Assessment of scarce resources consumption of robotic vacuum cleaners considering End-of-Life treatment in electronic waste shredder system

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Why this project?

Overall the development aim is to look at the question:

- Using more and more electronic devices/machines in our society it becomes increasingly important to keep the extracted resources in circulation in the industrial cycle
- In order to assess that, we look at different machines supplied by different cooperating industries - or by other means...

- NB: Work in Progress...!
Why Robotic Vacuum Cleaners

- Relative new product in the households – but increasing volume expected
- An example of new complex ‘intelligent’ machines with different sensors and controls

More specific aims:
- To what extent can they be handled in the existing systems for electronic waste?
- What will be the losses?
Related to the project ‘Rethink Resources’
- An innovation network project – granted by the Danish EPA

Partners

- Technological Institute, DK
  - Waste
  - Plastic
  - Logistic
  - Automation
- University of Southern Denmark
  - KBM*
  - ITI
- CLEAN
- Innovation network for Clothing and Textiles

Basic approach

- Focus on products...!
- **Re-design to match fate in End-of-life systems** – or extend lifetime...
- Optimisation towards conservation of (scarce) resources
- Simple assessment tools – like MECO...

Success criteria:

- Co-operation with (Danish) industries
- Impacts and case stories! (- not reports and papers...)

Institute for Chemical-, Bio- and Environmental Engineering (Life Cycle Group)
What we want to know:
- taking the RVCs as an example

1) What are the material-compositions of the RVCs? Which components contain which materials?
2) To what extent is it possible to recover these materials by existing shredder technology?
3) How is separation performed (typically)?
4) What is the efficiency of the separation with regards to specific components/materials?
5) Can that efficiency be improved?
   - a) by alternative construction/design?
   - b) by alternative disassembly/shredding?
6) What are the incentive/barriers related to:
   - a) implementing alternative construction/design?
   - b) improving disassembly/shredding?
Two different projects

Master project:
Manual disassembly of 10 different RVCs... (At this stage 7 have passed the quality control...)

Assessment of the results by use of the CES Edupack EcoAudit Tool

Waste Management Course project:
Test run with 250 kg mixed RVC in a Danish facility for handling electronic waste
Control of the ‘cleanness’ of the resulting 11 fractions

Assessment with the MECO Approach:
• Primary energy
• mPR
Which components do we find?

Weight (g)

- Cover
- Dust Bin (2)
- Wheel (3)
- Main Brush - Brushes (4)
- Battery (5)
- Casing (10)
- Body Frame (11)
- Screws (12)
- Vacuum (9)
- Sensors & Small electrical parts (8)
- Wires & Connections (7)
- Other (13)

Brands:
- Samsung Navibot
- iRoomba
- Melissa640-255
- Vileda
- Wasco
- Indream 9200
- Melissa OMB
Some of the components
What are the material-compositions of the RVCs?

![Graph showing material compositions of RVCs]

- **Plastic parts**
- **Battery**
- **Metal parts**
- **PCB**
- **Other**

- **Weight (g)**

- Samsung Navibot
- iRoomba
- Melissa640-255
- Vileda
- Wasco
- Indream 9200
- Melissa OMB
Expressed as primary energy invested:

Calculations by CES EduPack EcoAudit Tool
Based on literature data for composition of complex compounds like Printed Circuit Boards (PCBs) and electro motors – picked from the EcoInvent database. Regarding scarcity – data from CES EduPack is applied...
Based on literature data for composition of complex compounds like Printed Circuit Boards (PCBs) and electro motors – picked from the EcoInvent database. Regarding scarcity – data from CES EduPack is applied…

Converted to mPR:

**Scarce resources (mPR)**
The shredder
Some sorted frations
Detailed analysis of fraction 4
## Shredder fractions

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### Fate of the different fractions?
- Steel industries
- Refineries
- Combustion
- Further sorting
Fate of the different fractions

### Most valuable

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- Mostly Fe-metals,
  - **Steel industries**
    - Copper “trapped” in motor is unwanted in the steel industries. Plastics contributes as auxiliary fuel in the steel smelter process. If copper enters the steel production it is accounted as lost.
  - **Further sorting?**
    - Further separation of copper…?
## Fate of the different fractions

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### Most valuable

- Mostly Plastics and considerable amounts of PCB’s
  - **Combustion**
    - Plastic is “materialised” oil and performs well when combusted. The mix of plastics implicates the recycling of plastic. Often is combustion the end of life option for plastic.
    - The PCB’s contains a lot of epoxies which is utilised under combustion. Valuable substances lost when it ends up in the slag. The main share of PCB’s ends in the inert fraction
      - Similar case for wires. Almost all wire end in the inert fraction.
  - **Further sorting?**
    - Further separation of wires and PCBs?
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### Most valuable

- Mostly PCB
  - **Umicore/refinery**
    - Target elements recovered by 95% approximately. Epoxy in PCB's works as auxiliary fuel which reduces the need for fuel in the process.
  - **Further sorting?**
    - For further separation of especially copper
Fate of batteries

- Manually removed before shredding
- The typical battery for a RVC is a NIMH-battery
  - Contains mostly of nickel (39 %) and iron (23 %) but also rare earths (10 %)
- Stainless steel industry
  - Cheap source of nickel
    - But rare earths are lost
- Umicore
  - Rare earths not “target elements”
    - Also loss of rare earths
    - But Umicore investigates the possibility for rare earths recovery
Recovery rates...?

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**RECOVERY**

- Acceptable recovery of Plastic and iron
- PCB`s contains most scarce elements
  - Need for further separation in the different streams
- Almost 0 % wires ends in the desired waste fraction
  - Need for further separation of the wires from the inert fraction
Loss of resources...?

Assumptions:
- Fe-metal fractions are smelted in steel industries
- Inert fraction and air cleaner residues are combusted
- Nfe-metal fractions are refined at Umicore
Loss of resources...?

- Without gold from PCB
  - Same assumptions
    - All rare earths a lost, together with notable amounts of silver from PCB’s
Conclusions:

Methodological challenges:

- Assessment of compositions of the PCBs etc.
- Better understanding of fate of the fractions after shredder/sorting systems.

Learnings - so far:

- PCBs and batteries contain the most scarce elements.
- Batteries are sorted out and recovered but rare earth elements are lost...
- PCBs perform generally low in the shredder and sorting systems.
- Small electric motors is a problem due to the content of copper...
THANK YOU