Tech Topic Series: Eco-Design for Circular Electronics Economy

Session 4: Fronius & IBM
September 9, 2021

Listen to the recorded webinar: https://youtu.be/eqKCBuvOgnM

1. Our speakers will be highlighting best practices for eco-design for circular electronics

2. We welcome you to use the Chat to share your own best practices and to ask questions about the tools and resources used to achieve their eco-design successes

3. iNEMI will compile the information into a final report expected later in 2021
Next Sessions

Session 5: Thursday, October 14, 2021
Framework Computing
10:00-11:00 a.m. EDT (Americas)
4:00-5:00 p.m. CEST (Europe)
10:00-11:00 p.m. CST (China)
Framework Computing - Confirmed Speaker: Nirav Patel

Session 6: Thursday, November 4, 2021
Barco
10:00-11:00 a.m. EDT (Americas)
4:00-5:00 p.m. CEST (Europe)
10:00-11:00 p.m. CST (China)
Barco – Confirmed Speaker: Jan Daem
Note: All participants are on mute. Please ask questions via the chat.
Circular Electronics:
The GEN24 PV-Inverter
Agenda

• How do we **define** product sustainability and circularity?
• How do we **measure** product sustainability and what has Fronius achieved so far?
• How do we **improve** the sustainability and circularity of our products?
THREE BUSINESS UNITS

- 6000 Employees
- 32 Countries
- 1,264 Patents
How do we define product sustainability and circularity?
WHAT IS SUSTAINABILITY?

SUSTAINABLE DEVELOPMENT GOALS
SDGs

Source: Stockholm Resilience

Sustainability-Criteria Fronius Way 4.2

Product Sustainability

Source: Stockholm Resilience

https://www.stockholmresilience.org/research/research-news/2017-02-28-contributions-to-agenda-2030.html
SUSTAINABLE CIRCULAR PRODUCT-SERVICE-SYSTEMS

Overall goal: SDGs
Evidence-based Sustainability along the entire Product life cycle

IS ONLY POSSIBLE WITH FACTS, FACTS, FACTS
How do we measure product sustainability and what has Fronius achieved so far?
Life Cycle Assessment
GEN24 Plus
LIFECYCLE OF THE GEN24
LCA GEN24 SCENARIOS

1. Select Location of Usage
   - Austria
   - Germany
   - Poland
   - Brasil
   - Australia
   - USA NY
   - USA LA

2. Select PV-System
   - Conventional
   - More sustainable alternative

3. Select Fronius Inverter
   - Primo GEN24 3.0
   - Primo GEN24 6.0
   - Symo GEN24 5.0
   - Symo GEN24 10.0

4. Select Waste
   - Landfilling
   - Thermal Waste Treatment
   - Thermal Waste Treatment with subsequent Metal Recycling
   - Recycling
   - Recycling with disassembly of 6 main parts
LCA GEN24 PLUS DATA COLLECTION
THE CHALLENGE

490 components = 2533 pieces for one inverter (Fronius Primo GEN24 Plus 6.0)

4 inverters * 7 countries * 5 waste scenarios = 140 variants

120 values * 140 variants = 16,800 results
DATA COLLECTION BY DISMANTLING
DATA COLLECTION BY DISMANTLING
DATA COLLECTION
DATA COLLECTION
CLIMATE IMPACT OVER THE LIFE CYCLE

= Carbon Footprint = Global Warming Potential GWP in CO₂-Äquivalenten: 

- CH₄ = 25 | N₂O = 298 | HFCs = 124-14 800 | PFCs = 7 390 – 12 200 | SF₆ = 23 980 | NF₃ = 17 200

Symo GEN24 5.0

- 20 Years operation in Germany
- Conventional Modules
- Combination Metal Recycling & Thermal Waste Treatment

Climate Impact: 415 kg CO₂e

Electrical Losses during usage
PV modules & co. also have a CO₂ backpack originating from the complex production process, which is partly lost in the inverter as waste heat, with 97% (!) efficiency.

Transports to Customers
Production at Fronius
Transports to Fronius
Components
Recycling
= Credit with Recycling
CLIMATE IMPACT OF COMPONENTS

412 Components modeled
2500 pieces
276 kg CO₂ by production of all components

Components

- Aluminium: 29.3%
- Technical plastics: 12.4%
- Coils: 10.6%
- Capacitors: 12.6%
- ICs: 10.6%
- Galvanised Steel: 12.4%
- Complex Components: 8.4%
- Resistor: 4.2%
- Others: 6.1%

Printed circuit boards
REPAIR IS HIGHLY BENEFICIAL

Repair

All modelled repair processes generate high environmental benefits compared to an early replacement of the entire inverter.

/ Replacement of main fan on site
/ Replacement of the "pilot" component group on site
/ Replacement of 4 varistors on the power unit print
/ Replacement of the entire power unit print
Summary of the results

The environmental benefit exceeds the impact by a factor of 5.3 – 26 times.

Between 1,640 and 16,932 kg CO₂e are saved with one GEN24 Plus.

The payback time of climate impacts is in the range of 0.8 to 3.7 years.
LCA-CALCULATION WITH ISO-REVIEW

1 year
40-50 people
130 page LCA-Report
16 800 results
Webinars LCA GEN24 on YouTube

English
German
How do we improve the sustainability and circularity of our products?
How?

Generic process for reaching our sustainability-goals
How?
Generic process for reaching our sustainability-goals

Activities & Projects for establishing product-related Sustainability-Data

Components
- Material composition incl. recycling-share
- Geographic data
- LCA-specific data (GWP, CED,...)

...
How?

Generic process for reaching our sustainability-goals
How?

Generic process for reaching our sustainability-goals

Checklists based on LCAs

→ Focus on LCA-hot-spots
How?

Generic process for reaching our sustainability-goals

Usage of Checklists and generated data / insights during product development
Tests with recycled materials: rCFRP recycled Carbon-fiber reinforced plastics for EMC-use-cases
How?

Generic process for reaching our sustainability-goals

Success!
Fronius will push sustainability even further.

More LCAs and even better Solutions.

Come visit us, see it for yourself.
We are looking forward to meeting you!
Thank you for your engagement!
Dr. Maxwell Giammona
IBM

Note: All participants are on mute. Please ask questions via the chat.
Heavy-Metal Free Batteries, Battery Recycling, and the Circular Economy

Maxwell Giammona, Dmitry Zubarev, Yumi Kim, Andy Tek, Linda Sundberg, Khanh Nguyen, Anthony Fong, and Young-Hye Na

IBM Research
Outline

- Energy Storage at IBM
- Shortcomings of Li-Ion Batteries
- IBM’s Heavy Metal-Free Battery Chemistry
- Benefits of an Iodine/Iodide based battery chemistry for recycling compared to Li-ion
IBM’s Materials and Process Innovations for Energy Storage Industry

**Strategy:** Combine computational capability (HPC simulation / AI, cognitive computing) with experiment to accelerate materials discovery as well as to deeply understand fundamental properties of materials

- **High Capacity Anode / Cathode**
  - Metallic Anode / New Cathodes

- **Cost Efficient/Sustainable Materials and Process**
  - Free of Heavy Metals including Cobalt

- **Non-flammable Electrolyte**
  - Solid State / New Class of Liquids

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**Better Performing, Safer, and More Sustainable Batteries**
Li-ion Batteries are Central to Modern Electronics and Transportation

- Most commercial rechargeable lithium batteries are based on metal-oxide intercalation cathodes, flammable liquid electrolyte, and low energy density graphite anode

- Heavy metal recovery drives almost all battery recycling today
Key Shortcomings of Current Li-ion Battery Technologies

- Technologies need to be based on sustainable, ethically sourced materials to power our future
- Use of low flashpoint, highly flammable electrolyte solvents
- Higher energy density anode materials are required for the next generation of batteries

Cobalt is expensive and its mining is rife with human rights abuses.

Traditional LIBs utilize highly flammable electrolyte solvents.
IBM’s Heavy Metal-Free LiI Conversion Battery

Key Components

- Heavy Metal-Free Cathode (Lithium Iodide as an active cathode materials)
- Less-flammable (Safer) electrolytes
- Electrocatalyst – Stabilize SEI and Promote Redox Reactions
- High Energy Density Li-metal Anode

Porous Carbon

I⁻ → I₂/ I₅⁻ → Li⁺
Cathode Relies on Iodine Conversion Chemistry

- Reaction mechanism involves the 2-step conversion of LiI to LiI$_3$ and then LiI$_3$ to I$_2$

- This reaction is mediated by an oxidizing additive in the electrolyte
After charging, needle-like dendrites are observed in the Li-ion battery, but IBM's battery shows even lithium deposition.
An Ultra-Fast Charging, Heavy-Metal Free Battery

- IBM Battery has ultra-high rate capability for both charge and discharge in comparison with conventional lithium-ion battery.
- The amount of active material for IBM battery was $\sim 12 \text{ mg/cm}^2$, that of NMC111 cathode for lithium-ion battery was $\sim 13 \text{ mg/cm}^2$.

*Lithium-ion battery performance was obtained with an in-house prepared cell using lithium-metal anode and commercially available NMC111 cathode.*
LiI Batteries Can Have Thicker Cathodes for Higher Energy Density and Greater Recyclability

- Chemistry facilitates higher proportion of cathode in cell
- High cathode proportion enhances energy density and recyclability

*data acquired from a battery manufacturer*
The need for better battery recycling and a circular economy

Both governments and companies are recognizing the need for more sustainable manufacturing, materials, and process across the entire life cycle of manufactured goods.

Batteries featured prominently in the Europeans Union’s recently released Circular Economy Action Plan.

“Batteries placed on the EU market should become sustainable, high-performing and safe all along their entire life cycle.”

“Batteries have to be long-lasting and safe, and at the end of their life, they should be repurposed, remanufactured or recycled, feeding valuable materials back into the economy.”
Current Li-ion battery recycling is driven by their heavy metal content and rely on energy intensive pyrometallurgical recovery processes.

As heavy metal content is reduced to cut costs, or we adopt cheaper cathodes such as LFP recycling will become more challenging.
Existing Hydrometallurgy Processes Well Suited for Iodine Recycling

- Hydrometallurgy is a suitable process for extraction of key elements from spent batteries based on their solvent affinity.

- Recyclers can likely recover lithium iodide from batteries via a leaching process using mostly water as a leaching agent.

- Leaching of iodine at industrial scale is possible and is already the main pathway for iodine production in the world (leaching from Caliche ore).

- Battery developers can design batteries to optimize recycling processes, reducing energy footprint and economic cost associated with extraction and purification of iodine compared to mining.

- LCD manufacturers efficiently recover iodine today from their processes by extracting it from wastewater.
Iodine Recycling is Already Happening

Summary of quantities of iodine being recycled annually from different sources (2015).[1]

<table>
<thead>
<tr>
<th>Iodine Use</th>
<th>Recycling (Metric Ton x 1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCD Film polarizers</td>
<td>2-2.5</td>
</tr>
<tr>
<td>Fluorochemicals</td>
<td>~ 1.5</td>
</tr>
<tr>
<td>X-ray contrast media (3rd parties)</td>
<td>~0.6</td>
</tr>
<tr>
<td>Organic synthesis (process enabler)</td>
<td>~ 1.5</td>
</tr>
<tr>
<td>Other uses</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>~ 6</strong></td>
</tr>
</tbody>
</table>

[1] Iodine Recycling: Has the full potential been reached?, A. Eccheveria (Product Manager Iodine & Lithium, SQM), 2015

- While the specifics of the process will likely need to be adjusted for energy storage, the LCD display industry has already demonstrated that iodine recycling at an industrial scale is a viable strategy.
- Several iodine producers are already invested in the commercial recycling of iodine.
Conclusions

• IBM’s heavy metal free battery is expected to be faster-charging, safer, and more sustainable than current li-ion battery technologies

• Current li-ion battery recycling is driven by their heavy metal content. As this content is reduced to cut costs, recycling will become more challenging

• An iodine-based battery lends itself well to a circular economy and has several benefits in terms of recyclability due to the potential for facile iodine recovery using already in use aqueous leaching methods

• Extraction of Iodine is less environment taxing than mining of heavy metals, making this kind of cathode potentially more sustainable over its entire life cycle from raw materials sourcing to recycling.
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IBM Characterization
IBM Model Shop
Thank you

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Next Sessions

**Session 5: Thursday, October 14, 2021**
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