Comment

**Yield losses in electronics production are significant to LCA**

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Simplified Inventory procedure

- Material inventory determined by **disassembly of shipped product**
- **This approach is often used in LCA studies of electronic products**
- **Assumes a production yield of approximately 100%...**

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Material in shipped product

Material input to production

Consumer

Production process

Output = Input
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Inventory heeding yield losses...

Material in shipped product

Yield losses in production

Increased material input to production

Disposal

..and auxiliary materials

Material in shipped product

Yield losses in production

Material input to production

"non-product" materials needed in production

Disposal
The problem

Yield losses in production of electronic components are not generally negligible as sometimes assumed, i.e. can be much higher than a few percent.

Production yield losses can have a considerable effect on life-cycle inventories of electronic products:

• Increased material and energy demand
• Increased waste volumes to disposal

Example 1: Integrated Circuit (IC) production

Czochralski column
high-purity mono-
crystalline silicon
column

Silicon wafer
silicon disk
~ 250 nm thickness

Microchip or Die
Integrated Circuit (IC) var. sizes
**Wafer Sawing Losses**

- **Czochralski column**
- **Sawing slit**
  - Slit gap currently ~150 nm
- **End cone** to internal recycling
- **Wafer** currently ~250 nm
  - Yield = \( \frac{\text{Material in wafers}}{\text{Material in column}} = 62.5\% \)

- Losses of high-purity silicon = approx. 37.5% in this production step alone

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**Geometric Losses Wafer/Die**

- **IC layout on wafer**
- **Geometric losses** increase with bigger sized ICs
  - Yield = \( \frac{\text{Material in IC dies}}{\text{Material in wafer}} = 85\% \)

- Losses of wafer area = approx. 15% in this production step alone (depending on wafer and die sizes)
Yield losses in quality control

Not all produced ICs are functional due to defects.

Yield losses increase with IC area.
Yield losses decrease with development time and money.

Range of yield losses in IC production:

**Introduction** 84%
**Mature** 22%

Typical figures for Ultra-large systems Integration ULSI chips (eg. 486 or Pentium) from P. van Zant, 'Microchip Fabrication', McGraw-Hill, 1997

Yield and fabrication cost

Overall losses

Best case, i.e. 22% chip defect loss
Excluding other up- or downstream losses

100% Czochralski silicon monocrystal
43% silicon in shipped microchips
chip defect loss
wafer/chip geometric loss
wafer sawing losses
57% overall losses

Overall losses IC production

In the best case (with 22% chip defect loss) the overall loss is 57%.
This increases material and energy demand by a factor of 2.4

In the worst case (with 84% chip defect loss) the overall loss is 92%.
This increases material and energy demand by a factor of 12.
Example 2: LCD displays

Chunghwa Picture Tubes Ltd., Taiwan, reports a current (1999) production yield of 50%, i.e. **50% of the produced displays are not functional**.

Chunghwa Picture Tubes Ltd., Taiwan, hopes to achieve a yield of **70% in the future**. Still 30% of all displays would be not functional.

Other manufacturers like Acer Display Technologies (ADT) report similar future goals.

Source: China Economic News Service, Sep 29 1999

Example 2: LCD displays (cont.)

- TFT-LCD displays are produced from **glass panel substrates** of approx. 60 by 72 cm size
- **Six 13.3" or 14.1" displays** can be produced from one glass panel substrate.
- A **geometric loss of 15% to 23%** of the glass substrate results.
- **Overall loss** from substrate to shipped LCD display is **40% to 62%**, resulting in an increased material and energy demand by a factor 2.6 to 1.7 (as compared to an ideal 100%-yield production).
Conclusions

• Yield losses in production of electronic components can be much higher than usually encountered in industrial production.

• These yield losses can increase the material and energy demand and waste volumes in production inventories considerably.

• Infrastructure of electronic products and components might be environmentally more relevant than currently assessed (with a 100%-yield inventory).

• Neglecting yield losses or assuming a near 100%-yield production in product inventories needs to be verified.