Safe to circulate

Public report

Authors: Renaud Gutkin, Anders Wirje, Hanna Lindén, Birgit Brunklaus Sepideh Pashami, Jenny Lundahl, Krister Essvik, Emma Enebog, Christian Jonasson, Oscar Andersson

Date: 2023-10-13

Project within FFI: Accelerate the transition to sustainable road transport

FFI Fordonsstrategisk Forskning och Innovation

VINNOVA Energimyndigheten TRAFIKVERKET FKG VOLVO SCANIA VOLVO

Table of contents

1 Sammanfattning

Av de 6,2 miljoner uttjänta fordon som år 2012 överlämnades till bildemonterare inom EU, återvanns cirka 90 % för material, med endast 7,5 % av sitt ursprungliga värde. Däremot behåller processer som återanvändning, reparation, rekonditionering och återtillverkning upp till 85 % av det ursprungliga värdet och skulle spara 75 % av energin. Det visar att utöver elektrifiering behöver bilindustrin också hantera utsläpp relaterade till material och komponenter.

Förstudien *Safe to circulate* har haft som mål att definiera 1) omfattningen av scopet för "säker att cirkulera" som är gemensam för flera originaltillverkare och baserat på säkerhetskrav och hållbarhetsambitioner, nuvarande och framtida policyer och bestämmelser samt acceptans av olika lösningar; 2) systemkriterier för "säker att cirkulera" och planer för demonstration, samt; 3) konsortiet för ett steg 2 projekt. Förstudien omfattade också tre framtida mobilitetsscenarier: (i) mobilitet som tjänst, (ii) ett autonomt scenario och (iii) ett traditionellt försäljnings/leasing-scenario (med testbilar). Målet har varit att genom förstudien och ett steg 2 projekt demonstrera ett datadrivet system för att maximera återanvändning av komponenter samtidigt som höga säkerhetsstandarder bibehålls. Det förväntade resultatet är ett data- och modellbaserat system för säker återcirkulation på fordons-, system-, komponent- eller materialnivå.

Förstudien *Safe to circulate* har resulterat i en steg 2 ansökan kallad *Safe to RE-circulate* vilken är en systemdemonstrator sökt inom FFI Accelerate. Förutom RISE Research Institutes of Sweden (RISE) och Volvo Car Corporation (VCC), vilka är parter i förstudien, inkluderar steg 2 ansökan strategiska parter som är del av en värdekedja med fokus på återanvändning och återcirkulering av fordonskomponenter via ökad digitalisering och inkluderar; SKF, Jönköpings bildemontering (JB), ECRIS, Univrses, If / Volvia, Trafikverket och Högskolan i Halmstad.

Safe to RE-circulate är en systemdemonstrator för effektiv återcirkulation av bilkomponenter genom data- och modellanalys. Detta demonstratorprojekt syftar till att utveckla och testa skalbara lösningar för förbättrad och effektiv återanvändning i verkliga miljöer. Hälsodata för bilar omfattar olika typer av data relaterade till fordonsskador, vägbelastningspåverkan och krockinducerade påfrestningar. Dessa data kan genereras, hanteras och analyseras av olika intressenter, såsom fordonstillverkare, reparationsverkstäder, försäkringsbolag och återcirkulerande företag. Systemdemonstratorn förväntas utnyttja datadrivna och modelldrivna tekniker för att ge insikter i bilkomponenternas tillstånd i kombination med affärs- och hållbarhetsbedömning. Detta kan bana väg för att öka potentialen för komponentåteranvändning, optimera strategier för återcirkulering och förstå väglagets inverkan på fordonsslitage.

Safe to RE-circulate inkluderar ett explicit fokus på kraschbaserad utvärdering (AP1), livslängdsbaserad utvärdering (AP2), affärs- och hållbarhetseffekter (AP3), demonstration (AP4) och projektledning, kommunikation och kunskapsspridning (AP5). De tre föreslagna affärsscenarierna har specificerats till personligt ägande/leasing, mobilitet som tjänst, och VCC-driven taxiflotta, och kommer att tillämpas i AP3 vid bedömning av affärspotentialen och hållbarhetseffekten av demonstrerade lösningar.

2 Executive summary in English

Of the 6.2 million end-of-life vehicles handed over to auto assemblers in the EU in 2012, around 90% were recycled for materials, with only 7.5% of their original value. In contrast, processes such as reuse, repair, reconditioning and remanufacturing retain up to 85% of the original value and would save 75% of energy. This shows that, in addition to electrification, the automotive industry thus also needs to manage emissions related to materials and components.

The prestudy *Safe to circulate* has aimed to define 1) the extent of the scope for "safe to circulate" which is common to several original manufacturers and based on safety requirements and sustainability ambitions, current and future policies and regulations as well as acceptance of different solutions; 2) "safe to circulate" system criteria and plans for demonstration, as well as; 3) the consortium for a stage 2 project. The feasibility study also included three future mobility scenarios: (i) mobility as a service, (ii) an autonomous scenario and (iii) a traditional sales/leasing scenario (with test cars). The goal has been to demonstrate through the feasibility study and a step 2 project a data-driven system to maximize the reuse of components while maintaining high safety standards. The expected result is a data and model-based system for safe recirculation at the vehicle, system, component or material level.

The prestudy *Safe to circulate* has resulted in a step 2 application called *Safe to RE-circulate* which is a system demonstrator within FFI Accelerate. In addition to RISE Research Institutes of Sweden (RISE) and Volvo Car Corporation (VCC), which are parties to the feasibility study, the stage 2 application includes strategic parties that are part of a value chain with a focus on reuse and recycling of vehicle components via increased digitization and includes; SKF, Jönköpings bildemontering (JB), ECRIS, Univrses, If / Volvia, Trafikverket (eng: the Swedish Transport Administration) and University of Halmstad.

Safe to RE-circulate is a system demonstrator for efficient recirculation of car components through data and model analysis. This demonstrator project aims to develop and test scalable solutions for improved and efficient reuse in real-world environments. Automotive health data encompasses various types of data related to vehicle damage, road load impacts, and crash-induced stresses. This data can be generated, managed, and analyzed by different stakeholders, such as vehicle manufacturers, repair workshops, insurance companies, and recirculating firms. The system demonstrator is expected to harness data-driven and model-driven techniques to provide insights into the condition of car components combined with business and sustainability assessment. This can pave the way for enhancing the potential for component reuse, optimizing recirculating strategies, and understanding the influence of road conditions on vehicle wear and tear.

Safe to RE-circulate includes explicit focus on Crash Based Assessment (CBA) (WP1), Endurance Based Assessment (EBA) (WP2), Business and sustainability impacts (WP3), Demonstration (WP4) and Project management, communication and knowledge dissemination (WP5). The three proposed business scenarios have been refined into personal ownership / leasing, Mobility-as-a-Service (Maas) and, VCC operated taxi fleet, and will be applied in WP3 when assessing the business potential and sustainability impact of demonstrated solutions.

3 Background

The current transport system is a significant source of carbon emissions, driving climate change. As a response, many Original Equipment Manufacturers (OEMs) are transitioning to electrified vehicles. Recent carbon footprint studies of electric vehicles based on Life Cycle Assessments (LCA) reveal that electrification shifts carbon emissions from usage to material production and refining[1], largely due to the increased weight and use of high-footprint materials like aluminum and rare earth metals.

With resource scarcity becoming a pressing concern, the automotive industry must prioritize resource efficiency and embrace a circular economy. This approach emphasizes reducing primary resource consumption and waste, while promoting prolonged product lifetime. Furthermore, moving from private car ownership to fleet ownership and Mobility-as-a-Service (MaaS) solutions, (e.g. on-demand transport), will additionally support this shift to resource efficiency and circular economy.

Today's system focusing on recycling and energy recovery needs to evolve towards increased recirculation, i.e. remanufacturing, repair and direct reuse. While recycling is driven by legislation, there is today no legal requirement on reuse and remanufacturing, therefore, the incentive must come through attractive business and sustainability gains for all actors in the value chain, easy implementation of the system and market demand.

The potential for increase of remanufactured components is substantial, as a 2015 market survey concluded that the ration of remanufactured components to new manufactured automotive components reached only 1,1%[2]. Additionally, the European Commission has introduced a new proposal that emphasizes circularity in vehicle design and End of Life (EoL) management, aiming to replace the current ELV directive. As this proposal prioritizes remanufacturing, repair, and reuse, project activities are aimed at facilitating the future compliance to this directive within the specified time frame.

4 Aim, research questions and method

The prestudy *Safe to circulate* has aimed to define 1) the extent of the scope for "safe to circulate" which is common to several original manufacturers and based on safety requirements and sustainability ambitions, current and future policies and regulations as well as acceptance of different solutions; 2) "safe to circulate" system criteria and plans for demonstration, as well as; 3) the consortium for a stage 2 project. The feasibility study also included three future mobility scenarios: (i) mobility as a service, (ii) an autonomous scenario and (iii) a traditional sales/leasing scenario (with test cars).

5 Goal

The goal of the prestudy has been to demonstrate through the feasibility study and a step 2 project, a data-driven system to maximize the reuse of components while maintaining high safety standards. The expected result is a data and model-based system for safe recirculation at the vehicle, system, component or material level.

[1] Volvo Cars, Carbon footprint report - Volvo C40 Recharge. https://www.volvocars.com/images/v/-/media/market-assets/intl/applications/dotcom/pdf/c40/volvo-c40-recharge-lca-report.pdf

[2] Parker, Riley, Robinson, Symington, Tewson, Jansson, ... & Peck. (2015). Remanufacturing market study

6 Results and goal completion

6.1 Definition of system demonstrator scope

An objective of the Safe to circulate prestudy was to define the scope of the step 2 project, based on relevant safety requirements for several industrial partners.

In the current pre-study *Safe to circulate,* it was concluded that the circularity of automotive components could be increased if:

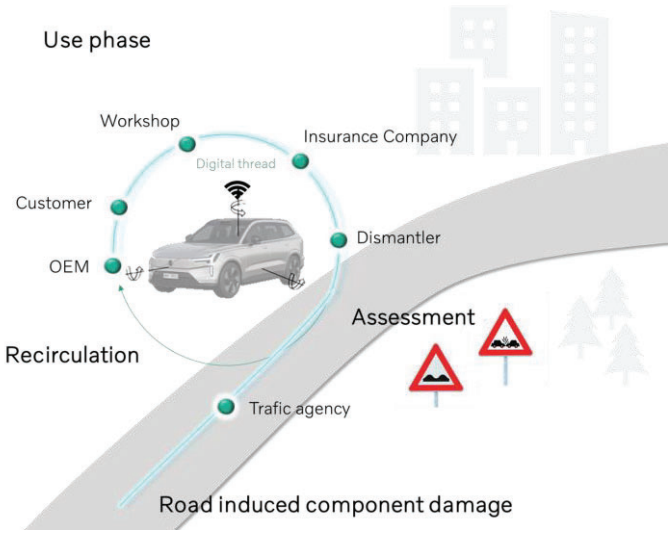
- Availability of components for repair, reuse and remanufacture is increased, i.e. increase market offer
- The cost and time to harvest components is decreased
- The need for specialized testing and analysis is removed
- The quality and safety of the components could be guaranteed to the customers, i.e. increase confidence to increase market demand

In the pre-study, a number of components with a high economic potential (high value) and/or environmental potential (high climate impact), such as doors, link arms and headlamps, were investigated. It was concluded that the points above could be addressed by creating a recirculate ecosystem with all the stakeholders along the value-chain, i.e. OEM, dismantlers, workshops, insurance companies and recirculation companies.

The prestudy resulted in a step 2 application, called *Safe to RE-circulate,* which is a system demonstrator for efficient recirculation of car components through data and model analysis. This demonstrator aims to develop and test scalable solutions for improved and efficient reuse in real-world environments. Automotive health data encompasses various types of data related to vehicle damage, road load impacts, and crash-induced stresses. This data can be generated, managed, and analyzed by different stakeholders, such as vehicle manufacturers, repair workshops, insurance companies, and recirculating firms.

The system demonstrator is expected to harness data-driven and model-driven techniques to provide insights into the condition of car components combined with business and sustainability assessment. This can pave the way for enhancing the potential for component reuse, optimizing recirculating strategies, and understanding the influence of road conditions on vehicle wear and tear.

The system to be demonstrated in the *Safe to RE-circulate* project refers to the integrated set of technologies, methodologies, and processes designed to collect, analyze, and interpret automotive state-of-health data to improve the harvesting of car components, promoting their efficient recirculation, and understanding the effects of road conditions on vehicle wear and tear. This encompasses the vehicle's on-board sensors, data transmission infrastructure, data processing and analysis tools, and the decision-making processes informed by the analyzed data.



Data and model enabled *Safe to RE-circulate* ecosystem

The pivotal aspect of the present system is the digital thread created throughout the life of the car, that can be shared and accessed by all stakeholders involved in the value chain and even to the traffic authority. A system based on a digital thread is expected to contribute to transparency on the car health, improving trust on the quality of recirculated parts, but also to contribute to secondary use for research and innovation. In other words, there is an opportunity to identify and demonstrate solutions for various needs that together build a long-term whole.

6.2 Policies and regulations

Another objective of the Safe to circulate prestudy was to analyze relevant present and expected policies, and regulations that will affect the design and management of vehicles.

In order to put vehicles on the market in Europe, manufacturers must ensure that they comply with vehicle regulations with technical requirements aimed at safety, environmental performance, etc. There are technical requirements for everything from lighting and braking systems to tires and windscreen wipers that must ensure that the vehicle is safe to use in traffic. There are also environmental requirements for e.g. emissions and fuel efficiency. Different categories of vehicles may have their own specific requirements. In order for the vehicle to be sold in Europe, it must first undergo a type approval process where the approval authority examines and approves the vehicle's compliance with the technical requirements.[3]

In addition to vehicle legislation, which is specific product safety legislation, there is also other relevant legislation that vehicle manufacturers must follow, for example chemical legislation (mainly REACH[4])

[3] Vehicle requirements are regulated at international, EU and national level. For EU level, see mainly Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC, https://eur-lex.europa.eu/eli/reg/2018/858/oj

[4] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restrictions of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No

which regulates the use of chemicals in products, including vehicles. There is also waste legislation relating to vehicles, i.e. producer responsibility for handling EoL cars and prevention of waste from cars. It is based on the EU directive on end-of-life vehicles (ELV directive[5]), which the Commission intends to replace with a new EU regulation on the management of EoL vehicles but which also includes circularity requirements in vehicle design, which means a greater focus on enabling remanufacturing, repair and reuse.[6] The EU is also working on other legislative initiatives aimed at reducing the environmental impact of products throughout their life cycle, e.g. a new framework with requirements for ecodesign and information requirements (including a digital product passport).[7] The intention is that most products will eventually be covered.

There is also legislation in the financial area that is relevant to mention, e.g. the EU Taxonomy Regulation[8], which is a classification system to help investors and companies understand which economic activities can be considered environmentally sustainable. The taxonomy thus provides a framework for assessing the degree to which an economic activity contributes to one or more of six environmental objectives: climate change mitigation, climate change adaptation, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and protection and restoration of biodiversity and ecosystems. For a business to be classified as environmentally sustainable, it should substantially contribute to one or more of the six environmental objectives, and at the same time not cause significant harm to any of the other objectives. Specific requirements and thresholds vary between different industries and are defined (as technical screening critieria) in delegated acts to the taxonomy. For example, there are specific requirements for sustainable vehicle manufacturing and battery manufacturing as well as sustainable transport services. Note that it is not mandatory for companies to meet the environmental sustainability standards of the taxonomy, but they must report (as part of their annual report) how they stand according to the taxonomy. The classification is still important because investors increasingly tend to invest sustainably and choose companies that are classified as such.

Within the EU, there is also an ambition of a "twin transition" that links the green and digital transition, i.e. an increasing and society-wide digitalisation in combination with increasingly stronger measures to mitigate climate change. One example is the coming European product policy on ecodesign where traceability through digital product passports has a central role.

Relevant to the project is also certain legislation in the area of digitalisation. The project has discussed the possibility of using sensors to collect data from the use phase of vehicles in order to know at end-of-life whether a component is safe to reuse. The General Data Protection Regulation (GDPR)[9] must be considered when an activity involves processing av personal data. Personal data is any information that refers to an identified or identifiable natural person. What is decisive is whether the information on its own or in combination with other information can be linked to a living person. What counts as personal

793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, https://eur-lex.europa.eu/eli/reg/2006/1907/oj

[5] Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles, https://eur-lex.europa.eu/eli/dir/2000/53/oj

[6] EU's website https://environment.ec.europa.eu/topics/waste-and-recycling/end-life-vehicles_en.

[7] EU's website, https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products-regulation_en

[8] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088, https://eur-lex.europa.eu/eli/reg/2020/852/oj

[9] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), https://eur-lex.europa.eu/eli/reg/2016/679/oj

data is therefore broad; it can also be indirect information that cannot be easily linked to an individual. For example, how a product is used can be personal data and the product's location data can be personal data. There are a number of rules in GDPR on how personal data must be handled and protected. Another relevant piece of legislation in the field of digitalisation is the upcoming Data Act[10], which aims to clarify who can create value from data (which is generated from connected products, among other things) and under what conditions. For example, if the manufacturer of a product collects data generated when the product is used, the user might have the right to access the same data.

6.3 Potential effects in a lifecycle perspective

Additionally, an objective of the Safe to circulate prestudy was assess potential effects in a lifecycle perspective, with regards to e.g. resource use, material use, circularity, climate effects.

Current LCA is used in product design with a focus on carbon footprint, however, the importance of the resources and materials and their social aspects are highlighted in recent scientific papers[11]. This goes in line with the three aspects of Volvo Cars (Personal, Sustainable and Safe). This goes hand in hand also with the recent sustainability goals, such as traceability, circularity and zero carbon emissions. While simple screening analysis is based on material level, we propose combined analysis based on the components, which gives a much better win-win analysis of sustainability and business value. Recent studies of components in the SE:Kond2Life project (2022)[12] found 85%-95% reduction in both carbon and resource depletion[13]. The costs reduction of components can vary between 60-75% for reuse and 38-47% for remanufacturing depending on the dismantling and the type of testing. The need for cost-efficient and sustainable reuse/remanufacturing is essential for upscaling[14] [15]. Therefore, new methods for economic and sustainability assessment need to be developed and implemented for the reuse and remanufacturing of components.

Studies show that reuse, repair, reconditioning, remanufacturing preserves 85% of the initial value, and use only 25% of the manufacturing energy[16] [17]. The battery and the electric motor indicate large environmental benefits from remanufacturing, and do not lose efficiency due to remanufacturing[18] [19] [20].

[10] European Commission, Data Act, https://digital-strategy.ec.europa.eu/en/policies/data-act

[11] Contributions to Life Cycle Management, 5-8 Sept 2023, Lille, France; [1] Carbon footprint study of Volvo C40 Recharge – use of conclusions in development work and implications for future studies, Palm & Berlin, [2] Volvo Cars' new methodology to rank the sustainability impacts of raw materials, Dahllöf, Petersson, Amwele, Aglund & Berlin, [3] Multi-criteria evaluation methods of environmental, social and economic impacts, Huppertz, Dulbecco, De Caevel & Zamagni, [4] Direct quantification of indicators in PSILCA – An example of Social Life Cycle Assessment of fuel cell electric vehicle production, Sally Kirsten Springer, Christina Wulf, Zapp Petra, [5] Enhancing circularity and resilience of the European industrial value chains through EU product & waste policy measures: insights from Lithium-ion battery, automotive and electronics sectors, Maury-Micolier, Tazi, Bobba, Orefice, Eynard, Latunussa & Mathieux

[12] SE:Kond2Life. https://www.ri.se/en/what-we-do/projects/sekond2life-ecosystem-for-reuse-of-automotive-components

[13] Life cycle assessment and potential of remanufacturing of vehicle components. Mats Zackrisson and Jutta Hildenbrand. RISE Report: 2022:119

[14] Reuse_of_automotive_components_from_dismantled_end.pdf

[15] JRC Technical Report EU (2022). Sustainable use of Materials through Automotive Remanufacturing to boost resource efficiency in the road Transport system (SMART). (2018–2020). 2021-01-14_smart_final_report_def_pubsy_def_1 (1).pdf

[16] Bobba et al. (2023)

[17] Berger (2022). The electrification of light vehicles. Boon or bane for the European aftermarket.

[18] Nordelöf & Alatalo (2018). A scalable life cycle inventory of an electrical automotive traction machine — Part I : design and composition. International Journal of Life Cycle Assessment Cycle Assessment, 55–69. https://doi.org/10.1007/s11367-017- 1308-9

[19] Tillman et al. (2020)

[20] Zackrisson (2019). Analys av hinder för återtillverkning och återanvändning samt avvägd miljönytta av fordonskomponenter - SE:kond2LIFE. RISE Research Institutes of Sweden. Research Report 27572

The LCA results for remanufactured car components suggested in a study related to insurance showed that transport dominates the impacts modelled for remanufacturing[21]. The environmental benefits of remanufacturing have been studied more in detail for reuse, repair, reconditioning and remanufacturing according to Ardente et al (2018)[22]. For the sake of simplicity, average values are used in comparison with the other components[23].

Additionally, recent scientific literature[24] and practical application show the importance of sustainable tools:

- The need for mapping the value chain for components. The need to collaborate regarding information sharing, logistics, warehousing and database for components and materials
- The need to explore the social risk (value chain, critical raw materials), and social benefits (job creation, social acceptance)
- The need to demonstrate environmental reduction and the need for a combined tool for economic and environmental assessment. The need to explore new business models and include sensor-based data and environmental data

Recent scientific literature and practical application also show the importance of sensor data:

- The need to demonstrate and upscale sensor data for the use phase and final phase (EoL). Explore customer attitudes
- The need to collaborate regarding information sharing, logistics, warehousing and database for components and materials
- The need to explore the health state of components and the need for sensor data[25]

In the transition towards emission free vehicle fleet, there is the importance of the share of electric vehicles. From 2020 all new models at Volvo have been fully electric. In 2021, the share of plug-in electric cars was 27% (189.000) of the total volume (698.693)[26]. In 2022, The share of full-electric vehicles was 10,9%[27] and battery electric vehicles are expected to expand to 100%. The transition itself includes some challenges and opportunities, for example the reduced number of components needed in full-electric cars (from 30.000 to 15.000[28] parts in total and from 200 to 20 parts for only the motor[29]) gives the possibility to reuse parts that deserve a second life after all. The International Material Data System (IMDS) material library (used by the automotive industry e.g. Volvo Cars) includes the material data per component representing a specific vehicle and around 70 material categories are used. The International Dismantling Information system (IDIS)[30] [31] is dedicated for dismantling stations and includes components and support data exchange with designers (IDIS includes 218 206 parts in total). Shifting from linear value chains to reuse and circular value chains will save resource used and energy used. Shifting from primary material sourcing to reusing components will eventually lead to avoided energy used in the value chain and reduced climate effects and eventually to reduced costs.

[21] Lundberg, Welling & Lindholm (2020). Klimatpåverkan av en reparation. På uppdrag av Länsförsäkringar. www.ivl.se

[22] Ardente, Talens Peiró, Mathieux & Polverini (2018). Accounting for the environmental benefits of remanufactured products: Method and application. Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2018.07.012

[23] Emilsson & Dahllöf (2019). Lithium-Ion Vehicle Battery Production Status 2019 on Energy Use, CO 2 Emissions, Use of Metals, Products Environmental Footprint, and Recycling. IVL Swedish Environmental Research Institute

[24] LCA and potential of remanufacturing of vehicle components 20221021.pdf

[25] LCA and potential of remanufacturing of vehicle components 20221021.pdf

[26] Annual and Sustainability Report 2021 (volvocars.com)

[27] www.best-selling-cars.com/brands/2022-full-year-global-volvo-worldwide-car

[28] https://motorandwheels.com/electric-cars-have-fewer-parts

[29] www.spotforcars.com/truth-about-how-many-parts-make-a-car/

[30] Reuse_of_automotive_components_from_dismantled_end.pdf

[31] IDIS | The International Dismantling Information System (idis2.com)

As part of the prestudy, workshops were held with experts from industry and academia[32]. The discussion focused on the following: expensive components that can survive two cars and that are not included in predictive maintenance, the number of sensors and diagnostic and the problem of recycling, the social aspects of sustainability and the social risk and economic risk of critical raw materials in electric vehicles, the safety issues and issues related to insurance, the testing in different fleets/business scenarios, as well as the economic and environmental aspects in heavy and expensive components like doors, E-machine and link arm.

The discussion made during the second workshop[33] involved more broader variety of experts from industry and research institutes (covering expertise from a range of relevant areas, including safety, data analysis, crash tests, sustainability, business and circularity). The discussion focused on the following: the difficulties of remanufacturing of doors due to design, the smart implementation of sensors and synergies for sensors, the environmental/carbon/social perspectives of remanufacturing, the distinction between mechanical components (long-life) and electrical components (short life), the economic point of view (material costs, labor costs), and the smart use of sensors (temperature, IR, vibration) that leads to sustainable and cost-efficient use of sensors.

Based on the opportunities found in the scientific literature and the practical needs derived in the previous study (*SE:Kond2Life*), the basis found lays for accelerating and discussed in the pre-study (*Safe to circulate*) in order to accelerate data-driven recirculation, the following areas for development were proposed: a combined tool for economic and environmental assessment, to explore the social risk (value chain), and social benefits (job creation, social acceptance), to map the value chain for components, to explore new business models and include sensor-based data and environmental data, to demonstrate and upscale sensor data for the use phase and final phase (EoL). The need to collaborate regarding information sharing, logistics, warehousing and database for components and materials, as well as to explore more effective and efficiently the health state and digitalize operations, previously done manually.

6.4 Definition of the system and plan for demonstration

The prestudy included an activity of further defining the system for "safe to circulate" and the plan for demonstration.

From the prestudy it was concluded that technologies were needed to assess damage induced in cars involved in traffic accident or for EoL assessment. For the crash based assessment, digitalization in the insurance industry has led to the development of artificial intelligence algorithms that enable image based recognition of damage from accidented cars, therefore guiding the need for part replacement. This assessment is however approximate and based on training algorithms from past models and accident situations. In the present project (*Safe to RE-circulate*) a more accurate method to evaluate damage is proposed. It is based on high quality finite element models typically used in car design. A database will be developed based on these models, both from standard design models but also from typical traffic situations. The database will be completed from surrogate models, i.e. reduced order models that offer high accuracy but low computational cost. Damage assessment based on this database and image recognition will therefore enable a safe, practical and accurate way of harvesting undamaged parts from damaged cars.

For EoL assessment, a new way of measuring road loads needs to be developed. Current road load measurements are dedicated to special measurement vehicles used in the product development. In the prestudy, a new technology developed by SKF was identified as a key enabler to provide road load measurements on a large fleet of vehicles. This technology will be demonstrated in the full-scale project

[32] RISE, Mölndal, 05/2023
[33] RISE, Mölndal, 06/2023

and compared to the current standard used in product development. Furthermore, an image based technique developed by Univrses and enabling assessment of road damage will also be investigated and compared to the more advanced sensors. This technique only requires road monitoring with a camera and offer therefore a great possibility to be implemented at a low cost and on a very large fleet.

Besides the development, validation and demonstration of these technologies, the whole system involving the ecosystem around recirculation will to be demonstrated. In particular the digital thread, i.e. the continuous flow of the damage and state of health for the particular car, needs to be established and verified that each actor of the value chain has access and understanding of this data.

The resulting application *Safe to RE-circulate* is scoped as a system demonstrator for efficient recirculation of car components through data and model analysis. This demonstrator project aims to develop and test scalable solutions for improved and efficient reuse in real-world environments. Automotive health data encompasses various types of data related to vehicle damage, road load impacts, and crash-induced stresses. This data can be generated, managed, and analyzed by different stakeholders, such as vehicle manufacturers, repair workshops, insurance companies, and recirculating firms. The system demonstrator is expected to harness data-driven and model-driven techniques to provide insights into the condition of car components combined with business and sustainability assessment. This can pave the way for enhancing the potential for component reuse, optimizing recirculating strategies, and understanding the influence of road conditions on vehicle wear and tear.

Safe to RE-circulate includes explicit focus on Crash based assessment (CBA) (WP1), Endurance based assessment (EBA) (WP2), Business and sustainability impacts (WP3), Demonstration (WP4) and Project management, communication and knowledge dissemination (WP5). The three proposed business scenarios (personal ownership / leasing, MaaS, VCC operated taxi fleet) will be applied in WP3 when assessing the business potential and sustainability impact of demonstrated solutions.

The prestudy investigations has generated the following project vision for *Safe to RE-circulate*:

“From linear and time-consuming manual reuse
to more sustainable and efficient data-driven reuse of components”

6.5 FFI goals

With the project scope of *Safe to RE-circulate* (the full-scale successor application of the prestudy) and the solid consortium part of the application, we see that the project is fully in line with the FFI goals and that the proposed solution will enable higher reuse of components and systems, extending their lifetime and reducing energy and resource consumption while ensuring high safety standards. Additionally, the system will be demonstrated in a physical environment enabling use by 2030 at the latest.

7 Dissemination and publication

7.1 Dissemination of knowledge and results

The *Safe to circulate* project has connections to other relevant projects in the area. During the scoping of step 2 application, active dialogue has been ongoing with Trafikverket (eng: Swedish Transport Administration) who considers the step 2 application *Safe to RE-circulate* of high relevance, as it will include a focus on measuring road conditions and establish their effects on component damage. Trafikverket is responsible for long-term planning of the transport system for all types of traffic, as well as for building, operating and maintaining public roads and railways. A better understanding of the interaction between the road surface (i.e. bumps and irregularities) will improve the accuracy when

determining road user costs related to pavement condition. The *Safe to RE-circulate* project can thus beneficially have cross-examination with other projects where Trafikverket is involved, such as *Connected road surface measurements*[34].

The electrification of the transportation sector is a parallel ongoing transition that is of relevance to project results and practices. This transition has led to a dramatic increase in electric vehicle (EV) battery production which is also expected to continue to grow exponentially in the coming decades. So far, EV battery design and manufacturing has focused on efficient and high-performing virgin products. However, to enable circularity in the EV battery industry, extra attention must be paid to re-use, re-manufacturing, and recycling aspects of the battery packs. To enable circularity, the battery packs must be designed with a new approach. More specifically, the joints in the battery packs must be manufactured to allow to be taken apart, (disassembled) and then joined again (re-assembled) if needed. These are issues in focus of the related *DIJON* (*Disassembly methods of joints for circular battery packs*) project with which there are cross-examination opportunities.

Also, projects that has not started yet will be of relevance to the full-scale successor of the prestudy (i.e. the *Safe to RE-circulate* project application) if they will be approved, such as *The circular car* and *Circular use of plastics in the automotive industry*. *The circular car* aims to take a systematic perspective on the circular transition in the car value chain so help accelerate the transition to a car fleet adapted for circularity in 2045. The project will include e.g. developments in future scenarios for circular cars, activities towards design for long life and disassembly for remanufacturing that will be of relevance for the *Safe to RE-circulate* project. The project *Circular use of plastics in the automotive industry* aims at increased reuse and recycling of plastics from end-of-life vehicles through dismantling and upgrading, where the material can be used in new components. Also here, can there be sharing of insights of relevance for the projects. Therefore, the consortium of *Safe to RE-circulate* will be completed with a reference group consisting of members from other FFI approved applications during the fall of 2023, where there are overlaps between project partners. This will make grounds for strategic knowledge sharing between projects that take different approaches to circularity in the automotive industry, but that benefit from joint learning of nonconfidential insights.

The prestudy *Safe to circulate* builds on the now finalized Vinnova funded project *SE:Kond2Life - ecosystem for reuse of automotive components*[35]. *SE:Kond2Life* has shown several results of relevance for the project. Among other things, LCAs showed a great potential for reduced environmental impact from the remanufacturing of vehicle components, compared to the manufacture of new components. For example, remanufacturing a battery from a Volvo XC90 Hybrid reduces the climate impact by at least 90% compared to new manufacture from primary resources. This shows the potential for decreased environmental load of reuse and remanufacturing practices very large.

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the area	X	Efforts on formulating the application for a step 2 project has included dialogue relevant actors and through this dialogue knowledge has been spread about the relevance and scope of the project and about challenges and opportunities in the area
Forwarded to other advanced technical development projects	X	The prestudy *Safe to circulate* has resulted in the application of a system demonstrator application

[34] Connected road surface measurements. https://univrses.com/press-releases/univrses-and-the-swedishtransport-*administration-join-forces-in-game-changing-road-management-initiative/*

[35] SE:Kond2Life. https://www.ri.se/en/what-we-do/projects/sekond2life-ecosystem-for-reuse-of-automotive-components

		called *Safe to RE-circulate* as part of FFI Accelerate
Forwarded to product development projects		
Introduced to the market		
Used in investigations / regulations / permit matters / political decisions		

7.2 Publications

The prestudy *Safe to circulate* included the goal to define the consortium for the step 2 application for a system demonstrator within FFI. As such, the prestudy has entailed focused efforts to communicate the *Safe to circulate* vision and scope to relevant actors needed for a solid system demonstrator. In this case, this has implied several joint workshops and one-to-one meetings with RISE and VCC together with strategic partners within the value chain of reused and recirculated automotive components via increased digitalized data, including; SKF, Jönköpings bildemontering (JB), ECRIS, Univrses, If / Volvia, Trafikverket and together with Halmstad University (all partners of the step 2 application *called Safe to RE-circulate*). Apart from active dialogue with partners, the project has made use of a webpage at ri.se[36].

8 Conclusions and continued research

The prestudy *Safe to circulate* has resulted in the application of a system demonstrator application called *Safe to RE-circulate* as part of FFI Accelerate. The consortium building part of the application process has confirmed that there is a big interest in scaling up of data and model based assessments of recirculated automotive components, and that there are partners that see great value in such developments.

[36] Safe to circulate. https://www.ri.se/en/what-we-do/projects/safe-to-circulate

9 Participating parties and contact persons

The prestudy *Safe to circulate* has been carried out in collaboration between Volvo Car Corporation and RISE Research Institutes of Sweden, where RISE acted as coordinator for the project.

VCC contact person: Renaud Gutkin, renaud.gutkin@volvocars.com

RISE contact person: Hanna Lindén, hanna.linden@ri.se