Modernizing a Life Cycle Eco-Impact Estimator for ICT Products

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Eco Impact LCA quantification:
- Companies, customers, analysts, legislators want to know
- Gauge progress, measure impacts, assess benefits / eco-opportunities

But...
- Eco-impact LCAs are complex and time demanding
- Technology advancing faster than LCIA data availability

Life Cycle Stage Eco-Impact Inventory Analysis and Assessment

Detailed LCAs are complex, and for many cases, more than one needs
Life Cycle Assessment
Major life cycle stages for ICT products

Four major life cycle stages for ICT products

- **Manufacturing Stage**
  - Raw Materials Extraction; Intermediate Components and Sub-assemblies Manufacturing

- **Transport Stage**
  - Intermediate Transport and Assembly of ICT Product

- **Use Stage**
  - Final Transport, Distribution, and Installation of ICT Product

- **End-of-Life Stage**
  - Use and Servicing of ICT Product

**Total Eco Footprint**

**Embodied Eco Footprint**

**Operational Eco Footprint**
LCA Estimation
Methods, Goals, Approach

- **Eco-impact Assessment of ICT Products**
  - Methods and data are similar for most classes of products
  - Most parts have common application in ICT product types

- **Goals/Approach**
  - Simplified processes to more easily derive eco-impact information
  - Categorize targeted components - that produce the dominant eco-impact
  - Provide a reasonable accuracy - suited to ICT industry’s needs
  - Provide a means for continuous improvement - relative to continuing technological developments
### ICT LCA Estimation Methodology – Common Component Categorization

#### Component groups with similar materials and manufacturing processes

<table>
<thead>
<tr>
<th>ICT – Common Component Groups</th>
<th>ICT - Specialized Component Groups</th>
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</thead>
<tbody>
<tr>
<td>Printed Wiring Boards (PWBs)</td>
<td>Optical / Opto-electronic Devices - laser amplifiers, etc.</td>
</tr>
<tr>
<td>Integrated Circuits - including semiconductor devices</td>
<td>Radio Frequency Components - power amplifiers, antennas, etc.</td>
</tr>
<tr>
<td>Electro–Mechanical Components - fans, motors, etc.</td>
<td>Disk Drives</td>
</tr>
<tr>
<td>Metals / Metallic Mechanical Components - cabinets, frames, structural parts, heat sinks, etc.</td>
<td>Camera Devices - CCDs, etc.</td>
</tr>
<tr>
<td>Polymeric Mechanical Components - plastic parts</td>
<td>Copier Components - photoreceptor drum, fuser, laser scanning unit, toner cartridge, printer head, ink cartridge</td>
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<tr>
<td>Displays - electronic display / imaging devices</td>
<td>Other – Lamps, Crystals, Polarized Glass</td>
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<td>Power Supplies</td>
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<tr>
<td>Large Capacitors</td>
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</tr>
<tr>
<td>Batteries</td>
<td></td>
</tr>
<tr>
<td>Cables - signal, RF, power cords, wires, optical fiber</td>
<td></td>
</tr>
</tbody>
</table>

*Common Component Characterization* methodology is further defined in GHG Protocol – “Built on GHGP” ICT Sector Guidance (Chapter 5: ICT Hardware)

ICT LCA Estimation Methodology – Component Type Eco-impacts

Eco-impact (GWP) of ICT Components

Electronic Component Type (quantity)
Bare Printed Wiring Boards (PWB)

- Estimation Parameters / Criteria:
  - Size (sq. cm)
  - Layers (#)
  - Surface finish (e.g. ImAg/Sn, ENIG)
  - Board material (e.g. FR4)

- Algorithm:
  - Simple summation model
  - Regression Analysis

\[
\text{GWP}_{\text{PWB}} = A_B [\alpha + (\beta S_F) + (\gamma B_L)]
\]

Where:
- \( \text{GWP}_{\text{PWB}} \) = Global warming Potential of manufactured PWB
- \( A_B \) = area of PWB
- \( \alpha \) = intercept coefficient
- \( \beta \) = PWB surface finish type coefficient
- \( S_F \) = PWB surface finish type
- \( \gamma \) = PWB layer coefficient
- \( B_L \) = number of layers in PWB
Integrated Circuits (ICs)

- **Estimation Parameters / Criteria:**
  - Package Type (e.g. BGA, PLCC, QFP, TQFP)
  - Inputs / Outputs (count)

- **Algorithm:**
  - Simple summation model
  - Regression Analysis

\[
GWP_{IC} = \alpha + (\beta I_T) + (\gamma C_{IO})
\]

Where:
- \(GWP_{IC}\) = Global Warming Potential (kgs CO\(_2\)e / IC device)
- \(\alpha\) = Intercept coefficient
- \(\beta\) = IC package type coefficient
- \(I_T\) = IC package type (e.g. SSOT, QFP, BGA)
- \(\gamma\) = IC input/output coefficient
- \(C_{IO}\) = number of IC inputs / outputs
Eco-impact of Manufacturing Stage

\[ \text{Eco-impact of Manufacturing Stage} = \]

\[\text{Contribution of components, sub-assemblies, cabinets and packaging materials} + \]

\[\text{Intermediate Transports} + \]

\[\text{ICT Assembly Processes} + \]

\[\text{Software Development} + \]

\[\text{ICT Product Testing} + \]

\[\text{Packaging Process} \]

* For estimation simplicity: factors are applied for process steps (in blue)
Transport Stage LCA

- **Estimation Parameters / Criteria:**
  - Location of final product assembly *(nodal point – by region)*
  - Location of product integration center / warehouse *(nodal point – by region)*
  - Location of final product installation *(nodal point – by region)*
  - Final product shipping weight
  - Transport mode – surface / air
  - Transport mode GWP factors *(per kilogram of shipped product weight per kilometer traveled)*

  **Additional factors to be considered include:**
  - Transportation equipment used
  - Fuel types used
  - Transport load factor
  - Empty return rate for transport means
Use Stage LCA

- **Estimation Parameters / Criteria:**
  - Location where product is used – by region
  - Power consumption profile – per typical product configuration and feature set
    - Function of product usage (active, idle / sleep modes, no power mode)
    - Include additional power to cool equipment internally and externally
  - Power usage per annum (includes servicing outages if required)
  - Product operating life (expected or design life)
  - Power consumption to GHG emissions conversion factors – by country / region

<table>
<thead>
<tr>
<th>Product Type</th>
<th>On Mode</th>
<th>Standby Mode</th>
<th>Off Mode</th>
<th>Avg Lifetime</th>
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<td>Hours/Year</td>
<td>Hours/Year</td>
<td>Years</td>
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<td>0</td>
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<td>Wireless base station</td>
<td>7008</td>
<td>1,752</td>
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<td>Optical switch (Central Office)</td>
<td>8760</td>
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</table>
End-of-Life Stage LCA

- **Estimation Parameters / Criteria:**
  - Breakdown of product into its constituent components and materials – e.g. circuit boards, frames / chassis, metals, polymerics
  - End-of-Life GHG factors – includes de-installation, transport to recycling facility / disposal site
    - Full recycling (w/ integration back into raw materials extraction / intermediate mfg)
    - Incineration (w/ energy recovery)
    - Landfill (w/ landfill gas energy recovery)
LCA Estimator Tool
(Early development spreadsheet-based)

Full life cycle eco-impact profile - PCF

- Equipment types can be aggregated into network / system configurations for further eco-impact assessment
- Life cycle Stage impacts vary greatly

Digital Microwave Link
(Network Communications Product)
- 1.1% Manufacturing
- 5.8% Transport
- 1.5% Use
- 91.6% End-of-Life
- Total PCF: 20,000 kg CO₂e

Wireless SOHO Router
(Network Communications Product)
- 0.9% Manufacturing
- 0.3% Transport
- 13.7% Use
- 85.1% End-of-Life
- Total PCF: 100 kg CO₂e

Satellite-linked Automobile Radio
(Consumer Entertainment Product)
- 43.0% Manufacturing
- 1.5% Transport
- 0.0% Use
- 55.5% End-of-Life
- Total PCF: 800 kg CO₂e

Full life cycle eco-impact profile - PCF
- Equipment types can be aggregated into network / system configurations for further eco-impact assessment
- Life cycle Stage impacts vary greatly
iNEMI Eco-impact Estimator Activities

- iNEMI LCA Eco-impact Estimator Project (Phase 3)
  - Eco-impact estimator ported to a hosted environment (Purdue Univ.)
  - Update life cycle eco impact data for key component categories / technology advances – e.g. PWBs, ICs, cables, mechanical parts
  - Expand eco-impact to additional aspects, e.g. water resource depletion
  - Longer term: model available for broader industry use with governance
  - Additional participants/contributors encouraged
## LCIA Dataset Update

### PWBs – Conventional Construct

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<th>PROCESS</th>
<th>EQUIPMENT</th>
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<th>POWER (KWh/m²)</th>
<th>WATER (Ltr/ft²)</th>
<th>WATER (Ltr/m²)</th>
<th>OUTPUT (ft²)</th>
<th>POWER (KWh)</th>
<th>WATER (L, 1,000 kg)</th>
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### Primary Datasets
LCIA Dataset Update

PWBs – HDI Construct

Primary Datasets
LCIA Dataset Update

- Energy consumption of IC manufacturing for different technology nodes
- GWP estimation of passive devices relative to PWB area
PWB – Proposed Screenshot
IC – Proposed Screenshot

Please Select the Type of Component:

**IC Component**

**Component Name:**

**Component No.:**

**No. of Units:**

### Standard IC Packages

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<thead>
<tr>
<th>IC Components</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWP (Kg of CO₂)</td>
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</tr>
<tr>
<td>Water Depletion (m³)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Seed Count</th>
<th>Select Date</th>
<th>Model</th>
<th>Select IC Type</th>
<th>GWP Output</th>
<th>Water Output</th>
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### Advanced IC Packages (modeling by wafer sizes)

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</tbody>
</table>

Want to override the values of eco-impact? [ ]

- GWP (Kg of CO₂):
- Water Depletion (m³):
Summary

- iNEMI’s LCA Eco-impact Estimator offers a means to more easily assess the GWP of ICT products over their full life cycle – manufacturing, transport, use, and end-of-life treatment.

- iNEMI members collected, assessed and integrated more contemporary information and data into the current Estimator (database-driven tool ported to a hosted environment within an academic institution).

- LCA estimator offers more open availability to its members and academic researchers.

- Additional eco-impact aspects, such as water usage, are relevant to the ICT industry, and may be included in the estimator tool as LCIA modeling for such eco-impact advances.

- Future endeavors may include opening the database formatted estimator to further ICT industry utilization as well as continued usability enhancements and dataset updates.
Thank You