D9.3 Impact Analysis Report

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Author/s:	**Jan Koller Julian Große Erdmann**
Reviewed:	**C-ECO, Gorenje, KTH, SIMAVI**
Approved:	**Magnus Wiktorsson**
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List of abbreviations

Abbreviation	*Explanation*
ICT	Information and communication technology
LCA	Life Cycle Assessment
PPU	Pay-Per-Use

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Executive Summary

This report describes the business case and upscaling plans for the ReCiPSS project, funded by the European Union's Programme Horizon 2020, under Grant Agreement number 776577. Deliverable 9.3, titled "Impact analysis report", is related to Task 9.2 "Developing business cases and upscaling plans"

Considering the white goods demonstrator, a new 'pay-per-use' (PPU) business model for washing machines and tumble dryers was introduced. During the project phase, more than 330 washing machines and tumble dryers were tested and validated in real-life environments in four different markets: Slovenia, Denmark, Sweden, and the Netherlands.

Regarding the automotive demonstrator, an Information and Communication Technology (ICT) platform was developed during the ReCiPSS project to increase transparency in the reverse supply chain. During the project phase, more than 80,000 cores were collected from two wholesalers, physically handled, and returned to the remanufacturers. The cores were identified and evaluated based on technical criteria and technical guidelines of the remanufacturers.

Therefore, to measure the success of the ReCiPSS project, this report provides a full business case for each demonstrator and extrapolates to the upscaling plans for the automotive and white goods industry, including financial, socio-economic, and environmental impacts. In both the white goods and the automotive use cases, the developments during the ReCiPSS project lead to improvements in the financial, socio-economic, and environmental impacts.

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Introduction

With global waste expected to increase to 3.40 billion tons by 2050 and a world that is only 8.6% circular, it is clear that our current way of life is not sustainable (Wit and Haigh 2022; Kaza 2018). According to the Global Footprint Network, 1.75 Earths are needed in 2022 to sustainably meet our current resource demands (Lin et al. 2022). The circular economy offers solutions that can contribute to economic growth and satisfy sustainability ambitions. It tackles the root causes of global challenges, such as climate change, biodiversity loss, and pollution. Compared to a linear economy based on the take-make-dispose principle, a circular economy is a regenerative system by design based on optimizing resource consumption and reducing waste.

ReCiPSS refers to *Resource-efficient Circular Product Service Systems*, an EU-funded project in the H2020 innovation action. The project's overarching goal is to demonstrate the implementation of circular manufacturing systems addressing different aspects of the industrial and business environment. Two large-scale demonstrators include case studies from key industries, the white goods and automotive sector represented by the project partners Gorenje and Bosch. The white goods demonstrator relates to a connected value chain and will demonstrate the successful implementation of circular manufacturing systems where the OEM (Gorenje) is in full control of the entire product throughout all the stages (i.e., design, manufacturing, forward supply chain, customer use phase, reverse supply chain, recovery activities, and redistribution). On the other hand, the automotive spare parts demonstrator relates to a more complex value chain where the OEM (Bosch) does not have full control of the product throughout all stages.

In this context, this report focuses on developing a full business case for each demonstrator, considering the impact of circular manufacturing systems regarding financial, socio-economic, and environmental aspects. Both business cases will be calculated for the current demonstrator and extrapolated to the upscaling plans of the specific industry sectors. The case countries for the white goods demonstrator are Denmark, the Netherlands, Slovenia, and Sweden, and for the automotive spare parts demonstrator France and Germany.

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Whitegoods Demonstrator Business Case

In the circular approach, Gorenje is taking a systemic approach to develop and implement a Pay-Per-Use offering in four European markets, including Slovenia, Denmark, Sweden, and the Netherlands, through the ASKO washing machine and tumble dryer model, built-to-last and smart products. These machines are designed for high durability and reuse capacity to facilitate multiple lifecycles. After each use cycle, the machines will be brought to as-new condition as part of the value recovery activity and redistributed to serve another customer. Gorenje is setting up the necessary reverse logistics infrastructure for value recovery and redistribution of the machines and creating dedicated service organizations that can proactively provide service in each market.

This section provides insights into the whitegoods demonstrator's economic, socio-economic, and environmental impacts and extrapolates to the upscaling future scenarios. Therefore, the data has been collected through online interviews and discussions with the white goods demonstrator representatives from Gorenje, their Sales and Business Units, and previous deliverables focused on Circular Supply Chain development (e.g., D2.2, D3.5, D4.1, and D6.6).

The calculation for the impacts shown in Table 1 is based on almost 330 deployed PPW washing machines and tumble dryers during the demonstrator phase and the potential yearly sales of PPW washing machines and tumble dryers for each market (based on D 2.2).

Table 1. Number of deployed washing machines and tumble dryers during the demonstrator phase and potential yearly market sales

Market	*Demonstrator phase*	*Potential yearly sales in PPU*
Slovenia	51	23.000
The Netherlands	80	145.000
Denmark	183	30.000
Sweden	16	40.000
Total	**327**	**238.000**

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Financial Impact

To assess the PPU offerings of the washing machines and tumble dryers with the effect of multiple lifecycle designs on the economic performance, manufacturing, forward and reverse transport, repair, deinstallation, refurbishment, and recycling costs were considered. Furthermore, the revenue calculation is based on the monthly subscription fee and the average lifecycle costs. The data used for the calculation is taken from previous deliverables and based on Gorenje's confidential data.

Based on the potential market volume and the calculated revenue per washing machine and tumble dryer, an overview of the potential revenue per market per year was created in Table 2.

Table 2: Revenue of deployed washing machines and tumble dryers per year

Market	*Potential revenue in demonstrator phase [€/a]*	*Potential revenue in PPU [€/a]*
Slovenia	15,300	7,000,000
The Netherlands	24,000	42,000,000
Denmark	62,400	9,000,000
Sweden	3,600	12,000,000
Total	**105,300**	**70,000,000**

Shifting to a service-oriented business model leads to continuous revenue flows compared to one-time cash flows in a sales-based business model. Therefore, higher lifecycle costs due to long-lasting products, multiple transportation, and recovery operations are offset by the revenues generated by multiple lifecycle products. The introduction of a PPU business model will result in the cumulative revenue of approximately €70,000,000 per year of Gorenje's market potential in the four markets, Slovenia, the Netherlands, Denmark, and Sweden.

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Socio-Economic Impact

Regarding the PPU business model, after each use cycle, the washing machine will be brought to as-new condition as part of the value recovery activity and redistributed to serve another customer. Hence, activities like reverse transport, repair, deinstallation, refurbishment, and recycling costs are needed. The extra effort of the PPU business model results in an increase of jobs per washing machine and tumble dryer compared to a sales business model.

According to internal assumptions, deploying the 330 washing machines and tumble dryers during the demonstrator phase resulted in job creation of 50. Regarding the upscaling plans, based on a quantity of 238,000 washing machines and tumble dryers sold per year in the PPU business model, this would lead to job creation of 10,500.

Table 3. Number of new jobs by PPW business model

	Demonstrator phase	*Upscaling plans*
Job creation	**50**	**10,500**

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Environmental Impact

The assessment of the environmental impact of the PPU business model is based on an attributional Life Cycle Assessment (LCA) following the methodological steps defined within the ISO 14040 standard. Therefore, the PPU business model is compared with the traditional sales model to measure and quantify the impact of the business model change.

Both business models were modeled with a cradle-to-grave approach, which means that processes from the extraction of the materials until the end-of-life of the washing machine are included. Thereby, regarding the sales business model, the washing machine and tumble dryers are bought and used by a customer and reach their end-of-life after 12 years on average. In the PPU business model, Gorenje stays the washing machine's and tumble dryer's owner, and the customer enters into a contract with Gorenje. The household pays per wash, and Gorenje installs, repairs, and refurbishes the machine. The coverage of processes is the production phase, use phase, and recycling operations for the sales model and additionally repair and refurbishment operations for the PPU business model. The functional unit of the LCA is set at one year of washing and drying a household's laundry.

The LCA is based on the ReCiPe impact categories, including acidification, climate change, eutrophication, freshwater ecotoxicity, human toxicity, agricultural land occupation, urban land occupation, marine ecotoxicity, photochemical oxidation, fossil depletion, ozone depletion, and terrestrial ecotoxicity. Table 4 shows the indicator results per impact category for both business models. The results show that the sales business model has a greater environmental impact regarding the impact categories than the PPW business model, except for the impact categories urban land occupation and terrestrial ecotoxicity.

Table 4. Comparative impact of the sales and PPW business model, ReCiPe impact categories

Impact category	Sales	PPW	Unit
Acidification	0.85	0.77	kg SO2 eq.
Climate change	275.15	262.79	kg CO2 eq.
Eutrophication	0.19	0.16	kg P eq.
Freshwater toxicity	26.07	20.76	kg 1.4-DC
Human toxicity	176.88	146.99	kg 1.4-DC
Agricultural land occupation	15.62	14.66	m2-year
Urban land occupation	1.86	1.88	m2-year
Marine ecotoxicity	23.24	18.47	kg 1.4-DB
Photochemical oxidation	0.65	0.60	kg NMVOC-
Fossil depletion	86.87	83.46	kg oil eq.
Metal depletion	43.05	29.75	kg Fe eq.
Ozone depletion	0.00	0.00	kg CFC-11
Terrestrial ecotoxicity	0.03	0.05	kg 1.4-DC

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Table 5 shows the environmental savings from introducing a PPU business model of the demonstrator phase and future scenarios. The calculation is based on the values determined for the impact categories from the LCA.

Table 5. Environmental savings during the demonstrator phase and future scenarios based on the ReCiPe impact categories

Impact category	Demonstrator phase	Potential yearly saves	Unit	Percentage [%]
Addification	28.08	19,040	kg SO2 eq.	10.4
Climate change	4,338.36	2,941,680	kg CO2 eq.	4.5
Eutrophication	10.53	7,140	kg P eq.	15.8
Freshwater toxicity	1,863.81	1,263,780	kg 1.4-DC	20.4
Human toxicity	10,491.39	7,113,820	kg 1.4-DC	16.9
Agricultural land occupation	336.96	228,480	m2-year	6.1
Urban land occupation	-7.02	-4,760	m2-year	-1.1
Marine ecotoxicity	1,674.27	1,135,260	kg 1.4-DB	20.5
Photochemical oxidation	17.55	11,900	kg NMVOC-	7.8
Fossil depletion	1,196.91	811,580	kg oil eq.	3.9
Metal depletion	4,668.3	3,165,400	kg Fe eq.	30.1
Ozone depletion	0.0	0.0	kg CFC-11	0.0
Terrestrial ecotoxicity	-7.02	-4,760	kg 1.4-DC	-0.67

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Automotive Business Case

The reverse logistics network with its stakeholders is decentrally organized, resulting in poor coordination and exchange of information among them. The reason for this occurrence is that the cores follow the same trade levels as in the forward supply chain until the cores are returned to the remanufacturer. As each core carries a value in the form of a surcharge with the 'right to return' that applies between two closest trade levels, cores are identified and evaluated several times, creating inefficiencies, additional transportation costs, and uncertainty of availability and delivery times of the cores at the remanufacturers.

ReCiPSS developed an ICT platform that aims at increasing the efficiency and transparency of reverse logistics for all stakeholders by decoupling the financial flow from the physical flow. In this way, it will be possible to expand the concept of the 'right to return' from the close bilateral relationship between two stakeholders to the overall commercial ecosystem.

This section provides insights into the automotive demonstrator's economic, socio-economic, and environmental impacts and extrapolates to the upscaling future scenarios. Therefore, the data has been collected during the operation of the demonstrator and handling of the more than 80,000 cores, as well as previous deliverables focused on Circular Supply Chain development (e.g., D2.2, D4.1, D4.2, and D7.5).

The calculation of the economic, socio-economic, and environmental impacts is based on 80,000 cores for the demonstrator and the potential cores handled in the European remanufacturing market, e.g., Germany, Sweden, Hungary, France, Switzerland, Finland, Austria, Poland, the Netherlands, and Romania, per year (assumption), see Table 6.

Table 6. Number of cores handled in Europe for remanufacturing

	Demonstrator phase	*Potential cores in Europe per year*
Number of cores	**80,000**	**10,000,000**

Financial Impact

To assess the effectiveness of the economic performance of the introduction of the ICT platform in the automotive demonstrator, the reverse supply chain setup before and after the ReCiPSS project was compared. For the assessment of the economic performance, the transport costs per core depending on the quantity, location, quality, and transport route were calculated, see Table 7.

Table 7. Assumptions on transport costs per truck

	<350 km (one way) [€]	*>350 km (one way) [€]*
13 pallets per truck	200	450
19 pallets per truck	235	600
30 pallets per truck	250	650

The solutions developed during the ReCiPSS project enable logistic bundling and economy of scale resulting in less transport, reduced handling effort, and increased efficiency in the reverse logistics processes. Table 8 shows the cost savings from introducing an ICT platform for the

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reverse logistics operations of the demonstrator phase and future scenarios. The calculation is based on the assumptions mentioned in Table 7.

Table 8. Cost savings for transportation activities

	Demonstrator phase [€]	*Upscaling plans [€]*
Without ICT platform	**2,000,000**	**300,000,000**
With ICT platform	**500,000**	**65,000,000**

Due to the implementation of the ICT platform, a saving of approx. 75 % in transport costs per core can be achieved. The wholesaler does not have to send the cores from its individual facilities to the remanufacturers, instead, the cores are first bundled and evaluated at the service provider and then shipped to the appropriate remanufacturer. Thereby, approx. 20 % can be achieved by early sorting out rejected cores and approx. 50 % through the bundling of the cores. Hence, the effects of the bundling and the economy of scale improve the financial impact due to better utilization of logistic resources resulting in cost savings of up to €235,000,000 per year in transportation.

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Socio-Economic Impact

The remanufacturer can create a comprehensive circular model by prolonging the life of a vehicle and its components, retaining value, and saving on energy while reducing waste. Circular manufacturing systems make regional job creation (i.e., within Europe) economically attractive.

Based on internal assumptions, the following rates for job creation in the automotive sector, depending on the waste hierarchy, exist. Waste disposal generates 0.1 jobs per 1,000 tonnes, recycling operations generate two jobs per 1,000 tonnes and remanufacturing generates 220 jobs per 1,000 tonnes per core.

According to the data received, a total of 320 tonnes of cores was handled during the demonstrator phase resulting in job creation of 70 jobs. Regarding the upscaling plans, based on a quantity of 40,000 tons of cores handled yearly, this would lead to job creation of 8,800 jobs.

Table 9. Number of new jobs in remanufacturing based on handled cores' weight

	Demonstrator phase	*Upscaling plans*
Sum of the cores' weight [tonnes]	**320 tonnes**	**40,000 tonnes**
Jobs [FTE]	**70**	**8,800**

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Environmental Impact

To assess the effectiveness of the ecological performance of the introduction of the ICT platform in the automotive demonstrator, the reverse supply chain setup before and after the ReCiPSS project was compared. For the assessment of the ecological performance, the CO_2 emissions per core, depending on the quantity, location, and number of transport routes were calculated. Based on the assumptions of a total of 10,000,000 cores handled in Europe, the following reduction in CO_2 emissions is possible.

Table 10. Savings in CO2 emissions for transportation activities

	Demonstrator phase	*Upscaling plans*
Without ICT platform [kg CO2 eq]	**400,500**	**5,100,000**
With ICT platform [kg CO2 eq]	**97,000**	**1,200,000**

Due to the implementation of the ICT platform, a saving of approx. 75 % in CO_2 emissions per core can be achieved. Thereby, approx. 20 % can be achieved by early sorting out rejected cores and approx. 50 % through the bundling of the cores. This results in savings in CO_2 emissions of up to 3,900,000 kg CO2 eq per year in transportation.

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Conclusion

This report focuses on developing a full business case for each demonstrator, considering the impact of circular manufacturing systems regarding financial, socio-economic, and environmental aspects. For both demonstrators, the impact of the solutions was measured during the project and determined for future scenarios.

During the research project, around 330 washing machines and tumble dryers were tested in a real-life environment in Slovenia, Denmark, Sweden, and the Netherlands. By introducing a PPU business model, Gorenje expanded its traditional sales business model integrating the customers as part of its business rationale. The PPU business model's success shows in revenue, job creation, and decreased environmental burden over the multiple lifecycles of the washing machines and tumble dryers. For the transition from a research environment to the market, additional functionalities will be developed to expand the PPU business model. The market entry of the PPU business model is planned for the year 2024 in the existing markets of the demonstrator phase. After a successful market entry, the PPU business model will be expanded to further markets.

By introducing an ICT platform during the ReCiPSS project, improved transparency, commercial viability, and minimized complexity in the reverse logistics could be improved, resulting in financial, socio-economic, and environmental improvements. Therefore, over 80,000 cores from two different wholesalers were collected, identified, evaluated, sorted, and transported to the remanufacturers during the demonstration phase. Next to the wholesalers already integrated during the project phase, further wholesalers will be connected with the ICT platform in the future.

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