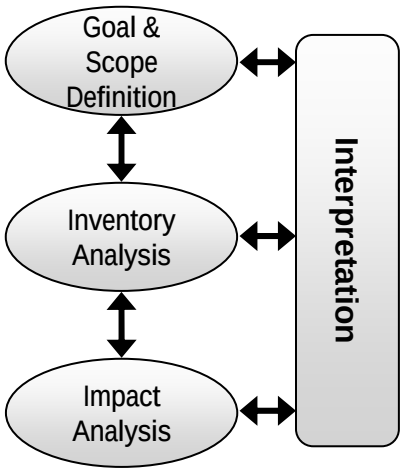
Session 3: Inventory Analysis

LCA: Methodology

- **Goal & Scope Definition**
  - **What is the unit of analysis?**
  - **What materials, processes, or products are to be considered?**
- **Inventory Analysis**
  - **Identify & quantify**
    - Energy inflows
    - Material inflows
    - Releases
- **Impact Analysis**
  - **Relating inventory to impact on world**



Inventory Analysis

- **Building a system model of the flows within your system**
  - **System boundaries and flow types defined in Goal & Scope**
  - **Typically includes only environmentally relevant flows**
    - E.g., exclude waste heat, water or O_2 emissions
- **Steps**
  - **Catalog what activities to include (draw a flowchart)**
  - **Data collection**
  - **Computation of flows per unit of analysis**
    - Serious challenges around allocation

Flowchart Examples: Intl Al Inst. 2003

2.1. Goal and Scope Definition

The intended purpose of this Inventory report is to accurately characterize resource consumption and significant environmental aspects associated with the worldwide production of primary aluminium. It reflects the fact that primary aluminium is a globally traded commodity.

Intl Al Inst. 2003

Figures removed due to copyright restrictions.

Source: Flowcharts on p. 5 and p. 15 in "Life Cycle Assessment of Aluminum: Inventory Data for the Worldwide Primary Aluminium Industry." International Aluminium Institute. March 2003.

Flowchart Examples: Intl Al Inst. 2003

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Inventory Analysis: Data collection

- **Data collection**
  - **Inflows**
    - Materials
    - Energy
  - **Outflows**
    - Primary product
    - Other products
    - Releases to land, water and air
  - **Transport**
    - Distance
    - Mode
- **Data collection (cont.)**
  - **Qualitative**
    - Description of activity under analysis
    - Geographic location
    - Timeframe
- **Key issue:**
  - **Site specific vs. Industry Avg**
- **Data sources**
  - **Scientific literature, Published studies**
  - **Industry & government records**
  - **Industry associations**
  - **Private consultants**

Calculating the Inventory

- **Identify interconnection flows**
- **Normalize data**
  - **Convert all absolute flows to a quantity relative to one outflow**
  - **Typically reference flow serves as interconnection**

    Note: Since LCAs are typically linear, choice of reference outflow is arbitrary
- **Calculate magnitude of interconnection flows**
  - **For linear system, soluble using linear algebra**
- **Scale all flows relative to interconnection flows**
- **Sum all equivalent flows**

Product Production Overview

- **Product *P* produced in plant *C***
  - ***C*: Metal sheets cut and pressed to make *P***
- **Plant *B* delivers metal sheets to plant *C***
  - ***B*: Ingots melted and rolled into sheets**
- **Ingots come from plant *A***
  - ***A*: Mineral is extracted, turned into metal, cast into ingots**

Product Production Details

- **Transport:**
  - ***A* to *B*: 1000 km, by truck**
  - ***B* to *C*: 0 km (adjacent)**
- **Scrap:**
  - **Process scrap from *C* returned to *B* for remelting**
- **Product *P*:**
  - **Weight = 40 g**
  - **6 m^2 metal sheet needed to make 1,000**
  - **Metal thickness = 1.0 mm**
  - **Metal Density = 8,000 kg/m^3**

Environmental Data – Plant A

Summary

Products	Metal ingots
Raw Material	Mineral

Inputs/Outputs

Description	Quantity	Units	Details
Total Annual Production	1200	tonnes/year	Product A
Use of raw material	4800	tonnes/year	Raw A
Use of energy in the process	6.00E+06	MJ/year	Oil Combustion
Emissions to air	600	kg/year	HCl
Emissions to water	600	kg/year	Cu
Non-hazardous solid waste	3800	tonnes/year	Solid Waste

Environmental Data – Plant B

Summary

Products	Metal Sheets
Raw Material	Metal ingots and process scrap

Inputs/Outputs

Description	Quantity	Units	Details
Total Annual Production	1600	tonnes/year	Sheets
Use of raw material - ingots	900	tonnes/year	Ingots
Use of raw material - scrap	700	tonnes/year	Scrap
Use of energy - heating	5.63E+05	kWh/year	Electricity
Use of energy - rolling	3.26E+05	kWh/year	Electricity
Emissions to air	480	kg/year	HC

Environmental Data – Plant C

Summary

Products	Consumer Product *P*
Raw Material	Metal Sheets

Inputs/Outputs

Description	Quantity	Units	Details
Total Annual Production	400	tonnes/year	Product *P*
Use of raw material	480	tonnes/year	Sheets
Use of energy - oil	3.00E+05	MJ/year	Oil
Use of energy - electricity	2.22E+05	kWh/year	Electricity
Emissions to air	250	kg/year	HC
Process Scrap for Recycling	80	tonnes/year	Scrap

Environmental Data – Transportation and Energy Production

Transportation – Diesel Fuel

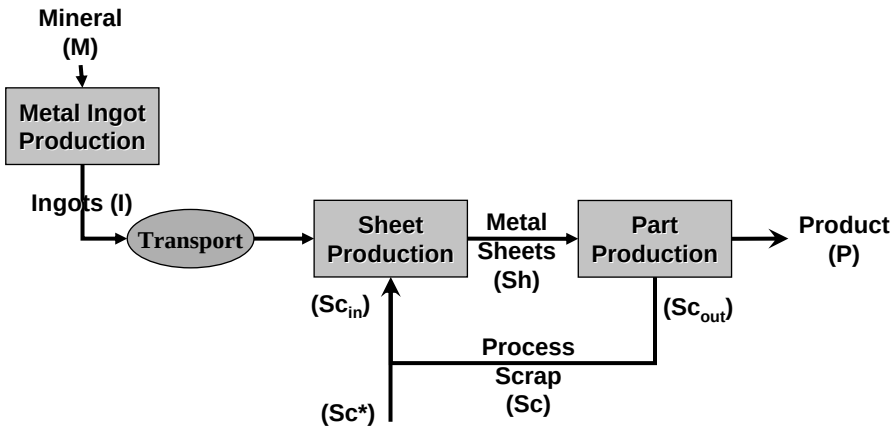
Energy

Driving Conditions	Energy Consumption	Units
Long Haul	1	MJ/tonne-km
City Traffic	2.7	MJ/tonne-km

Energy Production Emissions

Emissions (g/MJ fuel consumed)		
Substance	**Oil**	**Diesel**
HC	0.018	0.208
NOx	0.15	1.3
CO2	79.8	78.6

Flowchart of System Being Analyzed



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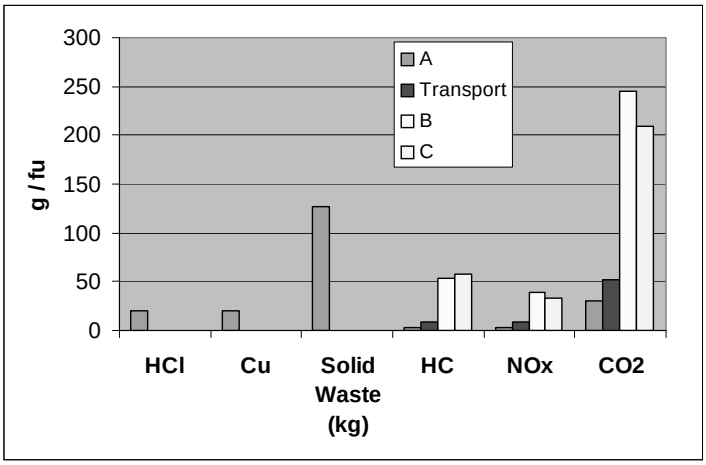
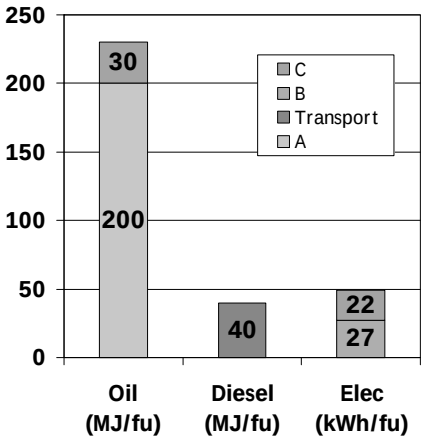
Results – Total Inventory



Results – How Much Energy?



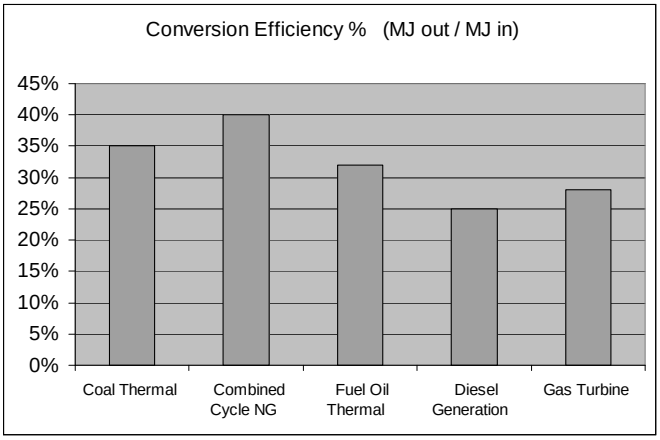
- **Totals:**
  - **Oil = 230 MJ / fu**
  - **Diesel = 40 MJ / fu**
  - **Electricity = 49 kWh/fu**
- **If electrical generation is 50% oil / 50 % Diesel, what is total energy carrier consumption?**
  - **24.5 kWh from Oil**
  - **24.5 kWh from diesel**
- **Units Conversion:**
  1 kWh = 3.6 MJ

Considering Energy from Electricity

- **Although we are consuming 49 kWh of energy, with 50% from Oil and 50% from Diesel**
- **We are NOT consuming**
  49 kWh x 3.6 MJ/kWh **= 176 MJ of energy carriers**

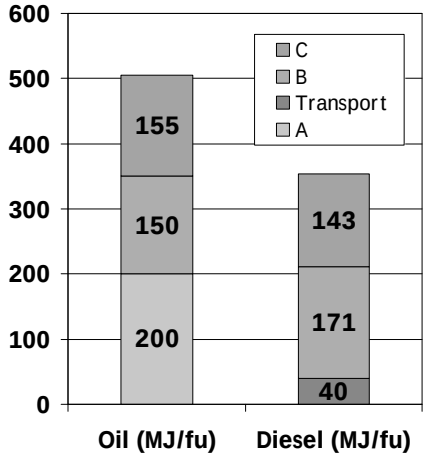
  Why?
- **Energy conversion to electricity is far from 100% efficient**

Considering Energy from Electricity



Results – How Much Energy?

Total Energy Carriers Consumed



- **Assuming a conversion efficiency of**
  - **Oil = 32%**
  - **Diesel = 28%**

Does this matter?

IAI Inventory for 1000 kg of Primary Aluminum

	Usage	Unit Energy Content	Total Energy Consumed
Coal	186 kg	32.5 MJ / kg	6,045
Diesel Oil	13 kg	48 MJ / kg	624
Heavy Oil	238 kg	42 MJ / kg	9,996
Natural Gas	308 m3	41 MJ / m3	12,628
Total Thermal		MJ	29,293

Electricity	15711 kWh	w/o efficiency (MJ)	56,560
		w/ efficiency (MJ)	171,393

Total		w/o efficiency (MJ)	85,853
		w/ efficiency (MJ)	200,686

Ignoring efficiency of electrical conversion, drastically alters energy picture!