Towards
Advanced Circular Economy for E-mobility

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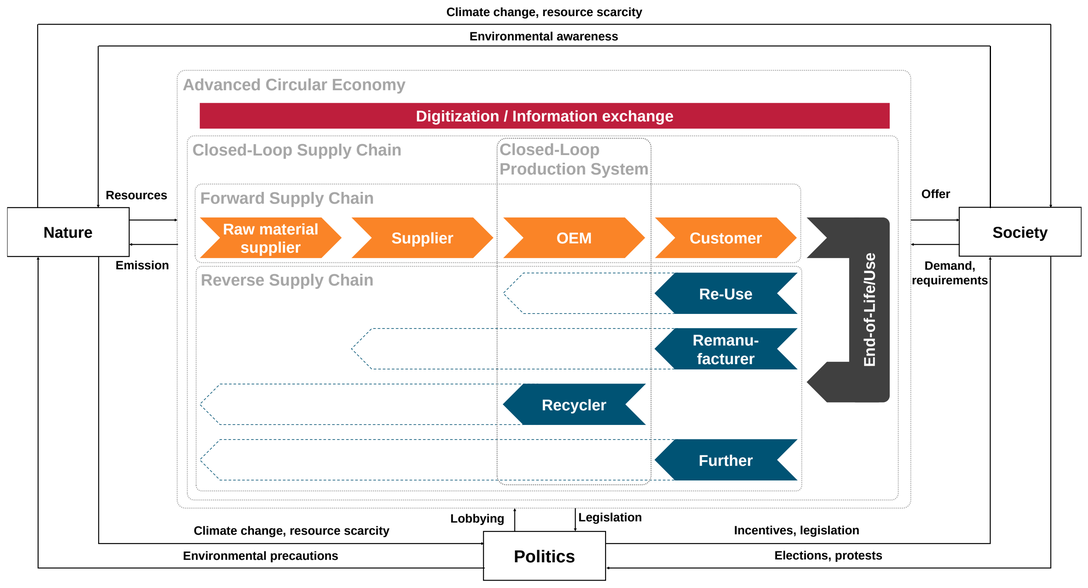
Introduction

Resource scarcity is a global challenge specially in E-mobility. The increase in the sales and acceptance of electric vehicles, and the scarce availability of numerous materials needed to manufacture the vehicles and their batteries create new challenges. In order to tackle this, optimized processes are needed. Today a variety of new technologies are affordable and have reached maturity, which was not the case some years ago. Like Industry 4.0, Recycling 4.0 also aims on digitalization of the processes.
This approach consists of the following:

- Closed-Loop Supply Chain Management
- Dynamic optimization of production
- Closed loop production systems
- Information marketplace
- Advanced disassembly system.

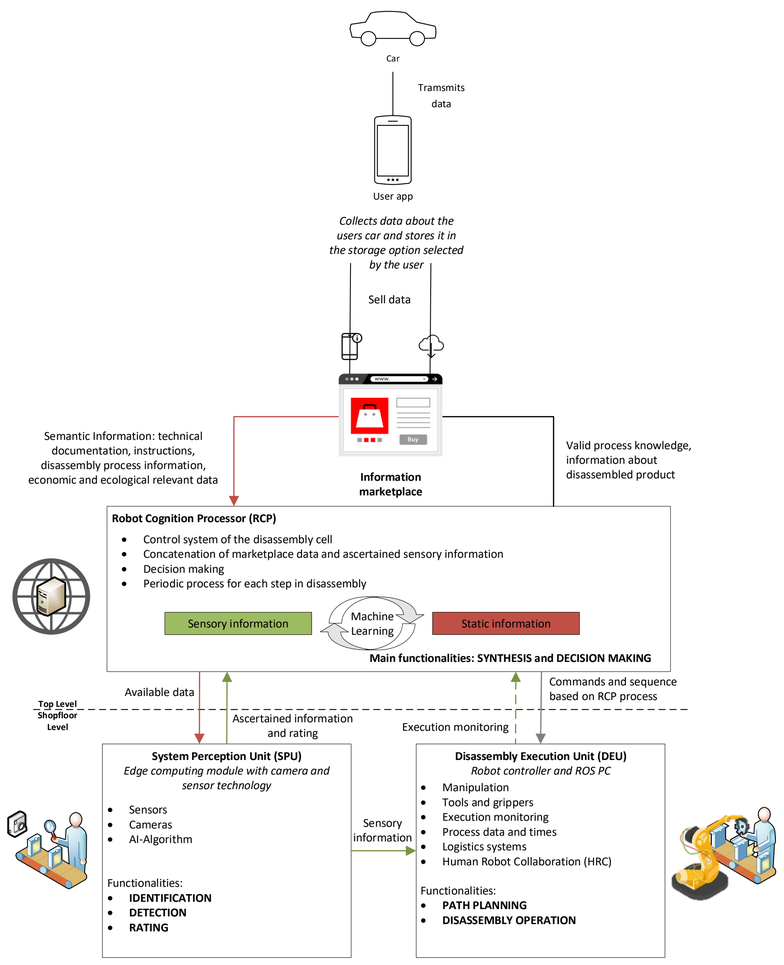
This poster evolved from the research project “Recycling 4.0” (digitalization as the key to the Advanced Circular Economy) which is funded by the European Regional Development Fund (EFRE | ZW 6-85017297).

Closed-Loop Supply Chain Management



- Suppliers and original equipment manufacturer (OEM) increasingly consider the reverse supply chains as potential to overcome resource scarcity.
- The increasing interdependences between the forward and reverse supply chain necessitate a closed-loop supply chain management in order to achieve optimal cooperation between the companies.
- Production and recycling planning models enable each company to achieve local optimums regarding their production or recycling plan.
- Local optimums lead to inefficiencies due to opportunistic behavior and information asymmetries.
- Adequate coordination mechanism give incentives to each company to deviate from their local optimums in such a manner that the supply chain optimums is met and each company profits from it.

Information marketplace and Advanced disassembly system

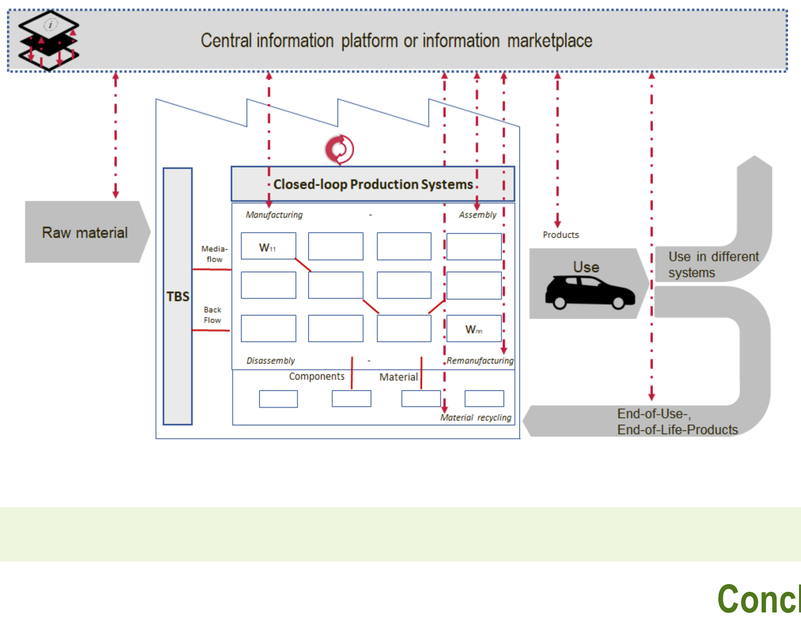


- For optimized processes, the role of information exchange is crucial. In order to increase the data and information flow between the stakeholders, we propose *an information marketplace*.
- Just like any other online marketplace an information/data marketplace is a platform which enables convenient buying and selling of products- in this case “data”.
- In contrast to other electronic marketplaces, we have to considered some special challenges here, such as :
  - Security
  - Openness of the platform
  - Data integrity
  - Data quality.
- In order to improve the CE processes on shop floor level, an *advanced robotic disassembly system* is developed. By using AI vision and decision agents, the system can efficiently include the information flow of disassembly seamlessly into the top-level ecosystem.
- The disassembly system needs information for disassembling the components, such information can be bought by the robot via the.

Material flow, component and information flow system

- In order to make the circular economy (CE) for traction batteries visualizable, controllable and assessable, a system-dynamic approach is pursued.
- With the developed model, which represents the material, component and information flows of the CE and takes into account all stakeholders along the value chain, the market participants are to be given assessment aids in order to make decisions for e.g. investments.
- In contrast to static models, dynamic models (SD models) take into account the temporal iteration of processes, which takes into account long-term developments, but at the same time makes SD models very data intensive.
- SD models are divided into closed-loop and open-loop systems. In open-loop systems, recycled material is no longer returned to the previous product system, often due to a downcycling of the raw materials, whereas in closed-loop systems, the secondary raw material is managed in the same system and a closed loop is formed.
- A further methodological distinction is made in the bottom-up or top-down approach. In the latter method, a certain amount of raw material per period is assumed, which is distributed over time to individual areas of use.

Closed loop production system



- Retroproduction offers secondary materials and components with a potentially lower environmental impact compared to primary materials.
- A system that combines production and retroproduction and optimizes resource and cost management is defined as a closed-loop production system (CLPS).
- Companies that implement a CLPS can i.e. include secondary materials and components in production processes to decrease cost and environmental impacts of their products.
- Planning and managing these complex systems requirers market and product information over the whole life cycle, which are provided by the information marketplace.
- The collection, storage and provision of this holistic product and market data offers additionally promising future business models

Conclusion

- We presented a holistic approach to handle the upcoming return of electric vehicles and their lithium ion batteries which prevents the problems of WEEE of the last century
- Industrial Internet of Things technology can be used to create a digital twin of the electric vehicle battery.
- An information marketplace serves as a central point of the information exchange, hence enabling better information flow and improved recycling process.
- The information marketplace not only facilitates buying and selling of information or data sets buts also has a novel architecture which is open, secure and tackles special challenges such as data quality and integrity.
- Advanced disassembly systems and automation strategies contribute beneficially to the overall economic and ecologic attractiveness of the recycling process by employing the information flow for AI-enforced processing.
- All in all this approach enables the implementation of an advanced circular economy based on improved information generation, exchange and use.

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