Method to take into account material recycling and end of life in LCA

LCA Forum Lausanne, 22 November 2007

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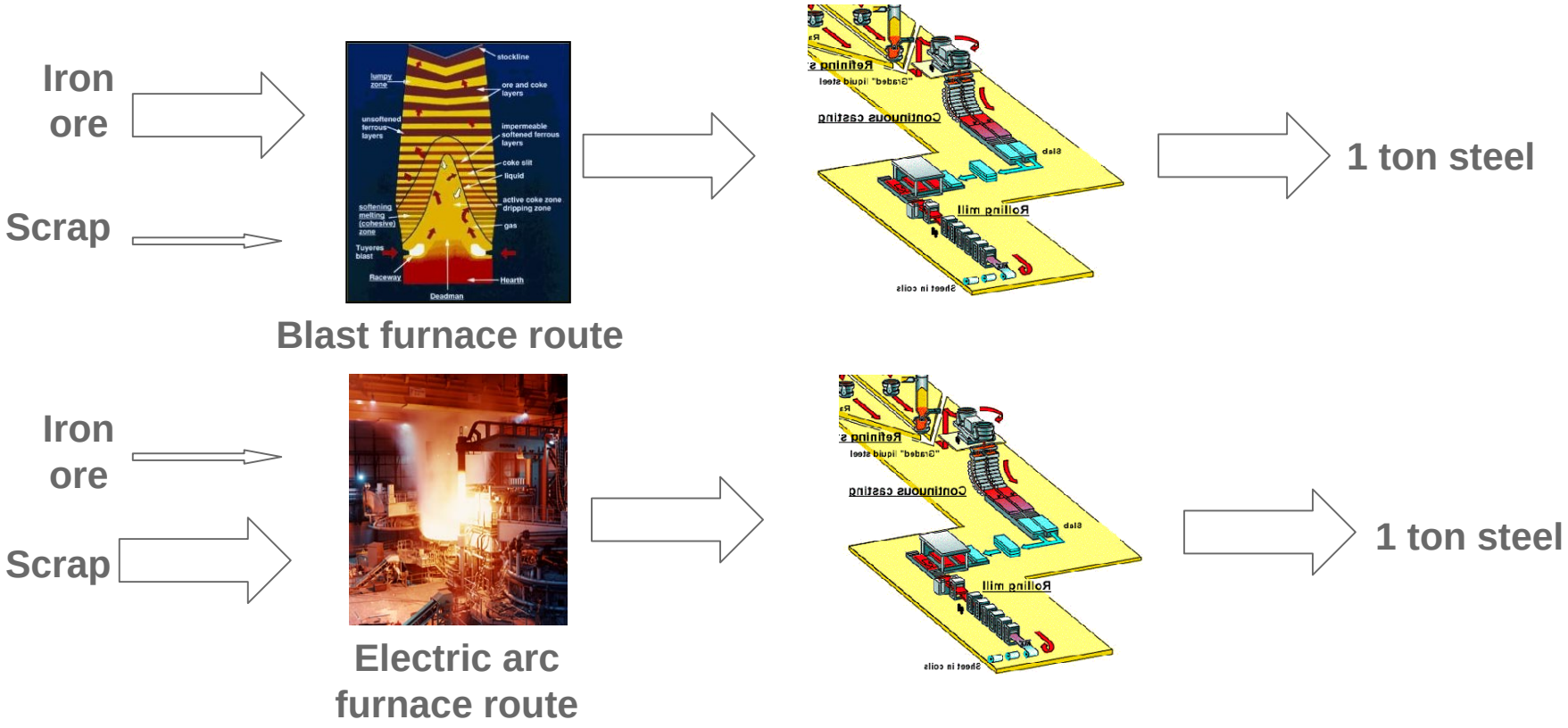
Overview

- Steel recycling
- IISI and Steel LCIs
- IISI LCI data with Recycling included
- Application in construction
- Conclusion

Steel recycling

Steel recycling : facts and figures (I)

- Two main technologies for steel manufacture:
  - EAF route (mostly secondary steel)
  - BF/BOF route (mostly primary steel)



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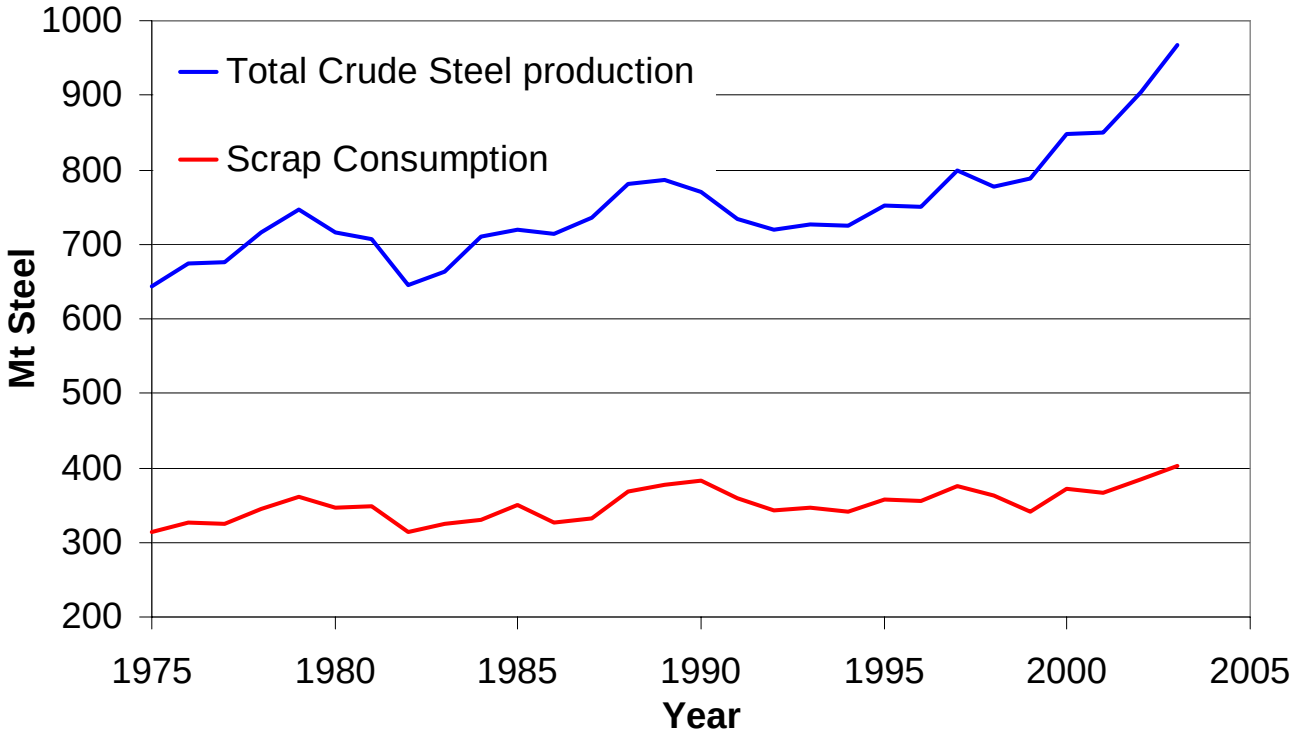
Steel recycling : facts and figures (II)

- Steel demand increasing
  - The increasing demand (especially China) explains why the primary production is still high in percentage (60% vs 40%). Not enough scrap to produce steel!



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Steel recycling : facts and figures (III)

- Average Recycling Input Rate ~ 40%
- Steel Overall Recycling Rate is already high

Sector	Market size	Overall RR
Packaging	5.5%	66%
Automotive	30.2%	99%
Domestic Appliances	5.0%	93%
Construction	43.6%	85%
Machinery	15.7%	91%

Steel Overall Recycling Rates based upon North American data (Steel Recycling Institute 2005)

- End-of-life steel is not sufficient to meet demand for new steel (even if 100% recovery!)
- Steel can be recycled over and over again

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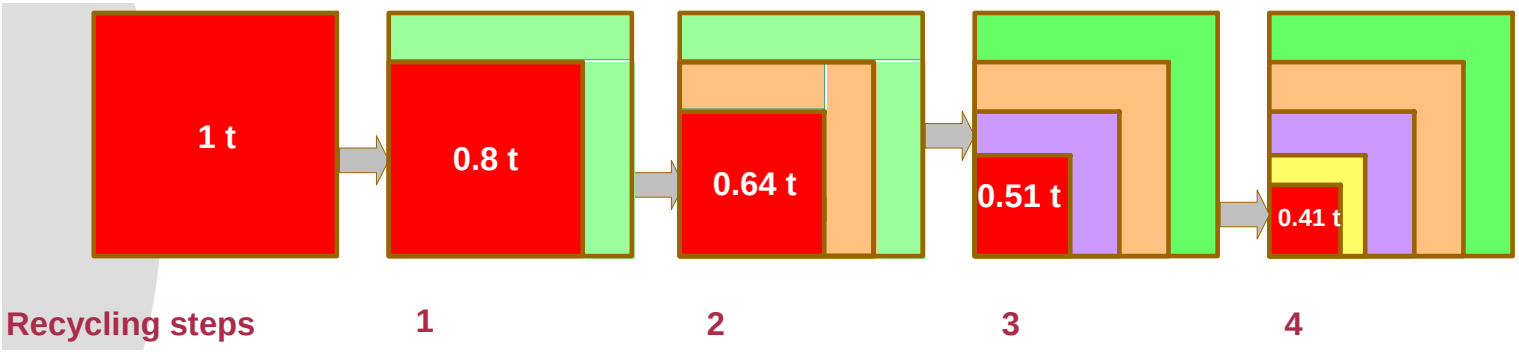
Benefit of steel recycling

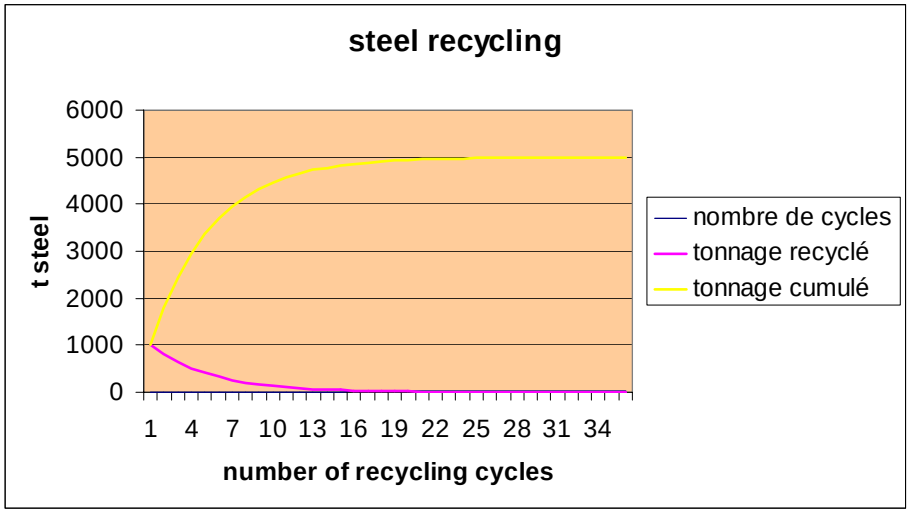


n number of cycle

$$Tcum = Tini \times \frac{(1 - R^{n+1})}{1 - R}$$

n infinite

$$Tcum = \frac{Tini}{1 - R}$$



For 80% recycling rate : 1 tonne of primary steel = 5 tonnes of steel

WE ARE SUSTAINABLY STOCKING FOR FUTURE GENERATIONS!

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IISI and Steel LCIs

IISI and Steel LCIs

- IISI has been providing LCIs for steel product, from cradle to gate of steel factory since 1995.
- Scrap was considered as a raw material with neither burden, nor credit.
- It was up to LCA practitioners to apply (or not) a methodology proposed in an appendix to allocate scrap

IISI and Steel LCIs

- IISI has now decided to provide steel LCI from cradle to gate, with end-of-life and recycling included
  - Recycling not always modelled correctly and accurately in LCA studies
    - Steel is a closed loop material
  - Some organisations interested in simplifying the LCA process

- Practitioners will only have to add the use phase

Methodology

What we had:

- **LCI data sheets – no allocation for scrap or recycling**
- **Guidance on recycling = Appendix 5 (avoided impacts)**
  - **Based on ISO standard guidance**

What we wanted:

- **Desire to communicate multiple step recycling (MSR)**
- **MSR (n=∞) equivalent to Appendix 5**
  - **Convenient since still complies with ISO standards**
  - **Applies to 'once through' and multiple systems**
- **Need to produce data sheets for external communication**
- **The Methodology is available and has been reviewed according to ISO 14040-44**

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Definitions

- ***RR =*** Recovery rate

  The fraction of steel recovered as scrap during one life cycle of a steel product. This includes prompt and end-of-life scrap.

- ***Y =*** Metallic yield

  The efficiency of the secondary process in converting scrap into steel. It is the ratio of steel otuput/scrap input

- ***Xpr =*** LCI **for primary steel production**

- ***Xre =*** LCI **for secondary steel production**

Methodology: Closed material loop

- ISO14040 defines allocation for closed loop recycling of a material:

  'The use of secondary material displaces the use of virgin materials' (6.5.4)

Allocating a value to scrap

ISO 14041 : can assume 1 kg of **recycled steel replaces primary steel**, giving:

In general terms:

$$\text{LCI for scrap} = (X_{pr} - X_{re})Y$$

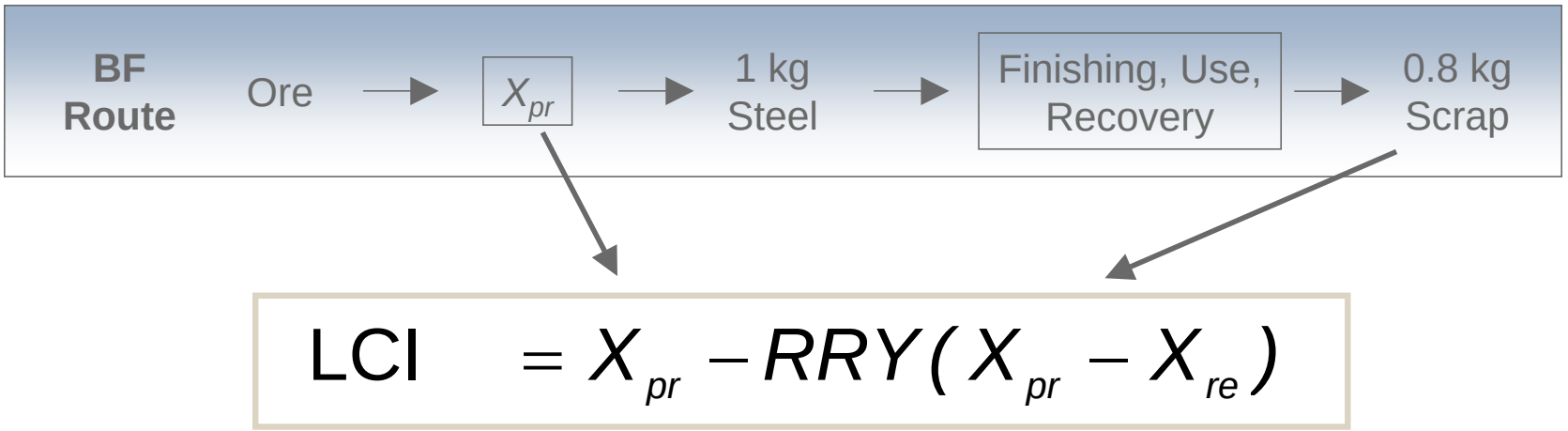
Where Y = through process yield

X_{pr} = LCI for primary manufacture

X_{re} = LCI for recycling process

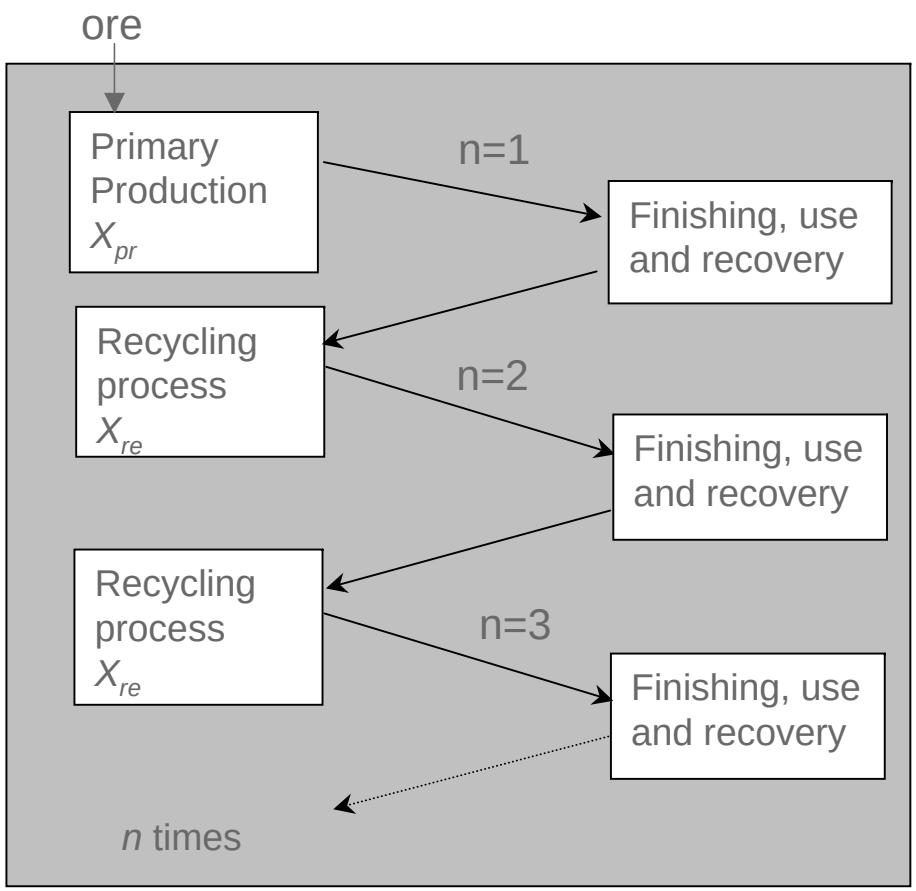
Applying the scrap credit

- LCI for system



where X_{pr} is the LCI for primary manufacture of the product

Multiple Recycling and Reuse



n = number of life cycles

LCI for the whole system $X = (X_{pr} - X_{re})\left[\frac{(1-RRY)}{(1-RRY^{n})}\right] + X_{re}$

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Multiple Recycling

$$\text{Total mass} = 1 + RRY + (RRY)^2 + ... + (RRY)^{n-1}$$

$$\text{Total cost} = X_{pr} + RRYX_{re} + (RRY)^2 X_{re} + ... + (RRY)^{n-1} X_{re}$$

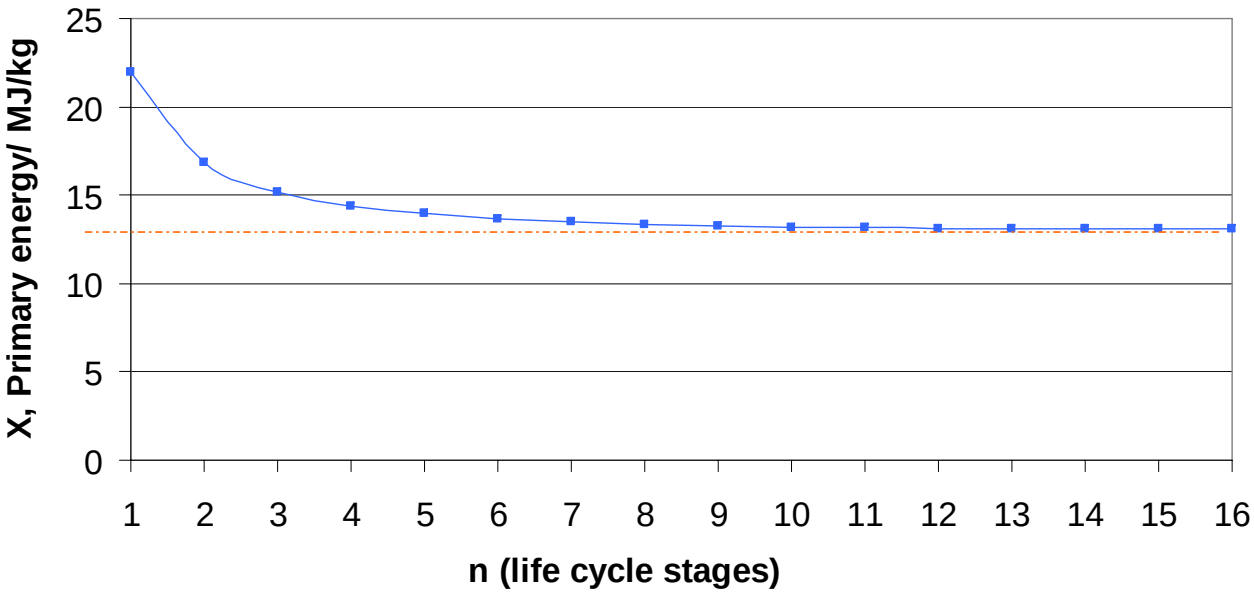
$$\text{LCI for the whole system} \quad X = \frac{X_{pr} + (RRY)X_{re} + (RRY)^2 X_{re} + ... + (RRY)^{n-1} X_{re}}{1 + RRY + (RRY)^2 + ... + (RRY)^{n\text{-}1}}$$

$$\text{LCI for the whole system} \quad X = (X_{pr} - X_{re})\left[\frac{(1-RRY)}{(1-RRY^n)}\right] + X_{re}$$

A Amato, L Brimacombe, N Howard. (1996) *Ironmaking and Steelmaking*, Vol23, No. 3, p235-241

Multiple Recycling

Steel can be recycled again and again (high values of n are possible)



$$n \longrightarrow \infty$$

$$(RRY)^n \longrightarrow 0$$

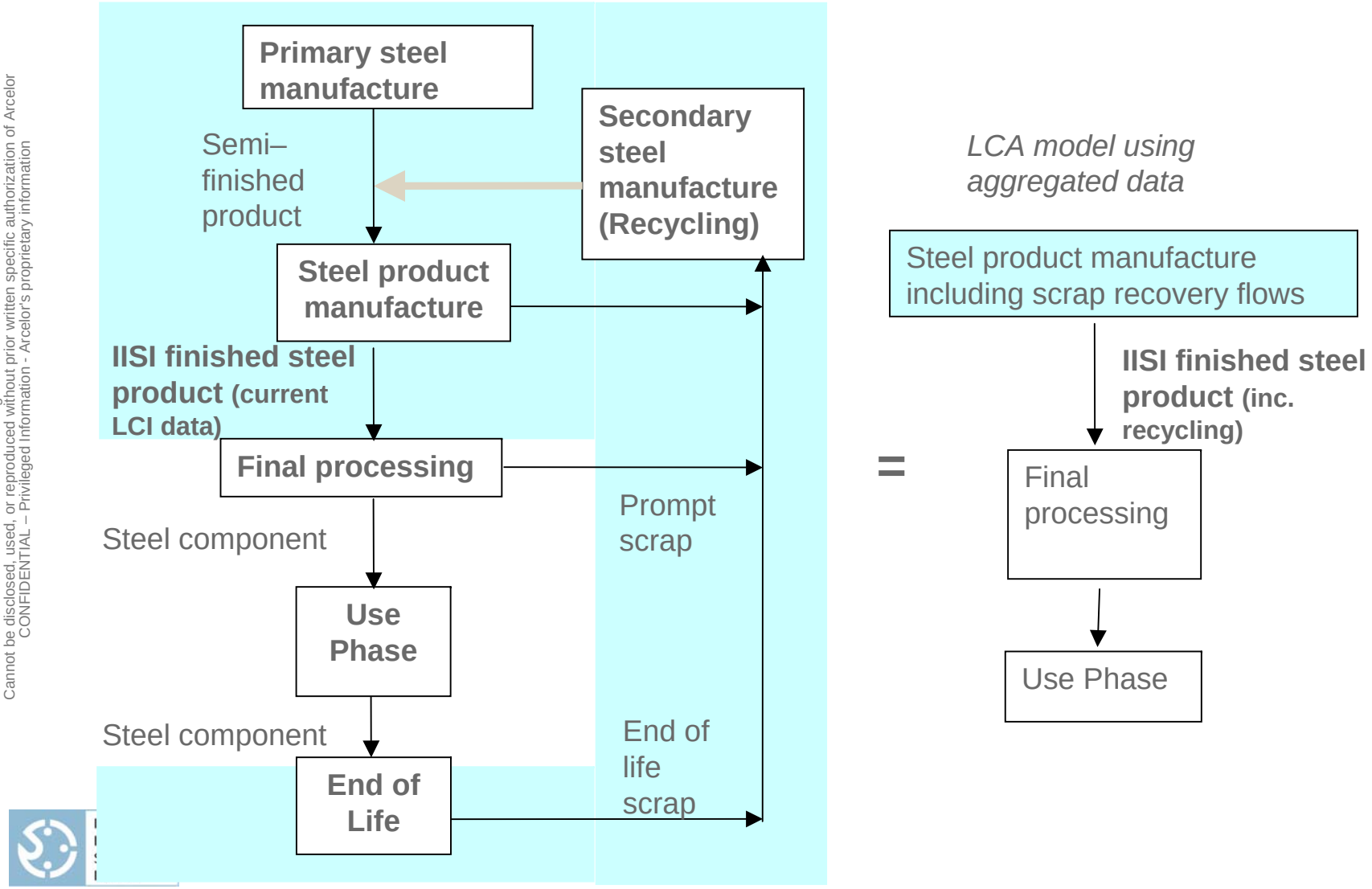
$$(1-(RRY)^n) \longrightarrow 1$$

$$X = X_{pr} - RRY(X_{pr} - X_{re})$$

MSR = Closed material loop methodology

IISI LCI data with Recycling included

Systems diagram



LCA model using aggregated data

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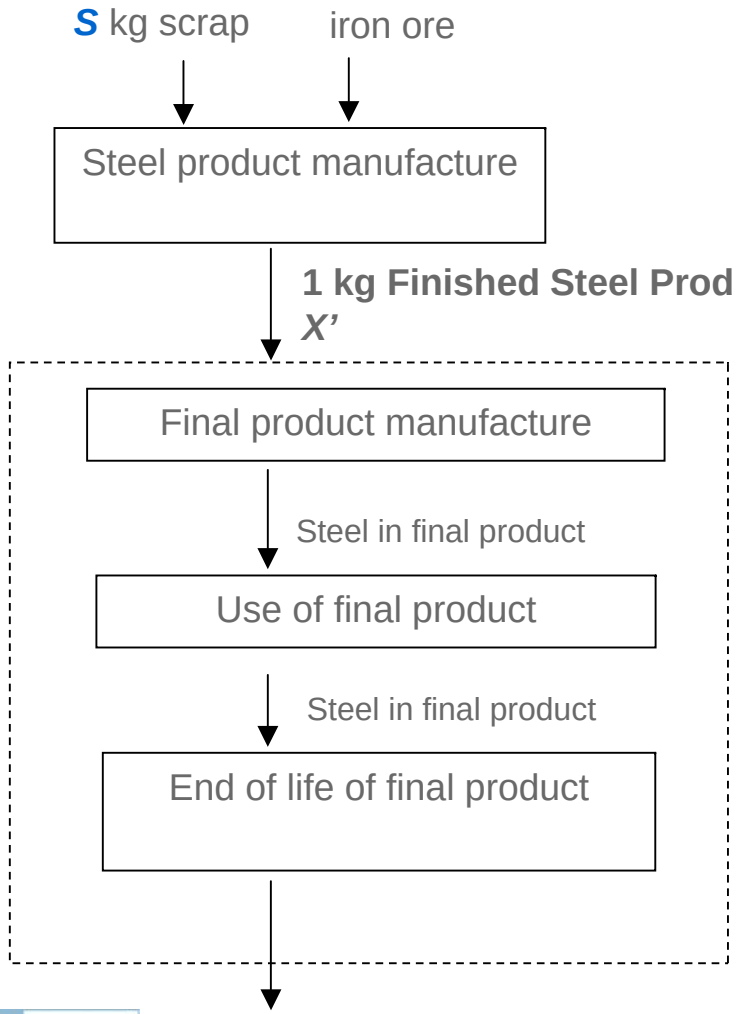
Calculation for data sheets



Net scrap produced = $RR - S$

LCI credit/debit = $(RR - S) \times Y(X_{pr}-X_{re})$

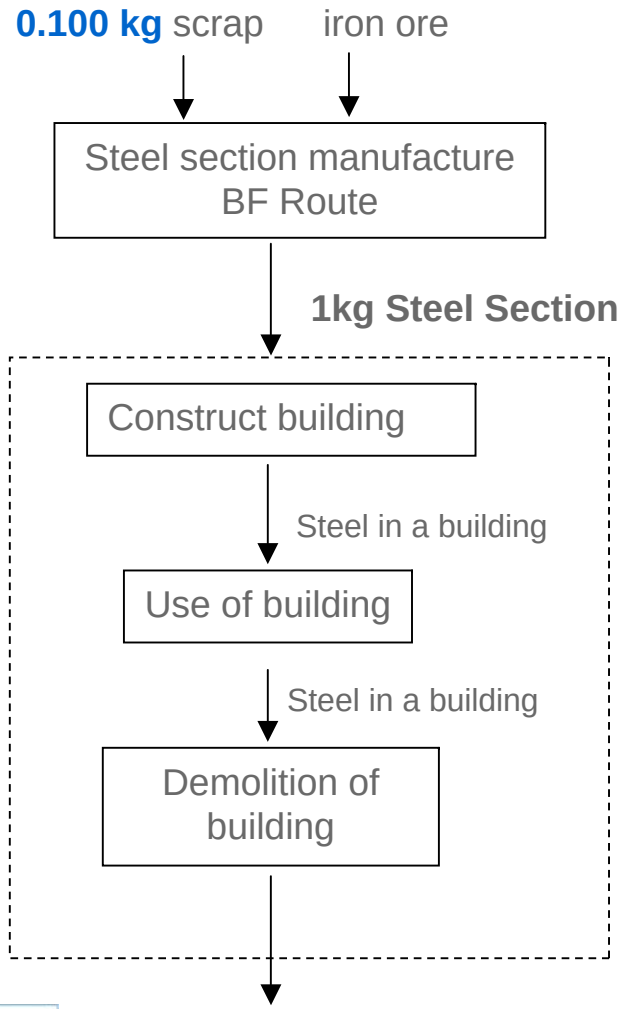
Product LCI = X'

Product LCI including recycling

$(X) = X' - [(RR - S) \times Y(X_{pr}-X_{re})]$

Example construction

Example: Construction



Recovery rate
89.6%

Net scrap produced

0.796 kg

Example: Construction

Examples of LCI flow	LCI for manufacture of 1 kg of sections via BF/BOF route without allocation for recycling (X')	net saving as a result of recycling 0.796 x $Y(X_{pr}-X_{re})$	Final product LCI for the manufacture of 1 kg of sections (X) Including recycling
Iron ore /kg	1.79	1.52	0.27
Carbon dioxide /kg	2447	1434	1012
Total Primary energy /MJ	29.0	12.9	16.1

Example: BF Sections

	World average, 1kg	**Date of data : 1999 - 2000**	
	Sector: All Sectors, Recovery Ratio: 89.6%		
	Production and end-of-life phases are included in the data. Allocation for End-of-life Recyling has been modelled accourding to the IISI recycling methodology.	**Person providing this data sheet:**	
		Name:	
		Company:	
		Person receiving this data sheet:	
		Name:	
		Company:	
		Date:	

	Major Articles*	Units	BF Sections
Inputs:	(r) Coal (in ground)	kg	0.24895265
	(r) Dolomite (CaCO3.MgCO3, in ground)	kg	0.02812997
	(r) Iron (Fe)	kg	0.26951152
	(r) Limestone (CaCO3, in ground)	kg	0.13013442
	(r) Natural Gas (in ground)	kg	0.07013371
	(r) Oil (in ground)	kg	0.0638794
	(r) Zinc (Zn)	kg	-0.00310911
	Ferrous Scrap (net)	kg	
	Water Used (total)	litre	1.2967569
Outputs:	(a) Cadmium (Cd)	g	6.6975E-05
	(a) Carbon Dioxide (CO2)	g	1012.10354
	(a) Carbon Monoxide (CO)	g	11.5434009
	(a) Chromium (Total)	g	6.466E-05
	(a) Dioxins (unspecified, as TEq)	g	-1.0958E-09
	(a) Hydrogen Chloride (HCl)	g	0.05379494

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Conclusion

Conclusions

- The only environmentally relevant way of taking recyclability into account consists in introducing the whole recycling dynamics in the model (Overall recycling rate)
- Metals are very sensitive to recycling
- Developed an Excel tool which includes recycling data
  - The tool provides LCI data in a publishable format
  - Written associated methodology with worked example
  - Capability to include scrap processing data at a future date
- How to handle data requests?

  http://www.worldsteel.org/

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