ERC Teleseminar

A Review of LCA Data Availability

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Outline

- **LCA White Paper (2001, Doc# 02014238A-TR)**
  - SEMATECH's Activity to Date: Mass / Energy Balance, CARRI, etc.
  - Tool Supplier's Initiative
  - Agere Systems' Approach
- **Review of LCA data availability (2002, Doc# 03014371A-TR)**
  - Databases searched
  - Findings

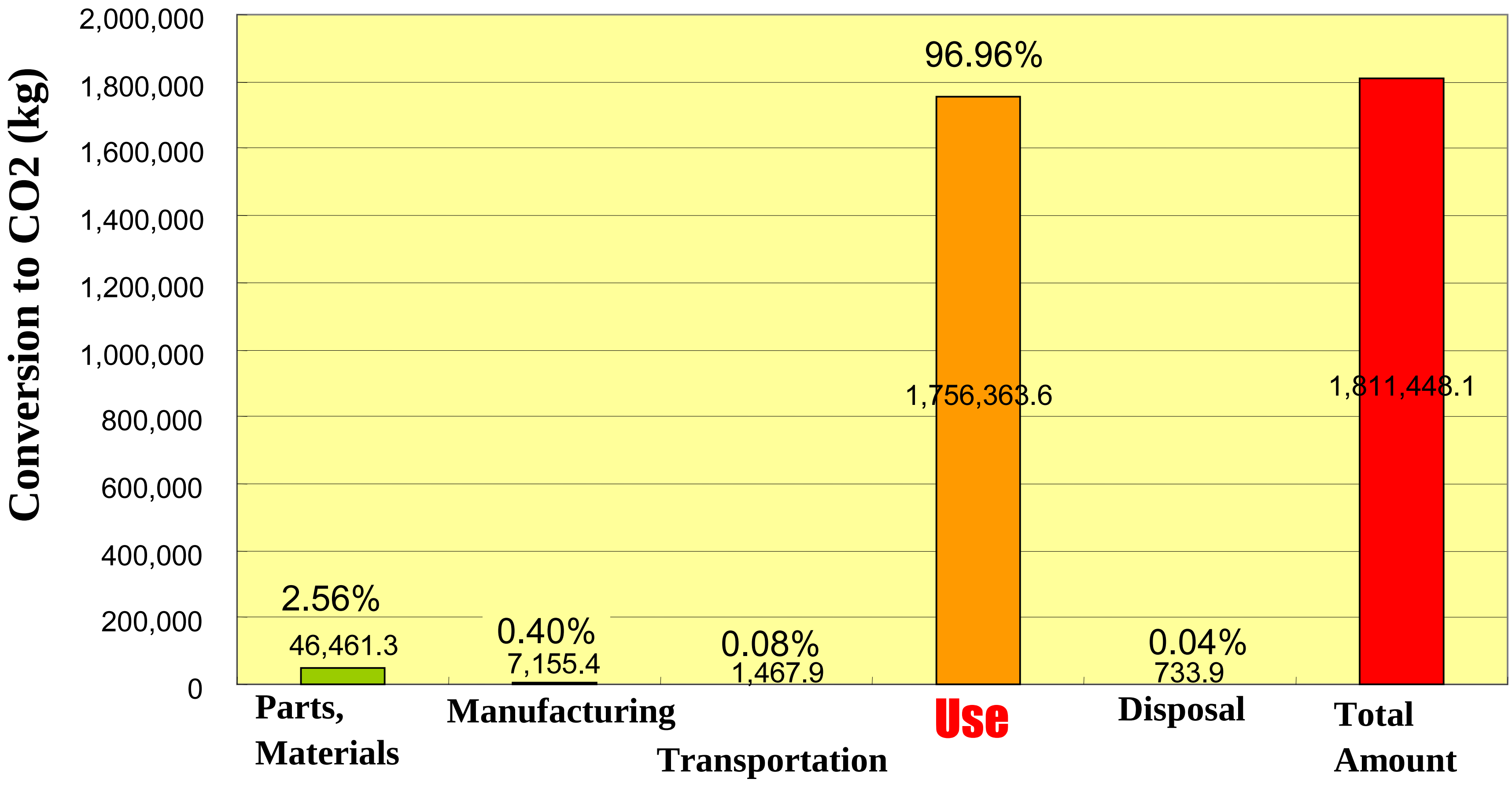
Motivation for LCA

- Increasing interest in LCA information
  - Customers are asking for such information
  - Want to know if product is environmentally sustainable
  - One of the goals of the ITRS
- Concerns/Difficulties
  - What do we mean by LCA?
  - General impression: LCA costs too much money and takes too long.

TEL LCA Result for Coater/Developer

Life Cycle Assessment Result of Coater/Developer (Global Warming Aspect)

For global warming consideration, CO_2 conversion is an index.



Courtesy of Tokyo Electron Ltd

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SEMATECH LCA White Paper

(Doc# 02014238A-TR, www.sematech.org/public/docubase/abstracts/4238atr.htm)

1. Literary search of case studies and associated software packages
2. Review of related SEMATECH reports:
   - CARRI
   - ESH Cost Model
   - Mass / Energy Balance
3. AMAT, EnV-S (Environmental Value System)
4. Lucent / Agere / NJIT Target Method
5. UT / Use-Cluster Inventory
6. Review of IC and non-IC case studies
7. Identification of commercial software packages

Environmental Value Systems (EnV-S) Analysis for Semiconductor Manufacturing

by

N.Krishnan, S.Thurwachter and P.Sheng

University of California, Berkeley

T. Francis (formerly with Applied Materials, Inc)

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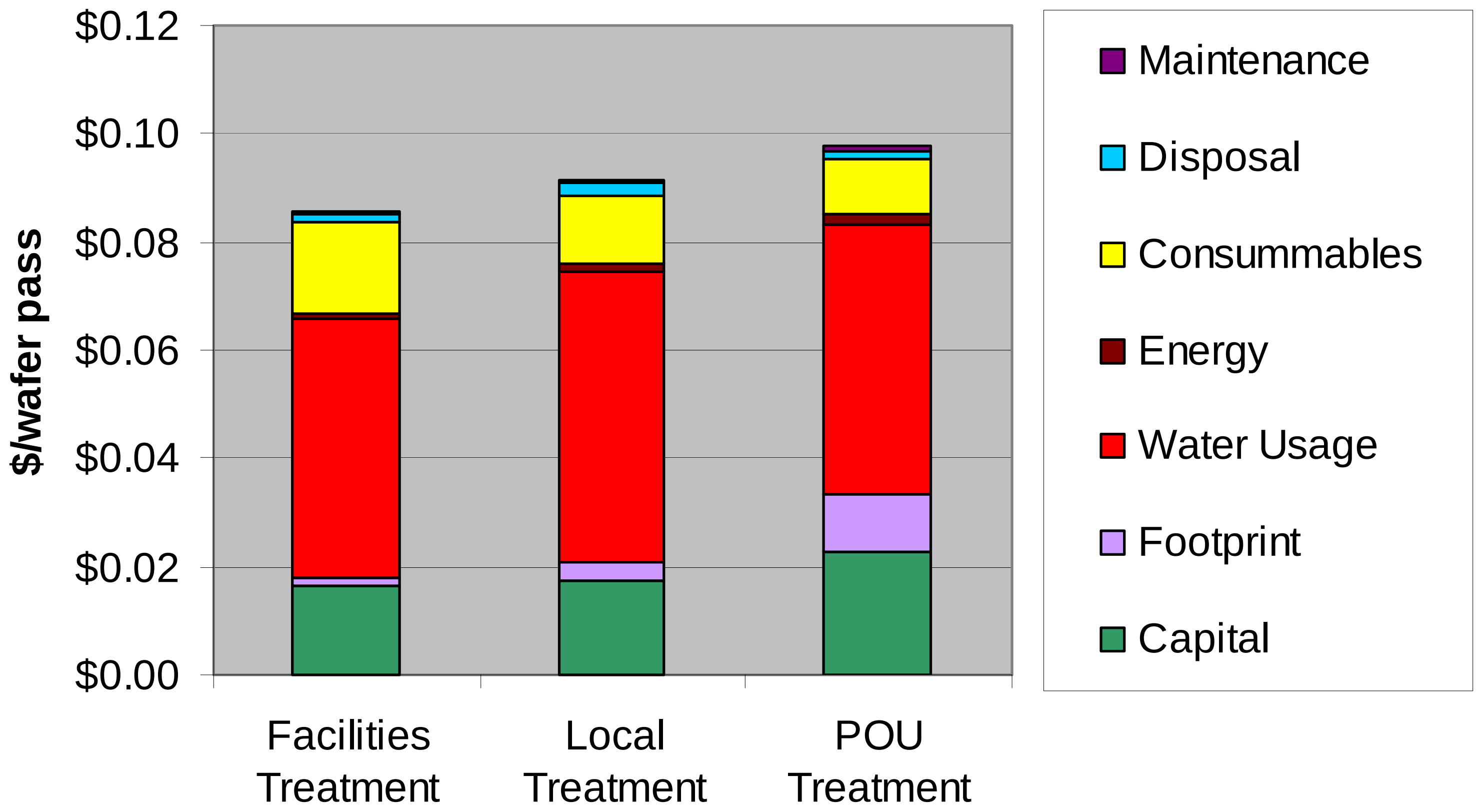
Case Studies for AMAT's EnV-S

- **Cu CMP**
  - Analysis of three alternative treatment strategies
  - Sensitivity analysis of the three strategies
  - Modified decision and strategic components in the EnV-S
- **PECVD Platform: the Centura RF C_2F_6 v.s. the Producer NF_3**

Comparison of CMP Wastewater Treatment Systems



- Water usage costs are approximately the same for all three systems
- Capital and footprint costs make POU more expensive

Courtesy of AMAT/UC-Berkley

“Target Method”

by

Agere Systems

NJIT MERC

Lucent Technologies, Bell Labs

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Target Method - Universal Environmental Metric

- **Environmental Impact**
  Quantifies environmental impact as a single number
  EI = Sum of A / A_R (A = Aspect Levels)

- **Resource Productivity**
  Production rate achieved per unit of environmental impact
  RP = P / EI (P = Production Rate)

- **Eco-Efficiency**
  Ratio of a firm's actual to sustainable value
  EE = ß / EI (ß = V / V_R)

- **Sustainability**
  Value generated is sufficient for the level of impact
  (EE is equal to or greater than one)

Courtesy of Agere Systems

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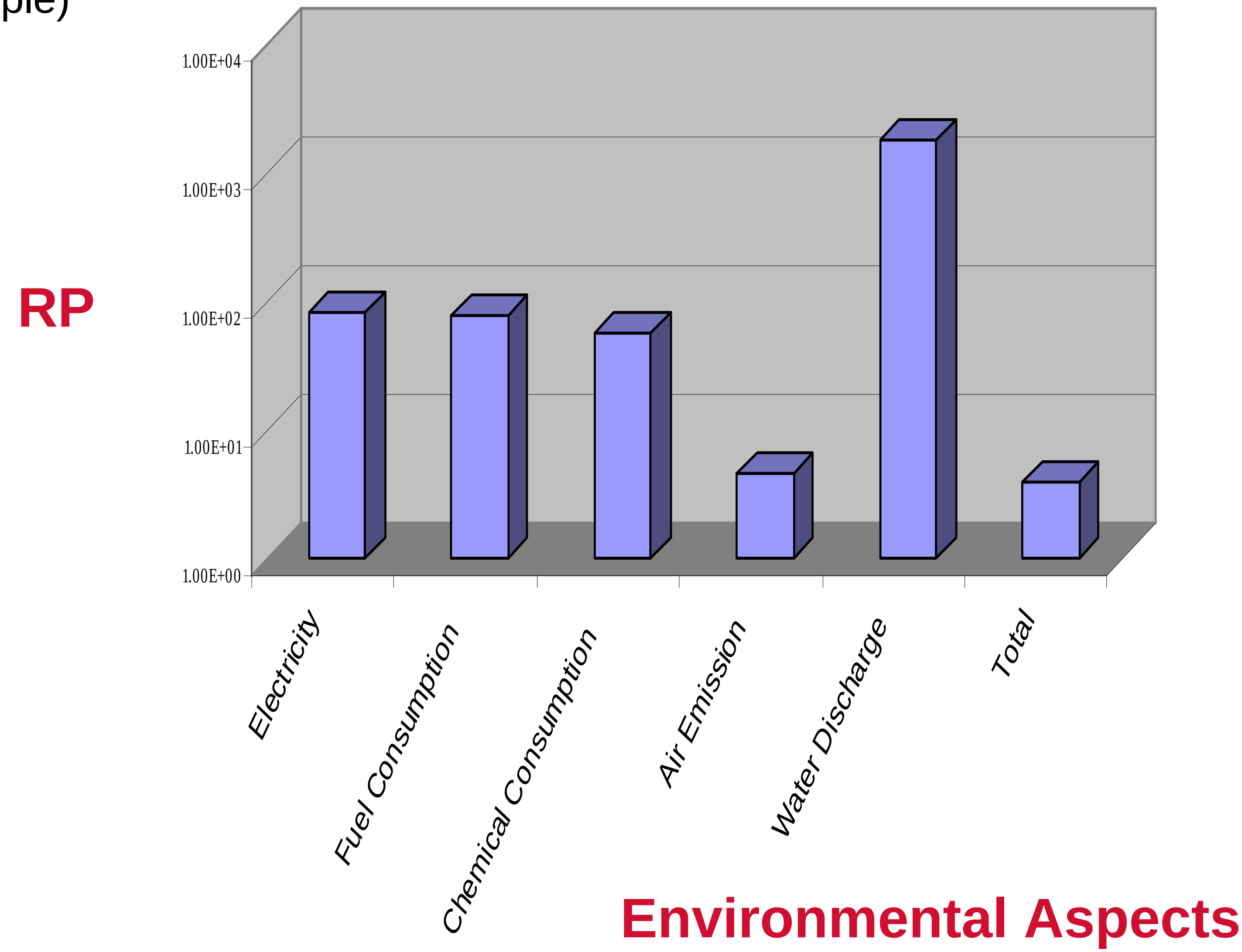
Resource Productivity (RP) vs. Environmental Aspects

(Example)



Courtesy of Agere Systems

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Case Studies from Semiconductor Industry

Company	Evaluation of	Inventory	Impact	Improve-ment	Methodology	Date
Applied Materials, NSF/SRC, Berkeley	Semi-conductor process	X	X	X	Environmental Value Systems (EnV-S) Analysis	2000
Applied Materials	Semi-conductor process				Environmental Analysis Software (EnV)	2000
Motorola, Fraunhofer IZM	Semi-conductor wafer	X	X		ProTox and GaBi 3.2	2001
Telecom Italia Lab S.p.a., STMicroelectronics	EPROM chip	X			TEAM, Boustead Model, EIME, and several ad hoc LCA "modules"	2001

Member Company Interview Feedback August 2001

- **Comments/Concerns**
  - **Need more semiconductor-specific inventory**
  - **Impact assessment not scientific enough**
  - **LCA takes too much time and money**
  - **Benefit of LCA in $ saved is not clear**
  - **Want a "fast" methodology**
  - **Be able to look at "future" and "current", not past**
  - **Need to look at Safety and Health impacts in addition to Environment**

SEMATECH LCA Project - 2002

- **Objective**
  - Improve inventory database by identifying gaps
  - Establish a data collection methodology
- **Approach**
  - Identify “Top X” chemical list for study
  - Review existing LCA databases to identify data gaps
    - Limited investigation to NINE databases due to budget constraints
  - Recommended data collection methodology for life cycle inventory

Criteria for “Top 20 List” Selection
(based on member company input)

- The Member Companies were free to choose their own selection criteria and here are examples of what they used:
  - Critical to the manufacturing process
  - High volume/consumption/usage
  - Combination of: cost (25%), consumption (25%) and ESH impact (50%)

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"Top 20 List"

Name	CAS#	votes
Sulfuric Acid	7664-93-9	9
Isopropyl Alcohol	67-63-0	9
Phosphoric Acid	7664-38-2	8
HCl	7647-01-0	8
Tetramethyl ammonium hydroxide	75-59-2	7
Nitric Acid	7697-37-2	7
HF	7664-39-3	7
Ozone	10028-15-6	7
H2O2	7722-84-1	6

"Top 20 List" (cont'd)

Name	CAS#	votes
N-Methyl Pyrrolidone	872-50-4	5
NF3	7783-54-2	5
Ammonium Fluoride	12125-01-8	5
Ammonium Hydroxide	1336-21-6	5
Butylacetate	123-86-4	5
Ethyl Lactate	97-64-3	4
Hexamethyl disilazane	999-97-3	4
Silica, Amorphous	112945-52-5	4
NaOH	1310-73-2	4
Propylene Glycol Monomethyl Ether Ac	108-65-6	4
Acetic Acid	64-19-7	4

“Top 20 List” (cont’d)

Name	CAS#	vote
water	7732-18-5	3
Photo Resists		3
Energy		3
Ethanolamine	141-43-5	3
Acetone	67-64-1	3
Ethylene Glycol	107-21-1	3
Ammonia	7664-41-7	3
Hexafluoroethane	76-16-4	3

Below "Top 20 List"

Name	CAS#	votes
CMP slurry		2
KOH	1310-58-3	2
SF6	2551-62-4	2
Carbon tetrafluoride	75-73-0	2
PFC's		2
Lead	7439-92-1	2
N-methylethanolamine	109-83-1	2
N2O	10024-97-2	2
TEOS	78-10-4	2
WF6	7783-82-6	2
SiC	409-21-2	2

Candidates Finally Selected for Gap Analysis

1. **Tetramethyl ammonium hydroxide, CAS# 75-59-2**
2. **N-methyl pyrrolidone, CAS# 872-50-4**
3. **NF3, CAS# 7783-54-2**
4. **Hexamethyl disilazane, CAS# 999-97-3**
5. **One major photoresist which uses ethyl lactate as the primary solvent**
6. **sulfuric acid, CAS# 7664-93-9**

Inventory Databases

- **(1st) SimaPro**
  - BUWAL 250 (Swiss Ministry of the Environment)
  - Industry Data
  - Franklin USA 98
  - ETH-ESU 96
  - IDEMAT 2001
  - Archive Data

Inventory Databases (cont'd)

- **(2nd) EIME (Ecobilan Group)**
  - **TEAM/DEAM** is recommended by Ecobilan instead
- **(3rd) U.S.EPA.**
  - **TRACI (Tool for the Reduction and Assessment of Chemical and other Environmental Impacts)**
  - **Integrated Risk Information System (IRIS)**
  - **Health Effects Assessment Summary Tables (HEAST)**
  - **SCORECARD**
  - **Observation: Only TRACI is an LCI database, the other three contain information that can be used as input to develop LCI, but are not directly useful for LCI purposes**

Inventory Databases (cont'd)

- **AIChE (American Institute of Chemical Engineers)**
  - **DIPPR (Design Institute for Physical Properties) program, which determines and lists physical properties of chemicals, not directly related to LCI**
- **GaBi: includes production inventory and material impact of H2SO4**
- **No response from Boustead**
- **EIO-LCA (Economic Input Output-LCA)**
  - **Does not tract assessment data for individual chemicals**
  - **Rather at the industry sector level (aggregated nature of the model)**

Inventory Definitions

- Production Inventory
  - Environmental aspects and/or impacts resulting from the manufacture of the chemical
- Material Impacts
  - Impacts resulting from the chemical itself if freely present in the environment
- Both are quantified per unit mass of the chemical, i.e., impact per Kg of chemical

Impact Dimensions

Impact Dimensions (per kg Chemical)		
GW	kg CO_2 eq	Global Warming
OD	kg R11 eq	Ozone Depletion
Acidif.	kg SO_2 eq	Acidification
Eutroph,	kg PO_4 eq	Eutrophication
H.Metals	kg Pb eq	Heavy Metals
Carcin.	kg B(a)P eq	Carcinogens
W.Smog	kg SPM	Winter Smog
S.Smog	kg C_2H_4 eq	Summer Smog

Production Inventory for H_2SO_4

	Production Inventory		
Chemical:	**Sulfuric Acid**		
Data:	BUWAL	IDEMAT	ETH
Inventory:	69	11	239
	Impacts		
Global W.	8.97E-02	3.53E-03	2.39E-01
Ozone D.	1.01E-07	0	8.10E-08
Acidif.	2.63E-02	1.09E-02	6.37E-03
Eutroph.	1.60E-04	1.36E-05	5.35E-05
H.Metals	1.92E-06	0	1.10E-06
Carcin.	4.21E-09	0	1.18E-08
W. Smog	2.54E-02	1.08E-02	6.11E-03
S. Smog	8.89E-05	1.74E-09	5.65E-05
Aggreg.	**4**	**1.5**	**1**

Material Impacts for Four Chemicals

	Material Impacts			
Chemical:	**Sulf.Acid**	Eth. Lac.	**NF_3**	**NMP**
Data:	Calc.[1]	TRACI	TRACI	TRACI
Inventory:	--	--	--	--
	Impacts			
Global W.			1.08E+04	
Ozone D.				
Acidif.	6.53E-01			
Eutroph.				
H.Metals				
Carcin.				
W. Smog				
S. Smog		2.79E-01		2.79E-01
Aggreg.	**92**	**39**	**2070**	**39**

Production vs Material Impacts for H_2SO_4

	Production Inventory			Material Impact
Chemical	Sulfuric Acid			Sulf.Acid
Data	BUWAL	IDEMAT	ETH	Calc.[1]
Inventory	69	11	239	--
	Impacts			Impacts
Global W.	8.97E-02	3.53E-03	2.39E-01	
Ozone D.	1.01E-07	0	8.10E-08	
Acidif.	2.63E-02	1.09E-02	6.37E-03	6.53E-01
Eutroph.	1.60E-04	1.36E-05	5.35E-05	
H.Metals	1.92E-06	0	1.10E-06	
Carcin.	4.21E-09	0	1.18E-08	
W. Smog	2.54E-02	1.08E-02	6.11E-03	
S. Smog	8.89E-05	1.74E-09	5.65E-05	
Aggreg.	**4**	**1.5**	**1**	**92**

Major Conclusions from GAP Analysis

- **Production inventory**
  - Numerical value depends on database used
  - For H_2SO_4, aggregated values varied by 400%
  - For five other chemicals very little data was found
- **Material Impact Data**
  - Again, very little data found for the six chemicals chosen
  - Even for H_2S0_4, little data was available
  - In case of H_2SO_4, the material impact was almost 100X the production impact

Suggested Methodology for LCA Data Collection

1. **Use of existing sources such as LCA databases for the specific chemicals of interest**
2. **Identification of chemically similar materials for which data is available**
3. **Identification of primary chemical ingredients and synthesis processes for which data is available**
4. **Communication with chemical manufacturers to supplement such information**
5. **Use of published data for related generic supply line processes such as packaging and transportation**

Chemical Substitutes and Process Ingredients

CHEMICAL	SUBSTITUTES	Data Source	INGREDIENTS	Data Source
Sulfuric Acid	Sulfur Dioxide	1, 3	Sulfur Dioxide	1, 3
			Nitric Acid	2, 3
Ethyl Lactate	Ethanol	--	Ethanol	--
	Methanol	3	Lactic Acid	--
NF3	Ammonia	1, 2, 3	Ammonia	1, 2, 3
			Fluorine	3
			HF	2, 3
Data Sources: 1. BUWAL 2. ETH-ESU 3. DEAM				

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