EMECR2017

conditions of material recycling
and
material LCA reflecting closed-loop recycling

Steel as an eco-friendly material

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1. Importance of Life Cycle Thinking

What are eco-friendly materials?

- natural materials?
- recycled materials?
- carbon free materials?

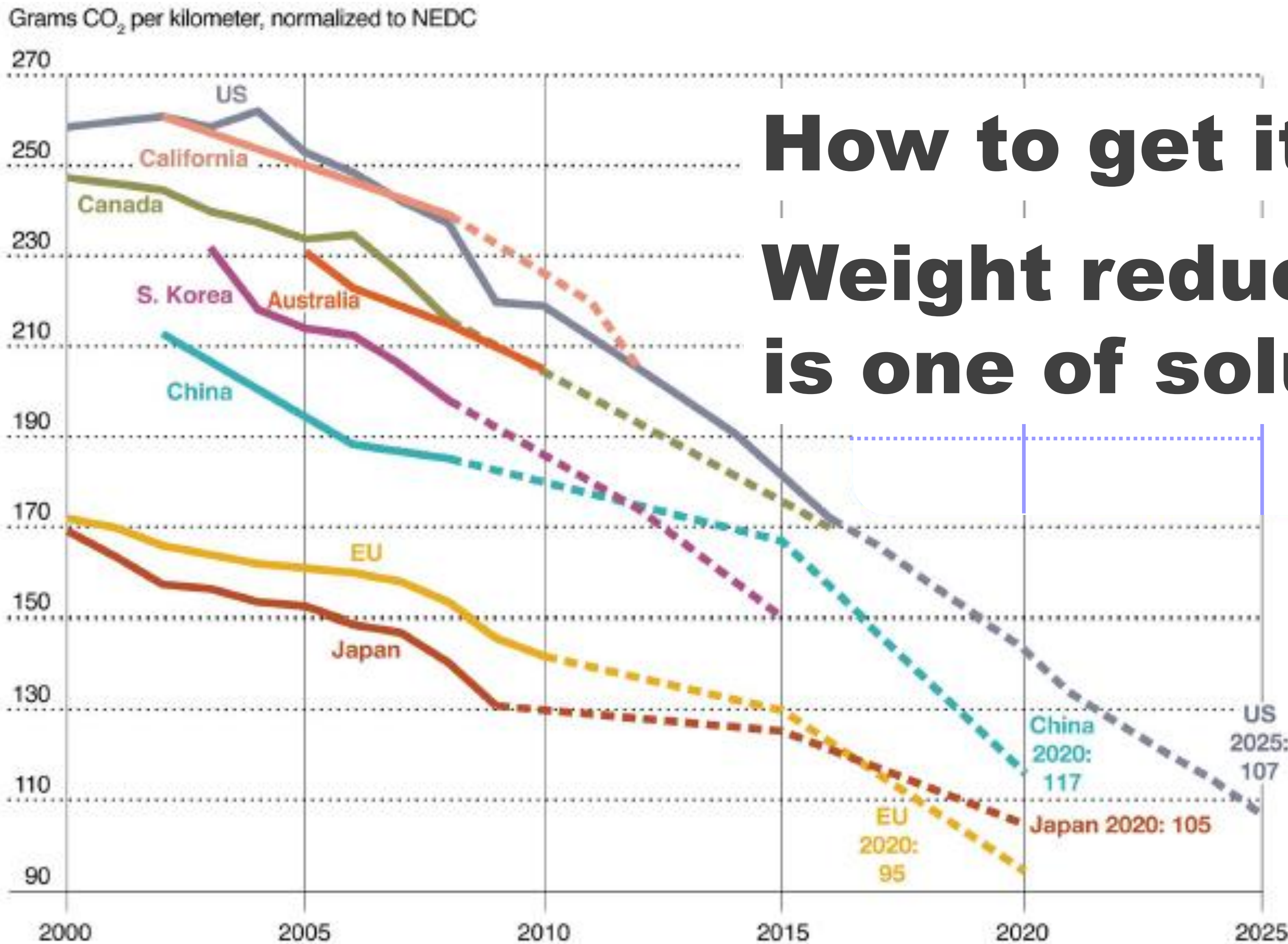
↓

Eco-friendly paper car...?

"Life Cycle Thinking" is very important !

A Case Study on Automobile

Tailpipe Emission Regulation



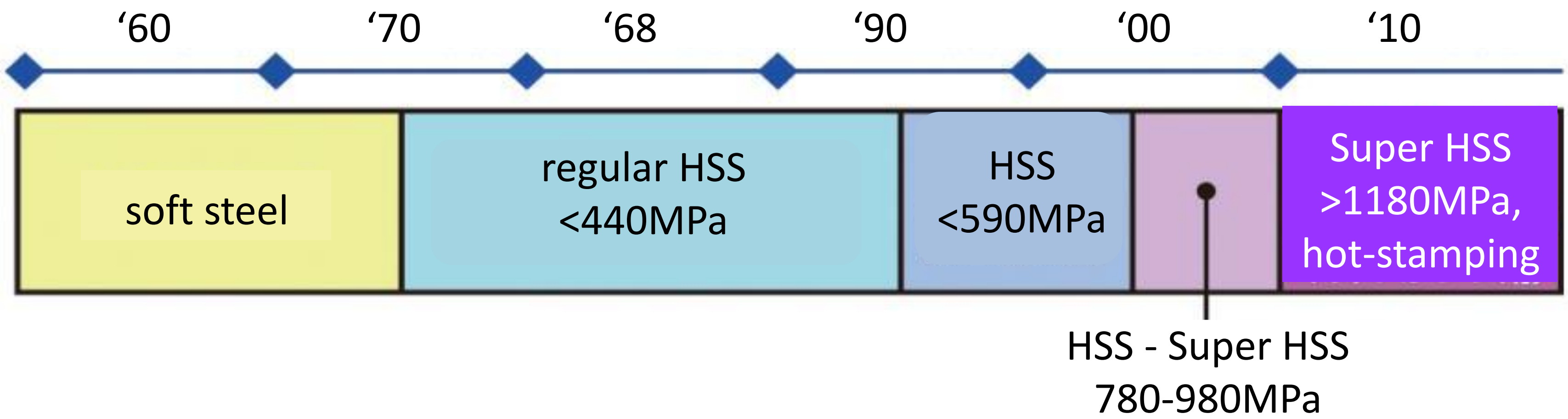
How to get it?

Weight reduction is one of solutions.

Source: International Council on Clean Transportation August 2011

WorldAutoSteel

Challenging weight reduction with HSS

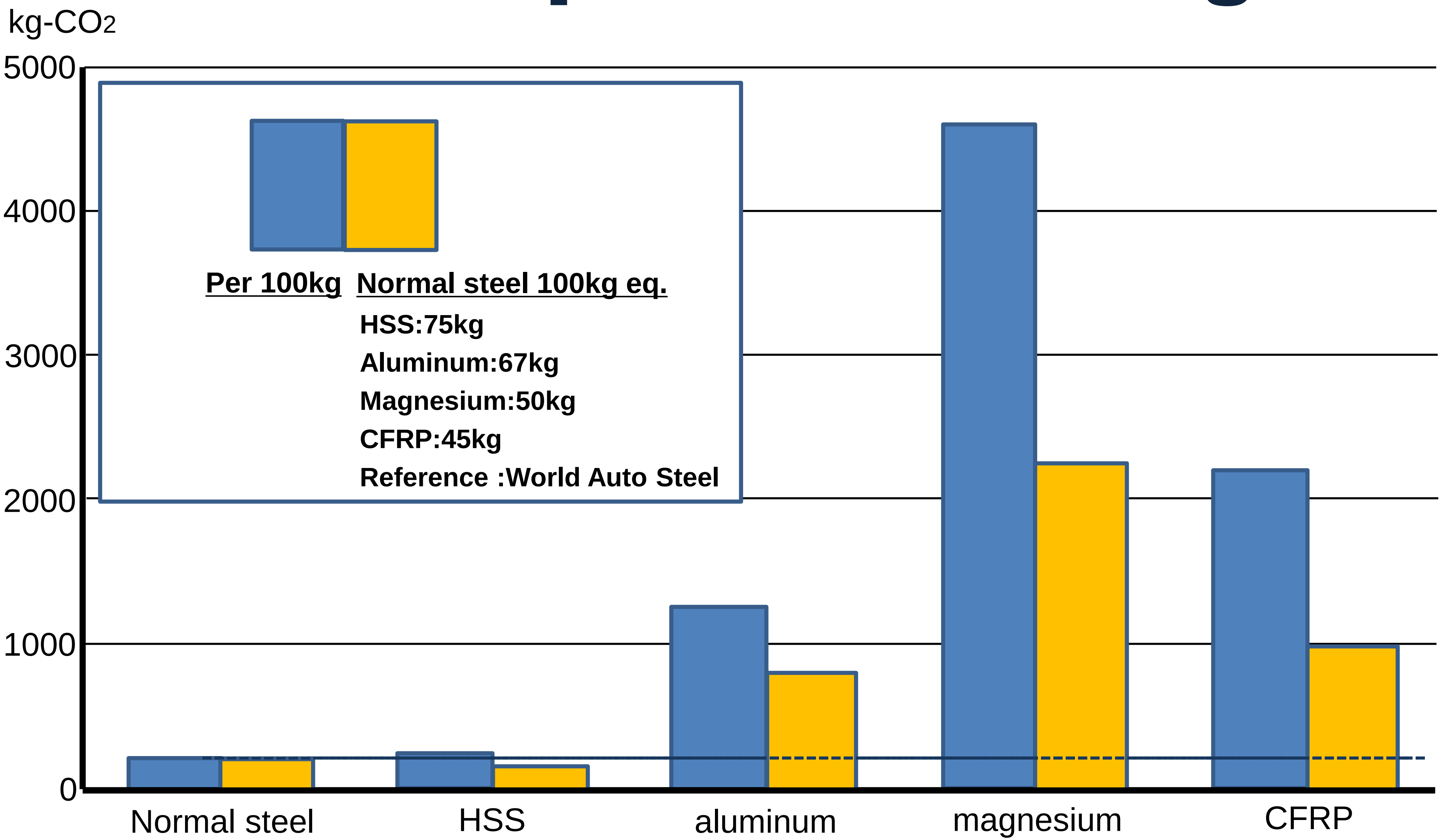


Theoretical strength of iron is 12GPa.

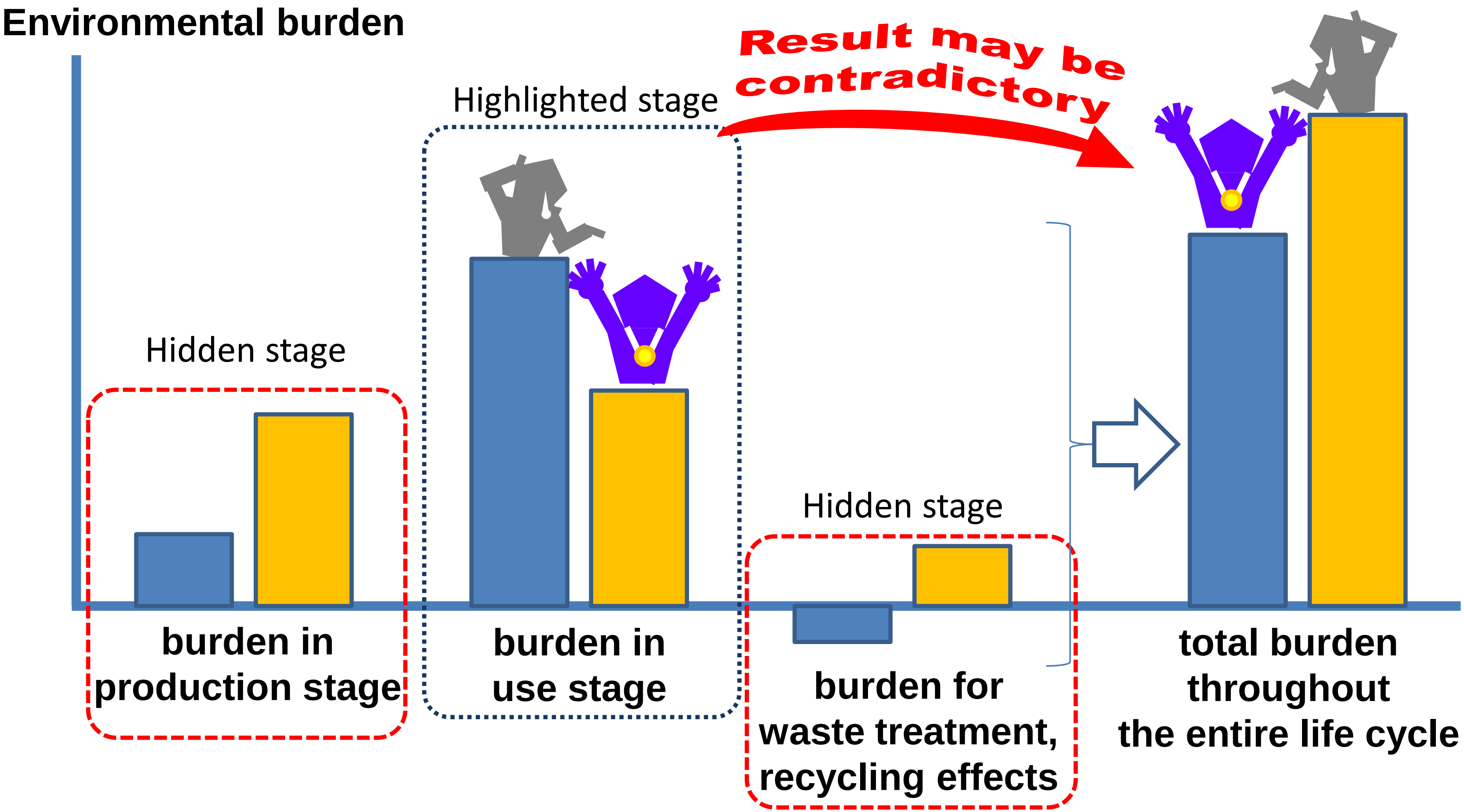
We have commercially reached 1-1.5GPa in flat products and 4-4.5GPa in wire products.

Parts		Required Performance				
		Tensile stiffness	Anti-dent	Stiffness	Endurance strength	Dynamic crush strength
outer	door outer	✓✓	✓			
inner	floor	✓✓		✓	✓	✓
structure	front rail rear pillar			✓✓	✓	✓
	front side member side sill			✓✓	✓	✓✓
	door guard cover			✓	✓	✓✓
under floor	suspension arm wheel disk			✓✓	✓✓	
dominant factor except for thickness		Young's modulus	Yield strength	Young's modulus	Strength	Strength

CO_2 emission from material production stage



Life Cycle Thinking

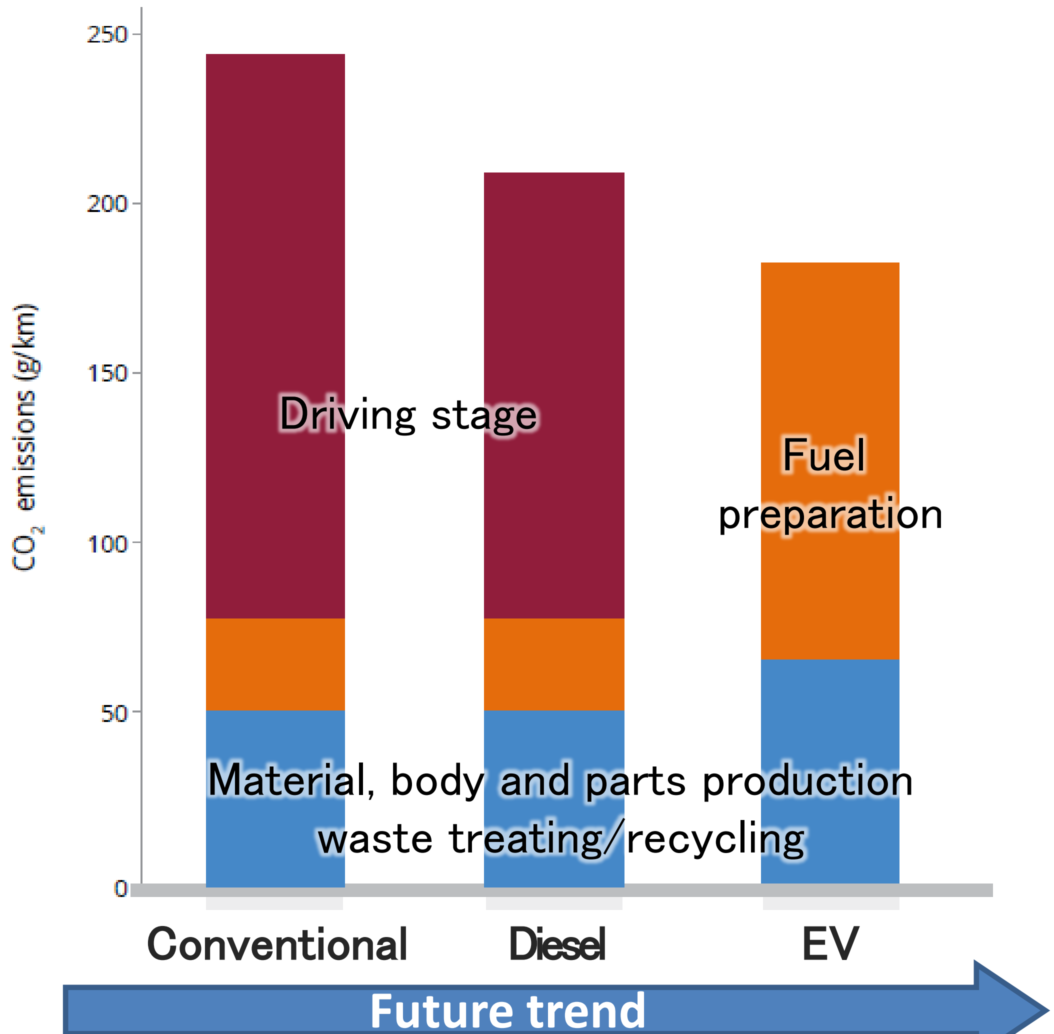


Evaluating only a partial stage (e.g. use stage) of the entire life cycle may lead us to a misleading result ➡ **Importance of Life Cycle Thinking**

Life Cycle CO_2 Emission Comparison among types of vehicle

Material selection becomes more important

←Fuel economy is dominant　　Material selection is dominant →



EEA Signals 2017

2. Advantages of steel in material recycling

Automobile Production in the World

automobile production (million)

JAMA

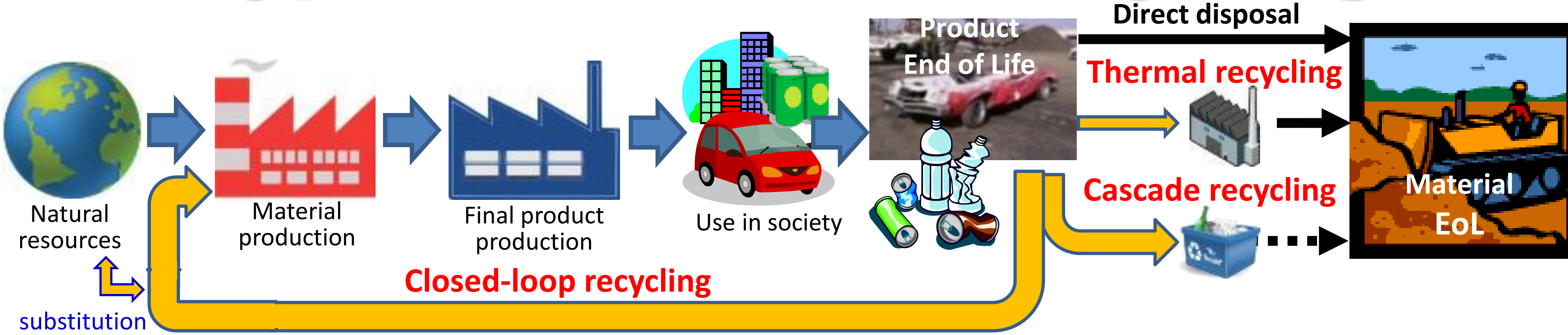
area	2014	2015	2016
EU	17.1	18.6	18.8
Japan	9.8	9.3	9.2
USA	11.7	12.1	12.2
China	23.7	24.6	28.1
world	89.8	90.8	95.0

Over 90 million cars are disposed in the world every year

What are the conditions for eco-material for mass production products?

mass productivity, economy and technical performances are essential, in addition to those, "recyclability" is the key

Types of Material Recycling



Thermal Recycling (Open-loop Recycling)

EoL products are incinerated and the heat is recovered as thermal energy to produce electricity or steam. The recovery has no effect on the reduction of natural resource consumption for virgin materials, but it is a low cost and energy saving way for recycling of flammable materials.

Cascade Recycling (Open-loop Recycling)

The material is used as a secondary material in another product. The recycle may continue cascadely in several steps. In each step, the material quality drops or changes and finally the material comes to the EoL.

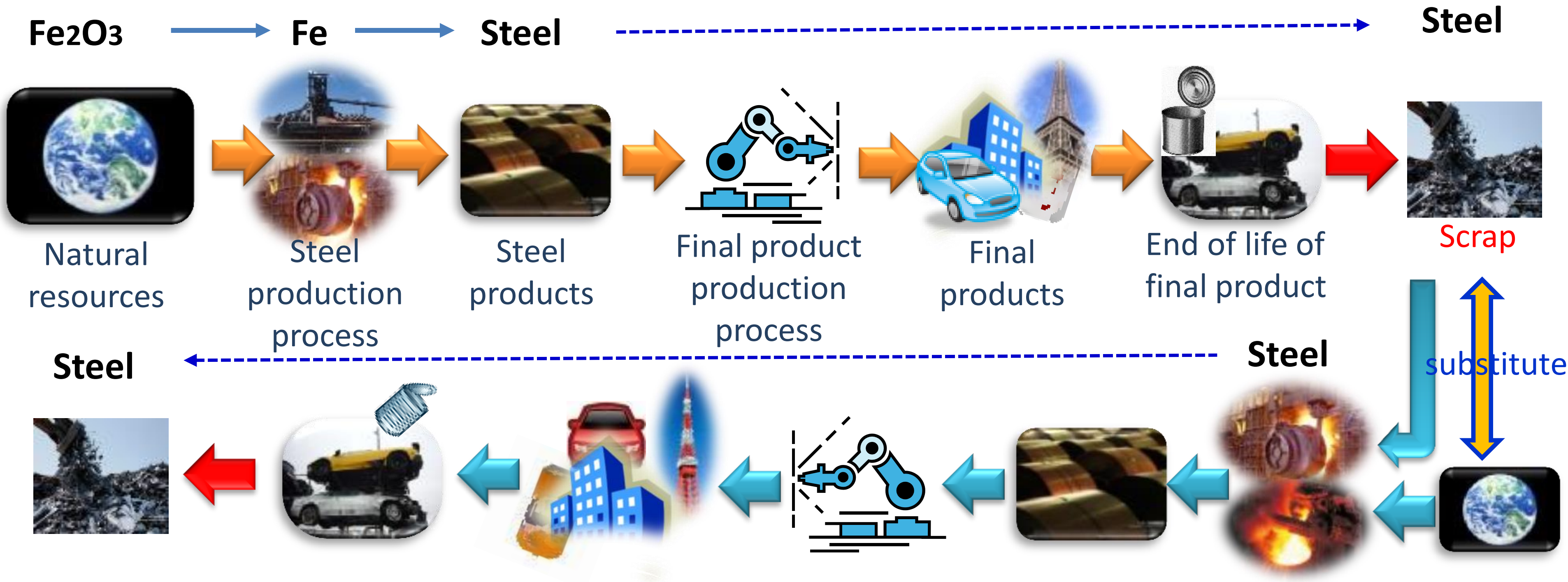
Closed-loop Recycling

The material is recycled to the original material without or with very little loss of its characteristics or quality so that the number of recycling can be infinite. Closed-loop recycling reduces consumption of natural resources of the material, accompanying environmental impacts, and generation of wastes. Closed-loop recycling is superior to open-loop recycling in terms of sustainability.

STEEL

Life Cycle of Steel Products

Steel keeps its metalic state even after the EoL of products **Steel is still Steel!**



Steel can be recycled however many times into whatever steel product you want…

Sustainable & Flexible Life Cycle

Conditions for Autonomous/Sustainable Material Recycling

a) Separation and collection is easy

b) Environmental impact of recycling is smaller compared to production using natural resources

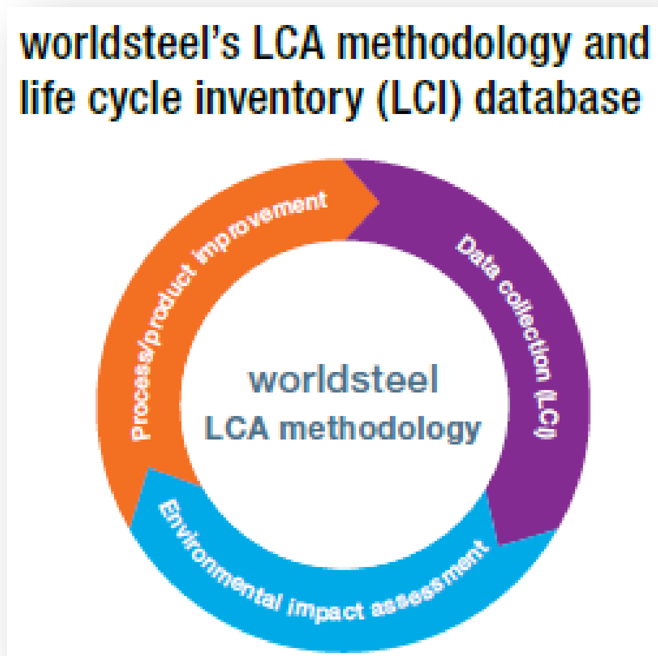
c) Recycling system is economically sustainable

Additional conditions for "Closed-loop Recycling"

d) No/small quality degradation through recycling

e) Can be recycled into various products

3. worldsteel LCA methodology for steel products reflecting scrap recycling



Lifelong Environmental Burden of Steel with eternal recycling

Lifelong production $= 1 + r + r^2 + r^3 + \cdots + r^{n-1}$

Lifelong burden $= Xpr + rXre + r^2Xre + \cdots + r^{n-1}Xre$

r : scrap recovery rate × yield

Xpr : burden for primary production

Xre : burden for recycling

Lifelong unit burden $= \dfrac{Xpr + rXre + r^2Xre + r^3Xre + \cdots + r^{n-1}Xre}{1 + r + r^2 + r^3 + \cdots + r^{n-1}} = (Xpr - Xre)\dfrac{(1-r)}{(1-r^n)} + Xre$

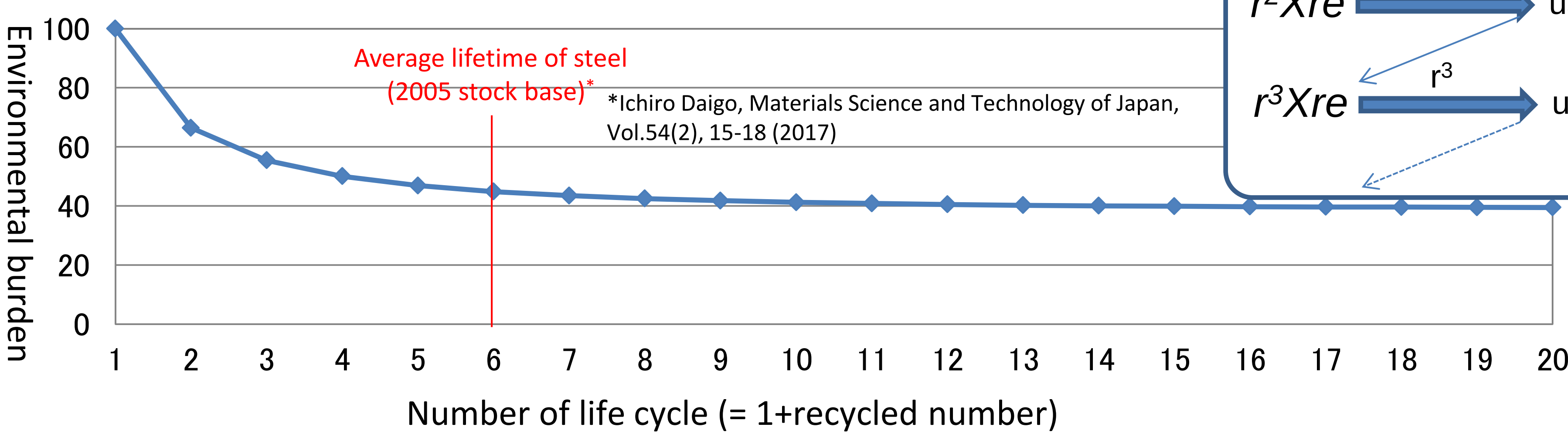
When infinite recycling ($n \to \infty$), then $r^n \to 0$、$1 - r^n \to 1$

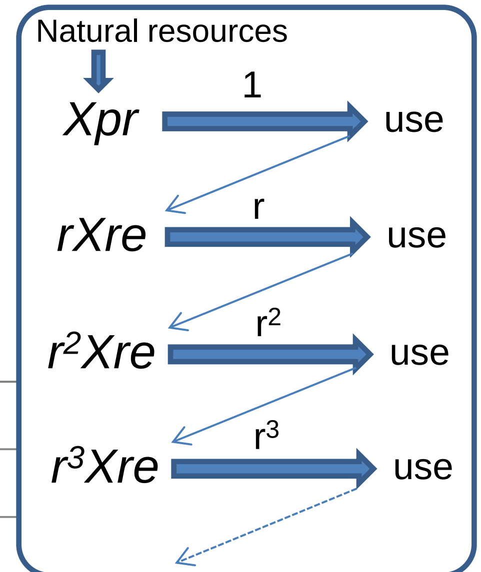
$= Xpr + r(Xre - Xpr)$

Substitute $r = 0.9 \times 0.9$, $Xpr = 100$, $Xre = 25$

$= 39.25$

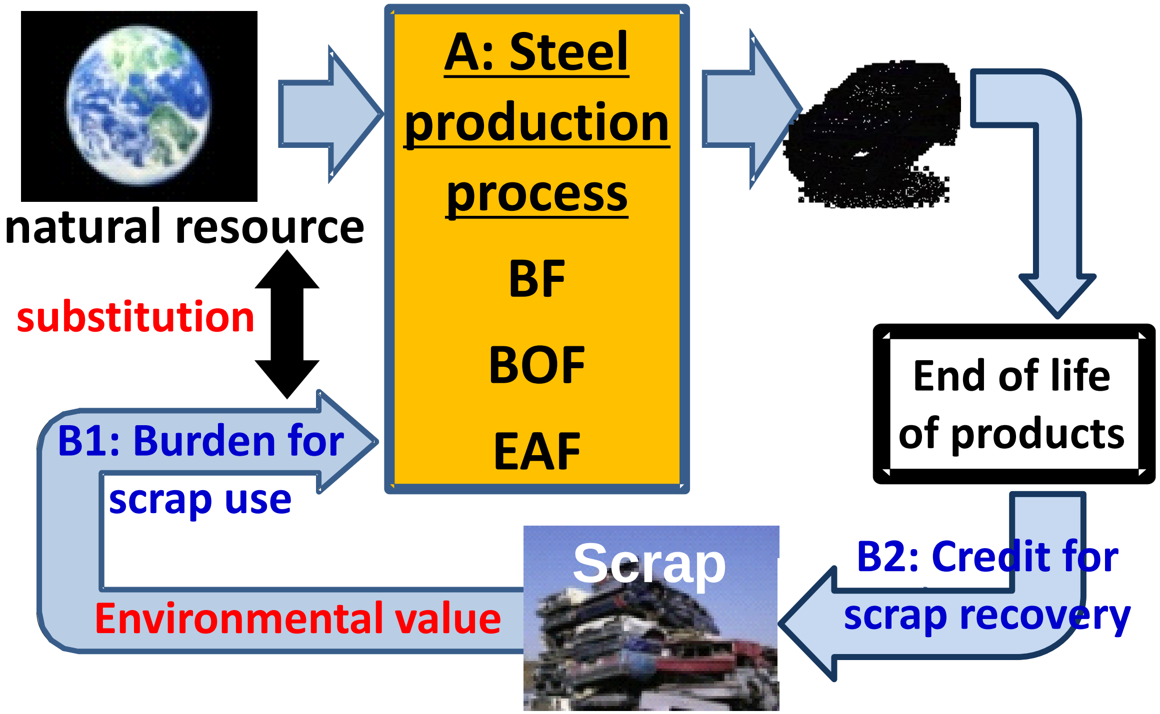
A Amato, L Brimacombe, N Howard. (1996) *Ironmaking and Steelmaking*, Vol23, No. 3, 235-241

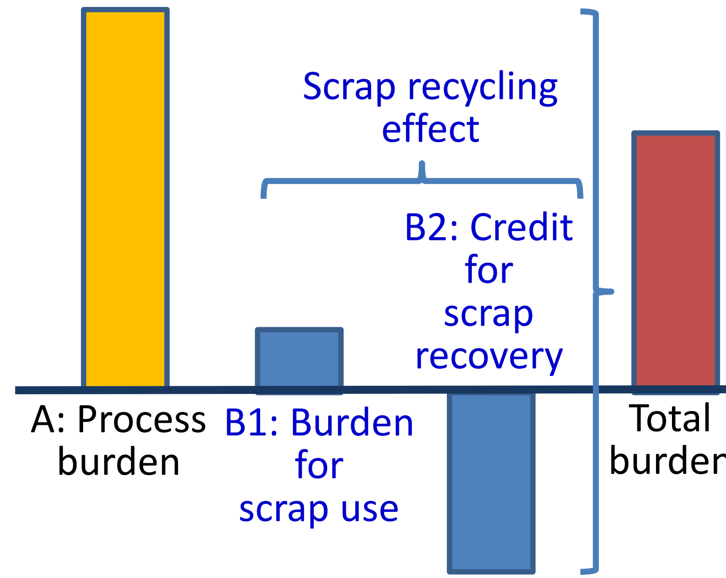




LCA methodology reflecting scrap recycling
- worldsteel-LCA methodology - Cradle to "No" grave…

- It evaluates both BF-BOF and EAF as one whole steel cycle system.
- Through scrap recycling, the natural resource consumption and related environmental impacts can be avoided (environmental value of scrap)
- Same as the economic value of scrap, the environmental value of scrap is credited for its recovery and burdened for its use





Evaluation of Scrap Recycling Effect

assuming
the burden to produce a unit of steel product only from natural resources is 100 (Xpr),
the burden to produce a unit of steel product only from scrap is 25 (Xre),
and yield of steel product from scrap is 0.9,

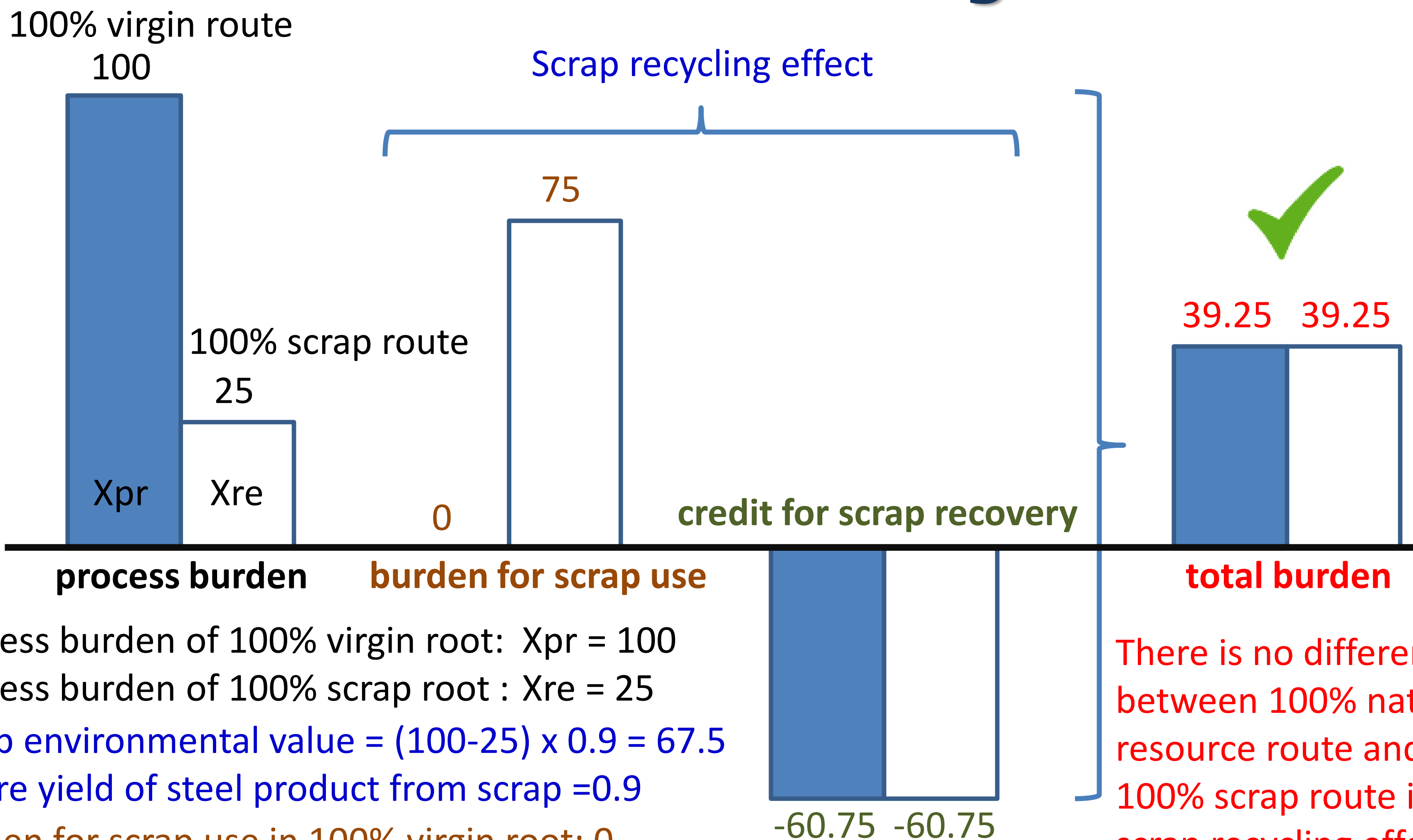
then
environmental value of scrap = (100-25) x 0.9 = 67.5

The environmental value of scrap is credited when it is recovered and burdened when it is used.

for example,
when the recovery rate of scrap is 0.9, then
credit for scrap recovery equals to 67.5 x 0.9 = 60.75
And when the yield is 0.9, then
burden for scrap use equals to 67.5/0.9 = 75

Scrap recycling effects

A case study



Process burden of 100% virgin root: Xpr = 100

Process burden of 100% scrap root : Xre = 25

Scrap environmental value = (100-25) x 0.9 = 67.5

where yield of steel product from scrap =0.9

Burden for scrap use in 100% virgin root: 0

Burden for scrap use in 100% scrap root : 67.5/0.9 = 75

where yield of steel products from scrap = 0.9

Credit for scrap recovery = 67.5x0.9 = 60.75

where scrap recovery rate = 0.9

There is no difference between 100% natural resource route and 100% scrap route if scrap recycling effects are correctly reflected.

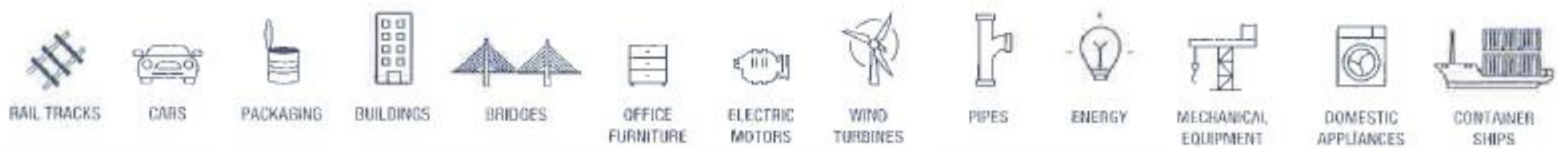
ISO Development of worldsteel-LCA Methodology

ISO 20915: LCI calculation methodology for steel products

worldsteel-LCI data collection

Access the most comprehensive and reliable steel life cycle inventory data today:

- 16 key steel products for use in multiple applications
- Global and regional (EU, Asia & Latin America) industry data, representing 250 Mt of global steel production
- Conforms to ISO 14040: 2006 and ISO 14044: 2006



DATA AVAILABLE VIA:
worldsteel.org

thinkstep GaBi
Currently available in GaBi

SimaPro
Coming soon in SimaPro

worldsteel ASSOCIATION

Conclusions

1. Life Cycle Thinking is the key to keep right direction in global environmental issues
2. Steel has great advantages in terms of material recycling
3. worldsteel LCA methodology gives a clear answer for steel LCA reflecting closed-loop scrap recycling

Thank you for your attention

Steel,

the most eco-friendly

material