Decision Making Framework for Greener Sheet Stamping Processes

LMAS

Funding source: SMP and industrial affiliates of LMAS

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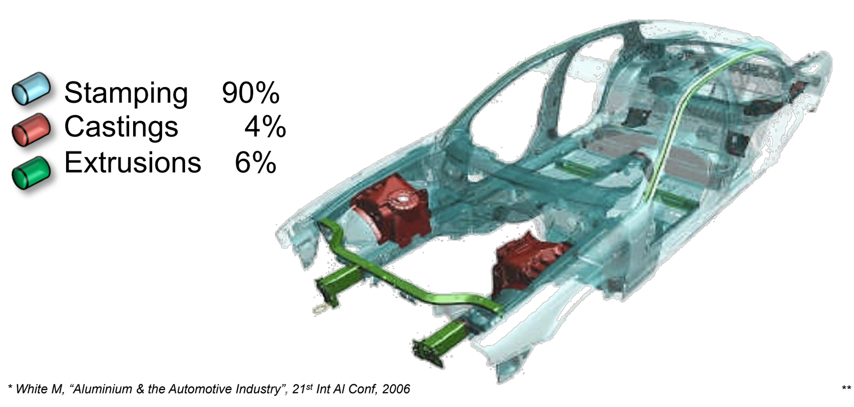
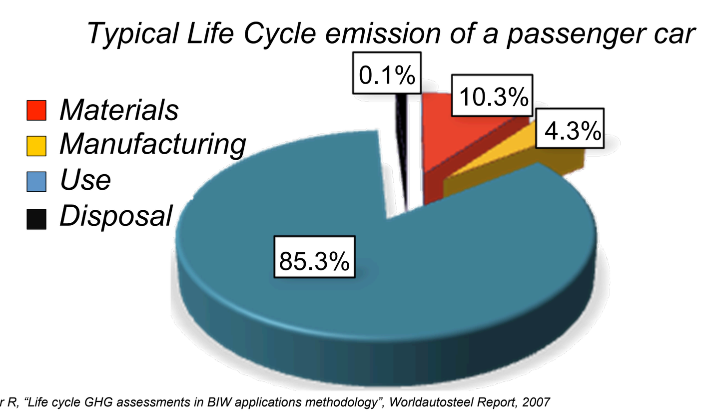
Motivations and Opportunities

- Green sheet stamping processes can trigger a significant leverage effect throughout the vehicle life cycle





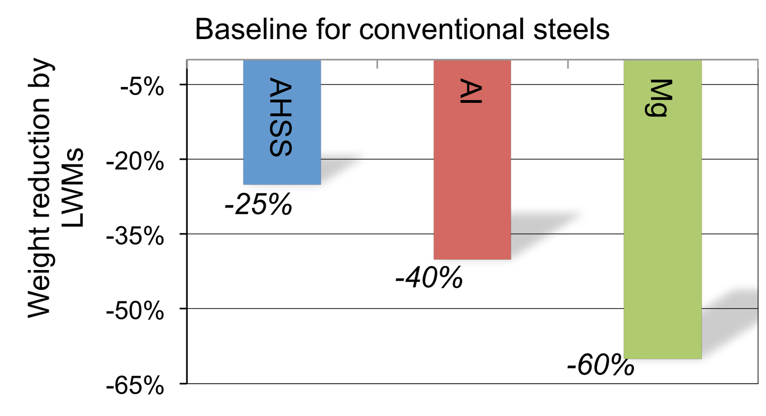
* White M, "Aluminium & the Automotive Industry", 21st Int Al Conf, 2006

** Geyer R, "Life cycle GHG assessments in BIW applications methodology", Worldautosteel Report, 2007

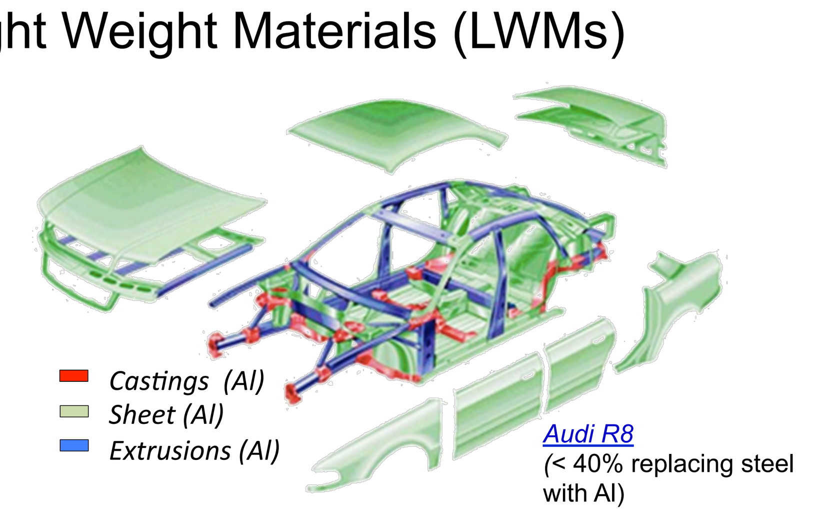
- Improving the manufacturing phase results in a more efficient material use and reduction of CO_2 in the use phase

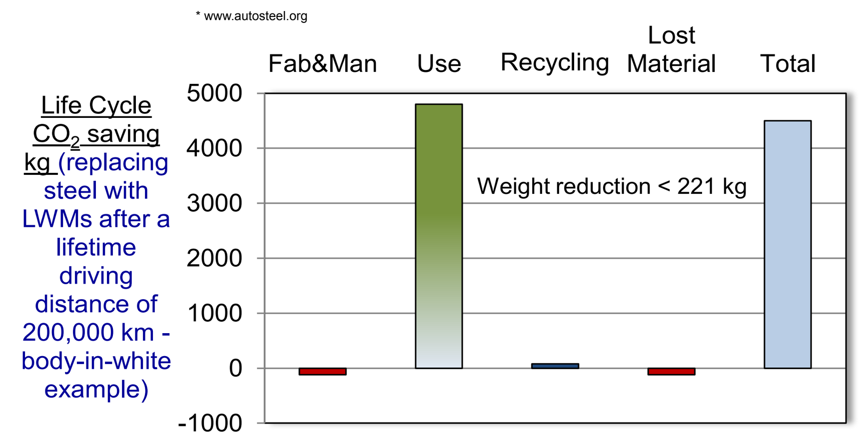
Weight reduction by LWMs

- A 6% to 8% fuel saving can be realized for every 10% reduction in weight by replacing steel with Light Weight Materials (LWMs)

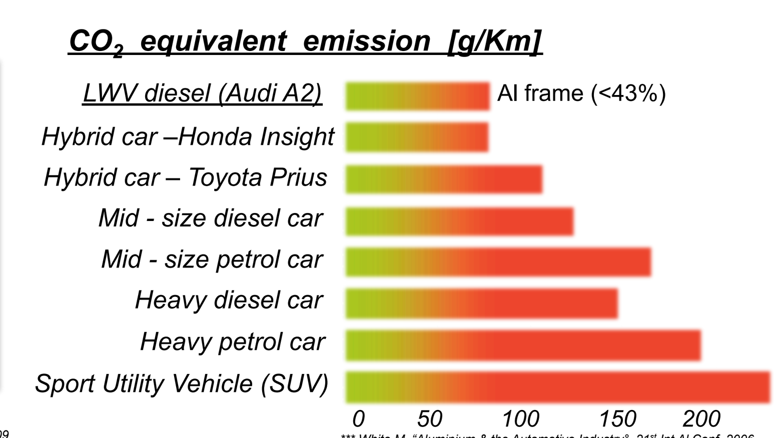


* www.autosteel.org





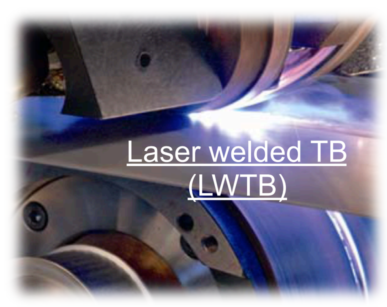
** Bertram M et al., Int J Life Cycle Assess ,"Analysis of greenhouse gas emissions related to aluminum transport applications", 2009

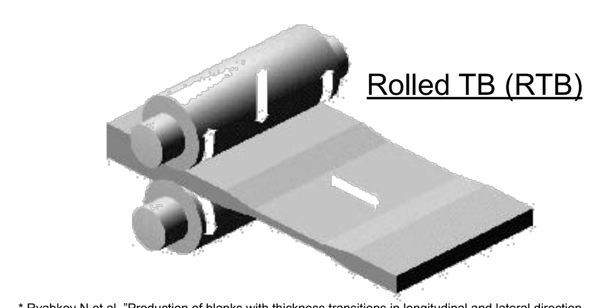


*** White M, "Aluminium & the Automotive Industry", 21st Int Al Conf, 2006

Tailored Blanks (TB)

- Blanks of varying thickness, material alloys and grades enable a proper location of the material properties according to the product requirements



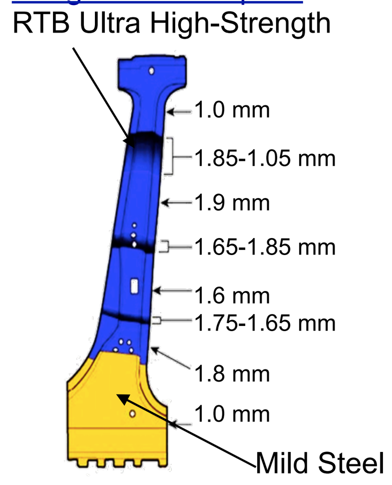


* Ryabkov N et al.,"Production of blanks with thickness transitions in longitudinal and lateral direction through 3D-Strip Profile Rolling", Int J Mater Form, 2008

VW JETTA (different materials on the side)

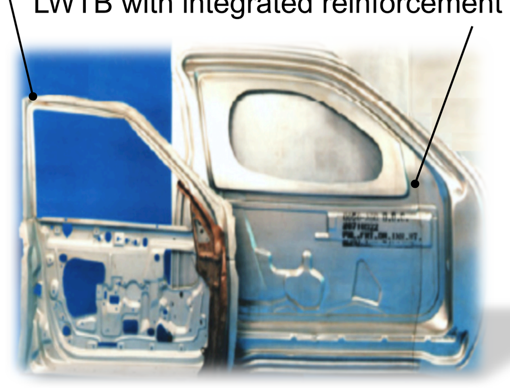
Dodge-Caliber-B-pillar

RTB Ultra High-Strength



Door Inner plus hinge reinforcement

LWTB with integrated reinforcement



** www.autosteel.org

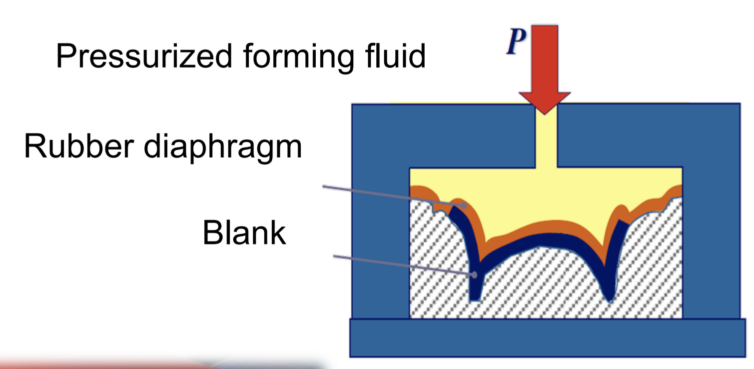
Advantages

- Higher final stiffness with thinner blanks
- No reinforcement where higher strength required
- ≤13% weight reduction
- Efficient material use

Non conventional stamping processes

- Non conventional stamping processes enable the use of 40%-50% thinner blanks due to a more uniform elongation of the material. LWMs with impractical formabilities can be stamped at lower temperature than traditional methods

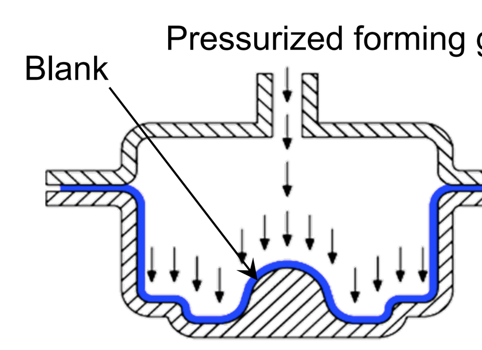
Hydro-forming



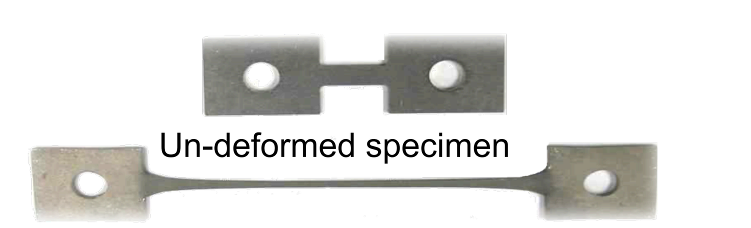
Pontiac Solstice (hydro-formed hood outer and decklid outer)

* http://www.aminonac.ca

Super-plastic forming



***Some LW alloys exhibit super-plasticity** above 50% the absolute melting point*

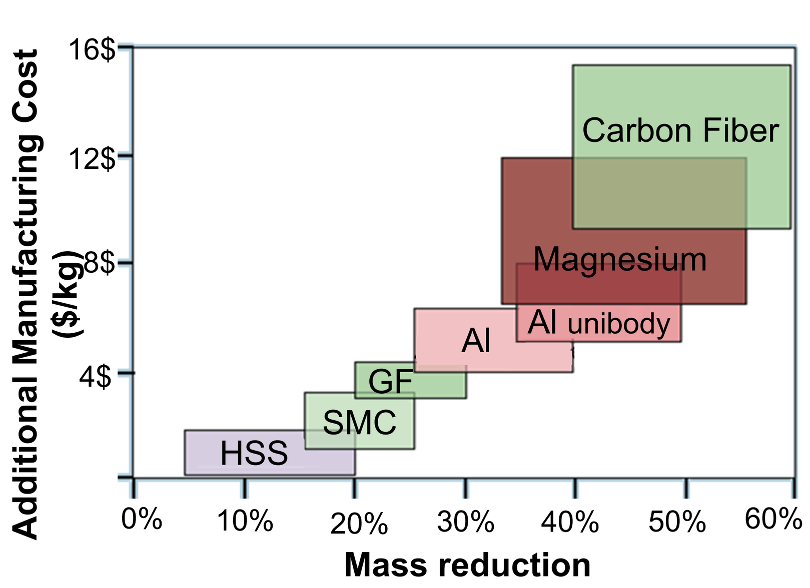


Super-plastically formed to 500% the original length

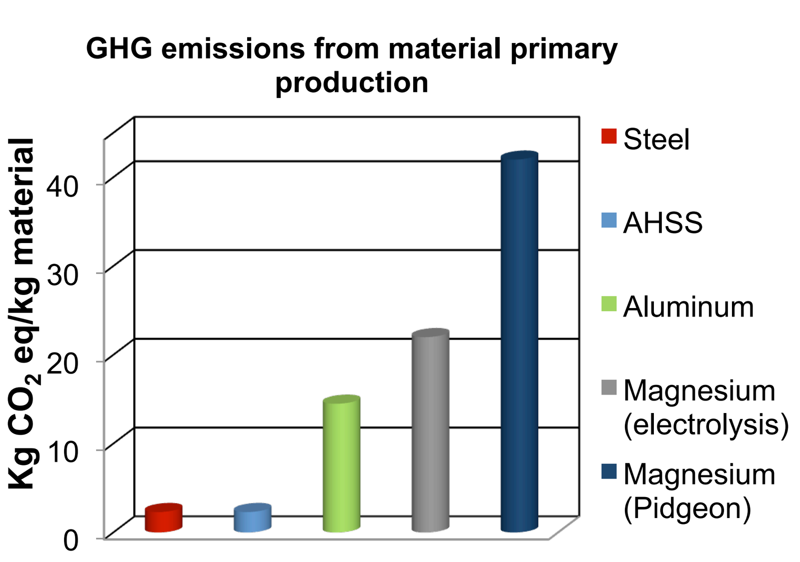
** Fadi K and Marwan KK, "Integrated approach to the Superplastic Forming of lightweight alloys: towards sustainable manufacturing", Int J Sust Manuf, 2008

Problem Statement

- LW Manufacturing (LWM) is economically challenging (higher cost of material supply and tooling)
- LWM is technologically challenging (LWMs exhibit lower formability: hot stamping may be needed)
- LWMs primary production is high energy consuming



* Fine C, Roth R, LWMs for Transport: Developing a Vehicle Technology Roadmap for the Use of Lightweight Materials, MIT Roundtable, 2010

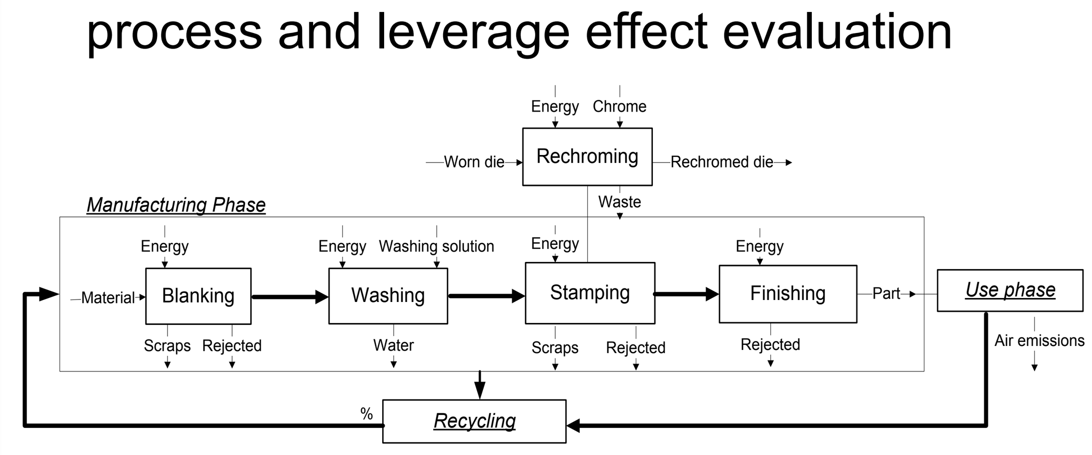


** www.worldautosteel.com

- Is LWM worth developing? Trade off analysis is required

Decision Making Framework – I

- Life Cycle Assessment (LCA) of the stamping processes: environmental impact evaluation. Eco-impact mapping of the process and leverage effect evaluation



$LE_{use\ phase} = \Delta m_{part} * V * e$

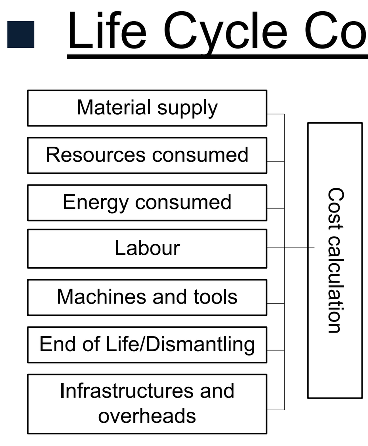
$LE_{use\ phase}$ = leverage effect

$\Delta m_{part} = m_{part,i} - m_{part,refer}$

V = weighted induced fuel consumption

e = CO_2-eq conversion factor

- Life Cycle Cost (LCC) and Technical Evaluation



Technical Performance Evaluation of the Investigated Material

Part requirements	Weight (%)	Yield Strenght (R_p)	Young's Modulus (E)	Density (ρ)	Ductility (strain at rupture)	Strain hardening exponent	Corrosion resistance	Hardness (H)	Ferromagnetism	Anisotropy
Strenght	25	10	5							
Lightness	15	4	4	7						
Corrosion resistance	5						15			
Stiffness	20		10							
Formability	15			5	5	5				5
Handling	10		2	5				8		
Dismantling	10			7					8	
Sum	100	3.1	4.05	3	0.75	0.75	0.75	0.8	0.8	0.75
Weighting (%)	-	**21.7**	**28.35**	**21**	**5.25**	**5.25**	**5.25**	**5.6**	**5.6**	**5.25**
Material Properties		*MPa*	*Gpa*	*Kg/m^3*	*kN m/kg*	*N m/kg*	-	*HV*	-	-

Technical Score

* Ribeiro I. et al. (Journal of Cleaner Production 16 (2008) pp. 1887-1899)

Decision Making Framework - II

- Eco-efficiency Analysis: trade off evaluation and scenario analysis combining green, economic and technical performances (uneven emphasis may be attributed by additional multi-criteria methods)

Data from: 1. LCA
2. LCC
3. Tech. Eval.

↓

Normalization

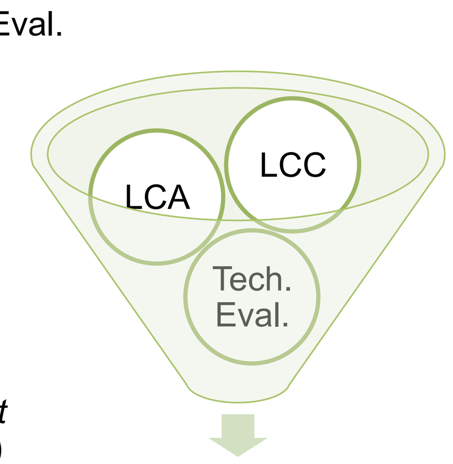
↓

Weighting

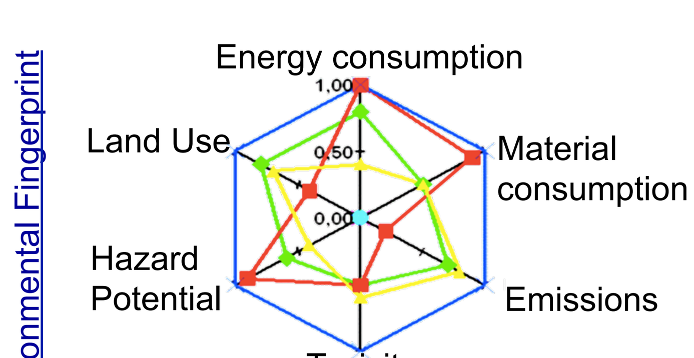
↓

Score

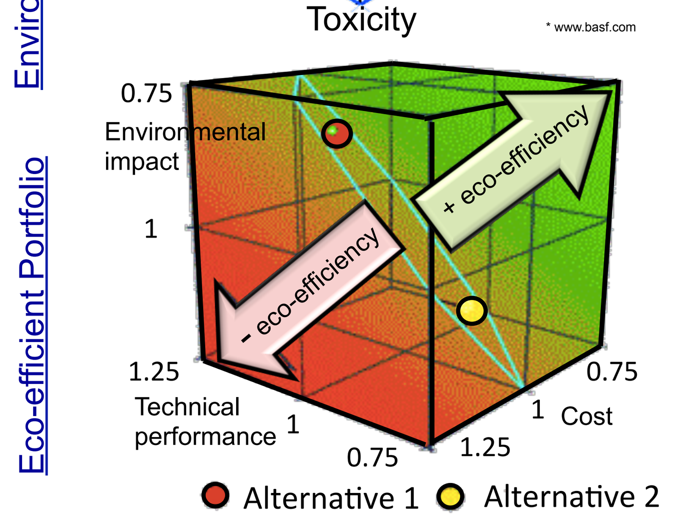
1. *Environmental Impact (Green performance)*
2. *Cost (Economic performance)*
3. *Technical performance*



Eco-efficient solutions



* www.basf.com



Conclusions and expected results

- Processes causing the lowest possible eco impact, while still offering economic and technical viability, are needed
- A standalone LCA application does not allow a thorough evaluation of the process performances
- The above Decision Making Framework allows to:
  - Harmonize ecological, economical and technical performances
  - Evaluate the impact of design choices by "*what if…?*" analysis
  - Guide design choices among alternative scenarios
  - Identify eco-improvement drivers
  - Address the material selection

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