**Motivation**

- Need for dynamic model of global copper flows
- Access stocks-in-use and recycling rates at a global level
- Material flow data needed for LCI and LCA work

**Goal:** Allow calculation of key recycling indicators at global level

- Recycling Input Rate
- Overall Recycling Efficiency Rate
- End of Life Recycling Efficiency Rate
- End of Life Collection Rate
- End of Life Recycling Processing Rate

**Project timeline (Phase I): January to September 2010**
Methodology – Building the model
Tasks

ICA end-use datasets

Literature

Published statistical data

Draft model

Global survey of selected ICA contacts

Survey within ICA network

Working Cu flow model (worldwide)
Implementation using Vensim
Data and calculations – Filling the model
# Model inputs and outputs

<table>
<thead>
<tr>
<th>Input</th>
<th>Type</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual semis prod.</td>
<td>Data (ICSG / ICA)</td>
<td>Stocks in use</td>
</tr>
<tr>
<td>Total ref. Cu prod.</td>
<td>Data (ICSG)</td>
<td>Annual waste flows</td>
</tr>
<tr>
<td>Total ref. Cu use</td>
<td>Data (ICSG)</td>
<td>Stocks in landfills</td>
</tr>
<tr>
<td>Total mining prod.</td>
<td>Data (ICSG)</td>
<td>Annual amounts of scrap</td>
</tr>
<tr>
<td>Range of end-uses</td>
<td>Data (ICA, IWCC)</td>
<td>Recycling input rate</td>
</tr>
<tr>
<td>Lifetimes for end-use products</td>
<td>Assumptions, literature,</td>
<td>Collection rates</td>
</tr>
<tr>
<td>Fabrication efficiencies: Formation</td>
<td>Assumptions, literature,</td>
<td>Different recycling efficiency rates</td>
</tr>
<tr>
<td>Sorting / disassembling / smelting</td>
<td>Assumptions, literature,</td>
<td>Flows of secondary copper</td>
</tr>
<tr>
<td>Factors to define different collection</td>
<td>Assumptions, literature,</td>
<td></td>
</tr>
<tr>
<td>rates</td>
<td>survey</td>
<td></td>
</tr>
</tbody>
</table>

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Total annual copper usage

Input data

Primary refined copper

Total refined copper production

Total refined copper usage

Input data

Refined copper stocks

Secondary refined copper

calculated

old scrap

Directly melted copper & alloy

calculated

old scrap

new scrap

survey input

Total annual copper usage

Input data
Stock in use phase

- Stock Telecommunication
- Stock Power Utility
- Stock Plumbing
- Stock Other Transport
- Stock Non Electrical Industrial
- Stock Non Electrical Automotive
- Stock Electronic
- Stock Electrical Power
- Stock Electrical Industrial
- Stock Electrical Automotive
- Stock Divers
Estimating Cu contained in landfills

Annual input from production and fabrication

Use
(16 different types with different lifetimes)

Annual total waste / scrap
(6 different types)

Collection rate for every scrap type

Cu to landfill or abandoned in place
(separate and for every type of scrap)

Cu scrap collected for recycling

Not recycled

Recycled (to production)

loss to other recycling products

dissipative loss

Landfill

Million tonnes

0 20 40 60 80 100 120

1910 1960 2010

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Average lifetime vs. average age (1)
Average lifetime vs. average age (2)
Average lifetime vs. average age (3)

- **Uses**
  - **A**: Avg. Lifetime: 15 years
  - **B**: Avg. Lifetime: 15 years

- **Today**
  - Avg. Lifetime: 15 years
  - Avg. age: < 15 years

- **Waste**
  - > 50%
  - < 50%
Use phase: average lifetime vs. average age

- Million tonnes

- Use 2010
- Use 1985
- Waste 2010

- Telecommunication
- Power Utility
- Plumbing
- Other Transport
- Non Electrical Industrial
- Non Electrical Automotive
- Electronic
- Electrical Power
- Electrical Industrial
- Electrical Automotive
- Diverse
- Cooling
- Consumer and general Products
- Communication
- Building Plant
Waste management: Process efficiency

- Collection rates are calculated depending on recycling process efficiency rates and input flows of total annual semis, refined copper and mining production.
- Collection rates are directly adapted to changes of input data.

<table>
<thead>
<tr>
<th>Waste Type</th>
<th>Collection Rate (current model calculated)</th>
<th>Separating / Sorting / Disassembling Efficiency</th>
<th>Efficiency of Smelting and Refining (metal recovery)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&amp;D</td>
<td>~ 0.70</td>
<td>0.90</td>
<td>0.96 – 0.98</td>
</tr>
<tr>
<td>WEEE</td>
<td>~ 0.60</td>
<td>0.45</td>
<td>0.96 – 0.98</td>
</tr>
<tr>
<td>ELV</td>
<td>~ 0.90</td>
<td>0.50</td>
<td>0.96 – 0.98</td>
</tr>
<tr>
<td>IEW</td>
<td>~ 0.65</td>
<td>0.65</td>
<td>0.96 – 0.98</td>
</tr>
<tr>
<td>INEW</td>
<td>~ 0.65</td>
<td>0.75</td>
<td>0.96 – 0.98</td>
</tr>
<tr>
<td>MSW</td>
<td>~ 0.05</td>
<td>0.15</td>
<td>0.96 – 0.98</td>
</tr>
</tbody>
</table>
Indicators – Using the model
Defining recycling rates

- Recycling Input Rate
  = \frac{\text{Total refined copper (cathode)}}{\text{Total annual copper usage}}

- Overall Recycling Efficiency Rate
  = \frac{\text{Total annual copper usage}}{\text{Recycling Input Rate}}

- End of Life Recycling Rate
  = \frac{\text{High grade copper / alloy scrap}}{\text{New copper scrap}}

- End of Life Collection Rate
  = \frac{\text{Scrap collected for recycling}}{\text{Incineration}}

- End of Life Recycling Processing Rate
  = \frac{\text{Total refined copper (cathode)}}{\text{Scrap smelting & refining}}
Recycling input rate

$RIR_{(1999-2010)} = 34 \pm 3\%$
End-of-life collection rate

- Total annual Cu production
  - Secondary refined Cu
  - Direct melted Cu & alloy
    - Scrap smelting & refining
      - High grade scrap
      - New scrap
        - Stock: Semis
        - Stock: Cathodes
        - Total annual Cu use
          - Production of semis
            - Production of end-use articles
              - Use
              - Total annual waste

Recycling rate

EoL-CR (1999-2010) = 65 ± 5%

Graph showing recycling and end-of-life collection rates from 2001 to 2009.
End-of-life recycling efficiency rate (EoL RR)
Recycling indicators estimated in the model

- Overall recycling process efficiency rate
- Recycling process efficiency rate
- End of life collection rate
- Old scrap ratio
- End of life recycling rate
- Recycling input rate
- EoL Recycling input Rate
Estimated recycling rates and sensitivity analysis
## Estimating collection and recycling rates by type of scrap

<table>
<thead>
<tr>
<th></th>
<th>EOL Collection Rate</th>
<th>EoL Recycling Proc. Rate</th>
<th>EoL Recycling Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Deviation over time</td>
<td>Average</td>
</tr>
<tr>
<td>C&amp;D</td>
<td>72%</td>
<td>6%</td>
<td>90%</td>
</tr>
<tr>
<td>MSW</td>
<td>5%</td>
<td>2%</td>
<td>20%</td>
</tr>
<tr>
<td>WEEE</td>
<td>62%</td>
<td>5%</td>
<td>54%</td>
</tr>
<tr>
<td>ELV</td>
<td>90%</td>
<td>5%</td>
<td>54%</td>
</tr>
<tr>
<td>IEW</td>
<td>66%</td>
<td>6%</td>
<td>69%</td>
</tr>
<tr>
<td>INEW</td>
<td>68%</td>
<td>5%</td>
<td>74%</td>
</tr>
</tbody>
</table>

Best estimates calculated with average lifetimes. Average and deviation over time (std. dev.) refer to estimates for the period 1999-2009.
Summary

1. The model itself
   - Is flexible, dynamic and includes the relevant copper flows at a global level
   - Is based on the best available datasets at the global level
   - Fully implements the ICA end-use datasets (semis, markets)
   - Includes input from a global survey of ICA staff and industry contacts (cross-checking of datasets and assumptions)

2. Using the model
   - Have access to all flows on a yearly basis
   - Can calculate key recycling indicators at a global level
   - Can provide estimates of recycling indicators by type of scrap
ICA GLOBAL COPPER FLOW MODEL

ICSG Environmental & Economic Committee
26 April 2012

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