



LIFE13 ENV/ES/000067

LIFE EXTRUCLEAN



LIFE Project Number
<**LIFE13 ENV/ES/000067**>

FINAL Report
Covering the project activities from **01/07/2014** to **30/06/2017**

Reporting Date
<**30/06/2017**>

LIFE+ PROJECT NAME or Acronym
<**LIFE EXTRUCLEAN**>

Project Data

Project location	N.A.
Project start date:	01/07/2014
Project end date:	31/12/2016 Extension date: 30/06/2017
Total Project duration (in months)	30 months (including Extension of 6 months)
Total budget	1,473,010 €
Total eligible budget	1,348,510 €
EU contribution:	674,254 €
(%) of total costs	45.77%
(%) of eligible costs	50%

Beneficiary Data

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2. Executive Summary

The project LIFE EXTRUCLEAN “Removal of hazardous substances in polyethylene packages using supercritical carbon dioxide (sc-CO₂) in recycling process” aims to demonstrate the viability of a new technique for eliminating hazardous substances from polyethylene (PE) waste packaging for solvents or phytosanitary products. The new technique applies sc-CO₂ in the extrusion phase of the plastic recycling process. It would allow reduce the use of water, energy and cleaning agents used in the current recycling processes for hazardous plastic waste, based on subsequent cleaning and drying stages, as well as water waste generation. Lower degradation of the final recycled material is also expected, being possible its use in the production of packages for hazardous substances after the corresponding homologation for this application.

The project started on 1st July 2014 and finished on 30th June 2017. This public final report covers the development of the project activities during the whole project. The purpose is to offer visibility of the results obtained and the conclusions achieved.

Table 1: LIFE EXTRUCLEAN key deliverables achieved

Updating of the state of the art.	Updated information on: current recycling processes for hazardous PE waste, hazardous contaminants in plastic waste, plastics recycling market and use of sc-CO ₂ in extrusion processes. Definition of the necessary adaptations in the pilot plant line for the treatment of hazardous plastic waste.
Definition of case studies (CS).	Two case studies according to the hazardous contaminants present in hazardous plastic waste: CS1: Hazardous PE waste from packages containing industrial products. CS2: Hazardous PE waste from packages containing phytosanitary products.
Selection of simulants of hazardous contaminants.	CS1. Four standard liquids. / CS2. Two model liquids.
Demonstration of the viability of EXTRUCLEAN technology in the decontamination of hazardous plastic waste.	EXTRUCLEAN technology, implemented at pilot plant scale, led to reductions of global contamination close to 80% on PE samples contaminated with standard/model liquids.
Definition of new recycling model for hazardous plastic waste.	EXTRUCLEAN high efficacy allows removing totally the 2nd and 3rd washes+drying stages of the traditional process. Additional modifications on waste treatment in the cleaning line were defined to increase cleaning effectiveness and save water, energy and chemicals.
EXTRUCLEAN technology implementation at industrial scale.	Design and optimization of the gas extrusion line. Decontamination of real hazardous waste and efficacy checking.



Production of packages using the recycled PE obtained through EXTRUCLEAN process.	20L and 10L jerrycans were produced using EXTRUCLEAN recycled PE in different contents (100, 80, 75 and 70%). The processing ability of the new material was assessed and a preliminary characterization of the packages was carried out for comparison with packages 100% virgin PE.
Characterization and validation of the new packages.	Validation tests for the certification according to ADR regulations were performed for several testing levels. Definition of the range of applications of new the packages according to the content of EXTRUCLEAN recycled PE in their composition.
Environmental monitoring.	Life Cycle Assessment (LCA) to check the environmental impact reduction in EXTRUCLEAN recycling process and the new packages. The analyses were performed on three main process steps: washing, extrusion and packaging production (considering different scenarios of composition and size). Ecoindicator 99 methodology was used to obtain environmental impact by impact categories to a final aggregation into a unique score.
Economic and logistic monitoring.	Economic viability of the whole new process (recycling+packages production) assessment. Logistics for the management and recycling of hazardous PE waste was defined for the new recycling model.
Regulatory analysis.	Periodic analysis/up-dating of current European legislation affecting the product developed.
Evaluation of the socio-economic impact of the project.	The socio-economic impacts on both the citizens and the companies were analyzed after measuring and updating the corresponding indicators.
Dissemination of the project.	Set up of project website and continuous updating, use of the dissemination material prepared in different events, technical publications in sectorial media. Project video in Spanish and English with subtitle.
Exploitation	Exploitation and commercialization plan ready.

Outputs and conclusions

EXTRUCLEAN technology aims to develop an innovative process to decontaminate plastic waste in an intensive and efficient way. Two case studies regarding the hazardous contaminants in PE packaging to be recycled were defined, one representing plastic waste from packages containing industrial products and other one representing plastic waste from packages containing phytosanitary products. The standard/model liquids representative of hazardous contaminants were selected for each case study .



The extrusion pilot plant equipment for decontamination using sc-CO₂ was configured and set-up. Different PE samples were contaminated with the selected standard/model liquids and decontamination trials at pilot plant scale were performed, optimizing the processing, which dealt to positive results: global reductions of hazardous contaminants were close to 80%, confirming the effectiveness of EXTRUCLEAN technology. Comparison between the traditional and EXTRUCLEAN recycling processes showed that EXTRUCLEAN technology led to more decontamination, allowing the elimination of the second and third cleaning steps involved in the traditional process.

Implementation at industrial scale was carried out. Different batches of EXTRUCLEAN recycled PE were obtained to produce jerrycans, where a processing assessment of EXTRUCLEAN material was carried out. 20L and 10L jerrycans with reduced odour, improved mechanical properties and better chemical resistance compared with packages from traditional recycled PE were produced. These packages were made of different EXTRUCLEAN material contents (100%, 80%, 75% and 70%), and were validated for the certification according to ADR regulations for several testing levels (different packaging groups according to the hazardous character of the good to be packed and transported). Results allowed determine the range of applications of the new packages:

	Traditional Packages	EXTRUCLEAN Packages				
PE Package Capacity	20L, 10L	20L			10L	
Package Composition	100% virgin PE	70% Extruclean	80% Extruclean	100% Extruclean	75% Extruclean	100% Extruclean
Applications	All	PGIII	Non-hazardous goods		PGII	PGIII

PGII: Packaging Group II of ADR regulations (packaging for the transport of moderate hazardous goods)

PGIII: Packaging Group III of ADR regulations (packaging for the transport of slightly hazardous goods)

An environmental monitoring was performed by an LCA to check the environmental impact reduction in EXTRUCLEAN recycling process and the new packages. The analyses were performed on three main process steps: washing, extrusion and packaging production. Ecoindicator 99 methodology allowed obtain environmental impact by impact categories to a final aggregation into a unique score. In the cleaning process, a 44% of global impact reduction was achieved. In the packaging, impact reductions between 56% and 86% can be achieved according to the different compositions and designs assessed.

An economic monitoring was performed by collecting and analyzing economic data of both traditional and EXTRUCLEAN processes. It was found that production costs of the new recycled PE allow its introduction on the market considering current prices of virgin PE and the higher quality of the new material. Regarding packages production, the replacement of virgin PE by recycled PE in significant amounts (70% to 100%) makes it very favorable.

In a logistics monitoring, the new practices for hazardous waste management were established. Some of these practices increase decontamination effectiveness of sc-CO₂ and are necessary for suitable operation in extrusion blow moulding and the quality of the final packages for hazardous goods applications.

Legislation monitoring was performed by analyzing current European legislation affecting the recycled material to be obtained in the project, considering aspects related to waste, hazardous waste, recycling and the markets to which the final product is aimed at (packaging, packaging waste and ADR).



A socio-economic impact of the project was also performed, dealing to the following conclusions: EXTRUCLEAN recycled PE fulfils both the plastics industry and the end users' conditions for its acceptance on the market (e.g. price, safety, traceability); a big interest in both waste valorization and new cleaning technologies was found by the plastics industry and the citizens.

Different communication and dissemination actions were performed during the whole project. The project website was set up in two languages (EN, SP) and it is ongoing, being followed by a great number of visitors. Dissemination material (notice boards, leaflets, newsletters and video) was prepared and different dissemination and networking activities have been performed.

In addition, since the beginning of the project networking actions with other LIFE projects and possible stakeholders were done. Out After-LIFE Plan was designed in order to fulfil the EU requirements. Communication, dissemination and networking actions continue according to our After-LIFE Plan.

At the end of the project, it is considered that the results achieved are very positive:

- **High effectiveness** of EXTRUCLEAN technology in the removal of hazardous contaminants: close to 70% more than in traditional processes.
- **Elimination of two washings & dryings** in hazardous plastic waste recycling.
- **Significant reductions** in water (56%), cleaning substances (23.4%) and energy consumption (56%), as well as the wastewater generation (56%).
- **Improved mechanical and organoleptic properties** (odour reduction) of recycled PE.
- The new recycled PE is **suitable for packaging of dangerous goods** production.
- **Global environmental impact reductions:** (1) In the cleaning process: 44%; (2) In the packaging, between 56% and 86% according to the composition and design.
- **Economic benefits:** directly related to (1) reductions in water, energy and cleaning agent's consumption; (2) EXTRUCLEAN PE quality, that allows the introduction on high-added value markets; (3) the replacement of significant amounts of virgin PE (from 70% to 100%) by recycled PE in packaging.
- **Socio-economic impacts:** EXTRUCLEAN recycled PE fulfils both the plastics industry and the end users' conditions for its **acceptance on the market**.
- **Transferability:** EXTRUCLEAN recycled PE could be introduced in **other markets** like packages for the transport of non-hazardous goods, pipes and containers for waste storage (hazardous & non-hazardous) without requirements for transport.



3. Introduction

Hazardous waste generated in EU27 has become a great problem for health and the environment. The hazardous waste legislation required by the Members States agrees to comply with certain rules for its collection, handling, recycling and treatment. This entails the regular inspection of companies that handle hazardous waste, introducing regulations to ensure that it is correctly packed, labelled and drawing up according to emergency procedures. European legislation introduces a five-step waste hierarchy (Directive 98/2008/EC) where prevention is the best option, followed by re-use, recycling and other forms of recovery, with disposal such as landfill as the last resort. This aspect is aligned with the European Directive on Packaging and Packaging Waste (Directive 94/62/EC).

Following EU environmental policies and legislation, LIFE EXTRUCLEAN demonstrative project should help in the development of approaches for hazardous packages waste recycling, packages production and minimization of the impact for the packaging of hazardous products.

The generally accepted method to eliminate the danger of a hazardous container is their emptied, the triple rinsed and draining. LIFE EXTRUCLEAN is focused on an innovative technology consisting on the use of supercritical carbon dioxide (sc-CO₂) in the extrusion process involved in plastics recycling to eliminate partially or totally two of the three prior labor intense and energy consuming cleanings needed nowadays. Considerable environmental improvement has been achieved in the project (in some cases, higher than expected), demonstrating the environmental feasibility of the EXTRUCLEAN process and the recycled product obtained.

European legislations and their objectives will be reviewed and increased in the development of EU Action Plan for the Circular Economy. The project will contribute to the new objectives and to have the transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs. The project contributes to the 7th Environment Action Programme (EAP) also by supporting development of eco-technologies and promoting thus foreign investments in environmental technologies leading to increased employment and economic growth within the EU.

As project results are good, the developed technology will be sent to IPTS (Institute for Prospective Technological Studies) to be analyzed and it may be included as Best Available Techniques (BAT) and emerging techniques, and therefore may be published as Best Reference document available techniques (BREF). This action has been included in the After-Life Plan.

Furthermore, LIFE EXTRUCLEAN has improved the properties of the recycled plastic obtained, being possible to use it in a broader range of applications, even in the production of packages for hazardous substances and miscellaneous. Achieving the project objectives will also allow the homologation of packages with recycled PE according to ADR (Agreement on Dangerous Goods by Road).

The project results, in particular the new technology, will be transferred and replicated at EU level. This is a key point of the long-term project results: an increasing quality of the recycled material. This aspect, along with the general lack of plastic raw materials in Europe, makes very interesting the use of the demonstrated technology as it allows these resources remaining within the EU. In this respect, the project contributes to the Circular Economy Plan of EU.



4. Administrative part

The consortium was comprised by 5 Spanish partners, which meant a really smooth consortium organization since the project was running entirely in Spanish.

We met regularly, and minimum every 6 months and kept all the meeting minutes and through our LIFE EXTRUCLEAN intranet website, we were able to exchange technical and official documents.

Networking

All the partners have participated in the Networking activities. As a result, we have done the following actions:

- 14 thematic meetings with other LIFE projects and in addition to several contacts through the project web site were made
- Information exchange among LIFE projects related to LIFE EXTRUCLEAN in 6 LIFE Infoday (5 in Spain and 1 in Croatia)
- 74 visits to companies promoting LIFE EXTRUCLEAN
- 3 potential future project/collaboration which will take as reference the work carried out within LIFE EXTRUCLEAN project.

As a result, there are several companies interested in commercialising not only the LIFE EXTRUCLEAN products, but also interested in buying the technology.

After-Life Communication Plan

We designed the After-Life Communication Plan, based on a broad dissemination of the project results and their environmental benefits in Europe, focusing not only in the industry sector but also in the society. These actions will be performed taking advantage of the already existing project dissemination materials (notice boards, newsletter, website, leaflets Green Paper and video in Spanish and English).



5. Technical part

5.1. Technical progress, per task

In LIFE EXTRUCLEAN project, a new recycling technology based on the use of sc-CO₂ in the extrusion process was implemented to remove hazardous contaminants from PE waste.

Two preparatory actions (Actions A) and four implementation actions (Actions B) allowed reach the project objectives. In addition, four monitoring actions (Actions C) complemented the technical work developed to monitor its impact from different points of view: environmental, economic/logistic, legislative and socio-economic.

Progress of each technical action during the reporting period is described in this section.

ACTION A1 – Update the review of the state of the art.

Start: July 2014

Duration: 3 months

End: September 2014

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- **Global status:** completed
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- **Output achieved**

- Updated state of the art, confirming that traditional cleaning techniques do not completely eliminate the contaminants of the containers, allowing the material to be reused in low-added value applications, and the fact that a new upcoming alternative is the use of sc-CO₂.
- Selection of providers that can make the corresponding adaptations at pilot plant scale of AIMPLAS decontamination gas line for the treatment of hazardous plastic waste.

- Action leader: AIMPLAS

- Other partners' contribution: AIDIMME, ACTECO and ENPLAST have actively participated in the updating of the state of the art and the preparation of Deliverable 1.

Specifically, the partners' contribution has been the following:

Impacts of current recycling processes for hazardous plastic waste.	ACTECO, AIMPLAS
Types of hazardous contaminants in plastic waste.	ENPLAST, AIDIMME
Plastics recycling market.	ACTECO, AIMPLAS
Use of sc-CO ₂ in plastics extrusion and decontamination processes.	AIMPLAS
Commercial systems for the treatment of contaminated sc-CO ₂ with hazardous substances.	AIMPLAS

- **Deliverables:** D.1 Report on the review of the state of the art (confidential report).

- **Milestones:** NA
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**ACTION A2 – Definition of case studies.**

Start: August 2014

Duration: 3 months

End: October 2014

- **Global status:** completed

- **Output achieved**
 - Definition of two case studies according to the hazardous substances present in PE hazardous waste.
 - Definition of two package models:
 - For industrial products: HDPE jerrycans 20 L – 25 L (nominal volume)
 - For phytosanitary products: HDPE jerrycans 1 L – 5 L (nominal volume)
 - Selection of the simulants of hazardous substances for each case study.
- Action leader: AIDIMME
- Other partners' contribution: AIMPLAS, ACTECO and ENPLAST have actively participated in the definition of case studies and the preparation of D2.

Specifically, the partners' contribution has been the following:

Analysis of the most common hazardous contaminants and phytosanitary products.	AIMPLAS, ENPLAST, ACTECO, AIDIMME
Contaminants and phytosanitary products sourcing.	ACTECO, AIDIMME
Packaging model definition.	ACTECO, AIDIMME
Selection of standard and model liquids.	ACTECO, AIDIMME

- **Deliverables:** D.2 Definition of case studies (group of contaminants) (confidential report).
- **Milestones:** M.1 Definition of case studies.

ACTION B1 – Implementation of sc-CO₂ technology in single screw extrusion for eliminating toxicity in PE waste. Process optimization at pilot plant scale.

Start: October 2014

Duration: 12 months

End: June 2015

- **Global status:** completed

- **Output achieved**
 - Set-up of the contamination procedure with standard/model liquids.
 - Set-up of EXTRUCLEAN technology at pilot plant scale and processing optimization.
 - Effective reduction in the hazardous substances present in PE samples contaminated with standard/model liquids: achieved percentages of global reduction of contaminants about 80%.
- Action leader: AIMPLAS
- Other partners' contribution: AIDIMME carried out the contamination of PE samples with the standard/model liquids and determined the degree of decontamination achieved using sc-CO₂. ENPLAST provided the PE materials (pellets, jerrycans) necessary for the study. ACTECO contributed to the analysis of the results of efficacy of the technology.



Specifically, the partners' contribution has been the following:

Production of PE jerrycans for their contamination with standard/model liquids.	ENPLAST
Contamination of PE pellets and jerrycans with standard/model liquids following an established procedure. Check of the efficacy of the contamination procedure used.	AIDIMME
Set-up of the sc-CO ₂ pilot plant extrusion line.	AIMPLAS
Different sets of decontamination trials using sc-CO ₂ flows. Samples preparation. Parameters optimization.	AIMPLAS
Characterization of decontaminated PE samples.	AIMPLAS, ACTECO
Determination of contaminants removal by EXTRUCLEAN technology at pilot plant scale over PE samples.	AIDIMME
Analysis of the results obtained and conclusions.	AIDIMME, AIMPLAS, ACTECO

- **Deliverables:** D.3 Report on the effectiveness of sc-CO₂ in the removal of hazardous substances from contaminated PE with standard models of contaminants (confidential report).
- **Milestones:** M.2 EXTRUCLEAN process optimization for the removal of toxic substances from contaminated PE with standard models of contaminants.

ACTION B2 – Extraction of hazardous substances from real hazardous plastic waste by both traditional recycling process and EXTRUCLEAN process.

Start: May 2015

Duration: 26 months

End: June 2017

- **Global status:** completed
- **Output achieved**
 - Comparison on effectiveness: traditional vs EXTRUCLEAN processes. After the traditional process (3 washes & drying + extrusion), global reduction of contaminants never was as high as the one obtained with EXTRUCLEAN technology. Using EXTRUCLEAN recycling technology after the first washing, global contamination of industrial samples was reduced in a 66%. Phytosanitary samples showed a global reduction of 72%. EXTRUCLEAN technology allow the elimination of the second and third washings from the traditional process, to be substituted by the use of sc-CO₂ in the extrusion stage,
 - Definition of the new model for the recycling of hazardous PE waste.
 - Implementation of EXTRUCLEAN technology at industrial scale.
 - Corroboration of EXTRUCLEAN effectiveness after industrial implementation.
 - Different optimizations in ACTECO's new extrusion line.
- Action leader: ACTECO
- Other partners' contribution: AIDIMME contaminated PE samples with the standard/model liquids and afterwards determined the degree of decontamination achieved using sc-CO₂ and by the traditional process. AIMPLAS carried out the



decontamination trials using EXTRUCLEAN technology. ENPLAST collaborated by providing the PE jerrycans necessary for the study at pilot plant scale. AIMPLAS supported ACTECO in the implementation activities. AIDIMME determined the degree of decontamination achieved at industrial scale.

Specifically, the partners' contribution has been the following:

Production of PE jerrycans for their contamination.	ENPLAST
Jerrycans contamination with standard/model liquids.	AIDIMME
EXTRUCLEAN pilot plant decontamination.	AIMPLAS
Decontamination by traditional process.	ACTECO, AIMPLAS
Determination of contaminants removal in EXTRUCLEAN and traditional processes.	AIDIMME
Analysis of the results obtained and definition of the new model for hazardous PE waste recycling.	AIDIMME, AIMPLAS, ACTECO
EXTRUCLEAN industrial implementation.	ACTECO, AIMPLAS
EXTRUCLEAN effectiveness at industrial scale.	AIDIMME
Subsequent optimizations in new ACTECO's extrusion line.	ACTECO, AIMPLAS

- **Deliverables:** D.4 Report on the comparison of the effectiveness of traditional recycling process to EXTRUCLEAN process' (confidential report).
- **Milestones:** M.4 Determination of the effectiveness of EXTRUCLEAN process versus the traditional recycling process; M.3 Extraction of hazardous substances from industrial PE waste; M.5 Implementation of EXTRUCLEAN process on the traditional recycling process.

ACTION B3 – Production of new packages using recycled PE (by traditional recycling process and by EXTRUCLEAN process).

Start: January 2016

Duration: 18 months

End: June 2017

- **Global status:** completed
- **Output achieved**
 - Processing assessment of traditional and EXTRUCLEAN recycled PE. Traditional recycled PE is currently intended to low quality applications, and needs to be adequate to be processed by extrusion blow moulding. EXTRUCLEAN recycled PE can be used in extrusion blow moulding processes to produce jerrycans with small adaptations on processing parameters.
 - Production of 20L jerrycans using traditional recycled PE. Jerrycans obtained showed a noticeable odour and the presence of aggregates on the internal surface.
 - Production of 10L and 20L jerrycans using EXTRUCLEAN recycled PE. Odour was reduced in a great extent compared to jerrycans from traditional recycled PE.
 - The new jerrycans obtained showed a very glossy surface appearance
 - Elaboration of processing datasheets of EXTRUCLEAN recycled PE.
 - Characterization of the new packages.



- Elaboration of the new packages datasheets.
 - Definition of the size and composition (content of recycled PE) of the new packages as candidates for the transport of hazardous goods: 20L jerrycans with 100% and 80% of recycled PE, 20L jerrycans with 70% of recycled PE and 10L jerrycans with 75% of recycled PE.
- Action leader: ENPLAST
 - Other partners' contribution: ACTECO provided different batches of traditional and EXTRUCLEAN recycled PE to produce packages at ENPLAST facilities. Adaptation of current decontaminated material for its processing in conventional blow moulding equipment. Feedback between ENPLAST and ACTECO: results from the processing assessment were put in common with ACTECO to take decisions about next PE recycled batches to test. Feedback between ENPLAST and AIDIMME for the selection of the packages composition and the packages to be characterized in action B4.

Specifically, the partners' contribution has been the following:

Preparation and adaptation of traditional recycled PE.	ACTECO
Production of EXTRUCLEAN recycled PE for packages manufacturing.	ACTECO
Blow moulding extrusion trials using traditional recycled PE. Processing evaluation.	ENPLAST, ACTECO
Blow moulding extrusion trials using EXTRUCLEAN recycled PE. Processing evaluation.	ENPLAST, ACTECO
Inspection of jerrycans obtained with traditional and EXTRUCLEAN recycled PE.	ENPLAST, ACTECO, AIDIMME
Production of jerrycans with EXTRUCLEAN material.	ENPLAST, ACTECO
Characterization of 10L and 20L jerrycans according to ENPLAST internal quality procedures.	ENPLAST
Selection of packages (design and composition) for the validation tests in action B4.	ENPLAST, AIDIMME

- **Deliverables:** D.5 Report of blow moulding parameters for the production of new recycled packages (confidential report). D.6 Data sheets of the new recycled PE packages (confidential report).
- **Milestones:** M.6 Production of PE containers from recycled PE (by traditional recycling and by EXTRUCLEAN process); M.7 Characterization of the recycled PE containers.

The figure below shows the evolution in jerrycans production from traditional recycled PE to optimized EXTRUCLEAN recycled PE.



Jerrycans from different types of PE waste. Left: from traditional recycled PE; Right: from EXTRUCLEAN recycled PE

ACTION B4 – Validation of the new PE containers for hazardous substances. Definition of possible applications for the recycled PE.

Start: January 2016

Duration: 18 months

End: June 2017

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- **Global status:** completed
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- **Output achieved**
 - Preparatory actions previous to the packaging validation tests like equipment calibrations, quality control of standard and model liquids to be used, check of storage installations for chemical products, packages, etc.
 - Packaging assessment through validation according to Regulations in force: 10 L jerrycans with a percentage of recycled plastic of 75% are valid to contain dangerous goods from packing group II (i.e. medium danger), whereas jerrycans of 20 L for the same percentage are only suitable for containing dangerous goods from packing group III (less hazardous). Jerrycans with 100% recycled material could only be used to transport non-dangerous goods, including those which are only dangerous for use or handling but not for transport, such as household bleach. In any case even if the substances are hazardous only when handling or using assessment to comply with specific Regulations applicable should be done.
 - Action leader: AIDIMME
 - Other partners' contribution: N.A at this stage.
 - **Deliverables:** D.7 Report on validation of the new PE containers for hazardous substances (confidential report).
 - **Milestones:** M.8 Successful validation of the new PE containers for hazardous substances.
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ACTION C1 – Monitoring of the project impact: environmental monitoring.

Start: July 2014

Duration: 36 months

End: June 2017

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- **Global status:** completed
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- **Output achieved**
 - Functional unit: “decontamination of 1000 tons of hazardous PE packaging waste”.
 - System boundaries and life cycle inventories of traditional (3-washing baths +
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extrusion) and EXTRUCLEAN process.

- Life cycle inventories of several packaging scenarios validated at B4 Action.
- Environmental impact of traditional processes and EXTRUCLEAN processes, and comparison of proposed packaging scenarios.

- Action leader: AIDIMME
- Other partners' contribution: ACTECO, ENPLAST

Specifically, the partners' contribution was the following:

Support providing data on traditional process system boundaries and quantities related to consumption of water, energy and other auxiliary raw materials at their traditional recycling process to elaborate the life cycle inventories of their processes (traditional and EXTRUCLEAN)	ACTECO, ENPLAST
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- **Deliverables:** D.8 Environmental Monitoring (confidential report).
- **Milestones:** M.9 Environmental, economic, logistic and legislative validation of the new recycled PE containers.

The main environmental success achieved by the project is to avoid the exportation to China with uncertainty on the control and environmental safety of following treatments, and to be used at very low value applications. This material can be treated with EXTRUCLEAN recycling (cleaning and sc-CO₂ extrusion) to obtain a high-quality HDPE recycled pellets, suitable for extrusion blow moulding production process (impossible before EXTRUCLEAN project), and able to manufacture dangerous goods packaging (depending on the design and the mix content with virgin material).

Final conclusions from the life cycle environmental assessment are the following ones:

- Cleaning improvement at ACTECO's cleaning phase generates:
 - Total water demand reduction (which is the same as the wastewater treated) is around 56% which is over the 50% expected.
 - 23.4% chemicals reduction considering tensoactives and those used at wastewater treatment plant. This it is below but near to the targeted 30% of reduction.
 - Energy demand reduction of 56%, which it is over the 30% expected.
 - Impact reduction at all of the environmental impact categories considered: from 36% to 52% with CML2000 or with EI-99 single score a global improvement in pts of 44% that could be from 17% to 51% depending on the impact category).
- Due to the use of sc-CO₂ as new raw material, there is an increase of the environmental impact at the extrusion process at all the impact categories considered: from 12% to more than double with CML2000 or with EI-99 single score a global improvement in pts of 71% (range of increase by impact category is really wide).
- When considering both cleaning plus extrusion process at ACTECO's recycling process, with both methodologies used there are environmental reductions or increases depending on the impact category. With EI-99 single score, global score shows an increase of environmental impact of 8%. In any case the great improvement of the project is the quality of the resulting recycled pellets.
- The high quality recycled pellets allow the total or partial substitution of virgin material. The EXTRUCLEAN recycled material have much less impact than virgin one:



- With CML2000 methodology, the reduction at 6 of the 10 impact categories is higher than 95%, near 15% in other 3 categories and only is increased at one category.
- With single score EI-99H/A methodology, the environmental impact of EXTRUCLEAN is only the 3% related the virgin one.

Considering this great result and that the virgin raw material is the most important environmental aspect at packaging production (it represents near the 90% with EI-99 methodology), the final packaging can reduce their impact up to 86% when 100% recycled material is used. Depending on the design and the mixing rates tested, the less favorable scenario is 20L and 70% recycled content. Even at these conditions, a 56% of environmental impact reduction is achieved.

Analyzing the CML2000 results, a global environmental improvement was found. On one hand, energy demand is the main aspect at four categories where there are lightly impact increases (because the additional energy demand when more material has to be processed related to virgin scenarios). On the other hand, virgin material it is main aspect at the other 6, where there are important impact reductions from 35% to 85%.

ACTION C2 – Monitoring of the project impact: economic and logistic monitoring.

Start: January 2016

Duration: 18 months

End: June 2017

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- **Global status:** completed
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- **Output achieved**
 - Identification of key aspects regarding traditional processes and products in ACTECO and ENPLAST for data collection.
 - Comparison of data from traditional processes with EXTRUCLEAN data (new recycling model and packages produced with the new recycled PE).
 - Analysis of data comparison to determine economic viability of the new recycled PE on the plastics recycling market and economic viability of the new packages. ACTECO's main economic benefits are directly related to the reduction of water, energy and cleaning agents 'consumption. The use of sc-CO₂ as an additional raw material in the extrusion process is compensated by far by these reductions together with the higher quality of recycled EXTRUCLEAN PE and consequently its higher potential selling price.
 - Selling price of EXTRUCLEAN recycled material, if compared with current prices of virgin PE that are pushing up, is 33% more economic. The introduction of EXTRUCLEAN material on the plastics recycling market is economically viable. Cost production of EXTRUCLEAN packages are lower than traditional packages, between the 17% and the 22%.
 - Definition of the logistics for the management of hazardous plastic waste in ACTECO's plant.
 - Action leader: ACTECO
 - Other partners' contribution: ENPLAST provided economic data about its current production process (PE jerrycans from virgin PE). They also defined the content of recycled PE in the new packages and applications that would make economically viable the new packages. AIMPLAS and ENPLAST, with ACTECO, analysed the current situation in the plastics recycling market to know the viability of the introduction of the
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new recycled PE and the new packages on the market. AIMPLAS and AIDIMME set the guides to perform the assessment. ENPLAST, AIDIMME and AIMPLAS contributed to establish logistics of hazardous waste. Specifically, the partner's contribution was the following:

Preparation of templates for data collection regarding current and new processes in ACTECO and ENPLAST	AIMPLAS, AIDIMME
Identification of economic key aspects regarding current processes.	AIMPLAS, AIDIMME, ACTECO, ENPLAST
Data collection about current and new processes.	ACTECO, ENPLAST
Analysis of economic data.	ACTECO, ENPLAST, AIMPLAS
Analysis of plastics recycling market.	ACTECO, ENPLAST, AIMPLAS
Study of the effect of waste source separation.	ACTECO, ENPLAST, AIMPLAS, AIDIMME
Definition of logistics for the management of hazardous plastic waste.	ACTECO, ENPLAST, AIMPLAS

- **Deliverables:** D.9 Economic and logistic monitoring report (confidential report).
- **Milestones:** M.9 Environmental, economic, logistic and legislative validation of the new recycled PE containers.

ACTION C3 – Monitoring of the project impact: legislation monitoring.

Start: July 2014

Duration: 36 months

End: June 2017

- **Global status:** completed
- **Output achieved**
 - Updated legislation (environmental and dangerous goods) gathered and revised.
- Action leader: AIMPLAS
- Other partners' contribution: AIDIMME shared this action with AIMPLAS.

Specifically, the partners' contribution was the following:

Monitoring legislation of dangerous goods and their transport.	AIDIMME
Monitoring legislation of waste legislation and recovery.	AIMPLAS

- **Deliverables:** D10.1 Annual legislative monitoring report; D10.2 Annual legislative monitoring report; D10.3 Annual legislative monitoring report (confidential reports).
- **Milestones:** M.9 Environmental, economic, logistic and legislative validation of the new recycled PE containers.

Legislation monitoring will continue after the project implementation regarding dangerous goods regulations, which may change periodically.

**ACTION C4 – Socio-economic impact of the project actions on the local economy and population.**

Start: July 2014

Duration: 31 months

End: January 2017

-
- **Global status:** completed
-

- **Output achieved**

- Updating of indicators' measurements of socio-economic impact of the project.
- Analysis of the indicators.
- Determination of the project impacts on both the citizens and the industry. EXTRUCLEAN recycled PE will contribute to the plastics industry by offering a new material to be used in an application where virgin material is always used, like the production of packages for the transport of hazardous substances, keeping safety and as expected at a lower cost than current packages. Other aspects like traceability of recycled material will also be solved, as the source can be controlled, and of course it will offer a more sustainable option to the plastics industry. All this means that EXTRUCLEAN recycled PE will fulfil both the plastics industry and the end users' conditions for its acceptance on the market. Contacts coming after the dissemination activities carried out by the partners showed a big interest in both waste valorisation and new cleaning technologies.

- Action leader: AIMPLAS

- Other partners' contribution: AIDIMME shared this action with AIMPLAS. ARVET contributed with the control and measuring of impact indicators.

Specifically, the partners' contribution was the following:

Control and measuring indicators on the socio-economic impacts on the citizens.	AIDIMME, AIMPLAS, ARVET
Preparation and delivery of a questionnaire to SMEs in the recycling and plastics converting industry.	AIDIMME, AIMPLAS, ARVET
Gathering information from questionnaires.	AIDIMME, AIMPLAS, ARVET
Analysis of the indicators (dissemination activities and questionnaires).	AIDIMME, AIMPLAS

- **Deliverables:** D.4 Report of the socio-economic analysis (confidential report).

- **Milestones:** NA
-



6. Dissemination actions

5.1.1 Objectives

The main objective is to disseminate the project at an European scale to make this initiative known as well as awaking awareness among citizens, research field, public bodies and industry about the LIFE EU funds and the importance of research on plastic recycling to reduce energy consumption, water consumption and plastic waste to protect the environment and contribute to a more sustainable way of life.

Statistics show that the initial objectives and targets on disseminating the project are currently met. The results and impact of dissemination activities can be categorized as positive.

Project Website accesses: 8.753 new users

(from end 2014-30th June 2017 Google Analytics report)

Initial target: 90 users/month

currently: 212 users/month

Accesses by channel:

4.441 users' referral links
2.189 direct
1.364 organic search
755 Social Media
4 Direct email

By country:

1.900 USA, 1.514 Spain, 1.017 not set
1.800 Russia, 199 China, 152 Japan
165 Germany, 137 Brazil, 123 Netherlands
385 UK

Accesses by media type:

249 Twitter 12 Stack Exchange
373 Reddit 1 Google +
65 Facebook
35 LinkedIn
20 Blogger

Website news: 21

Arvet blogs news: 21

Electronic newsletters: 5

Published articles in other websites: 53

Project Video

Total of visualizations: 303

Total minutes: 894

Visualizations by type: Spanish 198 English 89 Spanish w/subt 16

Conferences and seminars 14

initial minimum number of attendants 150 / current attendants more than 450

**Congress 2**

Publications and Press releases	105		
<i>Initial minimum of 4 sectorial articles.</i>			
Project leaflets	1.500	Mass Media (TV and radio)	0
Fairs	10	Video	1
Visits to industry companies	25	Notice Boards	5
Patents	0	Poster	3

Social Media: Facebook , Twitter	Number
Sent Newsletters by this means	5
News published via Facebook	33
Number of tuits	63
Twitter followers	182
Twitter following	430
Contacts by email	4

Apart from those dissemination activities, 18 networking activities we performed during the same period.

Dissemination: overview per activity**ACTION: D1 Project Website**

Start: July 2014

Duration: 6 months

End: December 2014

- **Global status:** completed
- **Output achieved** Project website running
- Action leader: ARVET
- Other partners' contribution:

Specifically, the contribution of the partners has been the following:

Contribution	PARTNER
Individual partner contents & project contents	AIMPLAS
Individual partner contents & project contents	AIDIMME
Individual partner contents & project contents	ACTECO
Individual partner contents & project contents	ENPLAST

- **Deliverables:** D.12 Project Website (confidential report).
- **Milestones:** M.10 EXTRUCLEAN Webpage running.

Main results/Conclusions

The work performed in the reporting period dealt to the following results:



The project website was developed and launched successfully as scheduled. It has two different types of areas one for public audience and a private area. The public area promotes the project, allows the dissemination of non-confidential results and allows the public to contact the coordinator and partners. The private area, accessible via login, includes confidential and project management documents and helps the partners to share information and communicate more effectively.

ACTION D2: Project Notice Boards

Start: July 2014

Duration: 6 months

End: December 2014

-
- **Global status:** completed
-
- **Output achieved**
 - 5 Notice Boards of the project were done and distributed to each partner.
 - Action leader: ARVET
 - Other partners' contribution: Specifically, the contribution of the partners has been the following:
- | | |
|--|---------|
| Contribution | PARTNER |
| Individual partner contents & project contents | AIMPLAS |
| Individual partner contents & project contents | AIDIMME |
| Individual partner contents & project contents | ACTECO |
| Individual partner contents & project contents | ENPLAST |
- **Deliverables:** D.13 Project Notice Boards (confidential report).
 - **Milestones:** M.11 Life+ information boards.
-

Main results/Conclusions

The work performed in the reporting period dealt to the following results:

5 notice boards were made (one for each project's partner) by ARVET in month 6 and distributed to all partners involved in the project. Each notice board is now displayed at strategic places in the headquarters of the partners involved in the LIFE EXTRUCLEAN project.

ACTION D3: Layman's Report

Start: May 2017

Duration: 2 months

End: June 2017

-
- **Global status:** completed
-
- **Output achieved**

We have prepared a ten pages document in order to arise awareness regarding not only the LIFE EXTRUCLEAN process and environmental impact but also its transferability and results exploitation importance for the project partners
 - Action leader: ARVET
-



- Other partners' contribution: Specifically, the contribution of the partners has been the following:

Contribution	PARTNER
Contents and information review	AIMPLAS
Contents and information review	AIDIMME
Contents and information review	ARVET
Contents and information review	ACTECO
Contents and information review	ENPLAST

- Deliverables:** D.14 Layman's Report.
- Milestones:** M.12 Completion of the foreseen dissemination activities.

Main results/Conclusions:

The main results can be found in the report annexes as well as in the LIFE EXTRUCLEAN website.

ACTION D4: Other non-compulsory activities

Start: July 2014

Duration: 36 months

End: June 2017

- Global status:** completed

- Output achieved**

Project Website accesses: 8.753 new users

(from end 2014-30th June 2017 Google Analytics report)

Initial target: 90 users/month

currently: 212 users/month

Accesses by channel:

4.441 users' referral links

2.189 direct

1.364 organic search

755 Social Media

4 Direct email

By country:

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Accesses by media type:

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35 LinkedIn

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Website news: 21

Arvet blogs news: 21

Electronic newsletters: 5

**Published articles in other websites: 53****Project Video**

Total of visualizations: 303

Total minutes: 894

Visualizations by type: Spanish 198 English 89 Spanish w/subt 16

Conferences and seminars 14*initial minimum number of attendants 150 / current attendants more than 450***Congress 2****Publications and Press releases 105***Initial minimum of 4 sectorial articles.***Project leaflets 1.500 Mass Media (TV and radio) 0****Fairs 10 Video 1****Visits to industry companies 25 Notice Boards 5****Patents 0 Poster 3**

Social Media: Facebook, Twitter	Number
Sent Newsletters by this means	5
News published via Facebook	33
Number of tuits	63
Twitter followers	182
Twitter following	430
Contacts by email	4

- Action leader: ARVET
- Other partners' contribution: Specifically, the contribution of the partners has been the following:

Contribution	PARTNER
Contents for articles, news, press releases, newsletters and participate as speakers in conferences and seminars	AIMPLAS
Contents for articles, news, press releases, newsletters and participate as speakers in conferences and seminars	AIDIMME
Design, edition and publishing of news articles, news, press releases, newsletters, fairs and participate as speakers in meetings, direct company visits.	ARVET
Contents for articles, news, press releases, newsletters and participate as speakers in conferences and seminars	ACTECO
Contents for articles, news, press releases, newsletters, fairs and direct company visits	ENPLAST

- **Deliverables:** D.15 Project information brochures. D.16 Annual clipping of communication and dissemination (confidential report).



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- **Milestones:** M.12 Completion of the foreseen dissemination activities.
-

Main results/Conclusions

The work performed in the reporting period dealt to the following results.

- Technical conferences and seminars
- Information leaflets
- Articles on Internet and press releases
- Electronic newsletters
- Website news
- Fairs
- Social Media via Facebook and Twitter
- Company visits