Circularity concept in the finishing industry

Cristina Onorato | AXIA Innovation

4 October 2022

The PureNano project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No. 821431

Outline

01 Introduction to the circular economy and the role of the finishing industry in the transition

02 Identification of the current End of Life management chain in the finishing industry

03 Waste Minimization (WM) applied to PureNano's technologies

04 Pure Nano circularity concept

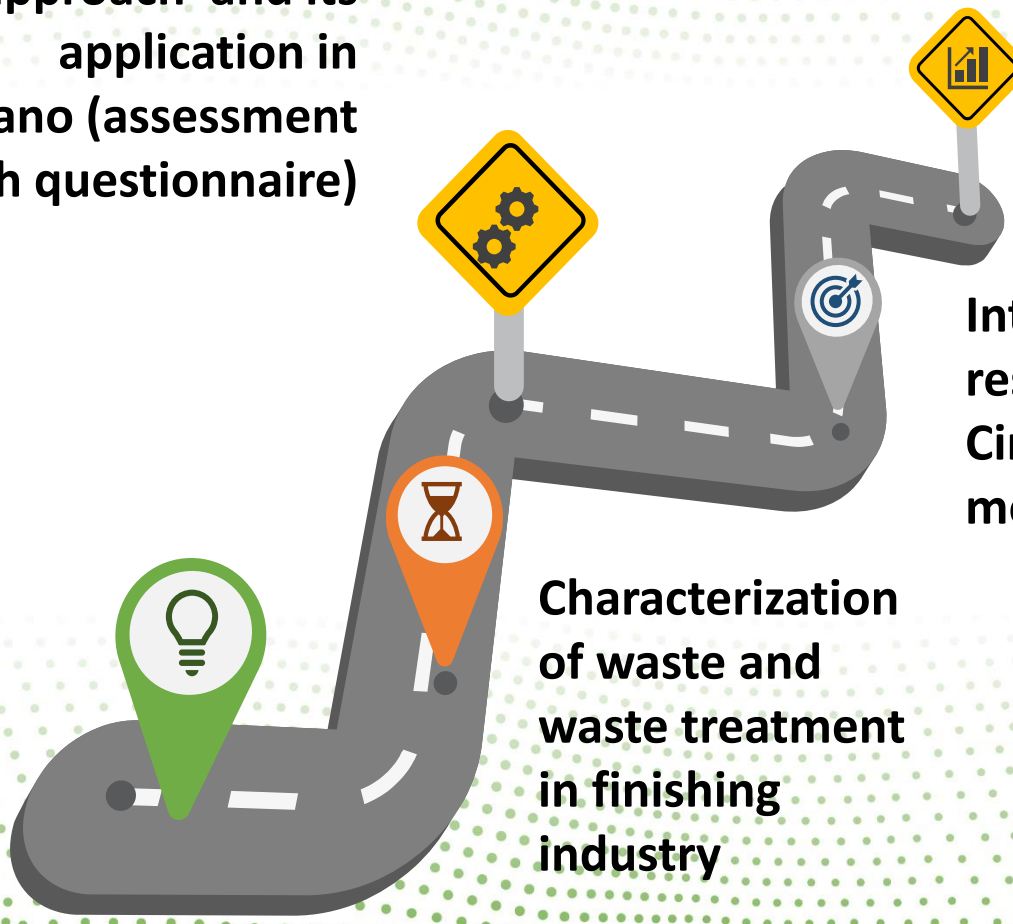
05 Introduction to the Circular Business Model concept and its application to the main PureNano's user cases

06 Conclusion and Remarks

Methodology

Waste minimization approach and its application in PureNano (assessment through questionnaire)

Application of the best CBM to the PureNano user cases



Intensive literature research on the Circular business models

Extensive literature review on the Circular Economy (CE) and CE in finishing industry

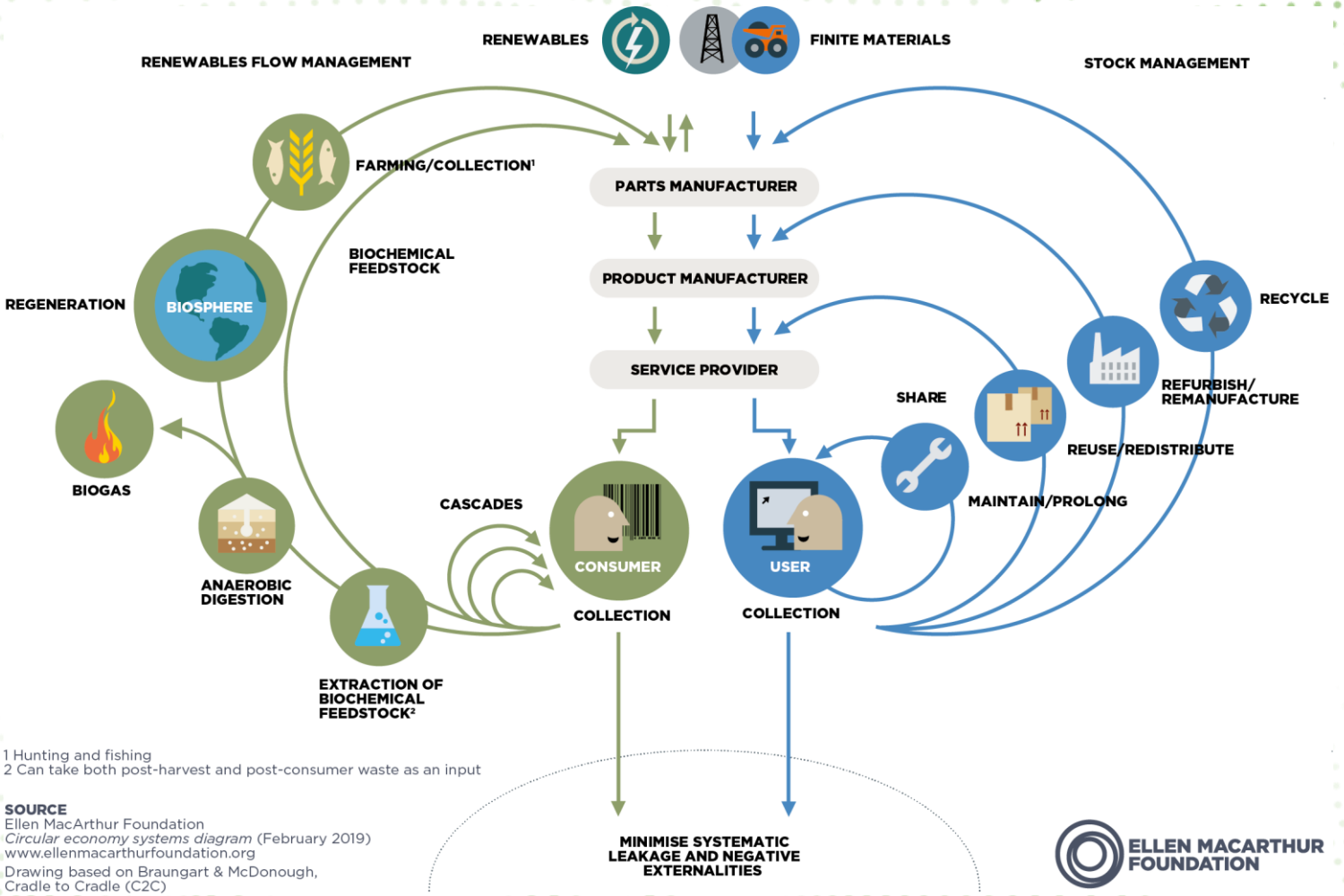
Characterization of waste and waste treatment in finishing industry

Introduction to the circular economy and the role of the finishing industry in the transition

What is a circular economy?

- The interest in recycling and in the circular economy concept from the government, society, academia, and industry is grown constantly in the last few years
- Linear economy point of view: natural resources are extracted, transformed into capital and consumer goods, and eventually disposed of in landfills or disposal facilities.
- From a circular perspective: designing long-lasting goods, easy to repair and reuse, that after recycling are as good as the virgin ones.
- In the last years, we have assisted in the rapid growth of the use of natural resources and the increase in waste generation. This phenomenon has economic, social and environmental consequences
- Goal: European Union to become the first “climate neutral” continent by 2050, in order to make a “cleaner and more competitive” Europe.

What is a circular economy?



CE benefits

01
Economc Benefits

- Reduction of overall costs
- Reducing business risks
- Revenues from secondary streams

02
Environmental benefits

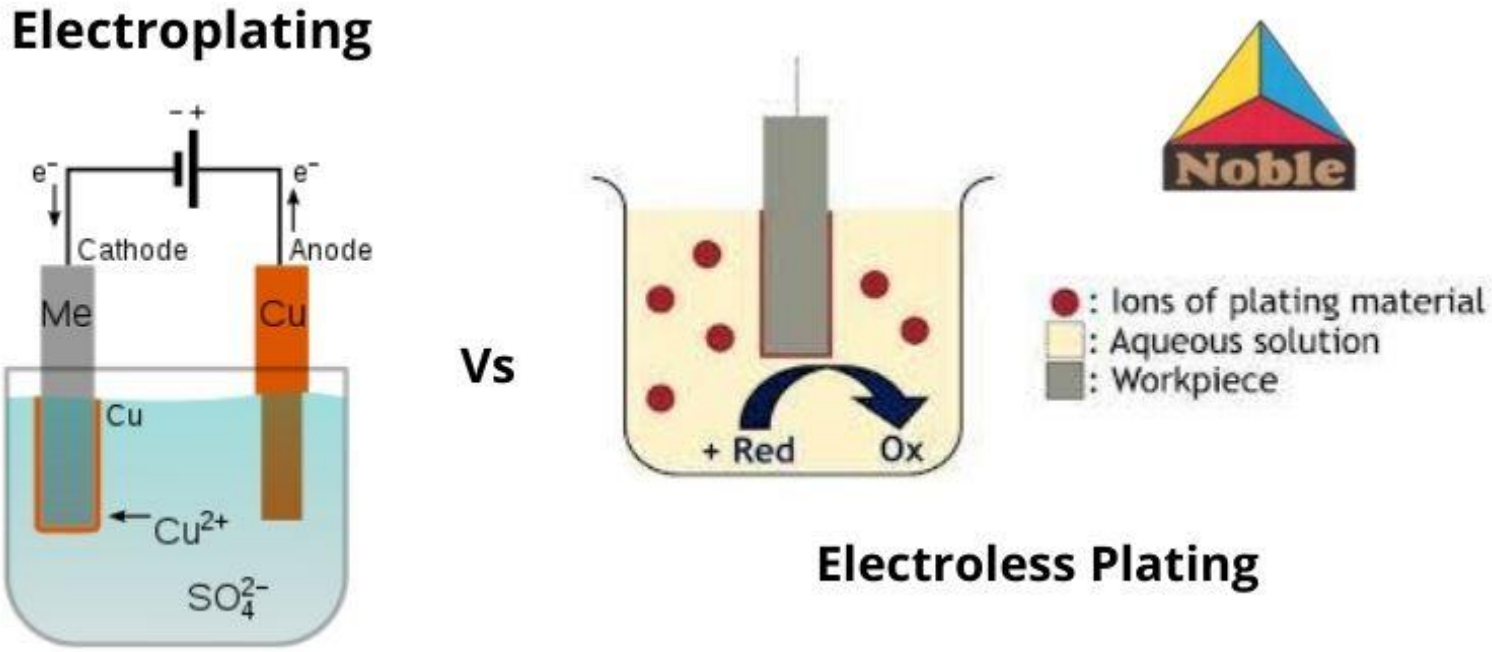
- Reducing environmental impacts
- Improve resurce efficiency
- Improve supply chain sustainability

03
Social Benefits

- Enhance reputation and brand value
- Enhance people awareness towards sustainability
- Develop innovative skills

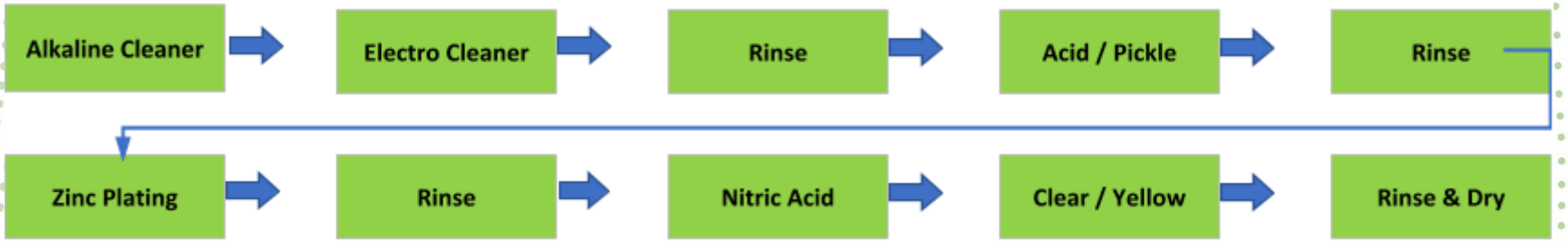
Metal finishing industry

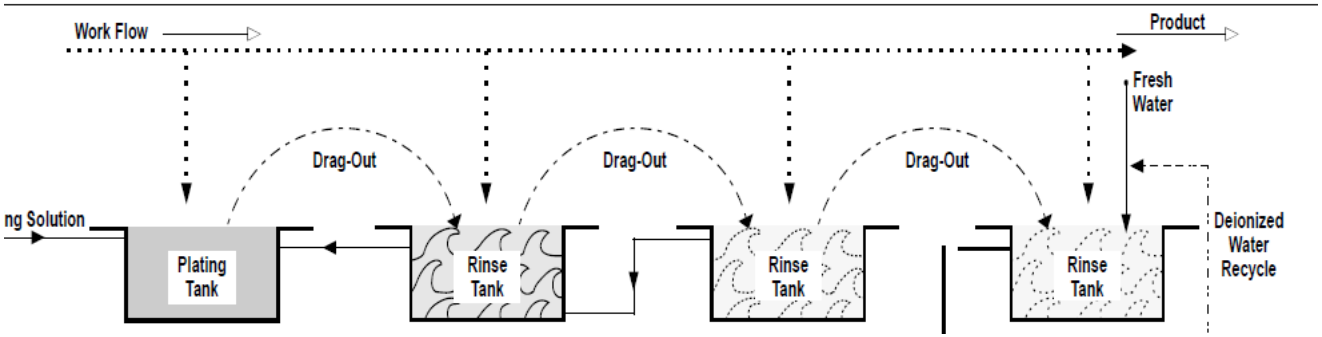
Metal finishing industry



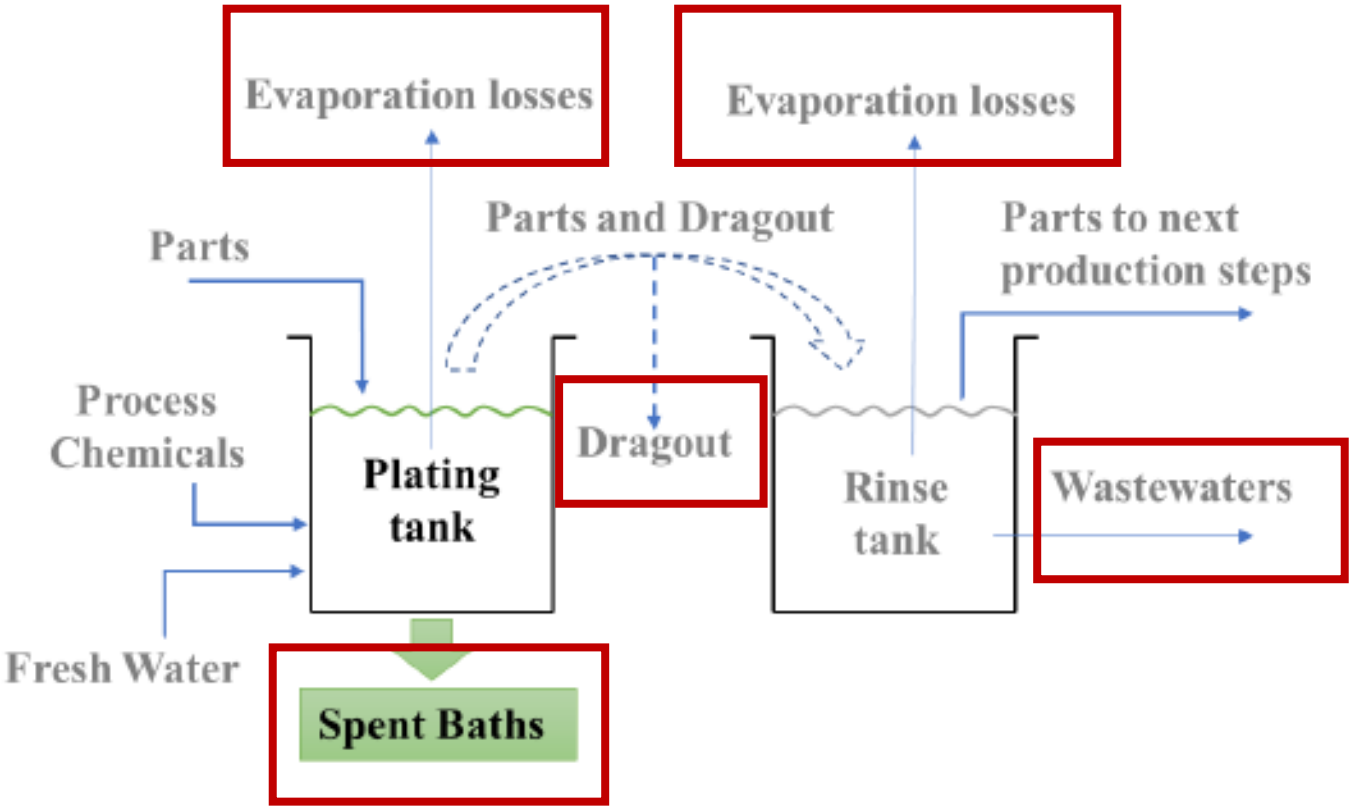
https://www.noblemetalcoating.com/electroplating-vs-electroless-plating-whats-the-difference/

Metal finishing: process flow examples





Metal finishing Process unit



Metal finishing: main wastes groups

- Evaporation losses: not relevant
- Dragout: solution remaining on products, barrels, and other equipment used to move the product through the various process bath.
- Wastewater
- Spent bath

Every year a total amount of 300.000 tons of hazardous waste is produced that is needed to be transported to a waste treatment site

The circular economy approach has not been applied yet in the whole electro-plating process design, where it is a common practice to dispose of the spent bath and the sludge produced by the process.

Identification of the current End of Life management chain in the Electroplating industry

Classification of Waste

WASTEWATER

Comes from equipment leaning, drag-out and spills processe. It contains the 10-12% of the metal plating bath solution[1].

SPENT SOLVENT

Concentrated spent cleaning solution coming from aqueus cleaning and acid pickling produced with a frequency which depends on the nature of the process.

SPENT PROCESS SOLUTION

Plating process solution which cannot be reused and generally cannot be regenerated and therefore is disposed.

SLUDGE

Constituted by soil, scale and and insoluble components that accumulate in the bottom of the tanks

Every day a plant can generate 80 to 200m^3 of wastewater, which contains heavy metals, cyanide, solvents, cleaners etc[2].

[1]Disposal of electroplating wastes – a review of current practices and recommendations for future management", A. Bingham, Department of Heath, New Zealand, 2010

[2]B. RAMESH BABU, S. UDAYA BHANU & K. SEENI MEERA (2009) Waste Minimization in Electroplating Industries: A Review, Journal of Environmental Science and Health, Part C, 27:3, 155-177

Waste treatment methodologies

- Disposal is undesirable due to the harmful contaminants
- Many waste treatment technologies are applied after the waste is produced (“end of pipe “ waste treatment)
- Electrodialysis and Ion exchange have been analysed as possible techniques to remove heavy metals from electroplating bath, but the cost is still not competitive
- Policy regulations for wastewater treatment are in place to decrease the risk of toxic substances affecting humans and the environment

Metal finishing: main wastes groups

- Evaporation losses: not relevant
- Wastewater
- Dragout

} Waste Minimization (WM) approach and waste treatment technologies

- Spent bath → PureNano Technology

Waste Minimization approach

RESOURCE REDUCTION APPROACH

a) Process and equipment modification
b) process control optimization
c) material substitution

REDUCION OF THE DRAGOUT

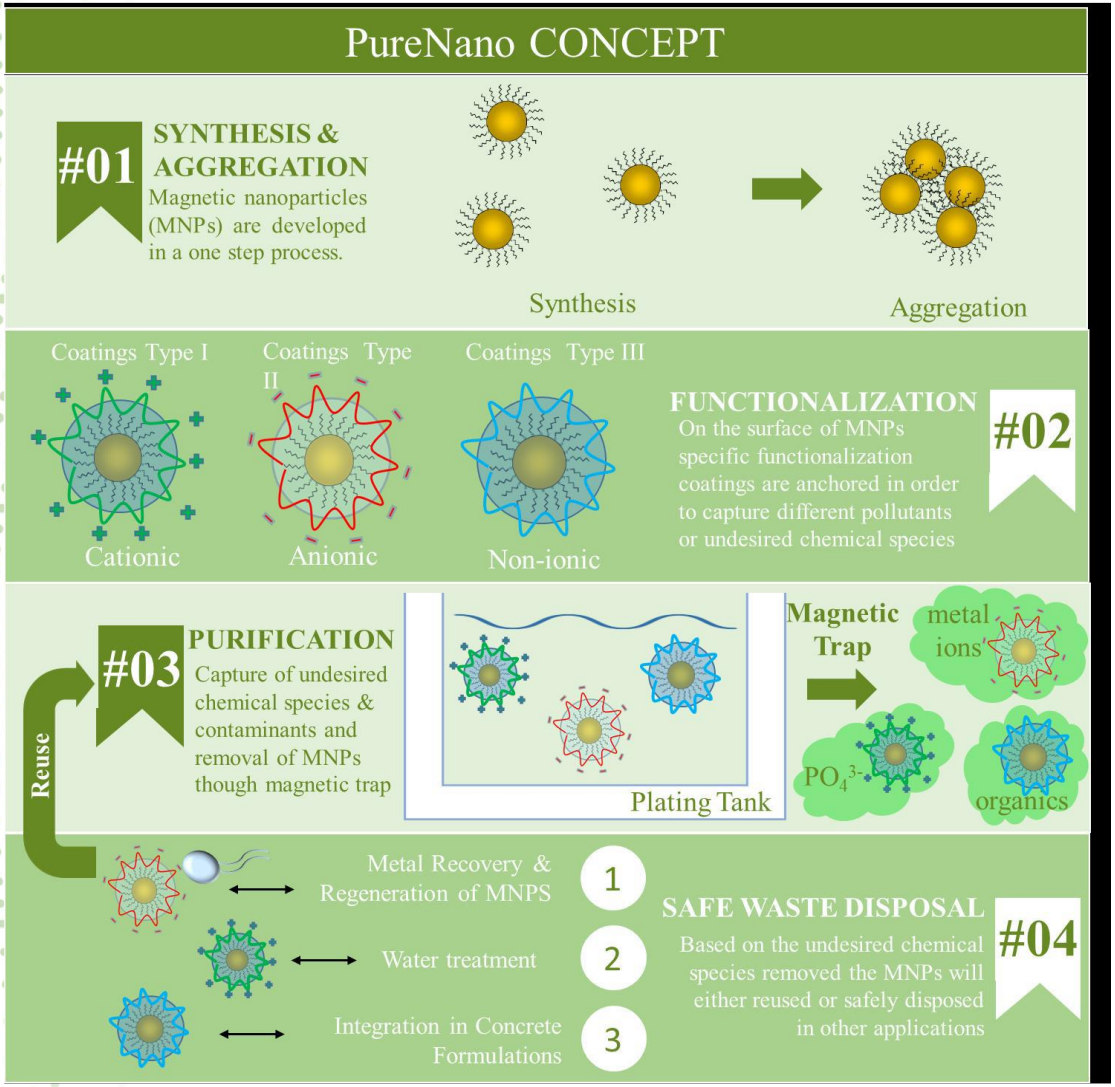
a) increasing dripping time to 10-20 seconds before rinsing
b) placing a recovery tank before the rinse tank
c) Introduce drip trays between tanks
d) Improving drainage system to reduce spillages on floor etc

REDUCTION OF WASTE

a) Improved housekeeping,
b) changing process technology changing products
c) changing input material
d) recycling process chemicals and raw materials,
e) recovering by-product/waste reducing input to the process

Pure Nano circularity concept

PureNano Concept



- Bath treatment on site
- Increase the plating bath life (5-20 regenerations per year)
- Biomaterials are used for the functionalization of the MNPs
- Sustainable disposal of the MNPs

Recyclability options

a) Recovery of metals and reuse (anionic MNPs)

- Electrolytic recovery of the captured metal (mainly Ni) and MNPs regeneration

b) Water purification (cationic MNPs)

- Captured orthophosphates can be used for removal of heavy metals & metalloids

c) Integration in concrete formulations (non-ionic MNPs)

- Addition in cement/concrete mix
  - improved durability
  - finer pore structure
  - enhanced compressive strength

PureNano user cases

a) Electroless Nickel plating
b) Zn /Cu electroplating
c) Nickel electroplating

01

Electroless Nichel

The electroless Nickel plating process is carried out at the Gaser facility. Therefore the in-line bath purification system was installed at Gaser.

02

Zn/Cu/Ni electroplating

The portable bath purification system is installed at Cnano facility to treat the spent baths coming from the Zn/Cu and Ni electroplating.

Waste Minimization (WM) applied to PureNano's technologies

WM: Gaser case study

Gaser Ossido Duro SRL is an Italian company working in the business of surface treatment of metals using chemical solutions and electrochemistry.

The produced wastes can be classified as wastewater, spent solutions and sludges

Gaser's facility wastes are treated both in-house and in an external waste treatment facility, they are ISO 14001 certified.

Waste treatment: wet processes such as precipitation, flocculation and filtration

The plating bath is not treated yet due to the high concentration even though some new techniques are currently tested on a lab scale.

The company is aware of waste minimization practices and is active in waste minimization research.

General practices: water management, evaporation and distillation and other are going to be applied later on to reach a higher TRL level

Gaser WM approach

REDUCION OF THE DRAGOUT

a) Slowing down the withdrawal time
b) Tank before the rising tank to recover the plating solution

RESOURCE REDUCTION APPROACH

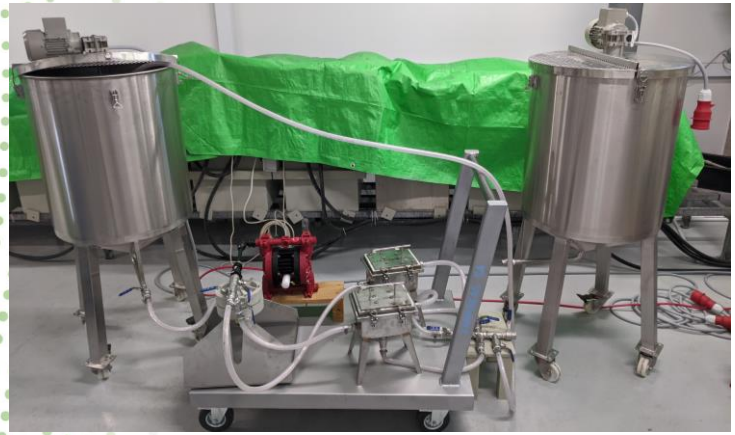
a) Process and equipment modification
b) process control optimization (plating bath parameters and condition)
c) Change the process technology using a different washing/cleaning procedure and cleaning frequency

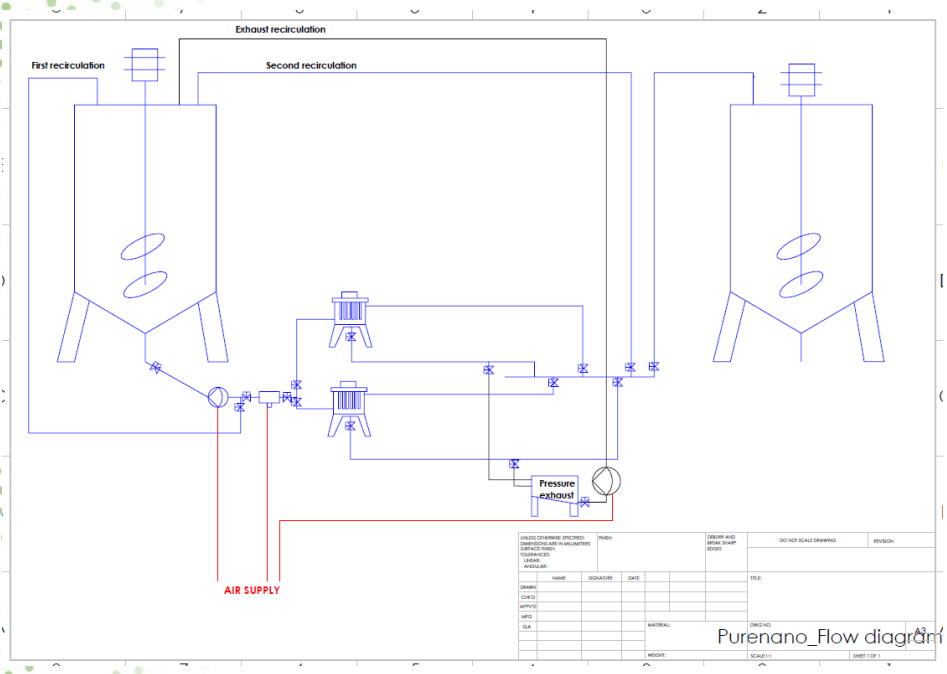
REDUCTION OF WASTE

a) Improved housekeeping,
b) changing process technology changing products
c) Recycling the process bath after concentration and filtration
d) Filtration of the produced waste solution

- ✓ **Increase the process efficiency**
- ✓ **Bring economic benefit**
- ✓ **This approach together with the PureNano technology ensure a more sustainable process**

WM: CNano case study





Creative Nano is a research intensive and commercialization company providing technological solutions in the field of materials' nanoscience and nanotechnology.

Cnano has considerable expertise in the fields of surface treatment, electroplating, development and validating advanced materials and nanomaterials and on the assessment of their environmental impact.

CNano's facility wastes are wastewater and spent solutions.

CNano's wastes are collected by an external contractor

Cnano conforms with the Greek industrial regulatory. Specifically, follows the 92108/1045/F.15/2020 regulation, that categorizes the environmental impact of industrial activities and gives the main directions for the waste management.

Currently in Cnano, there is an ongoing process under development, that will reduce the environmental impact of the electroplating process, through a U/S assisted electroplating cell.

Also, the Purenano technology is under development and optimization process in their premises.

The company is aware of waste minimization practices and is active in waste minimization research. General practices are already applied and other are going to be applied later on to reach a higher TRL level.

CNano WM approach

1

RESOURCE REDUCTION APPROACH

a) Process and equipment modification
b) process control optimization (plating bath parameters and condition)
c) Change the process technology using a different washing/cleaning procedure and cleaning frequency

REDUCION OF THE DRAGOUT

a) Tank before the rising tank to recover the plating solution
b) Development of a new electroplating method that reduces the solid and liquid wastes during the process with the aid of an U/S assisted electroplating cell.

2

3

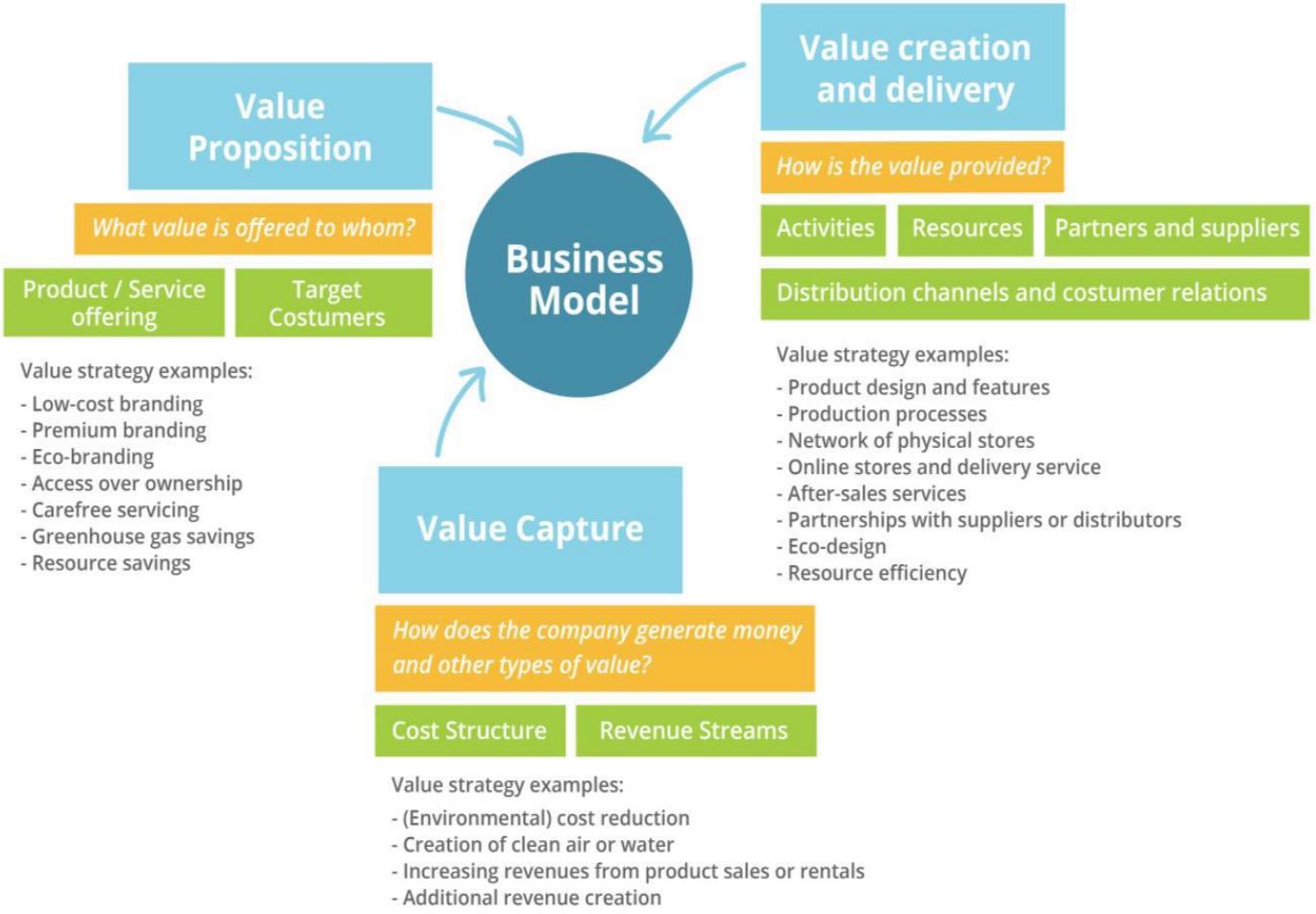
REDUCTION OF WASTE

a) Improved housekeeping,
b) changing process technology changing products
c) Recycling the process bath after concentration and filtration
d) Filtration of the produced waste solution

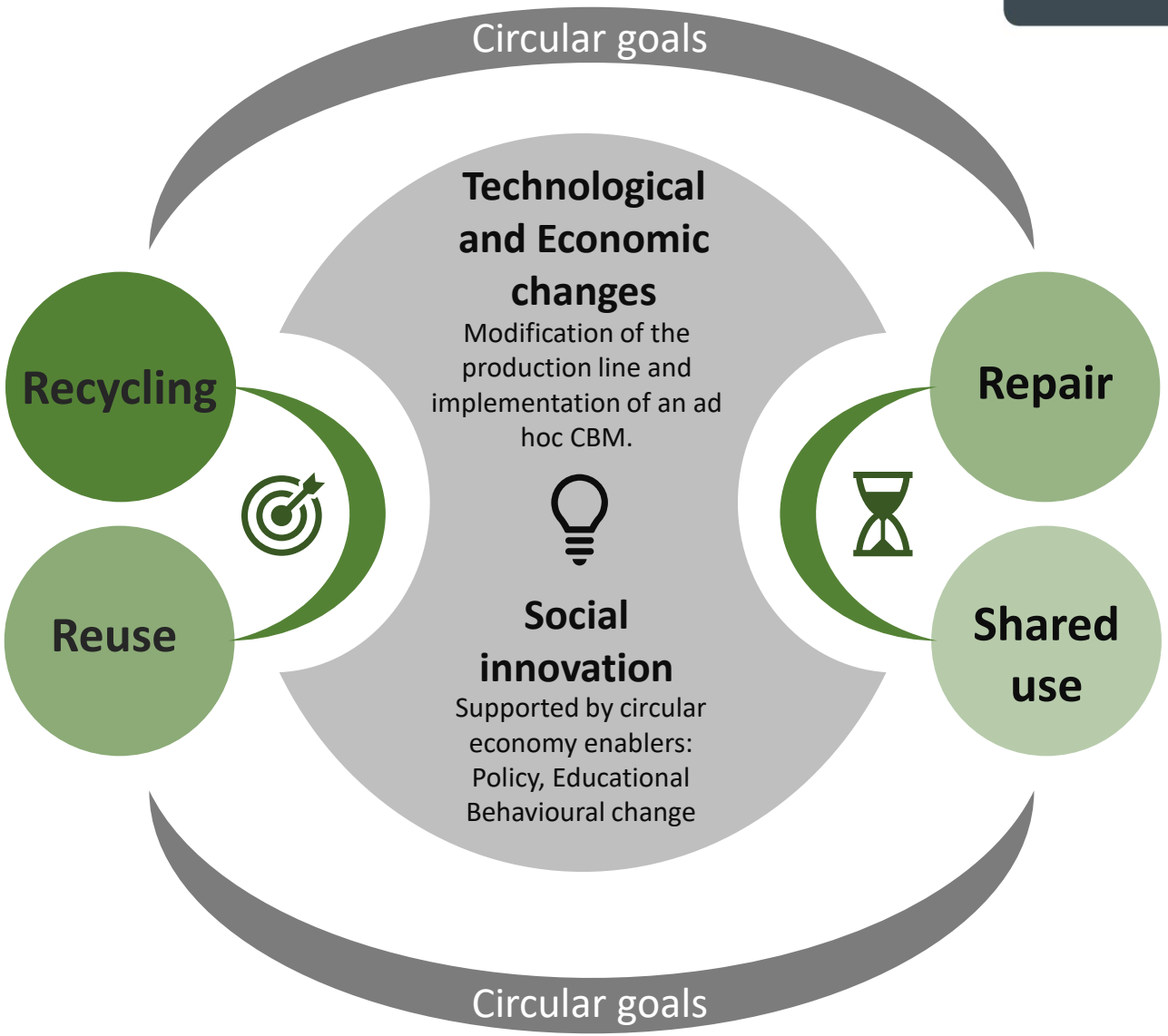
- ✓ **Increase the process efficiency (enhance the products properties)**
- ✓ **Bring economic benefit (reduce the cost of waste collection)**
- ✓ **Reduce the solid wastes (SiC or TiO_2 particles) and the nickel ions in the wastewaters**
- ✓ **This approach together with the PureNano technology ensure a more sustainable process**

Circular Business Model (CBM)

Linear Business model concept



CBM and circular goals



CBM typologies

Circular supply model

Replace the traditional material inputs derived from virgin resources with **bio-based, renewable, or recovered materials**, which reduces the demand for virgin resources and substitutes it to some extent. A company can claim green products and it reduces the supply chain risks.

Resource recovery models

Recycling waste into secondary raw materials. This business **model gives value to the materials contained in the waste streams**. This model can be applied if there is a market for secondary raw materials and if the required waste is produced in large volumes

Product life extension model

This models aim at **extending the life of products**. a) Increase the durability adapting the design, b) reuse and repair activities c) remanufacturing

Sharing model

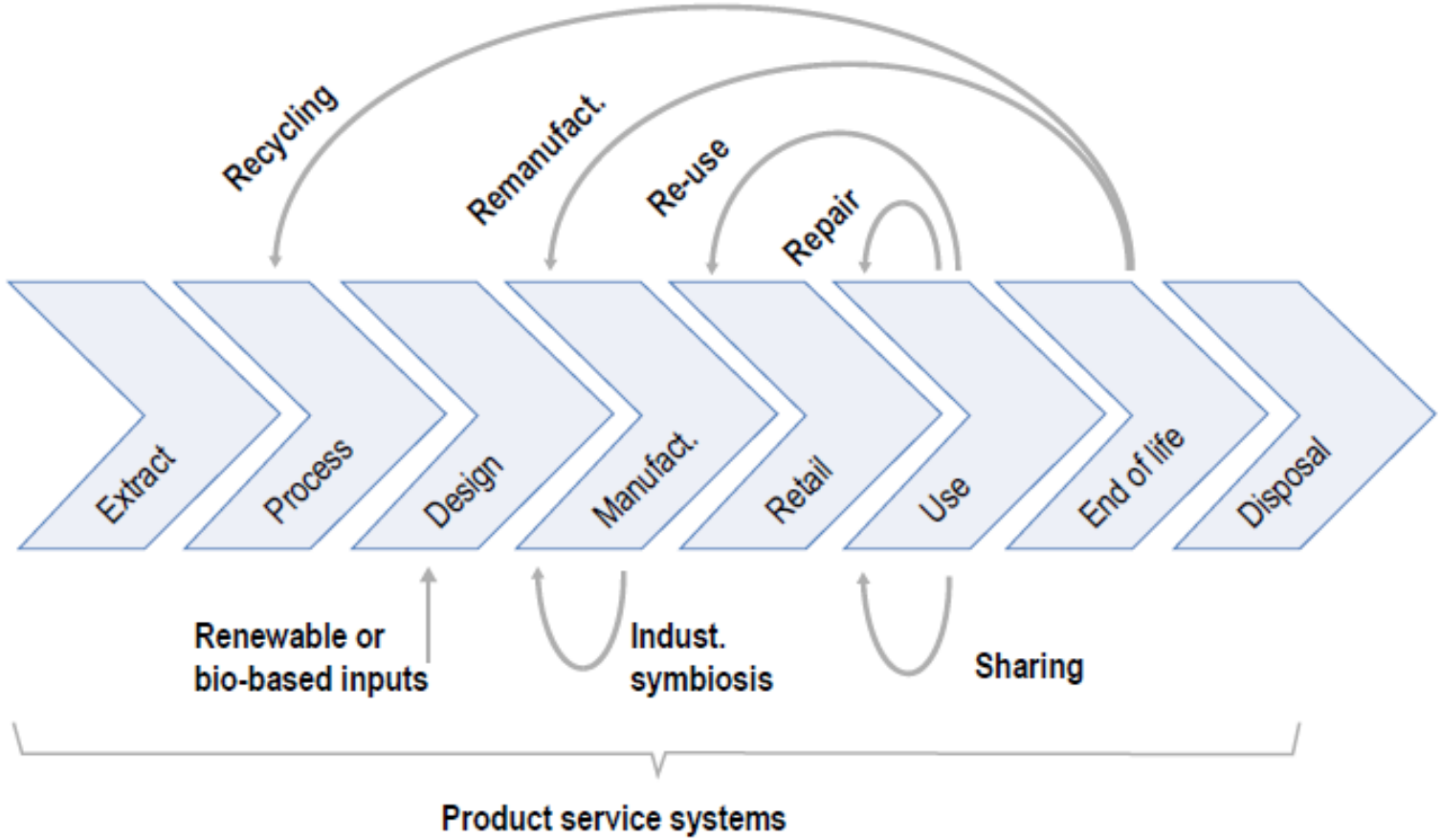
Sharing models involve the temporary, rather than permanent transfer of product ownership.

Product service system model

In this business model, instead of selling their product, the owner keeps owning it but makes it available to one or more users either through a lease contract or a rental fee.

1. **Product-oriented PSS models** are focused mostly on the product: Manufacturing firms include additional after-sales service in the value proposition.
2. **User-Oriented PSS models** focus both on products and services. Customers pay for temporary access to a particular product, typically through a short- or long-term lease agreement, while the service provider retains full ownership of the product.
3. **Result-oriented PSS models**: Instead of marketing manufactured assets or goods in a traditional way, adopting firms market the services or outcomes provided by these goods.

CBM and circular economy

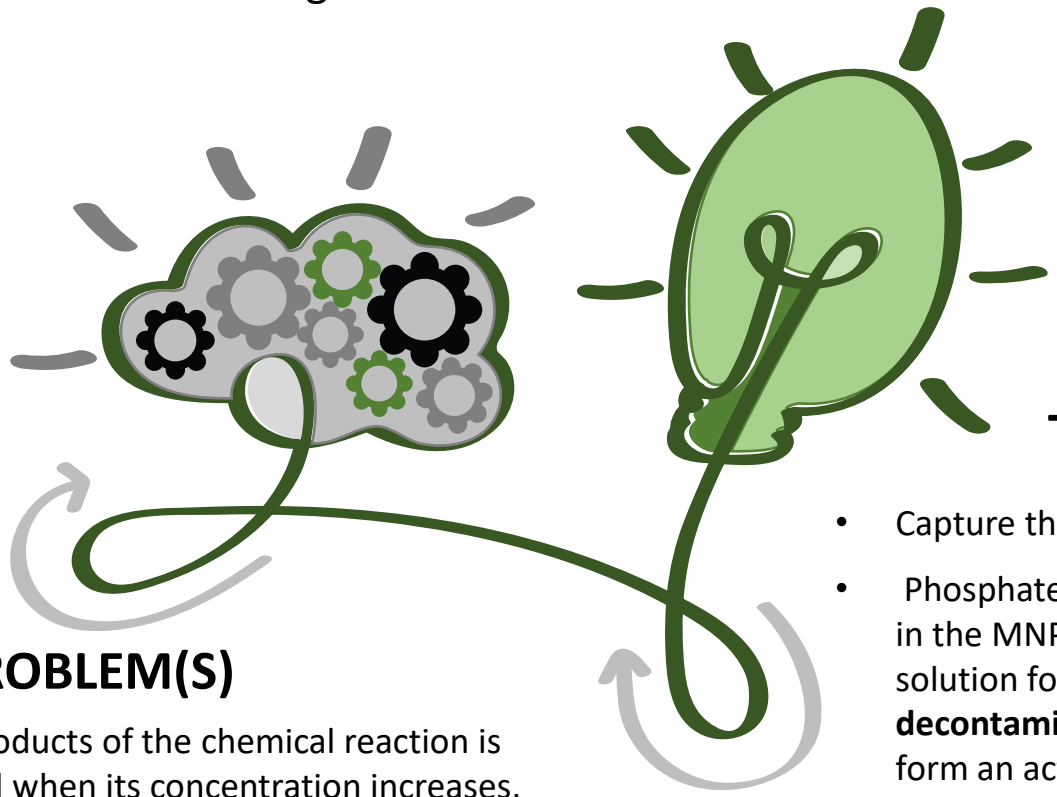


OECD (2019), Business Models for the Circular Economy: Opportunities and Challenges for Policy, OECD Publishing, Paris, https://doi.org/10.1787/g2g9dd62-en.

Application of the Best Circular Business Model to the PureNano use cases

CBM for the in-line spent bath purification system

Gaser: Electroless Nickel Plating bath



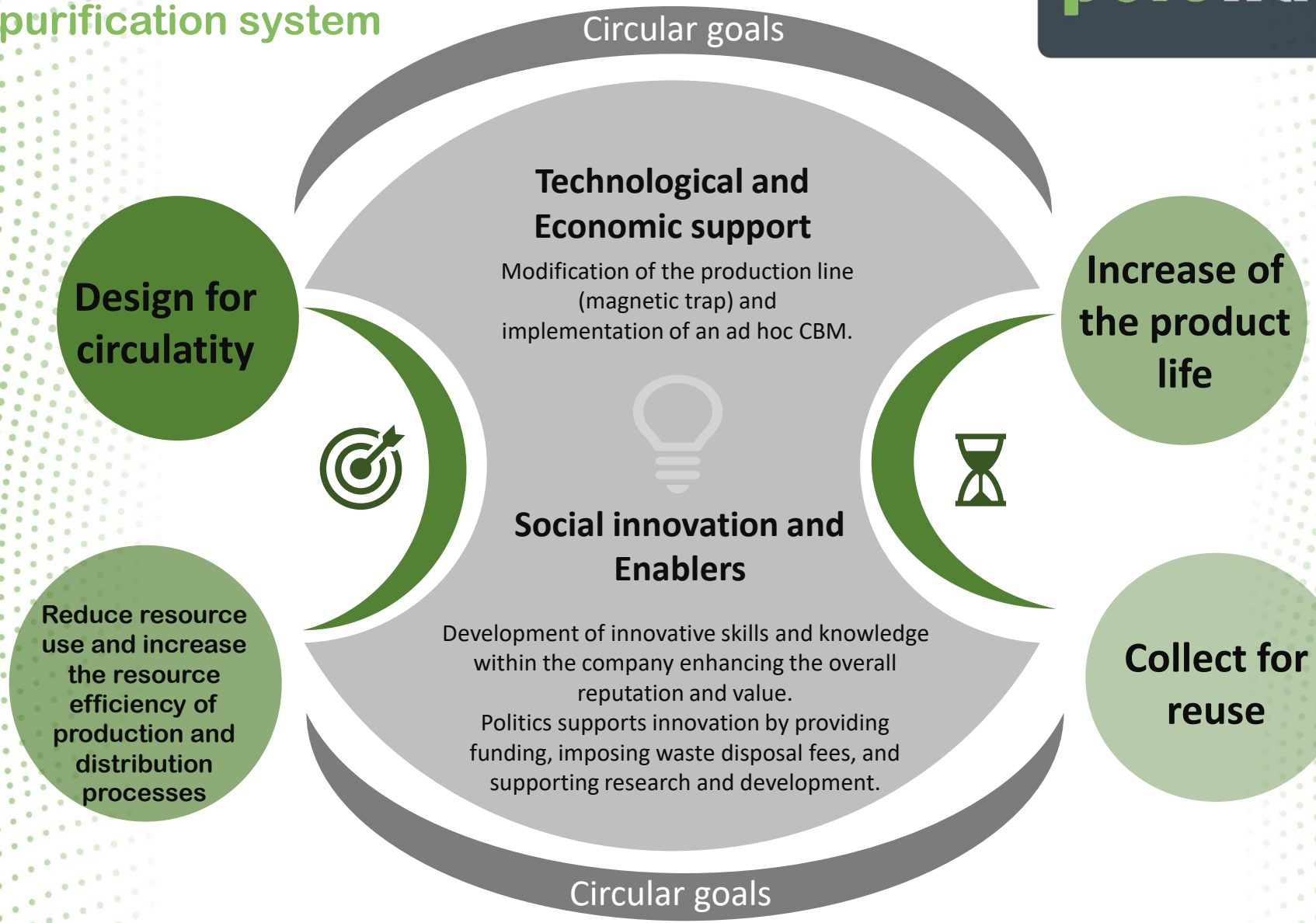
THE PROBLEM(S)

One of the main by-products of the chemical reaction is the **ortophosphite** and when its concentration increases, the nickel deposition rate decreases and the properties of the deposited layers change. **At a certain concentration, the bath cannot be used anymore and need to be chemically treated before being discharged** into a wastewater treatment system or sent to a treatment facility and then disposed of.

THE SOLUTION(S)

- Capture through cationic MNPs.
- Phosphates captured and immobilized in the MNPs can be a cheap and easy solution for **non-potable water decontamination.** The used MNPs form an active phosphate source in a dry powder and can be used for the removal of heavy metals (mainly lead, arsenic, iron and copper).

CBM and circular goals for the in-line spent bath purification system



CBM typologies for the in-line spent bath purification system

Product service system model

1. **User-Oriented PSS model**. Customers pay to access the facility, typically through a **short-long term lease agreement**, while Gaser maintains the ownership of the facility. In this case, a strong involvement of people in the process is needed and the full potential of the pilot will be exploited not only by Gaser but also by private customers willing to implement their ideas.

2. **Result-oriented PSS Model:** Gaser could indeed **offer a service** instead of the access in his facility, and take the spent bath, regenerate it, and give it back.

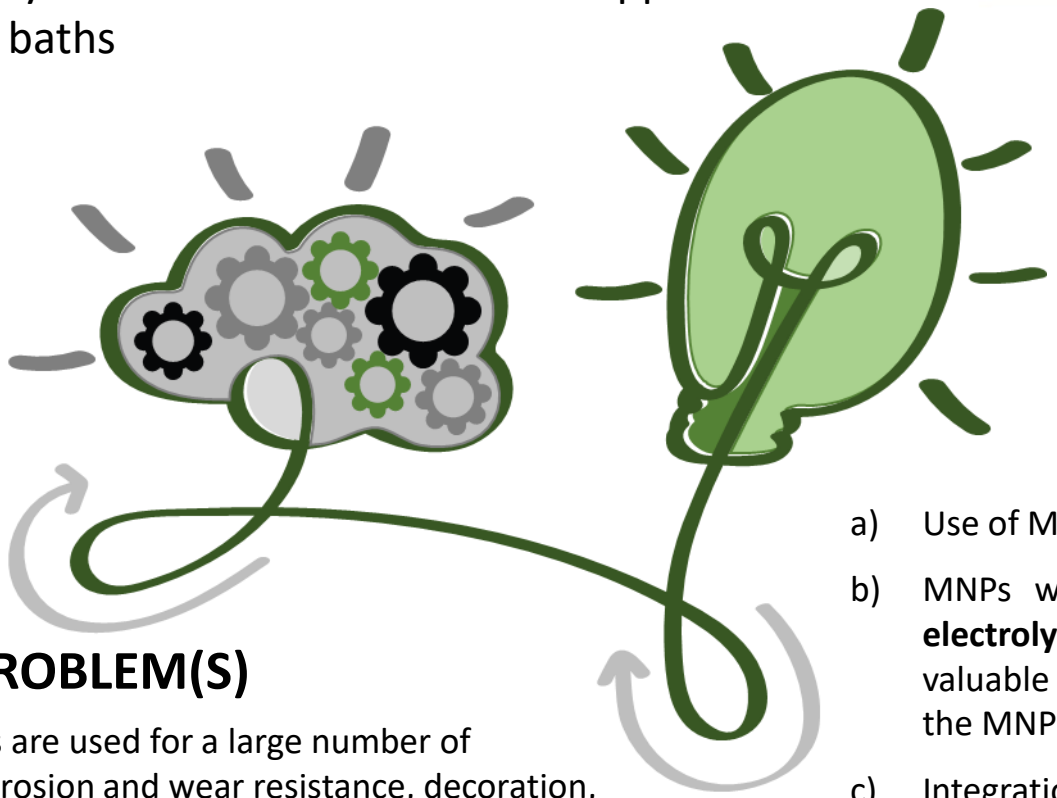
3. **Product-oriented PSS model:** Gaser could sell modular pilot plans able to regenerate the plating bath and recover materials. In addition to normal selling, Gaser could provide after-selling services such as maintenance contracts and repair offerings.

Resource recovery models

Looking at the last circular goal another business model that can be applied, is the resource recovery model in the form of industrial symbiosis. **The spent MNPs used in the recycling process can indeed be used in a water treatment plant** for the removal of heavy metals from water. The further use of the MNPs is indeed one of the recyclability goals of the PureNano project.

CBM for the portable spent bath purification system

Cnano: Electrolytic Nickel and the Zinc and Copper electroplating baths



THE PROBLEM(S)

Electrolytic Nickel baths are used for a large number of applications such as corrosion and wear resistance, decoration, electric properties etc. The bath is sensible to the presence of **impurities and the increase of Ni ions**. When the concentration increase a specific limit, the bath cannot be operated anymore. The same situation occurs with Zn and Cu plating, where the accumulation of o**rganic additives and decomposition products burdens the bath**, and the quality of the coatings is getting low

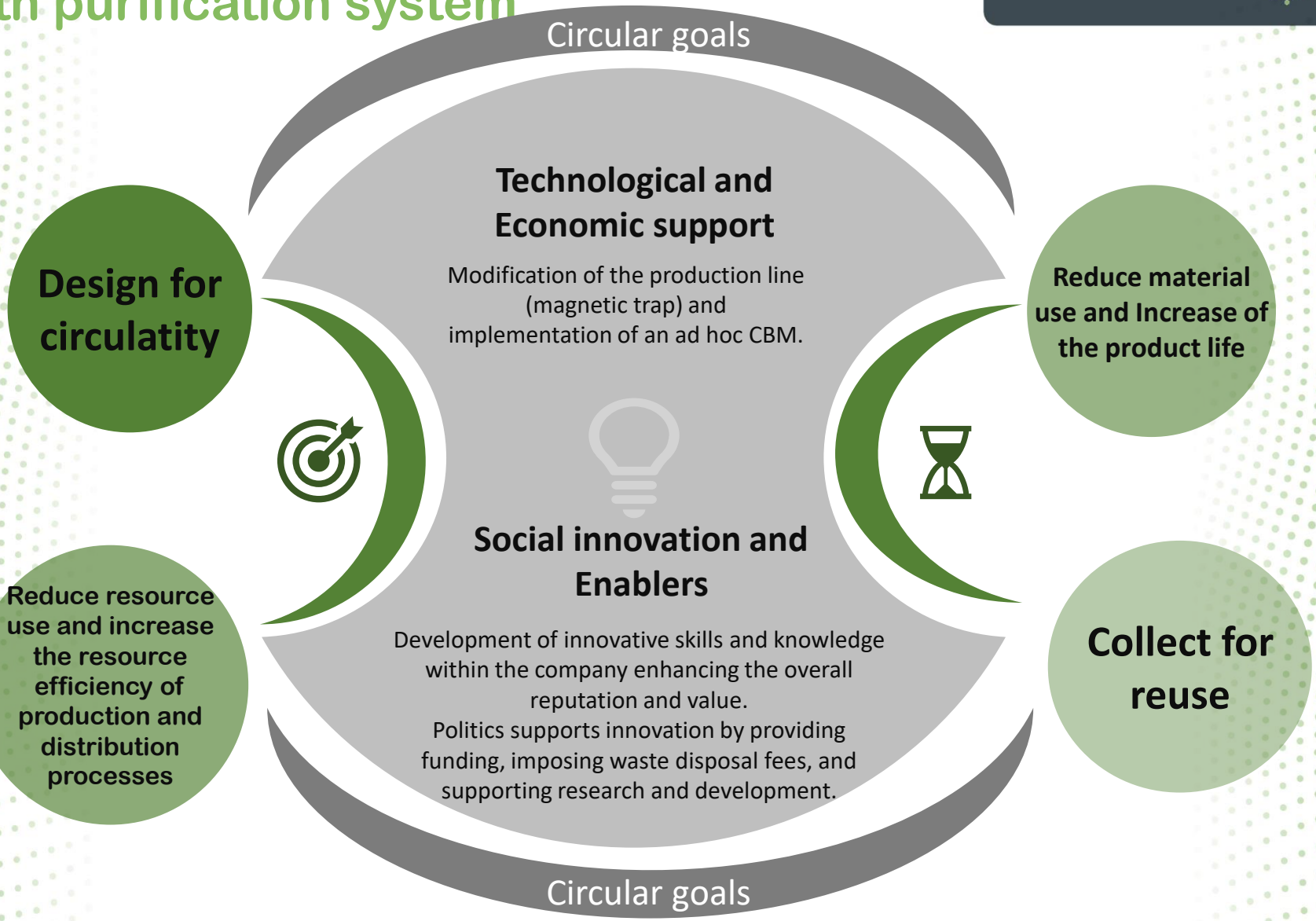
THE SOLUTION(S)

a) Use of MNPs

b) MNPs will be regenerated through **electrolytic process** to recover valuable cations (mainly Ni) and reuse the MNPs

c) Integration in concrete formulation for the production of composite reinforced concrete. The aim of PureNano is the incorporation of the recycled MNPs into cement enhancing the compressive strength of self-compacting concrete

CBM and circular goals the portable spent bath purification system



CBM typologies the portable spent bath purification system

Product service system model

1. **User-Oriented PSS model**. In this model customers pay to access the facility, typically through **a short-long term lease agreement**, while CNano maintains the ownership of the facility. Since the developed system is a portable one, Cnano could offer to the customer an in-house regeneration service. In this case, Cnano will go to the customer site, install the unit, regenerate the bath and take it back. Also, in this case, the advantage is the ownership of the equipment. In this case a strong involvement of people in the process is needed and the full potential of the pilot will be exploited not only by CNano but also by private customers willing to implement their ideas.

2. **Result-oriented PS:** Cnano could indeed **offer a service** instead of the access in his facility and take the spent bath, regenerate it, and give it back.

3. **Product-oriented business model:** CNano could **sell modular pilot plans** able to regenerate the plating bath and recover materials. In addition to normal selling, CNano could provide after-selling services such as maintenance contracts and repair offerings.

Resource recovery models

Looking at the last circular goal (g) another business model that can be applied, is the resource recovery model in the form of industrial symbiosis. The spent MNPs used in the recycling process can be **integrated into the concrete formulation** for the production of **composite reinforced concrete**. The other route is the regeneration of the MNPs. In this case, the MNPs could be regenerated **through the electrolytic process** in order to have MNPs and cations. The regeneration could be performed from the MPNs provider (Captive in this case) or in the same area of Cnano's facility.

Assessment of the CBMs applied to the Use-cases

CBM for the in-line spent bath purification system

	Product-oriented PSS	Use-oriented PSS	Result-oriented PSS	Resource recovery model
Reducing overall costs	U	U	U	U-P
Reducing business risks	U	U	U	U-P
Opening new revenue streams	P	P	P	P
Improving competitive advantage	U	U	U-P	U-P
Complying with environmental regulations	U	U	U	U-P
Reducing environmental impacts	U	U	U	U-P
Improving resource efficiency	U	U	U	U-P
Improving supply chain sustainability & provisioning	U	U	U	U-P
Reducing supply chain complexity	U	U	U	U-P
Enhancing reputation and brand value	U	U-P	U-P	U-P
Reaching new markets & countries	P	P	P	P
Developing innovative skills and knowledge	P	P-U	P	P

Paolo Rosa, Claudio Sassanelli, Sergio Terzi, Circular Business Models versus circular benefits: An assessment in the waste from Electrical and Electronic Equipments sector, Journal of Cleaner Production, Volume 231, 2019, Pages 940-952.

Conclusion

- AXIA performed a deep analysis of the circular economy concept and the role of the finishing industry for creating more sustainable processes by applying the Waste Minimization (WM) approach and the innovative PureNano methodology.
- The transition toward a more sustainable process needs the application of new technologies together with the support of new business models and social enablers
- The questionnaires that have been distributed provides an overview of the actions that can be undertaken to improve the existing technology toward more sustainable processes
- The implementation of the WM practices has shown economic and environmental benefits and at the same time the application of the selected sustainable circular business models has highlighted that in most of the cases both the provider and the final users get economic, environmental and social advantages
- It is important to highlight that this research should be further developed considering other user cases, that will implement the WM approach and the PureNano methodology at higher TRL

Thank you for your attention

Name: M.Sc. Cristina Onorato, Project Manager
Email: con@axia-innovation.com

The PureNano project has received funding from the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No. 821431