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Deliverable No. 4.5

Techno-economic assessment of the PASSENGER value chain-R1

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PARTNERS

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LIST OF ACRONYMS

Abbreviation	Meaning
BAU	Business-As-Usual
CA	Consortium Agreement
EC	European Commission
FU	Functional Unit
TEA	Techno-Economic Assessment
CBA	Cost Benefit Analysis
PM	Permanent Magnets
REE	Rare Earths
WP	Work Package
SEA	Socio-Economic Analysis

SUMMARY

This document contains the main results from task 4.2 of PASSENGER project. The document reports about the techno-economic assessment of the PASSENGER value chain-R1. The purpose of the current report is to present the work that has been done in the first 24 months of the techno-economic assessment of the PASSENGER value chain processes that are being developed inside PASSENGER project. D4.5 is the first deliverable of WP4 related to technoeconomic assessment. The objective of this report is to present the work that has been done in the framework of the Techno-Economic Assessment (TEA) performed under Task 4.1 entitled "Framework of the techno-economic, safety and environmental assessment", Task 4.4 entitled "Life Cycle Assessment and Life Cycle Cost" and Task 4.8 entitled "Cost-Benefit Analysis (CBA) of the new permanent magnets with substitution of CRMs". The objective of Task 4.1 that has already been completed was to define the framework of the techno-economic and environmental assessments and to ensure: a common understanding from all the partners of the work to be performed throughout WP4 and a common basis for the assessment of the PASSENGER value chain. Task 4.1 comprised the goal and scope definition of the techno-economic, safety and environmental life cycle assessments, as well as the data collection management plan.

Management of data (including coordination among partners, preparation of data collection templates, overall time plan, etc.) will be part of this task. All partners had to be trained and committed to the process of data collection according to WP4 needs. Partners which are not in charge of the WP4 needed a good understanding of the objectives of the WP and how they can benefit from the results of the techno-economic, safety and environmental assessments. ICAMCYL ensured an interactive dialogue throughout the project, by means of regular actions and interventions during meetings. The latter guaranteed a good and efficient flow of information between the partners who need the data and those who will provide the data, and will reduce the risk associated with the data collection process. The management of the data collection (including coordination among partners, preparation of data collection templates, overall time plan, etc.) is addressed as part of the framework definition. Data collection is indeed a crucial part of the techno-economic and environmental assessment.

The main part of Task 4.4 is focused on performing several LCAs and LCCs in order to incorporate the environmental results in the technologies and products. A benchmark LCA of the conventional technologies will be performed as a baseline LCA for the existing current technology and value chain for comparison purposes. The main part of this task is focused on LCA, LCC of the upscaled technologies from the lab till the pilot scale phase. That approach will allow early quantification of the eventual large-scale environmental impacts of upscaled technologies, which allows the use of them to make comparisons between benchmark solutions and circular economy solutions of the project. The several LCAs of this task are included in the Deliverable 4.2 entitled "Report on Life Cycle Assessment and Material Flow analysis" In this deliverable will be included the part related to Life Cycle Cost.

Furthermore, the work that has been done regarding the Task 4.8 will be also included. The main aim of this task is to quantify the overall net benefits, i.e., the additional health and environmental benefits of substituting rare-earth elements and cobalt in PASSENGER PMs. The CBA was carried out at EU market level and be based on materials and chemicals flow analyses and specific risk assessment involved in the different current and new PMs value

chains representing an effective substitution, on the LCA results and on the cost, assessments carried out in task 4.4 Methodological steps of a CBA are the following:

Definition, in collaboration with partners, of the aims and scope of the CBA, in terms of one or two EU market deployment scenarios corresponding to the overall PASSENGER commercial validation value chains. The definition of a business as usual (BAU, or “no change”) scenario as a counter factual to which to compare advantages and disadvantages of the PASSENGER new magnets innovation. Identification and assessment of the environmental and health impacts of the scenarios, i.e. of the positive and negative market-scale impacts, here after referred to as “benefits” and “costs”. PASSENGER benefits for society will include reduced GHG emissions and other positive environmental impacts from avoided energy and resource use. However, implementation and deployment of the PASSENGER value chains require consumption of financial resources (opportunity costs) and may involve potential health and environmental problems in case of risk associated with the technology deployment (e.g. risks for workers, re-looping of hazardous chemicals). Valuation of alternatives in view of decision-support. The aim is to monetize the identified sustainability indicators of the PASSENGER technology vs. a BAU scenario and to assess their significance. Since environmental and health impacts cannot always be assessed with certainty, uncertainties or unknowns of the assessment also need to be addressed carefully.

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1. INTRODUCTION

The PASSENGER project contributes to a green, sustainable Europe by developing an alternative to raw materials in the construction of permanent magnets and testing their performance in the electromobility sector. Specifically, PASSENGER project focuses on removing the EU's dependence on CRMs like REEs. Today's the Europe's industries have a total dependence on imported materials for its REE- based magnets. The huge disparity in the numbers is extremely worrying as the EU imports almost 100% of its REEs, while the rate of REE recycling is less than 1%. The currently available recycling routes are just too energy intensive and accompanied with large environmental footprints. There are also severe material losses during the product's lifecycle, which makes REE recycling commercially unattractive currently. The PASSENGER project aims to demonstrate manufacturing of improved hard ferrites, while avoiding the use of critical materials as proposed by PASSENGER, will enable a sustainable partial substitution of bonded rare earth-based magnets based on elements available in Europe. PASSENGER proposes improved strontium ferrite (Sr-ferrite) and a Manganese-Aluminum-Carbon (MnAlC) alloy as a substitute to contribute to guarantee a sustainable production of permanent magnets in Europe: an alternative for key specific applications (e.g. pump systems, actuators, and small e-vehicles such as e-scooters, a-bikes and e-motorbikes) without critical raw elements, based on resources that are widely available in Europe, with enough research to provide a solid base for a successful transition from the lab to the industrial production in the Pilot Plants.

The aim of WP4 is to assess the sustainability, techno-economic, health and safety impacts of the PASSENGER value chains and to provide knowledge and support to the different stakeholders and decision makers like the investors, industries, European Commission services, research institutions and government agencies. The objective of the task 4.2 entitled "Techno-economic assessment" is to provide the techno-economic assessment of one reference scenario (baseline), as developed in tasks defining the full technologies and pilots' integration. The technical assessment will include a descriptive facility report, alternative configurations and suggestions for optimization, main devices: specifications and datasheets, bill of quantities, equipment lists, (estimated) performance and operational parameters, attachments: plans, diagrams, etc. The economic assessment will include mass and energy balances, feasibility studies, CAPEX, OPEX and installation costs. In a nutshell, deliverable D4.5 defines the scope for the technoeconomic study. Consortium partners were asked for data regarding the related costs.

1.1. ORGANIZATION OF WP4

WP4 is composed of 3 partners who act as task leaders and assess the different pillars of the techno-economic, health, safety and environmental assessment of PASSENGER value chains as shown in Figure 1 with ICAMCYL acting as WP leader. The main task leaders of WP4 are ICAMCYL, MNLT and SWE. Other partners who are also involved in the effective development of WP4 and during data collection and coordination of the work package are IMDEA NANO, Metalpine, IMA, MBN, KOLEKTOR, CRF, EIT RM, TUDA,

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ESF, ILPEA, OSLV, UNE, BARLOG, TIZONA, JSI, WILO, LCM. In Figure 2 is presented the WP4 timeline.

WP4 Partners

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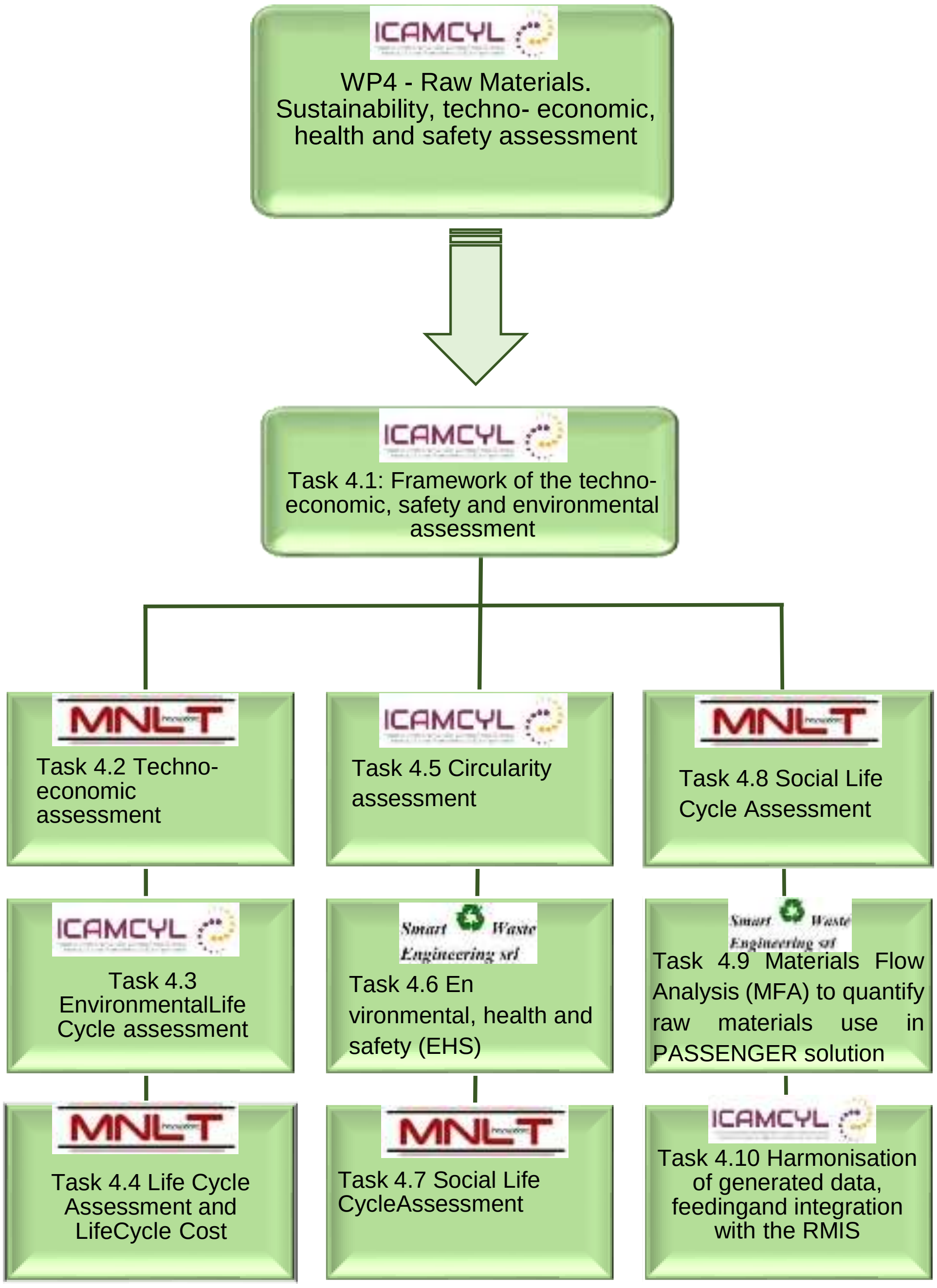

Figure 1 Scheme of interaction between the tasks within WP4 limit.

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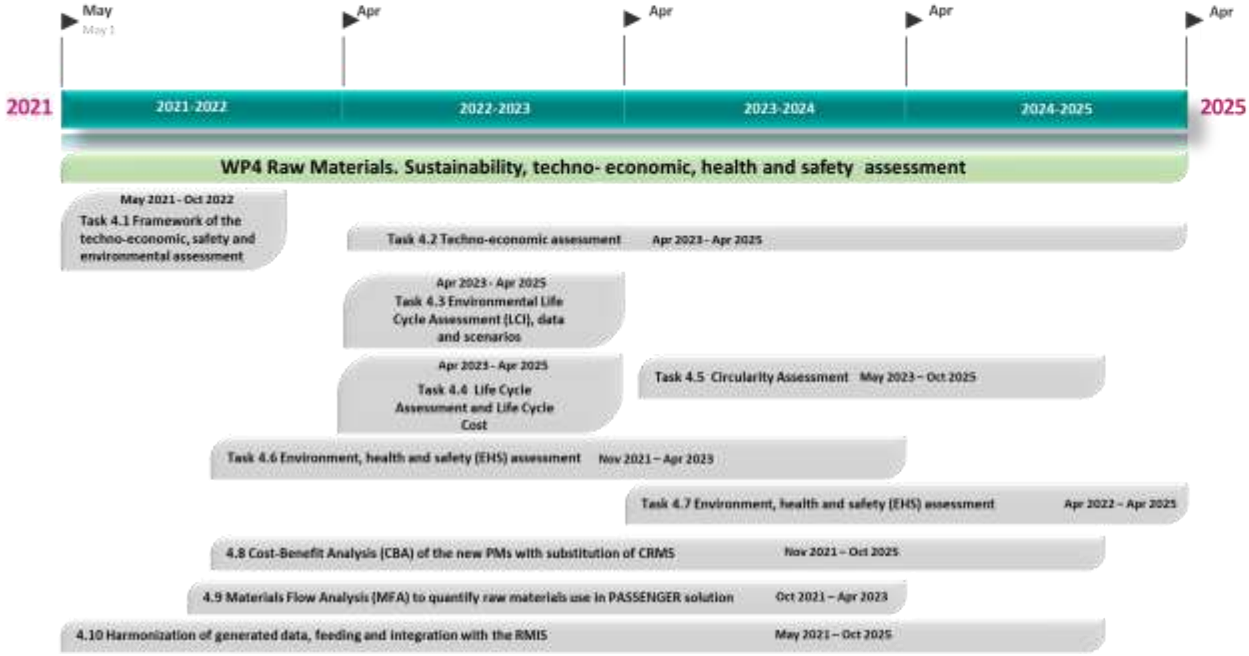

Figure 2 WP4 Timeline

2. FRAMEWORK OF THE TECHNOECONOMIC ASSESSMENT

2.1. TECHNO-ECONOMIC ASSESSMENT (TEA)

Techno-Economic Assessment (TEA) is a methodological framework to analyze the technical and economic performance of a process, product or service. A TEA generally relies on a cost-benefit analysis, and it is used for tasks such as:

- Evaluate the economic feasibility of a specific project
- Investigate cash flows (e.g., financing problems) over the lifetime
- Evaluate the likelihood of different technology scales and applications.

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Compare the economic quality of different technology applications providing the same service. A proposed TEA can be subdivided in the following phases (Figure 3): 1) goal and scope, 2) inventory, 3) calculation of indicators and 4) interpretation (3). The goal provides guidance for the overall study, while the scope defines what aspects are included and how the comparison is being conducted. The inventory collects all relevant data, while the calculation of indicators simulates the cash-flows of the company and assess the economic results. As each phase is carried out, the consistency and robustness of its outcomes have to be evaluated and, if necessary, modifications are recommended in the interpretation phase. As TEA is an iterative process, it is often required to go back to a prior phase to modify the assessment if recommended by interpretation. This is the case, for example, when new data has been made available over the life of the project or external events make it necessary to change some basic assumptions of the model. As a last step, the goal, scope, inventory and results and their interpretation are all part of the TEA report.

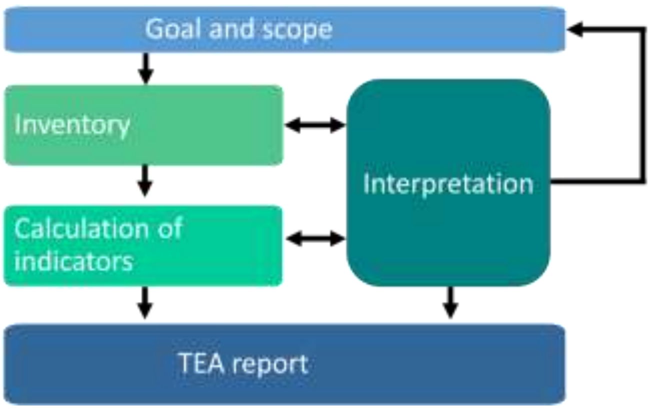

Figure 3 TEA phases

2.2. LIFE CYCLE COST (LCC)

Life cycle cost (LCC) is the sum of the costs throughout the whole life cycle of a product (Figure 4). Theoretically, an LCC covers the entire life cycle of a product or an engineering project. It means the total cost ownership of an asset. Life Cycle Cost assessment consists of the Initial Costs the Recurring costs that includes operating and maintenance cost, disposal cost and residual value. Recurring costs are those that continue to occur after the purchase, like operations costs, maintenance, and upgrades. Operations costs are recurring costs that are associated with the use of the product. Maintenance costs are the costs affiliated with the upkeep of the product. Disposal costs are the costs associated with the disposal of the product once its useful life ends. Finally, residual value is considered the value of the product after it reaches its useful life[3].

[3] https://www.wbdg.org/resources/life-cycle-cost-analysis-lcca

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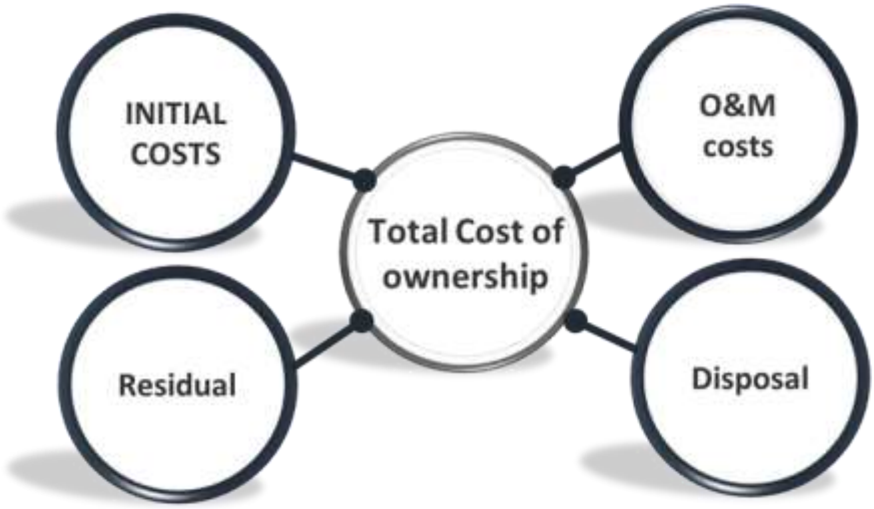

Figure 4 Representative scheme of the LCC definition.

2.3. ECONOMIC INDICATORS

The evaluation of the economic viability of product systems and, consequently, decision-making is typically based on multiple criteria and indicator types. Both, an internal – company – and – external – market view needs to be included as analysing product systems purely on an internal cost basis is not sufficient. On the one hand, the cost of internal processing will inform on Capital and Opex expenditures, while, on the other hand, the sales price and sales forecasts based on similar products currently in the market and on the size of the market, respectively, will be key to establish the economic viability. In Table 1 are summarized the Economic indicators.

Table 1. Economic Indicators

Indicator	Abbreviation	Description
Selling price (€)	-	-
Product total cost (€)	-	It is the total cost to produce and sell a product
Capital Expenditure (€)	CAPEX	These are funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment (in general all items extending one-year useful life).
Operating Expenditure (€)	OPEX	All expenses a business incurs through its normal business operations (e.g., rent, equipment, inventory costs, marketing, payroll, insurance etc.)
Cost of Goods Sold (€)	COGS	It refers to the direct costs of producing the goods sold by a company. This amount includes the cost of the raw materials and labour directly used to create the good.
Raw material cost (€)	-	Cost of raw materials required to produce

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		the goods
Net present value (€)	NPV	It is the difference between the present value of cash inflows and the present value of cash outflows over a period of time.
Return on Investment (%)	ROI	It is a performance measure to evaluate the efficiency or profitability of an investment or compare the efficiency of a number of different investments. It measures the amount of return on a particular investment, relative to the investment's cost.
Internal rate of return (%)	IRR	It is a metric used in financial analysis to estimate the profitability of potential investments. It is equal to the discount rate that makes the net present value (NPV) of all cash flows equal to zero in a discounted cash flow analysis.
Payback period (n)	PBP	It refers to the amount of time (years) it takes to recover the cost of an investment. Simply put, it is the length of time an investment reaches a breakeven point.
Gross Profit Margin (%)	GPM	It is a metric to assess a company's financial health by calculating the amount of money left over from product sales after subtracting the cost of goods sold (COGS).
Operating Profit Margin (%)	OPM	It is a metric to assess how efficiently a company is able to generate profit through its core operations.
Net Profit Margin (%)	€	It is a metric indicating if a company's management is generating enough profit from its sales and whether operating costs and overhead costs are under control

3. GOAL & SCOPE DEFINITION

3.1. GOAL

The goal and scope of the analysis are very similar to that explained in D4.2 entitled "Report on preliminary Life Cycle Assessment and Material Flow Analysis-R1. Furthermore, a summary has been included here to ensure understandability of the results. The aim of this study is to detect the economic hotspots in the technologies developed in the framework of the PASSENGER project

3.2. INTENDED APPLICATION

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The present deliverable is confidential and only intended for the members of the consortium (including the Commission Services). The type of dissemination and public communication of the other WP4 deliverables vary between confidential and intended for public disclosure.

3.3. TARGET AUDIENCE

The status of this deliverable is confidential. Therefore, the main target audience are the members of the consortium (including the Commission Services).

3.4. OBJECTIVES

The objective of this deliverable it to quantify the overall net benefits at EU market level and be based on materials and chemicals flow analyses and specific risk assessment involved in the different current and new PMs value chains representing an effective substitution.

3.5. COMPARATIVE ASSERTIONS

No comparative assertions are included in this analysis.

3.6. FUNCTIONAL UNIT

The functional unit (FU) quantifies the performance of a product system and is used as a reference unit for which the LCA study is performed and the results are presented. For the production of SrFe, NdFeB and MnAlC magnets the functional unit is “1kg”.

3.7. DATA INVENTORY

The data inventory includes all relevant technical and economic information of the product (e.g., raw material quantity and cost) and its system boundary (i.e., the production phases and relative production factors included in the analysis). The creation of a data inventory is an iterative process that starts from collecting basic information and then updates it based on 1) new information available 2) changes in the modelling approach that require a different set of data, 3) preliminary results which highlight the need for greater detail in specific aspects of the analysis. A data collection file (Figure 5) was provided to the consortium partners in order to be filled. In the table below are presented the required values and units for the TEA- Inventory of plant- and production-related costs. In Table 2, 3 and 4 are presented the provided data from the partner IMA and KOLEKTOR and METALPINE.

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TEA- Inventory of plant- and production-related costs*

*Note that this is an overview of overall costs borne by the commercial partners

Plant information*			
Description	**Value**	**Unit**	**Comments**
Initial investment (it refers to capital investment for plant/equipments construction and it includes purchase and installation costs). Please, provide unit equipment cost if available.		Million €	
Financing rate (if any) (it refers to the interest rate paid for the loan) (please specify if it refers to the whole initial investment or part of it)		Percentage	
Depreciation		€/years	
Useful life		Years	
Nr of workers (Please specify if nr of workers refers to the total plant, or only to the process analysed)		Nr.	
Hours worked per year per employee		Employee/hours/year	
Salary		€/month	
Insurances (if any)		€/years	
Renting (if any)		€/years	
Licenses (if any)		€/years	
Ordinary maintenance			
Extraordinary maintenance (if any)		€/years	
Overall utility costs (not directly related with the production process, e.g.: electricity, water, telephone-internet, paper etc.)		€/years	
Overall management cost (not directly related with the production process, e.g. marketing, legal or client service expense)		€/years	
Disposal cost (for the plant)		€	

*This information should be only compiled by those partners concerned with the final pilot production plant.

Figure 5 Excel file: Sheet regarding the inventory of plant and production related costs that was sent to partners

Table 2: Data collection: TEA- Inventory of plant- and production-related costs (from IMA)

Description	Value	Unit
Initial investment (it refers to capital investment for plant/equipments construction and it includes purchase and installation costs). Please, provide unit equipment cost if available.	0,5	Million €
Financing rate (if any) (it refers to the interest rate paid for the loan) (please specify if it refers to the whole initial investment or part of it)	N.A.	Percentage
Depreciation	N.A.	€/years
Useful life	N.A.	Years
Nr of workers (Please specify if nr of workers refers to the total plant, or only to the process analysed)	2	Nr.
Hours worked per year per employee	8	Employee/hours/year
Salary	2500	€/month
Insurances (if any)		€/years
Renting (if any)	N.A.	€/years
Licenses (if any)	N.A.	€/years
Ordinary maintenance	25000	€/years

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Extraordinary maintenance (if any)	2500	€/years
Overall utility costs (not directly related with the production process, e.g.: electricity, water, telephone-internet, paper etc.)	10000	€/years
Overall management cost (not directly related with the production process, e.g. marketing, legal or client service expense)	15000	€/years
Disposal cost (for the plant)	N.A.	€

Table 3: TEA- Inventory of plant- and production-related costs (from KOLEKTOR)

Description	**Value**	**Unit**	**Comments**
Initial investment (it refers to capital investment for plant/equipments construction and it includes purchase and installation costs). Please, provide unit equipment cost if available.	0,75	Million €	
Financing rate (if any) (it refers to the interest rate paid for the loan) (please specify if it refers to the whole initial investment or part of it)	2	Percentage	
Depreciation	50000	€/years	
Useful life	15	Years	
Nr of workers (Please specify if nr of workers refers to the total plant, or only to the process analysed)	4	Nr.	2 shifts, 5 days a week
Hours worked per year per employee	2000	Employee/ hours/year	
Salary	24000	€/month	for worker
Insurances (if any)	2000	€/years	difficult one (complete Kolektor Group) has one insurance policy)
Renting (if any)	0	€/years	
Licenses (if any)	0	€/years	
Ordinary maintenance	50000	eur/year	

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Extraordinary maintenance (if any)		€/years	
Overall utility costs (not directly related with the production process, e.g.: electricity, water, telephone-internet, paper etc.)	50000	€/years	
Overall management cost (not directly related with the production process, e.g. marketing, legal or client service expense)	50000	€/years	
Disposal cost (for the plant)	1000	€	

Table 4: TEA- Inventory of plant- and production-related costs (from METALPINE)

Description	Value	Unit	Comments
Initial investment (it refers to capital investment for plant/equipments construction and it includes purchase and installation costs). Please, provide unit equipment cost if available.	1,2	Million €	Pilot Plant for Powder Production - adapted for the production of MnAlC-Alloys, Screen, Classifier
Financing rate (if any) (it refers to the interest rate paid for the loan) (please specify if it refers to the whole initial investment or part of it)	10	Percentage	
Depreciation	120000	€/years	
Useful life	15	Years	
Nr of workers (Please specify if nr of workers refers to the total plant, or only to the process analysed)	6	Nr.	only to the process analysed
Hours worked per year per employee	650	Employee/hours/year	1,5 days a week are reserved for the project
Salary	7300	€/month	for worker
Insurances (if any)		€/years	difficult one (complete Kolektor Group) has one insurance policy)
Renting (if any)		€/years	

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Licenses (if any)		€/years	
Ordinary maintenance	2	maintenance-week/year	
Extraordinary maintenance (if any)		€/years	
Overall utility costs (not directly related with the production process, e.g.: electricity, water, telephone-internet, paper etc.)		€/years	
Overall management cost (not directly related with the production process, e.g. marketing, legal or client service expense)		€/years	
Disposal cost (for the plant)		€	

4. FRAMEWORK OF COST BENEFIT ANALYSIS

4.1. COST-BENEFIT ANALYSIS (CBA) OF PERMANENT MAGNETS PRODUCTION AND UTILIZATION (BAU SCENARIO)

CBA is an analytical tool to be used to appraise an investment decision in order to assess the welfare change attributable to it and, in so doing, the contribution to EU cohesion policy objectives[4]. The purpose of CBA is to facilitate a more efficient allocation of resources, demonstrating the convenience for society of a particular intervention rather than possible alternatives. CBA is assessing the real impact (economic, health and environment) of PASSENGER innovations on society and will summarize it in a single monetary indicator, in general Net Present Value (NPV). NPV integrates costs and benefits over a period using discounting. Intermediate indicators are also estimated specifically for environmental impacts or health impacts in order to study impacts of the introduction of this technology on specific points. A range of different methodological tools may be used within SEA. Commonly methodologies used are cost-benefit analysis (CBA), cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA). These methodologies themselves call upon the use of a number of different analytical techniques.

Within the PASSENGER project is carried out a CBA in order to balance costs and benefits generated by the introduction of the technology. Analysis performer will follow and adapt to the project requirements guidelines provided by the Organization for

[4] Sartori, D., Catalano, G., Genco, M., Pancotti, C., Sirtori, E., Vignetti, S., & Del Bo, C. (2014). Guide to cost-benefit analysis of investment projects. Economic appraisal tool for Cohesion Policy, 2020

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Economic Co-operation and Development (OECD)5 or by the European Chemicals Agency (ECHA)6

First step of the CBA consists of the definition of the scope of the study and scenarios. The scope corresponds to define the area and the time horizon of the analysis. Also, at this stage define the value chain considered and the material flow studied. In order to study the introduction of the PASSENGER technology, two scenarios at least must be defined. The definition of scenarios will require answers to such questions as where and when the technology will be developed, what will be capacities of treatment, which treatment the PASSENGER technology will substitute for PMs? Because CBA will use as input results from other tasks (LCA results, techno-economic assessment and EHS results…), scenarios must be defined jointly with partners in charge of these tasks in order to obtain coherent scenarios and be certain that results from other tasks will be useable by the CBA. This process of shared definition must be based on discussion between partners including the industrial supply chains. The definition of scenario will also be based on technical data collected from consortium partners

In Table 5 is presented a cost benefit analysis (CBA) of NdFeB magnets. In Table 5 are summarized some costs of the NdFeB such as the use of Critical materials, they are using REE that are 98% produced in China so the EU is depended on the import from China. The EU production is less than 1%. The benefit here is that we have a very high strength – 1.4 tesla compared to 0.5-1 tesla of common ceramic magnets.

The benefit here is the low cost by “Dollar per BHmax" (BHmax providing the magnetic energy density) about 1.5x lower than ferrite magnets. However, the properties deteriorate rapidly at temperatures in excess of about 120°C (operating temperature of a car) depending on grade and permeance coefficient at which the magnet operates at but the benefit here is that we have a relatively easy to machine (sintering, injection molding) process, compared to alnico and samarium cobalt magnets. Most grades of NdFeB magnets need to be protected against oxidation by coating or plating the magnets with nickel-copper-nickel multilayers or epoxy (extra cost and difficult recycling due to difficulty in separating the layers) and the benefit here is that they are easy to process into special shapes, e.g., blocks, bars, discs, rings, arc segments, etc. Sr-ferrite does not require of any coating (they are already oxide materials) and preliminary studies carried out in PASSENGER by IMDEA and TUDA on MnAlC show an excellent corrosion resistance. An additional cost may be the high consumption in financial resources for setting up the industrial unit and establishing new potential techniques (e.g. flash milling and gas atomization) for up-scaled production, but the benefit is that in this case we avoid resources use in CRMs because we have a broad substitution of bonded NdFeB magnets by the resulting permanent magnet materials: MnAlC and improved Sr-ferrite magnets. Use of aluminium, manganese, strontium and iron, which can be sourced within Europe and/or obtained from countries with strong EU’s alliances already established or in-progress), and thus we do not have supply-chain restrictions. Also, in

[5] Analyse coûts-avantages et environnement: Avancées théoriques et utilisation par les pouvoirs," Editions OCDE, Paris, 2018.

[6] ECHA, "Guidance on Socio-economic Analysis Restrictions," 2008

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this case we have contribution in securement of the supply of REE in the EU. An additional cost, as for every technological material, may be the potential health risks (under evaluation) for technology deployment (e.g. exposure of workers to possibly hazardous chemicals and unstandardized procedures). In this case we have societal benefits, i.e. job creation (design and production 5-10tn/year in the EU area). Another cost that needs to be considered is any potential environmental risks for technology deployment (e.g. hazardous chemicals disposal, manufacturing facilities built in rural areas) and the benefit here refers to financial Benefits for stakeholders/producers (Mn-Al-C produced at 20 EUR/kg -4 times lower than commercial bonded NdFeB – same strength) Another benefit that is included in Health and environmental benefits are the highly reduced GHG emissions due to deployment of electromobility facilitated by PASSENGER.

Table 5. Cost benefit analysis (CBA) of NdFeB magnets	
Costs	**Benefits**
Use of Critical materials (average 1.5kg NdFeB per e-car) Nd 330g Pr 100g Dy 120g Co 45g REE are 98% produced in China, EU production <1%.	Very high strength – 1.4 tesla compared to 0.5-1 tesla of common ceramic magnets
Cost ca 85 EUR/kg	Low cost by "Dollar per BHmax" about 1.5x lower than ferrite magnets.
Properties deteriorate rapidly at temperatures in excess of about 120°C (operating temperature of a car) depending on grade and permeance coefficient at which the magnet operates at.	Relatively easy to machine (sintering, injection molding), compared to alnico and samarium cobalt magnets
Most grades of NdFeB magnets need to be protected against oxidation by coating or plating the magnets with nickel-copper-nickel multilayers or epoxy (extra cost and difficult recycling due to difficulty in separating the layers).	Easy to process into special shapes, e.g. blocks, bars, discs, rings, arc segments, etc. Sr-ferrite does not require coating. First evaluation of MnAlC shows high-corrosion resistance.

Table 5: Cost Benefit Analysis of PASSENGER magnets

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Table 5: Cost Benefit Analysis of PASSENGER magnets	
establishing the new flash milling and gas atomization technique for up-scaled production	by Sr-Fe). Use of aluminium, manganese, strontium and iron, which can be sourced within Europe, no supply-chain restrictions Contribution in securement of the supply of REE in the EU
Potential health risks (to be assessed) for technology deployment (e.g. exposure of workers to possibly hazardous chemicals and unstandardized procedures)	Societal benefits, i.e. job creation (design and production 5-10tn/year in the EU area)
Potential environmental risks (to be assessed) for technology deployment (e.g. hazardous chemicals disposal, manufacturing facilities built in rural areas)	Financial Benefits for stakeholders/producers. Mn-Al-C produced at 20 EUR/kg (4 times lower than commercial bonded NdFeB – same strength)
	Health and environmental benefits- highly reduced GHG emissions due to deployment of electromobility facilitated by PASSENGER

Table 5: Cost Benefit Analysis of PASSENGER magnets

4.2. COST-BENEFIT ANALYSIS (CBA) OF BUSINESS AS USUAL SCENARIO (BAU) IN NdFeB PRODUCTION IN CHINA VS WESTERN COUNTRIES

Most of the costs included in magnet production are shown here – at least in general terms. There are often large differences between these costs in various regions of the world. Differences between China and the US have diminished over time, but remain very large. In Figures 6 and 7is depicted a comparative analysis of the NdFeB magnets that are produced in China and in WEST. As we can see in the Figures the material cost is lower in China in comparison with the material cost in WEST this is due to the mines and the materials that are all produced in China in contrast with the WEST that has to import those materials so the price is increased. The actual material cost to the magnet manufacturer is a closed contract price with the supplier(s) and prices are almost always

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considerably less than published prices. Prices within China have been 25 to 35% below published while the few western material suppliers have been able to negotiate prices that are just somewhat (ca 5-7%) lower than published prices. REE content has a profound effect on material cost. As it is depicted in the cost structure for NdFeB magnets the 2.8% Dy content results in being 33.8% of the material cost. The total of all rare earth content is 92% of the material cost. Some of the scrap associated with unacceptable product (e.g., cracked or dimensionally out of spec magnets) can be recycled within the manufacturing facility resulting in a material yield that is a considerably higher percentage. Profit margins among the 300 Chinese manufacturers vary considerably (ca 10%). With many smaller companies, profit margins are squeezed and companies struggle to survive. China taxes; there is currently a VAT rebate on exported magnet but not on rare earth raw material. This allows to sell at lower profit margins thus overall lower price.

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Cost Structure for NdFeB Sintered Magnets: China					
Material	Weight%	EUR/kg	EUR per kg of alloy	% of materials	Comments
Nd	24,2	36,96	8,94	48,2	
Pr	5	36,96	1,85	10	From NdPr
Dy	2,8	224	6,27	33,8	From Fe-Dy
SubTot	*32*		*17,06*	*92*	
Fe	64,09	0,44	0,28	1,5	Fe plus Fe-B
Co	1	31	0,31	1,7	
SubTot	*65,09*		*0,59*	*3,2*	
B	1,05	0,53	0,01	0	B from Ferro-Boron
C	0,01	0,5	0	0	
SubTot	*1,06*		*0,01*	*0*	
Al	0,3	1,77	0,01	0	
Cu	0,5	6,15	0,03	0,2	
Ga	0,5	135	0,68	3,6	
Nd	0,5	36	0,18	1	
SubTot	*1,8*		*0,89*	*4,8*	
Other	0,05				Contaminants: Mn, O, S, etc
Total	100		**18,55**	**EUR/kg**	**Material cost**
			2,4	**EUR/kg**	**Magnet manufacturing w/o materials**
			23,82	**EUR/kg**	**Magnet manufacturing with materials assuming material yield 86,6%**
			26,202	**EUR/kg**	**Magnet Selling Price with 10% selling margin**

Figure 6. Cost Structure for NdFeB Sintered Magnets in China.

Cost Structure for NdFeB Sintered Magnets: West					
Material	Weight%	EUR/kg	EUR per kg of alloy	% of materials	Comments
Nd	24,2	47,5	11,5	49,1	
Pr	5	47,5	2,38	10,1	From NdPr
Dy	2,8	288	8,06	34,4	From Fe-Dy
SubTot	*32*		*21,4*	*93,6*	
Fe	64,09	0,44	0,28	1,2	Fe plus Fe-B
Co	1	31	0,31	1,3	
SubTot	*65,09*		*0,59*	*2,5*	
B	1,05	0,53	0,01	0	B from Ferro-Boron
C	0,01	0,5	0	0	
SubTot	*1,06*		*0,01*	*0*	
Al	0,3	1,77	0,01	0	
Cu	0,5	6,15	0,03	0,2	
Ga	0,5	135	0,68	2,9	
Nd	0,5	36	0,18	0,8	
SubTot	*1,8*		*0,89*	*3,8*	
Other	0,05				Contaminants: Mn, O, S, etc
Total	100		**22,89**	**EUR/kg**	**Material cost**
			6,71	**EUR/kg**	**Magnet manufacturing w/o materials**
			33,14	**EUR/kg**	**Magnet manufacturing with materials assuming material yield 86,6%**
			43,082	**EUR/kg**	**Magnet Selling Price with 30% selling margin**

Figure 6 . Cost Structure for NdFeB Sintered Magnets in West

4.3. QUANTIFICATION ASSESSMENT

In the context of this task is conducted a plan in order to prepare a qualitative assessment and will be further updated in the updated version of the techno economic assessment on D4.6 entitled “Techno-economic assessment of the PASSENGER value chain-R2”. Regarding the next steps on the Cost Benefit Analysis the below (Figure 8) cost benefit

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analysis graph will be used for the assessment and the next steps that will be conducted are to:

- ➢ Make a qualitative assessment and place them on the matrix to create a prioritization
- ➢ Make an accurate quantification (assign value to each direct/indirect cost and each benefit)

Figure 7 Assessment and quantification

5. CONCLUSIONS

Discussions among WP4 partners through physical and remote meetings lead to the definition of key elements to set the basis for the techno-economic, sustainability, health and safety assessments. Several online meetings took place until the D4.5 was issued and have been complemented by email communications. Deliverable D4.5 summarizes the outcome of the internal WP4 meetings together with specific contributions of industrial partners in regard to the scope description of their task(s). This report presented the framework of the Techno-Economic Assessment performed under Task 4.5 and forming part of the WP4 “Raw Materials. Sustainability, techno-economic, health and safety “assessment”. In addition, the definition of the needed data for technoeconomic assessment has been identified, and an inventory of plant- and production-related costs was defined. Consortium partners were needed to be guided in order to complete the excel file sheet regarding the inventory of plant and production related costs. IMA and METALPINE provided data related to TEA analysis.

Additional information regarding the completion of the TEA analysis will be included on the updated version of this report that will be submitted on M42 entitled “Techno-

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economic assessment of the PASSENGER value chain-R2” The present Deliverable presented the work that has been conducted within the 42 months.

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