ICTP Conference

Cambridge, 21 September 2017

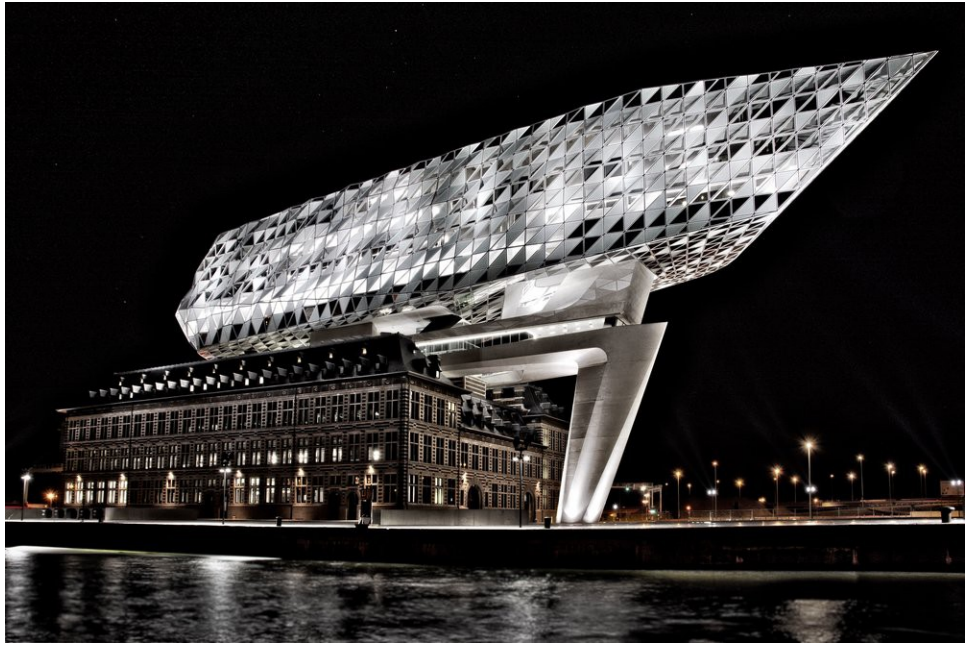
ArcelorMittal

Sustainability and Steel

Inspiration through Collaboration

Carl De Maré, Vice-President Technology Strategy

The perception of Steel



Port House Antwerp, Architect Zaha Hadid

10.000 kg/person steel in use

1 kg/person/day steel consumption

30 billion ton “steel in use” in the global economy today

Global Sustainable Development
From 30 to > 60 b ton Steel in Use

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20 x

10 > 8 > 6 ton/p steel in use
1000 g/day/p steel consumption

= **400kg/p** steel stock +
50 g/day/p steel consumption

Steel is the example of a global circular economy already today…

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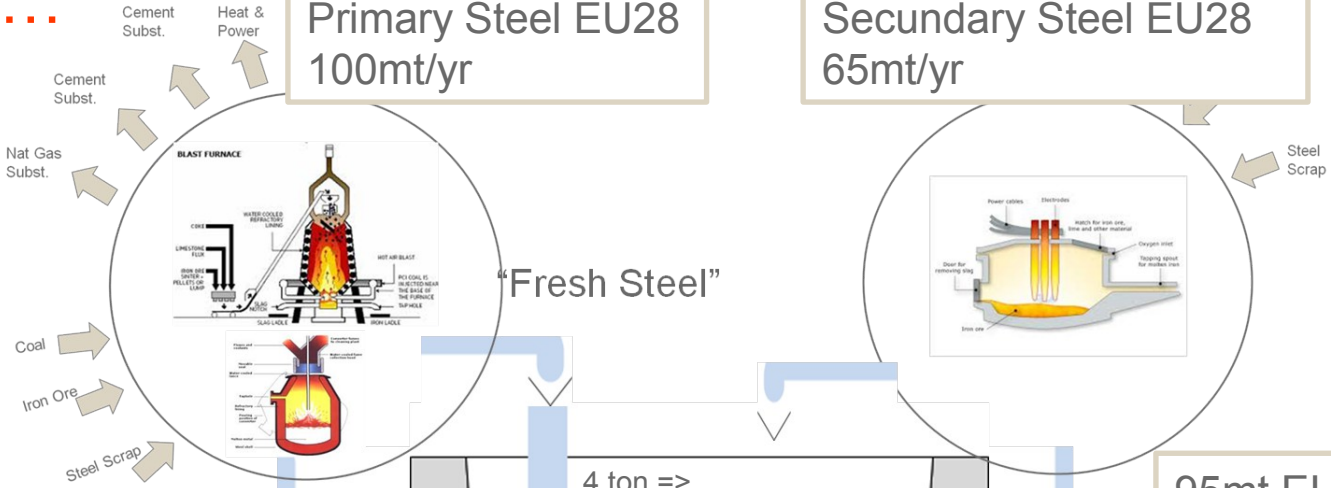
Primary Steel EU28
100mt/yr

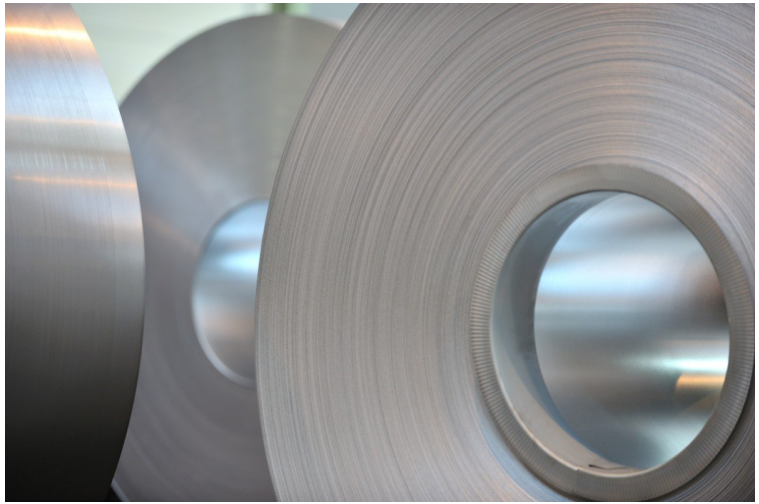
Secundary Steel EU28
65mt/yr



25mt Cement substitute

95mt EU 28 Scrap Arising

... and based on Life Cycle Analysis it is a low emission material



860 g CO2/kg steel (1)

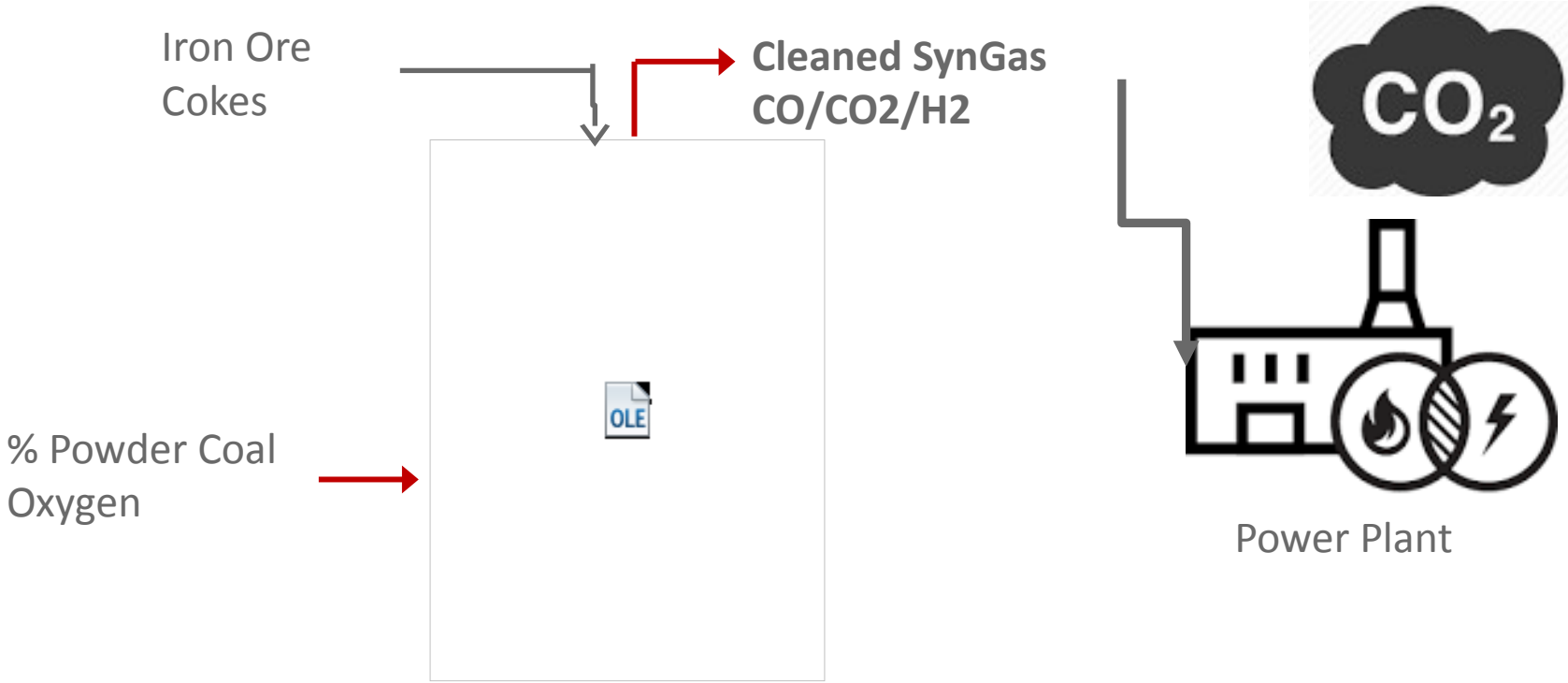
1.370 g CO2/kg milk

+50% GHG

(1) Average over century including steel recycling,

Business model of Primary steelmaking is build on the efficient use of carbon

$$FeO + C + O2 \rightarrow Fe + CO + CO2$$



Hydrogen as alternative for Carbon to reduce iron ore to steel in Europe?

FeO + H2 + power → Fe + H2O

60 nuclear reactors of 1000MW

60.000 windmills of 3,2MW

Not the use of Carbon,
but the emission of CO2 is the problem

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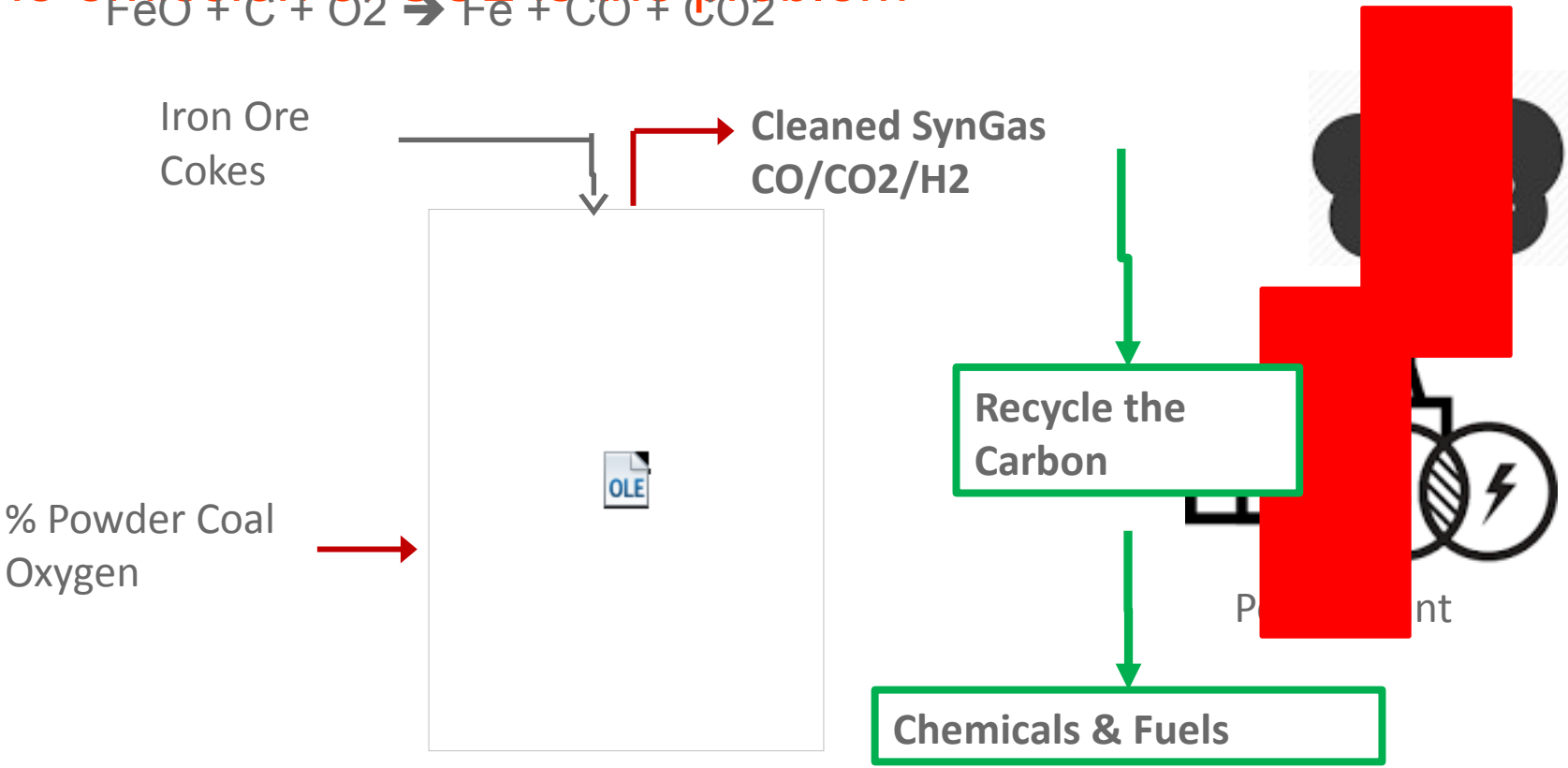
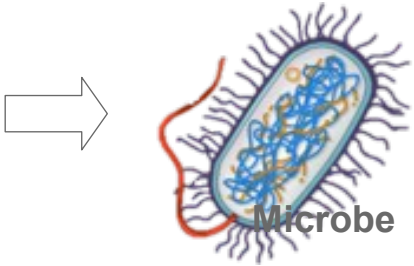
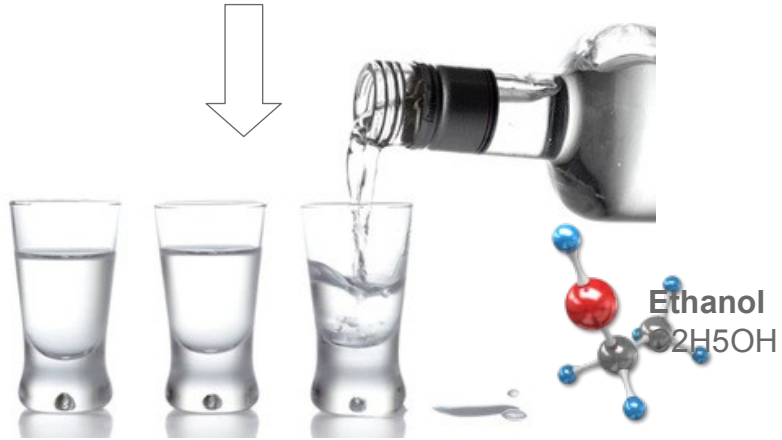
$FeO + C + O_2 \rightarrow Fe + CO + CO_2$



Nature is already recycling Carbon billions of years

Carbon Waste Gas (CO) from
Iron-Ore Reduction
In **Blast Furnace**





Ethanol is used for transport (fuel), chemicals (plastics), food and pharmaceutics

AM Gent Commercial Demonstration Project to produce Ethanol from waste gas with our partner Lanzatech

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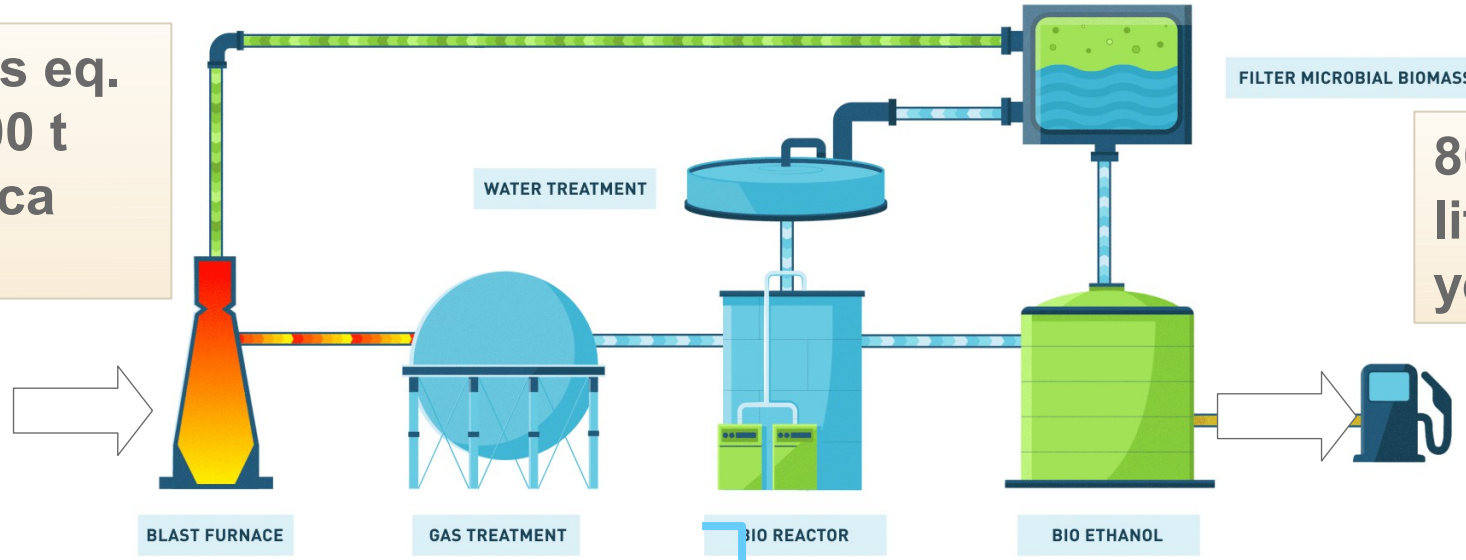
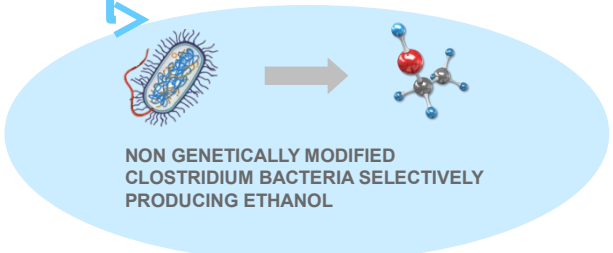
BF Gas eq. 600.000 t steel (ca 15%)



80 million liter per year



Steelanol
Fueling a sustainable future

LanzaTech

Sponsored by Horizon2020 LCE-12

Sustainability impact of Steelanol Demo

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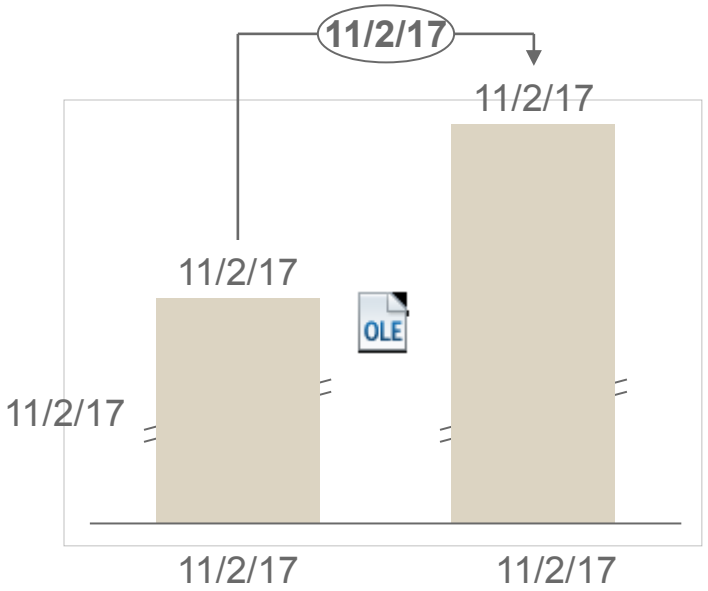
le up to global steel industry : 1000x



80million liter of Demo Project =
100.000 electrical cars

27% less kWh consumed per 100km
(w/o energy impact of battery disposal end of life)

Cradle to Cradle: closing the carbon loop

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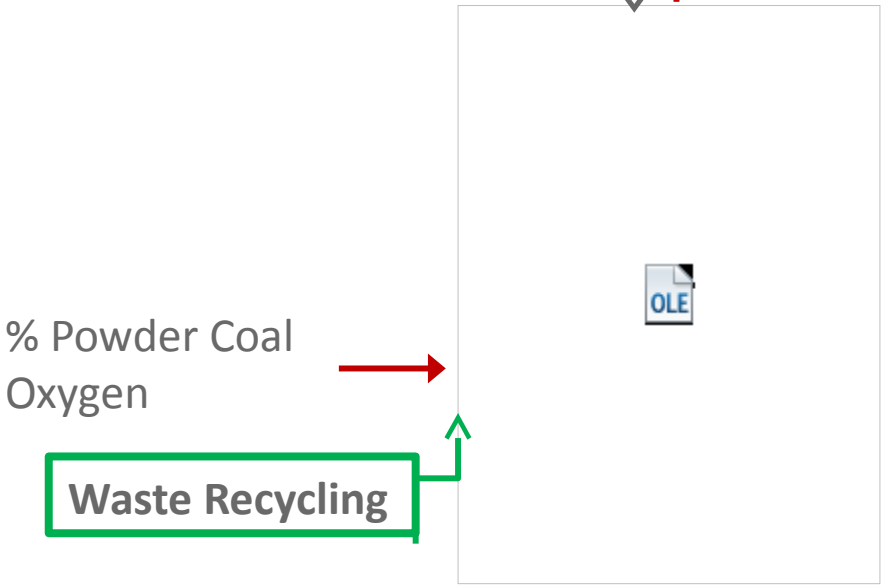
$FeO + C + O2 \rightarrow Fe + CO + CO2$

Iron Ore
Cokes

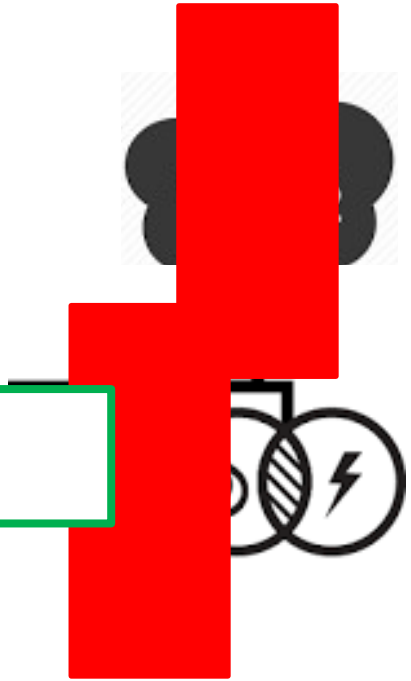
Cleaned SynGas
CO/CO2/H2



% Powder Coal
Oxygen

Waste Recycling

Recycle the Carbon



Chemicals & Fuels

Steel is a key enabler for circular economy and cross sectorial collaboration

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Steelanol
Fueling a sustainable future

Renewable Fuels

Renewable Plastics

Polyurethane seating foams

Exterior paints and coatings

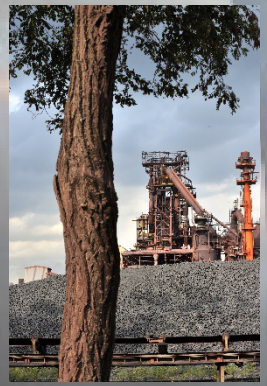
Synthetic rubbers

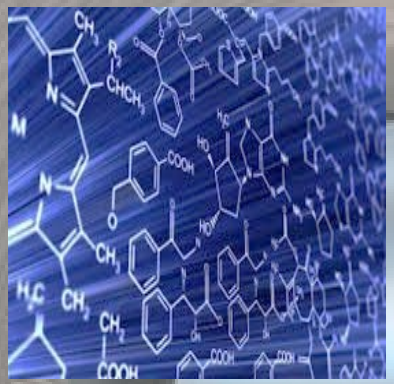
CO and Hydrogen Reuse

Bio-Chemical & Electrical Conversion

Proteins

Interior plastic mouldings





Inspiration through Collaboration

Thanks for your attention
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carl.demare@a tal.com

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THE USE | LESS GROUP
LIVING WELL WHILE USING LESS

Making Cars from Less Metal

Metal Forming and Sustainability Industry Workshop, ICTP 2017

How can we use less metal?

Make smaller cars

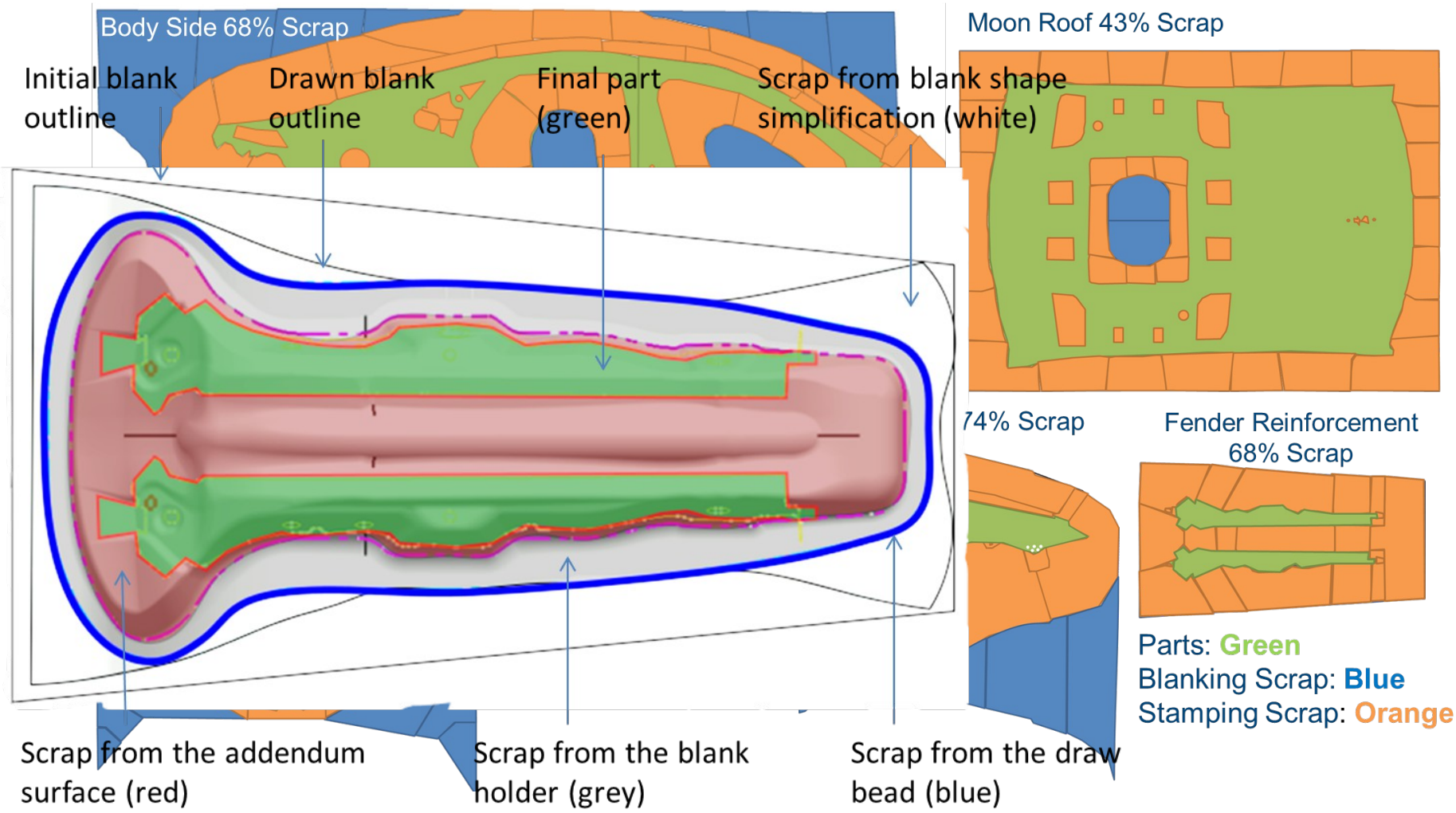
Make fewer cars

We can do something about this

Make cars from less metal

UNIVERSITY OF CAMBRIDGE

Yield losses from blanking &



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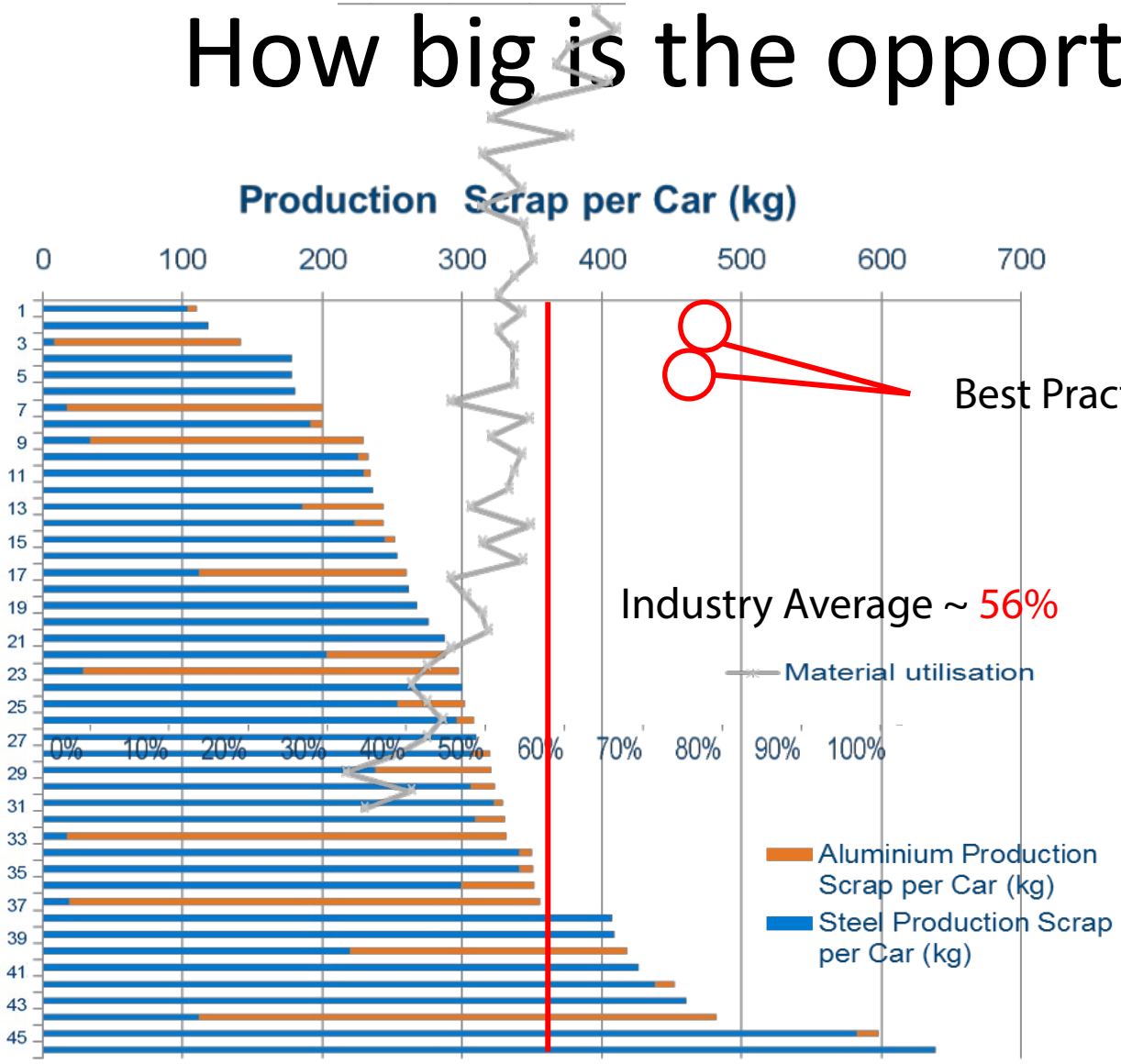
Yield Improvement Opportunities for Manufacturing Automotive Sheet Metal Components , Horton & Allwood (2017), JMPT

How big is the opportunity?



Best Practice ~ 70%

Industry Average ~ 56%

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Yield Improvement Opportunities for Manufacturing Automotive Sheet Metal Components , Horton & Allwood (2017), JMPT

Wrocław
University
of Science
and Technology

Can metal forming processes be applied in order to recycle long run production scrap ?

Zbigniew Gronostajski

ICTP , 2017

The company will make significant progress on sustainability: its bottles and cans will be 100% recyclable; packages will be lighter and the amount of recycled plastic in its bottles will increase from 25% to 40% by 2020.

Ictp , 2017

Recycling of aluminium

1. The most common metallic element in the earth's crust
2. The economic reason

Prices paid per tonne of waste materials [EUR]	
Aluminium cans	1.000
Plastic PET bottles	300
Steel cans	80
Glass bottles	50
Newspapers	140

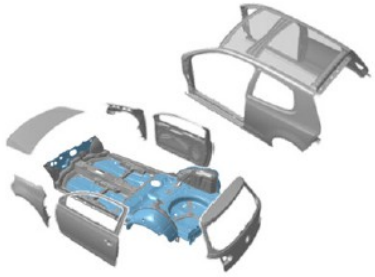
3. Ecology

Ecology

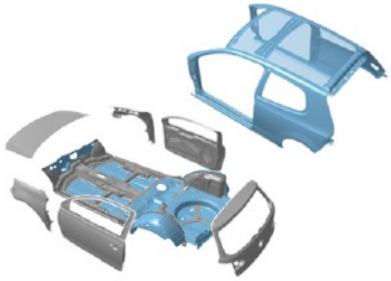
Lightweight design for body in white concepts

Golf VI

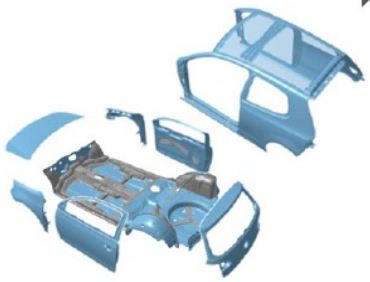
decreasing weight of the body in white



Golf VI = 352kg	
Steel:	335,5 kg
Hot formed steel:	16,5 kg
Aluminum:	-



Golf VI + MQB = 324kg	
Steel:	255,6 kg
Hot formed steel:	68,4 kg
Aluminum:	-



Golf VI+MQB+St/Al=263kg	
Steel:	102,1 kg
Hot formed steel:	68,4 kg
Aluminum:	93,0 kg

Golf VI = 352kg
1387 kg CO_2eq

Golf VI + MQB = 324kg
1325 kg CO_2eq

Golf VI+MQB+St/Al=263kg
1982 kg CO_2eq

- The usage of hot formed steel (MQB-measures) already reduces the CO2 emissions in the production phase. Break-even: 0 km
- The usage of aluminum leads to an increase of CO2 emissions in the production phase.

Source: VDI Leightweight Meeting Ludwigsburg 2011

Ictp , 2017

Metallurgical recycling of the aluminum

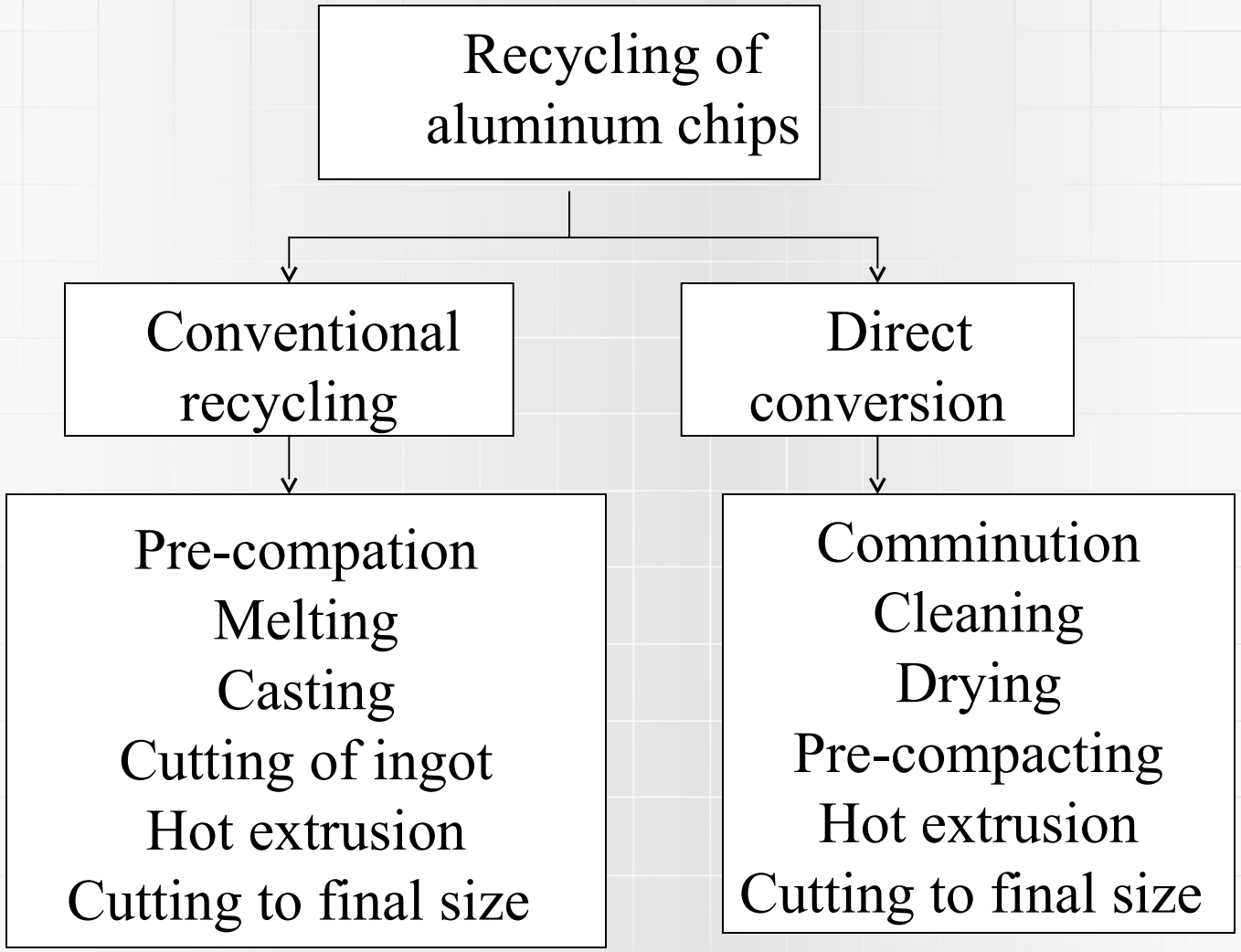
- 10% of the metal is burnt
- 10% of it is lost in the slag
- 8 % loss during casting
- 18% loss during the processing of aluminum ingots

= about 50 % loss

Usually the energy consumed for the conventional (metallurgical) recycling of aluminum is 16-19 GJ/T

The new method of recycling is searched

About 20 years ago the direct conversion of the aluminum chips into solid material was applied first time


Recycling of aluminum chips
Conventional recycling
Direct conversion
Pre-compation
Melting
Casting
Cutting of ingot
Hot extrusion
Cutting to final size
Comminution
Cleaning
Drying
Pre-compacting
Hot extrusion
Cutting to final size

Ictp , 2017

Recycling of aluminum chips - direct conversion

Advantages

-95% of the metal is recovered.

-Lower energy consumption 5-6 GJ/T (metallurgical 16-19 GJ/T)

-It can be applied to other materials

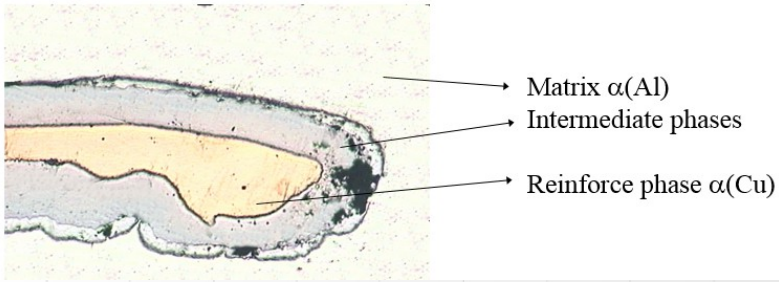
-Manufacturing of composites (bearing material characterized by very good wear resistance

Disadvantages

-Low strength due to the problem with pollution and next compacting of chips

-Low efficiency because the extrusion is not continues

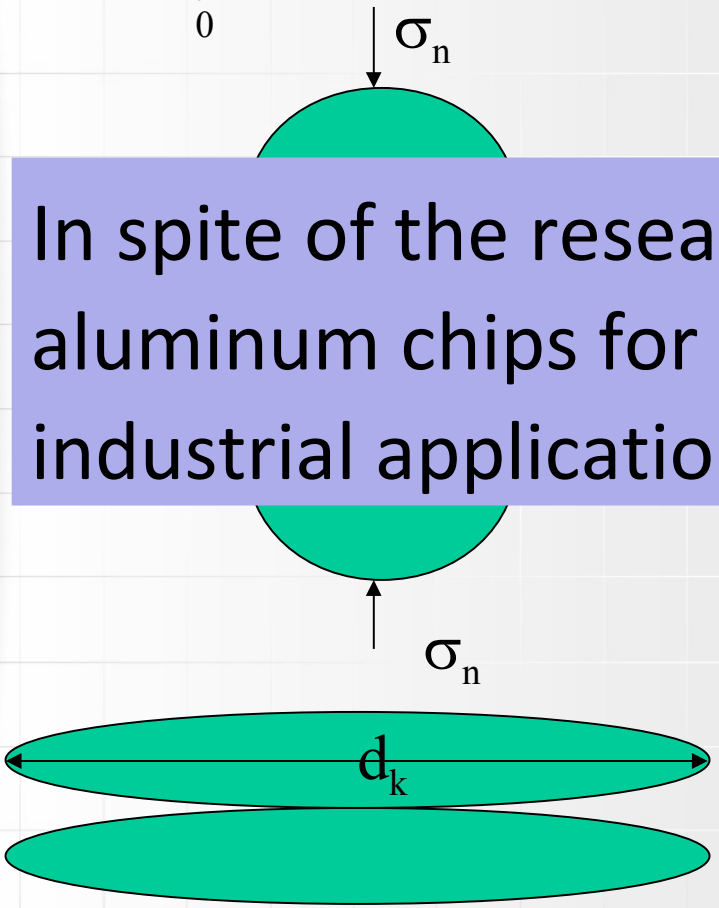
Structure of composite containing 22% of CuAl8 reinforcing phase after annealing in 545^{0}C during 7 hours



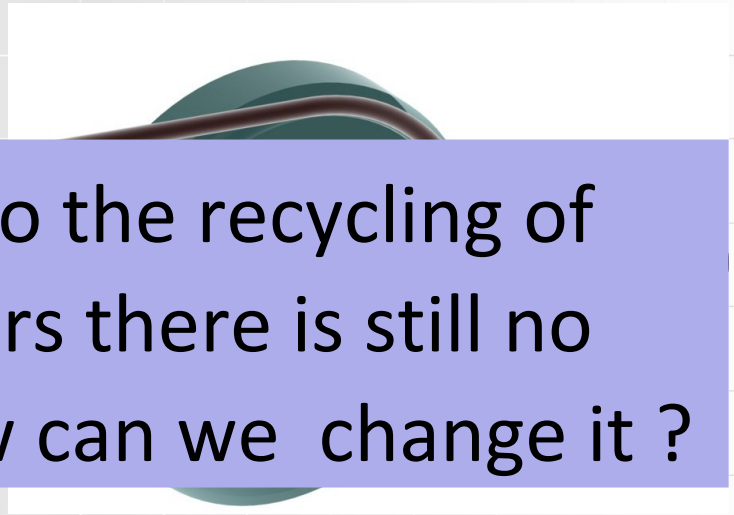
Overcoming the disadvantages

SINTERING CRITERION

$$W_s = \int_0^{\varepsilon_1} \sigma_3 d\varepsilon_1 = C_{cr}$$



CONTINOUS EXTRUSION



In spite of the research into the recycling of aluminum chips for 20 years there is still no industrial application. How can we change it ?

CONFORM

plastic work needed to joining of particles

Wrocław University of Science and Technology

Lightweight design for body in white concepts

Golf VI

Does it mean that the ecology is omitted in metal forming processes ?

Aluminum: -	Aluminum: -	Aluminum: 93.0 kg
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1387 kg CO_2eq	1325 kg CO_2eq	1982 kg CO_2eq

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Source: VDI Leightweight Meeting Ludwigsburg 2011

Wrocław University of Science and Technology

Thank you for your attention

Ictp , 2017

ICTP 2017 Industry Workshop 3
2017.09.21 Cambridge, U.K.

Metal forming and Sustainability from View Point of Industrial Revolution

Kozo Osakada
Osaka University, Japan

Industrial revolution & metal forming

Industrial revolution	1770 A.D.-	1870 A.D.-	1970 A.D.-
Source of change	Steam engine	Electricity	Computer & IT
New energy source	Coal	Petroleum	Solar & wind
Industrial demand	Factory production	Mass production	Clean production
Social demand	Fast transportation	Consumer goods, cars	Electric vehicle
Metal forming product	Industrial machines Steel rail & ship plate	Automobile parts Electrical appliances	Light weight & high strength parts
Metal forming machine & process	Steam hammer & steam rolling mill	Mechanical press Tandem rolling mill	Servo press Controlled rolling

The 1st Industrial Revolution started in Britain around 1770 by the invention of steam engine. Coal was used as the new energy. Factory production and fast transportation were the demands at the time. Industrial machines, steel rails and ship plate were produced by metal forming with steam hammer & steam rolling mill, the outputs of the revolution.

Industrial revolution & metal forming

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Next change occurred about 100 years later with electricity. Petroleum appeared as new energy. Mass production of consumer goods and cars enabled mass consumption. Mass production was carried out by metal forming with mechanical press and tandem rolling mill. But, mass consumption caused environmental pollution and the sustainability problem. Since we still live in the influence of this time, we have to solve the problem by our selves.

Industrial revolution & metal forming

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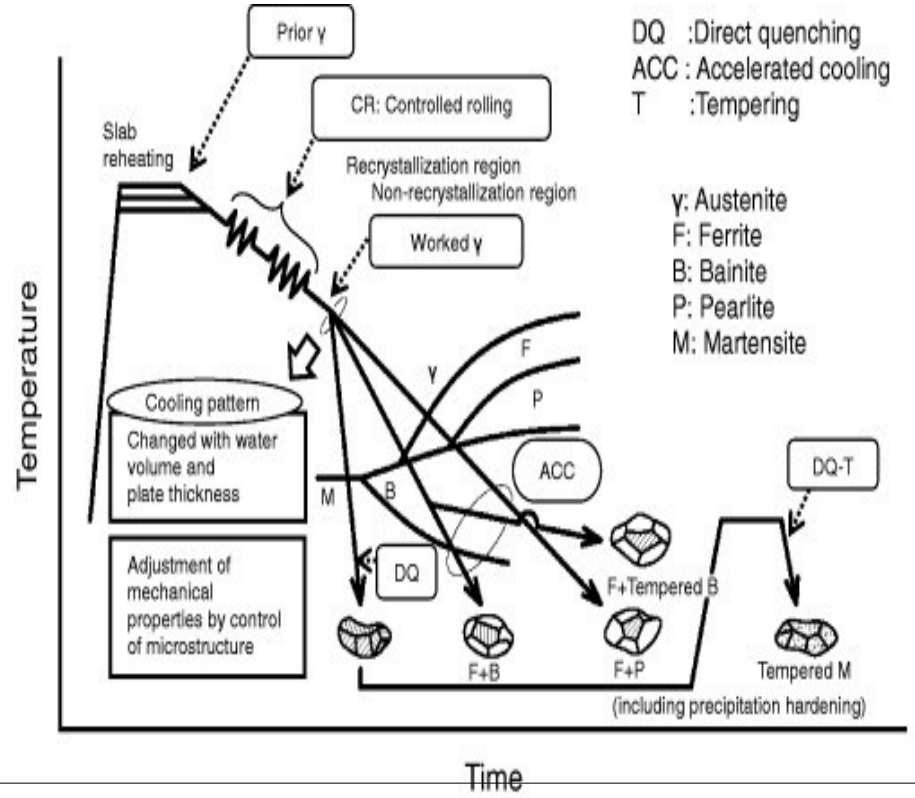
Now IT revolution is progressing. Sustainability is the most important issue and solar and wind energies have become to be used. Clean production is essential in manufacturing. Only electric vehicles may be sold after 2030-40 in some countries.
Metal forming is expected to decrease material loss by replacing from metal cutting, and to produce light weight and high strength products using servo press and controlled rolling.

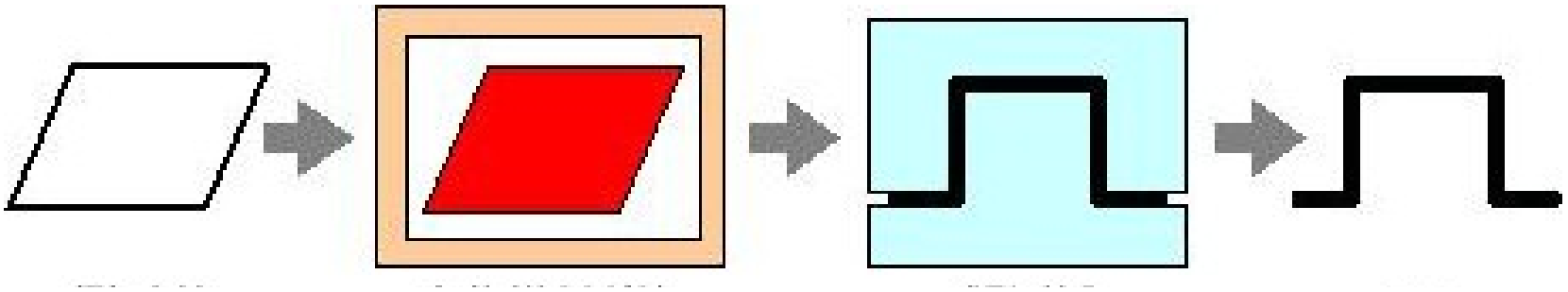
Microstructure control by TMCP

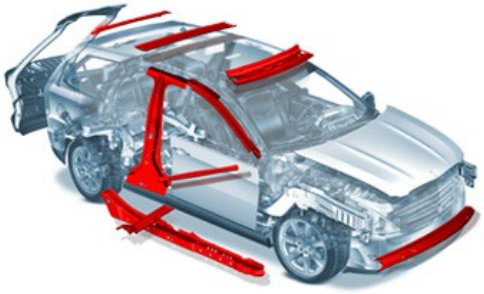
Thermo-mechanical control process



To reduce the weight of parts, the material strength should be increased . One of the methods to produce high strength steel may be thermomechanical control process. In this process, rolling temperature and cooling rate are controlled to realize desirable material properties. This sort of combination of metal forming and heat treatment can also be utilized in sheet metal forming and bulk forming.

Hot stamping

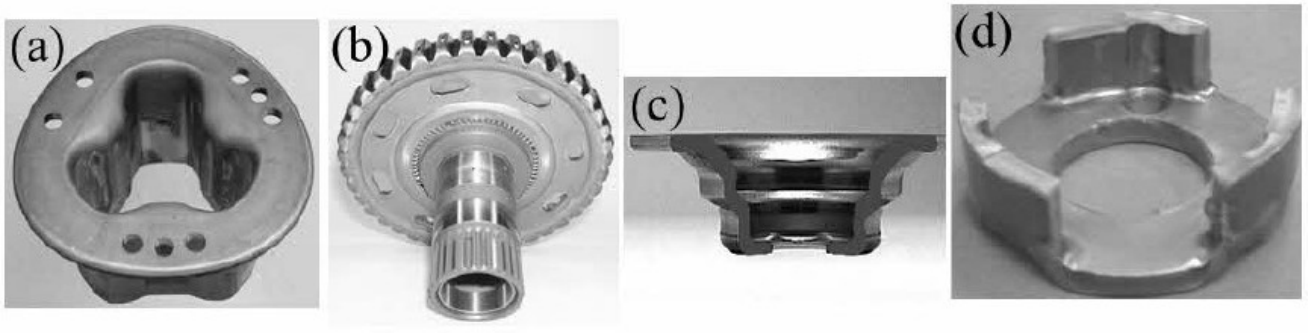




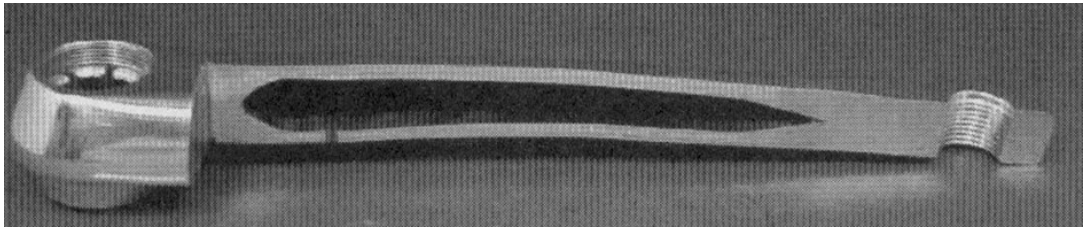
In hot stamping, ultra high strength steel sheet is formed into complex shapes. The process involves heating of the steel blanks up to about 900 °C to increase formability, followed by press forming and then rapid cooling by compressing the formed blank between the dies. By this method, high strength thin beams of car are produced.

Similar process was used in direct quenching after hot forging, and new combinations of forging and heat treatments are appearing.

Cold forging of light weight product



Automobile parts made by plate forging



Hollow crank for bicycle

Another possibility to reduce the product weight is geometry innovation by utilizing the ability of metal forming methods and machines. In cold forging, new light weight shapes for automobile parts and bicycle crank were realized as shown. The redundant regions in the forged product are omitted by reducing the wall thickness and making inside hole. Servo-presses with multiple loading axes are expected to be utilized for this purpose.

Conclusions

- Metal forming can contribute to the on-going Industrial Revolution
- Servo forming machines and metallurgical control have become usable
- Precision forming methods can save material by reducing metal cutting
- Combination of hot rolling and controlled cooling can produce high strength and ductile sheets and bars for light weight vehicles
- Cold and hot stamping can produce high strength sheet products
- Optimized shapes by new forging process can reduce weight of parts