Call for Proposal n° 11

Brussels, January 19th 2012

JTI-CS-2012-1-ECO-01-050-Metal recycling: Recycling routes screening and Design for Environment

End of life of an aircraft

- Per year up to 300 aircrafts are going to be put out of service
- Lifetime of an aircraft: 30-40 years
- Actual solutions:
  - Disposed in desert graveyard
  - Rough dismantling
    - Engine (up to 80% of the total price)
    - Landing gears
    - Few materials sorting
- Aircraft recycling:
  - ASI (Air Salvage International – UK -1995)
  - Bartin Recycling Group (F – 2005) …
  - PAMELA Project (F - 2005-2007)

The *Aircraft Fleet Recycling Association* was founded in 2005 to enhance aircraft recycling.

Aircraft desert graveyard USA

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Alloys

Metal alloys in aircraft are basically made of 3 different types of alloys:

- Al - alloys
- Ti - alloys
- Ni - alloys

Classification of Al-alloys

1000	pure Aluminum
2000	Cu
3000	Mn
4000	Si
5000	Mg
6000	Si + Mg
7000	Zn
8000	Li
9000	others

3 types of manufacturing of Al-alloys

A: forging alloys

e.g.: AlMn, AlMg, AlMgMn

B: precipitation hardening alloy

e.g.: AlCuMg, AlCuSiMn, AlMgSi

C: die-casting alloy

e.g.: AlSi, AlSiMg, AlSiCu, AlCuTi

Examples of alloys

		Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti
2014 T4510	AlCu4SiMg	90,4 - 95	0,5 - 1,2	0,7	3,9 - 5,00	0,4 - 1,2	0,2 - 0,8	0,1	0,25	0,15
2014 T4511	AlCu4SiMg	90,4 - 95	0,5 - 0,9	0,0 - 0,5	3,9 - 5,00	0,4 - 1,2	0,2 - 0,8	0,0 - 0,1	0,0 - 0,2	0,0 - 0,2
2014 T6	AlCu4SiMg	90,4 - 95	0,5 - 1,2	< 0,7	3,9 - 5,00	0,4 - 1,2	0,2 - 0,8	<0,1	< 0,25	< 0,25
2014 T6510	AlCu4SiMg	90,4 - 95	0,5 - 1,2	< 0,7	3,9 - 5,00	0,4 - 1,2	0,2 - 1,8	< 0,1	< 0,25	< 0,15
2014 T6511	AlCu4SiMg	90,4 - 95	0,5 - 1,2	< 0,7	3,9 - 5,00	0,4 - 1,2	0,2 - 1,8	< 0,1	< 0,25	< 0,15
2014 F	AlCu4SiMg	90,4 - 95	0,5 - 1,2	< 0,7	3,9 - 5,00	0,4 - 1,2	0,2 - 1,8	< 0,1	< 0,25	< 0,15
2017	AlCuMgSi	91,5 - 95,5	0,2 - 0,8	< 0,7	3,5 - 4,5	0,4 - 1,0	0,4 - 0,8	< 0,1	< 0,25	< 0,15
2024 T3	AlCu4Mg1	90,7 - 94,7	< 0,5	< 0,5	3,8 - 4,9	0,3 - 0,9	1,2 - 1,8	< 0,1	<0,25	<0,15
2024 T351	AlCu4Mg1	90,7 - 94,7	< 0,5	< 0,5	3,8 - 4,9	0,3 - 0,9	1,2 - 1,8	< 0,1	<0,25	<0,15
2024 T3511	AlCu4Mg1	90,7 - 94,7	< 0,5	< 0,5	3,8 - 4,9	0,3 - 0,9	1,2 - 1,8	< 0,1	<0,25	<0,15
2090-O	AlLi	93,2 - 95,6	< 0,1	< 0,12	2,4 - 3,0	< 0,05	< 0,25	< 0,05	< 0,1	< 0,15
2091-T8x	AlLi	91,9 - 95,4	< 0,2	< 0,3	1,8 - 2,5	< 0,1	1,1 - 1,9	< 0,1	< 0,25	< 0,1
2098	AlLi		0 - 0,12	0 - 0,15	3,2 - 3,8	0 - 0,35	0,25 - 0,8	0 - 0,05	0 - 0,35	
2099	AlLi	bal	max. 0,05	max. 0,07	2,4 - 3,0	0,1 - 0,5	0,1 - 0,5		0,4 - 1,0	max. 0,1
2124	AlCu	91,2 - 94,7	< 0,2	< 0,3	3,8 - 4,9	0,3 - 0,9	1,2 - 1,8	< 0,1	< 0,25	< 0,15
2124-T351	AlCu	91,2 - 94,7	< 0,2	< 0,3	3,8 - 4,9	0,3 - 0,9	1,2 - 1,8	< 0,1	< 0,25	< 0,15
2124-T851	AlCu	91,2 - 94,7	< 0,2	< 0,3	3,8 - 4,9	0,3 - 0,9	1,2 - 1,8	< 0,1	< 0,25	< 0,15
2198	AlLi		0 - 0,8	0 - 0,1	2,9 - 3,5	0 - 0,5	0,25 - 0,8	0 - 0,05	0 - 0,35	
2214	AlCu6Mn	91,2 - 94,7	0,5 - 1,2	< 0,3	3,9 - 5,0	0,4 - 1,2	0,2 - 0,8	< 0,1	< 0,25	< 0,15
2219-O	AlCu6Mn	91,5 - 93,8	< 0,2	< 0,3	5,8 - 6,8	0,2 - 0,4	< 0,02		< 0,1	0,02 - 0,1
2219-T31	AlCu6Mn	91,5 - 93,8	< 0,2	< 0,3	5,8 - 6,8	0,2 - 0,4	< 0,02		< 0,1	0,02 - 0,1
2618A T6	Al-Cu-Mg-Fe-Ni	92,4 - 94,9	0,1 - 0,25	0,9 - 1,3	1,9 - 2,7		1,3 - 1,8		< 0,1	0,04 - 0,1
2618A T851	Al-Cu-Mg-Fe-Ni	92,4 - 94,9	0,1 - 0,25	0,9 - 1,3	1,9 - 2,7		1,3 - 1,8		< 0,1	0,04 - 0,1
2618A T8511	Al-Cu-Mg-Fe-Ni	92,4 - 94,9	0,1 - 0,25	0,9 - 1,3	1,9 - 2,7		1,3 - 1,8		< 0,1	0,04 - 0,1
2618A F	Al-Cu-Mg-Fe-Ni	92,4 - 94,9	0,1 - 0,25	0,9 - 1,3	1,9 - 2,7		1,3 - 1,8		< 0,1	0,04 - 0,1
5052	AlMg2.5	95,7 - 97,7	< 0,25	< 0,4	< 0,1	< 0,1	2,2 - 2,8	0,15 - 0,35	< 0,1	
5083-O	AlMg4,5Mn(0,7)	92,4 - 95,6	< 0,4	< 0,4	< 0,1	0,4 - 1,0	4,0 - 4,9	0,05 - 0,25	< 0,25	< 0,15
5083-H112	AlMg4,5Mn(0,7)	92,4 - 95,6	< 0,4	< 0,4	< 0,1	0,4 - 1,0	4,0 - 4,9	0,05 - 0,25	< 0,25	< 0,15
5083-H116	AlMg4,5Mn(0,7)	92,4 - 95,6	< 0,4	< 0,4	< 0,1	0,4 - 1,0	4,0 - 4,9	0,05 - 0,25	< 0,25	< 0,15
5083-H32	AlMg4,5Mn(0,7)	92,4 - 95,6	< 0,4	< 0,4	< 0,1	0,4 - 1,0	4,0 - 4,9	0,05 - 0,25	< 0,25	< 0,15
5083-H34	AlMg4,5Mn(0,7)	92,4 - 95,6	< 0,4	< 0,4	< 0,1	0,4 - 1,0	4,0 - 4,9	0,05 - 0,25	< 0,25	< 0,15
5086-O	AlMg4	93,0 - 96,3	< 0,4	< 0,5	< 0,1	0,2 - 0,7	3,5 - 4,5	0,05 - 0,25	< 0,25	< 0,15
5086-H112	AlMg4	93,0 - 96,3	< 0,4	< 0,5	< 0,1	0,2 - 0,7	3,5 - 4,5	0,05 - 0,25	< 0,25	< 0,15
6061 -O	AlMg1SiCu	95,8 - 98,6	0,4 - 0,8	< 0,7	0,15 - 0,4	< 0,15	0,8 - 1,2	0,04 - 0,35	< 0,25	< 0,15
6061 T6	AlMg1SiCu	95,8 - 98,6	0,4 - 0,8	< 0,7	0,15 - 0,4	< 0,15	0,8 - 1,2	0,04 - 0,35	< 0,25	< 0,15
6061 T651	AlMg1SiCu	95,8 - 98,6	0,4 - 0,8	< 0,7	0,15 - 0,4	< 0,15	0,8 - 1,2	0,04 - 0,35	< 0,25	< 0,15
6061 T6510	AlMg1SiCu	95,8 - 98,6	0,4 - 0,8	< 0,7	0,15 - 0,4	< 0,15	0,8 - 1,2	0,04 - 0,35	< 0,25	< 0,15

Metal recycling – traditional ways

Melting and reshaping to alloys

Aircraft graveyard in the US desert

Bicycle frames

A/c alloys are melted and used for production of other alloy products

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Metal recycling – traditional ways

- The recycling rate of (old) aircrafts by **„shredding & melting“** could be up to 80 %
- Metals and alloys can be reused to produce engine blocks for cars, bicycles, cans or furniture
- From one “old” large twin aisle aircraft such as a Boeing 747 going out of service one can regain aluminium at a value of approx. 60.000 €
- **Constraints:**
  - Purity of alloys (identification and separation from other alloys and materials like polymers, coatings)

Alloy recycling

Objective:

- Recycling of scrap metal from aircrafts
- Use of old alloys for design of new products with regard to least environmental impact
- Consideration of Design for Environmental (DfE) aspects for the design of future (a/c) alloy parts

Alloy recycling

- Promising Al-alloys for recycling in construction materials

  - AlCu4SiMg
  - AlCu
  - AlMg2,5
  - AlMg1SiCu
  - AlCu
  - AlLi

- Grinding of alloys to desired grain size
- first trials to find potential application areas
  e. g. as foaming agent in autoclaved aerated concrete

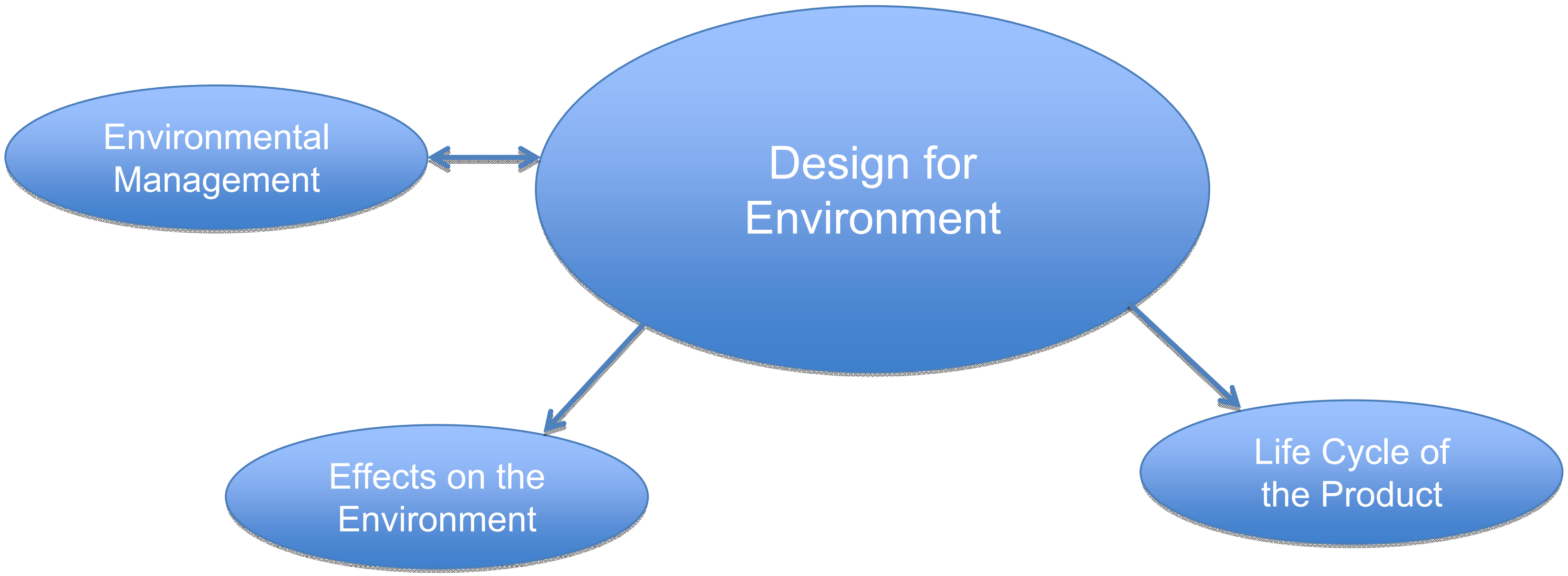
Definitions

- **Design for Environment (DfE)** is a concept to reduce the environmental impact of products, processes and services. Starting point is the development and design phase of a product in order to reduce the environmental impact over the whole life cycle of the product.

- **EcoDesign** is an approach to design a product with special consideration for the environmental impacts of the product during its whole lifecycle.

Design for environment

A product should be designed in a way that its impact on the environment is addressed over its whole life cycle from procurement of raw materials, over processing, manufacturing and use until disposal or recycling



Source: http://wirtschaftslexikon.gabler.de

Principles

- Material efficient design
  - Optimized material use through substitution of raw materials
  - Light weight construction
  - Cutting suitable design
  - Miniaturization
  - Multi-functionality and simplification (reduction on basic functions)

- Design appropriate for the material involved
  - Developing the right design for each material
  - Renewable resources should be preferred and new applications for them should be developed
  - Use of local raw materials if possible
  - Use of secondary / recycled raw materials

Source: http://www.econcept.org

Principles

- Energy efficient design
  - Reduction of energy consumption in all phases of product life cycle
  - Using renewable energy sources

- Low-polluting and waste avoiding design
  - Avoidance of heavy metal and hazardous substances containing additives

- Long life products, repair friendly design
  - Avoidance of products for one-time usage
  - Use of high quality and repairable materials
  - Stable construction principles
  - Reduction of material quantity
  - Easy changeable parts

Source: http://www.econcept.org

Principles

- Recyclable, dismantling friendly design
  - materials, parts and product characterization on surface
  - Recyclable materials choice
  - Use of biodegradable materials

- Logistic friendly design
  - Reduction of product volume and weight
  - Reduction of packaging volume and weight

Source: http://www.econcept.org

Tools

- Tools range from simple checklist to complex life cycle assessment.
- Three key factors for a successful tool are (Bovea and Pérez-Belis, 2010):
  - The integration of environmental requirements in the design phase
  - Application on all life cycle stages
  - Consideration of traditional requirements
- Checklists for material selection (e. g. car manufacturers like Volvo):
  - Blacklist with substances that are not allowed
  - Greylist with Materials that should be limited
  - Whitelist with Recommendations of substitution materials
- LCA: evaluating the environmental impacts of a product throughout its entire life cycle
- Software Tools like GaBi or SimaPro using databases with environmental impact data for carbon footprint calculation, Environmental Product Declarations EPDs, …

Design for Environment (DfE) in ship industry

- Example (Princaud et al., 2010):

  SimaPro as a basis for a ship's environmental impact analysis which was tested on a Lafayette frigate type to

  - Identify pollution sources
  - Compare different technologies

Source: DCNS

Design for Environment (DfE) in ship industry

- Propulsion

  Using natural resources such as wind and sun

Source: Skysails

Source: Hadfield

- Alternative fuels

Fuel	SOx (g/kWh)	NOx (g/kWh)	PM (g/kWh)	CO_2 (g/kWh)
Marine diesel oil (0.5% sulphur)	2	8-11	0.25-0.5	580-630
Gasoil (0.1% sulphur)	0.4	8-11	0.15-0.25	580-630
Natural gas (LNG)	0	2	~0	430-480

Source: Chart-Ferox

Design for Environment (DfE) in ship industry

- **End of Life**

  Adoption of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships

  Requirements for Ship owners (Lloyd's Register, 2011):

  – Inventory of hazardous material
    - Appendix 1: asbestos, PCB, TBT antifouling and ozone-depleting substances
    - Appendix 2: cadmium, hexavalent chromium, lead, mercury etc.

  – Final survey
    - a final check on the Inventory of Hazardous Materials
    - carried out by the flag state or a recognised organisation

  Requirements for Ship Recycling Facility:

  – Authorisation
    - from the government of the country where the ship recycling facility is based

  – Ship Recycling Plan
    - using the information provided by the owner in the inventory of hazardous materials
    - negotiation between ship owners and the facility

Design for Environment (DfE) in rail car industry

- To ensure the products negative influences on the environment are as low as possible over its whole life, different points should be taken into account (Bombardier Centre of Competences for Design for Environment, CoC DfE):
  - Functionality (most efficient function, but as less harmful as possible)
  - Use of hazardous substances (avoidance of using hazardous materials or using closed loop processes)
  - Minimizing energy and resource consumption during production and transport
  - Weight reduction through light weight construction and high strength materials
  - Minimizing energy and resource consumption during life phase
  - Reparability and ability of post processing especially for system addicted components

Design for Environment (DfE) in electronic industry

- DfE program of HP has three main priorities (hp.com):
  - Energy efficiency: reduction of energy consumption during production and life phase of products
  - Materials: amount reduction, using of environmental more friendly materials and extension of product life phase
  - Recycling friendly design: development of products with better upgrade and recycling options

Design for Environment (DfE) in electronic industry

- For performing these priorities following arrangements are used:
  - Embedding environmental stewards in all development teams to establish changes in design for reduction of negative influences on environment during the whole life cycle
  - Reduction of used number of different polymer types and standardizing used resins
  - Using coloured polymers instead of paints
  - Reuse of production scrap
  - Reduction of waste through reducing package material
  - Recycling and demounting friendly design through using polymer identification standard ISO 11469 and minimizing necessary number of instruments needed for dismantling

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Status

- Metals form the most relevant materials share of a/c in operation. For recycling they are usually melted and new alloy products - often for non a/c applications - are produced (e. g. engine blocks)
- a/c alloy scrap metal used e. g. as foaming agent for autoclaved aerated concrete

Objectives:

- Main expectancies
  - To identify real-life recycling potential of a/c alloys today and in future
  - Method for a/c part / material identification
  - Detailed description of dismantling, recycling processes and alloy development steps with regard to Design for Environment
  - Assessment regarding compatibility of new alloys with current recycling routes and recommendations for future recycling steps
  - Secondary objectives to be addressed:
    - Overview of all a/c alloys, including specific information on each alloy.
    - Providing selected alloy samples / a/c parts as demonstrators for recycling

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WP Location

- WP 2 – Eco-Design for Airframe
  - WP 2.4 – End of Life
    - WP A.2.4.1-05 - Metals Recycling
      - WP A.2.4.1-05-01 – Recycling routes screening

Special skills: The applicants should have :

- A track record in hands-on dismantling of large complex products such as e. g. cars, railcar or possibly a/c and in development of or contribution to recycling guidelines
- Experience in Design for Environment solutions for complex products
- In-depth practical and theoretical experiences in mechanical treatment of waste streams including sorting and grinding
- Provision of demonstrators (a/c parts), identification technologies and recycling products
- Metallurgical competencies

Duration: 20 Months

Topic value: not to exceed 280k€