"Development of a new STEEL grade to increase High Pressure Die Casting dies life"

Project Acronym: HPDCSTEEL

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V3.0	01/04/2021	Third draft reviewed by Ibán Vicario and Patricia Caballero
V4.0	16/04/2021	Fourth draft reviewed by Ibán Vicario

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1 EXECUTIVE SUMMARY

The purpose of this document is to make a compilation of the impact study of project results and exploitation of the die, with SCHMIEDEWERKE GRÖDITZ (SWG) as deliverable leader and the collaboration of 2a S.P.A., LEBARIO RO and TECNALIA.

1.1. Abbreviation list

ACP	Acidification
ADP/FFP	Depletion of abiotic resources
AP	Acidification Potential
EAF	Electric Arc Furnace
EDM	Electro Discharge Machining
EUP	Eutrophication
ESR	Electro Slag Re-melting
Kg	Kilogram
KWh	Kilowatt hour
GWP	Climate change
HPDC	High Pressure Die Casting
IPPC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
NP	Nutrification potential
ODP	Stratospheric Ozone depletion
POX	Photo-oxidant formation
SHS	Self-propagating High-temperature Synthesis
t	Tonne
WMO	World Meteorological Organization
WP	Work Package

2 INTRODUCTION

This document is the report that is the deliverable D6.2 of the HPDCSTEEL project. The project is partially funded by the European Commission under the RFCS program call as an answer to the RFCS-2-2016.

This document can be considered as a compilation of the LCC and LCA calculation with the new developed steel and the final assessment, exploitation and impact information. This report is based on the alloy compositions obtained on the previous WP2, results from WP3, the material manufactured in Task 4.1, the metallurgical, mechanical, thermal fatigue, stress and thermal characterization of die material from Task 4.2, the machining operation characterization from Task 5.1, the finishing and repairing operation characterisation from Task 5.2, and the industrial validation at 2a from Task 6.1.

The main goals of the report are summarized below:

- To perform the LCC and LCA compilation.
- To define the exploitation strategy.
- To define the impact of the project.

3 LCC AND LCA CALCULATION

With HPDC die built in WP5 and made with the new steel alloy and the die tests in industrial production conditions at 2A SPA facilities, all the partners have collaborated in the cost and environmental impact assessment.

A cost and environmental impact estimation of producing and using the new steel with reinforcing carbides and alloying elements, and manufacturing /maintaining cost of the dies with the new steel have be done in order to analyse the potential savings; analysing the potential of the new steel in terms of cost (LCC), environmental impact (LCA) and performance. In this way, costs and environmental impact estimation has been made over the knowledge and experience of working with special steels by every industrial partner.

From the results of previous WPs, an estimated increase of die life has been stablished in a 60%, with an increase of tooling and machining cost of a 2% and a reduction in solidification time of 2 seconds.

3.1. LCA (Life Cycle Assessment) estimation:

This task aims at evaluating the environmental improvements in HPDC (High Pressure Die Casting) due to the development of a new type of steel to manufacture the dies to be used when injecting molten aluminium.

To achieve this, Life Cycle Assessment (LCA on forward) methodology has been applied. LCA methodology evaluates the environmental burdens of product or service during its whole life cycle, from raw materials extraction till the end of life.

This methodology is based on mass and energy balances of the system under study, in order to identify all inputs and outputs throughout all life cycle steps. According to the ISO 14044:2016 standard, these steps are as it follows:

1. Raw materials extraction.
2. Production at plant.
3. Distribution and sale.
4. Use.
5. End of life.

All these steps have their own inputs and outputs, which can be classified in different environmental compartments, which in this study have been:

Table 1. Environmental compartments

Inputs	Outputs
Energy consumption	Waste
Materials	Emissions
Transport	Products
Water use	By-products

Being that the final use of the different parts manufactured with this new die alloy is very variable, only the phases prior to distribution and sale has been considered, namely, raw materials extraction and production at plant.

In order to calculate the environmental impact, a Life Cycle Inventory (LCI) has been built using the information provided by the industrial partners in the project and then the environmental impact has been calculated using the software LCA tool Simapro 9 together with Ecoinvent 3.5 database.

3.1.1 Functional unit:

3.1.1.1 Functional unit

The functional unit must represent the function of the product or service and must allow comparisons with other similar products and services. Considering this, it has been decided that the functional unit is 1 tonne of injected aluminium.

3.1.1.2 System boundaries

The system boundaries define which parts of the life cycle and which processes belong to the analysed system, i.e. are required for providing its function as defined by its functional unit. They hence separate the analysed system from the rest of the technosphere. At the same time, the system boundaries also define the boundary between the analysed system and the ecosphere, i.e. define across which boundary the exchange of elementary flows with nature takes place.

Within the scope of this study, two different systems have been analysed, both comprising the same steps:

Table 2. Life cycle steps

PROCESS	STEP
• Traditional production process	1. Melting
	2. Holding
	3. Die casting (traditional die)
• HPDCSTEEL production process	1. Melting
	2. Holding
	3. Die casting (HPDCSTEEL die)

3.1.1.3 Geographical boundaries

Geographical boundaries define the geographical area in which the study results are representative and comparable with other studies focused on similar products. In this assessment, the production process (melting, holding and die casting) is carried out in Italy, the die is manufactured in Romania and the innovative steel is produced in Germany. The conventional steel has been assumed to be produced in Germany too.

3.1.1.4 Temporal boundaries

Temporal boundaries define the time period for which the LCI is representative. This study is representative for the year 2021, being that all data have been gathered for this year.

3.1.1.5 Cut-off rules

"Cut-off" refers to the omission of not relevant life cycle stages, activity types (e.g. investment goods, storage...), specific processes and products (e.g. re-granulating of internally recycled polymer production waste before re-melting) and elementary flows from the system model.

No cut-off rules have been applied in this study.

3.1.2 Characterization method and impact categories

In order to calculate the environmental impact of the systems defined in the framework of this study, it's necessary to apply a characterization method with several impact categories. The selected method has been the "CML-IA Baseline", developed by the Centre of Environmental Science of Leiden University. Regarding this impact category, the baseline indicators are category indicators at a "mid-point level" (problem-oriented approach) and they are presented below.

- Climate change (GWP): climate change can result in adverse effects upon ecosystem health, human health and material welfare. Climate change is related to emissions of greenhouse gases to air. The characterization model as developed by the Intergovernmental Panel on Climate Change (IPPC) is selected for development of characterization factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide/kg emission. The geographic scope of this indicator is at global scale.

- Stratospheric Ozone depletion (ODP): because of stratospheric ozone depletion, a larger fraction of UV-B radiation reaches the earth surface. This can have harmful effects upon human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and on materials. This category is output-related and at global scale. The characterization model is developed by the World Meteorological Organization (WMO) and defines ozone depletion potential of different gases (kg CFC-11 equivalent/kg emission). The geographic scope of this indicator is at global scale. The time span is infinity.

- Photo-oxidant formation (POX): photo-oxidant formation is the formation of reactive substances (mainly ozone) which are injurious to human health and ecosystems and which also may damage crops. This problem is also indicated with "summer smog". Winter smog is outside the scope of this category. Photochemical Ozone Creating Potential (POCP) for emission of substances to air is calculated with the UNECE Trajectory model (including fate) and expressed in kg ethylene equivalents/kg emissions. The time span is 5 days and the geographical scale varies between local and continental scale.

- Acidification (ACP): acidifying substances cause a wide range of impacts on soil, groundwater, surface water, organisms, ecosystems and materials (buildings). Acidification Potential (AP) for emissions to air is calculated with the adapted RAINS 10 model, describing the fate and deposition of acidifying substances. AP is expressed as kg SO_2 equivalents/kg emission. The time span is eternity and the geographical scale varies between local scale and continental scale.

- Eutrophication (EUP): eutrophication (also known as nutrification) includes all impacts due to excessive levels of macro-nutrients in the environment caused by emissions of nutrients to air, water and soil. Nutrification potential (NP) is based on the stoichiometric procedure of Heijungs (1992) and expressed as kg PO_4 equivalents per kg emission. Fate and exposure is not included, time span is eternity and the geographical scale varies between local and continental scale.

- Depletion of abiotic resources (ADP/FFP): this impact category is concerned with protection of human welfare, human health and ecosystem health. This impact category indicator is related to extraction of minerals and fossil fuels, both related to input of materials and energy in the studied system. Mineral extraction is expressed ad kg Sb equivalents/kg extraction and fossil fuels depletions as MJ. The geographic scope of this indicator is at global scale.

3.1.3 Estimations

3.1.3.1 Traditional process

Melting:

- Energy consumption:
    - Natural gas: the quantity has been calculated using IDEA's heat of combustion values.
- Materials:
    - Internal returns: this material is internally reused, so its impact has been considered as 0.
    - Salts: this material is assumed as aluminium chloride.
    - Drosses: this material is internally reused, so its impact has been considered as 0. This value represents 42% of total drosses generated as a waste in "holding"
    - Melting furnace: a service life of 50 years has been assumed.
- Emissions:
    - All emissions have been estimated using the EEA methodology for combustion in manufacturing industries and construction (1.A.2).
- Products & by-products:
    - Molten aluminium from melting: no mass loss is assumed.

Holding:

- Energy consumption:
  - Natural gas: the quantity has been calculated using IDEA's heat of combustion values.
- Materials:
  - Holding furnace: a service life of 50 years has been assumed.
- Emissions:
  - All emissions have been estimated using the EEA methodology for combustion in manufacturing industries and construction (1.A.2).
- Product:
  - Molten aluminium from holding: no mass loss is assumed.

Die casting:

- Energy consumption:
  - Electricity: the Italian electric mix has been assumed as the source of energy.
- Materials:
  - Lubricant: a lubricant similar to http://www.hi-tecoils.com.au/wp-content/uploads/2015/04/Soluble_Cutting_Fluid_Nov14.pdf has been assumed.
- Water consumption:
  - Water: water has been assumed as deionised water.

Die manufacturing (it has been assumed a consumption of 3,7 dies/year):

- Energy consumption:
  - Electricity: the Romanian electric mix has been assumed as the source of energy.
- Materials:
  - Steel 1.2343 (H11): it has been assumed as an alloyed steel for high temperatures applications.
  - Steel 1.2344 (H13): it has been assumed as an alloyed steel for high temperatures applications.
  - Dievar/HP1: it has been assumed as an alloyed steel for high temperatures applications.
  - Liquid dielectric: deionised water has been assumed as a dielectric.
  - Cutting tool: tungsten carbide has been assumed as the principal material.

3.1.3.2 HPDCSTEEL process

Melting:

- Energy consumption:
  - Natural gas: the quantity has been calculated using IDEA's heat of combustion values.

- Materials:
  - Internal returns: this material is internally reused, so its impact has been considered as 0.
  - Salts: this material is assumed as aluminium chloride.
  - Drosses: this material is internally reused, so its impact has been considered as 0. This value represents 42% of total drosses generated as a waste in "holding"
  - Melting furnace: a service life of 50 years has been assumed.
- Emissions:
  - All emissions have been estimated using the EEA methodology for combustion in manufacturing industries and construction (1.A.2).
- Products & by-products:
  - Molten aluminium from melting: no mass loss is assumed.

Holding:

- Energy consumption:
  - Natural gas: the quantity has been calculated using IDEA's heat of combustion values.
- Materials:
  - Holding furnace: a service life of 50 years has been assumed.

- Emissions:
  - All emissions have been estimated using the EEA methodology for combustion in manufacturing industries and construction (1.A.2).
- Product:
  - Molten aluminium from holding: no mass loss is assumed.

Die casting:

- Energy consumption:
  - Electricity: the Italian electric mix has been assumed as the source of energy.
- Materials:
  - Lubricant: a lubricant similar to http://www.hi-tecoils.com.au/wp-content/uploads/2015/04/Soluble_Cutting_Fluid_Nov14.pdf has been assumed.
- Water consumption:
  - Water: water has been assumed as deionised water.

Steel manufacturing:

- Energy consumption:
  - Electricity: the German electric mix has been assumed as the source of energy.
- Materials:
  - Alloys: a mean between different alloys has been done to calculate its environmental impact.

Die manufacturing (it has been assumed a consumption of 2,5 dies/year):

- Energy consumption:
  - Electricity: the Romanian electric mix has been assumed as the source of energy. This value is only a 2% higher than the value for the traditional process.
- Materials:
  - All the steel is assumed to be the one produced by SWG.
  - Liquid dielectric: deionised water has been assumed as a dielectric.
  - Cutting tool: tungsten carbide has been assumed as the principal material. This value is only a 2% higher than the value for the traditional process.

3.2. LCI (Life Cycle Inventory) estimation:

In the tables below, the Life Cycle Inventory of both processes (traditional and HPDCSTEEL) are presented.

Table 3. LCI of traditional process (FU: 1 tonne of injected aluminium)

TRADITIONAL PROCESS					
Step	Input / Output	Quantity (fu)	Unit	Indicator	Source
Melting	Energy consumption				
	Natural gas	6.43E+01	kg	Natural gas, from high pressure network (1-5 bar), at service station {RoW}| processing | Cut-off, S	2A SPA
	Materials				
	Secondary aluminium	4.66E+02	kg	Aluminium, cast alloy {RER}| treatment of aluminium scrap, new, at refiner | Cut-off, S	2A SPA
	Internal returns	5.34E+02	kg	Internal reuse	2A SPA
	Salts	4.70E-01	kg	Aluminium chloride {GLO}| aluminium chloride production | Cut-off, S	2A SPA
	Drosses	2.47E+00	kg	Internal reuse	2A SPA
	Refractories	4.60E+00	kg	Refractory, fireclay, packed {RoW}| production | Cut-off, S	2A SPA
	Melting furnace	1.07E-06	p	Aluminium melting furnace {RER}| production | Cut-off, S	2A SPA
	Emissions				
	NOX	2.59E-01	kg	Emissions of NOX to air	2A SPA
	CO	1.02E-01	kg	Emissions of CO to air	2A SPA
	NMVOC	8.06E-02	kg	Emissions of NMVOC to air	2A SPA
	SOX	2.35E-03	kg	Emissions of SOX to air	2A SPA
	TSP	2.73E-03	kg	Emissions of TSP to air	2A SPA
	PM10	2.73E-03	kg	Emissions of PM10 to air	2A SPA
	PM2.5	2.73E-03	kg	Emissions of PM2.5 to air	2A SPA
	Black carbon	1.09E-04	kg	Emissions of black carbon to air	2A SPA

	Pb	3.85E-08	kg	Emissions of Pb to air	2A SPA
	Cd	3.15E-09	kg	Emissions of Cd to air	2A SPA
	Hg	1.89E-06	kg	Emissions of Hg to air	2A SPA
	As	3.50E-07	kg	Emissions of As to air	2A SPA
	Cr	3.50E-08	kg	Emissions of Cr to air	2A SPA
	Cu	9.11E-09	kg	Emissions of Cu to air	2A SPA
	Ni	4.55E-08	kg	Emissions of Ni to air	2A SPA
	Se	2.03E-07	kg	Emissions of Se to air	2A SPA
	Zn	2.56E-06	kg	Emissions of Zn to air	2A SPA
	PCDD/F	1.82E-06	kg	Emissions of PCDD/F to air	2A SPA
	Benzo(a)pyrene	2.52E-06	kg	Emissions of benzo(a)pyrene to air	2A SPA
	Benzo(b)fluoranthene	1.02E-05	kg	Emissions of benzo(b)fluoranthene to air	2A SPA
	Benzo(k)fluoranthene	3.85E-06	kg	Emissions of benzo(k)fluoranthene to air	2A SPA
	Indeno(1,2,3-cd)pyrene	3.78E-06	kg	Emissions of indeno(1,2,3-cd)pyrene to air	2A SPA
	Products & by-products				
	Molten aluminium from melting	1.00E+03	kg	Intermediate product	2A SPA
Holding	Energy consumption				
	Natural gas	8.95E+00	kg	Natural gas, from high pressure network (1-5 bar), at service station {RoW}| processing | Cut-off, S	2A SPA
	Materials				
	Molten aluminium	1.00E+03	kg	Intermediate product	2A SPA
	Refractories	1.70E-03	kg	Refractory, fireclay, packed {RoW}| production | Cut-off, S	2A SPA
	Holding furnace	1.07E-06	p	Aluminium melting furnace {RER}| production | Cut-off, S	2A SPA
	Waste				
	White drosses	3.41E+00	kg	Dross from Al electrolysis {RoW}| treatment of dross from Al electrolysis, residual material landfill | Cut-off, S	2A SPA
	Emissions				
	NOX	3.61E-02	kg	Emissions of NOX to air	2A SPA
	CO	1.41E-02	kg	Emissions of CO to air	2A SPA

	NMVOC	1.12E-02	kg	Emissions of NMVOC to air	2A SPA
	SOX	3.27E-04	kg	Emissions of SOX to air	2A SPA
	TSP	3.80E-04	kg	Emissions of TSP to air	2A SPA
	PM10	3.80E-04	kg	Emissions of PM10 to air	2A SPA
	PM2.5	3.80E-04	kg	Emissions of PM2.5 to air	2A SPA
	Black carbon	1.52E-05	kg	Emissions of black carbon to air	2A SPA
	Pb	5.37E-09	kg	Emissions of Pb to air	2A SPA
	Cd	4.39E-10	kg	Emissions of Cd to air	2A SPA
	Hg	2.63E-07	kg	Emissions of Hg to air	2A SPA
	As	4.88E-08	kg	Emissions of As to air	2A SPA
	Cr	4.88E-09	kg	Emissions of Cr to air	2A SPA
	Cu	1.27E-09	kg	Emissions of Cu to air	2A SPA
	Ni	6.34E-09	kg	Emissions of Ni to air	2A SPA
	Se	2.83E-08	kg	Emissions of Se to air	2A SPA
	Zn	3.56E-07	kg	Emissions of Zn to air	2A SPA
	PCDD/F	2.54E-07	kg	Emissions of PCDD/F to air	2A SPA
	Benzo(a)pyrene	3.51E-07	kg	Emissions of benzo(a)pyrene to air	2A SPA
	Benzo(b)fluoranthene	1.41E-06	kg	Emissions of benzo(b)fluoranthene to air	2A SPA
	Benzo(k)fluoranthene	5.37E-07	kg	Emissions of benzo(k)fluoranthene to air	2A SPA
	Indeno(1,2,3-cd)pyrene	5.27E-07	kg	Emissions of indeno (1,2,3-cd) pyrene to air	2A SPA
	Products & by-products				
	Molten aluminium (from holding)	1.00E+03	kg	Intermediate product	2A SPA
Die casting	Energy consumption				
	Electricity	4.13E+02	kWh	Electricity, low voltage {IT}| market for | Cut-off, S	2A SPA
	Materials				
	Molten aluminium (from holding)	1.00E+03	kg	Intermediate product	2A SPA
	Lubricant	1.36E+01	kg	Lubricating oil {RER}| production | Cut-off, S	2A SPA
	Die	2.02E-04	p	Intermediate product	Lebario RO Srl

	Water consumption				
	Water	7.59E+02	m3	Water, deionised, from tap water, at user {Europe without Switzerland}| water production, deionised, from tap water, at user | Cut-off, S	2A SPA
Die manufacturing	Energy consumption				
	Electricity	2.32E+00	kWh	Electricity, low voltage {RO}| market for | Cut-off, S	Lebario RO Srl
	Materials				
	Steel 1.2343 (H11)	1.21E-01	kg	Steel, low-alloyed {RER}| steel production, converter, low-alloyed | Cut-off, S	Lebario RO Srl
	Steel 1.2344 (H13)	1.21E-01	kg	Steel, low-alloyed {RER}| steel production, converter, low-alloyed | Cut-off, S	Lebario RO Srl
	Dievar/HP1	1.72E-01	kg	Steel, low-alloyed {RER}| steel production, converter, low-alloyed | Cut-off, S	Lebario RO Srl
	Graphite	2.52E-04	kg	Graphite {RER}| production | Cut-off, S	Lebario RO Srl
	Copper	1.51E-04	kg	Copper {RER}| production, primary | Cut-off, S	Lebario RO Srl
	Liquid electric	5.05E-04	kg	Water, deionised, from tap water, at user {Europe without Switzerland}| water production, deionised, from tap water, at user | Cut-off, S	Lebario RO Srl
	Cutting tool	2.02E-04	kg	(Ma, Qi, Ye, Yang, & Hong, 2017)	Lebario RO Srl
	Waste				
	Steel	7.21E-02	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Cut-off, S	Lebario RO Srl
	Waste cutting tools	7.21E-05	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel, inert material landfill | Cut-off, S	Lebario RO Srl
	Products & by-products				
	Die	2.02E-04	p	Intermediate product	Lebario RO Srl

Table 4. LCI of HPDCSTEEL process (FU: 1 tonne of injected aluminium)

HPDCSTEEL PROCESS					
Step	Input / Output	Quantity (fu)	Unit	Indicator	Source
Melting	Energy consumption				
	Natural gas	6.43E+01	kg	Natural gas, from high pressure network (1-5 bar), at service station {RoW}| processing | Cut-off, S	2A SPA
	Materials				
	Secondary aluminium	4.66E+02	kg	Aluminium, cast alloy {RER}| treatment of aluminium scrap, new, at refiner | Cut-off, S	2A SPA
	Internal returns	5.34E+02	kg	Internal reuse	2A SPA
	Salts	4.70E-01	kg	Aluminium chloride {GLO}| aluminium chloride production | Cut-off, S	2A SPA
	Drosses	2.47E+00	kg	Internal reuse	2A SPA
	Refractories	4.60E+00	kg	Refractory, fireclay, packed {RoW}| production | Cut-off, S	2A SPA
	Melting furnace	1.07E-06	p	Aluminium melting furnace {RER}| production | Cut-off, S	2A SPA
	Emissions				
	NOX	2.59E-01	kg	Emissions of NOX to air	2A SPA
	CO	1.02E-01	kg	Emissions of CO to air	2A SPA
	NMVOC	8.06E-02	kg	Emissions of NMVOC to air	2A SPA
	SOX	2.35E-03	kg	Emissions of SOX to air	2A SPA
	TSP	2.73E-03	kg	Emissions of TSP to air	2A SPA
	PM10	2.73E-03	kg	Emissions of PM10 to air	2A SPA
	PM2.5	2.73E-03	kg	Emissions of PM2.5 to air	2A SPA
	Black carbon	1.09E-04	kg	Emissions of black carbon to air	2A SPA
	Pb	3.85E-08	kg	Emissions of Pb to air	2A SPA
	Cd	3.15E-09	kg	Emissions of Cd to air	2A SPA
	Hg	1.89E-06	kg	Emissions of Hg to air	2A SPA
	As	3.50E-07	kg	Emissions of As to air	2A SPA
	Cr	3.50E-08	kg	Emissions of Cr to air	2A SPA

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	Cu	9.11E-09	kg	Emissions of Cu to air	2A SPA
	Ni	4.55E-08	kg	Emissions of Ni to air	2A SPA
	Se	2.03E-07	kg	Emissions of Se to air	2A SPA
	Zn	2.56E-06	kg	Emissions of Zn to air	2A SPA
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	Products & by-products				
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Holding	Energy consumption				
	Natural gas	8.95E+00	kg	Natural gas, from high pressure network (1-5 bar), at service station {RoW}| processing | Cut-off, S	2A SPA
	Materials				
	Molten aluminium (from melting)	1.00E+03	kg	Intermediate product	2A SPA
	Refractories	1.70E-03	kg	Refractory, fireclay, packed {RoW}| production | Cut-off, S	2A SPA
	Holding furnace	1.07E-06	p	Aluminium melting furnace {RER}| production | Cut-off, S	2A SPA
	Waste				
	White drosses	3.41E+00	kg	Dross from Al electrolysis {RoW}| treatment of dross from Al electrolysis, residual material landfill | Cut-off, S	2A SPA
	Emissions				
	NOX	3.61E-02	kg	Emissions of NOX to air	2A SPA
	CO	1.41E-02	kg	Emissions of CO to air	2A SPA
	NMVOC	1.12E-02	kg	Emissions of NMVOC to air	2A SPA
	SOX	3.27E-04	kg	Emissions of SOX to air	2A SPA
	TSP	3.80E-04	kg	Emissions of TSP to air	2A SPA
	PM10	3.80E-04	kg	Emissions of PM10 to air	2A SPA

	PM2.5	3.80E-04	kg	Emissions of PM2.5 to air	2A SPA
	Black carbon	1.52E-05	kg	Emissions of black carbon to air	2A SPA
	Pb	5.37E-09	kg	Emissions of Pb to air	2A SPA
	Cd	4.39E-10	kg	Emissions of Cd to air	2A SPA
	Hg	2.63E-07	kg	Emissions of Hg to air	2A SPA
	As	4.88E-08	kg	Emissions of As to air	2A SPA
	Cr	4.88E-09	kg	Emissions of Cr to air	2A SPA
	Cu	1.27E-09	kg	Emissions of Cu to air	2A SPA
	Ni	6.34E-09	kg	Emissions of Ni to air	2A SPA
	Se	2.83E-08	kg	Emissions of Se to air	2A SPA
	Zn	3.56E-07	kg	Emissions of Zn to air	2A SPA
	PCDD/F	2.54E-07	kg	Emissions of PCDD/F to air	2A SPA
	Benzo(a)pyrene	3.51E-07	kg	Emissions of benzo(a)pyrene to air	2A SPA
	Benzo(b)fluoranthene	1.41E-06	kg	Emissions of benzo(b)fluoranthene to air	2A SPA
	Benzo(k)fluoranthene	5.37E-07	kg	Emissions of benzo(k)fluoranthene to air	2A SPA
	Indeno(1,2,3-cd)pyrene	5.27E-07	kg	Emissions of indeno(1,2,3-cd)pyrene to air	2A SPA
	Products & by-products				
	Molten aluminium (from holding)	1.00E+03	kg	Intermediate product	2A SPA
Die casting	Energy consumption				
	Electricity	4.13E+02	kWh	Electricity, low voltage {IT}| market for | Cut-off, S	2A SPA
	Materials				
	Molten aluminium (from holding)	1.00E+03	kg	Intermediate product	2A SPA
	Lubricant	1.36E+01	kg	Lubricating oil {RER}| production | Cut-off, S	2A SPA
	Die	1.35E-04	p	Intermediate product	2A SPA
	Water consumption				
	Water	7.59E+02	kg	Water, deionised, from tap water, at user {Europe without Switzerland}| water production, deionised, from tap water, at user | Cut-off, S	2A SPA
Steel	Energy consumption				

manufacturing	Electricity	2.19E-01	kWh	Electricity, low voltage {DE}| market for | Alloc Rec, S	SGW
	Natural gas	3.62E-03	kg	Natural gas, from high pressure network (1-5 bar), at service station {RoW}| processing | Alloc Rec, S	SGW
	Materials				
	Scrap	2.68E-01	kg	Iron scrap, sorted, pressed {RER}| sorting and pressing of iron scrap | Alloc Rec, S	SGW
	Alloys	4.11E-02	kg	Mean between 4 ferroalloys	SGW
	Emissions				
	NOX	1.46E-05	kg	Emissions of NOX to air	SGW
	CO	5.71E-06	kg	Emissions of CO to air	SGW
	NMVOC	4.53E-06	kg	Emissions of NMVOC to air	SGW
	SOX	1.32E-07	kg	Emissions of SOX to air	SGW
	TSP	1.54E-07	kg	Emissions of TSP to air	SGW
	PM10	1.54E-07	kg	Emissions of PM10 to air	SGW
	PM2.5	1.54E-07	kg	Emissions of PM2.5 to air	SGW
	Black carbon	6.15E-09	kg	Emissions of black carbon to air	SGW
	Pb	2.17E-12	kg	Emissions of Pb to air	SGW
	Cd	1.77E-13	kg	Emissions of Cd to air	SGW
	Hg	1.06E-10	kg	Emissions of Hg to air	SGW
	As	1.97E-11	kg	Emissions of As to air	SGW
	Cr	1.97E-12	kg	Emissions of Cr to air	SGW
	Cu	5.12E-13	kg	Emissions of Cu to air	SGW
	Ni	2.56E-12	kg	Emissions of Ni to air	SGW

	Se	1.14E-11	kg	Emissions of Se to air	SGW
	Zn	1.44E-10	kg	Emissions of Zn to air	SGW
	PCDD/F	1.02E-10	kg	Emissions of PCDD/F to air	SGW
	Benzo(a)pyrene	1.42E-10	kg	Emissions of benzo(a)pyrene to air	SGW
	Benzo(b)fluoranthene	5.71E-10	kg	Emissions of benzo(b)fluoranthene to air	SGW
	Benzo(k)fluoranthene	2.17E-10	kg	Emissions of benzo(k)fluoranthene to air	SGW
	Indeno(1.2.3-cd)pyrene	2.13E-10	kg	Emissions of indeno(1.2.3-cd)pyrene to air	SGW
	Products & by-products				
	SWG steel	2.74E-01	kg	Intermediate product	SWG
Die manufacturing	Energy consumption				
	Electricity	1.57E+00	kWh	Electricity. low voltage {RO}| market for | Alloc Rec. S	Lebario RO Srl
	Materials				
	SWG steel	2.74E-01	kg	Steel. low-alloyed {RER}| steel production. converter. low-alloyed | Alloc Rec. S	Lebario RO Srl
	Graphite	1.67E-04	kg	Graphite {RER}| production | Alloc Rec. S	Lebario RO Srl
	Copper	1.00E-04	kg	Copper {RER}| production. primary | Alloc Rec. S	Lebario RO Srl
	Liquid electric	3.34E-04	kg	Water. deionised. from tap water. at user {Europe without Switzerland}| water production. deionised. from tap water. at user | Alloc Rec. S	Lebario RO Srl
	Cutting tool	1.34E-04	kg	(Ma. Qi. Ye. Yang. & Hong. 2017)	Lebario RO Srl
	Waste				
	Steel	6.68E-02	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel. inert material landfill | Alloc Rec. S	Lebario RO Srl
	Waste cutting tools	6.68E-05	kg	Scrap steel {Europe without Switzerland}| treatment of scrap steel. inert material landfill | Alloc Rec. S	Lebario RO Srl
	Products & by-products				
	Die	1.34E-04	p	Intermediate product	Lebario RO Srl

Research Fund for Coal & Steel

The results of the impact assessment of the LCI presented are presented here.

3.2.1. Traditional process

Table 5. Environmental impact of the traditional process.

	GWP	ODP	POX	ACP	EUP	ADP	FFP
	kg CO_2 eq	kg CFC-11 eq	kg C_2H_4 eq	kg SO_2 eq	kg PO_4^{3-} eq	kg Sb-eq	MJ eq
TOTAL	**5.82E+02**	**7.66E-05**	**1.46E-01**	**3.64E+00**	**1.29E+00**	**1.66E-01**	**1.03E+04**
Energy	2.16E+02	4.11E-05	5.28E-02	1.50E+00	3.91E-01	3.48E-04	5.66E+03
Materials	3.66E+02	3.55E-05	9.06E-02	1.99E+00	8.23E-01	1.66E-01	4.64E+03
Emissions	0.00E+00	0.00E+00	3.12E-03	1.48E-01	3.84E-02	0.00E+00	0.00E+00
Waste	3.42E-02	1.13E-08	1.53E-05	2.45E-04	3.19E-02	4.64E-08	1.02E+00

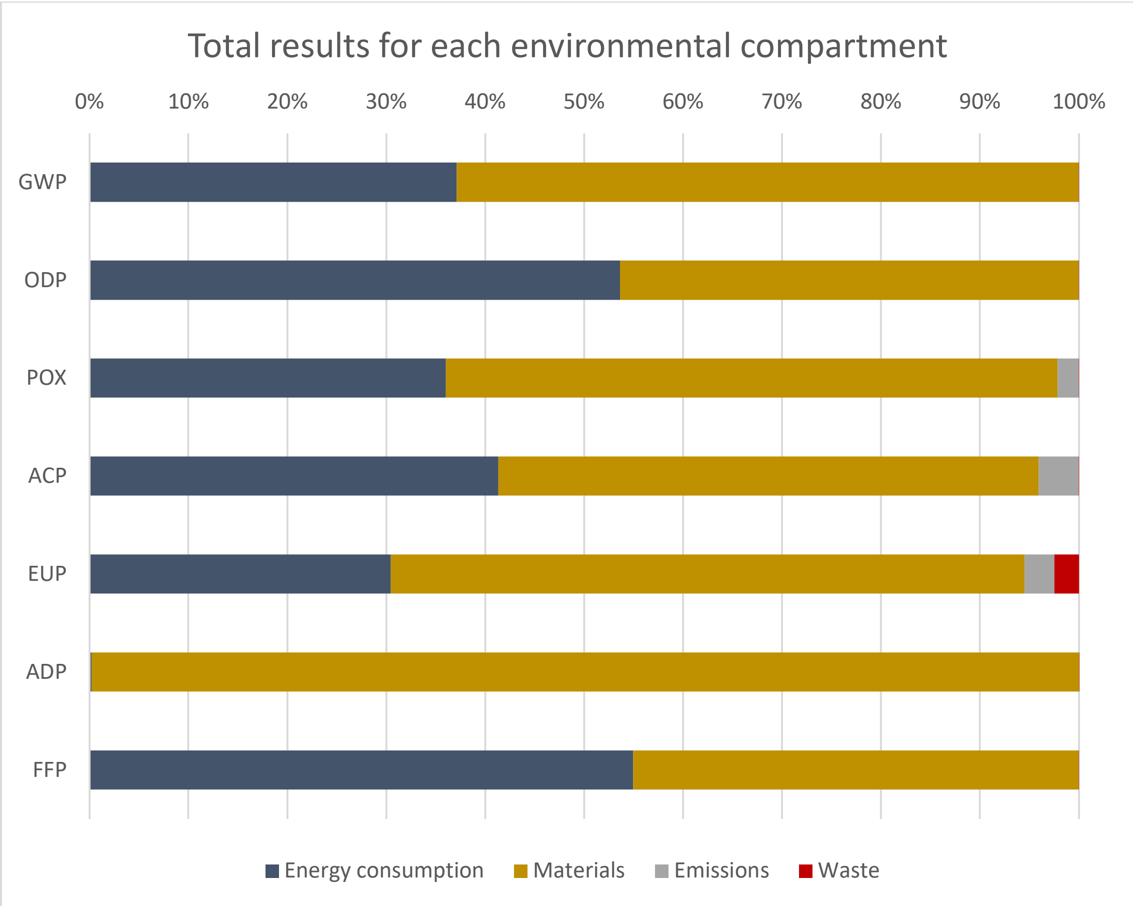

Figure 1. Contribution of environmental aspects to total impact (traditional process)

Table 6. Comparison between the different steps of the traditional process

	GWP	ODP	POX	ACP	EUP	ADP	FFP
	kg CO_2 eq	kg CFC-11 eq	kg C_2H_4 eq	kg SO_2 eq	kg PO_4^{3-} eq	kg Sb-eq	MJ eq
Melting	3.87E+02	4.51E-05	1.00E-01	2.18E+00	8.52E-01	1.66E-01	6.97E+03
Holding	6.39E+00	2.68E-06	2.81E-03	4.94E-02	4.41E-02	3.85E-05	4.53E+02
Die manufacturing	2.07E+00	8.44E-08	8.67E-04	1.14E-02	1.11E-02	1.73E-05	2.13E+01
Die casting	1.87E+02	2.87E-05	4.25E-02	1.40E+00	3.78E-01	4.84E-04	2.86E+03

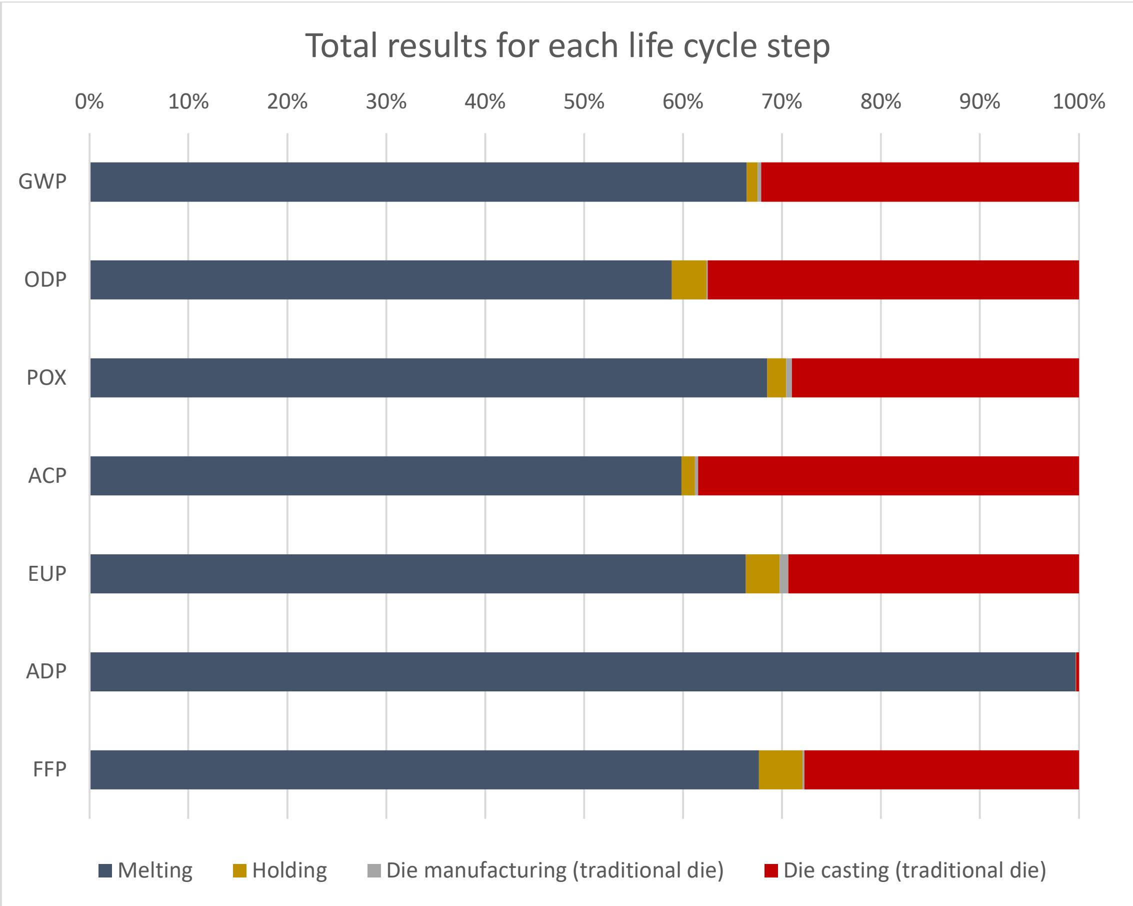

Figure 2. Environmental contribution of the different steps of the traditional process

3.2.2. HPDCSTEEL process

Table 7. Environmental impact of the HPDCSTEEL process.

	GWP	ODP	POX	ACP	EUP	ADP	FFP
	kg CO_2 eq	kg CFC-11 eq	kg C_2H_4 eq	kg SO_2 eq	kg PO_4^{3-} eq	kg Sb-eq	MJ eq
TOTAL	**5.81E+02**	**7.66E-05**	**1.46E-01**	**3.65E+00**	**1.28E+00**	**1.66E-01**	**1.03E+04**
Energy	2.16E+02	4.11E-05	5.27E-02	1.50E+00	3.89E-01	3.48E-04	6.97E+03
Materials	3.65E+02	3.55E-05	9.04E-02	1.99E+00	8.20E-01	1.66E-01	4.64E+03
Emissions	0.00E+00	0.00E+00	3.12E-03	1.48E-01	3.84E-02	0.00E+00	0.00E+00
Waste	3.37E-02	1.12E-08	1.52E-05	2.43E-04	3.19E-02	4.57E-08	1.01E+00

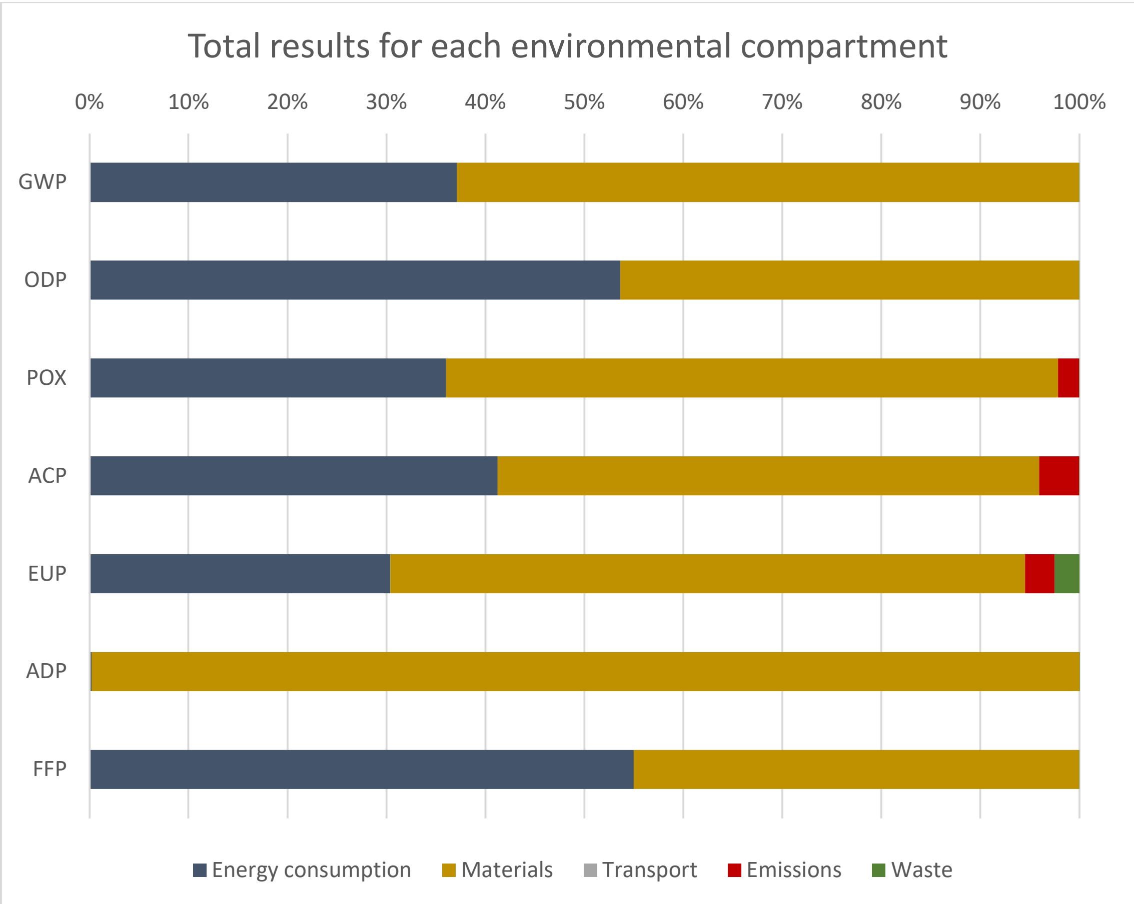

Figure 3. Contribution of environmental aspects to total impact (HPDCSTEEL process)

Table 8. Comparison between the different steps of the HPDCSTEEL process

	GWP	ODP	POX	ACP	EUP	ADP	FFP
	kg CO_2 eq	kg CFC-11 eq	kg C_2H_4 eq	kg SO_2 eq	kg PO_4^{3-} eq	kg Sb-eq	MJ eq
Melting	3.87E+02	4.51E-05	1.00E-01	2.18E+00	8.52E-01	1.66E-01	6.97E+03
Holding	6.39E+00	2.68E-06	2.81E-03	4.94E-02	4.41E-02	3.83E-05	4.53E+02
Steel production	1.84E-01	1.12E-08	4.40E-04	1.10E-02	6.56E-04	9.12E-06	1.96E+00
Die manufacturing	7.71E-01	2.26E-08	1.83E-04	4.80E-03	4.97E-03	1.35E-06	8.06E+00
Die casting	2.33E+02	3.76E-05	5.49E-02	1.10E+00	2.67E-01	3.79E-04	3.84E+03

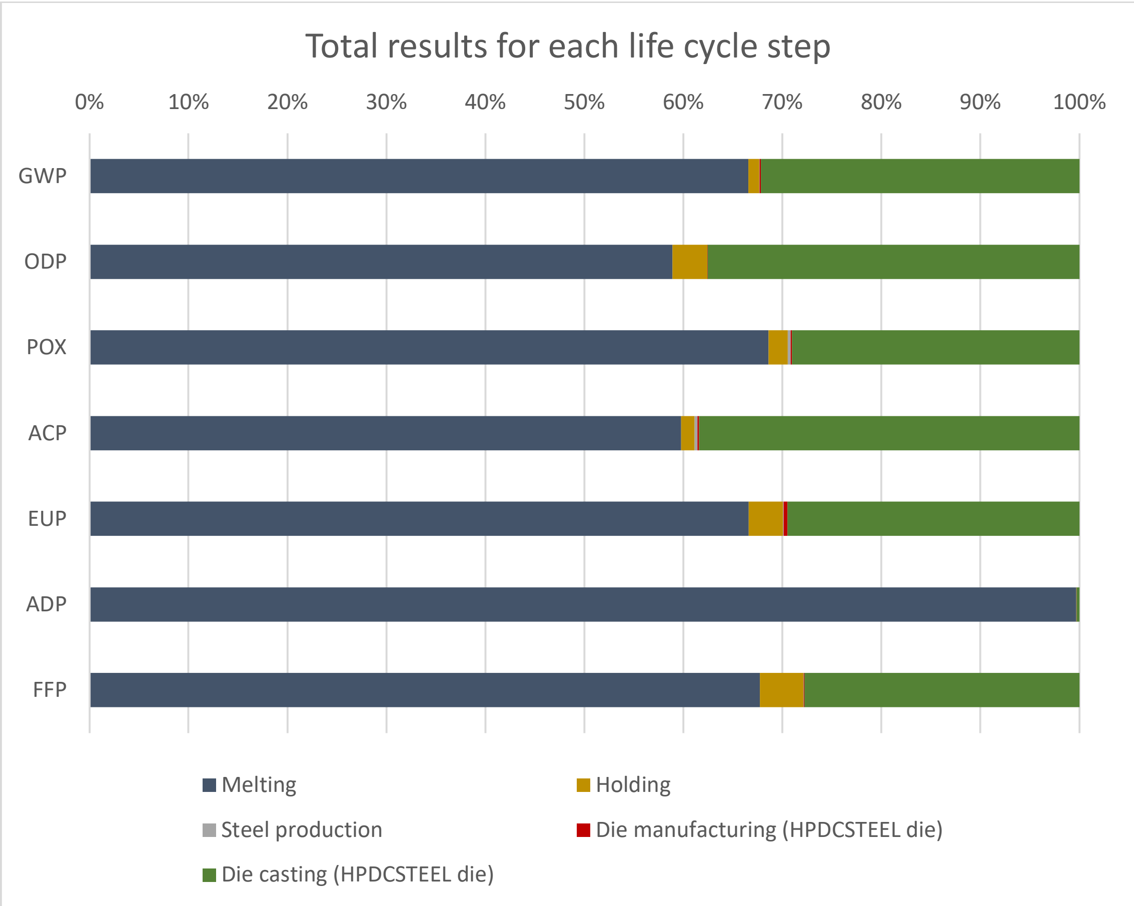

Figure 4. Environmental contribution of the different steps of the HPDCSTEEL process

3.2.3. Interpretation of results

The results of both analyses will be discussed in this chapter. As it's shown in Table 5 and Table 7, both processes have a similar environmental impact in all the categories included in the study. The main reason is because the life cycle steps with a higher contribution in the whole life cycle are "Melting" and "Die casting", and both have similar inputs and outputs, as it is presented in Table 3 and Table 4. In fact, the only difference between the traditional process and the HPDCSTEEL process in these steps it's that the quantity of needed dies is different. In the framework of the HPDCSTEEL project a new composition for die steels has been formulated, which extends the service life of a die by 60%. On the other hand, the new composition rises energy consumption by 2%.

Being that both case studies present similar results, it's not worth discussing them separately. The main environmental compartment in the process can vary depending on the impact category. Both "energy consumption" and "materials" are important hotspots, being the first one the main contributor to "Ozone layer depletion" and "Abiotic depletion (fossil fuels)" and the second has the highest environmental impact in the other 5 impact categories (Figure 1 and Figure 3).

The aforementioned statement can be checked looking into Figure 2 and Figure 4, where "melting" and "die casting" are the most polluting steps of the life cycle. The reason is that the highest consumption of materials and energy (when referencing them to the functional unit) corresponds to these two steps. In addition, as it can be seen in Figure 2 and Figure 4, "melting" represent almost the 100% of the environmental impact in "Abiotic depletion", showing the importance of this step in the whole life cycle.

The remaining environmental compartments "waste" and "emissions" are not significant at all. Figure 1 and Figure 3 show that the greatest contribution of these compartments is in "eutrophication" and it's only 5% of the total.

But even though both case studies seem quite similar, there are substantial differences when it comes to "die manufacturing". The expected service life of the die has been increased in the project, so the new die will last a 60% more (160.000 injections). This causes that less dies are needed in a whole year activity, so the environmental impact attributed to this material has been reduced.

Table 9. Difference between die manufacturing in both processes

	GWP	ODP	POX	ACP	EUP	ADP	FFP
	kg CO_2 eq	kg CFC-11 eq	kg C_2H_4 eq	kg SO_2 eq	kg PO_4^{3-} eq	kg Sb-eq	MJ eq
Traditional process	2.07E+00	8.44E-08	8.67E-04	1.14E-02	1.11E-02	1.73E-05	2.13E+01
HPDCSTEEL process	9.55E-01	3.38E-08	6.23E-04	1.58E-02	5.63E-03	1.05E-05	1.00E+01
Difference	-53.86%	-59.95%	-28.14%	38.60%	-49.28%	-39.31%	-53.05%

As seen in Table 9, there's a significant difference between both dies for almost all impact categories, with "Acidification" being the exception. It must be considered that, although the environmental impact of the electricity has been increased, this increment is offset by the longer duration of the die. As a side note, in the traditional process 3.78 dies are needed per year, while the HPDCSTEEL process needs only 2.5 dies.

3.2.4. References

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3.3. LCC (Life Cycle Cost) estimation:

The LCC estimation has been performed for every of the enterprises comprises in the manufacturing process of the new HPDCSTEEL die.

SWG:

A resumed estimation between the cost of manufacturing a standard 1.2343 steel and HPDCSTEELS developed new steel in SWG is resumed below:

Standard 1.2343 steel:

1.2343 steel manufacturing calculation in a production environment		
Finished steel alloy	110,000	t/year
Scrap (EAF)	980	€/t
Alloying elements	1,120	€/t
Electricity costs	102	€/t
Natural gas costs	52	€/t
Other costs	1,811	€/t

Total steel costs	**4,060**	**Euros/t**

New 1.2343 HPDC steel:

HPDCSTEEL NEW steel calculation in a production environment

Finished steel alloy	110,000	t/year
Scrap (EAF)	980	€/t
Alloying elements	1,120	€/t
Electricity costs	102	€/t
Natural gas costs	52	€/t
Other costs	1,811	€/t
New alloying elements	24	€/t
New over costs	250	€/t

Total steel costs	**4,339**	**Euros/t**

Comparing the actual induced costs with the estimated costs for the new developed steel, there is an estimated 275 €/t cost increase with the new steel.

LEBARIO RO:

A resumed estimation between the cost of manufacturing standard 1.2343 steel and HPDCSTEELS developed new steel die (ladler frame) in Lebario Ro is resumed below:

Standard Ladler frame die:

Ladler frame cavities manufacturing calculation with a standard 1.2343 steel in a production environment

1.2343 steel	4.5	t/die
Electrical consumption	25,244	KWh
Electricity cost	3,484	€
Machining tooling cost	3,294	€
EDM tooling cost	44	€
Machining costs	26,600	€
EDM costs	6,738	€
Others	6,440	€

Total die manufacturing costs **46,600** **Euros/die**

New 1.2343 HPDC steel:

Ladler frame cavities manufacturing calculation with HPDCSTEEL steel in a production environment

1.2343 steel	4.5	t/die
Electrical consumption	25,749	KWh
Electricity cost	3,553	€
Machining tooling cost	3,360	€
EDM tooling cost	44	€
Machining costs	27,132	€
EDM costs	6,738	€
Others	6,440	€

Total die manufacturing costs	**47,268**	**Euros/die**

Comparing the actual induced costs with the estimated costs for the newly developed steel, it's estimated that there is a 1.5% cost increase in die manufacturing with the new steel.

2A SPa:

A resumed estimation between the cost of employing actual die and HPDCSTEELS developed die in 2A Spa is resumed below:

HPDCSTEEL Ladler frame die:

1.2343 Die Life expectancy calculation in a production environment		
Total estimated injections (Life)	100,000	Injections
Cycle time	4,926	hours
Production rate	20.3	Injections/hour
Working days/year	300	days
Working hours/day	24	h
Total working hours	7,200	h/year
Uptime	75%	hypothesis
Net working hours	5,400	h/year
Total maximum Casts/year	**109,620**	**Injections/year**
Lifetime estimation of the die	0.91	years
Total production lifetime	100,000	Injections

Die maintenance interval every	20,000	cycles
Number of die maintenances	4	times
Average cost of die maintenance	5,000	Euros
Total average maintenance costs	20,000	Euros/die
Average deburring costs	0.15	Euros/part
Total deburring over costs	15,000	Euros/die
Total die induced costs	**1.85**	**Euros/part**

HPDCSTEEL Ladler frame die:

HPDCSTEEL NEW Die Life expectancy calculation in a production environment		
Total estimated injections (Life)	160,000	Injections
Cycle time	7,778	hours
Production rate	20.57	Injections/hour
Working days/year	300	days
Working hours/day	24	h
Total working hours	7,200	h/year
Uptime	75%	hypothesis
Net working hours	5,400	h/year
Total maximum Casts/year	**111,078**	**Injections/year**
Lifetime estimation of the die	1.44	years
Total production lifetime	160,000	Injections

Die maintenance interval every	40,000	cycles
Number of die maintenances	3	times
Average cost of die maintenance	5,000	Euros
Total average maintenance costs	15,000	Euros/die
Average deburring costs	0.10	Euros/part
Total deburring over costs	16,000	Euros/die
Total die induced costs	**1.20**	**Euros/part**

Comparing the actual induced costs with the estimated costs for the new developed die, it is estimated that there is a 35% cost reduction with the new steel in the manufacturing process.

4. FINAL ASSESSMENT. EXPLOITATION AND IMPACT

With the LCC studies, 2A SPA. in cooperation with TECNALIA. has performed an impact study with the information obtained from the industrial tests made at its casting facilities in WP6, incorporating to this study the information of its own current manufacturing process of the target part. Improvements in die life evaluations have been estimated in terms of manufacturing costs. The impact on these manufacturing costs comes mainly from increased die lifetimes, the elimination of some of the die changes due to die failures and a reduction in rejected parts. 2A SPA has quantified the direct benefits obtained from HPDCSTEEL project. SWG performer the impact study over the manufacturing of reinforced steels and LEBARIO has defined the impact over the die market, incorporating its own in-house costs to manufacture the new die.

4.2.1. Identification of all exploitable products and technologies:

European automotive industry, focused on the lightweight and reliability, employs sound and complex components of aluminum and magnesium produced by HPDC (High Pressure Die Casting) at a competitive price. Steel dies are used to shape components in liquid state, but extremely high pressures (up to 1,200 bars), chemical attack of molten metal and high thermal-mechanical stresses produce premature die defects and failures.

This proposal has developed a new steel grade with a new composition that improves the mechanical, thermal and chemical properties of the dies, enhancing the competitiveness of European steel, die making and automotive industry.

At this stage, according to the project objectives and the expected outcomes, Table 10 identifies the main exploitable results of the project, defines the possible exploitation routes and identifies the respective beneficiaries.

Table 10. Exploitation elements of the HPDCSTEEL project

Project results	Anticipated routes for exploitation	Involved partners
A new high temperature steel family for HPDC with enhanced properties at high temperatures	- Patent license discarded. A patent study has been performed and a positive evaluation has been obtained. However, it's not possible to control the competitor's production sites, and the emission of a patent will allow to them to copy the technology. - Direct exploitation by partners according to the provisions established in Consortium Agreement signed by the consortium	SWG ALL

Models for predicting the phase transformation behaviour of the HPDCSTEEL alloys (reinforced with synthetic carbides) based on Thermocalc	- Additional research initiatives are expected to arise beyond the project: design of new high temperature steels for other applications - Scientific dissemination in journals (scientific, technical and/or industrial) and conferences - Scientific cooperation, by sharing the use of the models, with other research and industrial entities	TECNALIA ALL
A new industrial process to obtain low cost reinforcing master alloys	- Additional research to obtain new low-cost reinforcing master alloys by SHS	TECNALIA
Improved HPDC dies	- Production cost reduction by using new HPDCSTEEL with the best purchasing price	2A

The more important exploitation markets in relation with the developments of the project are described in more detailed below:

- SHS manufacturing of reinforcing master alloy:

- The improvements obtained during the development of the project to obtain low cost master alloys using atmospheric SHS reactions can be exploitable. Working with ferroalloys instead of pure alloying metals reduces the material costs of master alloys manufacturing, due to the use of less pure materials with a significant reduction on raw material costs.
- Increasing the size of the reactions reduces the amount of exothermic materials, reducing the manufacturing costs.
- Avoiding reactors that allow obtaining SHS reactions in controlled atmospheric conditions reduces the costs and allows obtaining higher quantities of materials per reaction.
- Especial synthetic carbides can be produced by this technology. The selection of the types of carbides and the proportion of each alloying element in the carbide can be tuned to obtain the desired properties per every different application.

- ESR manufacturing process with synthetic carbides:

- The developed process can introduce synthetic carbides uniformly and without agglomerations into the steel matrix. This can be employed to obtain new steels reinforced with synthetic carbides, increasing the steel alloys performance for high temperature or high wear applications.

- New HPDCSTEELS:

  The new HPDCSTEEL can have many other applications that the one's of HPDC. As the newly developed steels have a good combination of mechanical properties at high temperatures and very good wear properties, they can be also used in other applications / sectors. The main application and sectors are:

- Other casting processes: These steels can be used for other casting processes where metallic dies are employed, increasing die life, reducing maintenance, and decreasing solidification time. Between them, we can cite as the more important, the low-pressure aluminium and magnesium die casting, aluminium squeeze casting and non-ferrous die casting.
- Extrusion: The temperatures of extrusion process are normally lower than in HPDC, and the extrusion tooling suffers specially from wearing. The addition of synthetic carbides can improve the wearing response of the alloy, increasing the extrusion tooling life.
- Forge: Forging tools work at high temperatures with constant impacts to model the parts, so a combination of high temperature mechanical properties combined with high resilience and wearing resistance should be obtained. The addition of synthetic carbides can improve the wearing response of the alloy, but special care should be taken to avoid a decrease in resilience and elongation values.
- Hot stamping: Hot stamping tools work in a very similar way than forge tooling, so the same benefits could be obtained by using the reinforced alloys.
- Cold stamping: In the case of cold stamping, the use of reinforcing synthetic carbides could increase the wearing resistance, but also in this case, a reduction in the elongation and resilience properties of the steel should be avoided.
- Hot and cold rolling: In hot rolling operations a combination of wearing and thermal fatigue causes the degradation of rolling tools. So, the introduction of new steels that can reduce both problems can be a solution to increase the hot rolling tools life. In cold rolling, the most important factor is wearing. A higher percentage of reinforcing carbides could be added to the steel to increase the wear resistance of cold rolling tools.
- Plastic injection: Plastic injections dies have a very long life, but when working with new reinforced technical plastics, they can suffer from wear in the die, reducing its life and increasing maintenance costs. New alloys with a controlled percentage of reinforcing ceramic particles could increase wear, specially near the injection gates, with the possibility of employing inserts of this new steel in those areas.

- Milling applications: In milling applications, special steels reinforced with ceramic preforms are employed for increasing the life of milling hammers. Ceramic performs are normally located in a specific area of the hammer, and there are not distributed over the whole area of the hammer, what it can be improved by having a reinforced steel matrix.
- Glass industry: The glass industry employs premium steels for high quality / requirements products. The steel dies suffer from thermal stress, and the use of the new steel could increase the life of the dies and reduce maintenance and quality costs.

4.2.2. Assessment of the expected economic and environmental impact of the project results:

As described in the LCA and LCC study included in this report, there is a clear positive effect over the economic and environmental impact. As a resume of the economic impact, we can observe the global cost comparison between the standard and the HPDCSTEEL alloy.

Global cost comparison:

In the next table there is a resume of global over costs and savings estimations induced by using the new developed steel:

Table 11: Total cost comparison

Total costs (ladle frame) (€)	1.2342 steel	HPDC new steel	Difference
Steel manufacturing costs	18,293	19,524	1,232
Die manufacturing costs	46,600	47,268	668
Die casting manufacturing cost (Estimated die life 160.000 injections)	277,500	189,334	-88,166
TOTALS (€)	**342,393**	**256,126**	**-86,267**

Comparing the actual induced costs with the estimated costs for the new developed die, there is an estimated 25.2% cost reduction in the overall manufacturing and producing process

4.2.3. Identification of the possible technical and non-technical barriers to the exploitation of the project results:

The possible technical and non-technical barrier to the exploitation of the project results have been determined:

- Standardisation:

One possible technical barrier is linked with the need of employing steel alloys under a determined standard for some customers that they are forced by the final users to employ a determinate standard for the steel. In this case, some ways can be employed to overcome this problem:

- Reducing the reinforcing percentage of carbides: In this way, the composition of the steel will be under the defined standard.
- Develop a new standard for reinforced steels: New families of reinforced steels can be defined.
- Homologate the new steel for the final user: Many steels are employed nowadays out the standards. Final users can homologate a new steel out of the standards if it shows increased performance in comparison with others, what it must imply a final reduction of total costs.

- Competence:

There are few steel makers in the market that employs the advanced ESR process to obtain premium steels, and it’s also complicate to have the know-how to produce synthetic carbides that can be added to the steel to obtain better properties with a good distribution and without agglomeration into the steel matrix at a competitive price.

New steels are continuously under development by competitors, increasing the performance of nowadays steel alloys for HPDC. As SWG have the know-how and the necessary equipment, he can compete with them.

- Price:

  Premium steels have an over-cost that it's assumed by the market, because they have improved characteristics that make more interesting to work with them than employing standard steel alloys. In the case of the developed steel, the addition of synthetic carbides only increases slightly the price of the new alloy, being as in the premium steels, the ESR manufacturing cost the most relevant cost. So, with the expected life improvement of the die, it would be sensible to change to the new steel with a very slight difference in the steel price in comparison with other premium steels. Also, in some cases, where steel premium alloys are made with a high percentage of high cost alloying elements (Ni, V…), the price will be smaller in the developed steel.

- Commercialization:

  SWG is not very involved in the market of HPDC, what it can be a market barrier. However, it has die manufacturers between their customers and the presence of Lebario group implanted in Romania, Spain and Mexico and the presence of 2a with presence in Italy and USA give to SWG a good way to present the new HPDCSTEEL alloy in the market. As SWG has presence all over the world, the commercialisation of the new steel can be easily done, with key partners in different countries.

- Specific thermal treatments:

  SWG has his own utilities to perform thermal treatments, but the vacuum treatments needed for this type of steel cannot be performed at SWG. Some of his competitors have specific installations to perform the vacuum thermal treatments needed for HPDC applications. However, most steel makers don't have vacuum furnaces and die makers subcontract the thermal treatments. If in the future the market for SWG is increased in this field, it could install a vacuum furnace to cover the necessity.

4. CONCLUSIONS

The impact study of project results and exploitation shows that the new project steel have a lower environmental impact, and the expected improved life makes it more economic in comparison with commercial superior steels. Exploitable products and technologies have been defined, with the assessment of the expected economic and environmental impact of the project results, and the identification of the possible technical and non-technical barriers to the exploitation of the project results.

The main conclusions are:

- The production of developed steel has a similar environmental impact in all the categories in comparison with premium steels.
- The use of the new developed steel promotes an estimated 35% cost reduction in the manufacturing process of HPDC cast parts. The increase in the price of the steel and the die manufacturing costs is very reduced in comparison with the obtained final economic results, with a comparable price with premium steels.
- Many new applications have been defined to employ the developed processes and new steel.
- The technical and non-technical barriers are not supposed to be a problem for the exploitation of project results.