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polynSPIRE
Innovative technologies for plastic recycling

Handbook on IPD working methodology

Deliverable 2.1 (v1)

WP2 Demo cases specifications and integration

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EXECUTIVE SUMMARY

The main objective of this document is to define and implement a complete framework within polynSPIRE project in order to prepare future tasks and relationships between partners. The Integrated Project Delivery (IPD) methodology described here allows minimizing risks along project development, setting up mainly information that each Work Package (WP) requires to carry out their activities and achieving the project goals.

Technical dependencies among Work Packages have contributed to the creation of specific Working Teams (WTs) to assure the proper development of the project and work beyond those tasks and partners defined in the GA. All working teams have been identified according the role of each partner, the main incomes and outcomes of flow information and the tasks to be developed. It has been useful to visualize project core flow and foresee bottlenecks or deviations related to the achievement of the WT aim. These are all of the WT identified in polynSPIRE project:

- Microwaves: To develop and test an innovative route for chemical recycling based on the integration of microwaves to improve the efficiency of the system.
- Smart Magnetic Materials (SMM): To develop and test an innovative route for chemical recycling based on the use and further recovery of smart magnetic materials (SMM) as catalysers to improve the efficiency of the process.
- Advance Techniques: To develop valuable materials by designing combinations of recycled thermoplastic polymers and functional additives.
- Valorisation in steel: To develop an injection system for the utilisation of recycled heterogonous plastic materials into Electric Arc Furnace (EAF), in order to reduce the consumption of coal (as carbon supply and foaming agent) by the use of a significant quantity of plastic waste.
- Validation: To validate at industrial relevant environment the final products obtained in working teams from 1 to 4, assessing and demonstrating the feasibility of the innovative recycling technologies.
- LCA/LCC/TE: To design a methodology to address and optimise the environmental performance of the recycling scheme taking into account the whole value chain for the targeted waste streams.
- Exploitation: Defining the exploitation and commercialization plan to pave the way for market uptake of polynSPIRE in the industrial environment of furnace manufacturers and users
- Dissemination: Spreading the results of polynSPIRE among stakeholders and target groups.

For each WT, the identification of the most important properties/parameters of the target recycled monomers and plastic wastes used as raw material are defined. These variables will be compared before and after the implementation of the innovative polynSPIRE technologies in order to assess the obtained improvements. Besides, the most relevant parameters for the characterization of the developed technologies are also identified in this deliverable. The proposed parameters set the basis to assess the success of the project and are specifically customized for each WT under a common agreement among the partners involved. In addition, the production process baseline is determined in those processes where the innovations will be directly integrated in the current process line, namely in the steel sector with the injection system incorporation (WT4).

In line with the above, Figure *a* shows the main incomes, outcomes and the main interdependencies among the WTs previously defined. This information will support all project partners in order to fulfil the data

gathering procedure according to the organization requirements to ensure the success of the project development. In this light, the current study will be able to predict future needs of data in order to collect all required information according to the established timing conditions and by using appropriate communication channels (e.g., on-line communication with partners, meetings, excel files, drawings and deliverables technical visits).

Finally, an overview of the main risks detected and their potential mitigation approaches has been presented. Based on this revision, it is foreseen that expected problems can be overcome by considering different media available by the consortium in order to successfully attain the execution of all the WT duties and project aims.

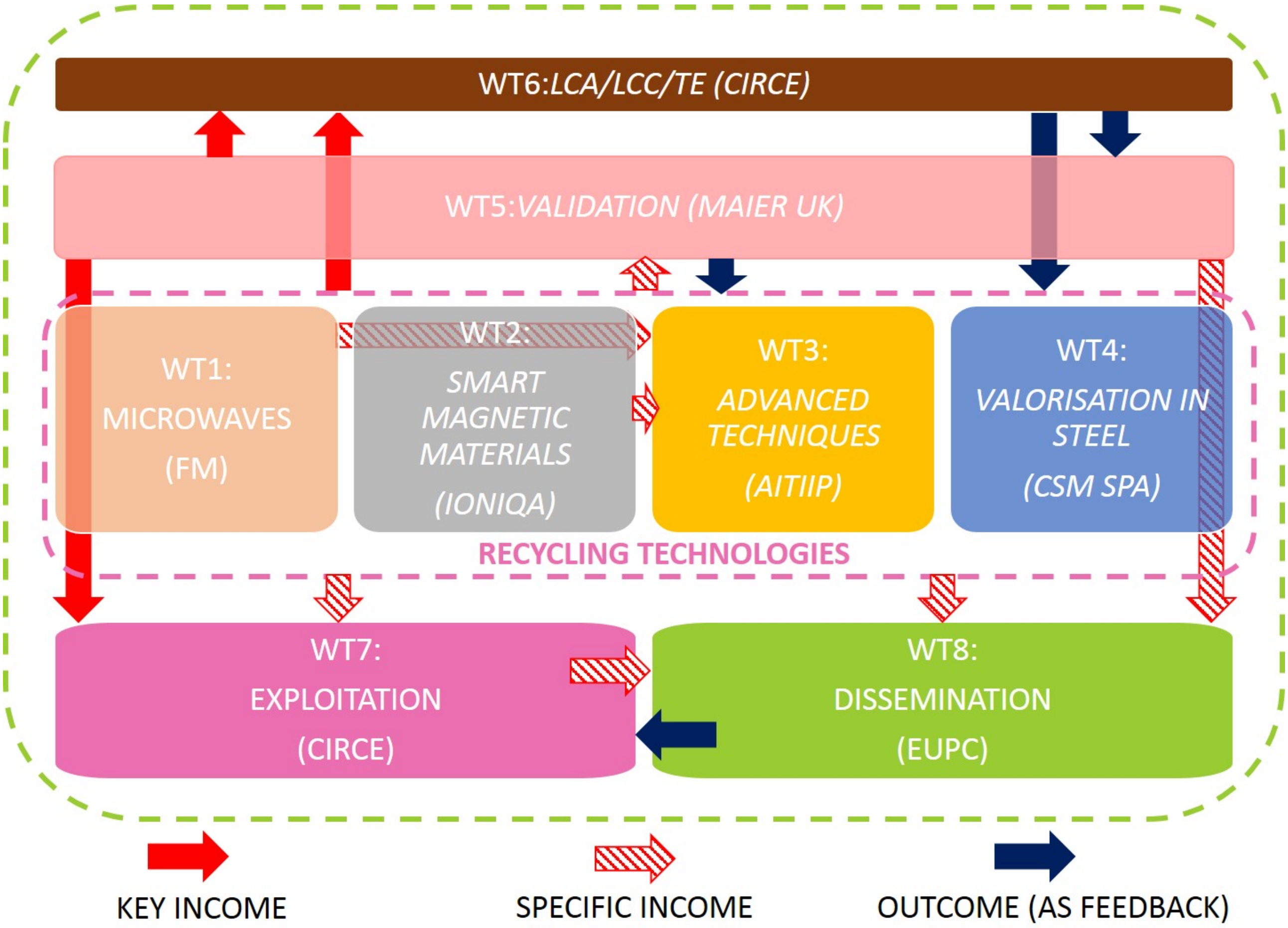


Figure a. Information flow chart: Technical dependences among WTs.

TABLE OF CONTENTS

OVERVIEW OF THE DELIVERABLE

WP:	2
Task :	2.1 Integrated Project Delivery towards team alignment
Title :	Handbook on IPD working methodology

General description of the deliverable, as in the DoA, describing:

- The main objective of this document is to define the reference working framework in order to establish an Integrated Project Delivery (IPD) methodology to assure the proper information and materials (plastic wastes and recycled monomers) flows among all the Work Packages (WPs) and Working Teams (WTs), identifying the expected inputs and outputs for each task in terms of quality, quantity and timing. A complementary objective is to identify main properties/parameters of the plastic wastes and their limitations as well as proposing contingency plans to guarantee successful project execution.
- The IPD methodology stablishes mutual respect and trust, active contributions of individual expertise, effective collaboration and open information sharing among partners, value-based decision making, shared risks, maximum profit of technological capabilities and team support.

LIST OF ABBREVIATIONS AND ACRONYMS

CA – Consortium Agreement

D – Deliverable
DoA – Description of Action
EAF - Electric Arc Furnace
EC – European Commission
EUPC – European Plastics Converters
FP – Framework Programme
GA – General Assembly
H2020 – Horizon 2020 The EU Framework Programme for Research and Innovation
IPD - Integrated Project Delivery
IPR – Intellectual Property Right
KPI - Key Performance Parameters
LCA – Life Cycle Assessment
LCC - Life Cycle Costing
MW – Microwave
PA – Polyamides
PC – Project Coordinator
polynSPIRE - Demonstration of Innovative Technologies towards a more Efficient and Sustainable Plastic Recycling
PU – Polyurethanes
SC – Steering Committee
SME – Small and Medium Enterprise
SMM - Smart Magnetic Materials
TE – Thermoeconomic analysis
TRL - Technology readiness level
UV – Ultraviolet radiation
WP – Work package
WT – Working Team

1 INTRODUCTION

This document is the Handbook on Integrated Project Delivery (IPD) Working Methodology prepared under the Project polynSPIRE EC-GA contract no 820665.

The deliverable 2.1 has been developed based on the activities of the task 2.1. Integrated Project Delivery towards team alignment within the DoA of the project polynSPIRE:

- Sub-task 2.1.1. Definition of technical boundary conditions.
- Sub-task 2.1.2. Alignment of working teams.

The purpose of this document is to define the reference working framework, which establish an Integrated Project Delivery (IPD) methodology to assure the proper information flow between all the working teams. It will contribute to identify expected inputs and outputs for each task in terms of quality, quantity and timing. To this end, some specific objectives need to be accomplished:

- To categorise the working teams and establish their roles and responsibilities.
- To define the information that each working team needs to carry out their activities and achieve the project goals.
- To detect the technical dependencies between the working teams.
- To agree materials or information required according to specific needs of the involved working teams.
- To create a common working framework and facilitate the development of the project activities, agreeing the boundary conditions for each working team and a global timing for achieving the objectives.
- To identify any other potential limitations with respect the properties/parameters of the plastic wastes that could hinder/improve the implementation of the new technologies in order to propose contingency plans.
- To define a data gathering protocol, which not only involves methods to be used but also a detailed protocol for provide the data according to the project needs.
- To present a strategy focused on decision making and problems control.
- To develop a risks analysis and mitigation approach.

Due to the public condition of this document, the intended audience of the IPD Handbook is firstly each individual participant of the Project Consortium and secondly, stakeholders as well as public and private institutions.

2 Main principles of integrated project delivery

Integrated Project Delivery (IPD) is a methodological approach that coordinates people, systems, business structures and practices to optimize project results and the talents and insights of all participants. It is built in collaboration of all partners and encourage them to focus on project outcomes rather than individual goals [1].

The main goal of an IPD methodology is to highlight the value of cooperation as a team in the best interest of the project by establishing a common framework where the individual interest of each party is properly recognized in order to achieve an early involvement in the project objectives. Here, the key participants are involved from the earliest moment in order to join their knowledge and expertise to determine the optimum combination of efforts. To this end, the efforts in planning have to be increased in comparison to conventional projects in order to maximise the efficiency and reduce risks during the project execution.

In this sense, the core of an IPD methodology consists in the creation of working teams based on the following principles:

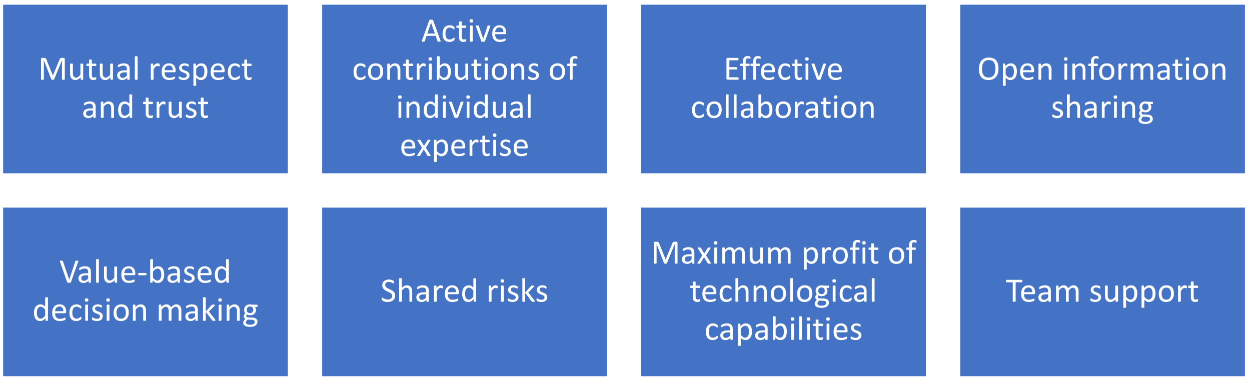


Figure 1 Core of an IPD methodology

3 Definition of technical boundary conditions and timing

The main goal of this section is to determine the information that each working team identified requires to carry out their activities and achieve the project goals. It should be noticed that, although there are connections among Working Teams (WTs) and a Work Packages (WPs), those are different concepts and their boundary conditions can be different. The figure presented in ANNEX 1 shows a general description of the work packages and how information is shared among tasks. This figure shows the interconnection among WP's and the need to create working groups beyond those partners defined in the GA to assure the proper development of the project.

Project core is based on four different recycling technologies (microwaves, smart magnetic materials, advance techniques and valorisation in steel industry) with their respective validations and data analysis. These four technologies are planned to be executed in WPs 3-6 during the period M1-M42. All products, mainly monomers, from the recycling technologies are going to be analysed, tested and validated on industrial environments, which creates a strong dependence among recycling technologies (WP3 to WP6) and the WPs of validation and data analysis (WP7 and WP8). Particularly, WP7 will be carried out during the period M19-M45 whereas WP8 during the months M1-M48. Other important dependence is found between WP3/WP4 and WP5, where all fillers and additives recovered are going to be re-introduced to the value chain of plastics through the use of recycling advance techniques.

On the other hand, WP9 (Market analysis, Exploitation and Business plan) and WP10 (Communication and Dissemination) require all output data and results generated previously in order to develop their work based on project progress and knowledge. All of these two WPs will be executed during the period M1-M48.

Therefore, the technical dependencies among the work packages make necessary the creation of working teams to work beyond the boundaries defined in ANNEX 1. The involved working teams and the agreement on materials or information required to develop their specific needs are presented below.

3.1 ESTABLISHMENT OF KEY WORKING TEAMS

3.1.1 Identification of working teams: Composition and role

A first step to the creation of the most appropriate working teams (WT) is to analyse the capabilities of each partner and their responsibilities among work packages and along the project. Each WT represents the collaboration of a group of partners with the same goal within polynSPIRE project. A well balanced team needs members with complementary technical expertise, alignment towards problem solving and decision making and interpersonal other skills such as the ability to listen effectively, provide feedback and resolve conflict [2].

Table 1 shows the different working teams identified within the boundary conditions presented in ANNEX 1. In addition, each working team is composed of two types of members: a) the responsible or main participant, who is aimed to ensure a coordination within the members of the team and a proper flow of information with other working teams, and b) the key supporting participants, who are the rest of partners involved in the development of the tasks.

POLYNSPIRE WORKING TEAMS: ROLE AND RESPONSIBILITIES				
WT nº	Working team	Responsible	Supporting participants	Role and responsibility
1	Microwaves (MW)	FM	CIRCE, ARKEMA, NIC, KORDSA, REPSOL, NUREL	To develop and test an innovative route for chemical recycling based on the integration of microwaves to improve the efficiency of the system.
2	Smart Magnetic Materials (SMM)	IONIQA	REPSOL, NUREL, KORDSA, ARKEMA, TU/e, NIC, CIRCE, CPPE	To develop and test an innovative route for chemical recycling based on the use and further recovery of smart magnetic materials (SMM) as catalysers to improve the efficiency of the process.
3	Advanced techniques	AITIIP	REPSOL, BADA, FM, IONIQA, TU/e, NIC, CIRCE, MAIER	To develop valuable materials by designed combinations of recycled thermoplastic polymers and functional additives.
4	Valorisation in steel	CSM SPA	REPSOL, IDEALSERVICE, HTT, CIRCE, FERRIERE NORD	To develop an injection system for the utilisation of recycled heterogonous plastic materials into Electric Arc Furnace (EAF), in order to reduce the consumption of coal (as carbon supply and foaming agent) by the use of a significant quantity of plastic waste.
5	Validation	Maier Uk Ltd	NUREL, ARKEMA, KORDSA, FM, IONIQA, NIC, NOVAMONT, REPSOL, CIRCE, CSM SPA, IDEALSERVICE, TU/e, AITIIP, BADA	To validate at industrial relevant environment the final products obtained in working teams from 1 to 4, assessing and demonstrating the feasibility of the innovative recycling technologies.
6	LCA/LCC/TE	CIRCE	FERRIERE NORD, CSM SPA, IDEALSERVICE, NIC, NUREL, ARKEMA, KORDSA, REPSOL, IONIQA, FM, AITIIP, BADA, MAIER, NOVAMONT	To design a methodology to address and optimise the environmental performance of the recycling scheme taking into account the whole value chain for the targeted waste streams.
7	Exploitation	CIRCE	ALL PARTNERS	Defining the exploitation and commercialization plan to pave the way for market uptake of polynSPIRE in the industrial environment of furnace manufacturers and users

8	Dissemination	EUPC	ALL PARTNERS	Looking for synergies among related EU projects and spreading the results of polynSPIRE among stakeholders and target groups.

Table 1 polynSPIRE Working teams composition and responsibilities.

3.1.2 Identification of main incomes and outcomes for each WT

Once the main WTs have been stablished, the next step comprises definition of the main incomes and outcomes required for the appropriate development of the activities of each WT. in this light, Table 2 shows general incomes and outcomes that are required and generated by each polynSPIRE working team.

POLYNSPIRE WORKING TEAMS: MAIN INCOMES AND OUTCOMES				
WT nº	Working team	Incomes	Key partners (responsible)	Outcomes
1	Microwaves (MW)	▪ Samples, detailed specifications of polymers and characterisation according chemical industrial partners.	FM, CIRCE, NIC, REPSOL, NUREL, KORDSA, ARKEMA	▪ Prototype of the MW assisted reactor. ▪ Demonstration trials results in MW chemical recycling.
2	Smart Magnetic Materials (SMM)	▪ Samples, detailed specifications of polymers and characterisation according chemical industrial partners.	IONIQA, CIRCE, NIC, CPPE, TU/e, REPSOL QUÍMICA, NUREL, KORDSA, ARKEMA	▪ Prototype of the reactor coupled with magnetic Filter. ▪ Demonstration trials results in SMM chemical recycling.
3	Advanced techniques	▪ Samples and detailed specifications of polymers and characterisation according chemical industrial partners. ▪ Fillers and additives from tests and demonstration trials of chemical depolymerisation by means of MW assisted reactions and SMM.	AITIIP, CIRCE, BADA, REPSOL QUÍMICA, FM, IONIQA, NIC, TU/e, MAIER	▪ Vitrimers production. ▪ High energy irradiation process. ▪ Integration of recovered additives and fillers into recycled materials. ▪ Demonstration of optimized recycled materials in a pilot line.
4	Valorisation in steel	▪ Samples, detailed specifications of polymers and	CSM SPA, CIRCE, REPSOL QUÍMICA,	▪ Characterization of Plastic waste as carbon source.

		characterisation according chemical and steel industrial partners.	IDEALSERVICE, HTT, FENO	▪ New injection device. ▪ Prototype installation on industrial plant and long term testing
5	Validation	▪ Samples, specification and characterisation of polymers obtained by previous technologies. ▪ Process data from innovations developed (as explained in working team Microwaves and SMM, Advances Techniques and Valorisation In Steel).	<u>MAIER UK LTD,</u> CIRCE, REPSOL QUÍMICA, ARKEMA, NOVAMONT, NUREL, KORDSA, NIC, AITIIP, BADA, CSM SPA, FENO, IDEALSERVICE, FM, IONIQA, TU/e	▪ PA6, PA6.6 & PU recycled product validation. ▪ The new process conditions with the new recycled monomers. ▪ Validation of upgraded final products coming from PA and PU plastic residues. ▪ Validation of the valorisation of plastic residues as carbon source for steel industry
6	LCA/LCC/TE	▪ Existing background for the assessment of Circular Economy focused on plastic recycling and valorisation. ▪ Previous FP7/H2020 projects. ▪ Research papers.	<u>CIRCE,</u> REPSOL QUÍMICA, ARKEMA, NOVAMONT, NUREL, KORDSA, IONIQA, NIC, FM, AITIIP, BADA, MAIER, CSM SPA, FENO, IDEALSERVICE	▪ Methodology to address and optimise the environmental performance of the recycling scheme. ▪ KPIs focused on plastic recycling process improvement.
7	Exploitation	▪ Market data, value proposition, customer needs in the target sectors. ▪ Estimated installation, startup and running costs of the outcomes in a preindustrial scenario. ▪ Key stakeholders. ▪ Expectation of exploitable results.	<u>CIRCE</u> All partners	▪ Exploitation plan. ▪ Detection of relevant markets.

8	Dissemination	▪ Detecting third related projects ▪ Reports on preliminary results. ▪ Records of dissemination activities.	EUPC, All partners	▪ Dissemination material. ▪ List of communication actions.

Table 2 polynSPIRE Working teams: key partners, main incomes and outcomes.

Main technical working teams (from WT1 to WT6) will be displayed according a flow information diagram created based on data gathered by means of questionnaires introduced to the project partners during the kick-off meeting (KoM). For the horizontal WTs (namely, WT7 and WT8), the flow information is continuous alongside the whole project.

3.1.3 WT1 Information flow: Chemical recycling using microwaves (MW).

polynSPIRE will address the chemical recycling of plastics by using MW assisted depolymerisation in order to obtain feedstock for manufacturing process of new virgin material. It will be focused on plastic polymers of PA and PU of base material. Furthermore, since MW assisted depolymerisation is affected by properties such us density, thermal properties or dielectric properties a complete characterization involving these parameters will be carried out to perform a complete study of the materials.

The starting point of WT1 is based on polymers samples provided by chemical industry partners and/or waste managers. Regarding PA virgin polymers, NUREL provides PA6, KORDSA provides PA6.6 and ARKEMA provides PA10, PA11, PA12 and composites. On the other hand, REPSOL is in charge of providing PU samples. In addition, additional samples will be bought from external waste managers to be defined during the project in order to cover the material necessities of the WT. For all kind of samples, chemical composition and specification of the recycled monomers are expected. The first samples to perform the preliminary activity of WP3 will be ready in the first months of the project (M1-M3).

During M3-M12, NIC will perform the first experiments on depolymerisation with microwaves and determine the optimized method to perform the recycling. Once the plastics and the methodology are specified, numerical simulations of chemical depolymerisation processes by microwave will be performed by CIRCE with the aim of being compared against a real physical model (M6-M18). Based on the simulations results, the basic engineering will be developed.

Finally , FM will define the detailed engineering (M16-26), construct the prototype (M25-34) and perform trials (M33-42). ANNEX 2 shows a detailed flow diagram regarding WT1. This diagram includes relevant information from the analysis of the samples until the demonstration trials.

3.1.4 WT2 Information flow: Chemical recycling using Smart Magnetic Materials (SMM).

polynSPIRE will address the chemical recycling of plastics by using Smart Magnetic Materials, which can be recovered after the process. This chemical recycling technology will be focused again on plastic polymers of PA and PU of base material. Similarly to WT1, a complete characterisation of feedstock is perform.

The starting point of WT2 is based on polymers samples provided by chemical industry partners. The first plastic samples are provided in the same way than in WT1 during the first months of the project.

Based on the samples received, IONIQA will perform laboratory test to select the best SMM catalyst to be used in depolymerisation tests (M1-M12). At the same time, NIC and TU/e will work together to determine the best methodology to perform the depolymerisation using SMM. All information obtained from NIC and TU/e will be delivered to IONIQA as advise to improve the process.

CIRCE and IONIQA will work together to define the conceptual design and basic engineering during M7-M18. CPPE will define the detailed engineering (M16-M26) and construct the prototype (M25-M34). Finally, IONIQA will perform trials which are planned to be completed in M42. ANNEX 3 shows a detailed flow diagram regarding WT2. This diagram includes relevant information from the analysis of the samples until the demonstration trials using SMM.

3.1.5 WT3 Information flow: Improvement of recycled materials by means of advanced techniques.

polynSPIRE will address the improvement of mechanically recycled plastic materials and the enhancement of their properties developing three technologies (vitrimers, compatibilizing additives and high energy radiation) applied during material manufacturing, after a mechanical or physical recycling process. Recycling technologies to be developed will be focused again on plastic polymers of PA and PU of base material.

Vitrimers are innovative materials that provides excellent mechanical properties. It will be very important to determinate properties before/after additivation of vitrimers in order to assess the improvement of mechanical properties. New innovative applications have been developed in this field by using recycled polymers and vitrimers in order to achieve high strength materials [3]. On the other hand, compatibilizing additives are widely used to enhance interaction between different polymers in blends and to enhance interaction between reinforcement (fillers/fibres) and plastic matrices in composites.

A better interaction between the different components (polymer-polymer or polymer-reinforcement) leads to a significant improvement in properties while also to more homogeneous properties in the material. There are already many different additives in the market and their efficiency has been already proved [4].

Finally, high energy radiation significantly improves the properties of recycled polymers and composites. Improvements will be obtained over mechanical properties and durability of new polymer.

This technology is already available at industrial scale [5] for some specific application such as electrical wire, where thermal stability is highly desirable. However, it could be also used to avoid down-cycling of engineering polymers such as PA and PU.

The starting point of WT3 is based on polymers samples provided by partners (chemical industries) during M1-M5. In this case, REPSOL will provide PU and BADA in collaboration with an external waste manager will provide the PA and composites samples. Recovered additives and fillers will be generated from demonstrations of chemical recycling (F&M and IONIQA) during M38-M42.

During M1-M26, TU/e will determine the chemical and mechanical formulations for recycling plastics via the use of vitrimers taking into account an industrial production.

CIRCE will develop a theoretical study of gamma ray and electron beam radiation to optimise the high energy radiation process during the period M7-M18. Based on those results, AITIIP will prepare and perform tests under different conditions to verify the previous results. At the end, the integration of recovered additives and fillers will be carried out in M25-M34, and the integration of recycled polymers, in M18-M42. Both tasks will be developed by AITIIP with the support from MAIER UK.

NIC will be in constant communication with all involved partners to determine the chemical properties of the polymers recycled. ANNEX 4 shows a detailed flow diagram regarding WT3. This diagram includes relevant information from the analysis of the samples until the use of vitrimers, high energy radiation and the inclusion of additives and fillers.

3.1.6 WT4 Information flow: Valorisation of plastic waste in the steel sector.

Electric Arc Furnace (EAF) uses fossil material (as anthracite and coke) to promote slag foaming due to FeO (ferrous oxide) reduction by carbon and subsequent CO formation. polynSPIRE will address the valorisation in EAF of low-grade plastic wastes such as plastic waste from packaging sector and reinforced composites.

Plastic wastes will be obtained from three different paths:

- PA and PU from post-industrial waste and post-consumer waste with low recycling potential;
- Mixed plastic from packaging sorting plants.
- Carbon containing residues derived from plastic materials in petrochemical industry.

All plastic waste incorporated in valorisation process does not require a specific sorting or characterization, all kind of heterogeneous materials are admissible in the process, filling the area where chemical recycling will not reach. In this scenery, important properties/parameters of plastic waste include are:

- Carbon content
- Water content.
- Ash content.
- Heating value.
- Economic value.

In the same frame, previously, carbon bearing materials (as biomass, rubber and plastic) have been tested as coal substitute [6].

The starting point of WT4 is based on plastic waste provided by partners (waste sorters) during M1-M5. Carbonaceous wastes are provided by REPSOL and IDEALSERVICE. In this case, besides the chemical compositions, it is important to detail information about availability of the plastics per year.

Plastic wastes will be analysed by CSM-SPA in order to know properties, characteristics and behaviour of material in contact with steel and slag. At the same time, according to waste characterization, a new plastic injector will be developed by HTT (M9-M18). IDEALSERVICE lead the optimization of polymers treatment to obtain the ideal plastic grains to be used in different configurations in FENO industrial facilities. Final results will be presented in D6.3 in M30. From this point, carrying out the installation and start-up of injection system, real industrial test will be performed to determinate:

- Analysis of steel, slag emissions.
- Energy recovery from plastic wastes.

- Slag foaming behaviour.
- Efficiency of EAF process.

The evaluation of results is based also on the comparison with standard industrial practice based on fossil coal utilization.

A detailed flow diagram of WT4 can be seen in ANNEX 5.

3.1.7 WT5 Information flow: Validation.

The aim of validation working team is to evaluate that targets are been reached for each recycling technology:

- Chemical recycling, Microwaves and Smart Magnetic Materials: monomers obtained as product on WT1 and WT2 will be tested and validated in chemical industries. NUREL is in charge of caprolactam samples (M20-M45), NOVAMONT validates adiptic acid and polyols (M20-M45). ARKEMA and KORDSA will work together to validate PA and finally REPSOL will be in charge of PU validation (M40-M45). For all cases, FM and IONIQA will be the partners responsible for providing monomers from its respective recycling technologies (M25-M42).
- Improvement of recycled materials by means of advanced techniques: validation of upgraded final products coming from PA and PU plastic residues. AITIIP (M30-M46) and TU/e (M26) will work together to define the best techniques to improve recycled materials and to obtain final formulations (in vitrimer case). BADA and MAIER (M33-M36) will evaluate the feasibility of the industrial applications.
- Valorisation of plastic waste in the steel sector: validation is mainly focused on the slag foaming behaviour and it aims at ensuring that new injection system has at least the same performances of the standard one (energetic performances of the furnace). REPSOL (M19-M23) and IDEALSERVICE (M35) will be in charge of characterizing the plastics that are used as carbonaceous resource. CSM-SPA (M45) and FENO (M20-M45) will define the process and operational parameters of the steel plant.

ANNEX 6 shows the flow diagram of WT5.

3.1.8 WT6 Information flow: LCA/LCC/TE.

The aim of LCA/LCC/TE working team is to generate a methodology to perform the value chain evaluation for the targeted waste streams. The starting point, during the period M1-M9, will be checking existing background for the assessment of Circular Economy focused on plastic recycling and valorisation. It will also imply to assess existing FP7/H2020 projects and research papers dedicated to the evaluation of reduction impact of plastic wastes leakage into marine environmental, taking into account the developed innovations.

According to that methodology, CIRCE will identify the main key performance parameters (KPIs) during M5-M14, carry out LCA/LCC/TE studies (M10-M27), implement a multicriteria optimisation and extrapolation using neuronal networks for each recycling technology (M31-M48), and prepare the corresponding deliverable reports.

All tasks in this WT highly depends on information from different partners working on their respectively recycling technologies. FENO, CSM-SPA and IDEALSERVICE will provide information about the industrial plastic utilization in steel (M5-M42). NOVAMONT (M5-M42) will be in charge of the data from bio-based polymers. The chemical characterization and reports of plastics and monomers streams will be delivered by NIC (M5-M42) and chemical industry partners (REPSOL, KORDSA, ARKEMA, NUREL) during M5-M42. Technical specifications from recycling technologies will be part of F&M, IONIQA, AITIIP and BADA partners. Flow diagram of WT6 is presented in ANNEX 7.

3.1.9 WT7 Market analysis, Exploitation and Business Plan

A consistent business plan and a market-oriented focus will provide better opportunities for the results to be rapidly adopted and hence expand the environmental, social and economic impact of polynSPIRE.

With this aim the validated outcomes from WT5 are expected to displace part or all of the current technologies in a relatively short period of time. To achieve a large market adoption, it will be necessary to be not only environmentally more efficient, but also cost effective and market-able than the pre-existing methods. For the efforts in WP10 to attract interested players, the economic proposition has to be estimated in the preindustrial phase and must show a reasonable expectative for the industrialization. The solutions offered as a value proposition must offer a competitive alternative not only to other recycling methods, but also to other processes to obtain equivalent final products, including new plastics.

Even though the business plan and business models are schedule in M24-M48, it will be important for all the WT key partners to provide a continuous information flow on the estimated costs in the closest-as-possible industrial scenario. The information will be focused on three pillars.

- Expected cost of implementation –technology displacement- for a potential industrial user.
- Expected running costs versus current technologies costs, from the industrial adopter perspective.
- If possible, technology change costs for the adopting industry.

This information will feed a “live document” to enrich the business plan and, more importantly, will continuously economically validate the market approach of the results. Once the WPs are successively closed, the information will evolve into a price boundaries and profit analysis.

3.1.10 WT8 Dissemination

The main goal of this WT is to ensure a proper dissemination of the project results. To this end, this WT will be focused on:

- Detecting third related projects to be aware about what is happening around Europe and therefore, detecting synergies to boost project deployment.
- Reports on preliminary results for a wide range of audience profiles.
- Records and encouragement of dissemination activities related to the project main results.

Due to the type of activities performed within this WT, all the reports and dissemination tool will be continuously updated taking into account other WTs’ feedback.

3.2 DESCRIPTION OF TECHNICAL DEPENDENCES

According to the main incomes and outcomes detailed in the previous section, the technical dependences among WTs have been detected. Figure 2 shows the information flow chart among the different WTs. As can be extracted from the figure of ANNEX 1, the information flows among WT's can be classified as:

- Key Income: Data known by technology provider and chemical industry partners, which is required by all the activities.
- Specific Income: Data known by recycling technology partners, which is specifically required for the development of the activities of a WT or group of WTs.
- Outcome: Data obtained from results of a given WT which can be used as feedback for others WTs.

Once the most relevant flows of information and the technical dependences among WTs have been detected, the next step is the detection of critical points to assure the proper development of polynSPIRE project. Some of the most critical information flows detected are:

- WT1, WT2, WT3, WT4. All recycling technologies (Microwaves, Smart Magnetic Materials, Advanced Techniques and Valorisation in Steel) are the central core of the project. There is a high dependence between chemical industry partners and technology developers (chemical analysis, simulations, construction), how information flows among partners within each working team is critical to assure the proper development of the tasks. In general terms, all recycling technologies are developed independent one from the other. Nevertheless, fillers and additives recovered from microwave and SMM reactors are utilized during the advance technique developments.
- WT5. Validation. Once all necessary data have been collected to perform a robust validation, it should be ensured from this WT a feedback over recycling technologies WT's. Validation results/conclusion should be reported to each recycling technology affected in order to be able to improve the process or correcting some issue if it is necessary. Moreover, validation WT output results are a key point to develop LCA/LCC/TE, exploitation and dissemination.
- WT7. Market analysis, Exploitation and Business plan. As a key concept within the development of polynSPIRE project, exploitation-related inputs from all/each WT will be requested and analysed as a transversal methodology for the project's purpose beyond its lifetime.

WT8 (Dissemination) not referred as a technical workteam is a paramount activity to ensure the project external communication and detection of synergies among related initiatives worldwide and, specially, at the EU scale. In this sense, public report D10.1 includes a series of recommendations and procedures to be followed from all project partners to guarantee an efficient development of polynSPIRE results dissemination and advertisement.

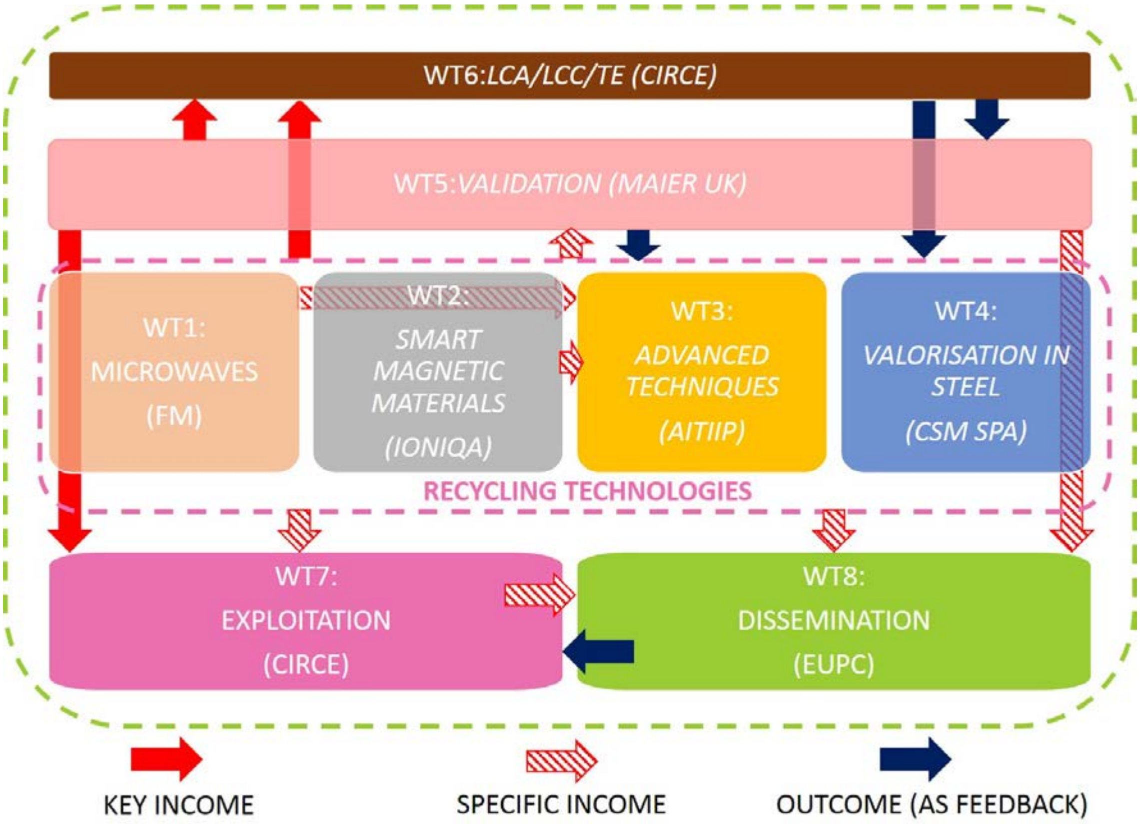


Figure 2 Information flow chart: Technical dependences among WTs.

4 REVISION OF DEMO SITES AND FUTURE CHARACTERIZATION PARAMETERS

The main purpose of this section is devoted to set all the relevant indicators that will define the level of success of the products and the operational parameters due to the integration of the polynSPIRE innovations. When possible, it will be determined the baseline of the production processes that will be compared to the recycling alternative as the project evolves.

To do so, two differentiated objectives are pursued:

- On the one hand, the first objective consists of identifying all the key parameters that will be measured and/or compared in order to evaluate the success of the project after implementing the innovative polynSPIRE technologies.
- On the other hand, the industrial process of the steel sector where the plastic waste injection system will be incorporated is also introduced in this section. The current processing will be used as a baseline from where to compare the improvements associated with the polynSPIRE project challenge.

It is worth mentioning that the key operational and characterization parameters are an alive list, that will be updated as the project advances in time and the most important properties and results are revealed.

4.1 DEFINITION OF CHARACTERIZATION PARAMETERS

As mentioned above, this section collects all the parameters identified as the most representative indicators of the progress and success of the project technologies implementation. With this purpose, a list of key parameters has been performed for each depolymerisation WT in order to better define the specifications of each technology as accurately as possible. This list has been agreed and validated by all the partners involved on each specific WT. Besides, an additional section has been added (plastic materials and samples) in order to stablish the methodology required to ensure the characterization of the waste plastic flows. This point is addressed below.

4.1.1 Plastic materials and samples

Plastic waste coming from different sectors as packaging reveals a lower rate of recycling. Most of these plastics containing materials are considered as not recyclable. One of the main reasons for the low recycling rate in plastic containing materials out of the packaging sector is their heterogeneity containing several additives and fillers. During recycling process (specially in mechanical recycling), material heterogeneity is being a problem to successfully carry out the process. Thus, partners require properties and parameters of plastic waste able to be measured and controlled in a normal process related with plastic wastes.

Material heterogeneity and origin could cause variations in structure and composition of the samples, existing acceptable differences between them. To avoid interferences in recycling process, a sufficient supply of plastic waste is ensured by chemical partners, providing a complete report of physical and mechanical characterisation for each sample. Moreover, innovative processes presented are focused on depolymerisation (independent of quality of processed plastic), and also focused on the improvement of mechanical recycling (and therefore recycled material). In the same line, valorisation of plastic waste innovation is planned for high consume of plastic waste and one of the main limitations will be the cost of plastic waste (external factor) as raw material.

4.1.2 WT1- Chemical recycling using microwaves

In WT1, the integration of microwave technology (MW) will be used as an innovative route to improve the efficiency of a chemical recycling system. A general process diagram of this system can be found in Figure 3.

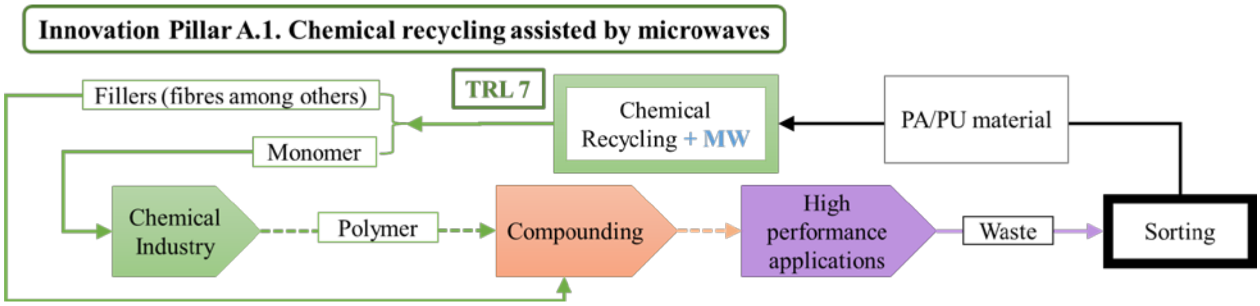


Figure 3 General chemical recycling process diagram of WT1 system (from the DoA document)

For this system, Table 3 contains a list with the most relevant parameters identified for the physical, chemical and mechanical characterization of both the raw material and monomer products, as well as those parameters related to the microwave processing.

PHYSICAL, CHEMICAL AND MECHANICAL CHARACTERIZATION OF INITIAL WASTE PRODUCT AND FINAL MONOMERS:
Form
Composition
Density
Dielectric properties (only for initial waste product)
Thermal properties (melting temperature and glass transition)
Fillers
Reinforcements
Additives
Plasticers
UV stabilizator
OPERATING PARAMETERS AND CONDITIONS FOR MW PROCESSING :
Energy consumption
Efficiency
Heating time
Power and frequency
Reactants used or other materials
Vessel manufacturing
Reactor manufacturing
Use of magnetron of solid-state as power generator
MW radiation (leakage) measuring

Table 3 Characteristics or parameters needed to evaluate the success of the project implementation in WT1.

4.1.3 WT2 - Chemical recycling using Smart Magnetic Materials (SMM)

This WT aims at developing an innovative route for chemical recycling based on the use and further recovery of smart magnetic materials (SMM) as catalysers to improve the efficiency of the process. A general process diagram of the system where the new technology will be incorporated is depicted in Figure 4.

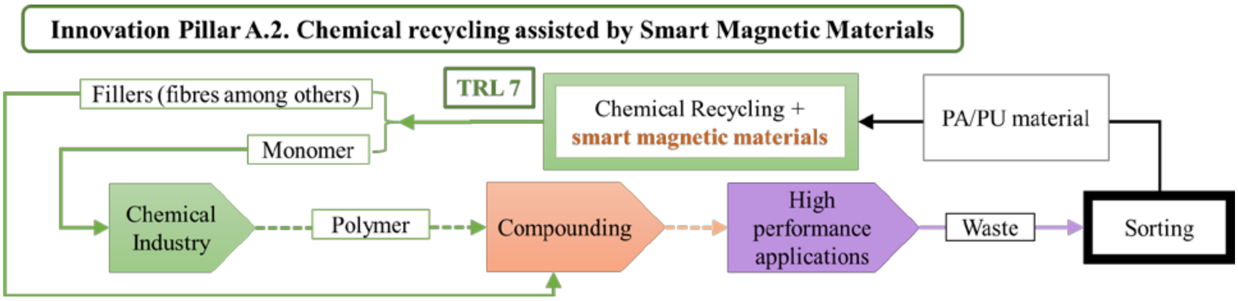


Figure 4. General chemical recycling process diagram of WT2 system (from the DoA document)

As it was done for the WT1, a list containing the most relevant characterization parameters can be found in Table 4. On the one hand, the same parameters defined in WT1 to characterize the physical, chemical and mechanical properties of the initial waste product and the final monomers are also relevant for WT2. In the table below, the operating parameters and conditions to define the chemical recycling by means of SMM (catalytic recuperation) are also contended. They all will be defined and widely analysed during the development of the WT2 activities.

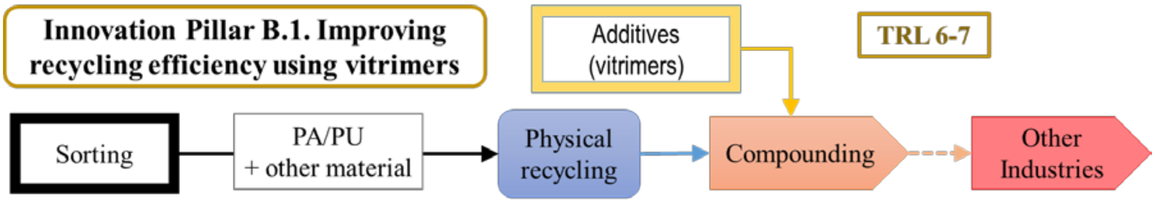
PHYSICAL, CHEMICAL AND MECHANICAL CHARACTERIZATION OF INITIAL WASTE PRODUCT AND FINAL MONOMERS:
Form
Composition and purity
Density
Dielectric properties (only for initial waste product)
Thermal properties (melting temperature and glass transition)
Fillers
Reinforcements
Additives
Plasticers
UV stabilizator
OPERATING PARAMETERS AND CONDITIONS FOR THE CATALYST RECUPERATOR:
Energy consumption
Efficiency
Processing time
Power
Reactants used or other materials
Feeding system manufacturing: vessel
Reactor manufacturing
Magnetic separator integrated downstream the process to extract and recover the SMM based catalysts.

Table 4 Characteristics or parameters needed to evaluate the success of the project implementation in WT2.

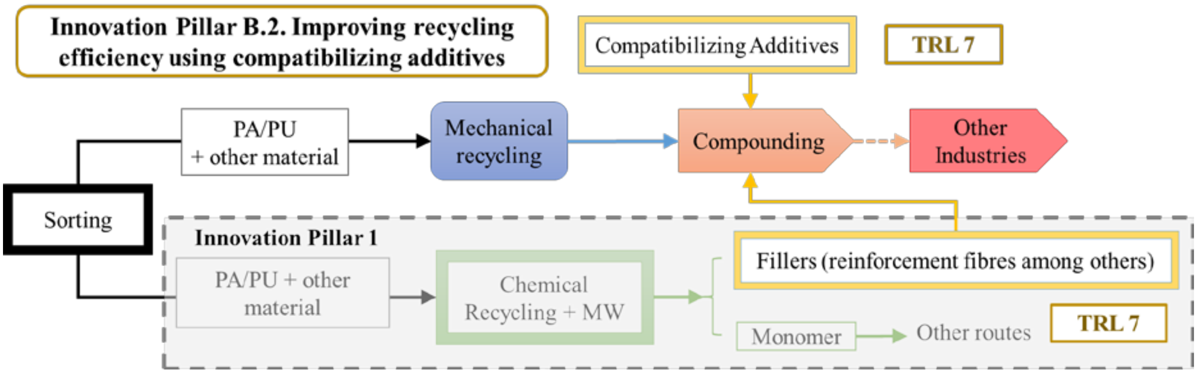
4.1.4 WT3 - Improvement of recycling-materials by means of advanced techniques

WT3 activities are focused on the improvement of mechanically recycled plastic materials and the enhancement of their properties. For this objective, three different approaches will be studied here: development of vitrimers and their incorporation into recycled materials, addition of additives to tune the formulation of recycled plastic materials and finally, enhancement of recycled materials by high-energy irradiation processes. A general process diagram of each innovative solution can be found in Figure 5.

a)



b)



c)

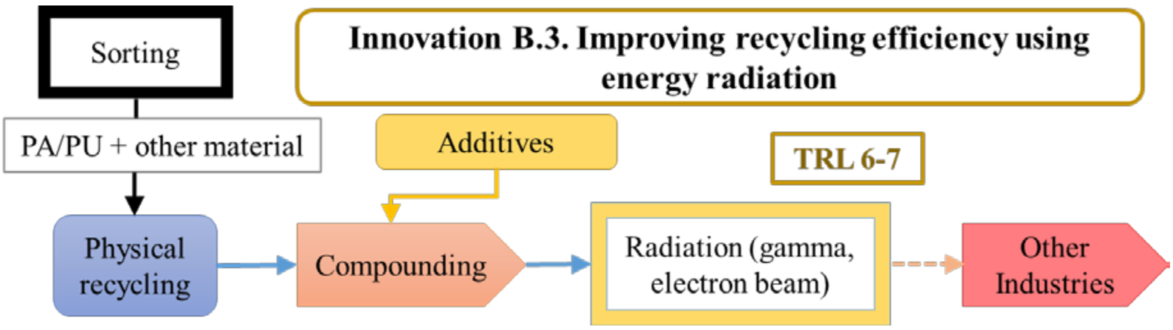


Figure 5. General recycling processes diagram of WT3 systems (from the DoA document. Improved recycling process a) using vitrimers, b) using compatibilizing additives, c) using radiation.

Regarding the characterization parameters of each proposed advanced technique, the full list is contented in Table 5. All of them were selected and/or validated by the responsible partners of each task.

PHYSICAL, CHEMICAL AND MECHANICAL CHARACTERIZATION OF INITIAL AND FINAL PRODUCT (including the formulation of new blends with additives):
Form
Composition and purity
Density
Fillers
Reinforcements
Additives
Impact resistance, Young's module, welding strength, hardness
Thermal resistance
Regarding the Wheel Trim prototype: • Disassembly test • Impact resistance at room and low temperature • Adhesion between substrate and coating
CHEMICAL AND MECHANICAL CHARACTERIZATION OF VITRIMERS:
Composition and purity
Density
Flowability (how will the processability of the vitrimers turn out to be when processing in classical thermoplastic extrusion equipment)
Network characteristics (e.g. segment lengths)
Morphology
Thermal performance: properties as a function of temperature
OPERATING PARAMETERS AND CONDITIONS FOR IRRADIATION PROCESS:
Irradiation dosage range
Crosslinking level
Chain scission
Oxidation
Long-chain
Grafting
Thermal properties
Mechanical properties
Chemical properties

Table 5 Characteristics or parameters needed to evaluate the success of the project implementation in WT3.

4.1.5 WT4 - Valorisation of plastic waste in the steel sector

Finally, the aim of WT4 is to replace the use of coal as carbon supply in the steel sector by plastics wastes obtaining from different paths: PA and PU waste with low recycling potential, mixed plastic from packaging sorting plants and carbon containing residues derived from plastic materials in petrochemical industry. In this light, the WT activities also address the optimization of waste pre-treatments and the design of an injection system for the plastic wastes.

As it was done for the previous WTs, the list containing all the representative parameters required to characterize the implementation progress and success are collected in Table 6. In this occasion, parameters are classified into: physical, chemical and mechanical parameters of plastic waste product and final steel product, parameters associated with the operating conditions of the injection system and operating conditions of the integrated system.

PHYSICAL, CHEMICAL AND MECHANICAL CHARACTERIZATION OF PLASTIC WASTE PRODUCT:
Form material
Composition and purity
Water content
Ash content
Density before extrusion
Heating value
Size distribution
Economic value
PHYSICAL, CHEMICAL AND MECHANICAL CHARACTERIZATION OF FINAL STEEL PRODUCT (after adding plastic wastes):
Form
Composition and purity
Density after extrusion
Heating value
Size distribution
Economic value
OPERATING PARAMETERS AND CONDITIONS FOR THE INJECTION SYSTEM:
Energy consumption
Efficiency
Amount of material injected per unit of produced steel
Processing time
Power
Pressure
Control method
Cooling needed
OPERATING PARAMETERS AND CONDITIONS FOR THE INTEGRATED SYSTEM (INDUSTRIAL PROCESS):
Productivity
Energy consumption
Efficiency
Heating time
Power and frequency

Table 6 Characteristics or parameters needed to evaluate the success of the project implementation in WT4.

4.1.6 Industrial process of the steel sector where the injection system will be incorporated

This section aims at describing the industrial process of the steel sector and the innovation pillar C (Figure 6), which consists of the valorisation of plastic residues by means of a product adaptation.

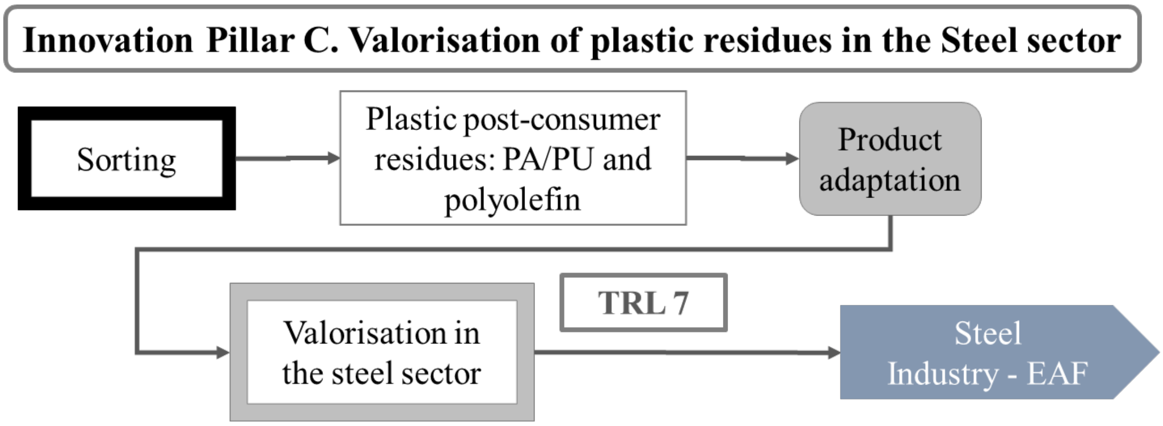


Figure 6. General valorisation of process diagram of WT4 system (from the DoA document)

The main modification in the current system corresponds to the installation of the new injection line itself, in parallel with the traditional system (coal based) currently used. Figure 7 contains a schematic process diagram of the FENO manufacturing system after incorporation the new technique developed by WT4.

To this end, the incorporation of the injection system will require a hopper, a pneumatic system and a lance with the injector purposely designed for this activity by HTT. A more detailed description about this system will be available once the WT4 activities are developed according to the project Gantt.

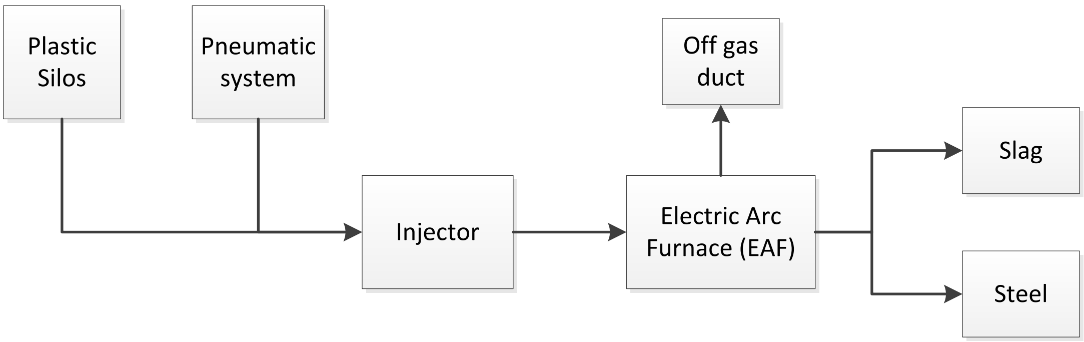


Figure 7. Process diagram of the industrial processing line where the injection system will be incorporated

5 DATA GATHERING METHODOLOGY

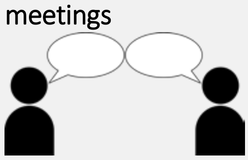
5.1 METHODOLOGY

This section presents a reference working methodology aimed to assure that all the initial data required to carry out the proposed polynSPIRE project activities and goals are properly provided. To this end, the present section has been structured as follows:

- Description of the main data gathering methods to be used in polynSPIRE (section 5.1.1).
- Main steps to be considered for the data gathering protocol according to the specific requirements of the project (section 5.1.2).

5.1.1 Data gathering methodology premises

In order to carry out collection of data according to the specific requirements of each WT, different communication channels are considered. Particularly, the selection of the most appropriated one will depend on the WT specific needs. The selected data gathering methods are summarized in the following table.

DATA GATHERING METHODS	
• On-line communication with partners 	This involves different media to communicate with each other over a computer network. This category is carried out based on considering three main tools: E-Mails, teleconferences, Intranet.
	E-Mails, it can be used to validate the values including in questionnaires and reports. They should be generally used to exchange general information on the WTs' activities progress and also to exchange documents. By default, the project coordinator and the WT responsible should be in copy.
	Teleconferences (via Webex), used to short-term exchange of information about important issues which requires a quick response and also to monitor the progress of the project and/or selected activities.
	Intranet (via Emdesk) will be used by polynSPIRE consortium as a collaborative working space to internally develop the project activities, update reports and coordinate WTs. In addition, to ensure a proper flow of information among WTs, the reports with the technical description of the innovations will be periodically updated in Emdesk. Then, all the members of the consortium will have data accessibility according to their activities.
• Face-to-face meetings 	This option will be used to exchange of information about important issues which requires close contact with partners and also to monitor the progress of the project and/or selected activities.

• Questionnaires 	This method is useful to collect and contrast high amounts of data and requires a good level of co-operation among partners. They will be preferably done in Excel format, which are completed and returned by respondents. In general, the information asked by this method needs the use of **direct measurements** or time records of instrumentation measurements of selected variables.
• Reports and/or internal working documents 	They can be used to describe processes in detail and completing the information filled in questionnaires.
• Delivery of samples	In particular, for the development of the new recycling technologies, the supply of samples from each innovative production process is necessary to meet the following purposes: o Studying the current plastic samples (polyamide, PA and polyurethane, PU) to identify in fulfil specifications (e.g., quality in terms of properties and chemical composition) needed to attaining the future developments based on e.g., recycling technologies improvements and additives incorporation. o Developing innovative plastic materials based on e.g., recycling technologies improvements and additives incorporation. o Optimizing new technologies operation and defining proper range of operation parameters.

Table 7 Data gathering methods

5.1.2 Protocol for data gathering

The data gathering protocol consists in the following steps:

1. **Detection of data need:** in order to detect data needs, specific questions and doubts related to general information about the processes should be performed.
2. **Selection of the most proper collection method:** this step should involve to identify potential data collection challenges and possible mitigation measures in order to guarantee the integrity of the data.
3. **Asking for data:** types of required data will depend on the corresponding WT where the data is pretended to be used.
4. **Data collection and reporting:** this step implies both monitoring and supporting data collection activities.
5. **Analysis of received data:** this is an important step to be carried out in order to detect possible gaps and/or inconsistencies in the information received.
6. **Preliminary results:** it consists on the collection of main results related to the corresponding WT.
7. **Analysis and validation of results:** review the consistency of the results and validate data. If further data is needed all steps previously described should be executed consecutively until no further information is needed.

5.2 COLLABORATIVE DECISION MAKING AND PROBLEMS CONTROL

Apart from the regular meetings according to the DoA, a problem solving methodology is established and adapted to project circumstances in order to address issues that require immediate resolution. It will involve the following steps:

1. Problem detection. It consists of the detection of the problem after it arises.
2. Communication of the detected situation to persons involved and affected by the problem. In this step the problem could be solved or, on the contrary, the following step should be done.
3. Report of the situation to the WT. After this step the problem could be solved or on the contrary, the procedure should continue to the following step.
4. Report of the situation to WP leader (if is not the WT responsible). After this action, the problem could be solved or on the contrary continue to the following step.
5. Report of the current situation to project coordinator. It is the final step and implies actions to solve the problem.

6 Risks analysis and mitigation approaches

Apart from the general risk analysis already included in "D1.1 Project Handbook", within this section, the most relevant risks that could affect the project performance and in particular, the data gathering process and the relation among WTs have been detected. In addition, to minimize the deleterious effects, contingency plans have been also defined. Table 8 displays an overview of the risks detected and their potential mitigation approaches.

Risks	Mitigation approach
Roles and responsibilities of each WT member are not clear	■ WT leader is the responsible of preparing the tentative schedule to achieve the WT goals, creating intermediate check points
Lack of updated information	■ WT leader will be in charge of reporting other WT members by means of periodic communications (mail, teleconferences). ■ Updated versions of working documents should be uploaded to Emdesk and communicated to all WT members ■ All the people involved in each WT (including PC) should be in copy of all the communications.
Information provided by questionnaires is insufficient or unclear	■ Clear instructions to fill out questionnaires should be provided by the person in charge of gathering information. ■ A teleconference to discuss questionnaires would be also recommendable.
Conference calls are not successfully attended by all WTs	■ The WT member that requires the teleconference should sent the agenda for the meeting at least 48hour before the meeting so all partners can review the issues to be discussed and prepare the related information ■ Minutes of each teleconference should be sent after the meeting by the partner responsible of the teleconference arrangement.

Table 8 Risks detected and mitigation approaches

7 Conclusions

The basis for the effective communication, information flow and data gathering alongside the partners has been set by means of this deliverable. In this light, a complete framework where all partners involved in the project are able to identify needs and technical dependencies among each other has been defined in the present deliverable. Among other, general and specific requirements, flow information and interrelations for each specific working group have been fixed.

The key parameters regarding the characterization of the initial and final products involved in the technology developed within the WT1, WT2, WT3 and WT4 have been established. Some examples of those relevant properties are composition, density, purity, sizing distribution, dielectric properties, etc. With regard to the innovative processes integration from the polynSPIRE project, also the most important operating parameters have been identified; namely energy consumption, efficiency, heating time, power and frequency, reactants used, etc. The analysis and comparison of all the previous key parameters will determine the suitability and accomplishment of the project objectives, as well as ensure a proper flow of information and a correct achievement of project goals.

The information that have been presented in this deliverable will be a useful tool to support all project partners on the understanding of the data gathering organization, being able to predict future need of information and establishing the polymers flows, times, and appropriate communication channels required during the project development.

Finally, according to a detailed revision of the main risks related to the project execution as well as the analysis of potential mitigation approaches, it is elucidated that expected problems can be overcome by the consortium expertise and resources available, and therefore, a successful execution of all the WT duties and project aims is foreseen.

LIST OF FIGURES

LIST OF TABLES

BIBLIOGRAPHY / REFERENCES

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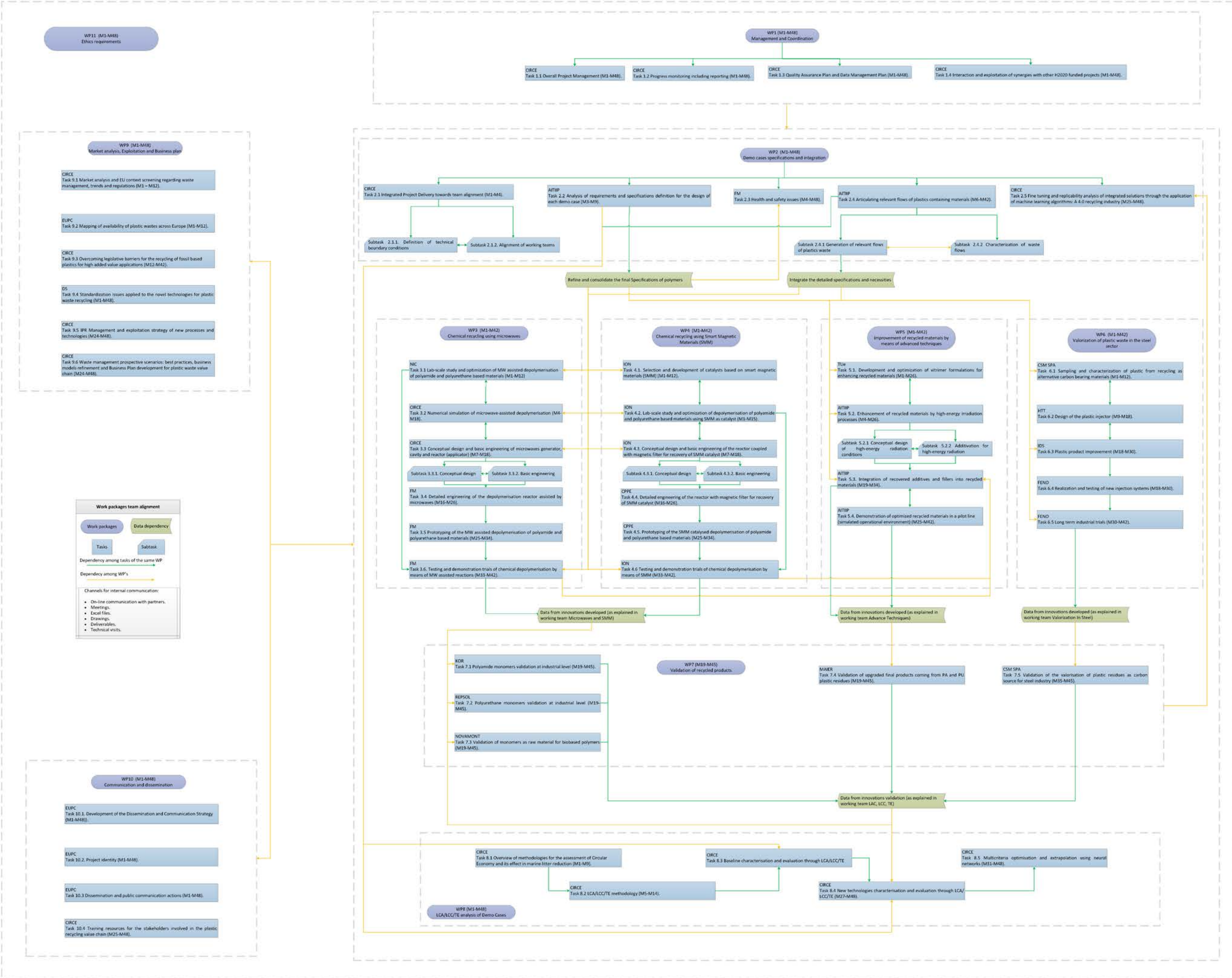
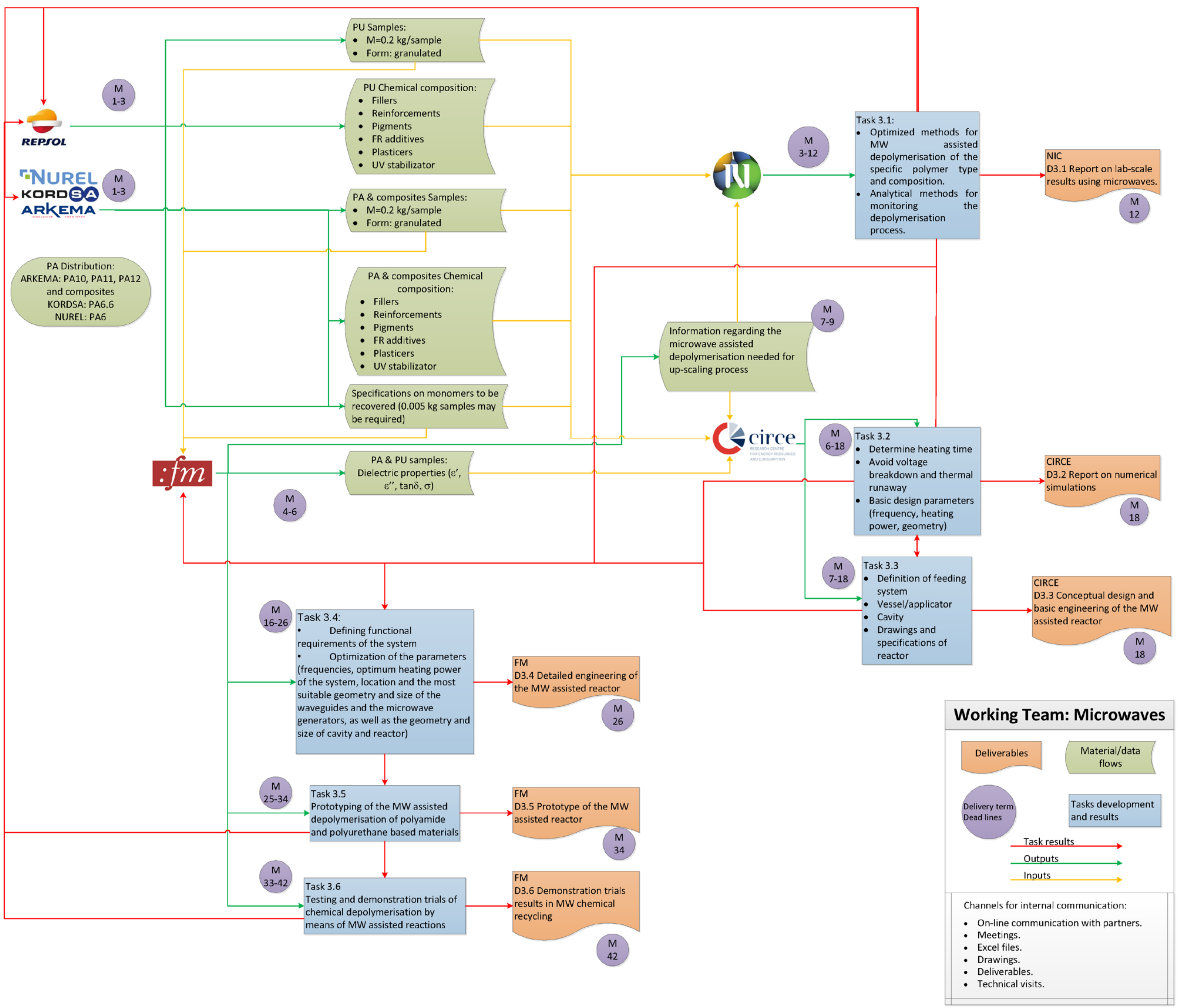
ANNEXES

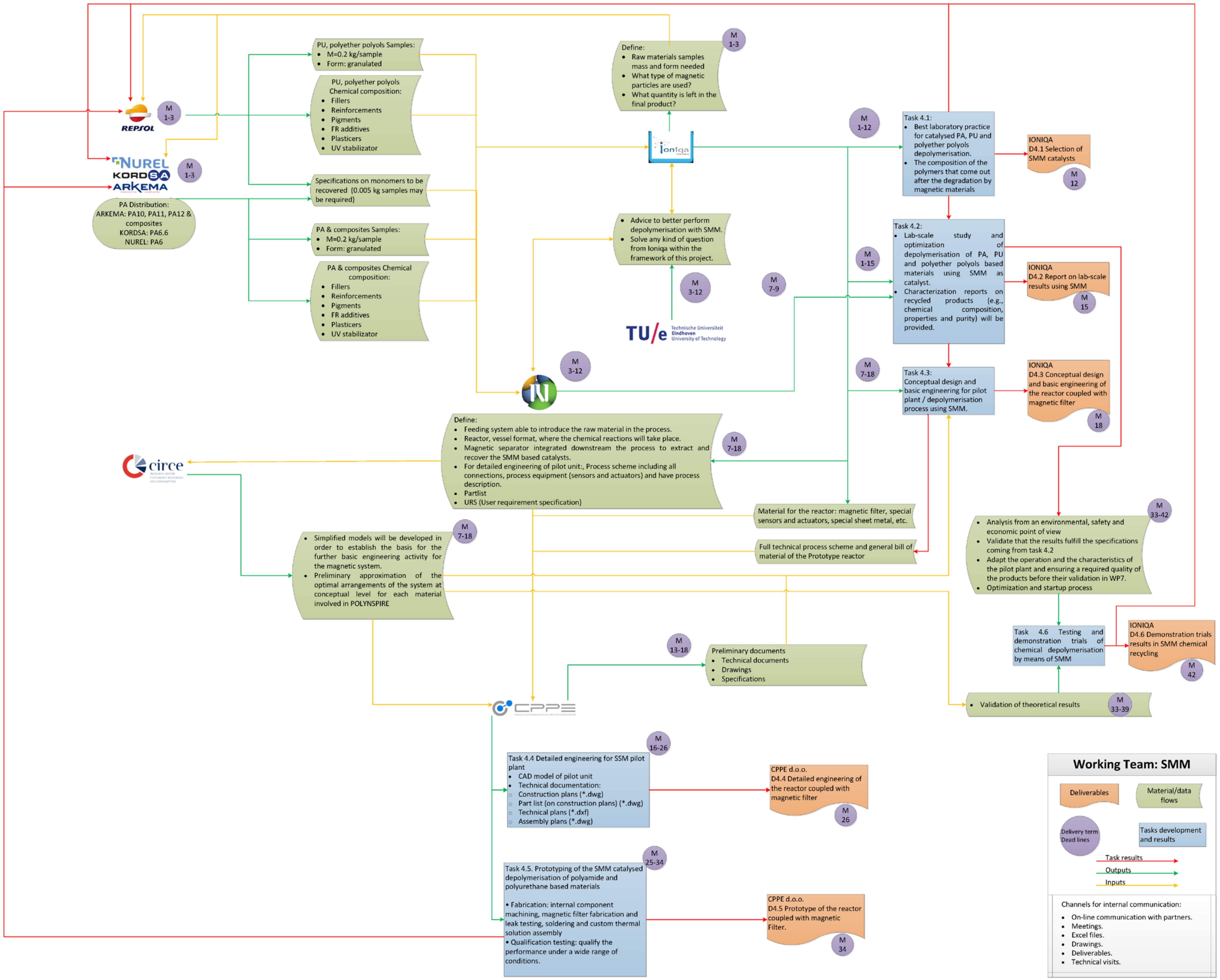
ANNEX 1 INFORMATION FLOW CHART: INCOMES AND OUTCOMES



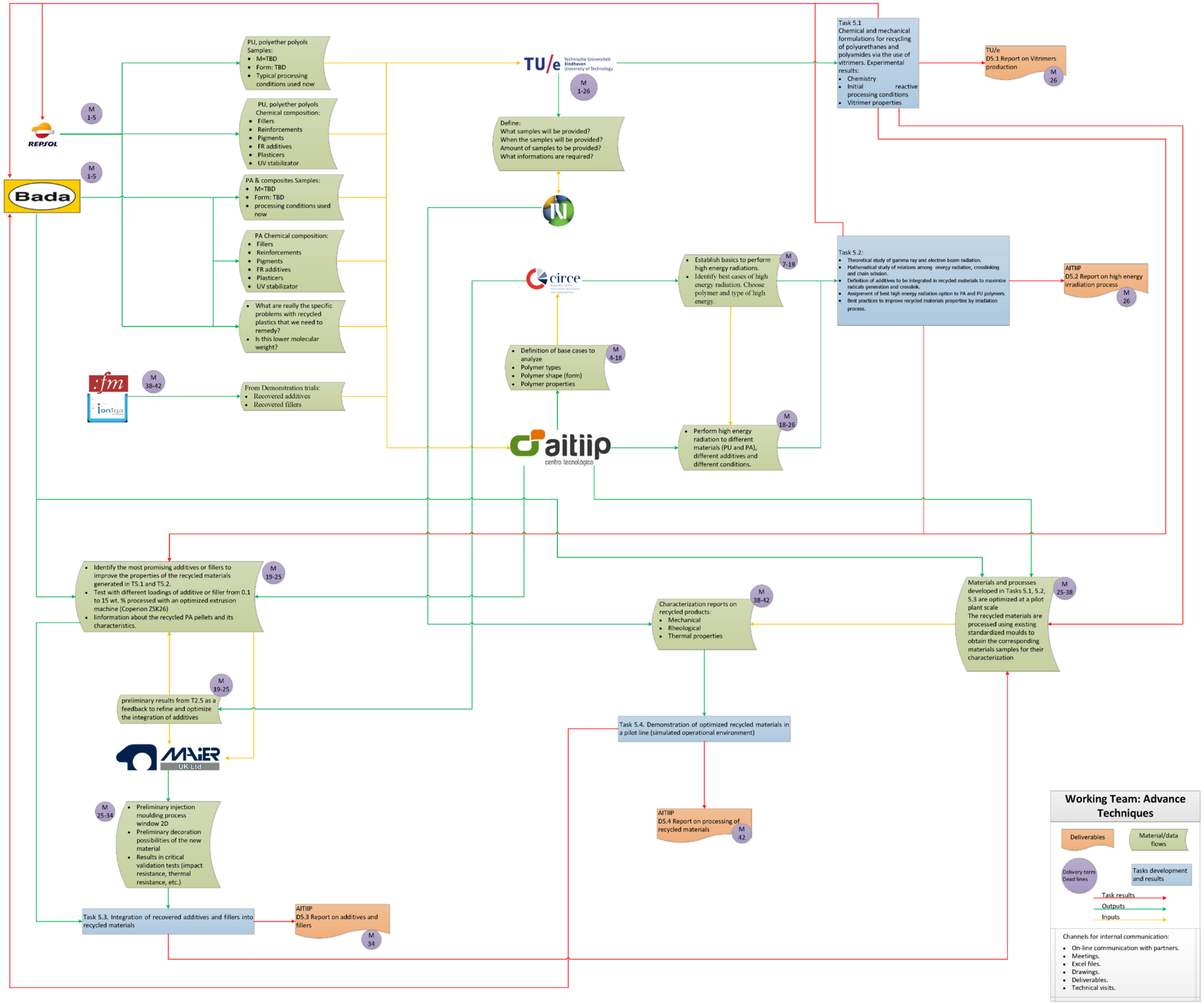
ANNEX 2 INFORMATION FLOW CHART: WT1 – MICROWAVES



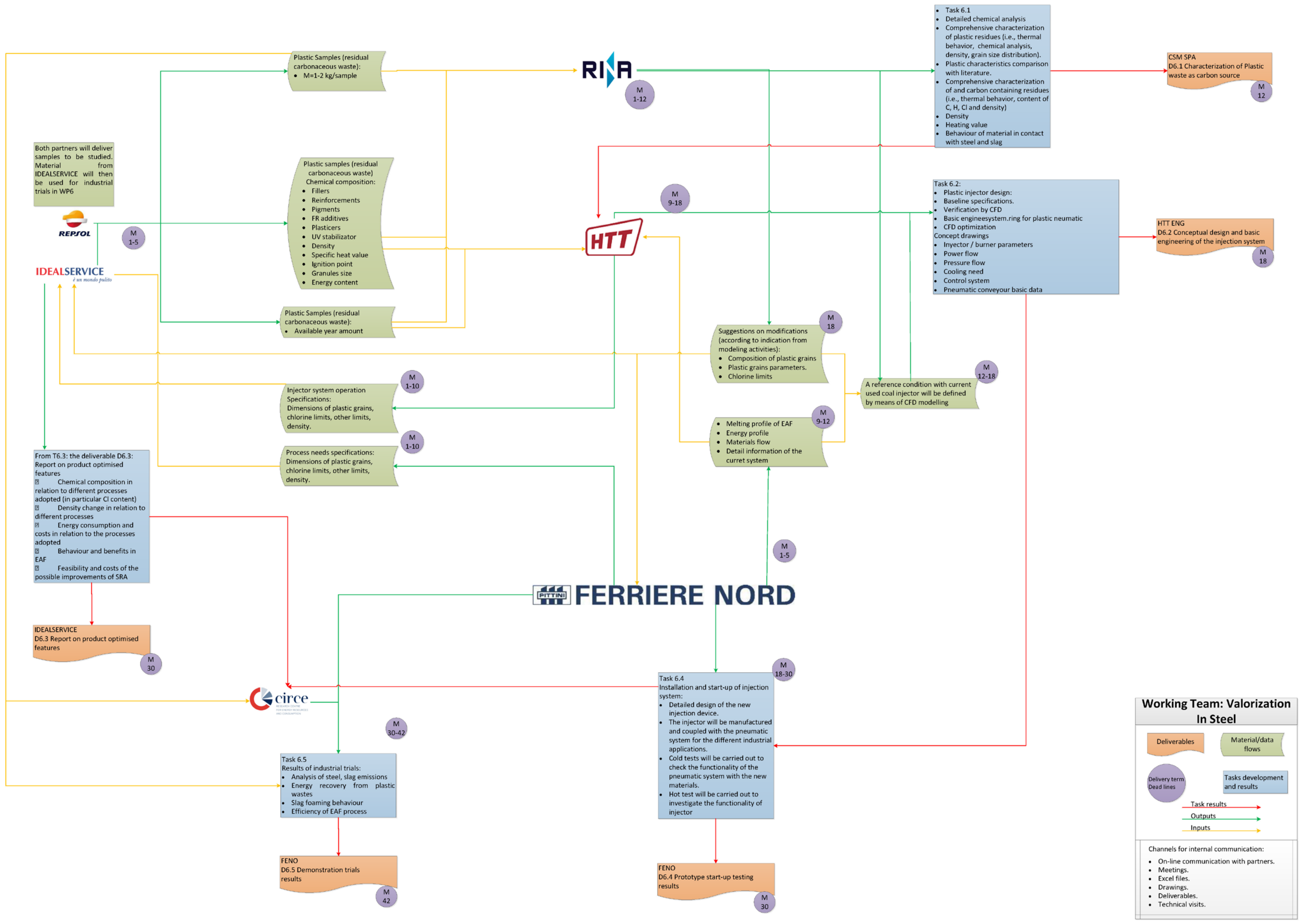
ANNEX 3 INFORMATION FLOW CHART: WT2 – SMART MAGNETIC MATERIALS



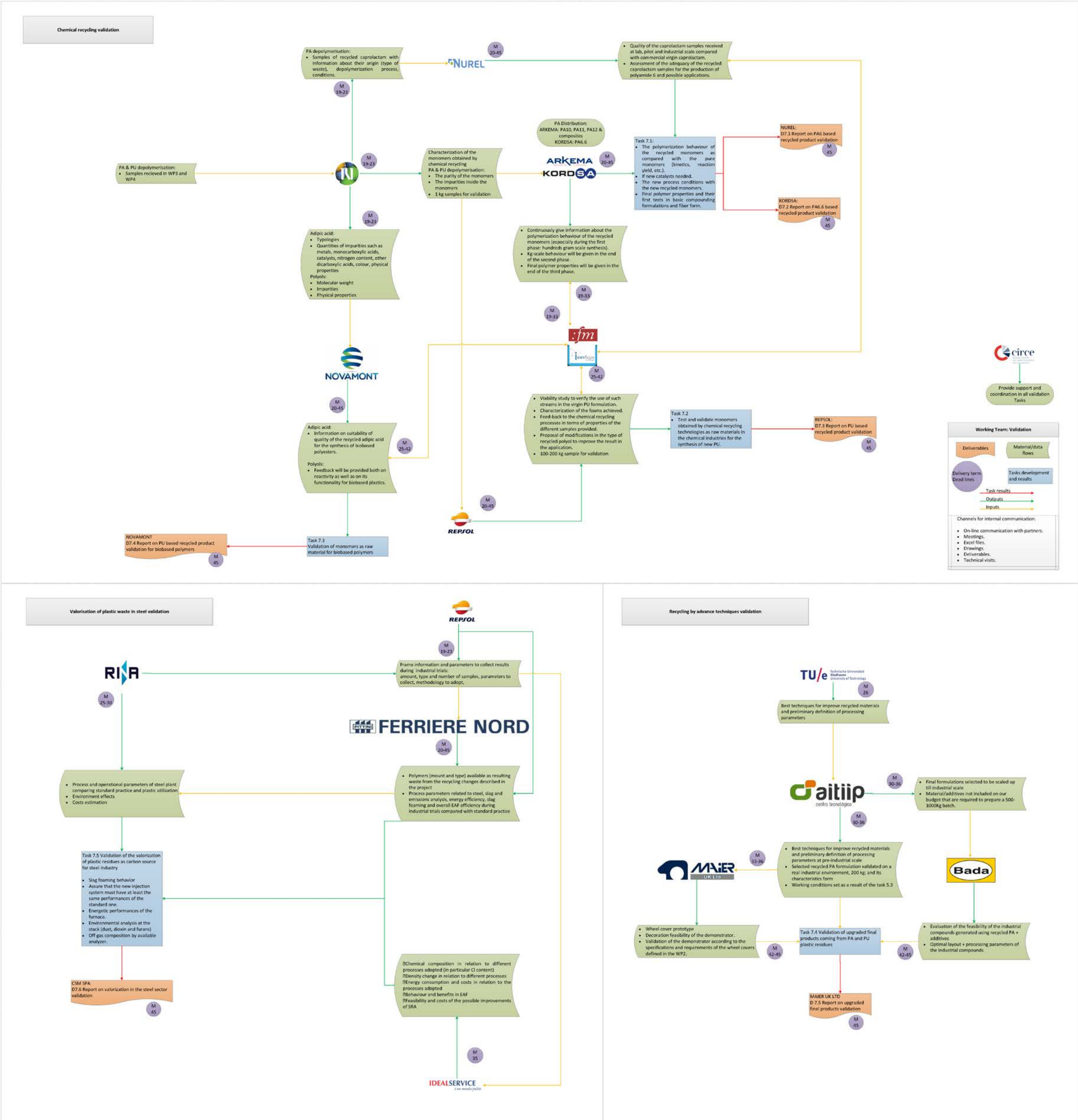
ANNEX 4 INFORMATION FLOW CHART: WT3 – ADVANCE TECHNIQUES



ANNEX 5 INFORMATION FLOW CHART: WT4 – VALORISATION OF PLASTIC WASTE IN THE STEEL SECTOR



ANNEX 6 INFORMATION FLOW CHART: WT5 – VALIDATION



ANNEX 7 INFORMATION FLOW CHART: WT6 – LCA/LCC/TE