The IMA study on Life Cycle Assessment (LCA) of Magnesium

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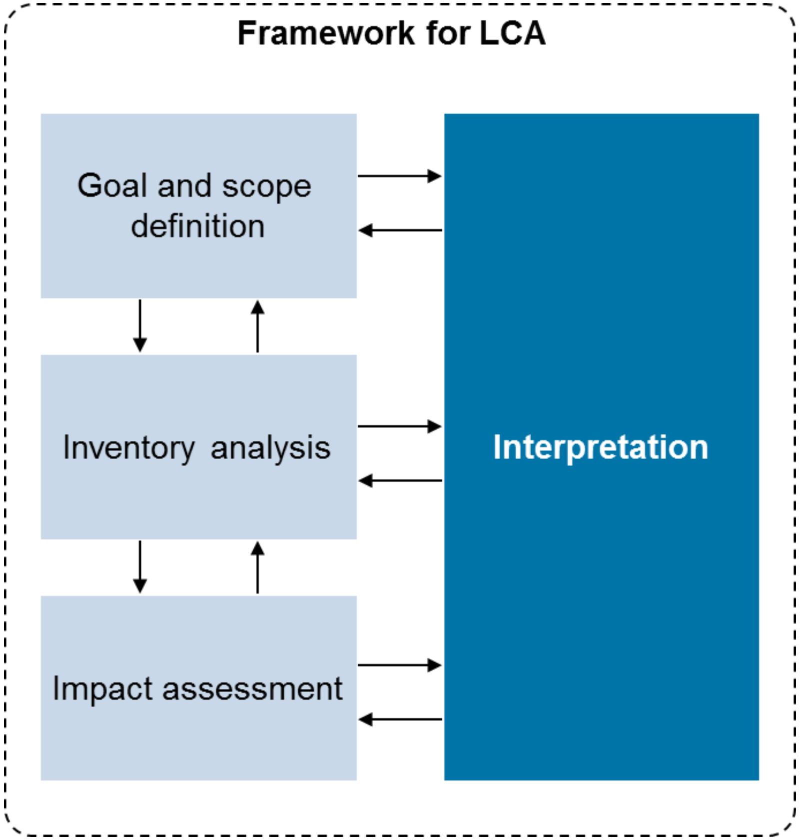
Why do we need a Life Cycle Assessment of Magnesium?

- Presenting the advantages of magnesium-specific design
- Update existing LCA data on magnesium production, processing and end-of-life
- Use a proactive discussion of the role of magnesium in sustainable development



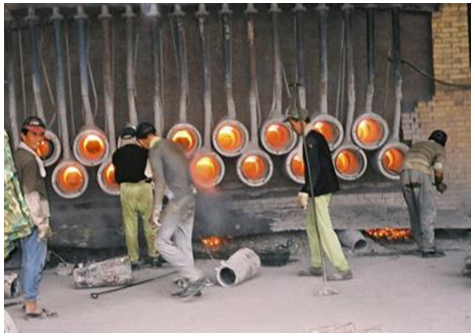
According to ISO 14040 and 14044

Overview of the IMA LCA Study

Module 1	**Primary magnesium production**
Module 2	**Advantages of magnesium-specific design and parts manufacturing**
Module 3	**Life cycle performance of magnesium in transport applications**
Module 4	**End-of-life and recycling**

- Use of two exemplary components in a gasoline passenger vehicle and a mid-haul aircraft and comparison with aluminium
- Included impact categories: climate change (CO_{2eq}), acidification, eutrophication and resource depletion
- Study follows cradle-to-grave approach
- Full accordance to ISO 14044 (including external critical review)

LCA of Primary Magnesium Production



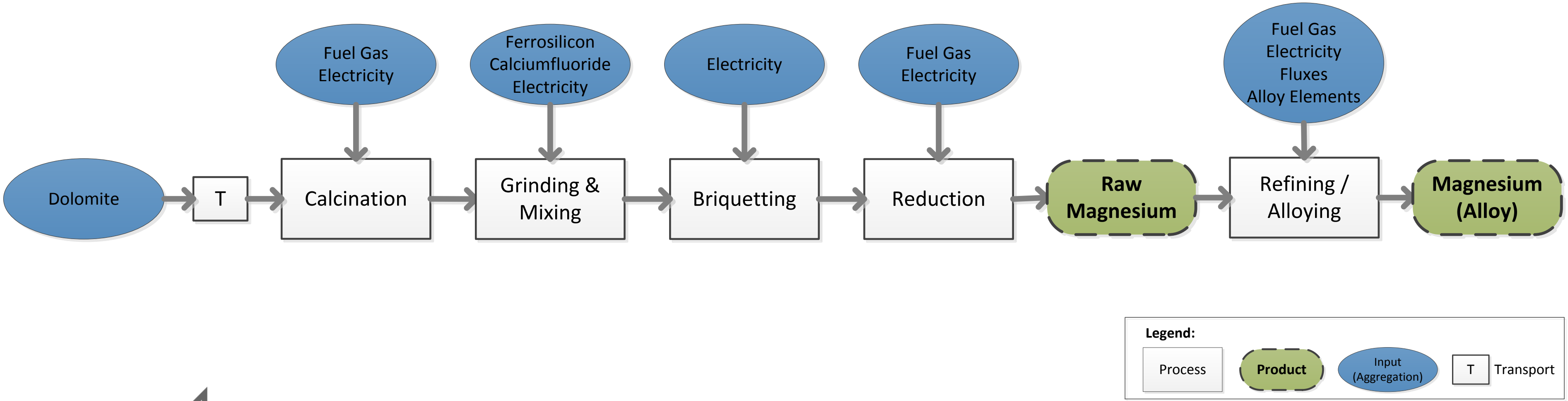
Picture sources: Internet, Harris (2004)

Life Cycle Assessment of Primary Production

Pidgeon Process - Overview

- Development of average dataset for Pidgeon process industry
- Covers more than 80 % of global Mg production
- Functional unit is 1 kg pure Mg
- Various fuels are used for calcination, reduction and refining

  Coke oven gas, Semi coke oven gas, Producer / Generator gas, Natural gas, Coal



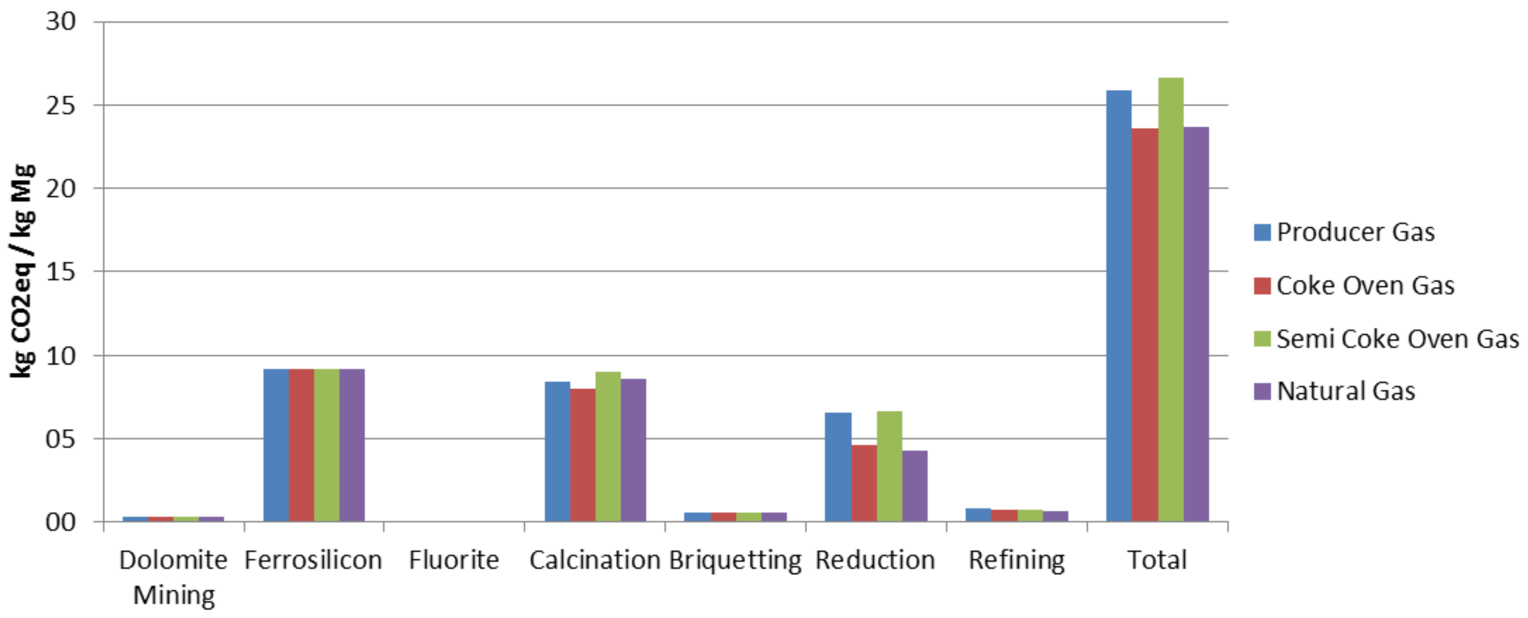
Life Cycle Assessment of Primary Production

Pidgeon Process - Results for Greenhouse Gas Emissions

- Weighted result (according to production volume of fuel gas):

  25.8 kg CO_{2eq} / kg Mg

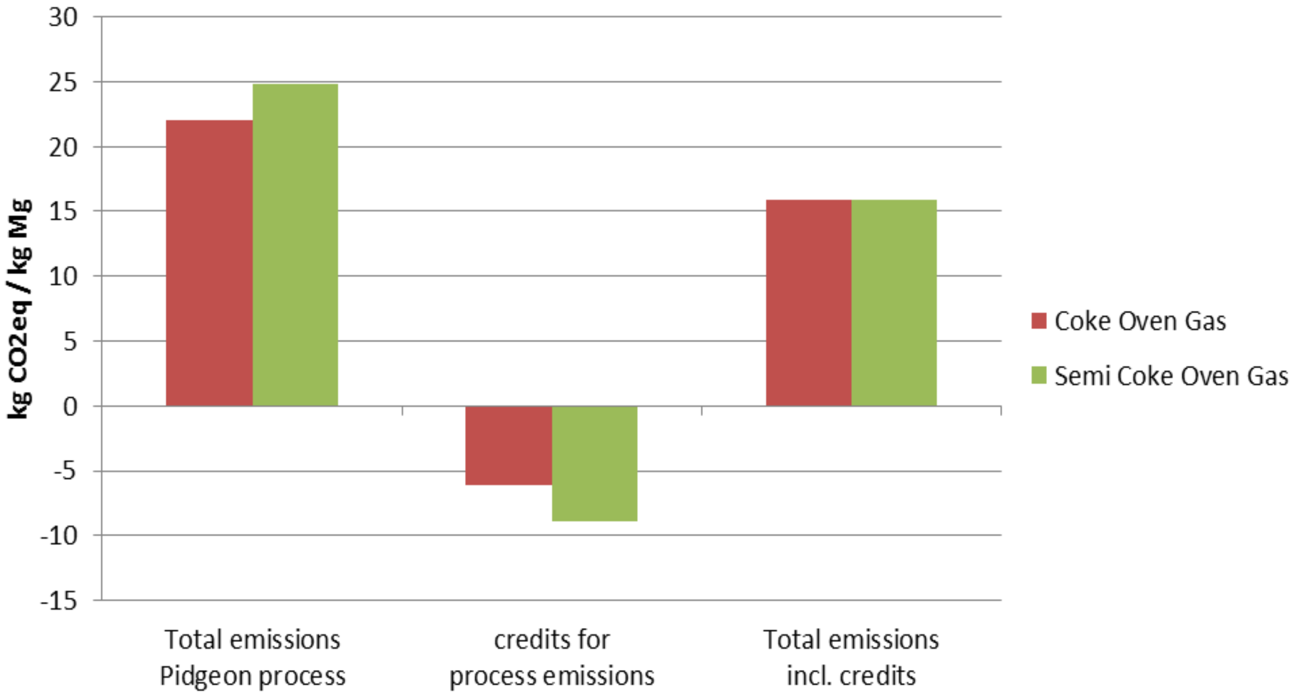
- Includes production of (semi) coke oven gas (allocation according to energy content)



Life Cycle Assessment of Primary Production

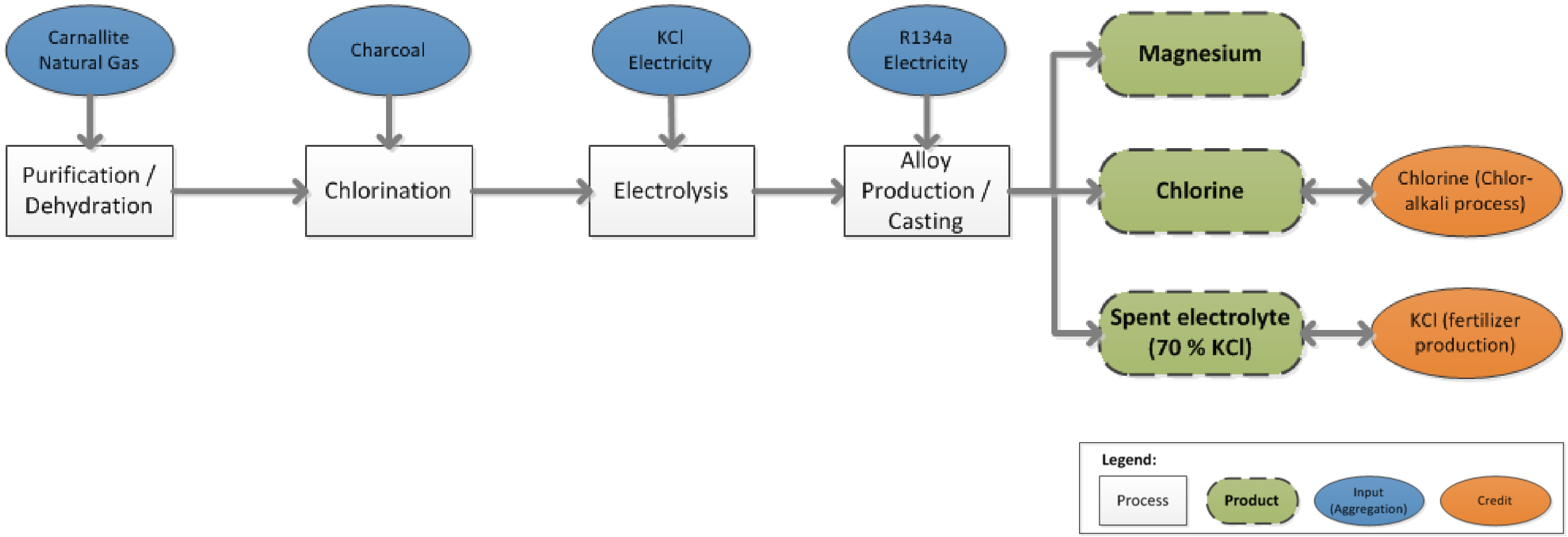
Pidgeon Process - Results for Greenhouse Gas Emissions

- Credits for the use of waste gases (coke and semi coke oven gas) can be given
- Weighted result inlcuding credits: **19.9 kg CO_{2eq} / kg Mg**



Life Cycle Assessment of Primary Production

Electrolysis – Overview

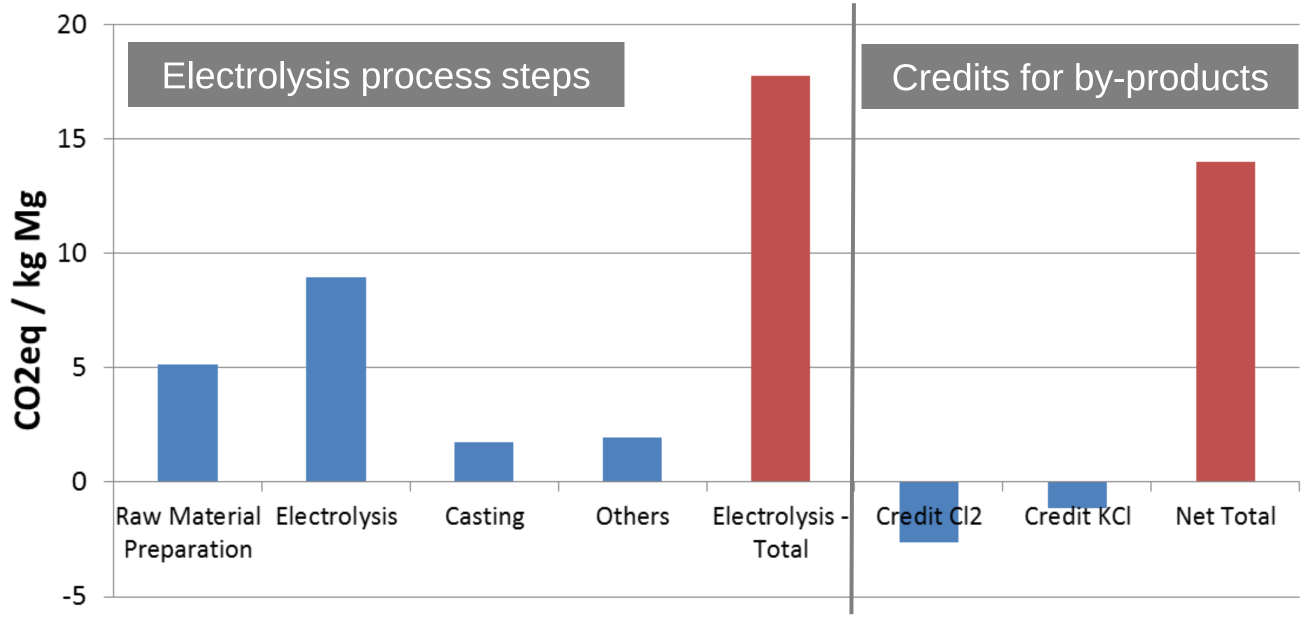


- Natural gas is source for energy production
- R134a is used as cover gas
- Functional unit is 1 kg pure Mg
- Credits for by-products (liquid Cl2 and KCl) can be given

Life Cycle Assessment of Primary Production

Electrolysis – Impact Assessment

- Result for greenhouse gas emissions
  - for process: **17.8 kg CO_{2eq} / kg Mg**
  - including credits for by-products: **14.0 kg CO_{2eq} / kg Mg**
- Main contribution results from electricity supply
- R134a as cover gas has minor relevance



Results for Primary Magnesium Production

Pidgeon process

- In 2011, all magnesium producers in China use gas as energy source for Pidgeon process
- Average weighted CO_{2eq} emissions for Pidgeon process 2011 is 25.8 kg per kg magnesium; when credits for use of waste gases are given, the emissions are 19.9 kg per kg magnesium
- Emissions have dropped significantly in the last few years
- FeSi contributes considerably to all impact categories

Electrolysis

- Greenhouse gas emissions for exemplary electrolysis is 17.8 kg per kg magnesium without credits for by-products
- Credits can be given for by-products (Cl2 and KCl): -3.8 kg CO_{2eq} / kg Mg
- The use of HCF 134a reduces greenhouse gas emissions significantly compared to the use of SF_6

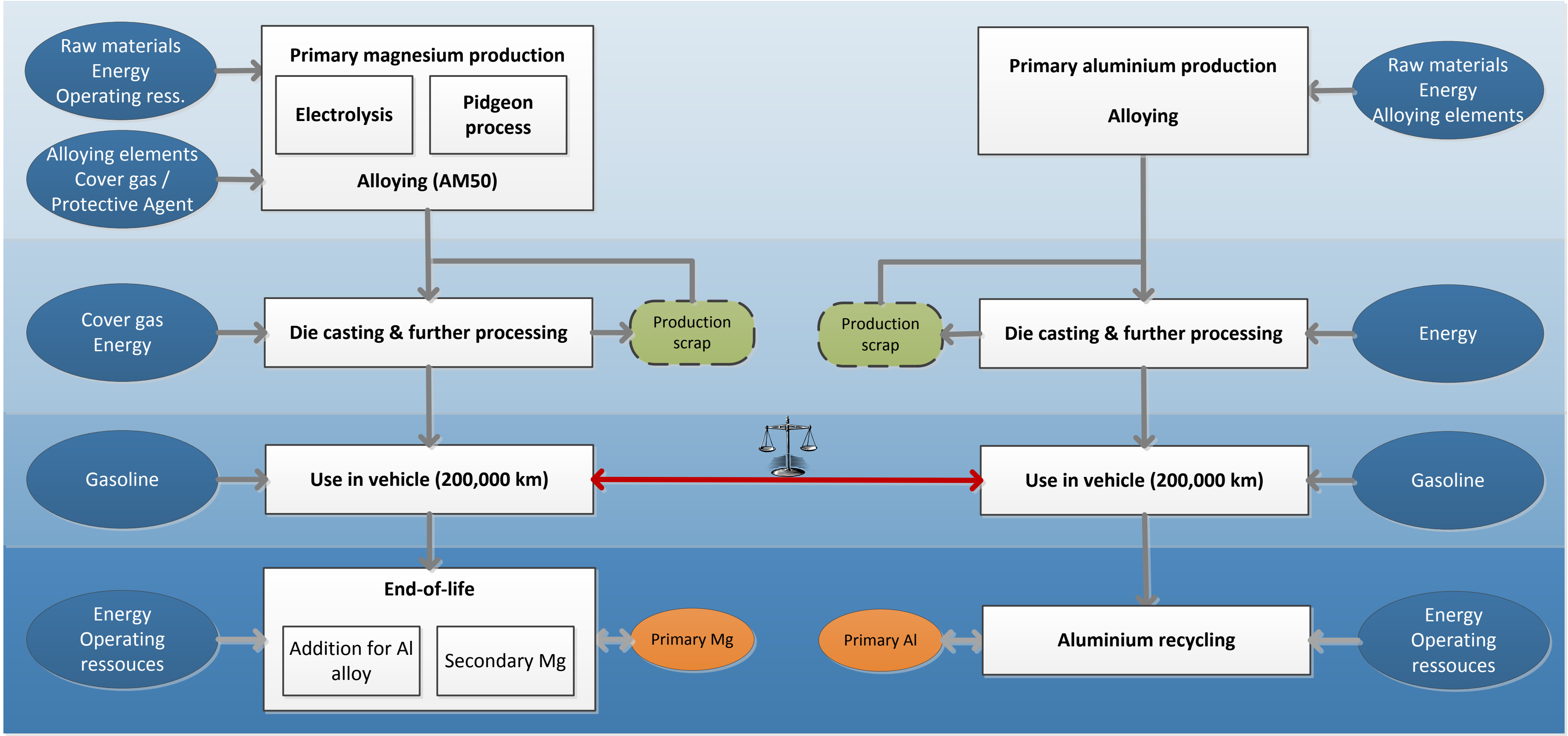
→ Widening the use of renewable energy sources will optimize the results for both processes

Life Cycle of Steering Wheel for Passenger Car and of Aircraft Parts

Picture sources: Kern GmbH for steering wheel

Life Cycle of Steering Wheel for Passenger Car

Comparison of Mg and Al - Overview



Life Cycle of Steering Wheel for Passenger Car

Main Parameters

- Steering wheel for the use in a passenger vehicle made from magnesium compared to steering wheel made from aluminium
- Parts are produced via die casting
- Primary Al world average used as reference (12.7 kg CO_{2eq} / kg Al*))

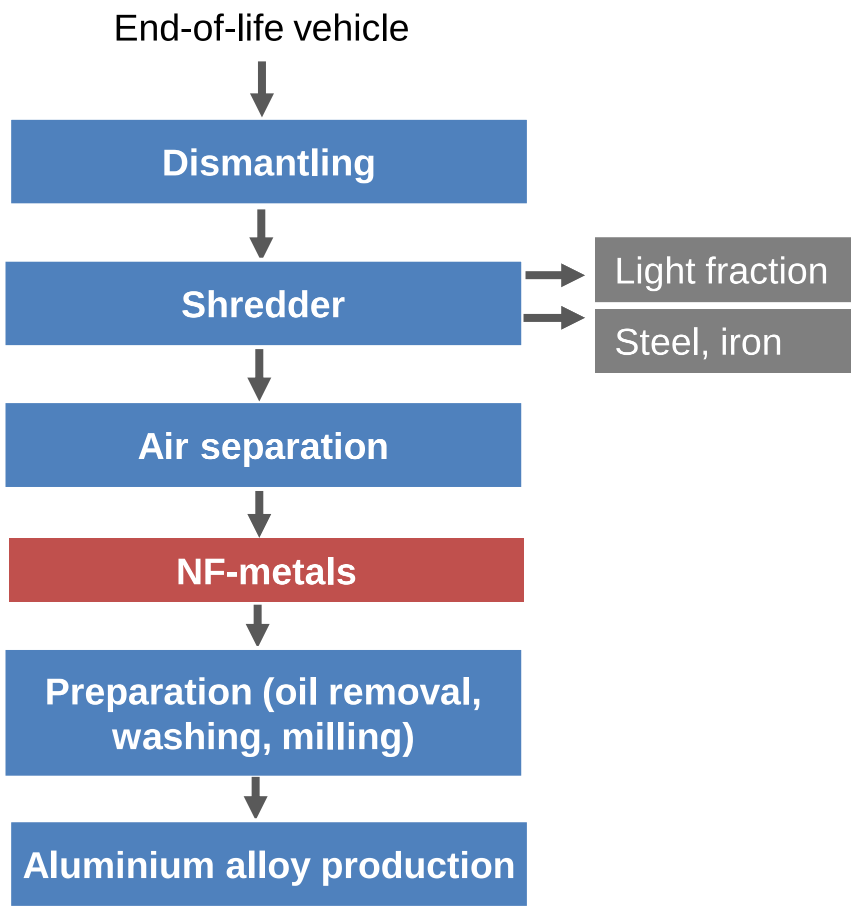
	Magnesium component	Aluminium component
Weight [kg]	0.55	0.74
Fuel reduction coefficient [l/100km*100kg]	**0.35**	
Mileage	200,000	200,000
Material recovery at vehicle end-of-life [%]	90	90
Material for further use [%]	90	90

Image source: Kern GmbH (http://www.kern-mg.de/de/Gussbeispiele/site__174/)

*) Gao 2009

Life Cycle of Steering Wheel for Passenger Car

Recycling of Vehicle Components

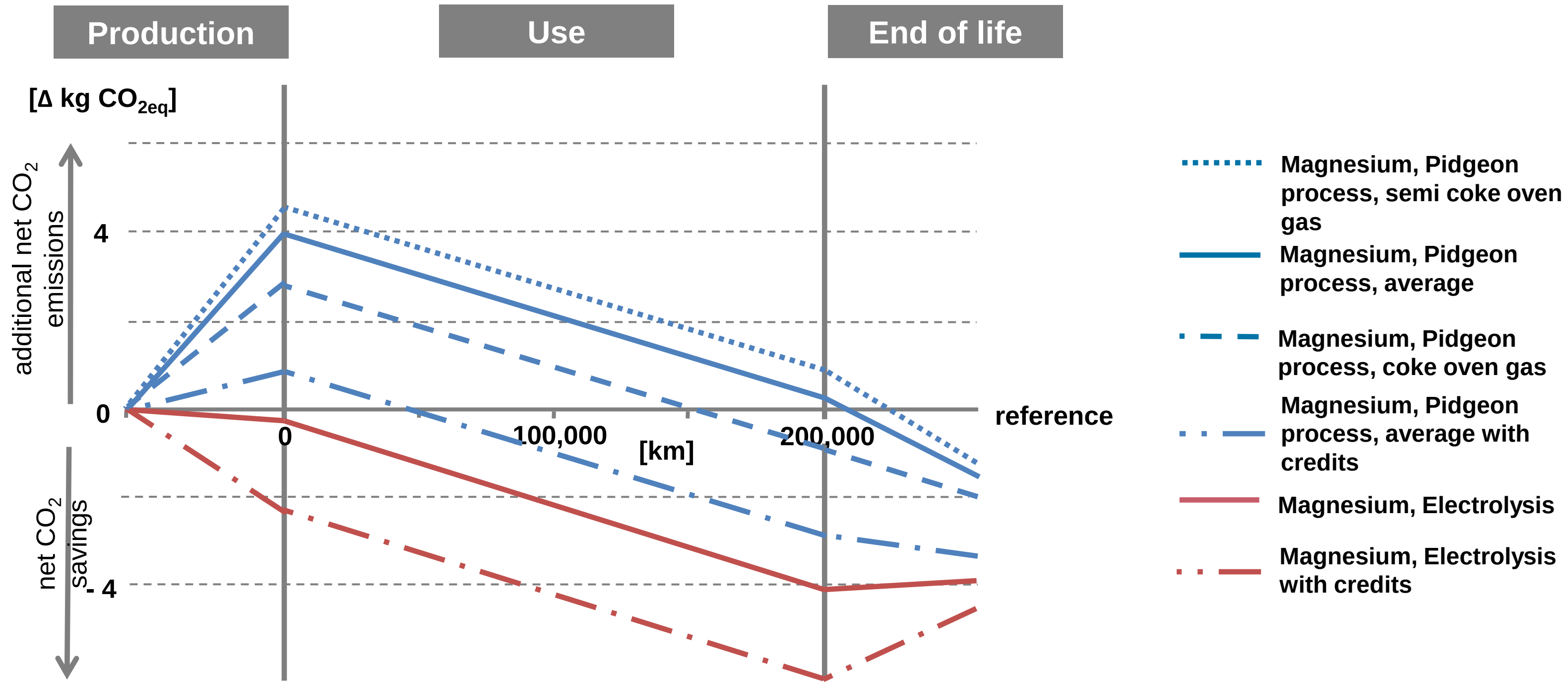


- Recycling path for magnesium:
  1. materials of end-of-life vehicle are separated
  2. Mg ends up in light metal fraction
  3. Production of Al alloy is secondary Mg use
- Full credit is given to recycled Mg which replaces primary Mg in Al alloy production (same applies to recycled Al)

Life Cycle of Steering Wheel for Passenger Car

Comparison of Mg and Al - Greenhouse Gas Emissions

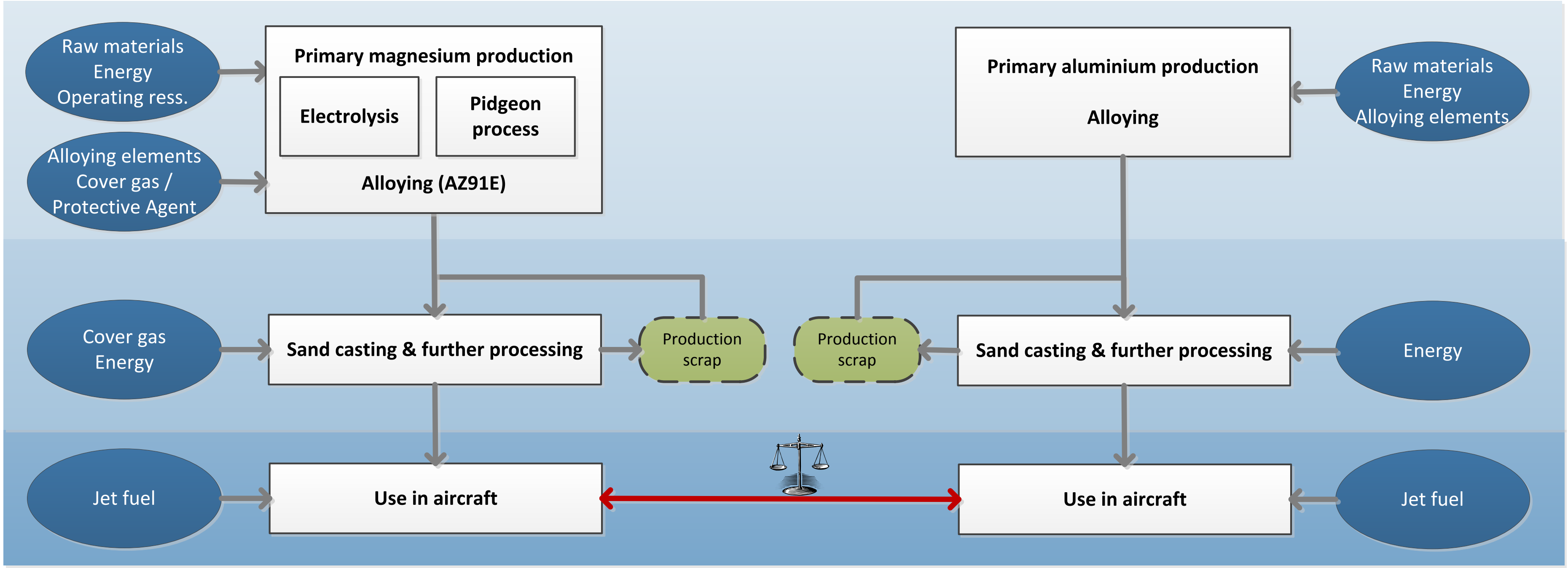
- Difference in production stage depends widely on source of magnesium
- CO_{2eq} savings of 3.8 kg from the use stage
- Positive net balance for all magnesium scenarios can be reached



DLR

Life Cycle of Aircraft Parts

Overview

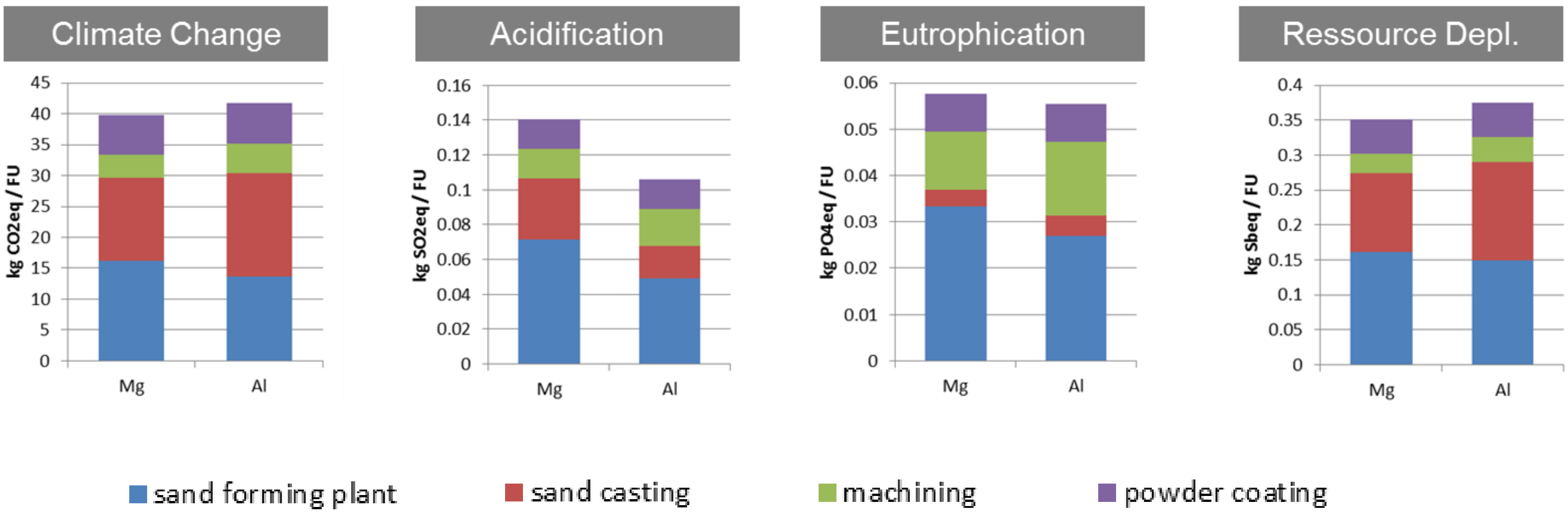


DLR

Life Cycle of Aircraft Parts

Production of Parts and Calculation of Fuel Saving

- Parts (gearbox and seal closer) are produced via sand casting
- Production of sand moulds and casting process with highest impacts



DLR

Life Cycle of Aircraft Parts

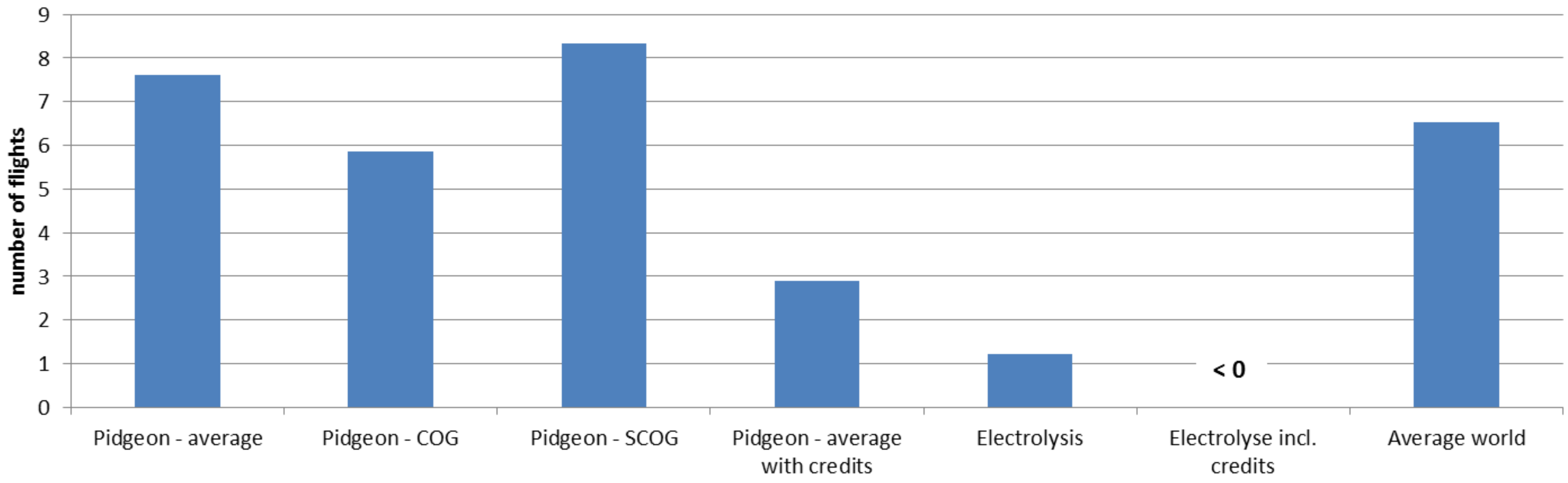
Production of Parts and Calculation of Fuel Saving

- Parts (gearbox and seal closer) are produced via sand casting
- Production of sand moulds and casting process with highest impacts
- Weight reduction is 22 %
- Calculation of fuel reduction with DLR model VAMPzero
    - representative short and medium haul aircraft (A320)
    - flying distance: 4,100 km
    - fuel saving per flight: 4.7 kg
- Recycling not included

Life Cycle of Aircraft Parts

Overall Balance for Greenhouse Gas Emissions

- Maximum difference to Al reference production: 0.14 t CO_{2eq}
- Break-even points reached in an early stage of aircraft life: < 10 flights
- Annual savings during aircraft operation*): 8 t CO_{2eq}



*) annual mileage: 1.9 Mio km

Life Cycle of Aircraft Parts

Overall Balance for Greenhouse Gas Emissions

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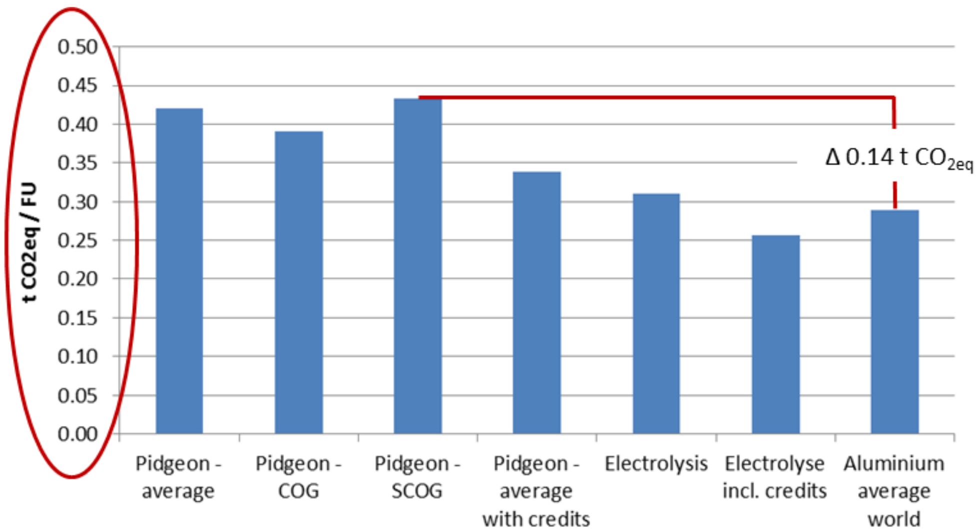
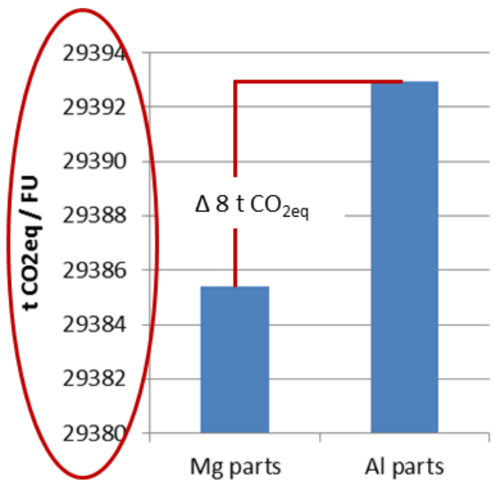
Production



Use per year



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DLR

Conclusions for Life Cycle of Magnesium Applications

Use for passenger cars

– Results show beneficial aspects of magnesium use for green mobility

– Adequate vehicle design and process optimization needed to ensure benefits

– Crediting reuse of magnesium shows an important influence on LCA

Use for aircraft

– Magnesium parts in aircrafts show significant benefits in terms of greenhouse gas emissions

– Production and end-of-life are of minor importance compared to use stage

– The magnesium industry could use the results for further product strategies

→ Reliable and up-to-date data source for magnesium LCA is now available

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