Session 4: Inventory Allocation

Issues in Calculating an Inventory -- Allocation

Consider adding two elements to the scope of the analysis
-- Use
-- Disposal
### Environmental Data - Use

**Summary**
- **Products**: EoL products of P
- **Raw Material**: Products P

**Inputs/Outputs**

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Units</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Purchased Nationwide</td>
<td>4.00E+07</td>
<td>kg/yr</td>
<td>Product P</td>
</tr>
<tr>
<td>Annual Disposal</td>
<td>4.00E+07</td>
<td>kg/yr</td>
<td>EoL P</td>
</tr>
<tr>
<td>Emissions to air</td>
<td>1.00E+05</td>
<td>kg/yr</td>
<td>HC</td>
</tr>
</tbody>
</table>

### Environmental Data - Disposal to Landfill

**Summary**
- **Products**: Methane
- **Raw Material**: EoL products of P, MSW

**Inputs/Outputs**

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Units</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual methane</td>
<td>93</td>
<td>tonnes/yr</td>
<td>HC</td>
</tr>
<tr>
<td>Use of raw material</td>
<td>118000</td>
<td>tonnes/yr</td>
<td>Solid Waste</td>
</tr>
<tr>
<td>Emissions to air</td>
<td>93</td>
<td>tonnes/yr</td>
<td>HC</td>
</tr>
</tbody>
</table>
How Much Should be Allocated to Metal Wastes?

Actual Landfill Material Flows

- Paper/c.-Yard: 0
- Food: 11,000
- Plastics: 10,000
- Steel: 5,000
- Glass: 7,000
- Wood: 4,000
- Textiles: 3,000
- Other: 2,000
- Rubber: 1,000
- Aluminum: 855
- Other NF: 55

Total: 118,000 tonnes

Actual Landfill Material Flows
- 93 tonnes CH₄
- 119 tonnes CO₂
- 136 tonnes N₂O

How Much Should be Allocated to Metal Wastes?

Observed Landfill Emissions

(a) Net GHG Emissions from CH₄ Generation
(b) Landfills Without LFG Recovery
(c) Landfills With LFG Recovery and Flaring
(d) Landfills With LFG Recovery and Electric Generation

- Aluminum Cans: 0.00
- Plastic Cans: 0.00
- Glass: 0.00
- Conventional Cardboard: 0.46
- Magazines/Third-class Mail: 0.26


Courtesy of U.S. EPA.
Allocation Issues in Inventory Analysis

• ISO Definition:
  Inventory allocation: *Partitioning the input or output flows of a unit process to the product system under focus*

• Emerges when a process within your product system is associated with a flow that is part of another product system (i.e., another life-cycle)
  - Multi-outflow
  - Multi-inflow

Allocation Examples: Chlor-Alkali Process

[Diagram of the Chlor-Alkali Process]

Schematic of a Diaphragm or Membrane Cell

Figure by MIT OCW.
How can we handle allocation?

Addressing Allocation Approaches

- **Partitioning**: Method to apportion impacts between life-cycle under analysis and “other” flows
  - More applicable to accounting-oriented analysis

- **System expansion**: Avoiding problem by expanding scope of analysis to include “other” flows
  - More applicable to change-oriented analysis
Classic Allocation Example:
Electricity with Surplus Heat — Partitioning

% to Electricity / Ingots

% to Heat

Some Use

Generator

Coal

Anodes

Alumina

Electrolysis

Ingot Casting

Functional Unit:
1 MT of Al Ingot

Partitioning Strategies

• Technical causality
  - Established relationship between magnitude of specific flows
  - E.g., science based assessment of landfill emissions
  - Usually requires treatment of intra-process flows to a great level of detail
    - E.g., energy used only for HCl production in chlor-alkali

• Physical quantity
  - Mass
  - Volume
  - Area
  - Energy content
  - Moles

• Social causality
• Arbitrary number
  - E.g., 50/50
Allocation Examples: Chlor-Alkali Process

Schematic of a Diaphragm or Membrane Cell

Figure by MIT OCW.

Chlor-Alkali

Courtesy of Aker Kvaerner Chemetics. Used with permission.
See http://www.akerkvaerner.com/Internet/IndustriesAndServices/Pulping/BleachingChemicals/ChloralkaliProcess.htm
Classic Allocation Example: Electricity with Surplus Heat — System Expansion

Functional Unit:
1 MT of Al Ingot + 1 year of building heat

Why System Expansion?

Option A
Option B
Why System Expansion?

• At first look, system expansion seems to greatly increase the scale of the analysis

• In fact, much of the implied expanded analysis can be excluded in a comparative analysis (i.e., change-oriented assessments)

• In practice
  - Scope should include activities required for credibility
  - Must be careful that activities are the same in different scenarios

Preferred Characteristics of an Allocation Scheme (Ekvall and Tillman 98, Klöpffer 96)

• Effect-oriented (non-perverse)
  - Activities with higher impact should receive higher load of inventory

• Politically acceptable to end-users

• Applicable with available information

• Consistent

• Prevents double counting
Preferred Allocation Approach

1. System Expansion
2. Technical Causality
3. Social Causality
4. Physical Quantity
5. Arbitrary Quantity

Open-loop Recycling:
A common allocation challenge
Open-loop Recycling:
A common allocation challenge

If the functional unit is 1 unit of Part A, we have a co-product of R1. How to allocate?
Let’s try system expansion...

How do we allocate across Parts A, B, or C?

Approaches to Open-Loop Allocations

- Cut-off method
  - Only loads directly caused by a product are assigned to that product
  - No data from outside of life-cycle are required
- Loss of Quality
  - Allocated according to “quality” of material used
- Closed-loop Approximation
  - All activities are part of a general materials system
  - Allocation across products could follow any partitioning strategy
    - Social causality, Mass
- 50/50 Approximation
  - Initial and terminal life-cycles share virgin production and disposal
  - Recycled life-cycles share recycling burden
Common Open-Loop Recycling Method

- System expansion approximation
  - Compared against lack of recycling (or another disposal option)
  - Typically only one generation
  - Easily extensible to multiple generations, but requires data
  - Leads to credits given to inventory

- Very widely applied
- Implicitly gives significant credit to primary production for making recyclable resources available (Newell & Field 98)
- In practice, often does not preserve additivity
- Generally, should be reserved for comparative assessments (change oriented LCA)

System Expansion Approximation

**With Recycling**

- Extraction \((V_1)\)
- Production Part A
- Recycling 1
- Production Part B
- Use Part A
- More

**Without Recycling**

- Extraction \((V_2)\)
- Production Part A
- Production Part B
- Use Part A
- Use Part B
- Disposal 1
- Less
Preferred Allocation Approach

1. System Expansion
2. Technical Causality
3. Social Causality
4. Physical Quantity
5. Arbitrary Quantity