ALUMINUM RECYCLING
AN INTEGRATED INDUSTRY – WIDE APPROACH

Recycle – Friendly Alloys, Recycling Indices and Carbon Management

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PHINIX, LLC

- **New company devoted to " Globally Responsible Resource Management "**
- **Assess, Develop and Commercialize low Carbon/Energy Footprint Processes and Products for the Minerals/Metals/Material Industries (MMMI)**
- **Provide Techno-Economic framework and forum for carbon management and trading for MMMI**

OUTLINE

- Background
  - Aluminum Recycling Driving Forces
  - Design Drivers
- Recycling Challenges by Market
  - Electrical & Packaging
  - Automotive
  - Building & Construction (B&C)
  - Aerospace
- New Paradigm
- Recycling Index
- Carbon Footprint , Carbon Management and Trading

Aluminum Industry emits 1 % of Global GHG 500 Billion Tonnes per Year

- Recycling aluminum impacts energy needs and carbon footprint
  - Requires only 5% of energy
    - ~2.8 kWh/kg Al vs. ~45 kWh/kg Al
  - Produces only 5% of CO_2
    - ~0.6 kg/kg Al vs. 12 kg/kg Al
  - Alloying Elements Conservation (Mg, Mn , Cu , Zn, Si)
    - Have higher energy and carbon footprints than Al

Recycling Driving Alloy Development

- Previous approach to alloy development
  - Driven solely by desired performance
  - Limited considerations of end-of-product-life
  - Less considerations for cost, carbon footprint and availability of alloying elements
- Beginning to recognize impact of recycling
  - How will product be recovered for recycling ?
  - How will composition impact cost & recyclability?
  - What will be it's carbon footprint?

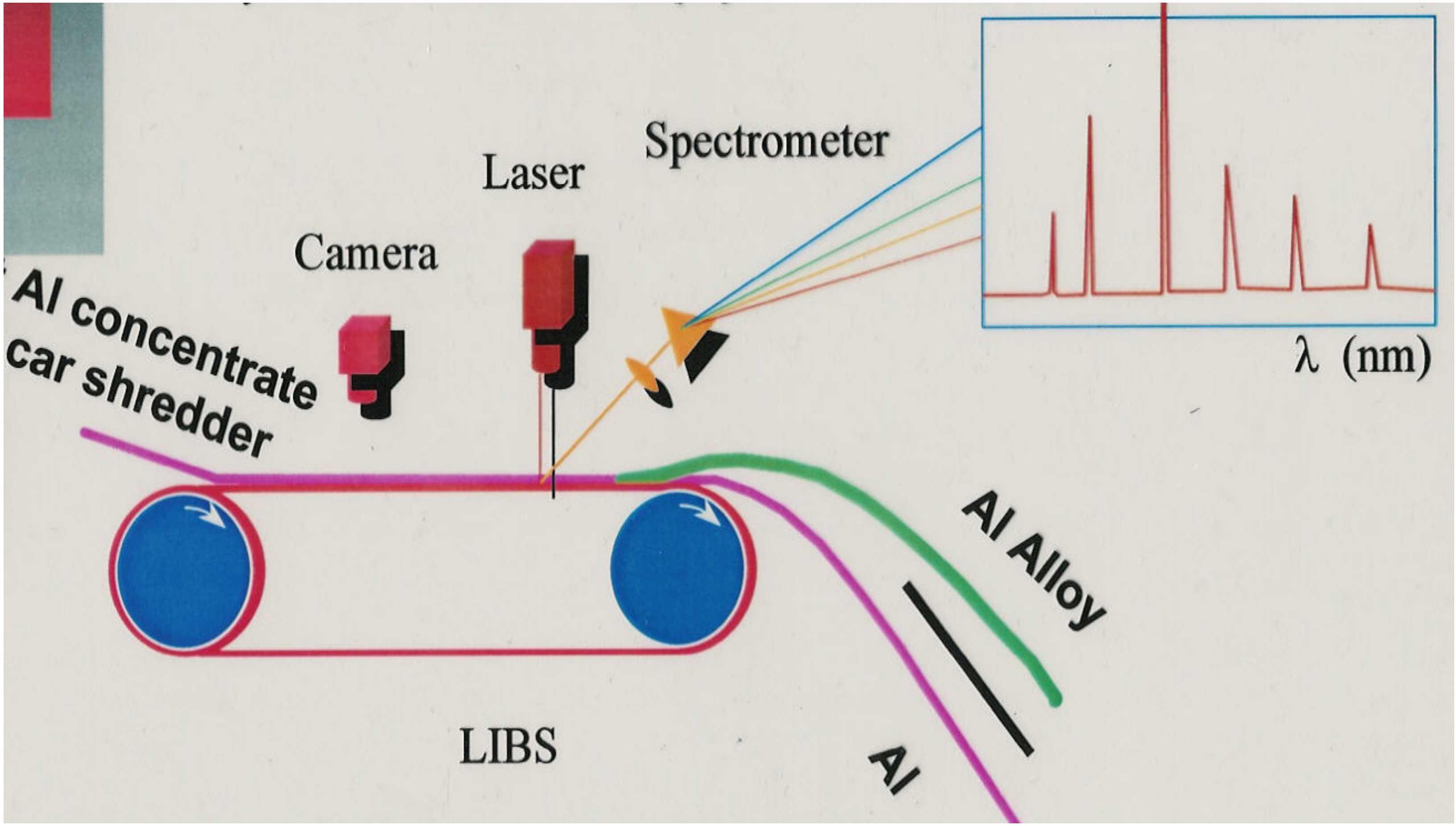
Challenges in Recycling of Aluminum Review by Market

- Electrical and beverage can markets have closed recycle loops requiring less attention
- Others are less complete requiring attention
  - Automotive
  - Building & Construction
  - Aircraft

Automotive Applications
Why Pre-Sorting is Highly Desirable?

- Bumper alloys have high Zn
- 2xxx body sheet alloys have high Cu
- Castings have high Si
- A356 wheels are high in purity for toughness
- 5xxx & 6xxx body panels provide compatible compositions
- Mixing alloy types not practical
- Segregated remelts could have directly reusable compositions

Laser Induced Breakdown Spectroscopy (LIBS) Technology



Maximize Value of Recycled Aluminum

- **Consider dismantling, segregating parts prior to remelt**
  - **Wheels, often A356, with high-Si, high purity**
  - **Bumpers, 7xxx alloys, with high Zn content**
  - **Outers, usually 6xxx alloys, low in Cu and Zn**
  - **Inners, often 5xxx alloys, also low in Cu and Zn**

- **Evaluate remelted alloys for recycling into similar components**

- **Look for opportunities for new alloy modifications**
  - **Non-heat treatable sheet alloy (similar to 5754)**
  - **Heat treatable alloy for exterior / structural applications (6063 or 6111)**
  - **High quality structural castings (like 332)**

New Recycle-Friendly Automotive Alloys

Source	Source Alloys	Si,%	Fe, %	Cu,%	Mn,%	Mg,%	Zn,%
panel alloys	2010, 5754, 6022, 6111	0.7	0.4	0.5	0.25	0.70	0.20max
bumper alloys	7116, 7029, 7129	0.10max	0.15max	0.75	0.10max	1.35	4.7
castings, wheels,	A356.0, 360.0, A380.0	8.5	1.2	1.0	0.25max	0.35	1.0

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Do "Unialloy(s)" Merit Further Attention?

- "Unialloy" approach has been proposed
- Difficult because
  - Body sheet inners require max formability
  - Body sheet outers require max strength, dent resistance
  - Bumpers require even higher strength
- One solution:
  - 6xxx-O for inners
  - 6xxx-T4 for outers.
  - 6xxx-T6 for bumpers and structural members
- Conclusion: yes, it does merit further attention

Building & Construction - Opportunities

- Building and construction applications include:
  - Skin and fascia of residential and commercial buildings
  - Structural components in buildings and towers
  - Highway structures:
    - Overhead and roadside signs,
    - Light poles
    - Bridge decks
- Aluminum alloys utilized are primarily:
  - 5xxx alloys for components of sheet or plate
  - 6xxx alloys for extruded shapes
- Active life may be 10 to 50 years

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Recycling of Al From B&C Structures

- Maximize advantages of demolition process:
  - Use demolition company workings with new building contractor who will reuse undamaged parts
  - As demolition proceeds, segregate Al and steel components from remaining aggregate mix
  - Segregate aluminum components into two categories:
    - Flat rolled products (sheet & Plate)
    - Extruded shapes
  - Retain segregation through remelting operation to separate 5xxx and 6xxx alloys

Recycled Alloys for B&C Applications

ALLOY TYPE & SOURCE	Al, %	Si, %	Fe, %	Cu, %	Mn, %	Mg, %	Cr, %	Zn, %	Ti, %
5xxx Sheet & Plate	~96	0.4	0.4	0.15	0.6	2.5	0.15	0.25	0.1
6xxx Extruded Shapes	~96	0.5	0.5	0.2	0.12	0.8	0.15	0.15	0.12

Why Recycle Aluminum Aircrafts ?

- Thousands of obsolete aircraft stored in "graveyards" around the world

- " Graveyards" are large, located in dry / hot places, establishment of recycling center practical

- Older aircraft are 90%-plus aluminum recovery feasible

Aircraft Recycling
Why Has it Not been Done to Date?

- Aircraft are made largely of high-strength aluminum alloyed with large amounts of Cu and Zn
- Such alloys are more difficult to recycle than lesser-alloyed aluminum used in most other applications
- Special recycling practices will be needed to make aircraft recycling economic

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Potential Remelt Compositions of Recycled Aircraft Components Assuming Pre-Sorting of 2xxx & 7xxx Alloys

	Al %	Cu %	Fe %	Mg %	Mn %	Si %	Zn %
2xxx	~93	4.4	0.5	1.0	0.7	0.5	0.1
7xxx	~90	2.0	0.4	2.5	0.2	0.2	6.0
Mix	~92	3.0	0.4	1.8	0.4	0.4	3.0

Opportunities for Direct Re-Use of 2xxx and 7xxx Compositions

- Non-fracture-critical, moderately stressed aircraft components
    - Stiffeners
    - Flaps

- Building and highway structural components

- Railroad and truck structural components

- Cast components as well as wrought

ALLOY RECYCLING INDEX (ARI)
RECYCLING PRODUCTION INDEX(RPI)

- ARI – Recyclability for recovering the maximum stored energy invested in the alloy , carbon footprint (Quantative)

- RPI – Ease of producing from recycled remelts(Qualitative)

ALLOY RECYCLING INDEX (ARI)

- Nominal alloy content is sum of the nominal alloy additions (mid-range)
- Sum of the mid-range of the impurity limits
- Total of nominal alloying content plus nominal total impurity content   subtracted from 100% = ARI.

RPI - Classification

- High (H) – Readily produced from recycled remelts in the same alloy
- Medium (M) – Readily produced from recycle remelts of scrap segregated at least by alloy series
- Low (L) – More difficult to recycle from recycle remelts
- Unlikely (U) – Composition doesn't lend to production from recycled remelts (Ag, Be, or Li)

ARI & RPI for Key Aerospace Alloys

ALLOYS	ARI	RPI
• 2XXX	94	M
• 7XXX	91	M/L
• 2XXX/7XXX	91	U

Aerospace Alloys -- Conclusions

- Aging / obsolete aircraft = **“urban aluminum mine”** , reuse will lowering carbon footprints
- **Alloy Recycling Index** and **Alloy Recycling Production Index** have been developed
- Alloys with high Cu / Zn **difficult to recycle together**, pre-shred **segregations** into 2xxx and 7xxx groups for remelting
- Manage alloying elements **Ag, Be, Bi, Pb, Li** and grain refiners **Cr, Zr, V**

Alloy Design Drivers

- **Previously primary design drivers were:**
  - **Performance, safety, fuel economy, primary & chemistry based tradition**

- **Secondary design drivers were:**
  - **Dismantling, recycling and end-of-life issues, multiple - materials , cost**

- **Problem:** **complicates eventual dismantling and recycling**

- **Solution:** **Combine primary and secondary design drivers**

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Globally Responsible Resource Management

New Paradigm

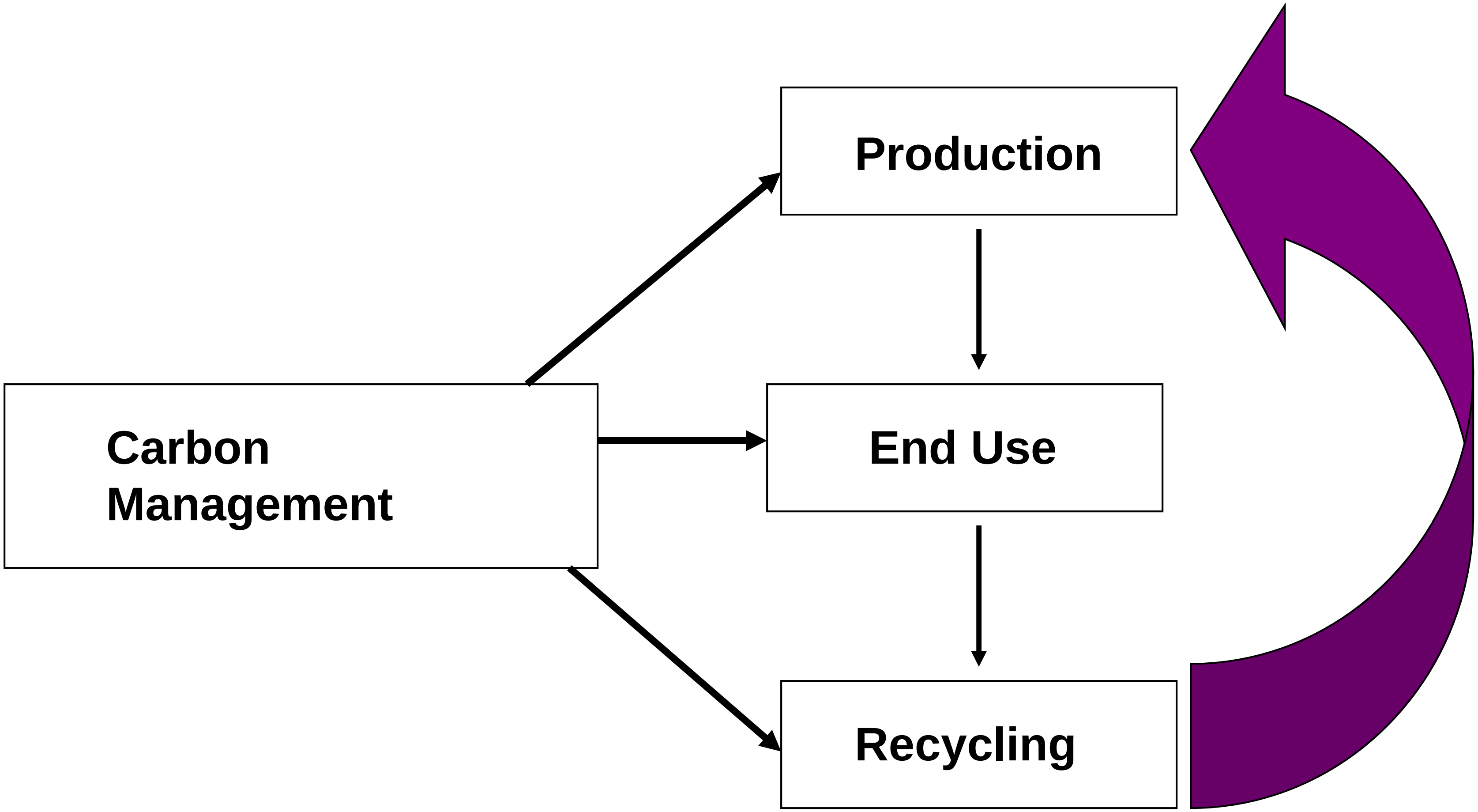
- **For both existing and new alloys --- Recycle to same product**
- **For existing alloys**
  - **Recognize relative value when recycled**
    - **How big are energy source and carbon footprint?**
  - **Group alloys for remelting to maximize value**
- **For designing new alloys**
  - **Consider how useful composition will be when remelted**
    - **Avoid adding elements that become contaminants**
  - **Consider possibility of direct production from recycle remelts**
    - **Avoid tight impurity limits unless required for performance**
    - **Consider compositions from automotive, B&C, packaging or aircraft recycling (new class of "elements")**

Challenge to Collaborate

Customers and Suppliers

- ***Working together to develop lowest carbon footprint multiple - material products !***
  - **Assess recycling index of multiple – material systems**
  - **Minimize multitude of alloys & excessive product differentiation**
  - **Consider logistics for recycling in advance**
  - **Consider mixing different multiple-material scrap**
  - **Design automotive alloys for safety, energy efficiency, consumer tastes, and *RECYCLING***

Promote Recycling as a Carbon Offset



CARBON MANAGEMENT STRATEGY

1. Legislations Under Way

    European Union 2013

    United States 2009

    EPA : Clean Air Act

    Waxman and Markey : Cap and Trade

2. Protocol Development for “ Recycling as a Carbon Offset or Credit”

3. Action Items

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