There's no end to a circle. A workshop on how to address circularity challenges in electronics

17 June 2024

Workshop B2 in Grenander 2

Electronics Goes Green 2024+, Berlin, Germany

Agenda

1. Introduction and Keynotes

- Carol Handwerker, Purdue University
  - > Circular economy for hard disk drives: a lesson in grit
- Stephan Harkema, Holst Centre
  - > Circular strategies for printed electronics

2. Overview of IPC and iNEMI

- Grace O'Malley, iNEMI
- Fran Fourcade, IPC

3. Working Roundtables: Problems

- Kelly Scanlon, IPC

4. Socialization: Solutions

- All

5. Discussion and Next Steps

- Mark Schaffer, iNEMI
- Fran Fourcade, IPC

Pre-workshop Survey Input

Survey Input

What does circularity mean to your company?

- Recycle, Refurbish or Reuse
- It is about closing the loop on the product life cycle and keeping materials at highest value as long as practical. This will ensure we meet the requirements of stakeholders and make progress to our circularity and climate goals.
- It means sustainable production for PCB.
- When done well: the opportunity for a comprehensive sustainable transformation
- Repairability, Usage of secondary materials, Reuse, Product pass, Resource efficiency during manufacturing
- It means to be able to use materials again in the next generation of products and avoiding the landfill
- Important target and future business model
- downstream materials are able to be tracked in a credible and standardized way to upstream material processors

Survey Input

Are there specific material, data, or product roadblocks preventing improvement?

- Recovery process research is still at laboratory scale, pilot projects and industry level research are needed to promote efficient and environmentally viable recovery processes.
- No suitable tools designers and engineers can use easily.
- One can not in retrospect identify what an electronic device has of chemicals, materials etc.
- Availability of material composition data, recycled content information. Transparency on components in general
- Adhesion of printed Cu layers
- Maybe some components cannot be easily recycled or reused because of contamination issues.
- The low price is an obstacle for small and inexpensive devices. With a 30 euro device that does not have a high material value, there is limited room for economic maneuver - but it should be created.
- Coordinated labels for sustainability in electronics as well as coordinated calculation bases for e.g. repair index or recyclability of a product to generate a better comparison.
- The use of plastic which needs to maintain the flammability so it can only reused and or regrinded a certain amount of time.
- Not aware of any fundamental issues but it must be also financially benefiting to make it happen widely

Survey Input

What is your circularity story today? Tell us about what you're doing now -- or have tried to do -- to address circularity challenges in electronics manufacturing.

- My current challenge is to demonstrate that critical raw materials (CRM) can be extracted from photovoltaic panels and reused in the mining production process. By leveraging the infrastructure already in place for mining, this approach could revolutionize the way we handle PV panels and contribute to a more circular economy in the PV market.
- Try to understand our current market position in terms of circularity by assessing it.
- Created a global solution to solve it
- Have multiple circularity goals and have integrate circular design requirements in all new product and packaging designs.

BUILD ELECTRONICS BETTER

Keynotes

Circular economy for hard disk drives: a lesson in grit

Carol A. Handwerker is the Reinhardt Schuhmann, Jr. Distinguished Professor of Materials Engineering and Professor of Environmental and Ecological Engineering at Purdue University. Her research areas include: developing innovative interconnect technologies for microelectronics and sustainable thin film solar cells, improving Pb-free solders interconnects for high performance systems, and integrating sustainability in new materials design. Before joining Purdue in 2005, she was at NIST for 21 years, co-leading Advanced Packaging and serving as the Chief of the NIST Metallurgy Division. She was a co-PI of SCALE, the Purdue-led, multi-university, DOD microelectronics workforce development program, co-chair of the Workforce Development Roadmap in the SRC Roadmap for Microelectronics and Advanced Packaging Technologies, served on the NIST-Department of Commerce Industrial Advisory Committee, charged with recommending how to close R&D gaps and WFD gaps for the CHIPS R&D Program, was co-chair of the iNEMI Technology Roadmap for Sustainable Electronics for several years, and co-led the iNEMI Circular Economy project on Value Recovery from End-of-Life Hard Drives.

Creating a Circular Economy for Used Hard-Disk Drives: *A Lesson in Grit*

Carol Handwerker
Purdue University
DoE Critical Materials Institute
iNEMI

Advancing manufacturing technology

Circular Economy for Used Hard-Disk Drives

iNEMI Phase 2 project – completed Oct. 2018

- **Demonstration of circular economy pathways for HDDs:**
  - **technologies, supply chain, economics, logistics**
- **In-kind funding model -**
  - **self-assembling and self-managing group setting common goals (Ostrom framework)**

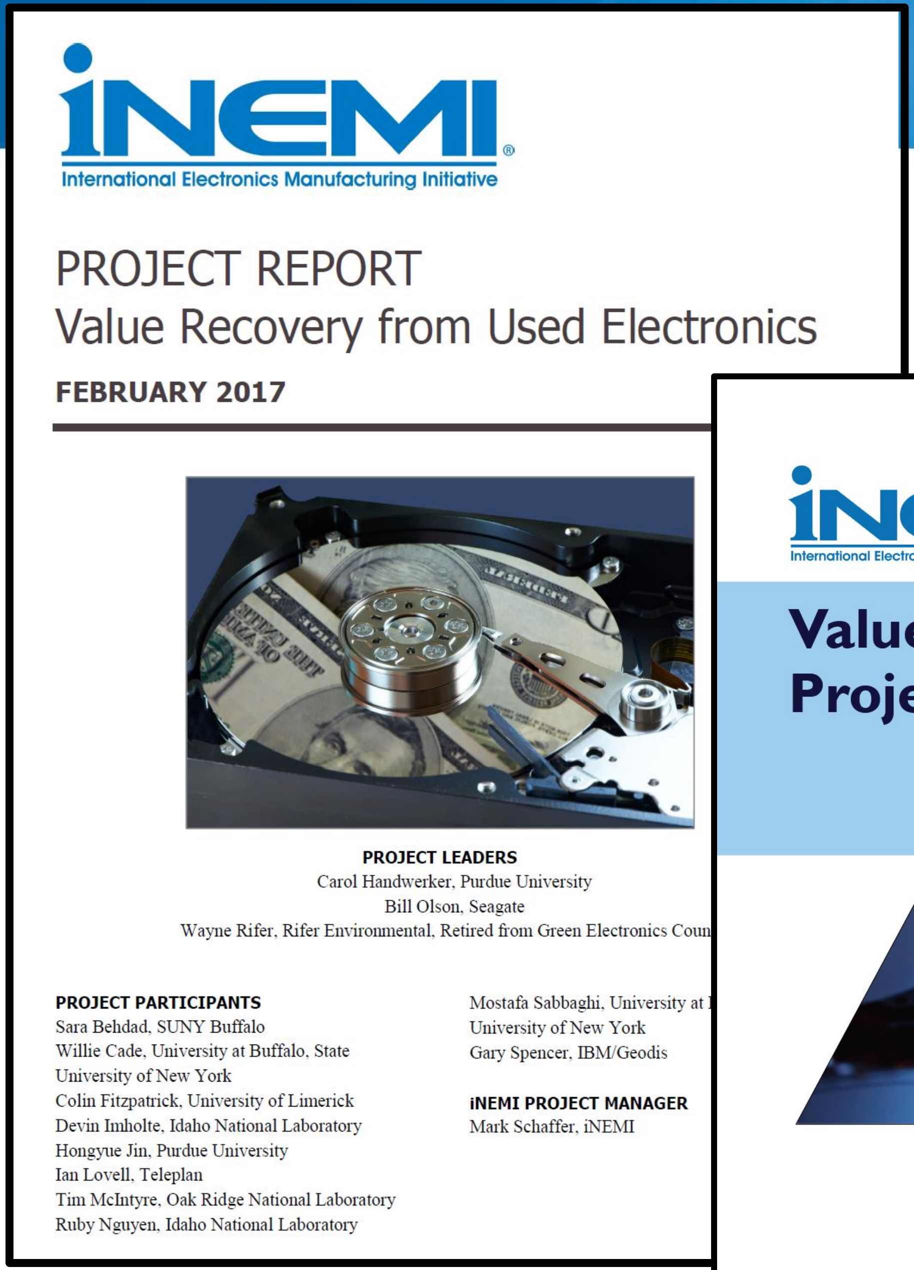
Critical Materials Institute
AN ENERGY INNOVATION HUB

Members:

Ames Lab, Cascade Asset Management, Cisco, Critical Materials Institute, Google, Green Electronics Council, IBM-Geodis, Idaho National Lab, Microsoft, Momentum Technologies, Oak Ridge National Labs, Purdue University, Seagate, Teleplan, University of Arizona, Urban Mining Company

Discussions with: NIST, Tradeloop, NATO, NAID, Western Digital …

iNEMI Program Manager: Mark Schaffer (marks@inemi.org)



iNEMI
International Electronics Manufacturing Initiative

PROJECT REPORT
Value Recovery from Used Electronics

FEBRUARY 2017

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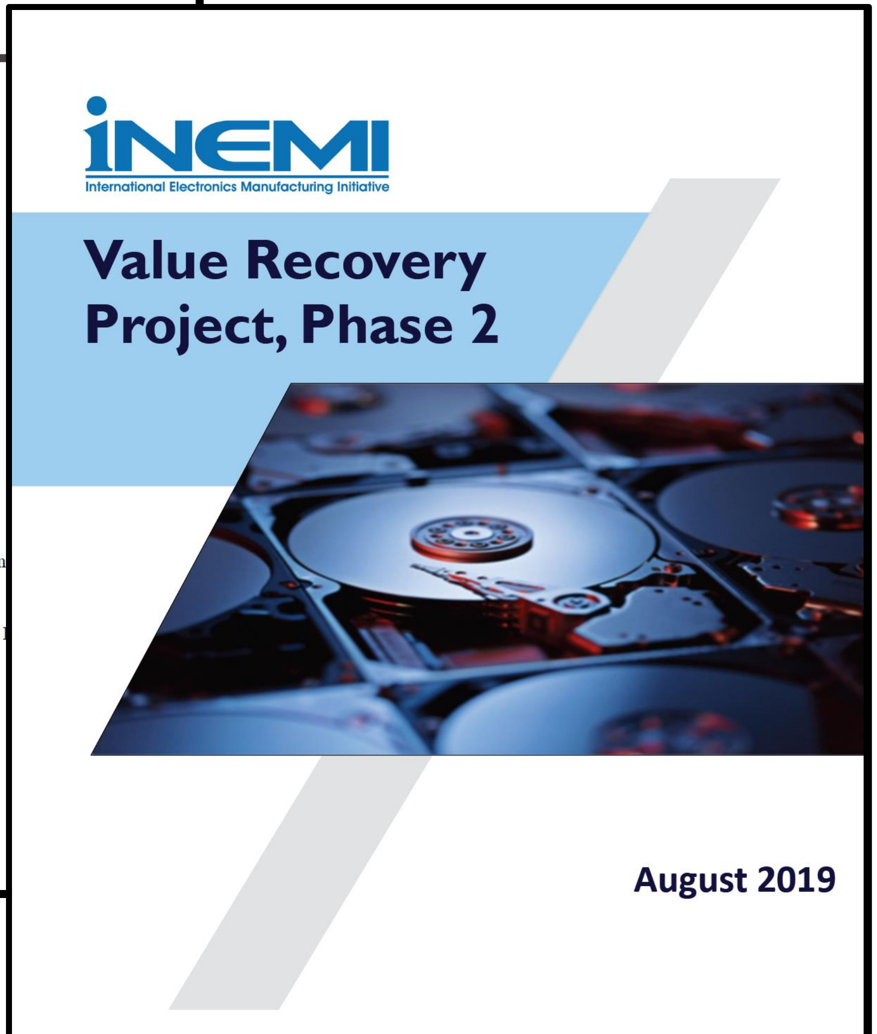
iNEMI PROJECT MANAGER
Mark Schaffer, iNEMI



iNEMI
International Electronics Manufacturing Initiative

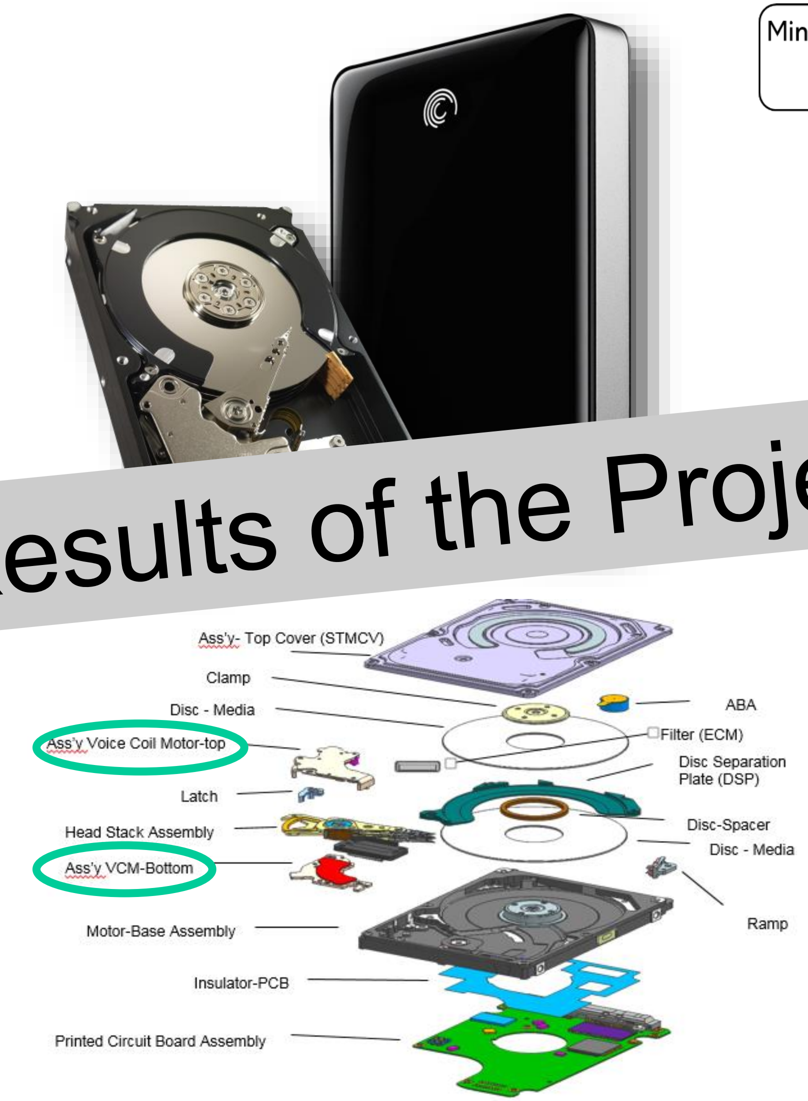
Value Recovery Project, Phase 2

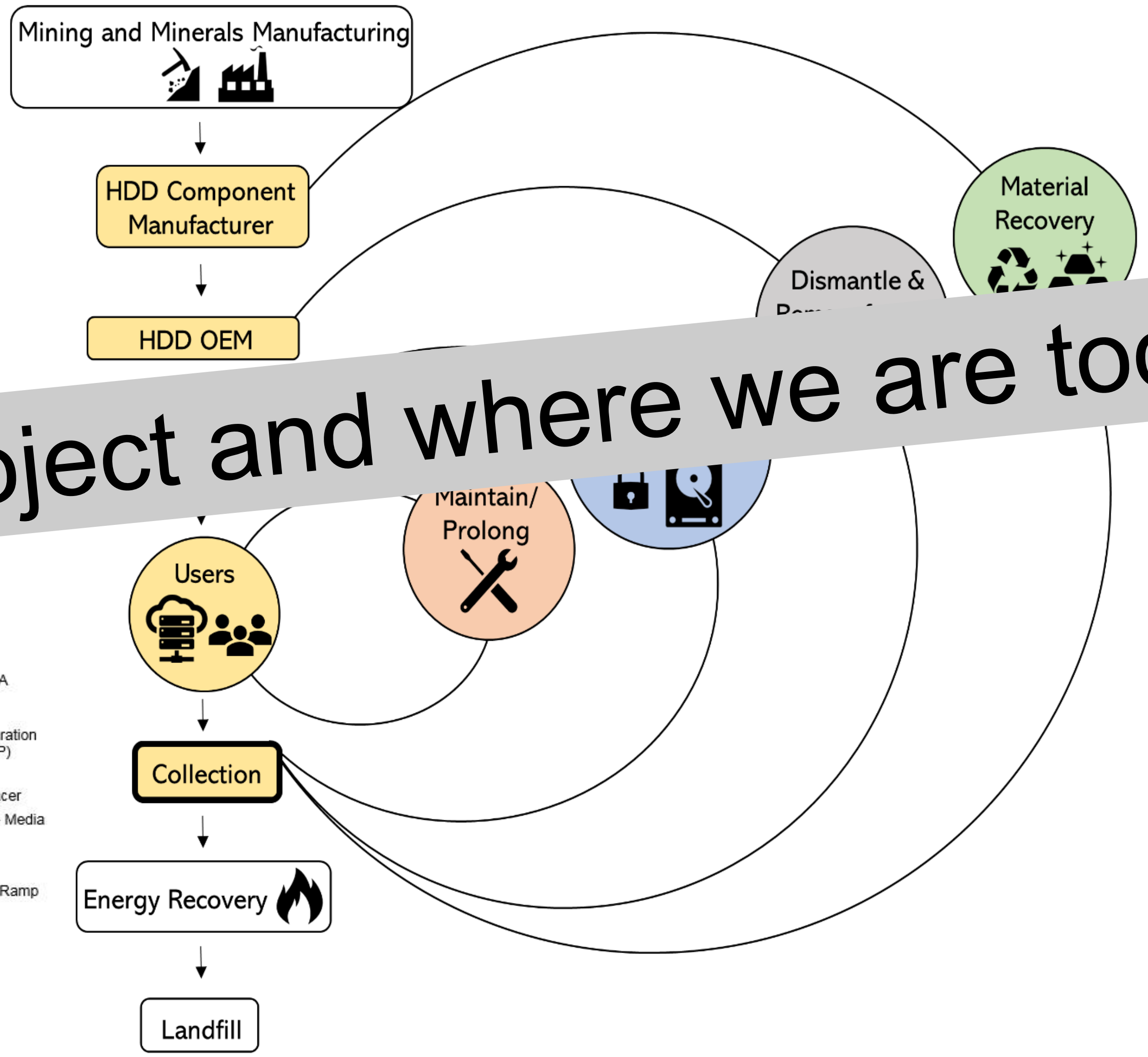
August 2019

Phase 1 and 2 Reports can be downloaded

www.inemi.org

Creating a Circular Economy for Used HDDs





Results of the Project and where we are today

International Electronics Manufacturing Initiative (iNEMI)

- not-for-profit, highly efficient R&D consortium of 80+ leading electronics manufacturers, suppliers, associations, government agencies and universities
- roadmaps the future technology requirements of the global electronics industry
- identifies and prioritizes technology and infrastructure gaps
- helps eliminate those gaps through timely, high-impact deployment projects conducted by iNEMI members – all in-kind funded

Creating a Circular Economy for Used HDDs

An Example of a New Circular Economy

- Hard disk drives in hyperscale data centers
- System approach, leadership, trust, and quantification
- Must be representatives of all steps in the supply chain at the table
- Aim for the highest value recovered – anything less is risky
  - Reuse of HDDs – wiping, sale, repair
  - Reuse components = remanufacturing
  - Recycle materials – as REE powder, as metal

Tools

- iNEMI – Major electronics consortium
- Ostrom Framework for Sustainable Social-Ecological Systems
- Shared goals, reinforced by action
- Honest communication, setting boundaries, constant testing of ideas and decision-making criteria

Ostrom Framework

Elinor Ostrom

Nobel Prize in Economic Sciences 2009

PERSPECTIVE

SCIENCE VOL 325 24 JULY 2009

A General Framework for Analyzing Sustainability of Social-Ecological Systems

Elinor Ostrom[1,2*]

A major problem worldwide is the potential loss of fisheries, forests, and water resources. Understanding of the processes that lead to improvements in or deterioration of natural resources is limited, because scientific disciplines use different concepts and languages to describe and explain complex social-ecological systems (SESs). Without a common framework to organize findings, isolated knowledge does not cumulate. Until recently, accepted theory has assumed that resource users will never self-organize to maintain their resources and that governments must impose solutions. Research in multiple disciplines, however, has found that some government policies accelerate resource destruction, whereas some resource users have invested their time and energy to achieve sustainability. A general framework is used to identify 10 subsystem variables that affect the likelihood of self-organization in efforts to achieve a sustainable SES.

Fast Turn Project –
Value Recovery from Hard Disk Drives

Momentum within the community –

Seagate President

'Hard drives from hard drives"

Critical Materials Institute (CMI), iNEMI Phase 0 and Phase 1, Seagate, Google, Teleplan/Reconext, and Urban Mining Company were examining various approaches to value recovery for HDDs:

- **new technologies for removing and reusing magnets from HDDs in new HDDs and for critical materials recovery**
- **economic, life cycle, and logistics analyses to examine the viability of various scenarios for used HDDs and other used electronics**

iNEMI

Phase 2 iNEMI Project – Value Recovery from Hard Disk Drives

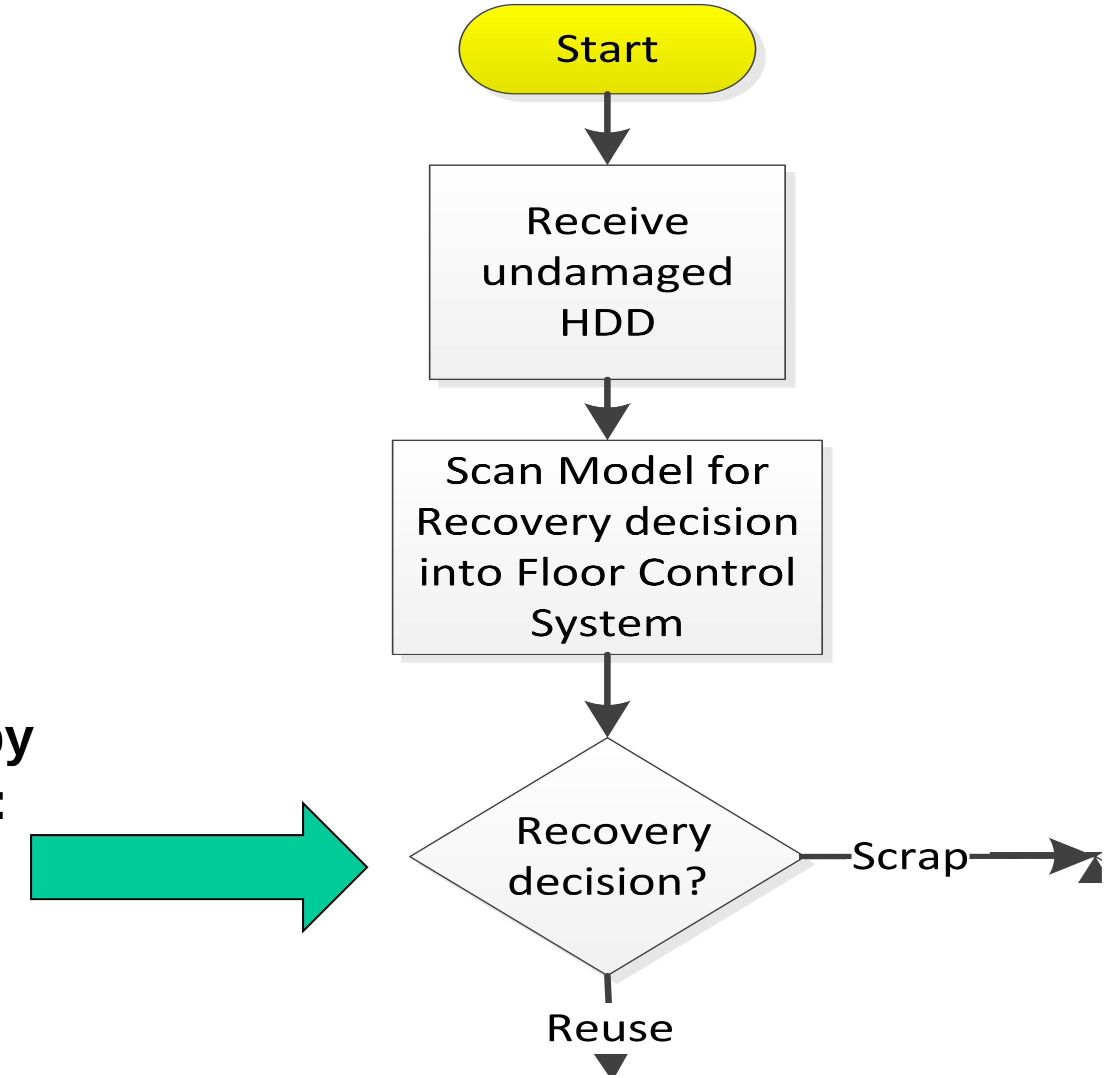
Project Members had a common goal and formed a complete supply chain

- **HDD Manufacturers – Seagate**
- **HDD Users – Cisco, Google, Microsoft**
- **Authorized After-market Service Providers – Teleplan/Reconext**
- **Recyclers and IT Asset Management Companies – IBM - Geodis, Cascade Asset Management, Echo Environmental**
- **Secondary Market Buyers and Sellers – connected through recyclers**
- **Magnet Value Recovery Companies - Momentum Technologies, Urban Mining Company/Noveon**
- **After First-Market Users - consumers, data center, enterprise, cloud, computer – connected through HDD Users + AM Service Providers**
- **Technology Developers – research organizations (national labs, universities, all the above) – CMI – Ames, INL, ORNL, Purdue**
- **Standards organizations – GEC (EPEAT)**

Decisions about Common Pool Resources

Focus on Key Decisions and the People Who Make Them

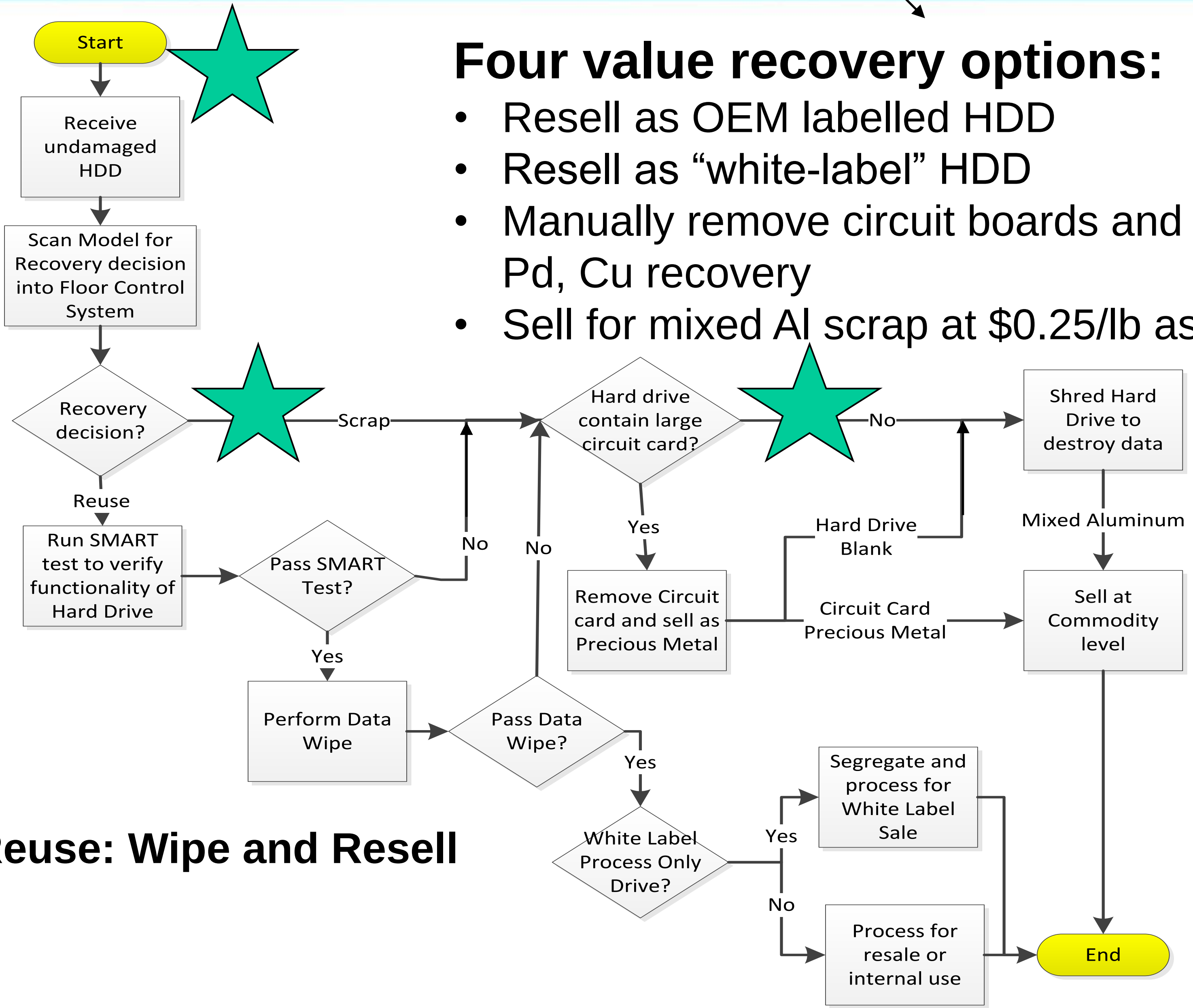
Determined by HDD Owners:
- **Google**
- **Microsoft**
- **Cisco**



Pre-Project Decision Tree for Used HDDs

Four value recovery options:

- Resell as OEM labelled HDD
- Resell as "white-label" HDD
- Manually remove circuit boards and sell for $7-$9/lb for Au, Pd, Cu recovery
- Sell for mixed Al scrap at $0.25/lb as shred or whole



Expand Options

Reuse: Wipe and Resell

iNEMI

Phase 2 iNEMI Project – New Technologies for Value Recovery

Pre-Processing

- Voice Coil Magnet Assembly Reuse
- Automated Magnet Punching
- Shredding with Separation

- Techno-economic analysis
- Life cycle analysis
- Logistics & supply chain analysis

Magnet Powder

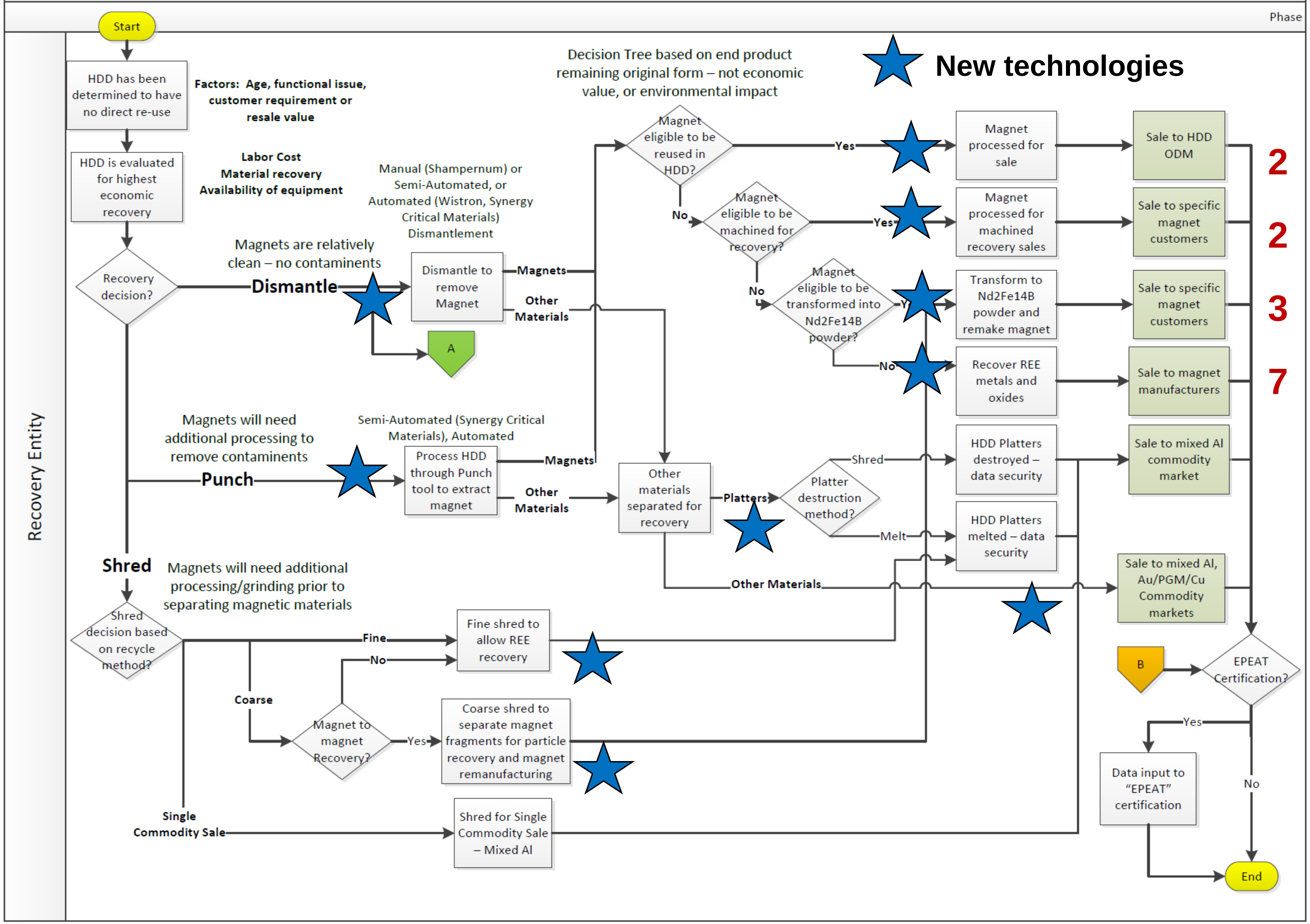
- Magnet to Magnet Processing: hydrogen decrepitation of magnets

Metals Recovery

- Acid-Free Dissolution and REO Recovery
- Membrane Solvent Extraction
- Biosorption & Bioleaching
- Electrochemical Metal and REO Recovery from Complex e-Waste
- Selective Sulfation of Shredded HDD Magnet Fractions
- Super-Critical Fluid Extraction
- Low Temperature β-diketonate Separation Processes
- Electrochemical Deposition of High Purity RE Metals using RTIL

iNEMI

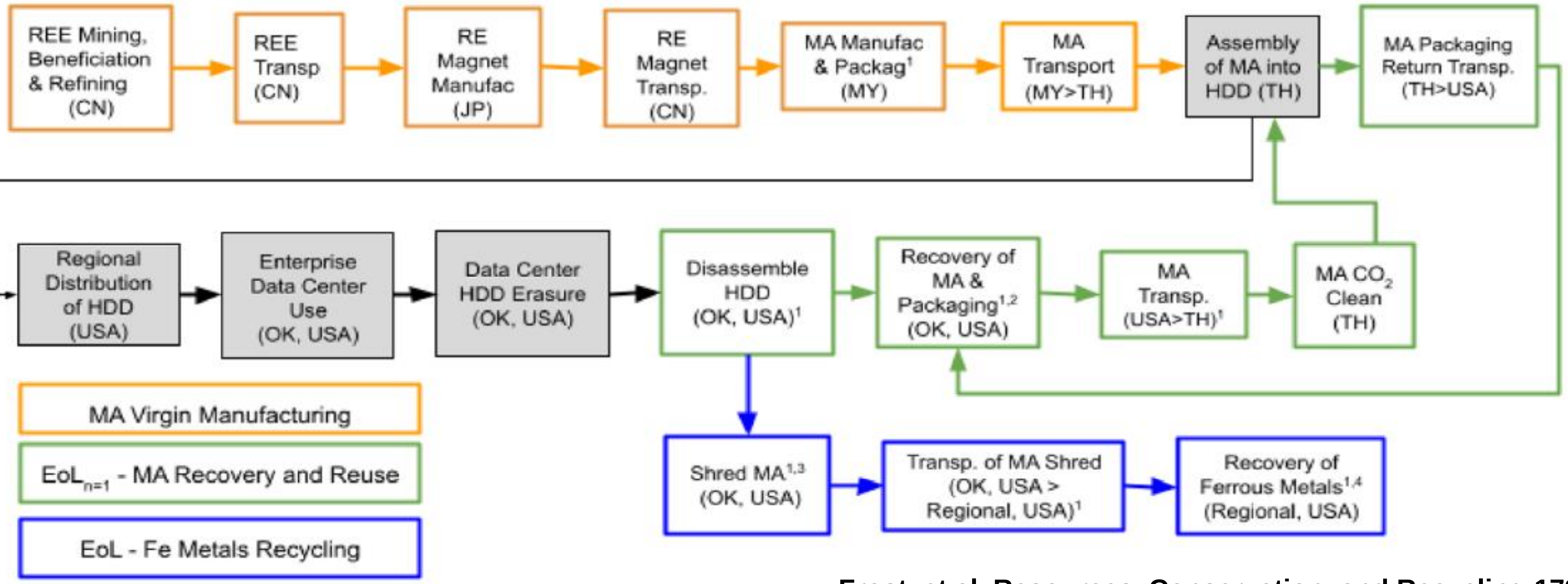
Decision Matrix – Magnet Focused recovery V9



Importance of this project

- Team analyzed the logistics and economics of secure, verifiable data wiping and identified barriers to its acceptance
- Team demonstrated cascading CE pathways: reuse of HDDs, recovery of VCMAs for reuse in new HDDs and REE recovery
- Team identified 5 pathways for high volume REE value recovery. Demonstration projects were created to assess overall feasibility.
- In the project and where they are now:
  - VCMA Recovery and Reuse: Seagate, Google, Teleplan/Recontext, Purdue – proof-of-concept tests – 6 HDDs
  - Magnet-to-Magnet Processing: Urban Mining Company/Noveon
  - Acid-Free Dissolution of REE Magnets: Seagate, Ames Lab

iNEMI



Frost, et al. Resources, Conservation, and Recycling 173 (2021) 105694

Pilot Project (2019)

- Google removed VCMAs from 6,100 enterprise helium Seagate HDDs in Oklahoma USA.
- Seagate arranged an exemption for shipping VCMA “e-waste” into Thailand and shipped them to Seagate manufacturing facility in Thailand
- Seagate cleaned VCMAs and used them in manufacturing 6100 new HDDs Sparked proof-of-concept Seagate project on PCBA reuse with Google and PCBA supplier
- Completed detailed LCA in 2021 with manual and automated disassembly showing automated disassembly needs to operate 24/7 + co-recovery of VCMAs, PCBAs, and other components
- Logistics issues: Can be used only in one drive model still being manufactured. Time for HDD retirement varies so uncertain recovery rate. Cost of logistics too high with recovery in US and HDD manufacturing in Asia

Where are we today?

Seagate - 2023

FY2023 Circularity Program Indicators

Extending Product Life

- 1.19 million HDDs and SSDs

Drives Returned to Service

HDDs: 1,174,939
SSDs: 15,043
Total: 1,189,982

Material Recycling

- Scrap Aluminum: 43.2 metric tons
- Scrap Magnets: 1.31 metric tons

Reconext

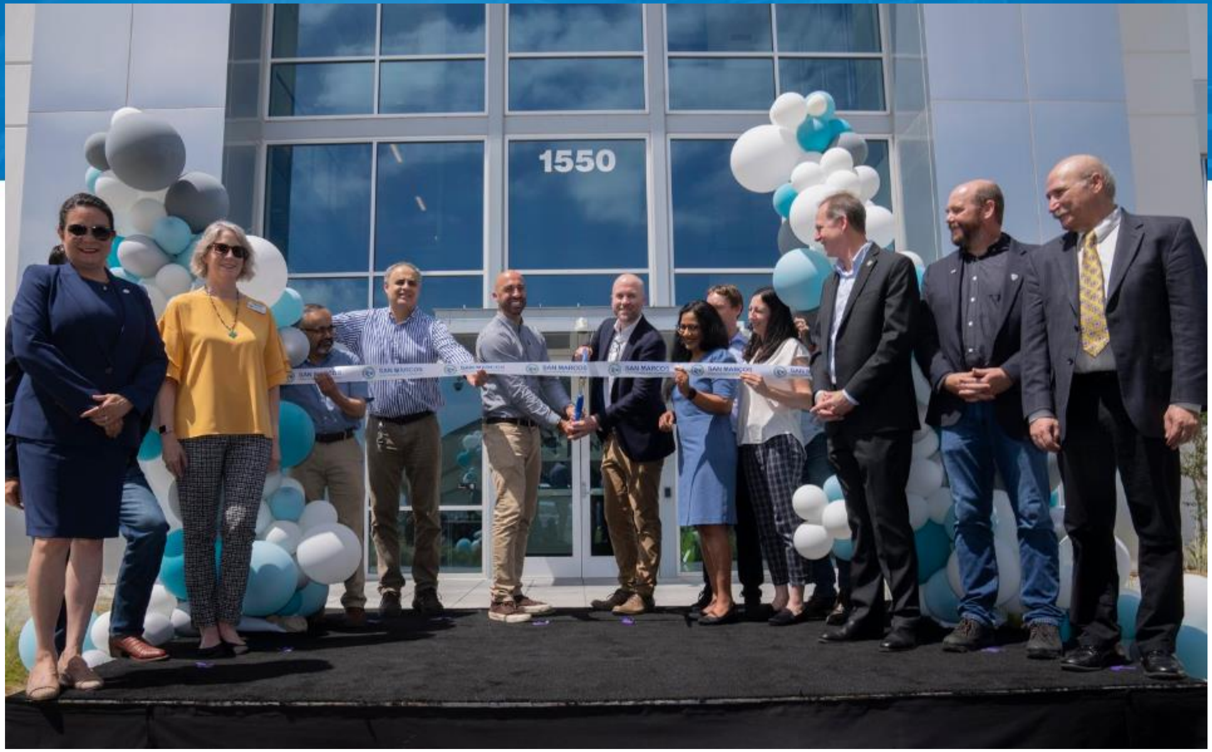
In partnership with **Dell, Seagate, Goodwill**, Reconext developed a process to reclaim rare-earth magnets from used hard drives, leading to 8600 kg REE magnets recovered in 2021. Finalist for **Data Centre Sustainability Project of the Year** in 2022

Wipes and sells HDDs as after-market service provider for **Seagate and WD**

After-market service and pre-market loaners and try-out for **Cisco**

Cloud Providers – higher priorities

- Net zero
- Energy efficiency
- Plastics recycling
- Higher volume, commodity materials
- Recycling of consumer products

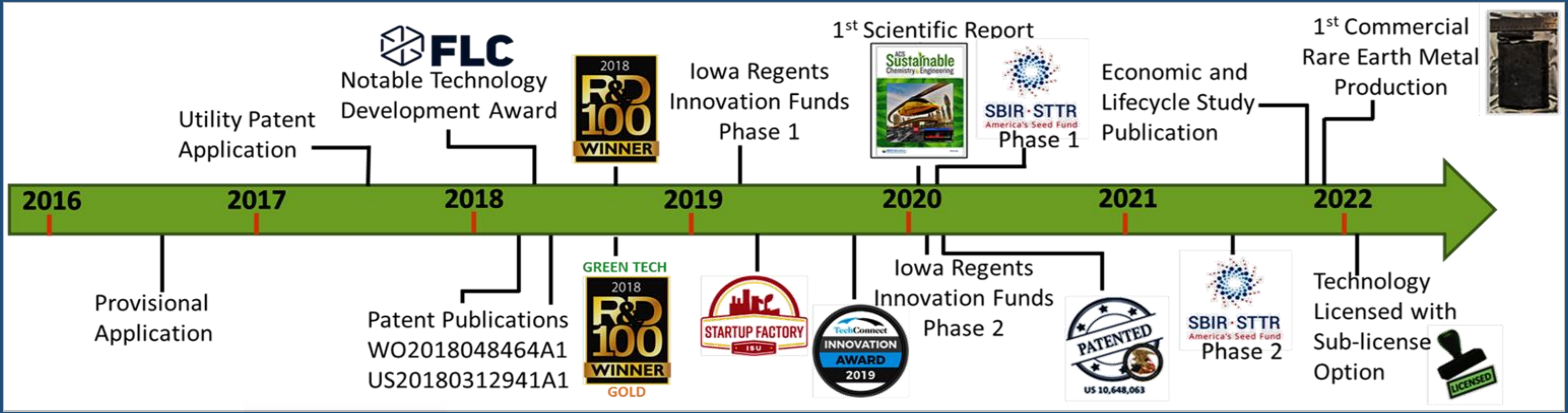


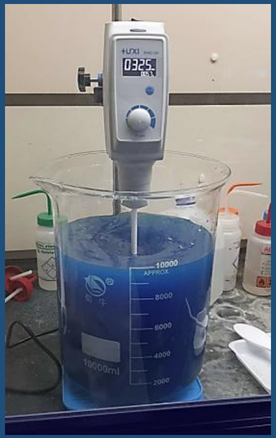
Noveon / Urban Mining Company

- Opened 150,000 sq ft facility (14000 m^2) in Texas in 2023
- Need much higher volumes than available from HDDs: wind turbines, electric scooters, and others
- Developed and patented high performance magnets with less REE than original
- Still in operation

Note: Hitachi developed integrated HDD recycling facility in 2013 and shut down due to lack of HDD supply

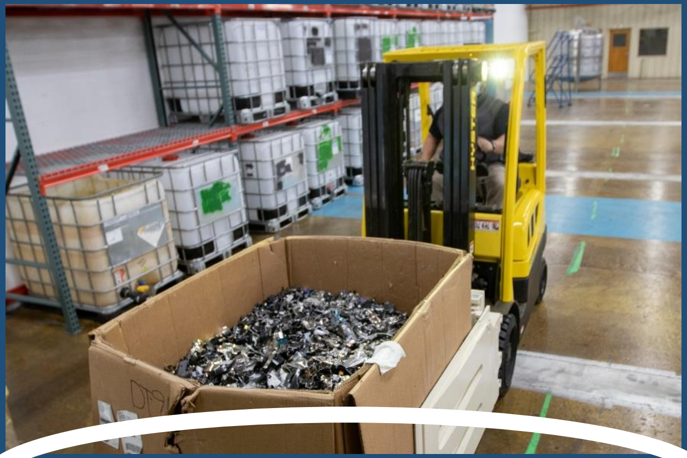
Acid-Free Dissolution Maturation Timeline





Grams-to-kilograms scale

10s of kilogram

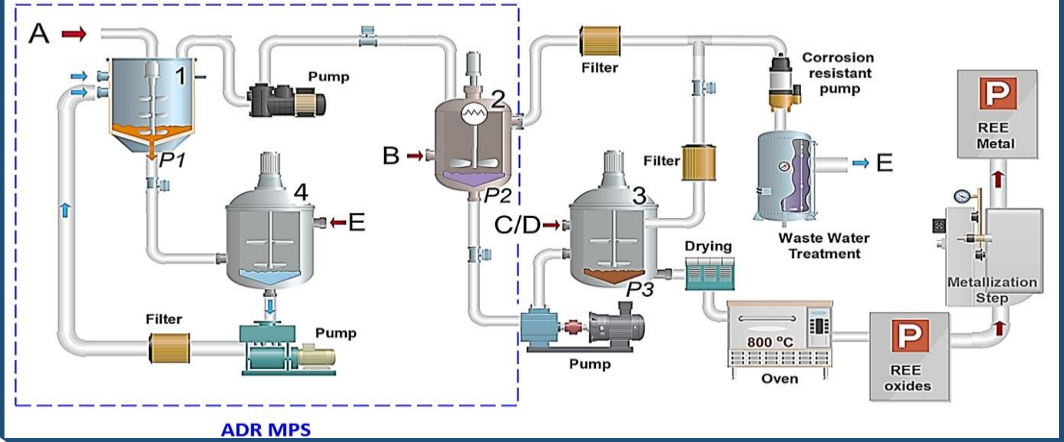


100s of kilogram

Acid-Free Dissolution Start-Up: TdVib

Process Modularization

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
ADVANCED MATERIALS & MANUFACTURING TECHNOLOGIES OFFICE

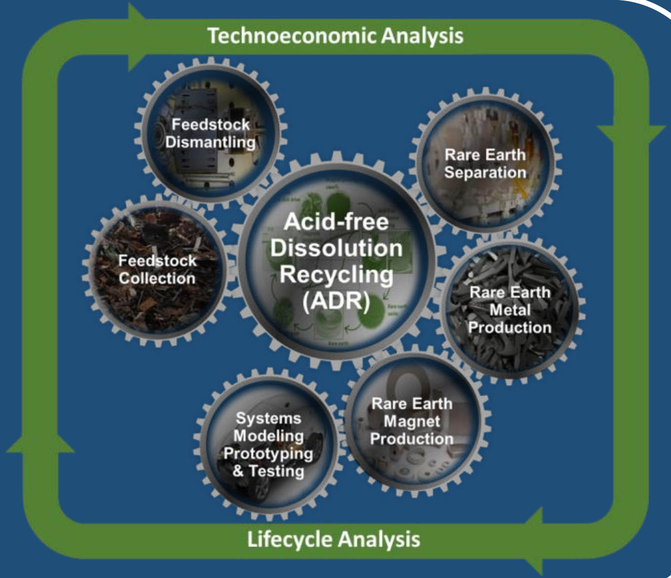


Electric Vehicles & Wind Turbines

SBIR·STTR America's Seed Fund

Value-chain integration

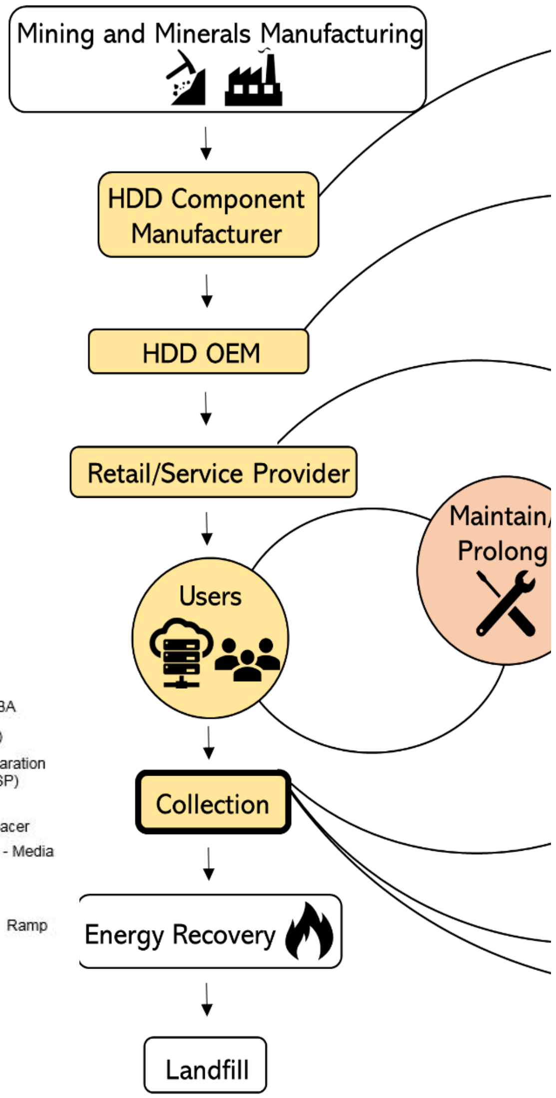
National Science Foundation



How to Engage

- Small-scale research
- Pilot-scale demonstration
- REE recovery service contracts
- Sub-licensing with/without MPS
- Others

Creating a Circular Economy for HDDs



Lessons Learned

- Project made us all smarter
- Have the full supply chain at the table – decision makers required
- Proof test the value for all companies in the supply chain – everyone must be honest
- Aim for the highest value
- Aim for the highest volumes
- Don't underestimate the difficulty or time to execute
- Analyze the logistics, LCA,TEA early and often
- Work fast - situations change
- Play the long game

Circular strategies for printed electronics

Stephan Harkema is a highly motivated and creative program manager. He has a PhD in Polymer Chemistry and close to 20 years of experience in research & development. At TNO at Holst Centre, he has been working on high-tech applications in both private and public funded projects with high customer satisfaction rates. For roughly a decade, he has studied flexible OLEDs for lighting and signage applications and - in hindsight - made his first strides in sustainable developments by reducing the amount of Indium in those OLEDs. In 2017, his focus shifted to Structural Electronics, particularly to human-machine interfacing using Hybrid & Printed Electronics as well as light management. Since early 2021, Stephan has been leading a team that leverages TNO's broad range of expertise to develop sustainable solutions for in-plastics embedded electronics. His findings have been published in multiple peer-review publications and are protected through well over a dozen patent applications.

Dr. Stephan Harkema
Program Manager

Circular Strategies for Printed Electronics

Workshop Circularity Challenges in Electronics Manufacturing
Electronics Goes Green 2024

Holst Centre – Workshop IPC/iNEMI - Dr. S. Harkema

Holst Centre
powered by imec & TNO

Who we are?

- Independent, non-for-profit R&D institute
- Founded in 2005 by two organizations:
  - TNO (NL, 4400 people)
  - imec (BE, 4300 people)
- Around 260 own employees, all located in Holst Centre premises

Our Location: High Tech Campus in Netherlands

- ***Site-sharing***: **>200 companies, >12000 researchers**
- ***Own facilities:*** **R&D labs, pilot manufacturing facilities for Printed and Flexible Electronics**
- ***Facility-sharing***: **Shared cleanroom and materials analysis**

Tech solution for a recycling problem?
(Or just go back to the old days?)

Automatic drip brewing

In 1954, the Wigomat, a German coffee maker, became the world's first electric drip brewer.

Single-serve coffee machines: pod-based systems

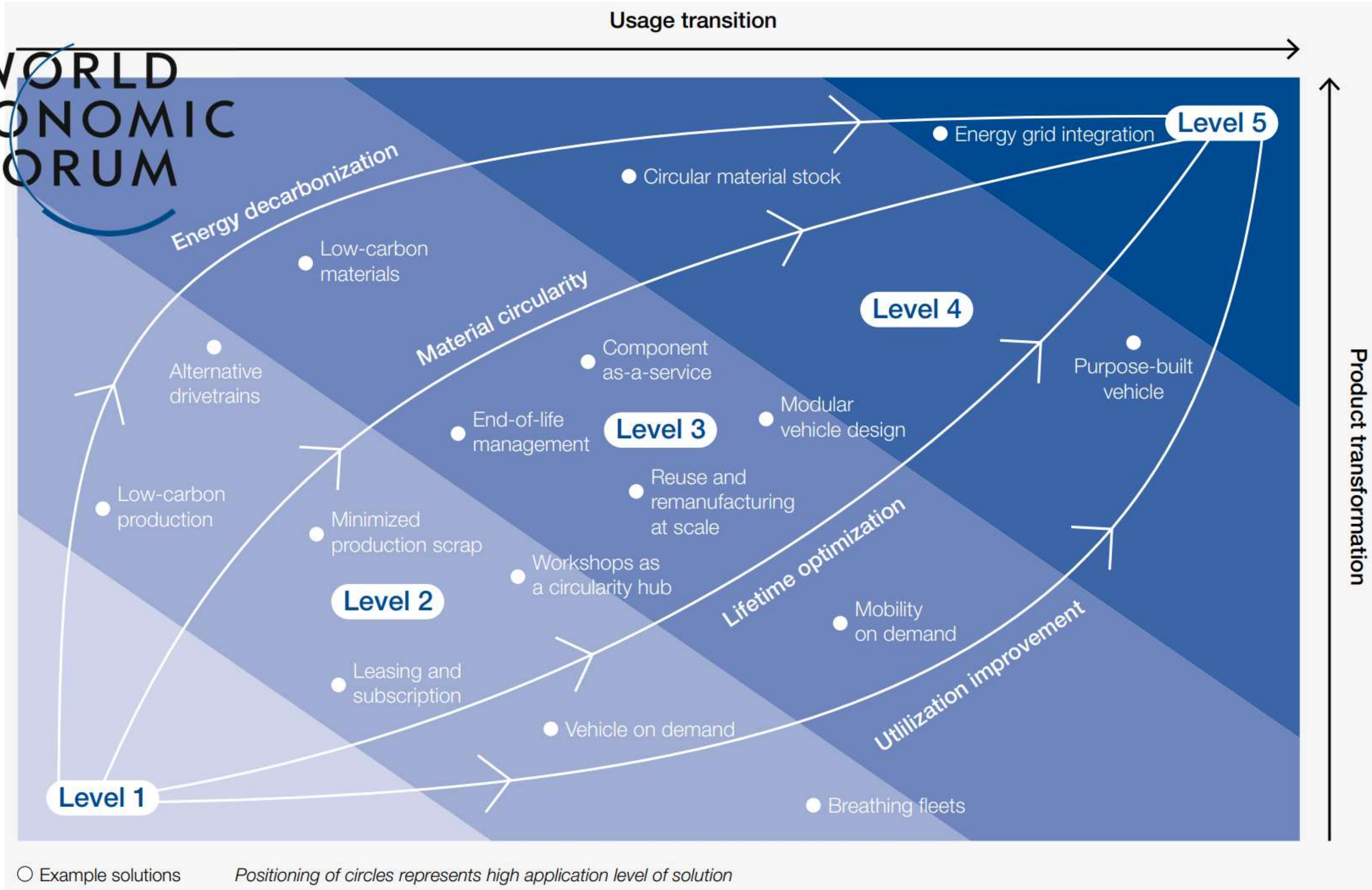
Former Nespresso boss warns coffee pods are killing environment - ABC News

- *"end up on a landfill"*
- *"recycling doesn't really work"*
- *"Aluminium capsules have to be shredded, coffee has to be taken away with water, the varnish to be burnt and aluminium has to be re-smelted again"*

Smart coffee brewers from beans

Compostable pods

Transformation pathways – key strategies towards circularity



1. Energy decarbonization
2. Material circularity
3. Lifetime optimization
4. Utilization improvement

Source: WEF Circular Cars Initiative 2020 Raising Ambitions: A new roadmap for the automotive circular economy

Combining circular pathways

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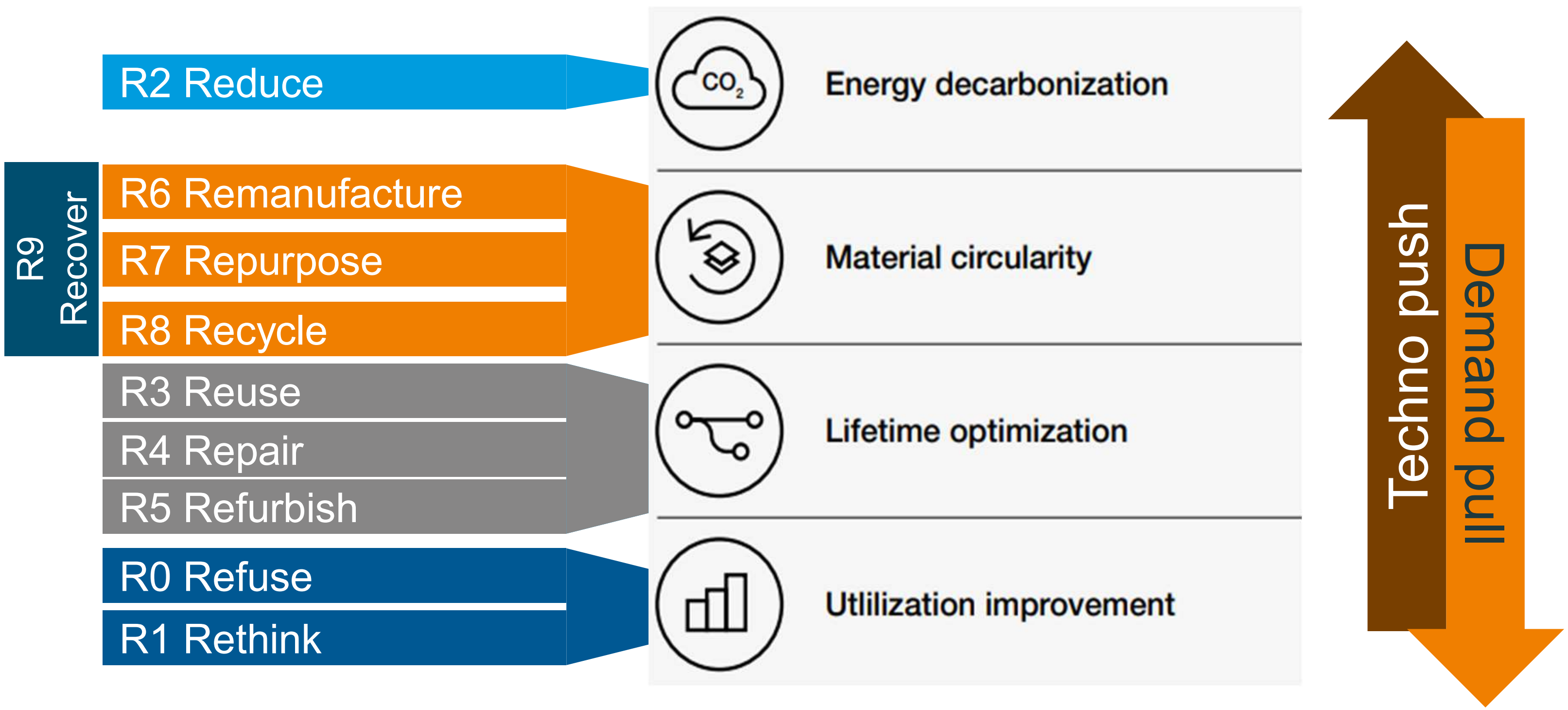
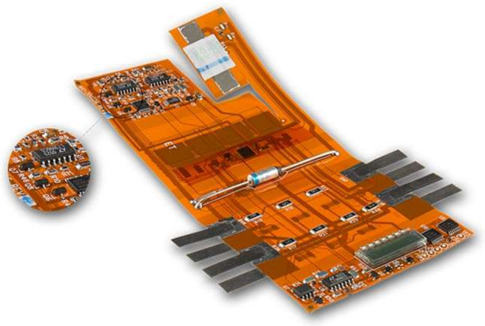


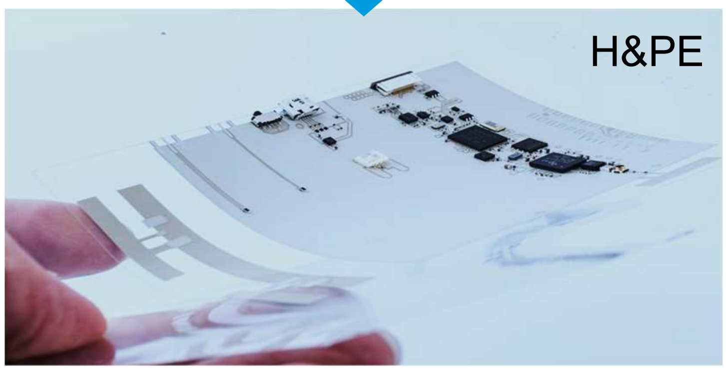
The 10 R's framework is a powerful instrument to reach higher circularity along the 4 pathways

Source: Raising ambitions: A new roadmap for the automotive circular economy (Circular Car Initiative; Accenture)

Credits slide: Nicolas Gouze, VDI/VDT IT

Holst Centre vision for Sustainable (Printed) Electronics





- **Hybrid & Printed Electronics to replace PCB-based electronics in future product**
- Rethinking design, manufacturing and recycling processes will further add to the sustainable value creation:
  - **Refuse the PCB**, the product embeds the PCB (as HP&E) (**R0***)
  - **Additive manufacturing** of/on **bio-based/renewable materials** (**R0,R2***)
  - **Efficient processing** techniques, use **less material** (**R2***)
  - **Repairability** enabled for encapsulated H&PE devices (**R4***)
  - **Facilitate reprocessing of materials** by design to obtain the same (closed loop) or lower quality (open loop) secondary materials (**R8***)

**Rs from waste hierarchy; lower value indicative of higher circularity*

What is Hybrid & Printed Electronics?

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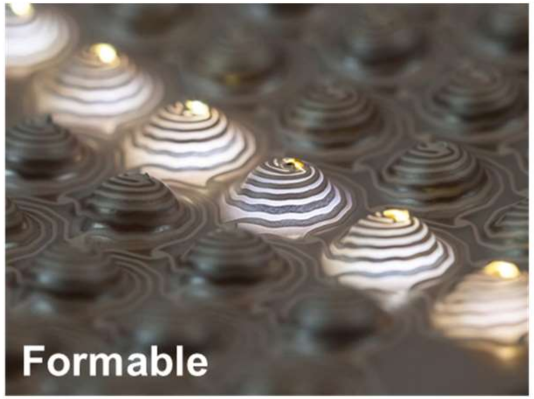
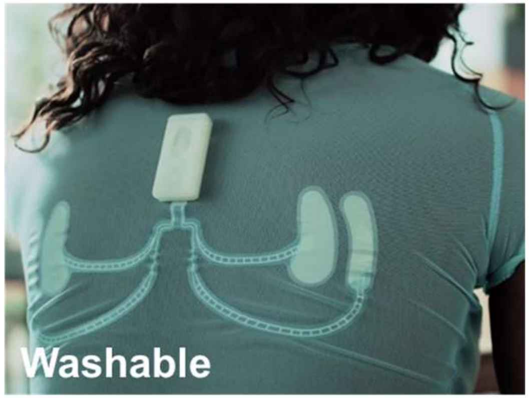
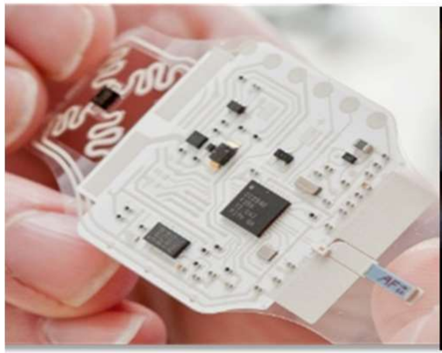
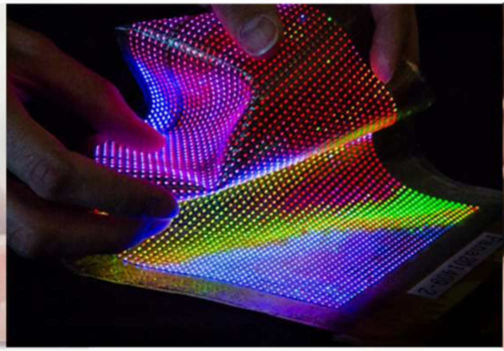
Create new form factors and designs freedom by **additive printing of metals…**

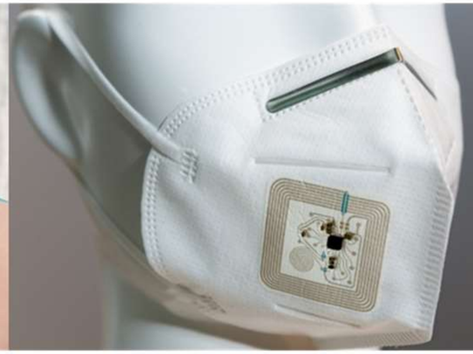


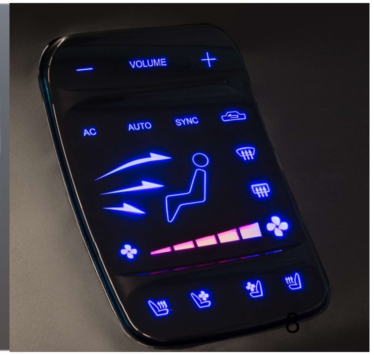


…and enabling new applications by combining these with traditional (SMT) components!

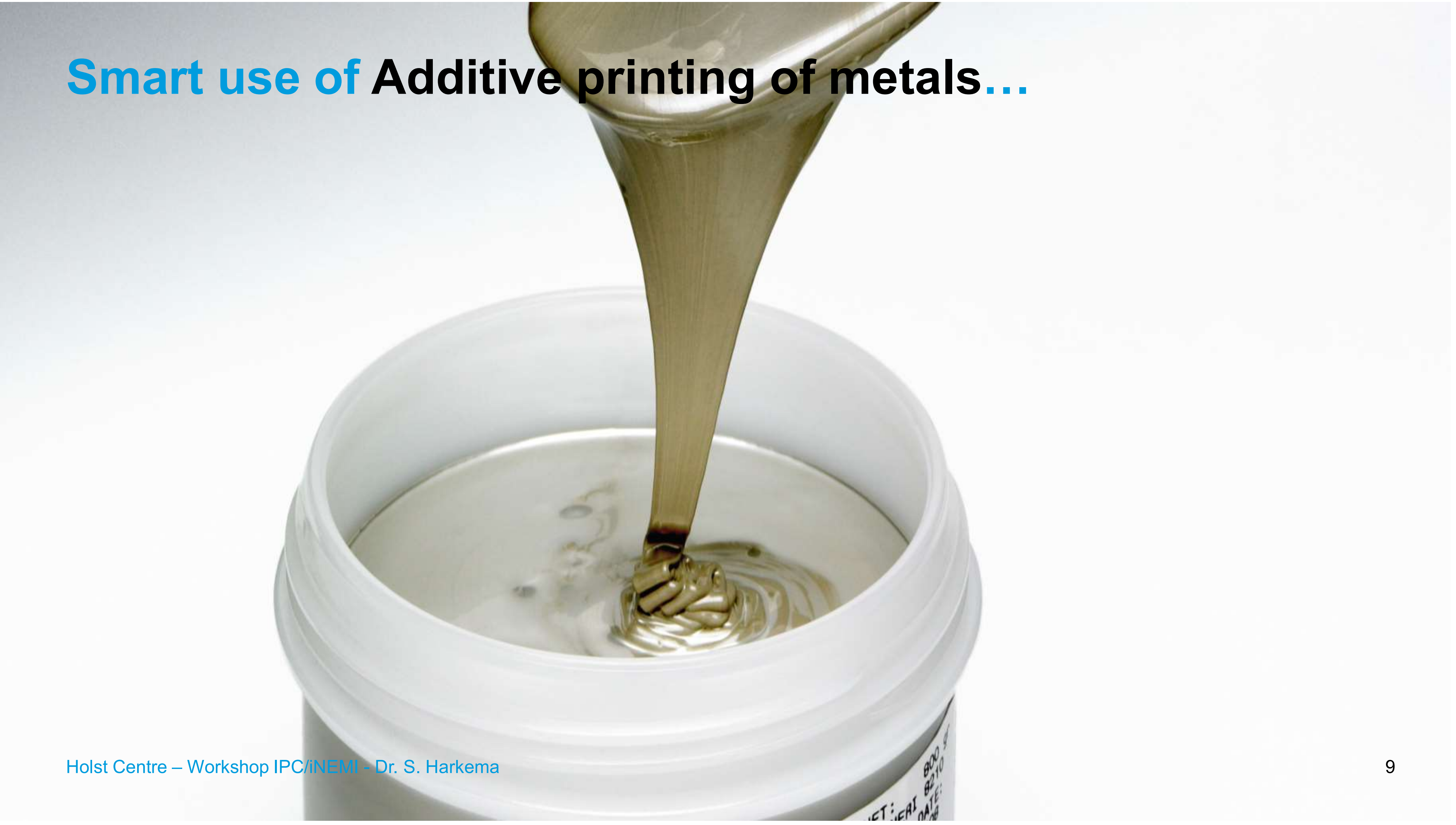






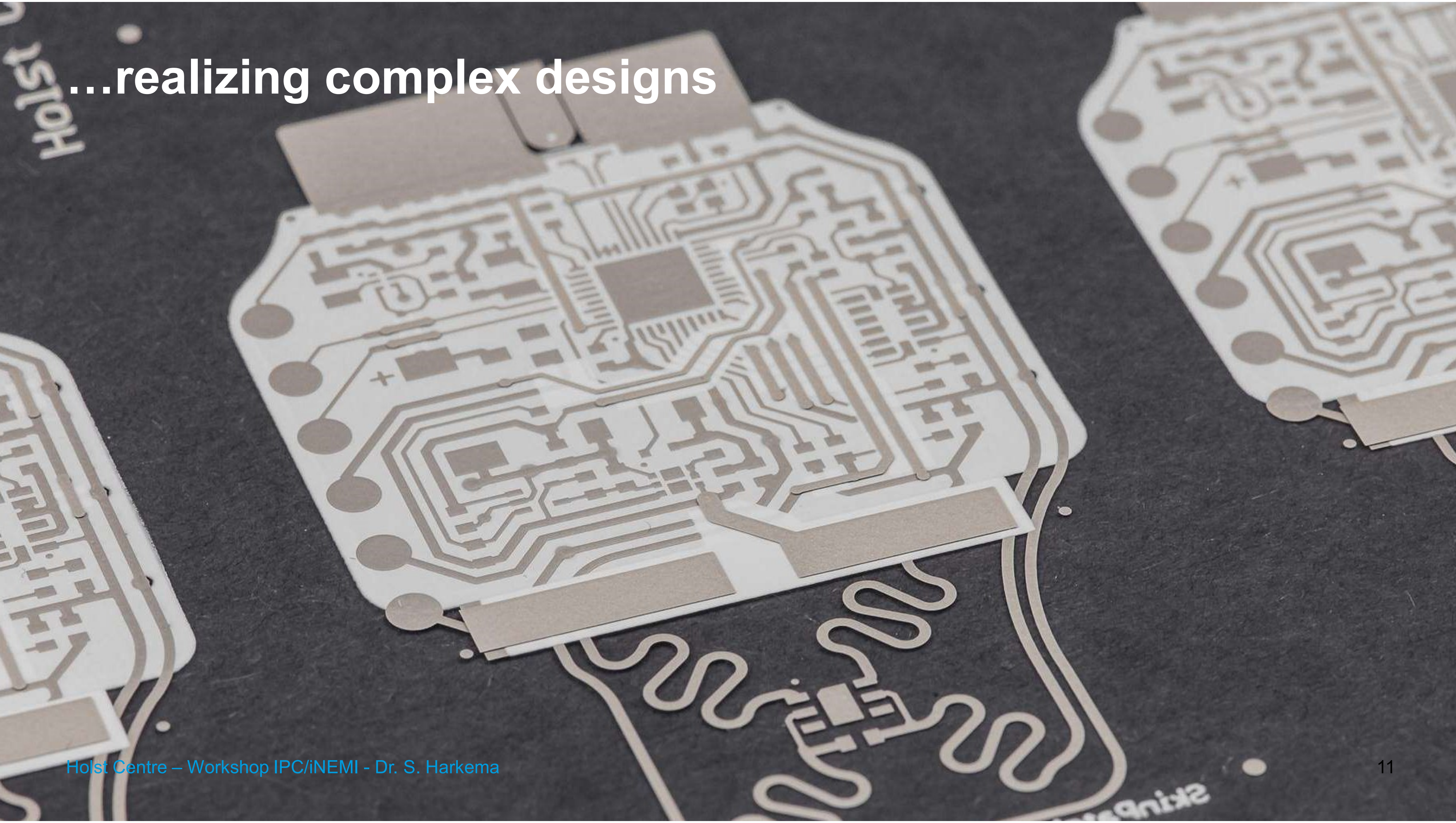


Smart use of Additive printing of metals…

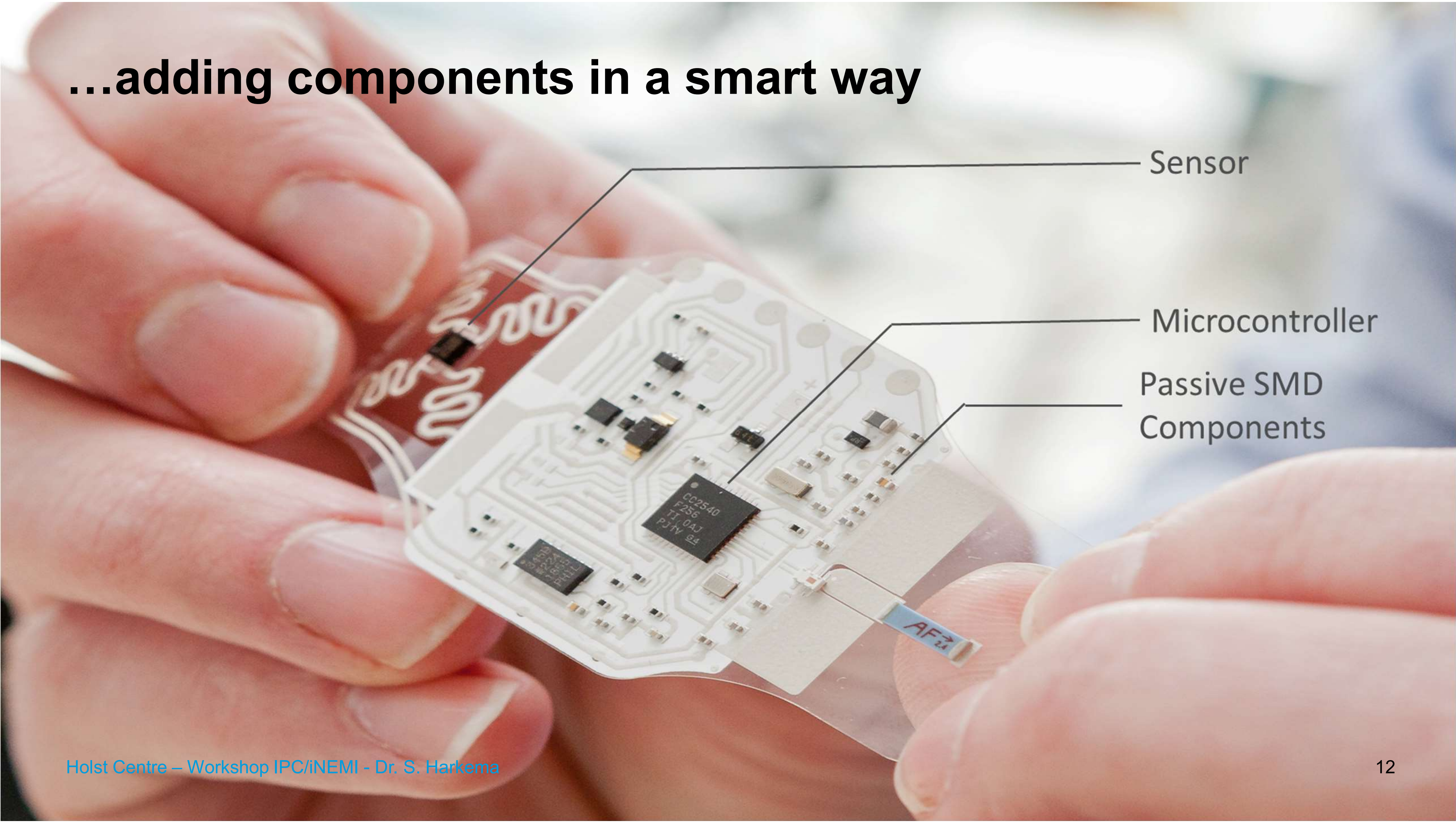


…on a variety of substrates

…realizing complex designs



…adding components in a smart way



Minimizing the dependency of PCBs
(pathway "Lifetime optimization": modular design)

Detachable & re-usable PCB
High environmental impact
Long lifetime (20 yrs)

Disposable patch
Low environmental impact
Short lifetime (weeks)

.. Or even fully integrate the PCB
example IMSE® with system-in-package (TactoTek)

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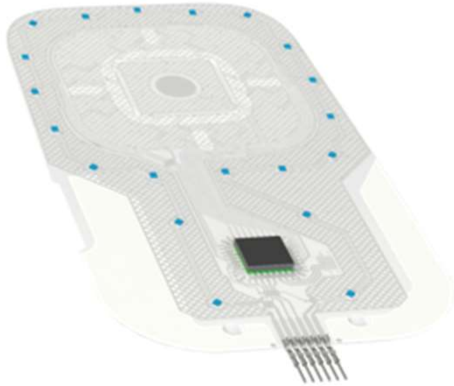
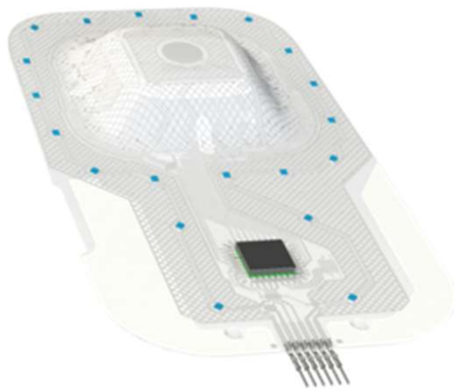
1.
Print decoration and electronics



2.
Mount components on **flat** film



3.
Form 3D shape **with** components

4.
Injection mold final single, seamless part

What about our electronics?

Holst Centre

62 million tonnes
of e-waste in 2022

82% up
from 2010

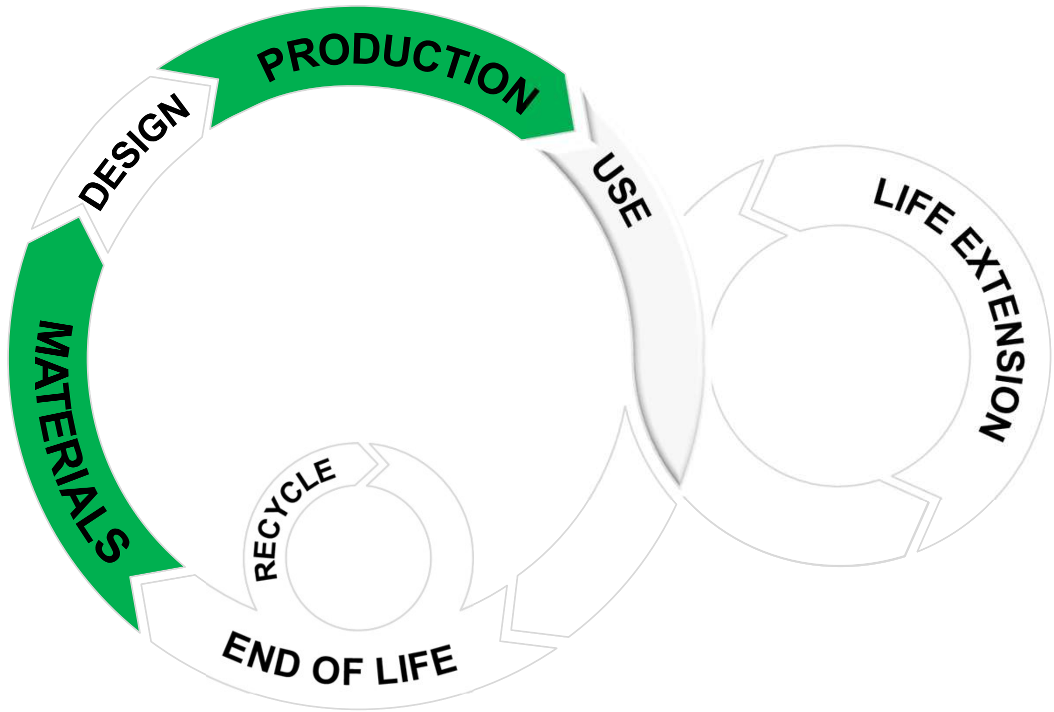
unitar
United Nations Institute for Training and Research

How can we make our electronics more sustainably?

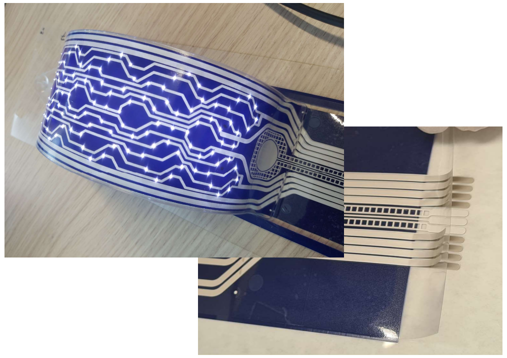
Old Fadama, Accra, Ghana, February 9, 2023. Simon Aniah, 24, burns scrap electrical cables to recover copper by the Korle Lagoon. © Muntaka Chasant for Fondation Carmignac

Transition to lower impact materials
pathway “energy decarbonization”

- Recycled, bio-based and renewable plastics & low-impact metals (Cu, r-Ag vs Ag)



*LEDs **soldered** onto **printed Cu** circuitry*

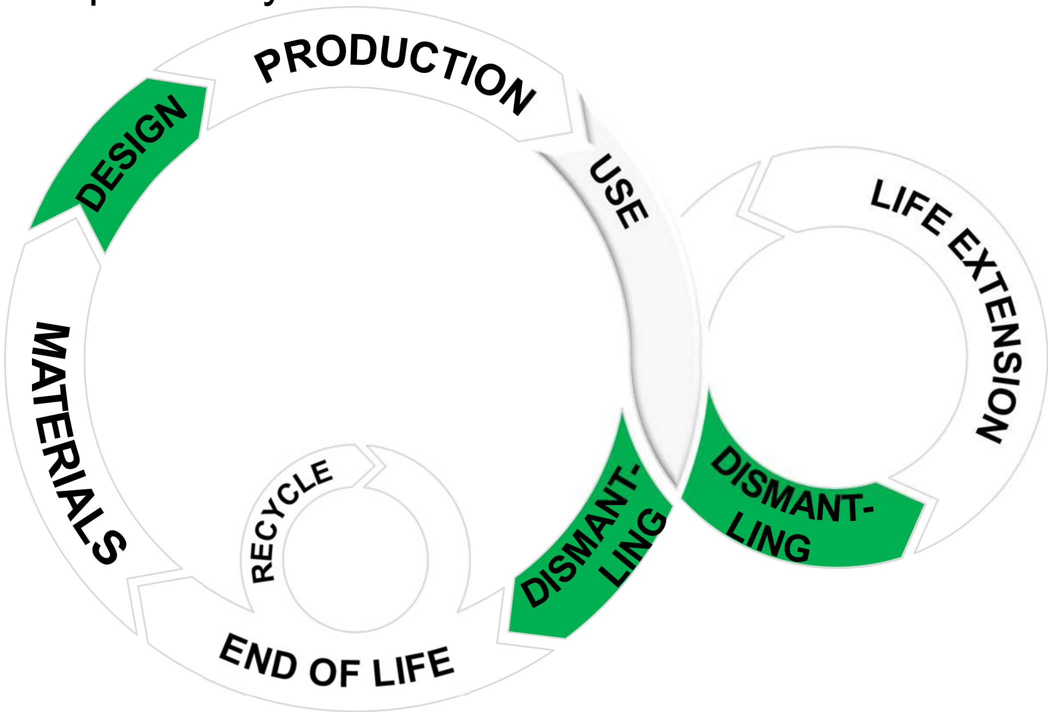


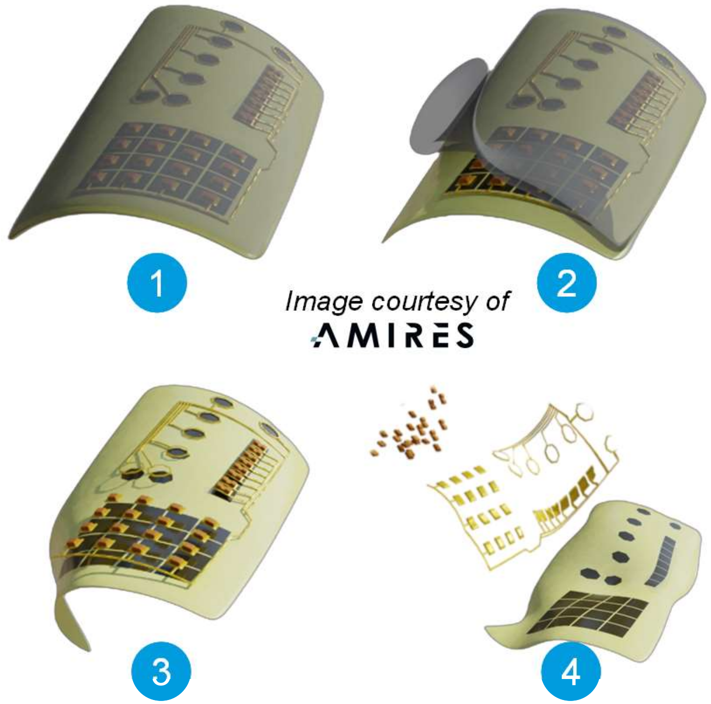
*Overmolded flat interconnect (**recycled PET)***

*Overmolding with **recycled PC***

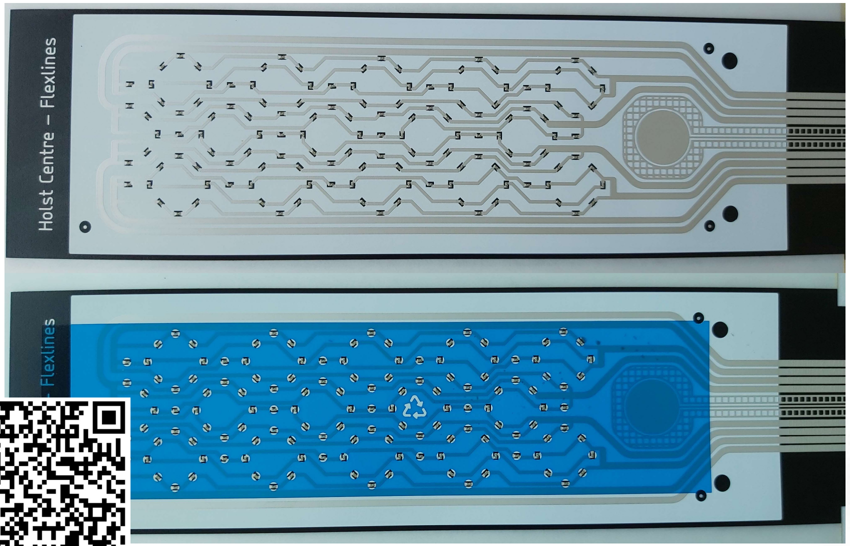
Use of design-for-recycling (DfR)
pathway "material circularity"

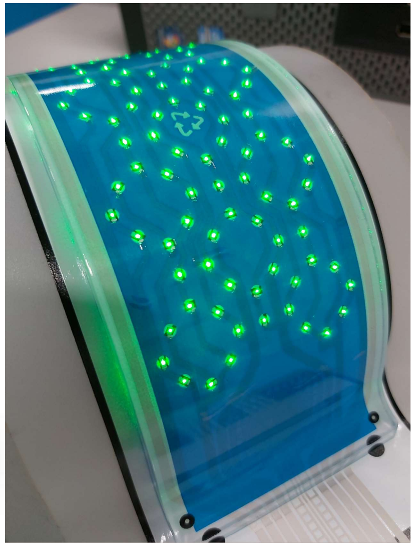
- Enable dismantling of product to liberate metals and components for improved recycling and repairability





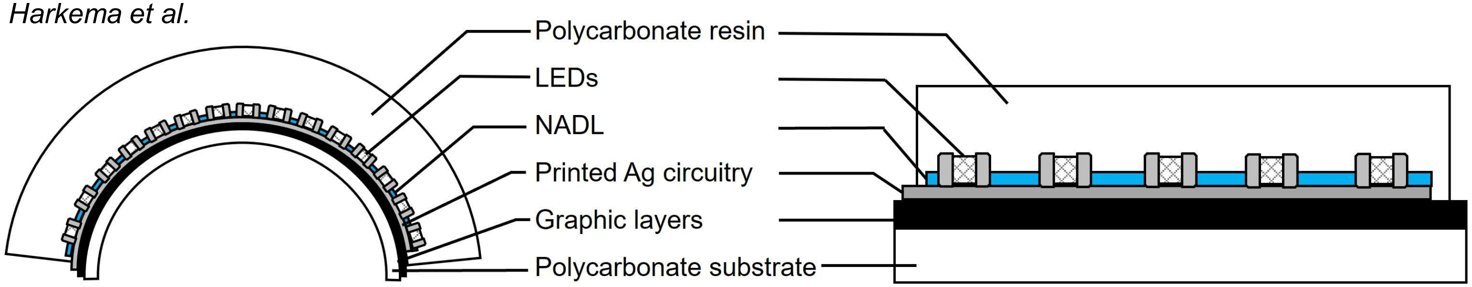
Example implementations of DfR in IME





Journal of Cleaner Production 2024, S. Harkema et al.

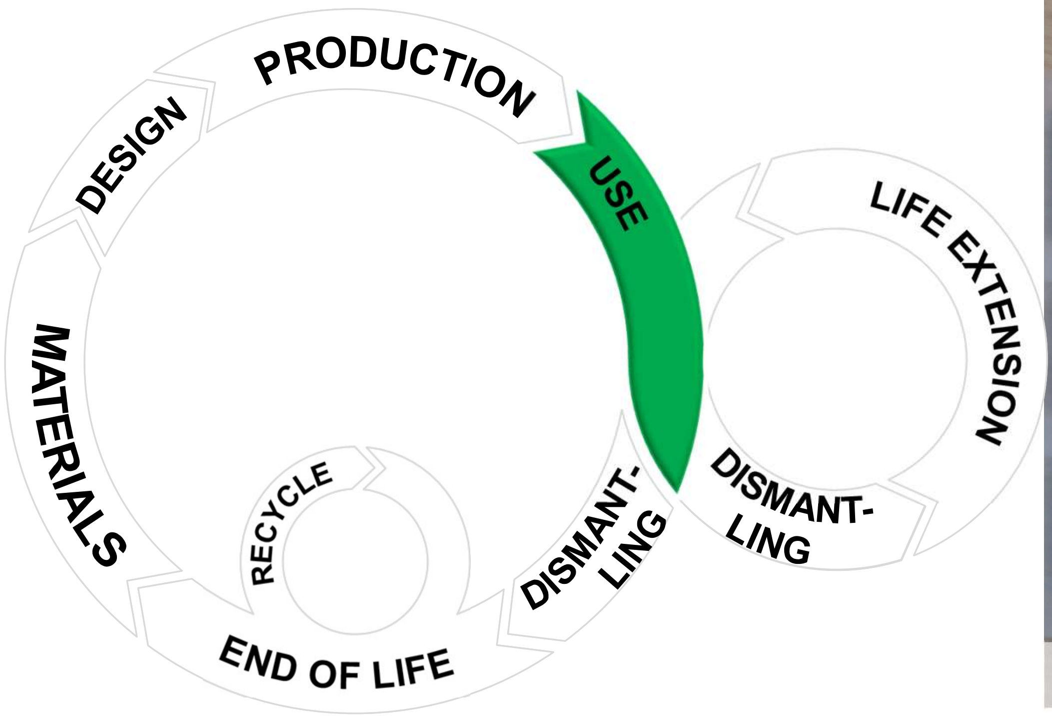
Examples:
1. Non-adhesives (see above)
2. Weak adhesives
3. Reversible adhesives

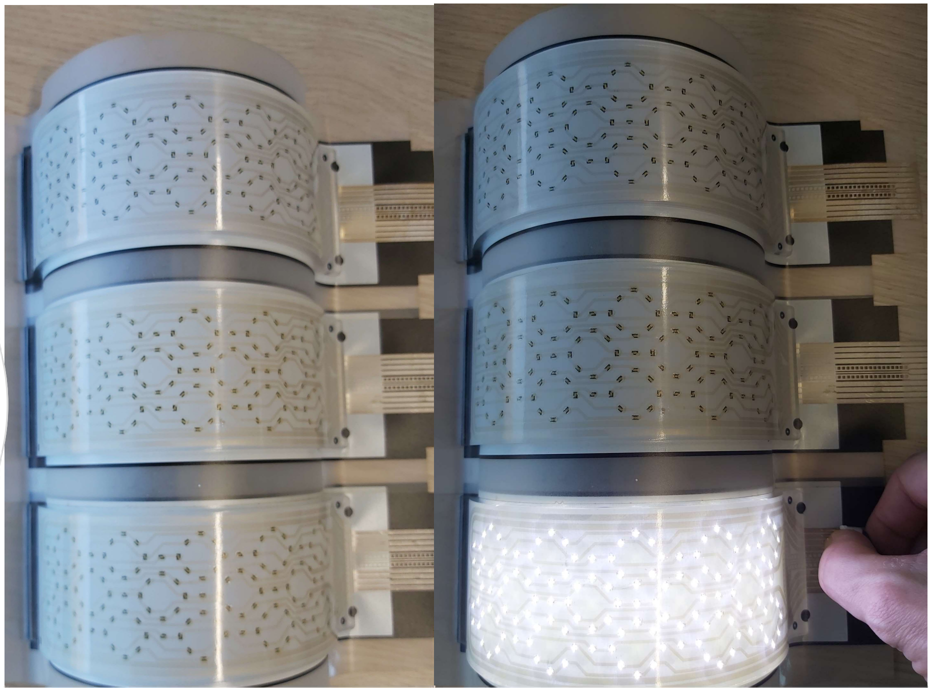


The Treasure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003587

Balance durability vs dismantlability

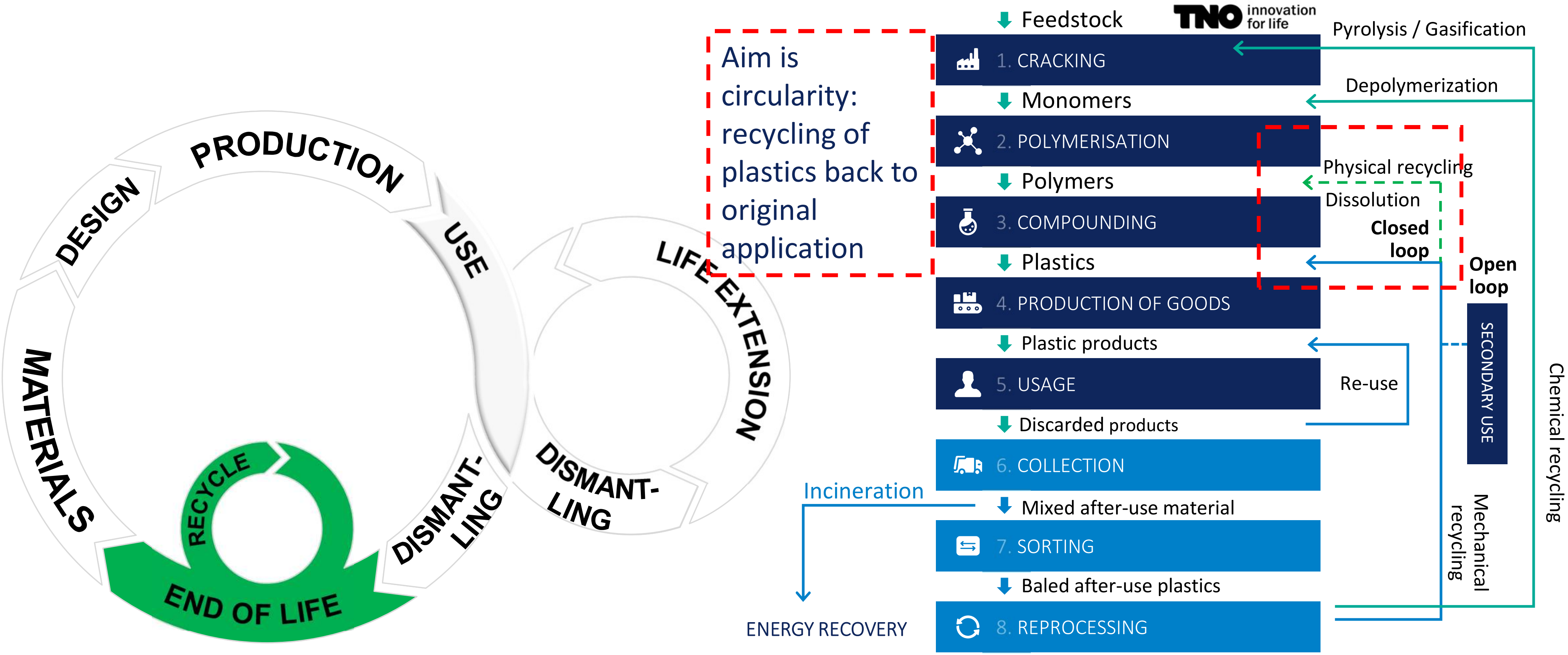
- Balance durability vs dismantlability: adding a dismantling layer should not impair reliability





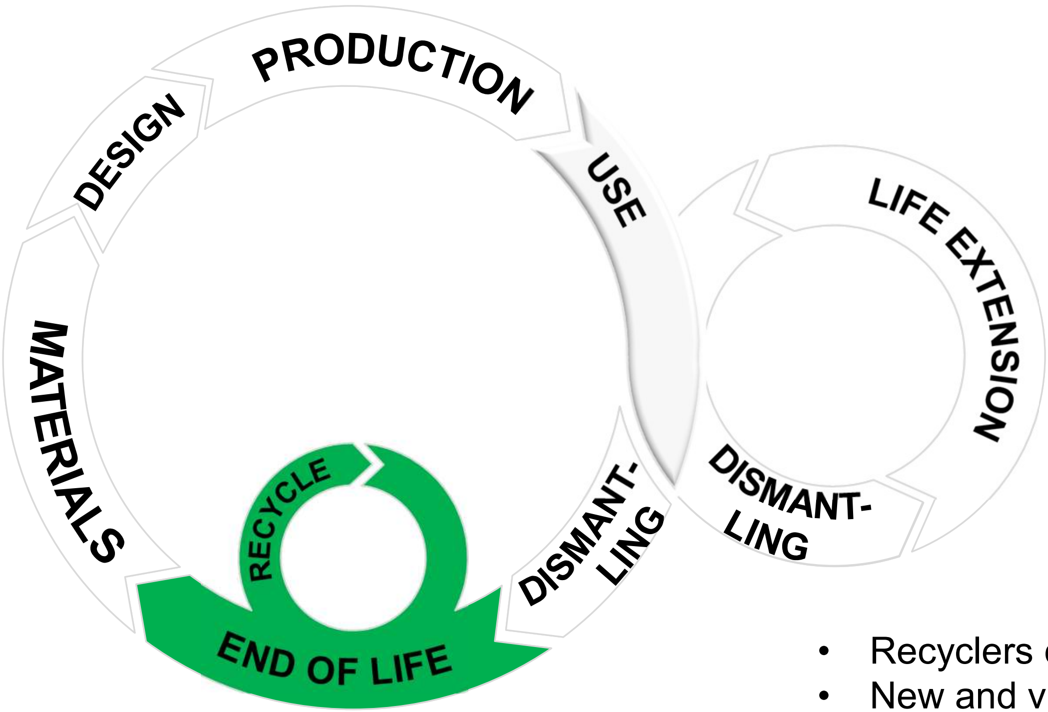
Humidity test: 1000 hours 85°C/85% RH

Recovery of plastics

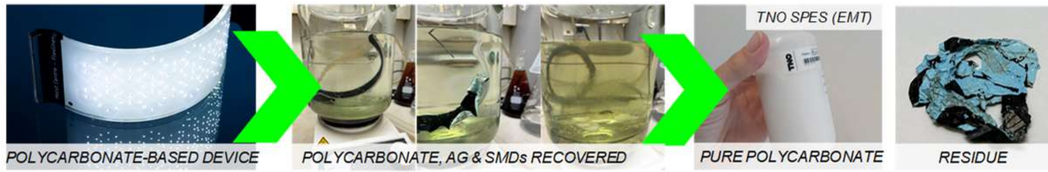


Developing approaches for EOL treatment

- Strategy towards environmentally sound and economically viable recycling



Recycling of IME devices with/without dismantling



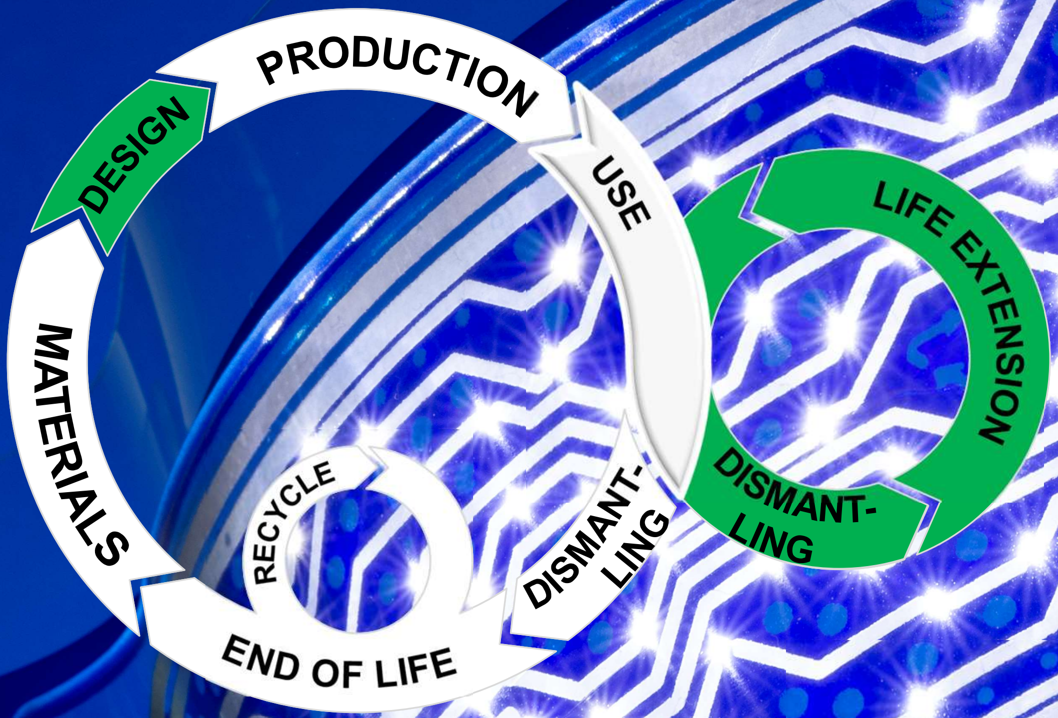
After PC recycling (TNO)

After hydrometallurgy by Univaq

UNIVERSITÀ DEGLI STUDI DE L'AQUILA

- Recyclers confirm: e-waste with high caloric value is not economically viable
- New and viable recycling routes are made possible by more dismantling

Repaired IME device
pathway “lifetime optimization”



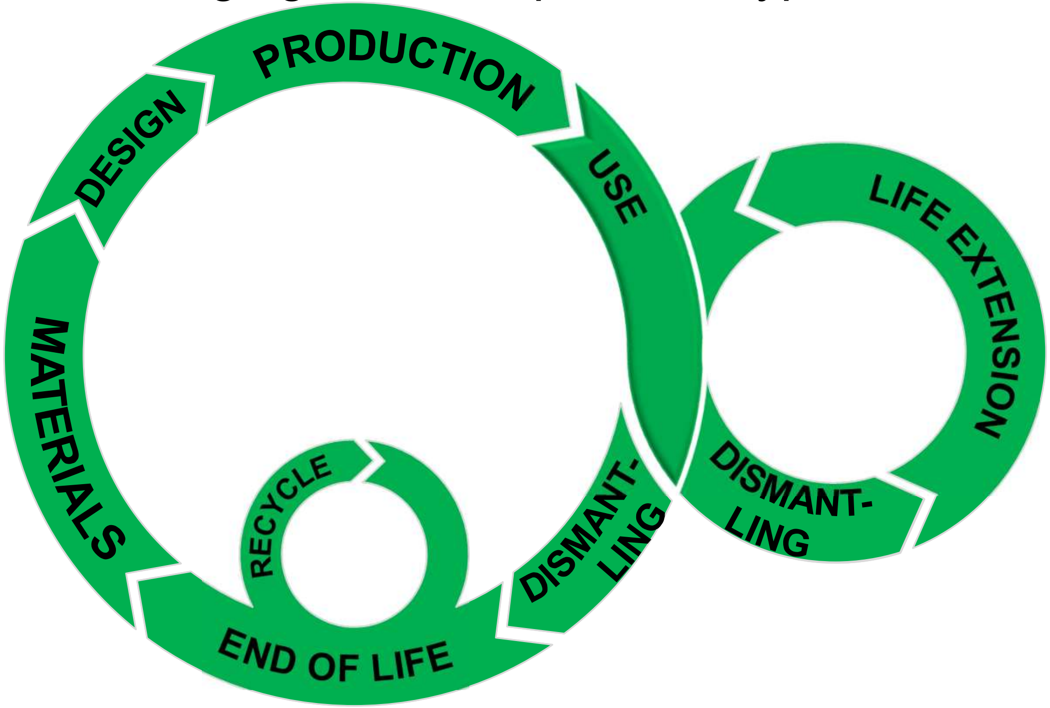
The CIRC-uits project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 101091490

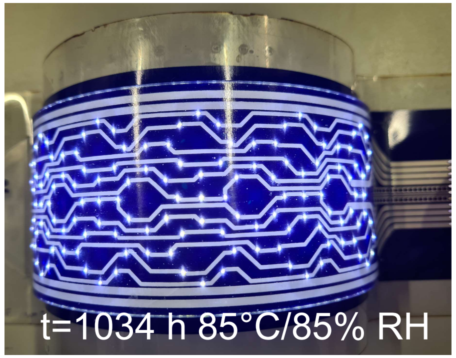
Repair of IME manufacturing fail

The CIRC-uits project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101091490

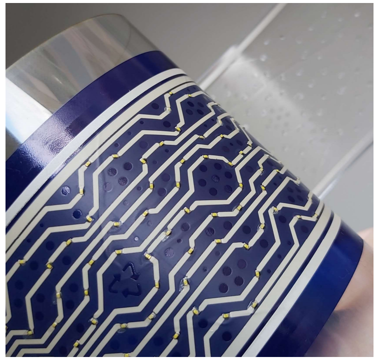
IME: a circular technology?

- Circular strategies successfully applied to a challenging and encapsulated type of H&PE



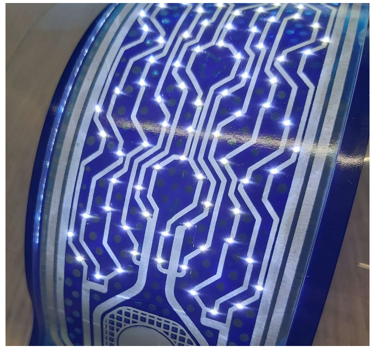


1 Durable



2 Dismantable

3 Recyclable



4 Repairable

Rethinking the future of sustainable electronics together

Holst Centre
powered by imec & TNO

Co-funded by the European Union

The Ecotron project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101070167

The Unicorn project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101070169

The Treasure project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003587

The CIRC-uits project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101091490

ECOTRON

UNICORN
Unveiling Innovation Potential of Circular Approaches in Automotive Electronics and Beyond

TREASURE

CIRC-UITS

holstcentre.com

BUILD ELECTRONICS BETTER

Overview iNEMI and IPC

Overview

> Fran Fourcade

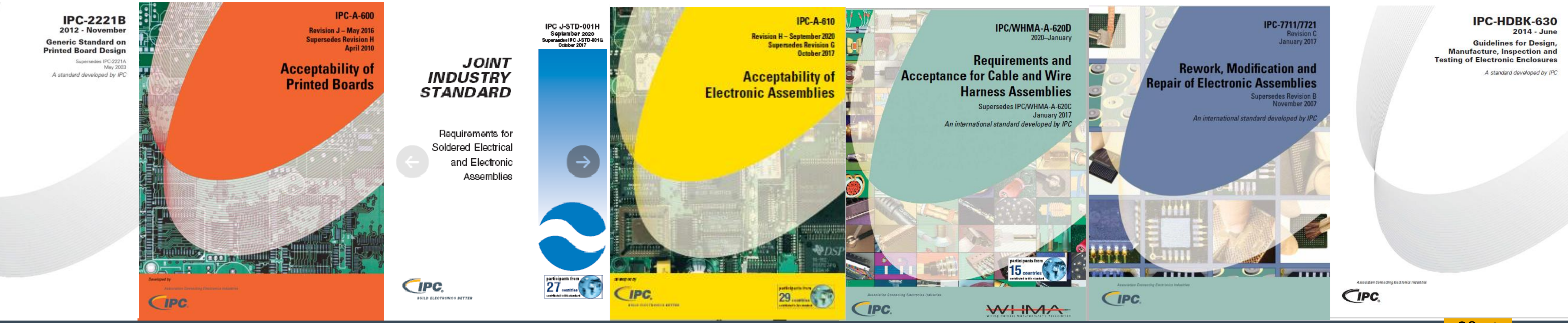
- IPC standards useful to solving the industry's circularity problems

> Grace O'Malley

- iNEMI products and services useful to solving the industry's circularity problems

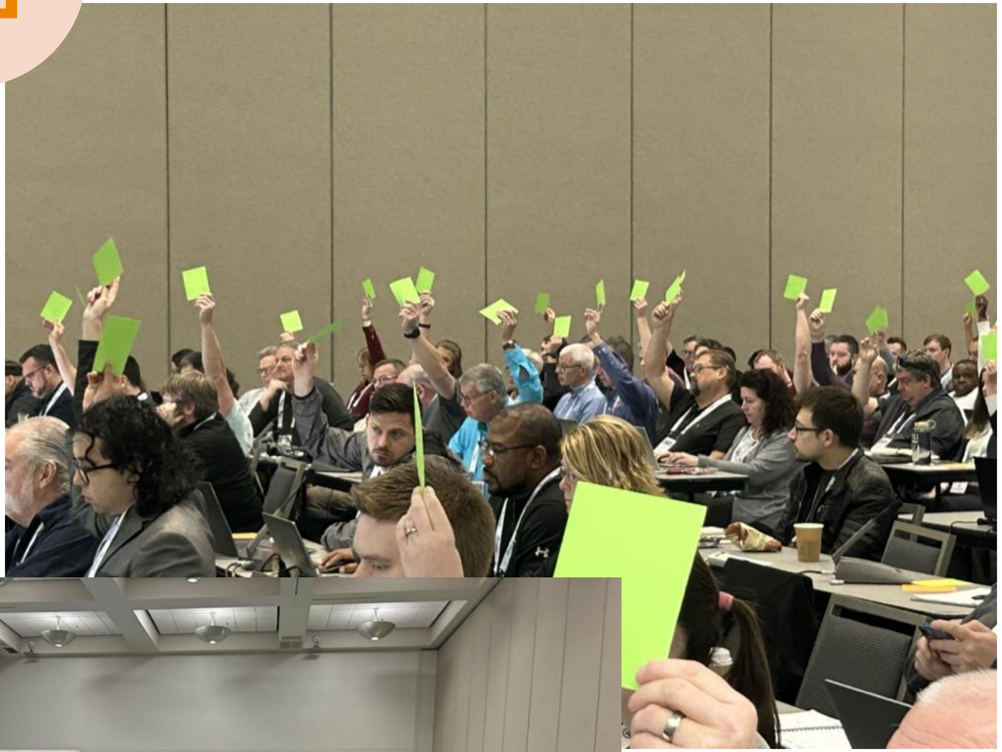
About IPC Standards

- Standards are a fundamental part of the design and manufacturing process
- More than 300 standards in the IPC library
- Used worldwide for designing and manufacturing electrical and electronic products and their materials
- Standards used for training, certification and validation audit programs



For Industry by Industry

- IPC Standards are **developed and maintained by industry volunteers globally**
- Participation at no cost
- Any interested person can join a committee
- Anyone can submit a comment
  - Committee members
  - Users of Standards
- Procedures accredited by American National Standards Institute (ANSI)
- Standardization process ensures:
  - Openness
  - Fairness
  - Antitrust protection



International Electronics Manufacturing Initiative

Website
- iNEMI Project information
- iNEMI upcoming events
- iNEMI Roadmap

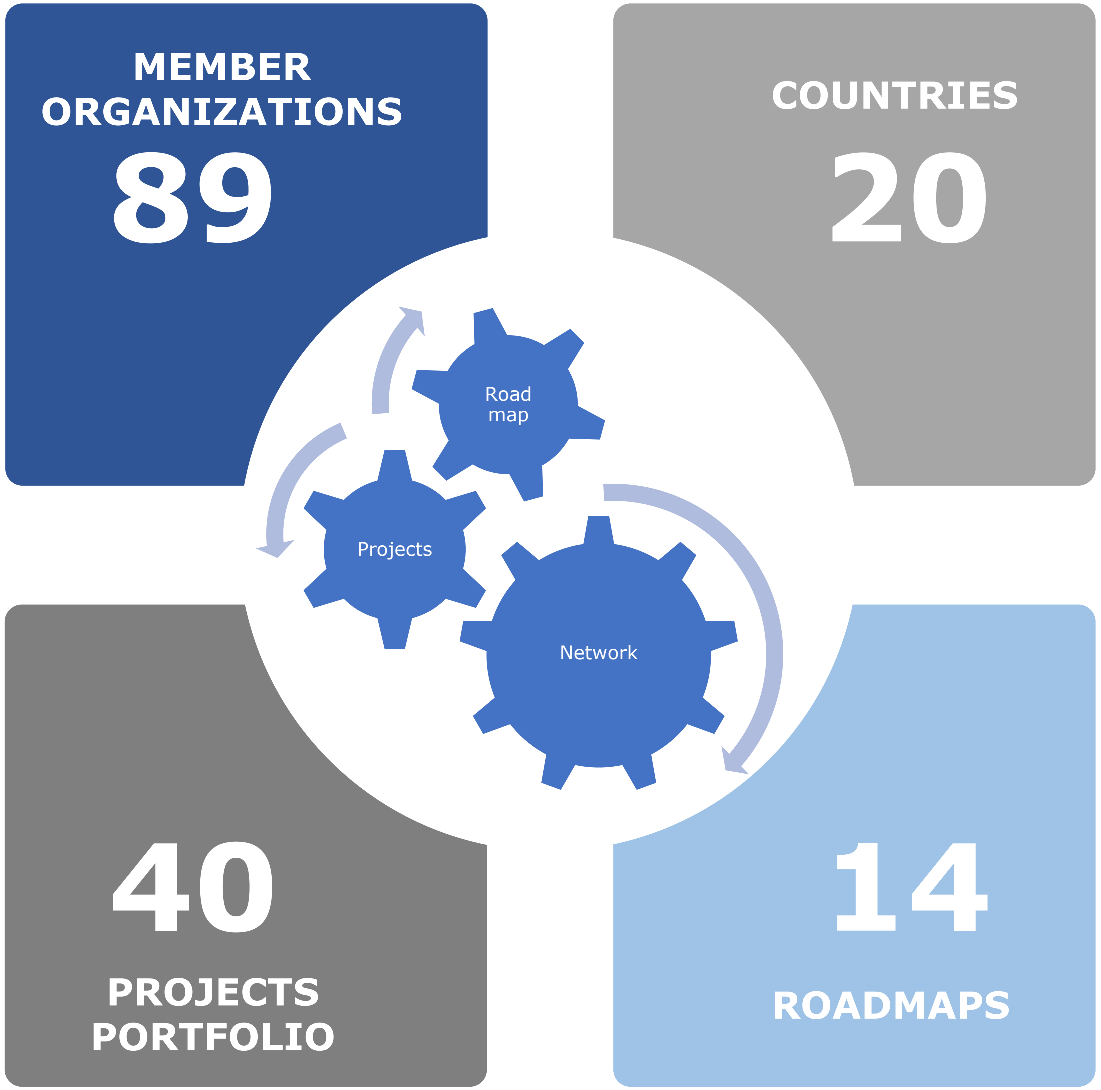
Grace O'Malley
CTO, iNEMI
gomalley@inemi.org

Social
- iNEMI TV on YouTube
- Follow iNEMI on LinkedIn

iNEMI – The Premier Collaboration Forum for the Electronics Manufacturing Value Chain

iNEMI since 1996, gives it members the ability to anticipate and shape industry needs, ensure supply chain readiness and accelerate innovation.

- **Think strategically** by roadmapping future technology needs
- **Collaborate wisely,** working with a network of technical leaders to identify and focus on common industry challenges
- **Solve creatively** through collaborative technical projects that amplify any one individual organization's expertise and resources



Industry-led Global Consortium for Electronics Manufacturing

iNEMI — International Electronics Manufacturing Initiative

IPC

Fabrication → Packaging → Board Assembly → Systems Integration

IBM, intel, GE, Microsoft, JABIL, NOKIA, Celestica, Georgia Institute of Technology, calce, hp, APPLIED MATERIALS make possible, MED-EL, DELL, imi, KEYSIGHT TECHNOLOGIES, PLEXUS, NIST National Institute of Standards and Technology, IEEC Integrated Electronics Engineering Center, Amphenol, FIT, Universal Instruments, ASMPT, Heraeus, JOHN DEERE, MIT Massachusetts Institute of Technology, PURDUE UNIVERSITY, AGC, SHINKO, INSIDIX, MacDermid Alpha, SAFRAN, SLB, CBA Group, Fraunhofer IZM, RIT Rochester Institute of Technology, akrometrix, Kulicke & Soffa, DELO, INTERFLUX ELECTRONICS, 3M, Nordson ELECTRONICS SOLUTIONS, cimetrix by PDF/SOLUTIONS, picosun, LOTES, TPCA Taiwan Printed Circuit Association, IBIDEN, AT&S, WINSOURCE ELECTRONICS, Besi, SEKISUI, NIHON SUPERIOR, MYCRONIC, Makersite, Moldex3D, 上海常劲通用设备有限公司, Thayer School of Engineering at Dartmouth, semi, isola, ITEQ, Panasonic INDUSTRY, INDIUM CORPORATION, Unow 優諾, سابك sabic, AJINOMOTO, IPC, U.S. Department of Defense, CRF Centro Ricerche Fiat, Tyndall, ZESTRON, ViTrox, SMIC Senju Comtek Corp., USCONEC, NIO, Extreme networks, SMTA, PSMA, DELTON TECHNOLOGY, Cargill, RESONAC, Celanese, Unimicron, ITRI Industrial Technology Research Institute, ecia, University at Buffalo, 生益科技, SENKO Advanced Components, FORESITE, MOSAIC microsystems, OPTICA Formerly OSA, FiberQA, KAIST

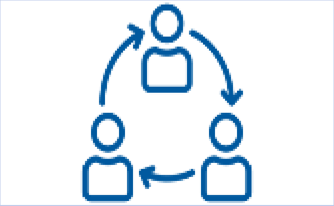
iNEMI Membership Value

Access to iNEMI Roadmap

- Anticipate and prepare for the inflections points in strategic areas such as 5G, Advanced Packaging, Smart Manufacturing and Circular Economy
- Identify and drive innovation and supply chain alignment.
- Opportunity to understand and contribute to 10 year+ vision of the industry

Engagement in iNEMI Projects

- Save time and minimize the risk of new technology adoption by leveraging resources across the supply chain to address common industry gaps and challenges
- Influence supply chain readiness and standards improvement through best practices and proven test methods development



Leverage the iNEMI Network

- Global membership across entire electronics manufacturing value chain
- Project Teams and technical groups share technical knowledge and insight into common industry challenges
- Strong applied interactions between industry and leading research community in electronic manufacturing

Working Session: Problems

Circularity means that electronics manufacturers have systems and processes in place that address remanufacturing, recycling, reparability, reusability, upgradability, and resource efficiency. Solutions driven by industry will help enable efficient and effective adoption of circularity through the electronics manufacturing value chain.

Attendees of this workshop should be procurement officers, policy experts, and technical experts who will work together in small teams to develop initial scopes for electronics industry solutions that address pressing circularity challenges.

At the end of the workshop, we will have foundational content – problem statements -- for new industry standards, tools, and workforce education.

Working Session: Problems

Ingredients for Successful Problem Formulation

- Write it down, appoint a notetaker
  - Paper and markers provided
- Evidence and data to support your claim that this is a problem
  - No complaints allowed
- Creativity
- Consider possible solutions as you create the problems
- Stay on time, appoint a timekeeper

Process for Successful Problem Formulation

1. What is the problem?
2. Why is it problem?
3. Where is it a problem?
   - By geography, supply chain segment, company size?
4. Rank your problems to identify top 3
   - Consider the severity of the problem: how bad is it (e.g., financial impacts, number of companies impacted), how much time does it take from daily tasks/operations
   - Consider the urgency of the problem: is this a compliance issue, is this affecting companies now or in the future?
5. Refine the list to be a specific as needed.
6. Create one statement per problem.

Example of a Problem Statement

The most pressing problem in circularity for electronics is ___________.

This is a problem for the electronics manufacturing industry because ___________.

This problem affects the industry most in ___________ (company size, supply chain segment, geography).

Working Session: Solutions

BUILD ELECTRONICS BETTER

Working Session: Solutions

Ingredients for a Successful Solution

- Walk around the room and socialize
- Advocate, appoint someone who can talk about the problem statements at your table
  - Be able to convince others that this is a problem that needs to be solved
- Creativity
  - Consider solutions that can take the form of industry standards, workforce education, advocacy to policymakers, research, software tools, databases
- Sticky notes and Markers

Process for Creating Solutions

- Write down your idea for a solution to the problem
  - Identify how this solution will address the problem
  - Use sticky notes to document your idea
  - Put your name(s) on your idea

Discussion

Discussion

> Total number of problem statements created
  - Any duplicates?

> Total number of solutions identified
  - Any duplicates?
  - Can we prioritize based on the number of solutions (sticky notes) provided?

> What did you learn today?

> Review of iNEMI and IPC opportunities
  - Call for participation!

iNEMI Roadmap: Technology Scope

Focus on Manufacturing and Supplychain challenges

iNEMI International Electronics Manufacturing Initiative ®

IPC ®

Complex Integrated Systems

Applications

- Data Centre/HPC Electronics
- High-Frequency Electronics
- Harsh Environment Electronics
- Consumer Electronics
- On-/In-Body Electronics

Assembly fabrics

- Board Assembly
- Flexible Hybrid Electronics
- PCB
- 5G Materials & Test
- Packaging & heterogenous integration

Components

- Semiconductor Technology
- Passive Components
- Connectors
- MEMS and Sensors
- Ceramic Interconnect & Photovoltaics

Subsystems

- Power Conversion Electronics
- Optoelectronics
- Mass Data Storage

Cross-cutting topics

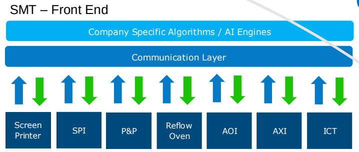
- Smart Manufacturing
- Supply Chain Resiliency
- Thermal Management
- Sustainable Electronics
- Modeling, Simulation and Design Tools

iNEMI Projects - Value

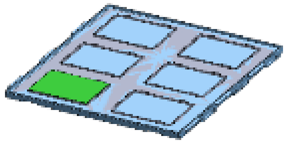
Examples of Project Outputs & Impact

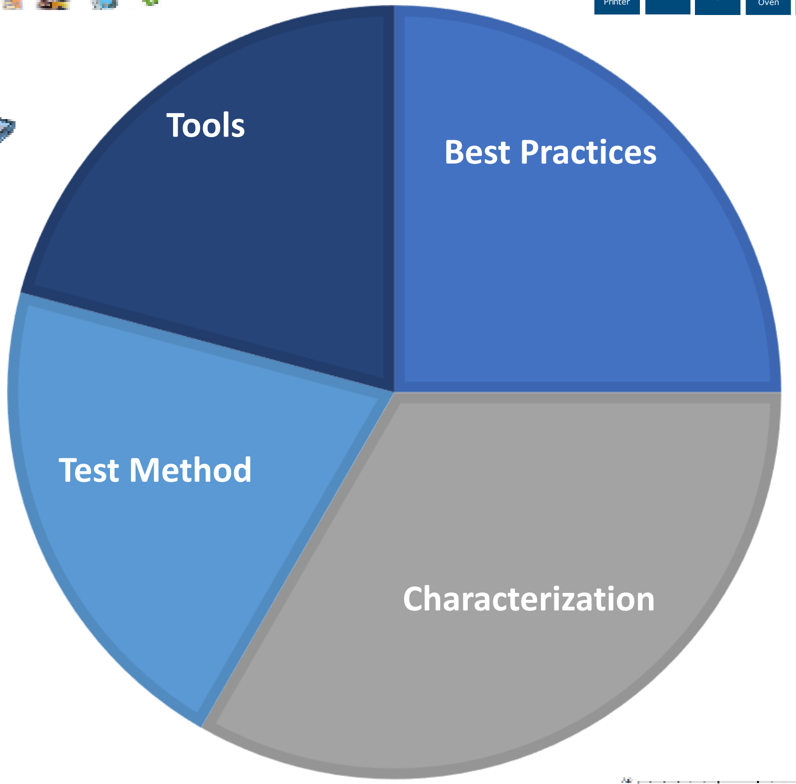
Web based LCA tool

Best practices for data management enabling Smart Manufacturing adoption

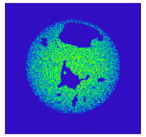


Design recommendations for effective handling tray for large formfactor packages



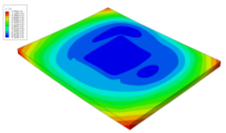


Cost model and best practices for Data Center implementation

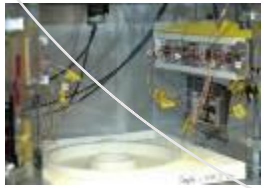


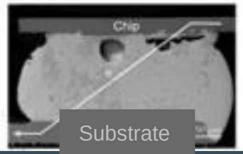
New industry test method

Characterization data to help develop model and drive design and manufacturing improvements

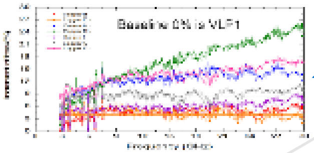


Validating faster more cost effective test methods



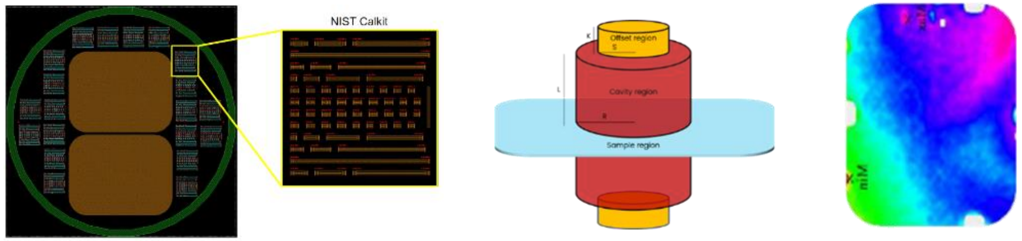


Characterization data to drive design and manufacturing improvements



Characterization of technology & equipment capabilities

mmWave Permittivity Reference Material



Motivation:

- 5G Solutions require ultra-low loss laminate materials and PCBs/substrates for efficient design of 5G communications equipment. Industry needs for standardized measurement methods were addressed by a 26-member iNEMI team in 2020-21. Identified an urgent need for the development of reference material that can be used reliably for low loss material measurements using commercially available tools

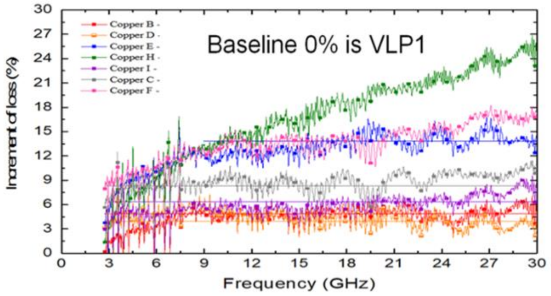
Objective:

- Develop reference material for consistent Df/Dk measurement methodologies for characterizing ultra low loss laminate materials in the range of 30 – 100GHz

Chaired by Intel and NIST

Project page

Reliability & Loss Properties of Copper Foils for 5G Applications



Motivation:

- Copper foil manufacturers and PCB fabricators treat copper surfaces to improve adhesion to resin systems. This 'roughening' treatment whilst essential for PCBs to survive 'thermal shock' has a detrimental effect to signal loss and integrity, particularly for high frequency 5G applications.

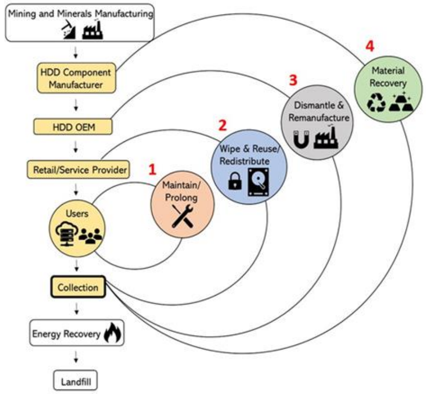
Objective:

- Determine signal loss characterization for various surface topology & profilometry results, for a range of signal frequencies used in high frequency / 5G applications.
- Correlation between surface roughness and surface conductivity and signal loss at high frequencies.

Chaired by Dell

Project page

Value Recovery from Used Electronics



Motivation:

- Need to demonstrate design and resource management models whereby the value of a HDD could be maximized throughout its working life.
- Absence of use cases including decision trees, economic and LCA models showing the benefit of moving from the current "Reuse or Shred" of HDDs to a "Reuse and Recover"

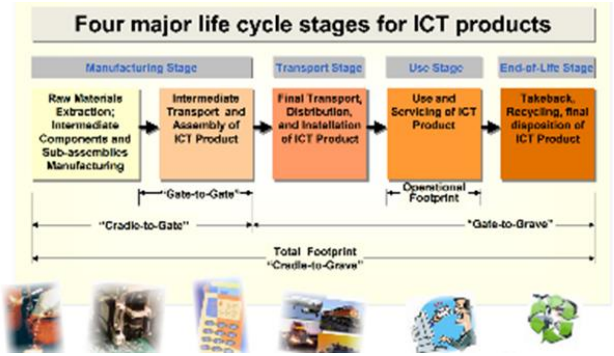
Objective:

- Identify and demonstrate (5) paths for high volume REE recovery that support a developing circular economy

Chaired by Purdue University and Seagate

Project Page Contact:marks@inemi.org

Eco-Impact Estimator Phase 4



Motivation:

- Focused ICT tool useful for electronics manufacturing supply chain. Full featured LCA burdensome and not necessary for many applications
- Increasing need for eco-impact transparency and decision support

Objective:

- Update and expand life cycle eco impact data for metals, plastics; add water usage data

Chaired by Nokia

Project Page Contact:marks@inemi.org

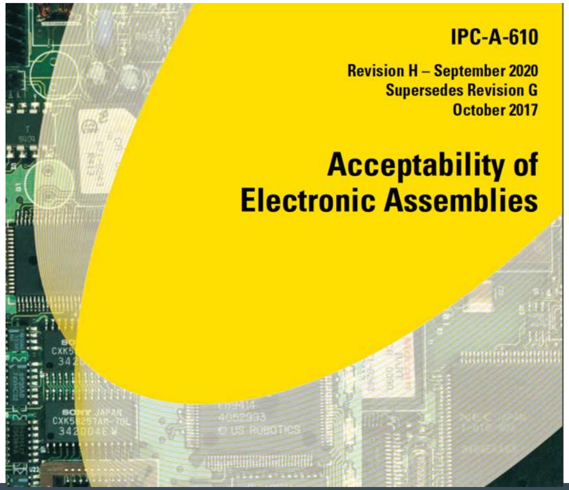
IPC-7711/21 - Leading Standard for Rework, Modification and Repair of Electronic Assemblies

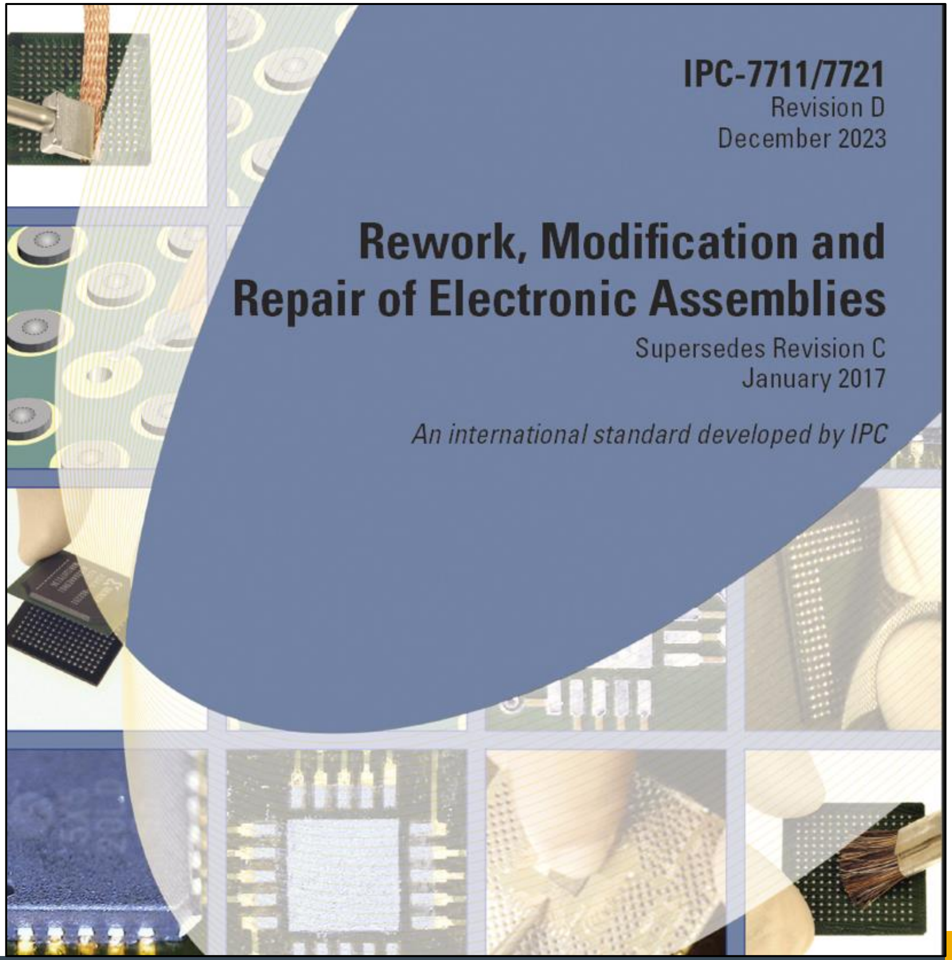
IPC-7711/21 is a key document in the rework and repair of electronic assemblies.

The acceptance criteria of the reprocessed assembly must comply with IPC-A-610 or J-STD-001 acceptance standards.

Defines the levels of conformance in relation to the classification of the assembly as well as the skill levels that operators require to perform the repair procedure.

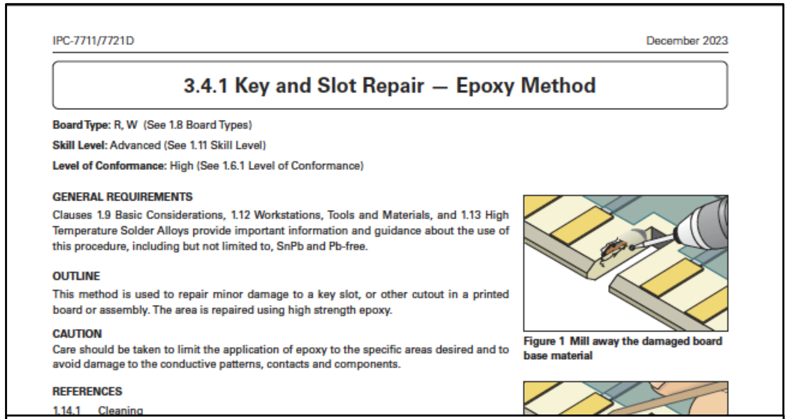
IPC-7711/21 REVISION D RELEASED DECEMBER 2023





IPC-7711/21 - Methods and Procedures

Provides criteria, material selection, methodology and procedures to ensure the reliability of products subject to rework, modification and repair.


IPC-7711/7721D December 2023

3.4.1 Key and Slot Repair — Epoxy Method

Board Type: R, W (See 1.8 Board Types)
Skill Level: Advanced (See 1.11 Skill Level)
Level of Conformance: High (See 1.6.1 Level of Conformance)

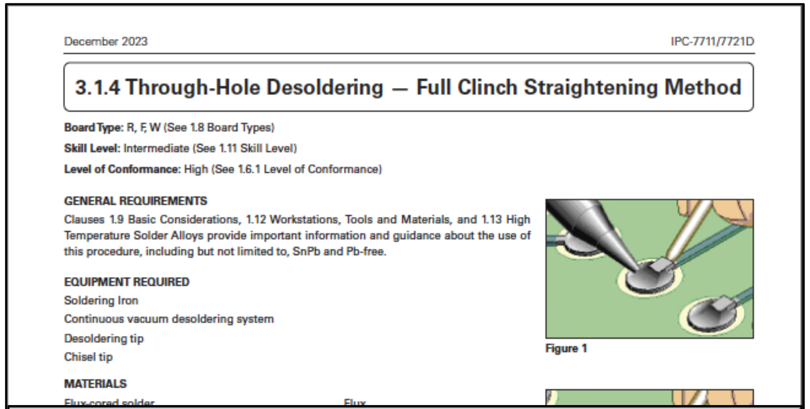
GENERAL REQUIREMENTS
Clauses 1.9 Basic Considerations, 1.12 Workstations, Tools and Materials, and 1.13 High Temperature Solder Alloys provide important information and guidance about the use of this procedure, including but not limited to, SnPb and Pb-free.

OUTLINE
This method is used to repair minor damage to a key slot, or other cutout in a printed board or assembly. The area is repaired using high strength epoxy.

CAUTION
Care should be taken to limit the application of epoxy to the specific areas desired and to avoid damage to the conductive patterns, contacts and components.

Figure 1 Mill away the damaged board base material

REFERENCES


December 2023 IPC-7711/7721D

3.1.4 Through-Hole Desoldering — Full Clinch Straightening Method

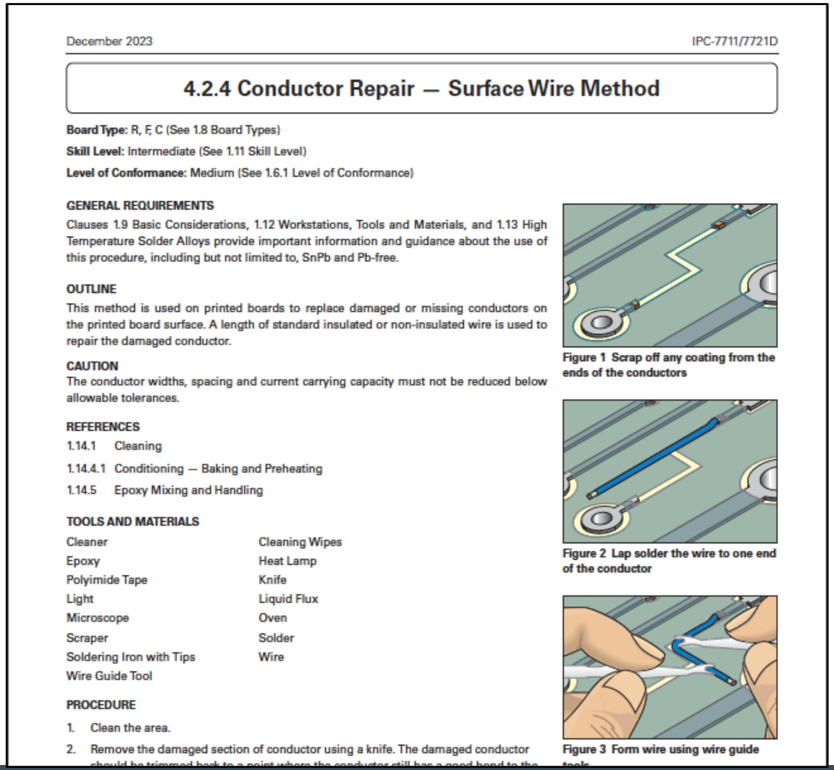
Board Type: R, F, W (See 1.8 Board Types)
Skill Level: Intermediate (See 1.11 Skill Level)
Level of Conformance: High (See 1.6.1 Level of Conformance)

GENERAL REQUIREMENTS
Clauses 1.9 Basic Considerations, 1.12 Workstations, Tools and Materials, and 1.13 High Temperature Solder Alloys provide important information and guidance about the use of this procedure, including but not limited to, SnPb and Pb-free.

EQUIPMENT REQUIRED
Soldering Iron
Continuous vacuum desoldering system
Desoldering tip
Chisel tip

Figure 1

MATERIALS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4.2.4 Conductor Repair — Surface Wire Method

Board Type: R, F, C (See 1.8 Board Types)
Skill Level: Intermediate (See 1.11 Skill Level)
Level of Conformance: Medium (See 1.6.1 Level of Conformance)

GENERAL REQUIREMENTS
Clauses 1.9 Basic Considerations, 1.12 Workstations, Tools and Materials, and 1.13 High Temperature Solder Alloys provide important information and guidance about the use of this procedure, including but not limited to, SnPb and Pb-free.

OUTLINE
This method is used on printed boards to replace damaged or missing conductors on the printed board surface. A length of standard insulated or non-insulated wire is used to repair the damaged conductor.

CAUTION
The conductor widths, spacing and current carrying capacity must not be reduced below allowable tolerances.

REFERENCES
1.14.1 Cleaning
1.14.4.1 Conditioning — Baking and Preheating
1.14.5 Epoxy Mixing and Handling

TOOLS AND MATERIALS

Cleaner	Cleaning Wipes
Epoxy	Heat Lamp
Polyimide Tape	Knife
Light	Liquid Flux
Microscope	Oven
Scraper	Solder
Soldering Iron with Tips	Wire
Wire Guide Tool	

PROCEDURE
1. Clean the area.
2. Remove the damaged section of conductor using a knife. The damaged conductor

Figure 1 Scrap off any coating from the ends of the conductors
Figure 2 Lap solder the wire to one end of the conductor
Figure 3 Form wire using wire guide


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5.8.1.2 Bottom Terminated Device Installation Pre-bump and Place with Stay in Place Stencil

Board Type: R, F, C (See 1.8 Board Types)
Skill Level: Expert (See 1.11 Skill Level)
Level of Conformance: Medium (See 1.6.1 Level of Conformance)

GENERAL REQUIREMENTS
Clauses 1.9 Basic Considerations, 1.12 Workstations, Tools and Materials, and 1.13 High Temperature Solder Alloys provide important information and guidance about the use of this procedure, including but not limited to, SnPb and Pb-free.

OUTLINE
The procedure outlined below is generic in nature and identifies the procedural steps which need to be accomplished to affect bottom termination component (BTC) installation. This process has been developed to eliminate the need for a split vision system for alignment of the BTC. Each step must be tailored to accommodate the attributes and characteristics of the specific system being used (system manufactures will customarily provide generalized operating procedures which must be further refined to achieve optimum results).

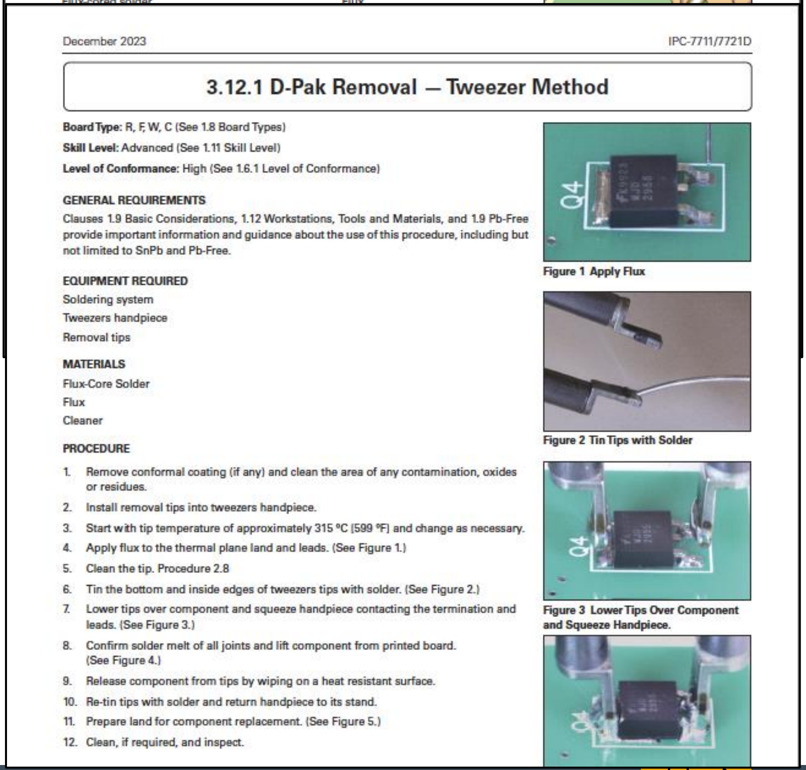
NOTE
The following preconditions should be accomplished prior to performing the procedures.
1. Develop a TTP for the specific BTC and BTC / Printed Board combination.
2. Moisture sensitive components (as classified by IPC/JEDEC J-STD-020 or equivalent documented procedure) must be handled in a manner consistent with IPC/JEDEC J-STD-033 or an equivalent documented procedure
3. Bake the printed board to remove moisture which may, if not removed, precipitate measling or delamination.

REFERENCE
1.14.1 Cleaning
1.14.4.1 Conditioning — Baking and Preheating

EQUIPMENT REQUIRED
Hot air or hot gas reflow system
Gas focusing nozzle (sized to package dimensions)
Gas supply (if other than ambient atmosphere)
Preheat method (oven, hotplate, high intensity lamp)
Handheld miniature squeegee

OPTIONAL EQUIPMENT
Bake-out oven (vacuum, convection) Inert gas supply, if used

Figure 1
Figure 2
Figure 3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3.12.1 D-Pak Removal — Tweezer Method

Board Type: R, F, W, C (See 1.8 Board Types)
Skill Level: Advanced (See 1.11 Skill Level)
Level of Conformance: High (See 1.6.1 Level of Conformance)

GENERAL REQUIREMENTS
Clauses 1.9 Basic Considerations, 1.12 Workstations, Tools and Materials, and 1.9 Pb-Free provide important information and guidance about the use of this procedure, including but not limited to SnPb and Pb-Free.

EQUIPMENT REQUIRED
Soldering system
Tweezers handpiece
Removal tips

MATERIALS
Flux-Core Solder
Flux
Cleaner

PROCEDURE
1. Remove conformal coating (if any) and clean the area of any contamination, oxides or residues.
2. Install removal tips into tweezers handpiece.
3. Start with tip temperature of approximately 315 °C [599 °F] and change as necessary.
4. Apply flux to the thermal plane land and leads. (See Figure 1.)
5. Clean the tip. Procedure 2.8
6. Tin the bottom and inside edges of tweezers tips with solder. (See Figure 2.)
7. Lower tips over component and squeeze handpiece contacting the termination and leads. (See Figure 3.)
8. Confirm solder melt of all joints and lift component from printed board. (See Figure 4.)
9. Release component from tips by wiping on a heat resistant surface.
10. Re-tin tips with solder and return handpiece to its stand.
11. Prepare land for component replacement. (See Figure 5.)
12. Clean, if required, and inspect.

Figure 1 Apply Flux
Figure 2 Tin Tips with Solder
Figure 3 Lower Tips Over Component and Squeeze Handpiece.

Example of Starting of Development Activity

Industry Need Identified:

Missing standardized set of guidelines for component conditioning procedures for part salvaging and reclaim/re-use: Component Reclaim Standard.

Companies involved in preliminary exploration:

- Retronix (UK)
- BEST (USA)

Current Activities:

- Drafting the Project Initiation Number Form (PIN Form)
- **Seeking volunteers to start A-TEAM and push forward the development document.**

Component Reclaim Standard

Topics included:

- Material verification – storage, handling, etc.
- Inspection tooling and equipment - XRF, X-ray, etc
- Procedures for Baking, Preheating, Cleaning, Reballing, Retinning, Prepping
- Visual Inspection – coplanarity, etc.
- Electrical Testing – AABUS
- Marking and Repacking/Reeling
- Process Automation

Some Standardization Activities Supporting Sustainability Data

- 2-10 Electronic Product Data Description Committee
  - 2-12 Digital Twin Subcommittee
    - 2-12a Generic Requirements for Digital Twin Task Group
    - 2-12b Model Based Definition (MBD) for Digital Twins Task Group
    - 2-12d Digital Sustainability Credentials Standard Task Group
- 2-16 Digital Product Model Exchange (DPMX) Subcommittee
  - 2-16d IPC-2581 Users Task Group
- 2-17 Connected Factory Initiative Subcommittee
  - 2-17a IPC-CFX Standard Task Group
- 2-18 Supplier Declaration Subcommittee
  - 2-18h Conflict Minerals Data Exchange Task Group
  - 2-18j Lab Report Declaration Task Group
  - 2-18k Materials and Substances Declaration for the Aerospace, Defense, HE and Other Industries
- 2-19 Supply Chain Traceability and Trust Subcommittee
  - 2-19a Critical Components Traceability Task Group
  - 2-19b Trusted Supplier Task Group
  - 2-19c Component-Level Authentication (CLA) Standard Task Group

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IPC-2591-Version 1.7

Connected Factory Exchange (CFX)

Developed by the IPC-CFX Standard Task Group (2-17a) of the Electronic Product Data Description Committee (2-10) of IPC

IPC-2581C

Generic Requirements for Printed Board Assembly Products Manufacturing Description Data and Transfer Methodology

Developed by the Digital Product Model Exchange (DPMX) Subcommittee (2-16) of the Electronics Product Data Description Committee (2-10) of IPC

How to get involved

- Visit our Committee Homepage and submit a comment to a standard or join a committee today
  - www.ipc.org/committee-page
- Joining a Committee:
  - Access to our collaboration platform IPCWORKS
    - Work on development files
    - Share information and store results
    - Networking
- Help us to move the industry forward by participating in any committee of your expertise

Next Steps

Next Steps

Goal: create new solutions that address the problems identified; consider standards, workforce education, advocacy, research, and software tools that can solve these problems

- A report on the results from this workshop
  - Webinar sponsored by iNEMI and IPC on Wednesday 17 July at 10:00 EDT / 16:00 CEST
- More workshops and opportunities to convene
  - American Center for Life Cycle Assessment conference, Utah, September 2024
  - Electronics Sustainability Summit, Texas, October 2024
  - electronica, Germany, November 2024
  - Pan-European Electronics Design Conference, Austria, January 2025
  - IPC APEX EXPO, California, March 2025

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