is not yet defined.

5.2.1. Exploitation routes and guidelines

The exploitation routes have not yet been defined. However, it may include use for further research as well as use for future standardisation activities.

5.3. IPR strategy

The IPR strategy is not yet defined.

5.3.1. Background IP access and ownership

Currently, no issues related to background IP and ownership are foreseen.

5.3.2. Foreground IP

Currently, no forms of protection are foreseen. This may evolve/change during the project.

5.3.2.1. IP strategy

A detailed IP strategy will be developed for the final version of the Deliverable (M36).

5.3.2.2. Analysis of filed patents

n.d.

5.4. Exploitation risk management

Currently no exploitation risk is foreseen.

6. EXPLOITATION PLAN: KER #3

No.	KER Name	Lead partner	Participants
3	Innovative technology for WPCBs treatment	UNIVAQ	n/a

Table 4: FENIX KER #3 details

6.1. Exploitable innovations and ambitions

UNIVAQ in the last 25 years has been engaged in the development of innovative hydrometallurgical operation to recover base, precious metals and rare hearth from e-waste and other industrial waste and mineral tailings. To complete the background UNIVAQ has been involved in other projects (with private company and in the ambit of EU calls: i.e. LIFE BITMAPS) also in the treatment of industrial wastewaters. Considering the developed knowledge UNIVAQ can carry out research activities in the field of Circular Economy giving a wider vision of this concept.

Next Table 4.1 and 4.2 summarize the state of the art (only considering patents) on hydrometallurgical processes to recovery precious metals from e-waste.

Table 4.1: Patents on waste printed circuit board treatment for recovery of both base and precious metals by hydrometallurgical procedures

Patent number and title	Reference	Description	Remarks
COMPLETE NON-CYANOGENS WET PROCESS FOR GREEN RECYCLING OF WASTE PRINTED CIRCUIT BOARD - US2012318681 (A1) 2012	Inventors: Zhang Shengen; Li Bin; Pan Dean; Tian Jianjun; Liu Bo. Applicants: Zhang Shengen; Li Bin; Pan Dean; Tian Jianjun; Liu Bo., Univ. Beijing Science & Tech., China Extension in US and China	This patent presents the following steps for recovery of Cu, Au, Ag, Pd, Pt, P and Sn from waste printed circuit boards: - Crushing and gravity separation to achieve a Cu concentrate and removal of nonmetallic part. - **Smelting of the Cu concentrate and its electro refining** in a solution of $CuSO_4$ and	The authors have developed a pyro-hydrometallurgical process that was applied on waste printed circuits boards after a physical-mechanical pretreatment. This procedure consists in crushing of the boards and then nonmetallic parts separation by the metallic ones by air classification. However no data on the efficiency of this technology have been provided within this invention. Generally this

		H_2SO_4 (a 4N copper ingot was achieved); - Recovery of anode slime and treatment with **NaCl, H_2SO_4 and $NaClO_3$ to selectively recover gold**, palladium and platinum. For the gold reduction from solution, Na_2SO_3 was used. Then, the solution was neutralized to pH 2 and zinc and iron powders were used for Pd and Pt displacement. - The resulted sludge after Au, Pd and Pt leaching, was further leached with Na_2SO_3 to recover silver. Afterwards, this was reduced with oxalic acid or formaldehyde. - The leaching solid residue was then heated in the mixed solution of HCl, NaCl and $CaCl_2$ to recover lead. After residual solid separation by filtration, the solution was cooled favoring within this way Pb precipitation. Thereafter, the solution regeneration was performed with calcium chloride and then reutilized within Pb leaching process. - The achieved solid residue was then roasted	process do not allows the complete separation of nonmetals and in addition, **by performing the smelting process, in case of nonmetals presence, toxic gases are produced.** The authors sustain that all the waste solutions have been recirculated within the process.

		in the presence of sodium hydroxide and sand to recover Sn. Then, the roasting product was mixed with water and the solid residue was filtered out. **To achieve the Sn recovery as Na_2SnO_3, the solution of was evaporated and crystallized.**	
Process for recycling gold from waste circuit boards CN104152696 (A) 2014	Inventors: Zha Hongping; He Lifa; Wen Weifeng; Liu Changsong Applicant: REDBOARD JIANGXI CO LTD Extension: China	The suspension electrolysis with titanium as anode and copper as cathode is used for the recovery of Cu from milled circuit boards. Moreover, before this treatment, the inventors have performed the shaking of milled PCBs in water medium **to separate the nonmetallic parts and the resulted metallic part was used within the electrochemical process**. Then, the achieved sludge is treated with nitric acid to dissolve all other elements excepting Au. The gold is then subjected to a further refining step that is not exposed within this patent.	The current procedure allows the recovery of Au and Cu from waste printed circuit boards by performing a mechanical-physical pretreatment and an aqueous process. This last, consist in a first electrochemical step where Cu is recovered and then the achieved anodic sludge is leached with nitric acid leaving gold as insoluble product. No data regarding the wastewater treatment and electrochemical process media are provided.
Method for recovering gold and copper from gold-plated printed circuit board waste material CN101024864 (A) — 2007	Inventor: Li Jinrong Chen Applicant: Dadi Environment Science Techn. (China) Extension: China	The high grade printed circuit boards have been treated in **sulfuric acid and hydrogen peroxide solution and then the detached gold fingers** have been treated by two ways: (i)leaching with diluted nitric acid for Cu removal and then the purified gold is smelted and (ii) **dissolution of gold fingers within aqua regia at**	The current invention presents different systems of reagents for Cu and Au recovery. No discussion regarding the waste solutions treatment or other elements recovery is shown.

		a certain temperature, cooling of solution, filtration, neutralization to pH 1, addition of zinc particles for Au cementation and then, to remove the excess of zinc, the treatment of the precipitate with diluted hydrochloric acid at certain temperature is performed. The resulted solution after copper leaching with sulfuric acid and hydrogen peroxide is concentrated by evaporation and $CuSO_4$ crystals are achieved.	
Method of reclaiming gold, palladium, platinum and silver from waste circuit board CN102277497 (B) — 2013	Inventor(s): Wang Qin; Wu Guangyuan; He Xianda; Liang Xiaokui; Su Taogui Applicant(s): WUHAN GELINMEI RESOURCE CYCLE CO LTD (China) Extension: China	Within the current invention the researchers have firstly performed **the roasting** of the boards, then the leaching with sulfuric acid to extract the base metals and **then the solid residue leaching with aqua regia at a certain range of temperature**. Thereafter, the nitric acid was completely removed by maintaining a certain level of temperature. The achieved solution was then used for selective precipitation of Ag, Pd and Au.	Within this invention, the recovery of precious metals after a thermal treatment and base metals removal by acid leaching was performed. Aqua regia was also used within this patent for Au, Ag and Pd dissolution and then, after selective precipitation of all three precious metals, the recirculation of solution was achieved.
Hydrometallurgy process for the recovery of materials from electronic boards WO2015052658 (A1) — 2015	Inventor(s): Brunori Claudia; Fontana Danilo; De Carolis Roberta; Pietrantonio Massimiliana; Pucciarmati Stefano; Guzzinati Roberta; Torelli Giorgia Nadia. Applicant(s): AGENZIA NAZ PER LE NUOVE	This invention relates a process where the entirely boards are treated **in a nitric acid solution and then the gold films resulted by base metals dissolution** on which these were deposited , tin and the e-components that have been also detached from the boards surface by solder leaching are separated from solution by a series of sieves. The resulted solution is further subjected to	The current procedure allows the recovery of Cu, Sn, Pb, Fe, Ag and Au without a preliminary pretreatment. However, this generate a large amount of hazardous wastewater and no data regarding the purity of the achieved products are provided.

	TECNOLOGIE L EN E LO SVILUPPO ECONOMICO SOSTENIBILE ENEA Italy Extension : EU	precipitation with sulfuric acid or sodium sulfate for Pb recovery. Then sodium chloride is added to recover silver. A further operation is the neutralization to various pH levels with sodium hydroxide or similar base which will lead to selective precipitation of iron and copper. The achieved copper hydroxide is further dissolved in sulfuric acid and then recovered as metal using the electrodeposition process.	
Methods, Materials and Techniques for Precious Metal Recovery US2017369967 (A1) — 2017	Inventor(s): Nelson Duane [CA]; Scott Steve [US]; Doostmohammadi Mohammad [CA]; Jafari Hanif [CA] Extension: International	The invention has as core to recover Au from minerals by leaching using **an iodine salt in presence of a carboxylic acid (citric and acetic acid), boric acid and optionally chlorine or bromine**. The leaching is performed on fine materials **in an electrochemical cell which allows the increase of the ORP to oxidize the iodide to iodine**. Moreover, the inventors have present as suitable alternatives **the addition of other oxidants (H_2O_2, NaOCl, O_3, etc.)** that are capable to perform the oxidation.	The advantage of this process is the fact that the solution can be regenerated and therefore used many times. However, the authors of this patent have not presented any data on the precious metals recovery from solution. In addition, there are also other elements that can be leached within this media. This fact is not pointed out within this patent.
Method for separating and recycling rare noble metals and waste plastics in waste circuit board CN102240663 (A) — 2011	Inventor(s): Kaihua Xu; Li Yan. Applicant(s): Shenzhen Green Eco Manufacture High Technology CO LTD Extension: China	This patent presents the recovery of precious and base metals from waste printed circuit boards using the following operations: - **Stripping process with concentrated nitric acid, ferric chloride and ferric nitrate** to recover	The current invention allows the recovery of both precious and base metals from WPCBs using various reagents. However, due to the fact that the patent is in Chinese language, was difficult to understand well the entirely process.

		Sn and Pb and the electronic components - Shredding of the boards, eddy current separation to achieve a high concentrate of metals, treatment of the **concentrate with sulfuric acid and an oxidant to recover Cu and Ni** and then electrolysis to achieve Cu and Ni metals. - Dissolution of silver and palladium from the solid residue of the previous leaching process using nitric acid. Then, by neutralization with NaOH till pH 3-5, the palladium recovery from solution was achieved. Silver was recovered by addition of a chloride salt. - The solid residue of previous step **was then leached with aqua regia to recover Au** and then electrowinning process was applied to recover metallic gold.	

Table 4.2: Patents on hydrometallurgical process for nonmetals and base metals recovery from waste printed circuit boards

Patent number and title	Reference	Description	Remarks
Copper recovery from discarded circuit boards - uses mixt. of organic acid and halogenated hydrocarbon(s) for sepn. and recovery DE4140640 (A1) — 1993	Inventor(s): Dammer Hans Dipl Ing Applicant(s): Dammer Hans Dipl Ing Extension: Germany	This patent describes a method where the milled WPCBs are treated **for 24 h in a solution of organic acid (acetic or formic acid) and an organic solvent (dichloromethane, or a mixture between dichloromethane and trichloroethylene).** This system allows the separation of Cu from the resins and a partial dissolution of this metal within the solution. For the PCBs separation from the aqueous phase, the sieving process is performed. Then, the solid material is washed with water and dried. To separate copper, the solid is further immersed within a cyclone separator. To achieve complete separation of the organic solvent by the organic acid, another quantity of organic solvent is added. After these two phases separation, the organic solvent can be reused only after distillation and the aqueous phase after purification.	The current invention presents the use of concentrated solution of organic acids and organic solvents followed by a physical process for Cu separation from WPCBs. This patent present also the possibility of both reagents reuse after proper treatments (organic solvents distillation and organic acids purification.
Method for utilizing waste copper material JP2001009283 (A) — 2001	Inventor(s): Tsuchiya Masaru; Kamakura Masahiro; Nakamura Kenichi; Tokumasu Hiroyuki; Fujii Yasuhiro Applicant(s): MATSUSHITA	The core of this invention was to recover copper from WPCBs and to use it for preparation of a catalyst. The recovery process of Cu consisted of leaching of this metal from the milled printed circuit boards **in nitric acid solution and then precipitation with ammonia.** The obtained	The present invention was only focused on Cu recovery from the WPCBs and no details on solid or liquid wastes generation and further processing was given.

	ELECTRIC IND CO LTD (Japan) Extension: Japan	hydroxide was then thermally treated with manganese oxide to achieve the catalyst.	
Method and devices for recycling copper from a discarded circuit board and a discarded fluid containing copper US2006191376 (A1) — 2006	Inventor(s): Wu Hsieh S Applicant (s): Wu Hsieh S Extension: Japan and US	This patent presents the recovery of Cu from waste printed circuit boards by leaching **with inorganic acids (hydrochloric acid, sulfuric acid) in presence of oxidants (hydrogen peroxide, air) or electrode, with organic acid (oxalic acid)** and also an etching solution coming from the production of printed circuit boards and further recovery of this element from its media by reduction with sodium hydroxide, aluminum material and sodium carbonate. After Cu recovery as hydroxides or **oxalates, these were calcined to achieve CuO and some of the residual solutions were evaporated to concentrate their content.** In addition there is patented a plant that consist in a reaction tank, a precipitating bath, an oven and a heater.	This invention has as core to patent a method of Cu recovery and a plant to perform this method. The inventor suggest that this method is environmental friendly but there are no data to certify this. In addition, the presented leaching systems are not able to achieve the selective extraction of copper.
Method of recycling wasted printed-circuit-board US2007169330 (A1) — 2007	Inventor(s): Wu Hsieh Sen Applicant (s): Wu Hsieh S Extension: International	The current patent presents a treatment that consists in: **heating the board to melt the tin-solder and recover the e-components;** the resulted boards and components are leached in a solution (HCL) for residual solder dissolution; treatment of the boards in a concentrated solution **of nitric or hydrochloric acid with small addition of nitric acid for Cu**	This patent uses both thermal and hydrometallurgical treatments for the recovery of Sn, Pb, Cu and nonmetallic parts from waste printed circuit boards. This patent do not specify any data on metals recovery from solution.

		removal; treatment of the resulted boards with melted sodium nitrate, potassium nitrate or sodium nitrite salts for epoxy resin separation by the fiberglass and producing within this way sodium bromide, carbonized fiberglass, copper foil, organic gas and nitrogenous oxides.	
A recycling method of copper, copper sulfate, and copper chloride waste of a discarded circuit board TW201029759 - 2010	Inventor(s): FANG HONG-YUAN; HUANG YU; CAI LONG-CHANG; SHEN SHU-MIN; CHEN JUN-WEI; YANG ZHI-HAO Applicant(s): UNIV NAT YUNLIN SCI & TECH [TW] Extension: Taiwan	The present invention has as core to recover copper from milled printed circuit boards **by leaching using copper chloride and nitric acid.** Then, the solution is purified with sodium sulfide to remove other elements. Then, iron metal is added within solution to recover Cu metal or the solution is concentrated by evaporation to achieve copper chloride crystals.	The current invention is focused on Cu recovery from WPCBs by leaching and precipitation/cementation or crystallization process. Can be said that this process leads to formation of large amounts of both solid and liquid wastes.

At the moment UNIVAQ has 1 hydrometallurgical patent (REE recovery from FCC) and two patent pending to the last phase of analysis (Permanent Magnets and PCB treatment). The PCB patent pending is a PCT proposal (PCT-14177 (metal recovery) - International PCT/IB2019/054381 - deposit on 27 May 2019. Anteriority Italian patent N° 102018000005826 IPT-14008 (recupero metalli). Domanda di brevetto N° 102018000005826 - 29 May 2018.

This patent pending represents an innovative solution with respect to the above mentioned patenting analysis. The key differences with respect to the state-of-the-art are:

- Use of acetic acid in HCl (and their possible recycling by distillation) with H2O2 to dissolve all the metals presents in the PCB;
- Production of acetic acid by biological process;
- Possibility to work on PCB without grinding (leaching in a basket reactor);
- Recovery of Cu and Sn with by cementation (with a particle size less than 50 μm for sintering processes);
- Exploitation of the organic and giber grass matrix of PCB;

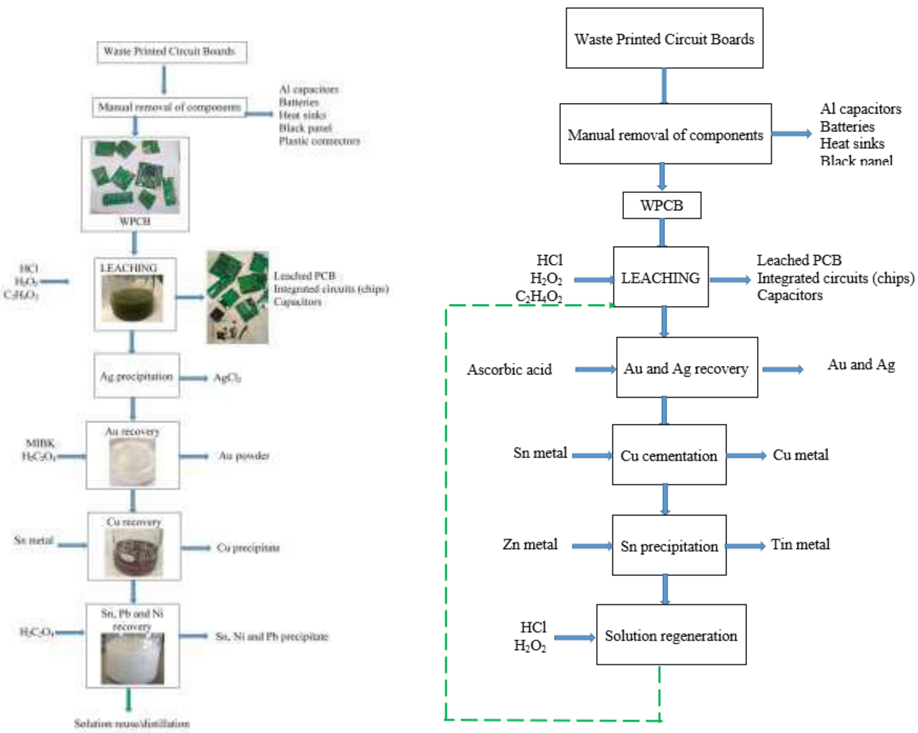
To exploit these patents UNIVAQ has founded a spin-off company "Smart Waste Engineering srl" (see next KER #4).

6.1.1. Technical description

This new technology consists of dissolution of both precious and base metals in one single step followed by selective extraction of elements using different reagents. The leaching process is performed within an acid solution at ambient conditions using hydrochloric acid, hydrogen peroxide and acetic acid as reagents. This system is applied on WPCBs that have previously subjected to manual removal of Al electrolytic capacitors, heat sinks, batteries, connectors and connection peripherals. This step is required to avoid the consumption of reagents and precipitation of Au after its dissolution. The procedure is performed for about 3 hours at a solid concentration not larger than 20% for motherboards and 30% for other kind of e-components (e.g. RAM, chips etc.) In this way a reach solution of both base and precious metals is achieved and furthermore subjected to metals ions reduction from solution. In addition, this leaching system facilitate the dissolution of solder used for the connection of integrated circuits and other capacitors, and furthermore their detaching from the board surface. The reactions involved in the leaching process with their calculated Gibbs Free Energy are as follows:

$Au + 1.5H_2O_2 + 3HCl = AuCl_3 + 3H_2O$	($\Delta G(21°C)$ =-45.504 kcal)	(1)
$Cu + 2HCl + H_2O_2 = CuCl_2 + 2H_2O$	($\Delta G(21°C)$ =-63.338 kcal)	(2)
$Sn + 2HCl + H_2O_2 = SnCl_2 + 2H_2O$	($\Delta G(21°C)$ =-91.410 kcal)	(3)
$Pb + 2HCl + H_2O_2 = PbCl_2 + 2H_2O$	($\Delta G(21°C)$ =-96.896 kcal)	(4)
$Fe + 3HCl + 1.5H_2O_2 = FeCl_3 + 3H_2O$	($\Delta G(21°C)$ =-112.107 kcal)	(5)
$C_2H_4O_2 + HCl + H_2O_2 = C_2H_3ClO_2 + 2H_2O$	($\Delta G(21°C)$ =-46.373 kcal)	(6)
$2Ag + 2HCl + H_2O_2 = 2AgCl + 2H_2O$	($\Delta G(21°C)$ =-74.262 kcal)	(7)
$Ni + 2HCl + H_2O_2 = NiCl_2 + 2H_2O$	($\Delta G(21°C)$ =-83.738 kcal)	(8)
$Zn + 2HCl + H_2O_2 = ZnCl_2 + 2H_2O$	($\Delta G(21°C)$ =-110.330 kcal)	(9)
$2C_2H_4O_2 + Cu + H_2O_2 = CuC_4O_4H_6 + 2H_2O$	($\Delta G(21°C)$ =-61.072 kcal)	(10)
$2C_2H_4O_2 + Zn + H_2O_2 = ZnC_4O_4H_6 + 2H_2O$	($\Delta G(21°C)$ =-111.718 kcal)	(11)
$2C_2H_4O_2 + Ni + H_2O_2 = NiC_4O_4H_6 + 2H_2O$	($\Delta G(21°C)$ =-85.926 kcal)	(12)
$2C_2H_4O_2 + Sn + H_2O_2 = SnC_4O_4H_6 + 2H_2O$	($\Delta G(21°C)$ =-84.173 kcal)	(13)
$2C_2H_4O_2 + Pb + H_2O_2 = PbC_4O_4H_6 + 2H_2O$	($\Delta G(21°C)$ =-74.121 kcal)	(14)
$2C_2H_4O_2 + Fe + H_2O_2 = FeC_4O_4H_6 + 2H_2O$	($\Delta G(21°C)$ =-97.109 kcal)	(15)
$2C_2H_4O_2 + 2Ag + H_2O_2 = 2AgC_2H_3O_2 + 2H_2O$	($\Delta G(21°C)$ =-42.271 kcal)	(16)
$2AgC_2H_3O_2 = 2Ag + 1.5\ C_2H_4O_2 + CO$	($\Delta G(21°C)$ =-27.572 kcal)	(17)
$2C_2H_4O_2 + 2Au + H_2O_2 = 2AuC_2H_3O_2 + 2H_2O$	($\Delta G(21°C)$ = 5.286 kcal)	(18)

Thereafter, the recovered solution is then cooled down to a temperature of about 4 o C to decrease the solubility of AgCl and therefore to precipitate it. Then this is recovered from solution by filtration. The resulted solution from the previous step is further subjected to Au recovery either, by solvent extraction with Methyl Isobutyl Ketone (at an aqueous to organic phase ratio of 2 to 1) and then stripped/precipitated from the organic solution with an oxalic acid solution or by reduction with ascorbic acid. In both alternatives, the solid suspensions are recovered by filtration and further washed with distilled water. Once that Au was recovered from solution, the cementation process with metallic tin for Cu recovery is performed. This is added into solution considering about 80 - 100% of the required reaction stoichiometric amount. Then the solution is filtered for solid precipitate recovery and further washed with distilled water. The reach solution of tin chloride achieved after Cu recovery is subjected to precipitation process with oxalic acid or to cementation with Zn metal powder. Once finished the reaction, the obtained precipitate is filtered out and washed with distilled water. The sketch of the developed procedures is shown in Figure 4.3 a) and b).



a) b)

Fig. 4.3 - Hydrometallurgical process for WPCBs treatment

This process approach is continuously updated. At the moment this system was applied also to the recovery of PGM from automotive spent catalyst.

TRL at the moment range between 4 and 5.

6.1.2. Innovation properties and benefits

The developed hydrometallurgical processes have an innovative content although a continuous optimization is in progress. This innovation could be used in the following forms: process solutions with a Business Plan, research services and policy recommendations.

6.1.3. Limitations

Actually any potential limitation of the innovation has been considered.

6.2. Exploitation strategy

The exploitation strategy must be well defined because the Consortium needs to decide which kind of agreement could be possible after FENIX project. In any case UNIVAQ usually use its spin-off "Smart Waste Engineering srl" to exploit its know-how.

6.2.1. Exploitation routes and guidelines

UNIVAQ will expect to define a detailed route and timeline in the next 6 months

6.3. IPR strategy

6.3.1. Background IP access and ownership

The PCT patent pending described in 6.1 was developed before FENIX project but it was submitted as a patent pending in the first 6 months of FENIX. Limitation about this know-how has not be yet discussed in the ambit of Consortium.

6.3.2. Foreground IP

To be discussed in the ambit of the Consortium.

6.3.2.1. IP strategy

A detailed IP strategy will be developed for the final version of the Deliverable (M36).

6.3.2.2. Analysis of filed patents

See par.6.1 as a summary of the potential patents in completion with UNIVAQ's patent pending.

6.4. Exploitation risk management

No risk analysis has been carried out at this stage.

7. EXPLOITATION PLAN: KER #4

No.	KER Name	Lead partner	Participants
4	Process engineering /Turnkey plant for the recovery of precious and critical metals from waste	UNIVAQ	n/a

Table 5: FENIX KER #4 details

7.1. Exploitable innovations and ambitions

UNIVAQ is interested to exploit their results to develop process engineering and pilot and industrial plants construction (turnkey) to recover precious, base metals and REE through its spin-off (Smart Waste Engineering srl, SWE). Process engineering and industrial plant construction will be based to the IPR of UNIVAQ that will be discussed in the ambit of the Consortium in the next month mainly considering the foundation or not of a NEWCO, with all or some partners of the Consortium.

7.1.1. Technical description

UNIVAQ is a partner of SWE and in this start-up are present as other partners a process and control engineering company and an engineering and construction company. In this way it will be possible to have all the facilities to realize turnkey hydrometallurgical plants.

7.1.2. Innovation properties and benefits

The innovation aspects are linked to the IPR of UNIVAQ and of all the Consortium. The installation of the pilot plant (it is under commissioning phase and start-up in middle June 2019) will be a key point to show the innovation potential of the findings to customers and to demonstrate the hydrometallurgical process at TRL 6. Benefits of this activity is under study with the development of a specific Business Plan and LCA.

7.1.3. Limitations

To be discussed in the ambit of the Consortium

7.2. Exploitation strategy

To be discussed in the ambit of the Consortium. In any case the already available pilot plant it's a very useful showroom for potential customers.

7.2.1. Exploitation routes and guidelines

To be defined after Business Plan development

7.3. IPR strategy

7.3.1. Background IP access and ownership

PCT patent pending belong to UNIVAQ. Its access to the other partners of Consortium will be discussed (included UNIVAQ's spin-off).

7.3.2. Foreground IP

PCT patent pending coupled with the capacity to realize industrial plant (by its spin-off) will be discussed in the next months in the ambit of Consortium.

7.3.2.1. IP strategy

To be discussed in the ambit of Consortium

7.3.2.2. Analysis of filed patents

n.a. for turnkey plants (see 6.3.3.2)

7.4. Exploitation risk management

Not discussed and defined at this stage

8. EXPLOITATION PLAN: KER #5

No.	KER Name	Lead partner	Participants
5	BAL.LCPA software tool	BAL	n/a

Table 6: FENIX KER #5 details

8.1. Exploitable innovations and ambitions

Life Cycle Costing and BALance Lifecycle Performance Assessment Tool (BAL.LCPA) serves as a tool to assess products and processes in terms of economic and environmental Key Performance Indicators (KPI). It aims a comparing different designs or process chains (production and recycling) against each other to identify the best of several options or to evaluate the success of an innovative solution compared to original one (the reference). An arbitrary number of business solutions may be defined and compared. The software covers the entire life cycle from the design phase over the operation to end of life phase. Models might be developed iteratively as in early project phase. The available input data is typically brief and becomes more comprehensive as the project evolves. LCPA models for the new business models and industrial strategies for novel supply chains will be defined and implemented within FENIX.

8.1.1. Technical description

BAL.LCPA is a tool that combines environmental and financial assessment of process and product concepts along their life cycle as an easy-to-use way. KER #5 currently has a TRL equal to 4 for electronic devices. The expected TRL until the end of the project is 6/7.

8.1.2. Innovation properties and benefits

The BAL.LCPA tool is already been used in the maritime industry during the design phase. Different design opportunities are evaluated related to life cycle costs and environmental impact. Within FENIX the tool covers mainly the recycling and scrapping phase of a product. The analysis of different recycling and scrapping processes will be reflected to a more realistic life cycle analysis.

8.1.3. Limitations

The models are always product related. But the tool enables users to set up new models for additional products and processes very easily.

8.2. Exploitation strategy

See chapter "routes and guidelines"

8.2.1. Exploitation routes and guidelines

The route includes: Support of BALance consulting activities (modelling and calculation as service), LCPA tool licenses to be offered to interested companies, user groups for universities and research organisations (non-commercial use only).

8.3. IPR strategy

A basic version of the LCPA is already marketed by BAL. The FENIX developments will extend the software once the project is finished.

8.3.1. Background IP access and ownership

BALance shall not be obliged to provide access to its background for the benefit of other partners that want to exploit results. If a partner would like to receive such access, BALance will consider in its sole discretion whether it wants to provide such access to its background and under which conditions.

8.3.2. Foreground IP

8.3.2.1. IP strategy

A detailed IP strategy will be developed for the final version of the deliverable.

8.3.2.2. Analysis of filed patents

The are some life cycle assessment tools available. But no parents have been identified in this field.

8.4. Exploitation risk management

For the moment there have no exploitation risks been identified.

9. EXPLOITATION PLAN: KER #6

No.	KER Name	Lead partner	Participants
6	High Energy high capacity mills for powders production	MBN	-

Table 7: FENIX KER #6 details

9.1. Exploitable innovations and ambitions

The Fenix project is giving the possibility to MBN of innovate its production processes to meet the increase demand for powder for Additive Manufacturing and in the meantime adapt its processing system to deal with variable raw material source from recycled metals and compounds.

9.1.1. Technical description

MBN target to intercept the growing market demand of advanced metal powders optimized for use in metal additive manufacturing. The many different technologies involved in additive manufacturing requires dedicated and specific powder grades and morphologies that, combined with the additive process, leads to the mechanical and functional properties designed. Most of the powders are nowadays produced by gas atomization and water atomization, two techniques that imply stating from a melt with limitation in composition of the alloy.

MBN has its own and patented material production system based on Mechanical alloying technique. Mechanical alloying (MA) is a solid state powder processing technique involving repeated welding, fracturing and rewelding of powder particles in a high energy ball mill. Originally developed to produce nano Oxide Dispersion strengthening nickel and Iron base superalloys for applications in the aerospace industry MA has now been shown to be capable of synthesizing a variety of equilibrium and non- equilibrium alloy phases starting from blended elemental or prealloyed powders.

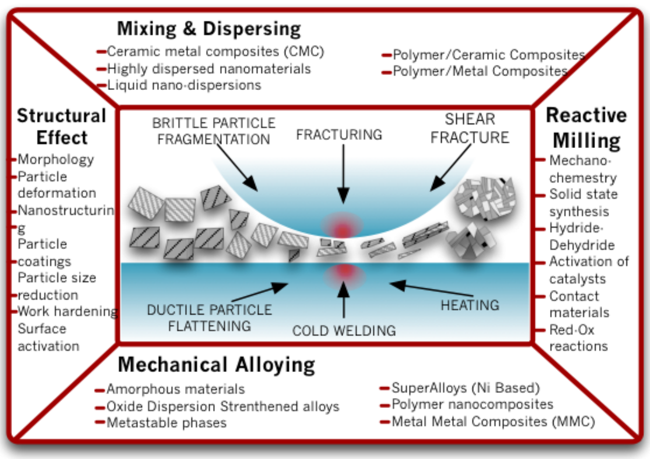


Figure 2 Effects and material achievable via HEBM

MA is best performed in conditions in which pure mechanical impacts are transferred to small volumes of particles that are entrapped during the impact in order to trig mechanochemical reactions that such impacts release shock waves to the material as well combine effects of "aggregation" and breaking. This is why MBN developed and installed a high energy ball mill (HEBM) in which kinetic energy is purely transferred during the impact to the powders and partly to the container, whereas ball/(powder)/ball interactions are minimized.

This technique is able to generate numerous variants of composites materials and structures to promote different synthesis effects depending on materials and process conditions used (above). In particular, HEBM is well suited for the fabrication of metal-metal composite for sintering application (i.e. as feedstock for MIM and binder assisted AM) and Ceramic-metal composites for coatings (i.e. thermal spraying processes) with compositions not accessible by other routes, and – beyond this – it creates unique microstructure thanks to the improved compatibility between matrix and reinforcement hard phase. For example, this technique gives access to composition based on **FeCuSn** materials which have a lower sintering conditions compared to Cobalt (-20% in temperature) but with a lower intrinsic cost of raw material.

But, unlikely gas atomization and water atomization, powder as produced by high energy ball milling (HEBM) does not usually meet morphology targets for AM processing, which requires a narrow Particle Size Distribution range and rounded particles. MBN have developed methods to improve the morphological characteristics of the material by acting on the ball milling process (with process control agent and milling means size/shape and milling machine design) and on post processing (with techniques as classification, sieving and Jet Milling). **In FENIX project MBN want to develop further this processing chain by allowing the close integration of the different manufacturing steps to** increase process efficiency of powder output in the AM particle size distribution to approx. 100% and enhancing the homogeneity of the material in terms of apparent density. On top of this, thanks to the capability of the process to deal with different raw material morphologies and compositions, MBN will improve the capabilities of its process to adapt to different kind of raw metal powder, either coming from traditional primary producers or from recycled e-waste processed via hydrometallurgical route.

9.1.2. Innovation properties and benefits

MBN will provide the AM market with new advanced materials optimized for processing with DIW and FDM that are not obtainable with other processing route. These new material will offer an alternative to current existing powders with increased mechanical properties and lower intrinsic costs. MBN production system is included in a circular economy business model allowing to re-use elements harvested from WEEE determining an additional benefit for the final user of MBN's product.

9.1.3. Limitations

The complete assessment of the circularity has not been completed yet and limitation of the innovation might not be fully highlighted. Currently some limitations are faced in the production of feedstock for MIM and FDM due to the higher surface area of the powder produced by MBN that determine different rheological behaviour on respect to spherical powders.

9.2. Exploitation strategy

The full exploitation strategy is not yet defined.

9.2.1. Exploitation routes and guidelines

Introduction of the new material to the market will be done in collaboration with FCIM and I3DU as early adopter of the materials. Their success case will be brought as example at trade fair in Powder Metallurgy sector (i.e. Euro PM2019 – Maastricht in October 2019) and Additive Manufacturing Sector (FormNext – Frankfurt in November 2019)

9.3. IPR strategy

9.3.1. Background IP access and ownership

MBN has a precise policy on its background in line with the IP strategy meant to protect the innovations developed in the company, in FENIX the MBN's on High Energy high capacity mills for powders production, that include their design concepts and constructive details as well as processing route parameters, is subject to restrictions. As specified in the consortium agreement, MBN will not grant access rights to the background

9.3.2. Foreground IP

9.3.2.1. IP strategy

The foreground is partially protected by the patents held by MBN about the HEBM process and its application to material for AM, the innovation that might fall outside the patent boundaries will be kept as trade secret.

9.3.2.2. Analysis of filed patents

MBN Nanomaterialia holds a dozen patents rights already filed and granted in different fields of *nanotechnologies*, *metallurgy*, *mechano-chemistry*, *additive manufacturing*, and *surface coating applications*. The most relevant technology to pursue the FENIX project action is "*Improvements to Mechanochemical reactors*" - EP2643089B1 , and "*Process for recycling, by milling, industrial waste and materials at the endo of their service life" - EP0850700B1*. The MBN freedom to operate is reinforced by a series of professional and extended FTO analysis – patent searches, already performed as outcome of the previously attended projects. These permitted to clarify the IPR situation thus identifying the similar patent already existing in this field and the possible threats. For what concerns the nano-structuring mechanochemical process, Mechanomade®, the patent EP2643089 has been already granted. Considering the current IPR assets and FTO analysis, none of the current and future competitor can interfere with MBN freedom to operate concerning and Mechanomade® technologies. The brand identity of Mechanomade® is further protected by a trademark ® this will support the acknowledgement of MBN's product values across the AM value chain.

9.4. Exploitation risk management

Not discussed and defined at this stage

10. EXPLOITATION PLAN: KER #7

No.	KER Name	Lead partner	Participants
7	3D printing	FCIM	n/a

Table 8: FENIX KER #7 details

1.1. Exploitable innovations and ambitions

This KER will explore the 3D printing technology developed for FENIX project. The results of the project to be transferred to the industry will be:

- 3D printer based in DIW (Direct Ink Writing) Technology for paste materials with a rheology that requires a high pressure of extrusion.

1.1.1. Technical description

A printing paste is formulated with a part of metals, obtained through recovery process, and with a ceramic part. Commercial 3D printers have been tested in order to study the printability of the materials developed. Due to the rheology of the materials, a higher pressure of extrusion is needed. For this reason, a new additive manufacturing equipment is designed and developed during the course of the project. This KER is currently at TRL 4 and is expected to reach TRL 7 by the end of the project.

1.1.2. Innovation properties and benefits

Innovation and advantages of the new DIW system for high pressures:

- The base platform made of marble provides excellent rigidity and dimensional stability.
- The support structure formed by blocks of aluminum profiles has a high stiffness and stability and provides multiple standard anchors for various components.
- The dosing piston moved by a stepper motor allows a high precision volumetric dosing.
- The dosing device fixed to the base platform or to the support structure makes it possible to lighten the mass of the components moved by the movement device in three axes and this enables the installation of a stepper motor of greater power to extrude pasty materials of higher viscosity .

1.1.3. Limitations

No limitations are identified.

1.2. Exploitation strategy

This KER created a spin off (BCN3D Technologies) that will be in charge of the results transfer. The exploitation strategy is to reach a TRL 7 by the end of this project and transfer the results to BCN3D Technologies so that they can develop it to a TRL 8 and 9.

1.2.1. Exploitation routes and guidelines

The full exploitation strategy is not yet defined.

As KER #7 provides a solution for printing metal materials mixed with a ceramic mash that may involve other KERs (e.g. KER #6 by using powders production), a full exploitation strategy could also be devised in parallel with the relevant KERs.

1.3. IPR strategy

A background study has been done in order to detect exploitation opportunities for a future development of an IPR plan.

1.3.1. Background IP access and ownership

The innovation developed object of property protection will be licensed to a KER's spin off (BCN3D Technologies) its access to the different KERs is not yet defined.

1.3.2. Foreground IP

1.3.2.1. IP strategy

A detailed IP strategy and access will be developed for the final version of the Deliverable (M36).

1.3.2.2. Analysis of filed patents

A consultancy study on the innovation developed concludes that none of the designs infringes actual patents. (The patents identified are available on request).

1.4. Exploitation risk management

Currently, no exploitation risk is identified.

11. EXPLOITATION PLAN: KER #8

No.	KER Name	Lead partner	Participants
8	3D scanning of human faces	I3DU	3DHUB

Table 9: FENIX KER #8 details

11.1. Exploitable innovations and ambitions

The concept is to develop a point of sale solution based on a face scanner capable of producing a high resolution mesh of the face that is then used to create customized and personalized jewelry with the use of additive manufacturing technologies and recycled precious metals from the FEXIX processes.

11.1.1. Technical description

The concept will work as follows:

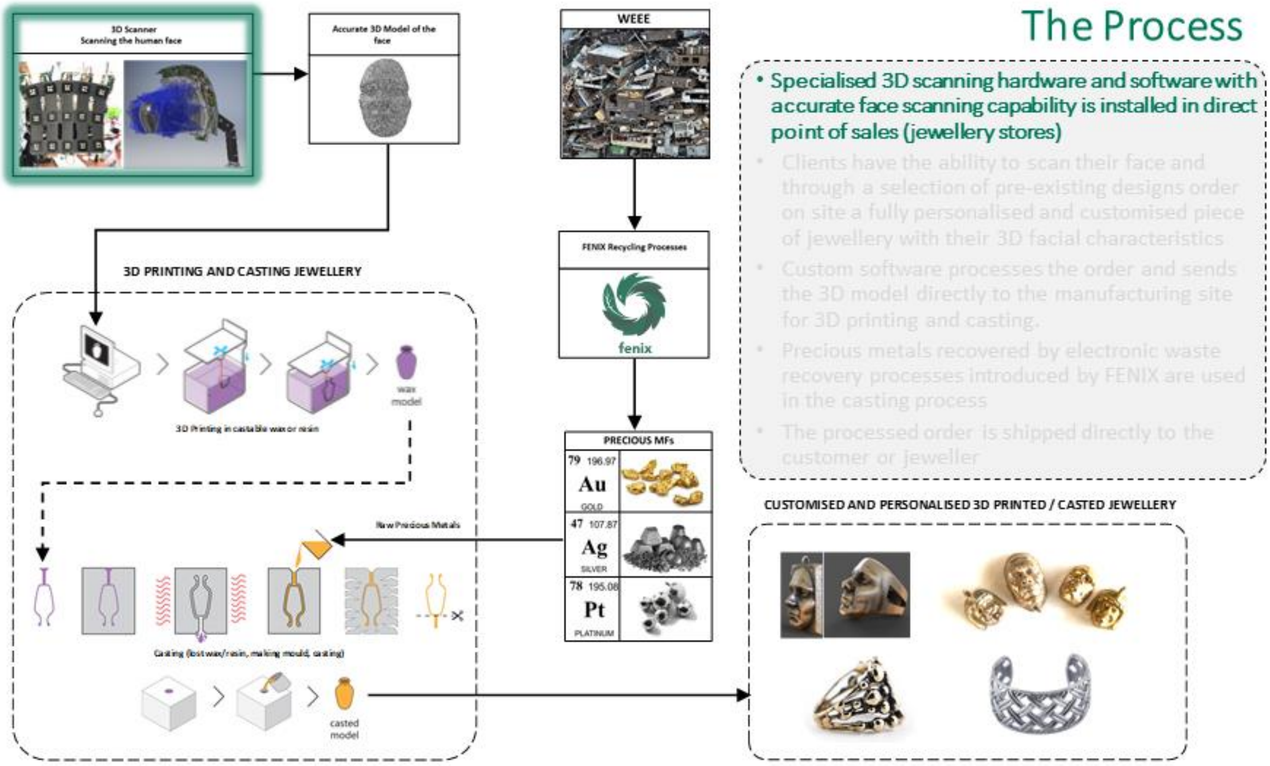
Ordering Phase

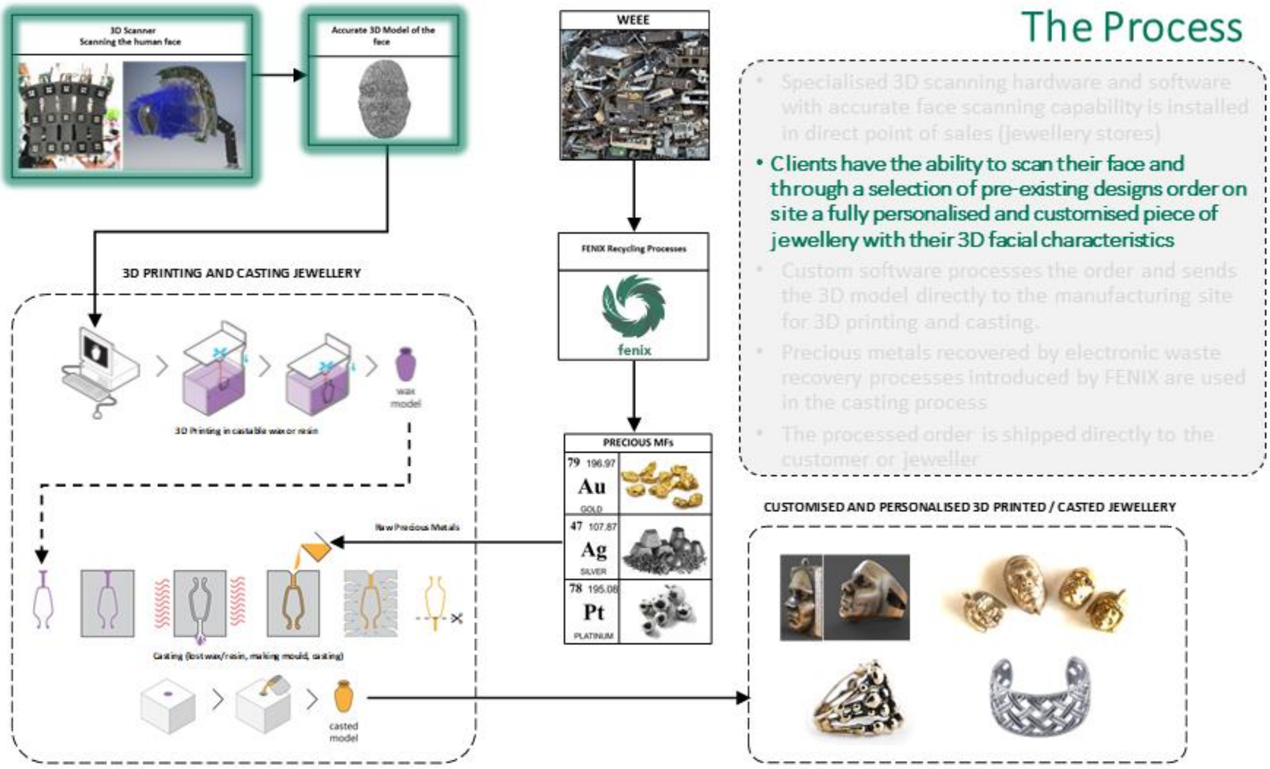
- The client walks into a jewellery store fitted with our solution (scanner plus back end services)
- He then puts his face on our scanner and with a single click we capture his face in 3D (high resolution mesh)
- He then selects from an app on site from a library/catalogue of jewels (rings, necklaces, earrings, cufflings etc.) with nice designs and different precious metals and including the 3d model of the clients face
- He then pays to the jewellery store and specifies in the system if he wants to collect in the store or have the order shipped at home for the order to begin.
- The scanner which is connected to an online back end sends the order through for manufacturing.

Processing Phase

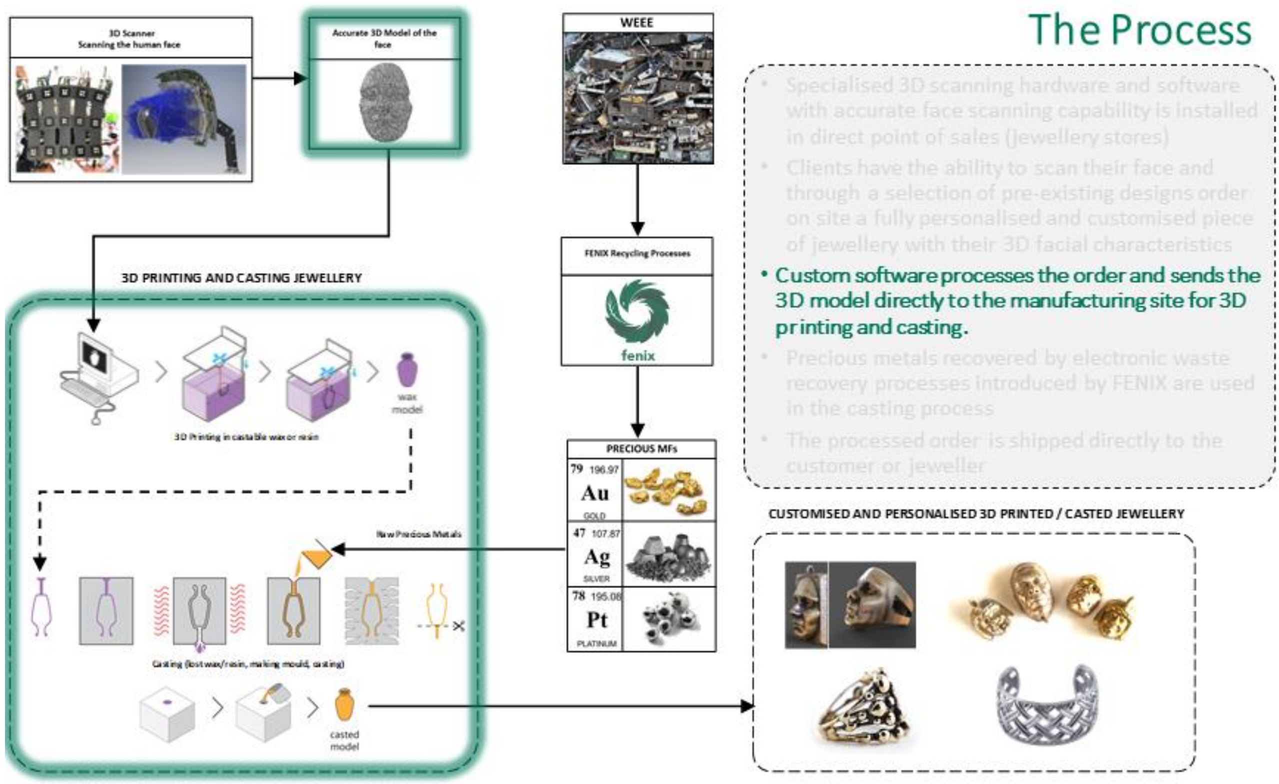
- The manufacturing site receives the order which is a 3D file (stl) of the jewel the client selected with his face
- The manufacturing site then
    - 3D prints the jewel in castable resin
    - Casts and post processes the jewel
    - Packages the jewel in nice packaging
    - Ships the jewel either to the client directly or to the jewellery store

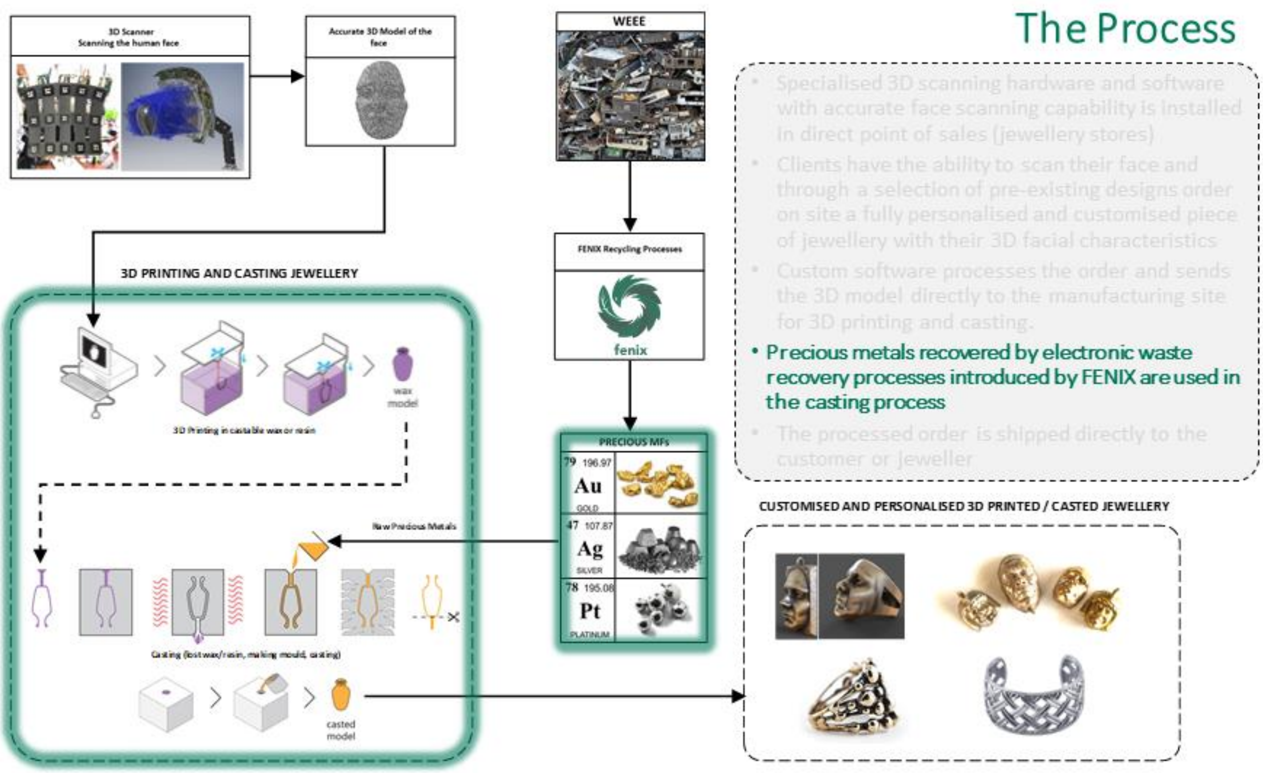
The following pages contain a more detailed technical description of KER #8 with images and graphics. It is separated to two sections one describing the workflow process and the other the business process.

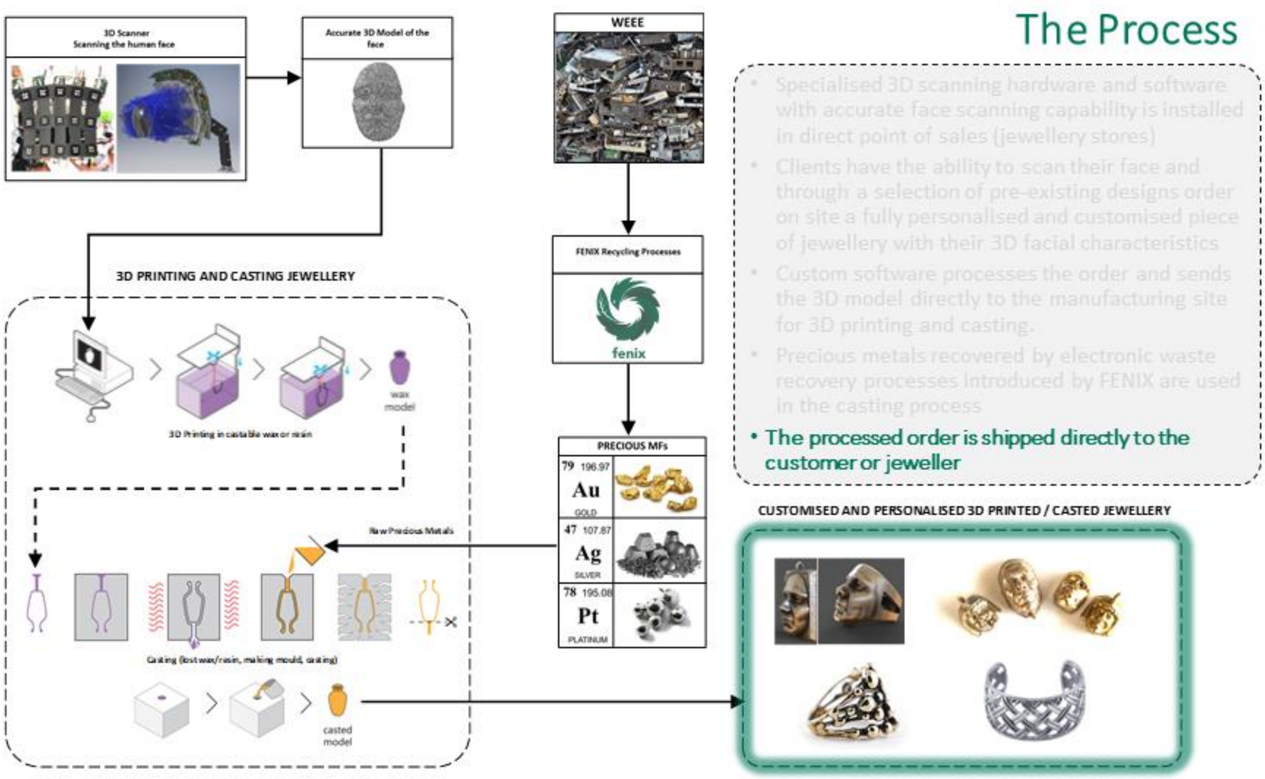

3D Scanner
Scanning the human face
Accurate 3D Model of the face
WEEE
FENIX Recycling Processes
fenix
PRECIOUS MFs
79 196.97 Au GOLD
47 107.87 Ag SILVER
78 195.08 Pt PLATINUM
3D PRINTING AND CASTING JEWELLERY
3D Printing in castable wax or resin
wax model
Raw Precious Metals
Casting (lost wax/resin, making mould, casting)
casted model
The Process
• Specialised 3D scanning hardware and software with accurate face scanning capability is installed in direct point of sales (jewellery stores)
• Clients have the ability to scan their face and through a selection of pre-existing designs order on site a fully personalised and customised piece of jewellery with their 3D facial characteristics
• Custom software processes the order and sends the 3D model directly to the manufacturing site for 3D printing and casting.
• Precious metals recovered by electronic waste recovery processes introduced by FENIX are used in the casting process
• The processed order is shipped directly to the customer or jeweller
CUSTOMISED AND PERSONALISED 3D PRINTED / CASTED JEWELLERY


3D Scanner
Scanning the human face
Accurate 3D Model of the face
WEEE
FENIX Recycling Processes
fenix
PRECIOUS MFs
79 196.97 Au GOLD
47 107.87 Ag SILVER
78 195.08 Pt PLATINUM
3D PRINTING AND CASTING JEWELLERY
3D Printing in castable wax or resin
wax model
Raw Precious Metals
Casting (lost wax/resin, making mould, casting)
casted model
The Process
• Specialised 3D scanning hardware and software with accurate face scanning capability is installed in direct point of sales (jewellery stores)
• Clients have the ability to scan their face and through a selection of pre-existing designs order on site a fully personalised and customised piece of jewellery with their 3D facial characteristics
• Custom software processes the order and sends the 3D model directly to the manufacturing site for 3D printing and casting.
• Precious metals recovered by electronic waste recovery processes introduced by FENIX are used in the casting process
• The processed order is shipped directly to the customer or jeweller
CUSTOMISED AND PERSONALISED 3D PRINTED / CASTED JEWELLERY

H2020 Innovation Action - This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 760792







11.1.2. Innovation properties and benefits

KER #8 has the following innovation properties and benefits:

- The concept of 3D scanning human faces for use in jewellery will be realised for the first time worldwide and this niche will allow for a first mover advantage to the global jewellery industry with enormous potential
- The highly innovative system under development will be the first photogrammetry based 3D scanner purpose built specifically for generating high resolution 3D geometry of the human face.
- The high resolution nature of the 3D data acquired will allow for aesthetically acceptable and marketable 3d printing of human faces onto jewellery which by its nature is done at small scales and with no colour texture (i.e. just metal)
- Jewelry personalization has so far been limited to engraving just a name or hand carving personal characteristics with small accuracy. 3D scanning brings more accurate recognizable results and an unprecedented level of realism
- KER #8 has the potential of a total reconfiguration of the channel landscape allowing the jewellers to achieve instant onsite sales with the onsite hardware and the online back end services that will be provided.

11.1.3. Limitations

There are some limitations related to the technology involved to achieve the objective of 3D scanning human faces for use in Jewellery such as:

- Correct lighting conditions need to be present for the 3D scanner to operate properly
- The subject must remain static for a few seconds for the 3D capture to be successful

11.2. Exploitation strategy

The full exploitation strategy is not yet defined. However, it may include use for further research as well as use for future business modelling activities.

11.2.1. Exploitation routes and guidelines

For the exploitation of 3D scanning of human faces and then converting those to customised and personalised jewellery for customers there are two main exploitation routes that are foreseen:

- **B2B route:** This one deals with the development of specialised hardware purpose built for 3D scanning of human faces and converting them to customised and personalised jewellery. The hardware will be exploited by coupling it with back end and front end Software services and selling it as a B2B solution to jewellery stores. The jewellery stores would then be able to use it (hardware and software) as a plug and play solution that enables them to sell directly to their own customers a series of brand new personalised jewels.
- **B2C route:** This one deals with the development of an online service purpose built for converting facial image data uploaded by users, to customised and personalised jewellery, and selling them directly to the customers.

11.3. IPR strategy

11.3.1. Background IP access and ownership

Currently, no issues related to background IP and ownership are foreseen.

11.3.2. Foreground IP

Currently, no forms of protection are in place. This may evolve/change during the project where it will be investigated weather a patent or a registered Community design is the is the best way forward for protecting any IP that will be generated through this activity.

11.3.2.1. IP strategy

A more detailed IP strategy will be developed for the final version of the Deliverable (M36).

11.3.2.2. Analysis of filed patents

n.d.

11.4. Exploitation risk management

Currently no exploitation risk is foreseen.

12. EXPLOITATION PLAN: KER #9

No.	KER Name	Lead partner	Participants
9	FENIX integrated platform	SINGULAR	n/a

Table 10: FENIX KER #9 details

12.1. Exploitable innovations and ambitions

This KER will provide a single point of access to users, from which they can access the main functionalities of FENIX. Key innovations that the web platform will expose include:

- Access to consumers to view best practice solutions and discuss and build upon them according to customized needs.
- Social feedback mechanisms from which feedback and user experience regarding application of circular models can be gathered and analysed. Moreover, the identification of trends based on the results of the analysis will be provided
- Integrated access to FENIX Decision Support System (DSS) from which users can define the parts of their plant, attach sensors to each part of interest and receive suggestions regarding best course of action from the DSS.

12.1.1. Technical description

KER #9 integrates the various services (e.g. Marketplace, DSS) and presents them to users via a single graphical interface. Moreover, it offers all services that are typical in a social media platform, allowing users to interact with each other directly or publicly.

As an integrated solution, KER #9 currently has a TRL equal to 2. Expected TRL until the end of the project is 7.

12.1.2. Innovation properties and benefits

Added value of KER #9 can be summarized in the following items:

- Easy access and utilization to the CPA Methodology (KER #2)
- Identification and continuous improvement of best practices via intra-consumer interaction.
- Dynamic recommendation engine with real time monitoring capabilities.

12.1.3. Limitations

Currently, no limitations have been identified.

12.2. Exploitation strategy

The full exploitation strategy is not yet defined. As KER #9 provides integrated access to various functionalities that may involve other KERs (e.g. via the DSS to KER #2), a full exploitation strategy must be devised in parallel with the relevant KERs. The solution of exploiting KER #9 in bundles is also considered. In the bundled approach, the KER will be exploited according to each customer needs by bundling together only the functionalities of interest. For example, a costumer that needs to use sensor analytics may use only the DSS bundle, while another interested in interactions with third parties may use a subset of the FENIX Marketplace.

12.2.1. Exploitation routes and guidelines

The exploitation routes have not yet been fully defined. Main approaches considered are a) the direct approach via the network of the consortium associates' network, b) the indirect approach via consulting firms and third parties and c) the establishing of a FENIX community.

12.3. IPR strategy

12.3.1. Background IP access and ownership

Parts of software that SINGULAR uses and can used by the KER #9 have a closed source policy.

12.3.2. Foreground IP

Parts that are protected under a closed source license will be utilized by the KER as a service deployed in a containerized environment.

12.3.2.1. IP strategy

A detailed IP strategy will be developed for the final version of the Deliverable (M36).

12.3.2.2. Analysis of filed patents

KER #9 involves techniques and software for integrating FENIX related services. There is a multitude of frameworks, libraries and best practices used, none of which has any patent.

12.4. Exploitation risk management

At this stage of development and exploitation plan analysis, no exploitation risk is identified.

H2020 Innovation Action - This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 760792

13. FENIX BUSINESS MODELS

13.1. FENIX Business Model Canvas #1 (Filaments-oriented)

Key partnerships: • R&D centres • Universities • Fablabs • Strategic industrial companies • I3DU, UNIVAQ, FCIM • Binder suppliers	**Key activities:** • Material characterization/development • Material production, • Quality check, • Material standardization	**Value proposition:** • Selling green/recycled materials for additive manufacturing (filaments)	**Customer relationship:** • Dedicated relation with fablabs/big customers • Common relation with final users (resellers)	**Customer segments:** • Fablabs • 3D printing companies • Private customers • SMEs • Prototyping companies • Binder suppliers
	Key resources: • Dedicated operation site • Proprietary knowledge • Patents • Business / chemical scientists • Sales force • Green raw materials • Extrusion systems		**Channels:** • Dedicated sales force (for big customers) • Web/phisical shops	

Cost structure: • Production costs • Transportation costs • Standardization costs (small %) • Marketing costs	**Revenue streams:** • Transaction and recurring revenues from selling materials

Table 11: FENIX Business Model Canvas #1 details

13.2. FENIX Business Model Canvas #2 (filaments service-oriented)

<table>
<tr>
<td rowspan="2">Key partnerships:
Fablabs
FENIX partners</td>
<td>Key activities:
Order/sales of 3D printed products
Design of personalized products
3D printing,
Debinding & Sintering
Polishing/Finishing
Shipping</td>
<td rowspan="2">Value proposition:
Selling services for producing products using green filaments for additive manufacturing</td>
<td>Customer relationship:
B2B & B2C relation with customers</td>
<td rowspan="2">Customer segments:
Private customers
Business customers</td>
</tr>
<tr>
<td>Key resources:
Manufacturing site
Proprietary knowledge
Patents
Legal advisory
Sales/marketing force
Green raw materials</td>
<td>Channels:
Internet (website, apps, etc.)</td>
</tr>
</table>

Cost structure: • Production costs • Development costs (R&D, etc.) • Marketing&sales costs • Shipping costs • Administration costs (insurance, certifications, etc.)	**Revenue streams:** • Recurring revenues from selling 3D printed products

Table 12: FENIX Business Model Canvas #2 details

13.3. FENIX Business Model Canvas #3 (Powders-oriented)

<table>
<tr>
<td rowspan="2">Key partnerships:
R&D centres
Universities
Fablabs
Strategic industrial companies
UNIVAQ</td>
<td>Key activities:
Material characterization/development
Material production,
Quality check,
Material standardization</td>
<td rowspan="2">Value proposition:
Selling green/recycled materials for additive manufacturing (metal powders)</td>
<td>Customer relationship:
Direct relation with customers</td>
<td rowspan="2">Customer segments:
Companies exploiting SLD/MLD/MLS technologies:
Fablabs
3D printing companies
SMEs
Prototyping companies</td>
</tr>
<tr>
<td>Key resources:
Dedicated operation site
Proprietary knowledge
Patents
Business scientists
Sales force
Green raw materials</td>
<td>Channels:
Dedicated sales force (for big customers)
Web/physical shops</td>
</tr>
<tr>
<td colspan="3">Cost structure:
Production costs
Transportation costs
Standardization costs (small %)
Marketing costs</td>
<td colspan="2">Revenue streams:
Transaction and recurring revenues from selling materials</td>
</tr>
</table>

Table 13: FENIX Business Model Canvas #3 details

13.4. FENIX Business Model Canvas #4 (Service-oriented)

<table>
<tr>
<td rowspan="2">Key partnerships:
R&D centres
Universities
Strategic industrial companies
UNIVAQ</td>
<td>Key activities:
Material characterization/development
Material production,
Qualitity check,
Material standardization</td>
<td rowspan="2">Value proposition:
Selling services producing metal powders for additive manufacturing</td>
<td>Customer relationship:
Direct relation with customers</td>
<td rowspan="2">Customer segments:
Companies exploiting SLD/MLD/MLS technologies:
3D printing companies
SMEs
Prototyping companies</td>
</tr>
<tr>
<td>Key resources:
Dedicated operation site
Proprietary knowledge
Patents
Business scientists
Sales force</td>
<td>Channels:
Dedicated sales force (for big customers)
Web/physical shops</td>
</tr>
<tr>
<td colspan="3">Cost structure:
Production costs
Transportation costs
Standardization costs (small %)
Marketing costs
Characterization costs</td>
<td colspan="2">Revenue streams:
Transaction and recurring revenues from selling production services</td>
</tr>
</table>

Table 14: FENIX Business Model Canvas #4 details

H2020 Innovation Action - This project has received funding from the European Union's
Horizon 2020 research and innovation programme under grant agreement N. 760792

13.5. FENIX Business Model Canvas #5 (B2B jewels - stores)

<table>
<tr>
<td rowspan="2">Key partnerships:
• Fablabs
• Jewelry manufacturers (forging/casting labs)
• Distribution chain (jewelry retailers)
• FENIX partners</td>
<td>Key activities:
• Order/sales of jewels
• Design of personalized jewels (3D scanning, 3D modelling, etc.),
• 3D printing,
• Casting/creation of jewels,
• Polishing/Finishing
• Shipping</td>
<td rowspan="2">Value proposition:
• Selling personalized /green 3D printed jewels (human face)</td>
<td>Customer relationship:
• B2B Direct relation with retailers
• B2C relation with customers
• B2C2B relation with customers and retailers</td>
<td rowspan="2">Customer segments:
• Jewelry stores
• Wholesalers
• Private customers</td>
</tr>
<tr>
<td>Key resources:
• Manufacturing site
• Proprietary knowledge
• Patents
• Legal advisory
• Sales/marketing force
• Green raw materials</td>
<td>Channels:
• Internet (website, apps, etc.)
• Retailer shops</td>
</tr>
</table>

Cost structure:	Revenue streams:

• Production costs
• Development costs (R&D, etc.
• Technical support costs (after-sales, etc.)
• Marketing&sales costs
• Transportation costs
• Administration costs (insurance, certifications, etc.)
	• Recurring revenues from selling jewels (for retailers and manufacturers)
	  ◦ Royalty revenues
	  ◦ Profit margin for manufacturer
	  ◦ Profit margin for retailer
	• Revenue from selling scanner machine
	  ◦ Recurring licence/maintenance fees

Table 15: FENIX Business Model Canvas #5 details

13.6. FENIX Business Model Canvas #6 (B2C jewels – online (service))

<table>
<tr>
<td rowspan="2">Key partnerships:
Fablabs
Jewelry manufacturers (forging/casting labs)
FENIX partners</td>
<td>Key activities:
Order/sales of jewels
Design of personalized jewels (3D scanning, 3D modelling, etc.),
3D printing,
Casting/creation of jewels,
Polishing/Finishing
Shipping</td>
<td rowspan="2">Value proposition:
Selling 3D printing services of green/personalized metal products (jewels, etc.)</td>
<td>Customer relationship:
B2C relation with customers</td>
<td rowspan="2">Customer segments:
Private customers</td>
</tr>
<tr>
<td>Key resources:
Manufacturing site
Proprietary knowledge
Patents
Legal advisory
Sales/marketing force
Green raw materials</td>
<td>Channels:
Internet (website, apps, etc.)</td>
</tr>
</table>

Cost structure:	Revenue streams:

• Production costs
• Development costs (R&D, etc.)
• Marketing&sales costs
• Shipping costs
• Administration costs (insurance, certifications, etc.)
	• Recurring revenues from selling jewels (for consumers)
	  • Royalty revenues
	  • Profit margin for manufacturer/retailer

Table 16: FENIX Business Model Canvas #6 details

13.7. FENIX Business Model Canvas #7 (Product-oriented)

<table>
<tr>
<td rowspan="2">Key partnerships:
R&D centres
Universities
Chemical equipment suppliers
Engineering companies
OEMs,
Industrial associations
Governments
Consumer associations
Public/local administrations</td>
<td>Key activities:
Technological / Sustainability assessment,
Pilot plant design / engineering / construction / testing / validation / startup
Standardization,
Transport,
Installation,
Maintenance
Problem solving
Consulting</td>
<td rowspan="2">Value proposition:
Selling pilot plants</td>
<td>Customer relationship:
Dedicated/personal assistance when purchasing a plant</td>
<td rowspan="2">Customer segments:
OEMs
Powder-metallurgy companies
Metal traders</td>
</tr>
<tr>
<td>Key resources:
Dedicated operation site
Proprietary knowledge
Patents
Business / chemical scientists
Sales force</td>
<td>Channels:
Sales force (for big customers)
Web sales (for small/one-shot customers)</td>
</tr>
</table>

Cost structure (Typical of a manufacturing company): • Production costs • Transportation costs • Installation costs • Standardization costs • Data management costs • After-sales service costs	**Revenue streams:** • Transaction and recurring revenues from selling plants • Asset sales • In terms of pricing strategies, volume dependent prices should be suitable for product feature dependent prices for plants

Table 17: FENIX Business Model Canvas #7 details

H2020 Innovation Action - This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N. 760792

13.8. FENIX Business Model Canvas #8 (Fablab like_use-oriented)

<table>
<tr>
<td rowspan="2">Key partnerships:
R&D centres
Universities
Chemical equipment suppliers
Engineering companies
OEMs
Industrial associations
Governments
Consumer associations
Public/local administrations
Training centres
Fablabs network</td>
<td>Key activities:
Technological / Sustainability assessment,
Pilot plant training,
Standardization,
Product distribution - Transport,
Set-up,
Maintenance
Problem solving
Consulting</td>
<td rowspan="2">Value proposition:
Selling pay-per-use services</td>
<td>Customer relationship:
Dedicated/personal assistance when using the plants (fablabs style)</td>
<td rowspan="2">Customer segments:
OEMs
CEMs
Powder-metallurgy companies?
Metal traders?
Fablabs</td>
</tr>
<tr>
<td>Key resources:
Dedicated operation site
Proprietary knowledge
Patents
Business / chemical scientists
Sales force</td>
<td>Channels:
Sales force (for big customers)
Web sales (for small/one-shot customers)
Fablabs network</td>
</tr>
</table>

Cost structure (Typical of a manufacturing company): • Operational costs • Transportation costs (additional service) • Maintenance costs • Training and supervising costs • Data management costs • Marketing costs	**Revenue streams:** • Fees from renting plants • Asset sales • In terms of pricing strategies, volume dependent prices.

Table 18: FENIX Business Model Canvas #8 details

13.9. FENIX Business Model Canvas #9 (result-oriented)

Key partnerships	Key activities / Key resources	Value proposition	Customer relationship / Channels	Customer segments
Key partnerships: • R&D centres • Universities • Chemical equipment suppliers • Engineering companies • OEMs • Industrial associations • Governments • Consumer associations • Public/local administrations • Training centres • Customer/user network	**Key activities:** • Technological / Sustainability assessment, • Pilot plant training and support, • Operational services • Consulting **Key resources:** • Dedicated operation site • Operational staff • Proprietary knowledge • Sales force	**Value proposition:** • Selling refining services • Experimentation as business development	**Customer relationship:** • Dedicated/personal assistance when delivering the service **Channels:** • Web sales (web portal) • Customer/user network	**Customer segments:** • OEMs • CEMs • Powder-metallurgy companies • Material traders & Recyclers

Cost structure (Typical of a manufacturing company): • Operational costs • Overhead costs • Marketing costs • Depreciation costs	**Revenue streams:** • Service recurring fees • Revenue share (provider/customer) • In terms of pricing strategies, volume dependent prices.

Table 19: FENIX Business Model Canvas #9 details

14. CONCLUSIONS

This draft Exploitation Plan contains 9 already identified Key Exploitable Results (KERs) as well as 9 business model canvases.

In the remaining 18 months of the FENIX project these preliminary exploitation plan will be continuously updated and further refined by combining individual KERs into clusters.

In addition, the FENIX consortium will investigate in more depth to found a start-up company exploiting the FENIX's results, by maximizing the exploitation of the developed pilot plant in the market. All the FENIX partners will benefit of the start-up both directly (e.g. being end-users of the plant or technology suppliers), by increasing competitiveness in local markets selling plants or services, and indirectly (e.g. being shareholders of the start-up). The FENIX start-up will have as main objective the commercialization of an integrated cross-sectorial and multi-material process for the assembly/disassembly of products, the recovery of secondary raw materials and the production of metal powders for the application fields described in FENIX. In addition, the start-up will sell also pay-per-use services to private users and SMEs. The company's structure will be determined basing on FENIX's results. However, there is also the option to involve external actors (who, obviously, would not be competitors of any FENIX partner) like plant manufacturing companies interested in selling innovative process plants in agreement with FENIX's partners. The ownership of the start-up will be based on individual contributions of each FENIX partner. The FENIX start-up will be:

- the only holder of all patents related to material recycling and
- the only reseller of plants and services through traditional selling, licensing, renting or franchising. FENIX partners will be the only to receive a free access to all of the start-up's material and immaterial resources.

Considering all the potential customers of FENIX (both B2B and B2C ones) on medium term, FENIX partners are seeing a market for 50-100 plants until 2030. This could represent roughly a turnover of 75-150 million €. Basing on industrial partners expectations, the partners expect that 150-200 new job opportunities will be created by the end of 2030. We estimate 2/3 of them related with the recovery plants engineering and construction, while 1/3 related to services (ICT, Consultancy, maintenance management, etc.).