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WP2 – NEW BUSINESS MODELS & PILOT PLANTS SUSTAINABILITY ASSESSMENT

Task 2.1 BUSINESS MODELS SUSTAINABILITY ANALYSIS

Person responsible / Author:	Reinhard Ahlers (BALance), Markus Lehne (BALance)
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Author(s) contact information

Name	Organisation	E-mail	Tel
Reinhard Ahlers	BALance TC	reinhard.ahlers@bal.eu	+49 421 33517 44
Markus Lehne	BALance TC	markus.lehne@bal.eu	+49 421 33517 17

ABSTRACT

The quicker response to customers' demands requires a shift especially for SMEs from mass production to high-value markets characterized by lower volumes. This trend is related to higher investments into production lines to reach the necessary flexibility. A comprehensive cost/benefit analysis is essential to evaluate future investments. The ecological awareness of customers is increasing in Europe. Therefore, the efficient recovery of secondary resources must be assured. Both aspects are in the focus of the FENIX project. Additionally, these aspects are combined with circular economy principles.

Workpackage 2 is responsible for the economical and ecological evaluation of the business models and the developed key enabling technologies to cover the three mentioned aspects of FENIX. This deliverable D-2-1 is the outline of the first evaluation approach and the parameters to focus on. The different evaluation results will be documented within the next versions of this deliverable.

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Abbreviations and Acronyms:	
AFP	Aerosol formation potential
AP	Acidification Potential
AM	Additive Manufacturing
BAL.LCPA	BALance Life Cycle Performance Analysis
BM	Business Model
BoM	Bill of Material
CAPEX	Capital Expenditure
CBM	Circular Business Model
CED	Cumulative Energy Demand
EP	Eutrophication Potential
GWP	Greenhouse warming Potential
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Costs
LCI	Life Cycle Inventory
NVP	Net-Present Value
OPEX	Operational Expenditure

1. INTRODUCTION

The major aim of FENIX workpackage 2 is the assessment of business models. The evaluation focuses on the economical, environmental, and social parameters. The Circular Business Models (CBMs) relevant for FENIX have been identified in cooperation with workpackage 1. Deliverable D.2.1 describes the first approach to prepare the detailed assessments. Therefore, the structure of the assessment is defined and described. D.2.1 is a living document and will be updated every 6 months until the project midterm.

2. ASSESSMENT APROACH

As one of the first assessment steps it is necessary to select Key Performance Indicators (KPIs) to measure the success of the FENIX concepts. This requires the definition of the characteristics of the circular economy.

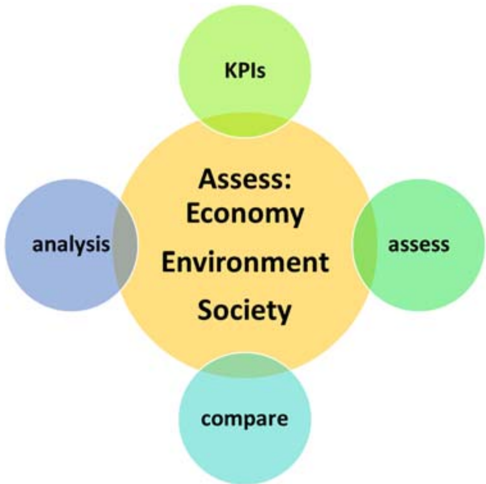

Figure 1: Workpackage 2 approach

Within a first approach in FENIX the economic and environmental aspect of the business models will be analysed based upon the theoretic description. After the implementation of the pilot plants (see workpackage 6) a second assessment will take place to evaluate the actual situation of the plants. Again, the focus will be on the economic and environmental analysis, but also the social analysis will become an important role within the second phase (see Figure 1). The results of both assessment steps will be compared to each other to support the further development of the underlying methods.

The theoretical businesses model descriptions and the pilot plant implementations will also be compared with the analysis results of the current circular economy. The continuous analysis results will be used to optimise the technical pilot implementation on one side and to adopt the Circular Business Models (CBMs) on the other side. The first model definitions and calculations will be realised manually while in the second analysis phase an evaluation tool (BAL.LCPA) will be used to simulate and optimise the different business models.

The evaluation results will be presented in an easy manageable representation. One opportunity is the spider diagram.

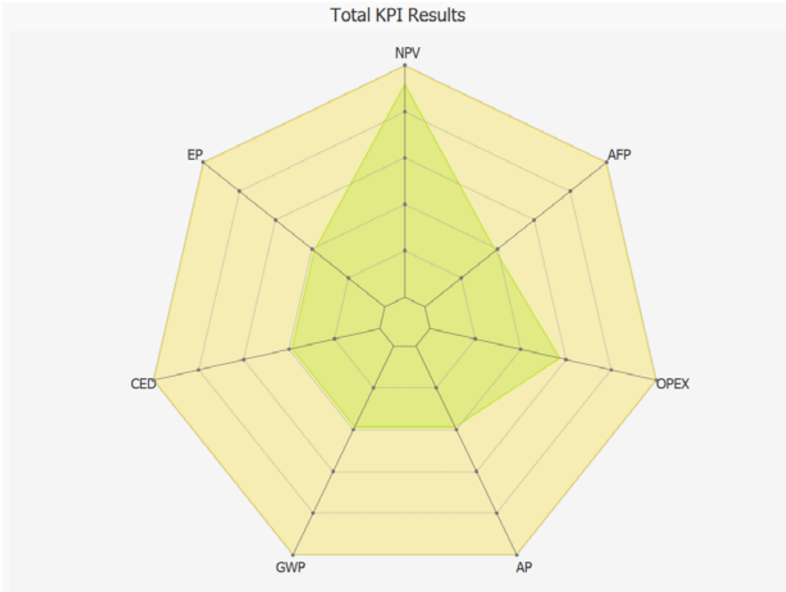

Figure 2: Analysis result representation (example)

The spider diagram shows the KPI values for different CBMs in one graph. It allows also the combined presentation of the economic, environmental, and later the social assessment results. Within the example (see Figure 2) the economical evaluation results are represented by OPEX (operational expenditure) and NVP (Net-present value) while the environmental results are represented by AFP (Aerosol formation potential), AP (Acidification potential), GWP (Greenhouse warming Potential), CED (Cumulative energy demand) and EP (Eutrophication potential). The yellow area within the graph shows the reference CBM (e.g. As-Is situation) while the green area presents the results of an improved CBM. The closer the graph comes to the centre of the spider the better are its values.

The KPIs shown in the spider diagram (see Figure 2) are examples. The KPIs important for the FENIX CBMs will be finally defined in cooperation with task 1.2. Within the following chapters some KPIs frequently taken for different analysis of products, business models or operational scenarios are described.

2.1. Economical Assessment – LCC

Life Cycle Costing (LCC) is a life cycle approach (i.e, cradle to grave) which focuses on the direct monetary costs involved in the production, after-sales, and recycling. Typical performance parameter for the economical assessment are:

KPI	Description
LCC	Life cycle costs
External costs	E.g. costs for environmental damages
NPV	Net-present value - some future value of the money when it has been invested
Payback time	Period required to recoup the money expended in an investment
Internal rate of return	Estimation of the profitability of potential investments
Amortisation	Spreading the cost of an intangible asset over a specific period of time
OPEX	OPerational EXpenditure is an ongoing cost for running a product, business, or system
CAPEX	CAPital EXpenditure is the cost of developing or providing non-consumable parts for the product or system.

Table 1: KPIs for the economical assessment

The list (Table 1) is a first draft of economical KPIs which will be adapted during the execution of the assessment in cooperation with task 1.2.

2.2. Environmental Assessment

Life Cycle Inventory (LCI) is the data collection part of LCA (LCA - Life Cycle Assessment). LCI is the straight-forward accounting of everything involved in the field or system of interest. It tracks all the input and output product system flows, including raw resources or materials, energy by type and water, as well as emissions to air, water, and land by specific substances. This kind of analysis may be extremely complex and could involve several individual unit processes in a supply chain (e.g. the extraction of raw resources, various primary and secondary production processes, transportation, etc.) as well as a huge amount (hundreds) of tracked substances.

Considering the LCA structure provided by the ISO 14040, LCI come after the Goal & Scope Definition where the following items shall be unambiguously stated:

- the intended application,
- the reasons for carrying out the study,
- the intended audience, i.e. to whom the results of the study are intended to be communicated,
- whether the results are intended to be used in comparative assertions intended to be disclosed to the public,
- the function, functional unit, and reference flow,

- the inventory modelling framework and
- the system boundaries and cut-off criteria.

Generally, the whole system could be divided into a foreground system and a background system under the specificity perspective. The foreground system embeds those processes that are specific to the analysed system, i.e. own operations, and fixed suppliers. The background system embeds those processes that are not specific to the analysed system, e.g. processes related to production of purchased components and waste treatment. Some KPIs for raw material are listed in Table 2.

KPI	Description
Material category	Select among the following categories: electronics, metals, minerals, plastics, textile, organic & inorganic intermediate products, paints, etc.
Weight & volume	Amount of the raw materials
Provider	Indicate the supplier
Destination & route	Transport destination and route of the raw material
Packaging / weight of packaging	Indicate of material and weight for the packaging –if applicable

Table 2: KPIs for the environmental assessment (raw material)

Splitting the analysis into the raw material evaluation and the production evaluation requires the definition of further KPIs for the production (Table 3). These KPIs include also the process relevant input.

KPI	Description
Input raw material	Indicate the materials involved like e.g. metals, minerals, plastics, textile, organic & inorganic intermediate products, paints, etc.
Input ancillary material	Indicate the materials involved like e.g. metals, minerals, plastics, textile, organic & inorganic intermediate products, paints, etc.
Electricity	Specify the Grid Mix indicating the country, or the specific mix known (e.g. 40% nuclear, 60% hydroelectric)
Thermal energy	Indicate the source and country location
Fuel	Indicate fuel typology
Mechanical energy	Compressed air – bar pression
Water consumption	Indicate water consumption for the production
Generated waste	Define waste typology (e.g. plastic, inert, hazardous, metals, waste water, liquid, emission)
Amount	Amount of materials used in this production step
Destination and means of transport	Define the transport destination and the mean of transport (truck, train, ship etc.)

Table 3: KPIs for the environmental assessment (production factors)

Two different templates will be elaborated for the data collection within the LCI phase for both the LCA and the LCC: one process-oriented (production) and one (Bill-of Material) BoM-oriented (raw material). The process-oriented one is more familiar to LCC and LCA practitioners since most of the assessment tools are process oriented; on the other hand, the BoM-oriented template is more familiar to designer that are usually managing the bill of material of their products.

The process-oriented approach starts with goal & scope definition. The main aim is to identify the logic of the life cycle steps. The main process steps from scrap acquisition until packing are inventoried with related energy consumptions, ancillaries, and wastes. After that the analysis of the use phase, including maintenance, refurbishments, accidents & repairs is performed, it closes with End-of-Life assessment.

For the BoM-Oriented approach the data collection is based on the final product, its components, consumables, and other auxiliaries. As already listed in Table 2 several information needs to be collected for each "item" like e.g.:

- Quantity: number of components,
- Description: description of part number,
- Material: the materials constituting the component are identified (a specific section is dedicated to identification of type of material, mass, and cost),
- Transportation: the transportation performed for each material are characterized (a specific section is dedicated to the selection of transportation mean, distance, cost),

After collecting the required information, the environmental impact assessment will be carried out by using the BAL.LCPA tool.

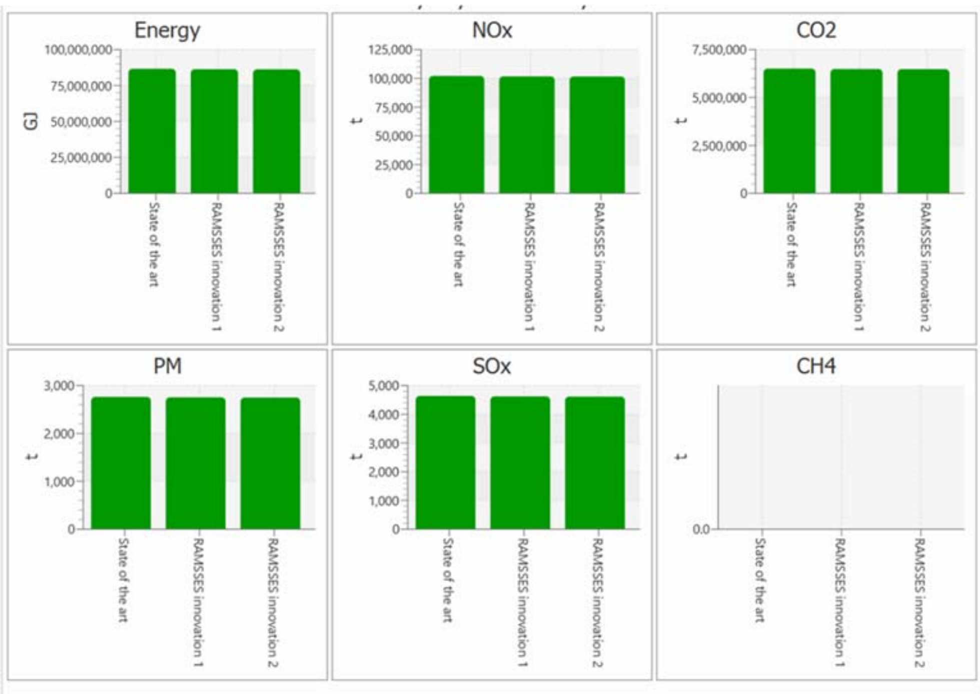

Figure 3: Selected environmental impact categories in BAL.LCPA (example)

The tool is flexible enough to calculate the immediate impact of process or material changes. Some of the environmental impact categories in BAL.LCPA are shown in Figure 3. The KPIs will be used to calculate additional indicators which suggest an environmental impact (see Table 4).

Indicator	Environmental impact category	Calculation
Greenhouse warming Potential (GWP)	Climate Change	GWP [kg CO_2 eq.] = 1*CO_2 [kg emission] + 25*CH_4 [kg emission]
Cumulative energy demand (CED)	Depletion of energy resources	Measured in MWh, Distinguished between fossil and renewable energy
Aerosol formation potential) (AFP)	Damage to human health due to particular matters	AFP [kg PM 2,5 eq.] = 0,5*PM 10 [kg emission] + 0,54 SOX [kg emission] + 0,88 NOX [kg emission]
Acidification potential (AP)	Acidification	AP [kg SO_2 eq.] = 1*SO_2 [kg emission] + 0,7 NOX [kg emission]
Eutrophication potential (EP)	Eutrophication	EP [kg PO_4 eq.] = 0,13 NOX [kg emission]

Table 4: Environmental impact categories in LCPA

2.3. Society assessment

There are several society assessment KPIs which must be adopted to the finally selected FENIX CBMs in the future (Table 5).

KPI	Description
Autonomy	Desire to maintain and extend control over one's own life
Cleanliness	Practices of hygiene
Comfort	Well-being in the physical environments in living in
Convenience,	Managing activities with a certain degree of flexibility;
Ecological Awareness	Effects of human behaviour on the environment;
Pleasure	Satisfaction of tastes and feeling at ease in a given context;
Privacy,	The need for reserve as regards behaviour;
Security/Safety,	Perception of environments as safe;
Sociability,	Ability to establish social relationships

Table 5: KPIs for the society and social assessment

Many of the society KPIs cannot be defined by measurements but only by subjective impressions.

3. LIFE CYCLE PERFORMANCE ANALYSIS TOOL (BAL.LCPA) – SHORT OVERVIEW

BALance Technology Consulting started the development of a life cycle assessment tool in the EU-funded projects BESST (FP 7) and Joules (H2020). The objective of the tool development was to create a methodology to evaluate the profitability and the environmental impact of alternative designs in direct comparison to support the complex decision-making process.

To fulfil the defined requirements, the life cycle performance assessment (LCPA) methodology has been elaborated, which combines the following assessment approaches:

- Economic assessment: LCPA supports several economic KPIs. Besides Life Cycle Costing (LCC) LCPA uses the net-present value (NPV) -concept to evaluate the profitability of the investigated investment object in terms of NPV or internal rate of return and to determine its pay-back time. In this regard, the tool allows to consider different price developments and -forecasts throughout the life cycle to test the economic viability in alternative future scenarios.
- Life cycle assessment-screening (LCA-screening): Conducting complete life cycle assessments for complex products requires a big amount of reliable data as well as a time consuming and cost-intensive analysis processes. LCA-Screening focuses on a limited amount of key performance indicators and their corresponding major impact categories, like global warming potential (GWP), cumulative energy demand (CED) and more. The results present a very good approximation of the environmental impact with reasonable effort.

The comparative approach allows to investigate the potential benefits of innovative system in direct comparison to state of the art solutions in economic and ecological terms. Thereby, the implementation of events and dynamic timelines enable the modelling process of complex life cycles. A sensitivity analysis allows to vary input parameters and assess their impact on the chosen KPIs. As a result, the sensitivity analysis helps to test the robustness of the object´s assessment results, by calculating LCPA-results for different future scenarios.

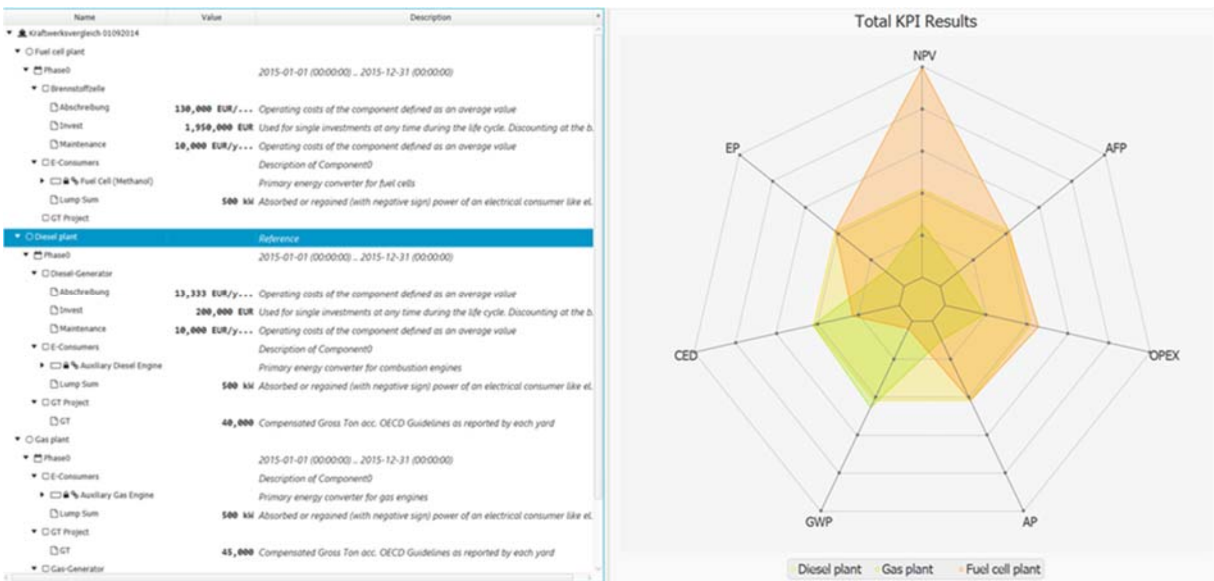

Figure 4: BAL.LCPA Modell description and result presentation

The success of an CBM also depends very much on the underlying application fields. Therefore, the tool enables to compare different CBMs among themselves and with the As-Is situation (scenario analysis). Special attention has been given to the implementation of external costs, which translates the emissions of the investigated objects into costs, defrayed by the society instead of the remittent. The analysis is accompanied by several visualization options to investigate and highlight the main conclusions, including an automatically generated report.

4. SELECTED FENIX CIRCULAR BUSINESS MODELS (CBM)

4.1. Production plant oriented CBMs

Within tasks 1.1 two different areas of FENIX CBMs have been identified. One area is the production plant oriented CBM (see Figure 5). It includes the three production pilots:

- Manufacturing/de-manufacturing pilot,
- Green materials recovery pilot ,
- Additive manufacturing pilot.

The CBMs related to the three pilots could be **product-oriented**. This would mean, that every of the three pilots or all together as a package could be sold as one product. The manufacturing/de-manufacturing pilots and the recovery pilot will be completely new developments. Therefore, the chance for becoming a product is quite high. The additive manufacturing will mainly use existing technologies. But the generation of the printing data models will be based on a new concept and hardware. That part will become interesting for the market. Additionally, the pilot will be optimized for Green based materials.

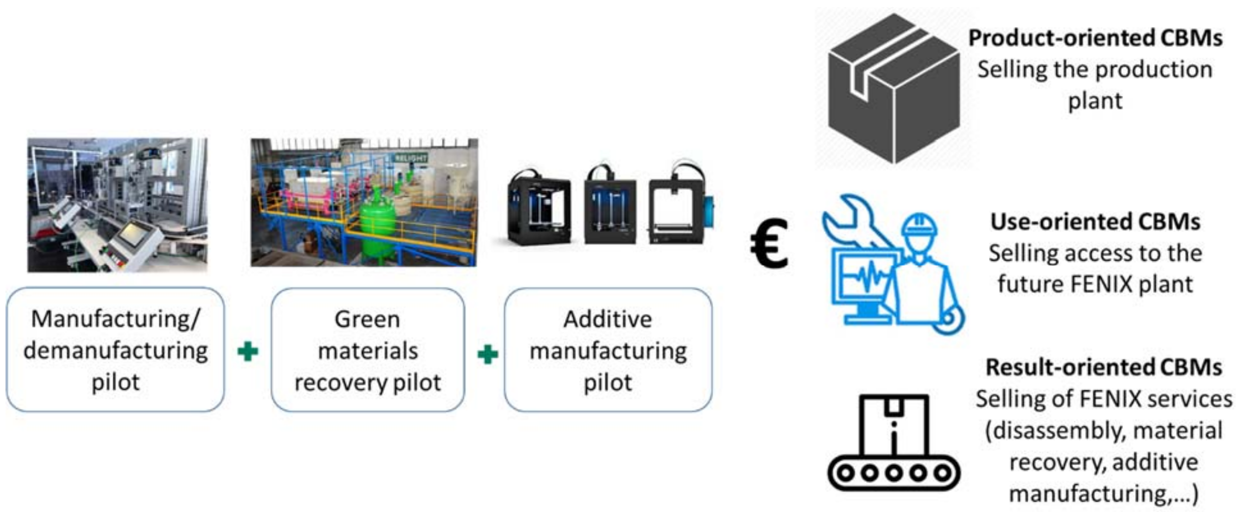

Figure 5: FENIX Production Plant CBMs

The **use-oriented** CBM might be interesting for experienced users. They can operate the pilot plant or a selected pilot implementation. Customers can extend their capacities in manufacturing/de-manufacturing as well as for the additive manufacturing without investments and installations to intercept order peaks. It would also be possible to operate the green material recovery pilot after the user gets an operation training.

The **result-oriented** CBM is the most comfortable service for customers. The users can buy the disassembly, material recovery and additive manufacturing service. This service will be offered for each pilot but also for the whole plant. The customer needs only to delivery his electronic scrap and the FENIX plant will disassembly it, produce green materials out of it and uses the green material to print products based on the customer specifications.

For the different CBMs the economic, environmental, and social KPIs must be analyzed. But also, the technical feasibility especially for the use-oriented CBM must be considered. Will the plant operation simple enough to enable a semiskilled user to operate it? These kind of questions needs to be answered during the test phase of the different pilots.

4.2. Product related CBMs

The second FENIX area focuses on the product-related CBMs. These circular business models support the complete business chain from the electronic scrap collection to the production of the green material (see Figure 6).

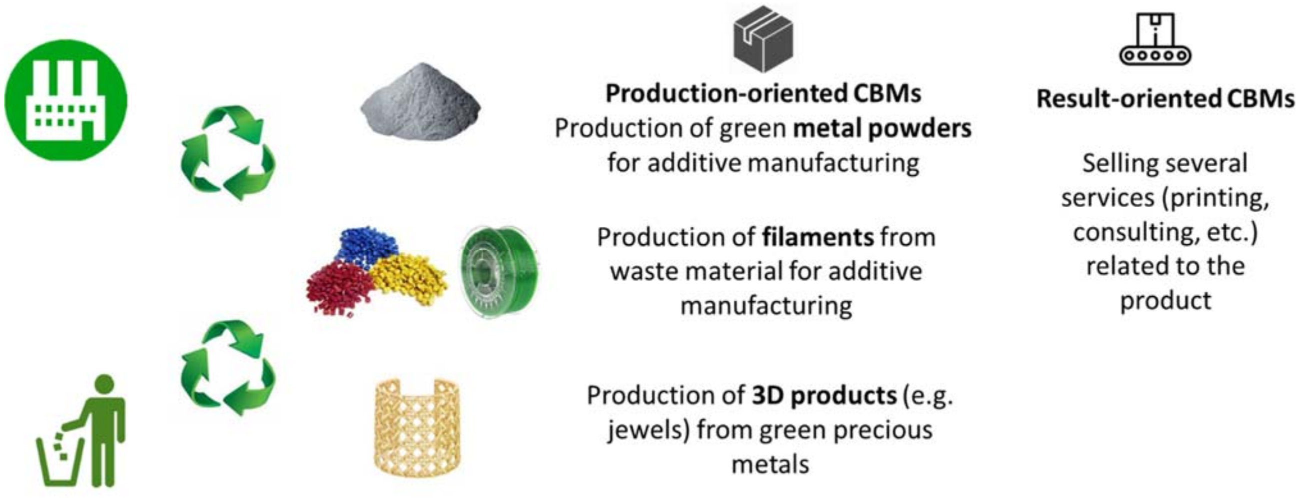

Figure 6: FENIX Product-related CBMs

The product oriented CBMs are divided into two different areas. One is the **production-oriented** CBM which includes the production and commercialisation of metal powders, filaments, and 3D products produced from recycled materials. It is expected that the FENIX processes will mainly focus on silver, gold, copper, steel, glass fibre, aluminium, and nickel. During the pilot plant definition and implementation additional materials might occur.

The **results-oriented** CBMs will sell different services around the recycled materials. This can be consulting to assure that optimised use of the FENIX recycled materials. But it can also be the printing of 3D green products based on FENIX recycled materials. The printing of jewels within the project is only the first step in a new product line based on green and recycled materials.

4.3. Evaluation of the CBMs

The FENIX results must prove the industrial benefit to be successful on the market. During a common workshop between WP-1 and WP-2 different industrial benefit parameters have already been defined (see Figure 7).

FENIX Industrial Benefits	FENIX "Exchange" Circular Business Models		
	Product-oriented PSSs	Use-oriented PSSs	Result-oriented PSSs
Reducing overall costs (function of amount of mats)	U	U	U
Reducing business risks	P	P	U
Opening new revenue streams		P	P/U
Improving competitive advantage	P/U	P/U	P/U
Complying with environmental regulations	P/U	P/U	
Reducing environmental impacts	P/U	P/U	P/U
Improving resource efficiency	P/U	P/U	P/U
Improving supply chain sustainability & provisioning	U	U	P
Reducing supply chain complexity	U	U	P
Enhancing reputation and brand value	P	U	U
Reaching new markets & countries			P
Developing innovative skills and knowledge	P/U	U	U

Figure 7: FENIX Industrial Benefits

The table is an open list and might be extended during the pilot implementation phase. Not all benefits are applicable for all CBMs selected by FENIX. The expected benefits are differentiated according producer benefit ("P" in the table) and user benefit ("U" in the table). It is the task of workpackage 2 to link the expected benefits with the selected KPIs to get objective analysis results.

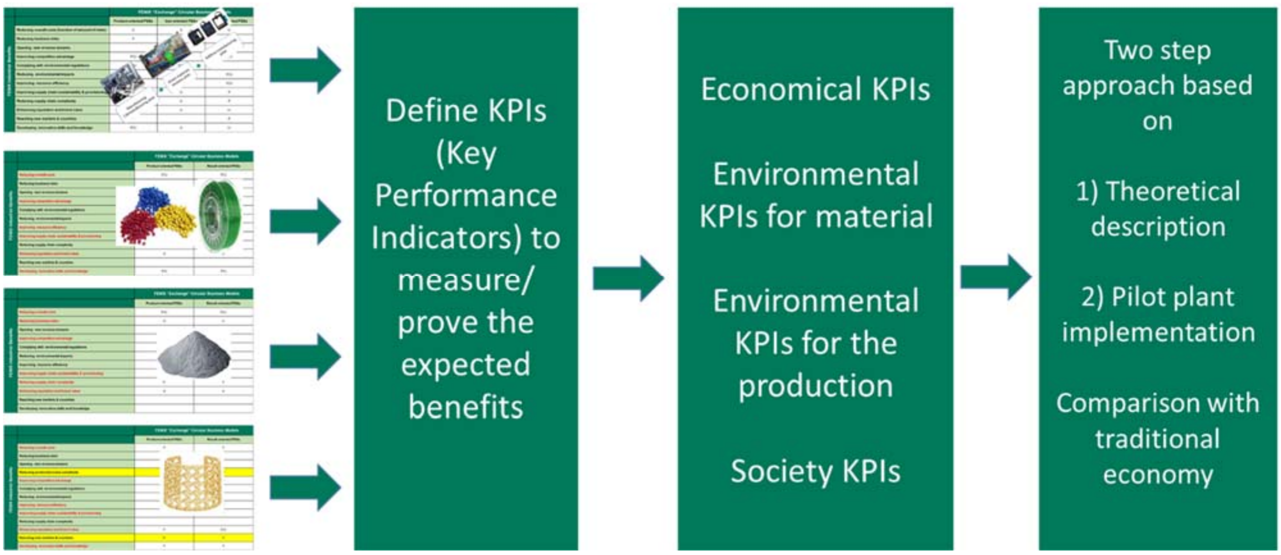

Figure 8: FENIX Evaluation steps

It must have to be assured that the production-oriented and the product related benefits can be evaluated by the defined and selected KPIs. Some benefits need to be analyzed by a proper combination of KPIs. The KPI definition and selection will be done in combination with task 1.2. As a next step the KPIs will be collected for the different FENIX CBMs but also for the traditional economy as it operates today. The traditional economy is the baseline for evaluation of the new FENIX CBMs. The analysis based on the theoretical description will identify weak points and risks of the new concepts. It should help to optimize the pilots before the implementation.

5. FIRST ROUGH COST CALCULATION FOR THE MATERIAL INPUT CHAIN

FENIX covers the covers the entire life cycle of the product with different solutions. FENIX starts with the collection or purchasing of the electronic scrap. If the scrap is already presorted it can be directly used as input material for the green material recovery pilot. Otherwise the de-manufacturing pilot gets the matrial, dismantles it and forwards it to the recovery plant. The LCC/LCA analysis has to be realised for each part of the FENIX circular chain (e.g. de-manufacturing, recovery amd additive manufacturing pilot) but also across different combinations (e.g. de-manufacturing plus recovery plant) (see Figure 9).

One of the FENIX advantages is the comprehensive control over all chain elements. Therfore, optimisation potentials within the chain can be opened up.

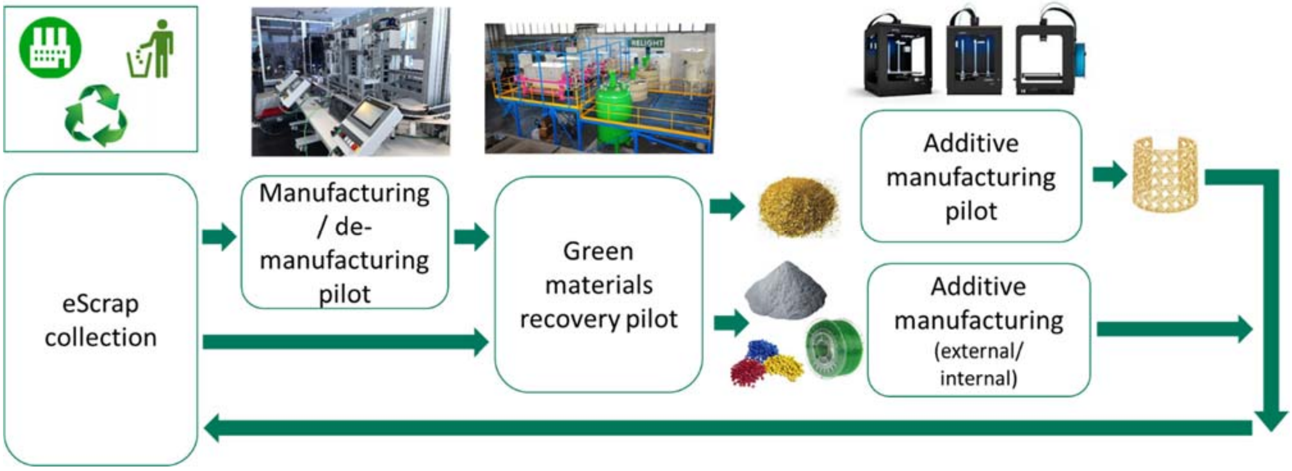

Figure 9: Elements of the FENIX circular chain

A first rough calculation model has been defined for mobile phones (see Figure 10). It is the starting point to define the LCA model for the CBM. After the final discussion the model template will be used for further electronic products and additional application cases. The results will always be used to compare it with the as is situation.

The analysis model starts with the scrap price and the weight for mobile phones to calculate the amount of valuable materials. Based on the actual raw material prices it turned out that the raw material for one mobile phone is between 1,00 € and 1,50 €. Combining the FENIX recovery costs, margins, raw material values and other costs the market price for FENIX recycled material can be calculated. But a backwards calculation is also possible. Knowing the raw material market prices and the material value of a mobile phone, the maximum price for the recycling process can be estimated.

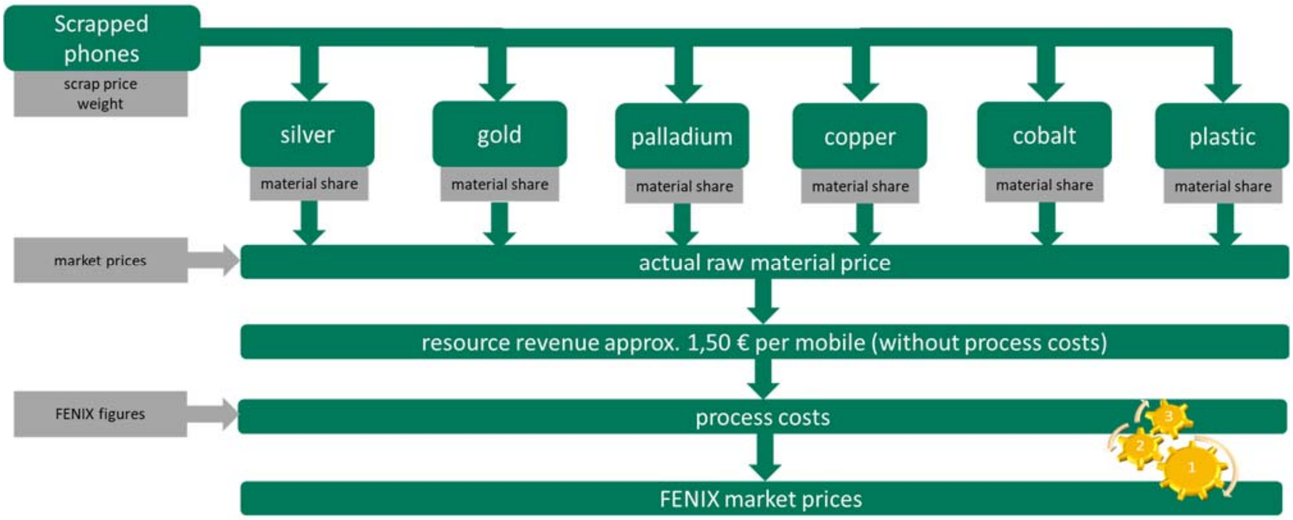

Figure 10: First approach for the top down economic analysis

6. CONCLUSION

The preparation for the new business models and the later pilot plant sustainability assessment has been started. Three Circular Business Models have been identified together with workpackage 1. These models are the basis for the further assessment. First parameter sets for the economic, ecological, and social assessment have been selected as a starting point. Together with workpackage 1 (task 1.2) these parameters will be checked and supplemented before starting the assessment. A first LCC approach as well as the further steps to go are described within this deliverable. After the assessment models have been tested and approved they will be implemented into the BAL.LCPA tool. The tool enables the flexible reconfiguration of the different CBM components as well as a fast assessment. First assessment results will be documented in the second version of this living deliverable after six months.

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