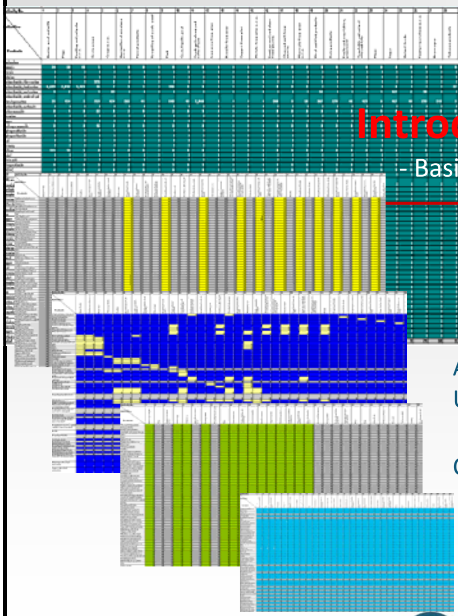

Introduction to IO-modelling

- Basic LCA-modelling, SUT, MFA, tradelinking

Jannick H Schmidt

Aalborg 4th September 2013

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CEO, 2.-0 LCA consultants

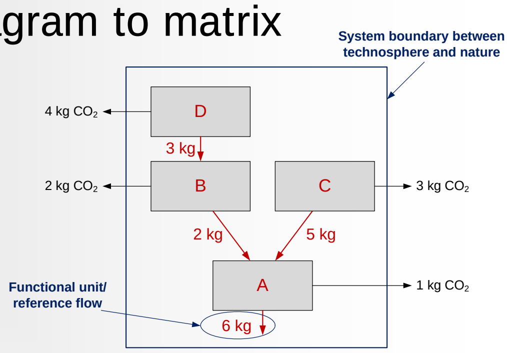
Content of the lecture

Now

- Analogy between flow charts and matrix representation of LCI
- LCA calculus
- Process LCA and IO-LCA
- Uses of IO-LCA
- Derivation of supply-use tables and IO-table
- Trade-linking
- Supply use data and Mass flow analysis
- Hybrid LCA

From product flow diagram to matrix
- no co-products

Process	A	B	C	D
Output	6	2	5	3
Inputs				
A				
B	2			
C	5			
D		3		
Emissions				
CO_2	1	2	3	4



Normalised

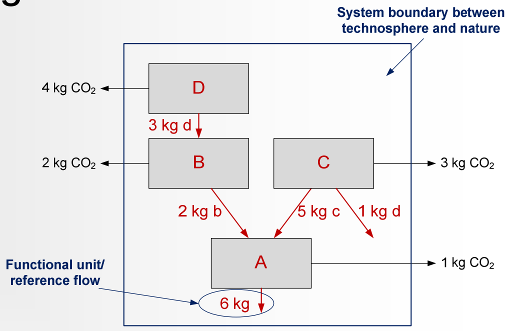
Process	A	B	C	D
Output	1	1	1	1
Inputs				
A				
B	0.33			
C	0.83			
D		1.50		
Emissions				
CO_2	0.17	1.00	0.60	1.33

Direct requirement coefficient matrix

$$\leftarrow \tilde{\mathbf{Z}}$$

From product flow diagram to matrix
- with co-products

Process	A	B	C	D
Outputs				
A	6			
B		2		
C			5	
D			1	3
Inputs				
A				
B	2			
C	5			
D		3		
Emissions				
CO_2	1	2	3	4



Direct requirement coefficient matrix depends on allocation/system expansion

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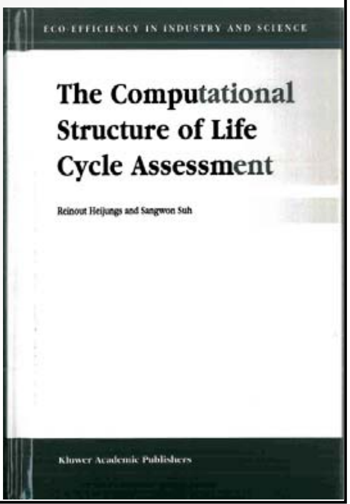
The very basics of IO-LCA

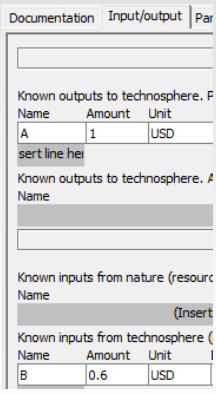
The inventory problem:

- Sector A) 1 USD A, uses 0.6 USD B
- Sector B) 1 USD B, uses 0.39 USD A
- I want to analyse 1 USD B – how much of sector A and B is needed?
- Solution: Use an LCA software

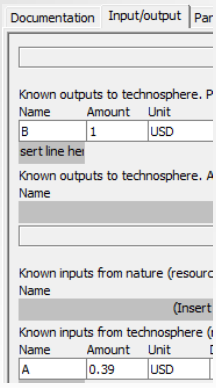


LCA software: SimaPro

Sector A: A



Sector B: B



1 USD B: Result in SimaPro

Process	Unit	B
A	USD	0.50914
B	USD	1.3055

What is the underlying calculation?

- Convention: **Output** = positive values, and **input** = negative values
- Our inventory problem: two equations with two unknowns:

$$\begin{array}{ccccc} \text{Sector A:} & & \text{Sector B:} & & \text{Demand} \\ \begin{matrix} 1\,\text{USD A} \\ -0.6\,\text{USD B} \end{matrix} & \begin{matrix} \times \boxed{s_1} + \\ \times \boxed{s_1} + \end{matrix} & \begin{matrix} -0.39\,\text{USD A} \\ 1\,\text{USD B} \end{matrix} & \begin{matrix} \times \boxed{s_2} \\ \times \boxed{s_2} \end{matrix} = & \begin{matrix} 0\,\text{USD A} \\ 1\,\text{USD B} \end{matrix} \end{array}$$

Scaling factors

Solve equation:

↓

http://www.bluebit.gr/matrix-calculator/

↓

$$s_1 = 0.51 \text{ and } s_2 = 1.3$$

Let's formalise the notion...

$$\underbrace{\begin{matrix} 1\,\text{USD A} \times s_1 + -0.39\,\text{USD A} \times s_2 \\ -0.6\,\text{USD B} \times s_1 + 1\,\text{USD B} \times s_2 \end{matrix}}_{\downarrow} = \underbrace{\begin{matrix} 0\,\text{USD A} \\ 1\,\text{USD B} \end{matrix}}_{\downarrow}$$

Technology matrix (**A**) Final demand vector (**f**)

$$\mathbf{A} = \begin{bmatrix} 1\,\text{USD A} & -0.39\,\text{USD A} \\ -0.61\,\text{USD B} & 1\,\text{USD B} \end{bmatrix} \qquad \mathbf{f} = \begin{bmatrix} 0\,\text{USD A} \\ 1\,\text{USD B} \end{bmatrix}$$

$$\begin{matrix} a_{11} \times s_1 + a_{12} \times s_2 \\ a_{21} \times s_1 + a_{22} \times s_2 \end{matrix} = \begin{matrix} f_1 \\ f_2 \end{matrix}$$

$$\mathbf{As} = \mathbf{f}$$

$$\boxed{\mathbf{s} = \mathbf{A}^{-1}\mathbf{f}}$$

$$\mathbf{s} = \mathbf{A}^{-1}\mathbf{f} \Rightarrow$$

$$\mathbf{s} = \begin{bmatrix} 1\,\text{USD A} & -0.39\,\text{USD A} \\ -0.6\,\text{USD B} & 1\,\text{USD B} \end{bmatrix}^{-1} \begin{bmatrix} 0\,\text{USD A} \\ 1\,\text{USD B} \end{bmatrix} \Rightarrow$$

$$\mathbf{s} = \begin{bmatrix} 1.3 & 0.51 \\ 0.78 & 1.3 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} \Rightarrow$$

$$\mathbf{s} = \begin{bmatrix} 0.51 \\ 1.3 \end{bmatrix}$$

Emissions

Emissions matrix (**B**)

$$\mathbf{B} = \begin{array}{cc} \text{Sector A} & \text{Sector B} \\ \left[\begin{matrix} 0\,\text{kg}\,CO_2 \\ 0\,\text{kg}\,SO_2 \\ 4.0\text{E}-11\,\text{kg arsenic, ion} \end{matrix}\right. & \left.\begin{matrix} 0.85\,\text{kg}\,CO_2 \\ 0.0012\,\text{kg}\,SO_2 \\ 0\,\text{kg arsenic, ion} \end{matrix}\right] \end{array}$$

Resulting emissions (**g**)

$$\begin{cases} 0\,\text{kg}\,CO_2 \times s_1 + 0.85\,\text{kg}\,CO_2 \times s_2 = g_1 \\ 0\,\text{kg}\,SO_2 \times s_1 + 0.0012\,\text{kg}\,SO_2 \times s_2 = g_2 \Rightarrow \\ 4.0\text{E-}11\,\text{kg arsenic, ion} \times s_1 + 0\,\text{kg arsenic, ion} \times s_2 = g_3 \end{cases}$$

$$g_1 = 1.1\,\text{kg}\,CO_2$$
$$g_2 = 0.0016\,\text{kg}\,SO_2$$
$$g_3 = 2.0\text{E-}11\,\text{kg arsenic, ion}$$

Formalised formula

$$\boxed{\mathbf{g} = \mathbf{Bs} = \mathbf{B}\left(\mathbf{A}^{-1}\mathbf{f}\right)}$$

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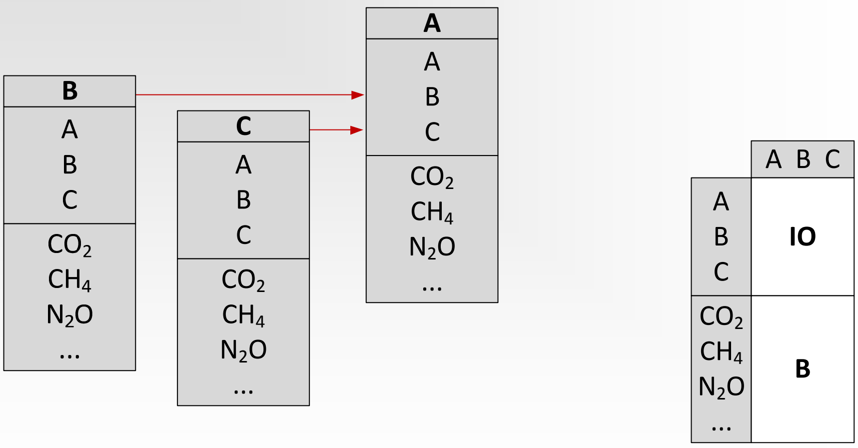
Process LCA and Input-Output LCA



Process LCA and Input-Output LCA

- In process LCA we have the technology matrix (**A**)

$$\mathbf{A} = \begin{bmatrix} 1\,\text{kg coal} & -0.39\,\text{kg coal} \\ -0.6\,\text{kWh elec.} & 1\,\text{kWh elec.} \end{bmatrix}$$

- In Input-Output LCA we have an IO-table
  - also called coefficient transaction matrix ($\tilde{\mathbf{Z}}$)
  - $\tilde{\mathbf{Z}}$ specifies the input per unit of output

$$\tilde{\mathbf{Z}} = \begin{bmatrix} 0\,\text{kg coal/kg coal} & 0.39\,\text{kg coal/kWh elec.} \\ 0.6\,\text{kWh elec./kg coal} & 0\,\text{kWh elec./kWh elec.} \end{bmatrix}$$

- If **A** has only ones on the diagonal (normalised), then:

$$\tilde{\mathbf{Z}} = \mathbf{I} - \mathbf{A}$$

- For IO-LCA we now have:

Format in process LCA	$\mathbf{s} = \mathbf{A}^{-1}\mathbf{f}$	$\mathbf{g} = \mathbf{B}\mathbf{s} = \mathbf{B}(\mathbf{A}^{-1}\mathbf{f})$
Format in IO LCA	$\mathbf{s} = (\mathbf{I} - \tilde{\mathbf{Z}})^{-1}\mathbf{f}$	$\mathbf{g} = \mathbf{B}(\mathbf{I} - \tilde{\mathbf{Z}})^{-1}\mathbf{f}$

Input-Output LCA: Units of the IO-table

- Units of the coefficient transaction matrix ($\tilde{\mathbf{Z}}$)
  - Typically monetary units, e.g.

$$\tilde{\mathbf{Z}} = \begin{bmatrix} 0\,\$/\$ & 0.1\,\$/\$ \\ 0.5\,\$/\$ & 0\,\$/\$ \end{bmatrix}$$

- If different units: Hybrid unit IO-model
  - Example where coal is in physical units:

$$\tilde{\mathbf{Z}} = \begin{bmatrix} 0\,\text{kg coal/kg coal} & 0.1\,\text{kg coal/\$ elec.} \\ 0.5\,\text{\$ elec./kg coal} & 0\,\text{\$ elec./\$ elec.} \end{bmatrix}$$

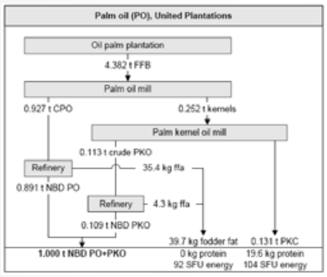
- $\tilde{\mathbf{Z}}_{\text{monetary}}$ and $\tilde{\mathbf{Z}}_{\text{physical}}$ are related via prices, e.g. USD/kg coal

$$\mathbf{P} = \begin{bmatrix} 0.081\,\text{\$/kg coal} & 0.081\,\text{\$/kg coal} \\ 0.070\,\text{\$/kWh elec.} & 0.070\,\text{\$/kWh elec.} \end{bmatrix}$$

$$\tilde{\mathbf{Z}}_{\text{monetary}} = \tilde{\mathbf{Z}}_{\text{physical}} \;.*\; \mathbf{P}$$

Process LCA versus IO-LCA

- So far: IO-LCA = process-LCA
- What is the difference?
  - IO-LCA: $\tilde{\mathbf{Z}}$
  - Process-LCA: **A**



- How do we derive **A** in process LCA?
  - Follow physical flows in process-diagram
  - Buttom-up approach
- How do we derive $\tilde{\mathbf{Z}}$ in IO-LCA?
  - Using information provided by statistical agencies: National accounts (supply and use tables)
  - Top-down approach
- Difference = the way **A** and $\tilde{\mathbf{Z}}$ are derived

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Process LCA versus IO-LCA – Data sources

- Process data (bottom-up)
  - Enterprise green accounts / direct data collection
  - Emission inventories
  - Technical handbooks and risk assessment estimates
  - Industry LCA databases
  - Commercial LCA databases

Detail

- Input-Output data (top-down)
  - Statistical agencies (based on industry data)
  - National projects to complete the emissions data

Completeness

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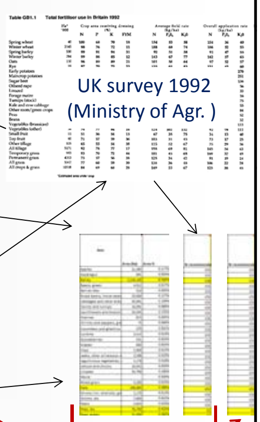
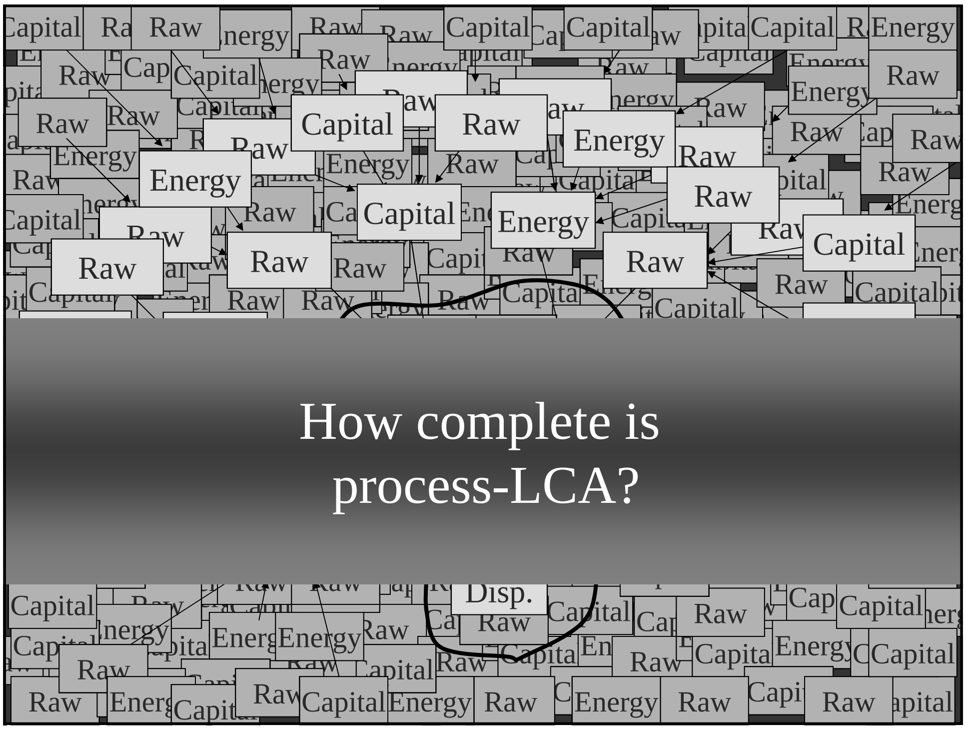
Bottom-up versus Top-down inventory:
- Example – LCI of crop production; focus on fertiliser use

- Advantages of the SUT and top-down approach:
  - Balanced modeling (total supply is used) => process LCA os only balanced at the process level (only clca), but IO is also balanced at the product level
  - Completeness

Bottom-up versus Top-down inventory:
- Example – LCI of crop production; focus on fertiliser use

- Bottom-up approach (most often used in process LCA)
  - Data collection unit: 1 ha yr of e.g. wheat in UK in 1990
  - Fertiliser per ha yr: Ministry of Agr. => 188 kg N/ha yr
- Top-down approach (used in process LCA)
  - Data collection unit: All agricultural land in UK in 1990
  - Area, all crops: FAOSTAT =>
  - Total land: FAOSTAT => Arable 6.62 Mn ha
    Pastures 11.5 Mn ha
  - Fertiliser UK: IFA => Mineral 1.52 Mn t N
    Calc => Manure 1.55 Mn t N
  - Distribution key: Fertiliser/ha yr per crop
  - Fertiliser per ha yr, all crops:
  - Fertiliser, wheat: 223 kg N/ha yr





How complete is process-LCA?

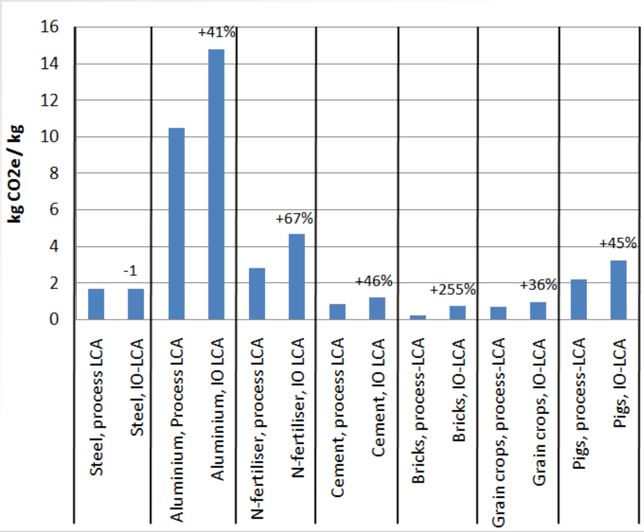
Process LCA versus IO-LCA

- IO-LCA: No cut-off
- Automatical inclusion of 'hard to quantify' inputs:
  - Accounting, marketing, use of postal services, banking services
  - Business travelling
  - Office machinery, printing paper, pencils, furniture etc.
  - Capital goods (buildings, machinery)

Process LCA versus IO-LCA – Results

Process-data:
Ecoinvent and LCAfood

IO-data:
Swedish IO-table
(FORWAST project)



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Uses of IO-LCA

- What can IO-LCA be used for?
  - Short-cut to screening LCAs
  - ... And maybe better than detailed LCAs???
  - Corporate footprinting
  - Provide inputs to process LCA => increase completeness (hybrid LCA)
  - LCA of nations/regions/municipalities: production and consumption
  - LCA of international trade

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Derivation of the IO-table

- How is $\tilde{\mathbf{Z}}$ derived?
- Supply (**V'**) and use (**U**) tables

Monetary supply table	Activities (a)	Import	Total
Products (c)	$\mathbf{V'_o}$	$\mathbf{N_c}$	**q**
Total	**g'**		

Final demand

Investments

Monetary use table	Activities (a)	Final uses			Total
Products (c)	$\mathbf{U_o}$	$\mathbf{y_0}$	Capital formation	$\mathbf{E_c}$	**q**
Primary inputs	Labour				
	Taxes				
	Use of fixed capital				
	Profit				
Total	**g'**				

Export

GDP

Emissions	**B**

Derivation of the IO-table

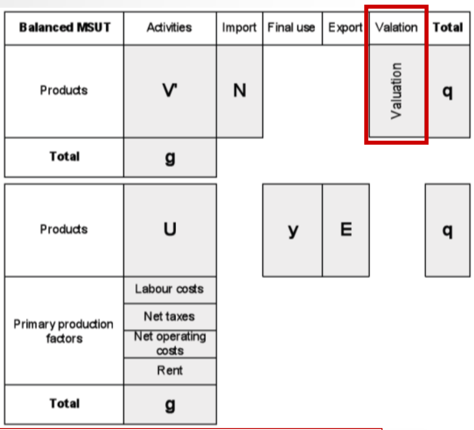
- Supply (**V'**) and use (**U**) tables are balanced

Balanced MSUT	Activities (a)	Import	Needs fulfilment	Export	Total
Products (c)	**V'**	$\mathbf{N_c}$			**q**
Total	**g'**				
Products (c)	**U**		**y**	$\mathbf{E_c}$	**q**
Primary inputs	Labour				
	Taxes				
	Profit				
Total	**g'**				

From purchaser's prices to basic prices

- What is purchaser's price?
- What is basic price?
- Why have table in basic prices?

- **q** is in purchaser's price
- **U** => purchaser's price
- **V'** + valuation => purchaser's price



Basic price = Purchasers price – Trade and transport margins – Taxes

Methodology and procedure:

Schmidt J H, Weidema B P, and Suh S (2010), *Documentation of the final model used for the scenario analyses*. Deliverable 6-4 of the EU FP6-project FORWAST. http://forwast.brgm.fr/

Derivation of the IO-table (simple case)

- Simplified case: No co-products

V'	Crop	Animal	Vegetable oil	Animal feed	Other food industry	Total
Crop	**485**	0	0	0	0	485
Animal	0	**51**	0	0	0	51
Vegetable oil	0	0	**260**	0	0	260
Animal feed	0	0	0	**600**	0	600
Other food industry	0	0	0	0	**241**	241
Total	485	51	260	600	241	1637

U	Crop	Animal	Vegetable oil	Animal feed	Other food industry	Final demand	Total
Crop	**10**	0	**180**	**200**	**22**	73	485
Animal	0	**1**	0	0	**40**	10	51
Vegetable oil	0	0	0	0	**129**	131	260
Animal feed	0	**21**	0	**50**	0	529	600
Other food industry	0	0	0	0	0	241	241
Primary inputs	**475**	**29**	**80**	**350**	**50**		
Total	485	51	260	600	241	984	1637

$\tilde{\mathbf{Z}} = \mathbf{U}\hat{\mathbf{g}}^{-1}$ ← U normalised by total supply from activities (**g**)

$\tilde{\mathbf{Z}}$	Crop	Animal	Vegetable oil	Animal feed	Other food industry
Crop	**0.021**	0.000	**0.692**	**0.333**	**0.091**
Animal	0.000	**0.020**	0.000	0.000	**0.166**
Vegetable oil	0.000	0.000	0.000	0.000	**0.535**
Animal feed	0.000	**0.412**	0.000	**0.083**	0.000
Other food industry	0.000	0.000	0.000	0.000	0.000

Derivation of the IO-table (normal case)

- How to deal with co-products?

V'	Crop	Animal	Vegetable oil	Animal feed	Other food industry		Total
Crop	485	0	0	0	0		485
Animal	0	51	0	0	0		51
Vegetable oil	0	0	260	0	0		260
Animal feed	0	0	40	560	0		600
Other food industry	0	0	0	0	241		241
Total	485	51	300	560	241		1637

U	Crop	Animal	Vegetable oil	Animal feed	Other food industry	Final demand	Total
Crop	10	0	180	200	22	73	485
Animal	0	1	0	0	40	10	51
Vegetable oil	0	0	0	0	129	131	260
Animal feed	0	21	0	50	0	529	600
Other food industry	0	0	0	0	0	241	241
Primary inputs	475	29	120	310	50		
Total	485	51	300	560	241	984	1637

- Two options:
  - Substitution
  - Co-product allocation

Derivation of the IO-table (normal case)

- Substitution (by-product technology assumption)

V'	Crop	Animal	Vegetable oil	Animal feed	Other food industry		Total
Crop	485	0	0	0	0		485
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Vegetable oil	0	0	260	0	0		260
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Other food industry	0	0	0	0	241		241
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Animal feed	0	21	-40	50	0	529	560
Other food industry	0	0	0	0	0	241	241
Primary inputs	475	29	120	310	50		
Total	485	51	260	560	241	984	1597

$$\tilde{\mathbf{Z}} = \mathbf{U}\hat{\mathbf{g}}^{-1}$$

U normalised by total supply from activities (**g**)

Derivation of the IO-table (normal case)

- Substitution (by-product technology assumption)

$$\tilde{\mathbf{Z}} = \left(\mathbf{U} - \tilde{\mathbf{V}}'\right)\left(\hat{\mathbf{V}}^{-1}\right)$$

where $\mathbf{V}$ is split into $\hat{\mathbf{V}}$ (diagonal entries in $\mathbf{V}$) and $\tilde{\mathbf{V}}$ (off-diagonal entries in $\mathbf{V}$).

Derivation of the IO-table (normal case)

- Economic allocation (industry-technology assumption)

V'	Crop	Animal	Vegetable oil	Animal feed	Other food industry	Total	
Crop	485	0	0	0	0	485	
Animal	0	51	0	0	0	51	q
Vegetable oil	0	0	260	0	0	260	
Animal feed	0	0	40	560	0	600	
Other food industry	0	0	0	0	241	241	
Total	485	51	300	560	241	1637	g'

U	Crop	Animal	Vegetable oil	Animal feed	Other food industry	Final demand	Total
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Other food industry	0	0	0	0	0	241	241
Primary inputs	475	29	120	310	50		
Total	485	51	300	560	241	984	1637

$$\tilde{\mathbf{Z}} = \left(\mathbf{U}\hat{\mathbf{g}}^{-1}\right)\left(\mathbf{V}'\hat{\mathbf{q}}^{-1}\right)$$

V' normalised by total supply of products (**q**)
=> average market supply, similar to attributional modelling

U Normalised by total supply from activities (**g**)
=> Economic allocation similar to attributional modelling

Allocation problems in the SUT framework

- Years of discussions on difficulties in substitution is now solved by using a simple matrix operation
- Allocation versus substitution: Two different matrix formulas

Suh S, Weidema B, Schmidt J H and Reinout H (2010), Generalized Make and Use Framework for Allocation in Life Cycle Assessment. *Journal of Industrial Ecology* 14(2): 335-353 < DOI: 10.1111/j.1530-9290.2010.00235.x>

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Tradelinking

- Example of tradelinked DK, EU27 (ex DK) and RoW IO-table

IO-table: DK	Import to EU27 (ex DK) from DK	Import to RoW from EU27 (ex DK)
Import to DK from EU27	IO-table: EU27 (ex DK)	Import to RoW from EU27 (ex DK)
Import to DK from RoW	Import to EU27 (ex DK) from RoW	IO-table: RoW
DK NAMEA: GHG-emissions	EU27 NAMEA: GHG-emissions	RoW NAMEA: GHG-emissions

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Physical Supply-Use Tables (PSUT)

Balanced PSUT	Activities (a)	Import		Needs fulfilment	Export		Total
Products (c)	V'	N_c	N_w				q
Total	g'						
Products (c)	U			y	E_c	E_w	q
Stock changes	$-\Delta S$						
Supply of residuals	$-W_V$						
Use of residuals	W_U						
Resources	R						
Emissions	$-B$						
Total	g'						

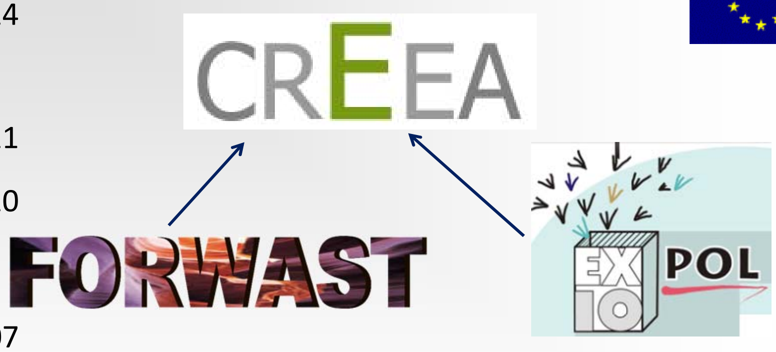
CREEA: state of art MRIO and MFA

2014

2011

2010

2007



FORWAST

- **FORWAST:** Project under the 6th European Union Framework Programme
- **Purpose:** Overall mapping of physical flows and stocks of resources to forecast waste quantities in Europe and identify life-cycle environmental stakes of waste prevention and recycling
- **Technical lead:** 2.-0 LCA consultants
- **Partners:** 6 partners throughout the EU
- **Duration:** March 2007 to February 2010
- **Project homepage:** http://forwast.brgm.fr/

CREEA

- **CREEA:** Project under the 7th European Union Framework Programme
- **Purpose:** Compiling and Refining Economic and Environmental Accounts
- **MFA / waste lead:** 2.-0 LCA consultants
- **Partners:** 12 partners throughout the EU
- **Duration:** April 2011 to April 2014
- **Project homepage:** http://creea.eu

Physical Supply-Use Tables (PSUT)

- Procedure for calculating waste
- Waste = balancing item

Balanced PSUT	Activities (a)	Import		Needs fulfilment	Export		Total
Products (c)	**V'**	**N_c**	**N_w**				**q**
Total	**g'**						
Products (c)	**U**			**y**	**E_c**	**E_w**	**q**
Stock changes	**$-\Delta S$**						
Supply of residuals	**$-W_V$**						
Use of residuals	**W_U**						
Resources	**R**						
Emissions	**-B**						
Total	**g'**						

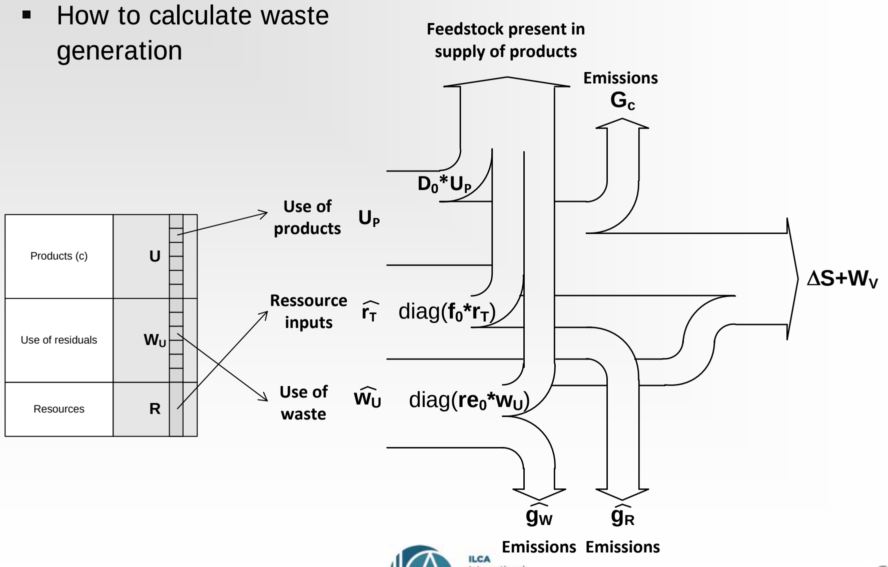
Calculated

WP4: Waste and MFA accounts

- **The FORWAST methodology:**
  - How to calculate waste accounts and how to integrate waste flows in PSUT and HIOT
  - Which data sets are required

Model principle and data

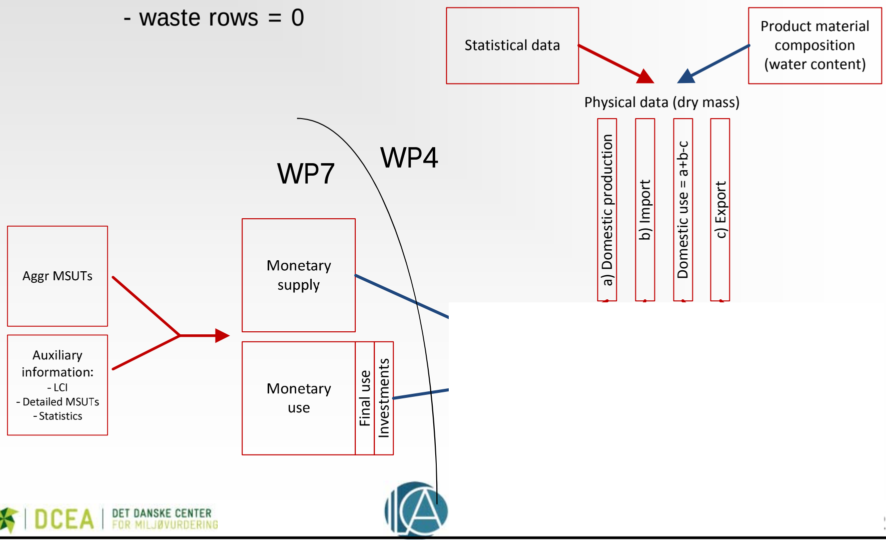
- How to calculate waste generation



How to create extended PSUTs?

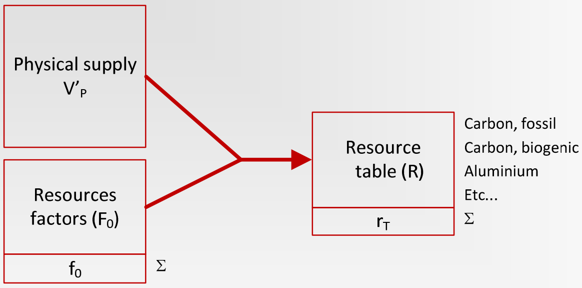
1. Physical supply and use table (dry matter mass)

- preliminary draft of use table ($\mathbf{U_P}$)
- waste rows = 0



How to create extended PSUTs?

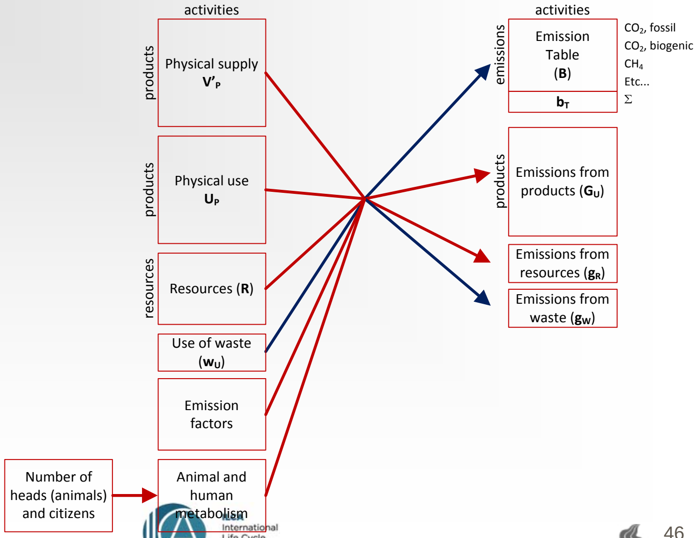
2. Resource table



- Additional information and alignment between **V, U** and **R** for some activities is required
- Example (maybe only case?): activity 'Cattle': Supply (**V**) originates from:
  - use of products (**U**), i.e. grain crops and oil meal, and
  - resources (**R**), i.e. grazing and ensilage

How to create extended PSUTs?

3. Emission tables: Emissions from products ($\mathbf{G_U}$), resources ($\mathbf{g_R}$) and waste ($\mathbf{g_W}$)



How to create extended PSUTs?

4. Auxiliary data:

- Feedstock specification ($\mathbf{D_1}$)

D_1

Activities (columns), Products (rows)

			1		
1	1				
0.8		1			
	1	1			

1	=>	This is a feedstock, feedstock efficiency **unknown**
]0;1[	=>	This is a feedstock, feedstock efficiency **specified**

- Resource efficiency ($\mathbf{f_0}$)
  - Unused extraction rate

- Recycling efficiency ($\mathbf{e_0}$)

How to create extended PSUTs?

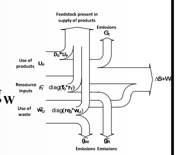
5. Calculation of waste generation:

- feedstock efficiency ($\mathbf{D_0}$): From $\mathbf{D_1}$ to $\mathbf{D_0}$

$$\mathbf{D}_{ij} = \begin{cases} \mathbf{D}_{1,ij} = 0 & \rightarrow \quad \mathbf{D}_{0,ij} = 0 \\ \mathbf{D}_{1,ij} =]0,1[& \rightarrow \quad \mathbf{D}_{0,ij} = \mathbf{D}_{1ij} \\ \mathbf{D}_{1,ij} = 1 & \rightarrow \quad \mathbf{D}_{0,ij} = \mathbf{i}\{[\mathbf{i'V'}_P - \mathbf{i'}(\mathbf{f}_0 * \mathbf{r}_T) - \mathbf{i'}(\mathbf{re}_0 * \mathbf{w}_U) - \mathbf{i'}(\mathbf{D}_{1,ij=]0,1[} * \mathbf{U}_P)]./ \\ & \qquad [\mathbf{i'}(\mathbf{D}_{1,ij=1} * \mathbf{U}_P)]\} \end{cases}$$

- waste+stock addition ($\mathbf{W_V + \Delta S}$)

$$\mathbf{\Delta S} + \mathbf{W}_V = \mathbf{U}_T - (\mathbf{D}_0 * \mathbf{U}_P) + \hat{\mathbf{r}}_T - diag(\mathbf{f}_0 * \mathbf{r}_T) + \hat{\mathbf{w}}_U - diag(\mathbf{re}_0 * \mathbf{w}_U) - \mathbf{G}_U - \hat{\mathbf{g}}_R - \hat{\mathbf{g}}_W$$



- split waste from stock addition

  e.g. use investment info in use table or general data from FORWAST

- => supply of waste table $\mathbf{W_V}$

W_V

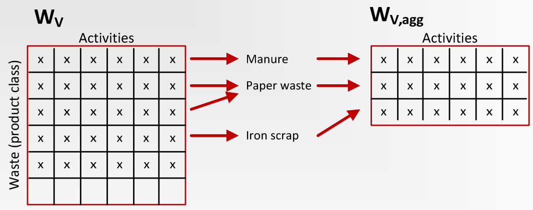
Activities (columns), Waste (product classification) (rows)

x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x
x	x	x	x	x	x

How to create extended PSUTs?

6. Waste fractions and standardised waste tables

- Classify $\mathbf{W_V}$ into standardised waste fractions and for standardised waste accounts: apply waste definition

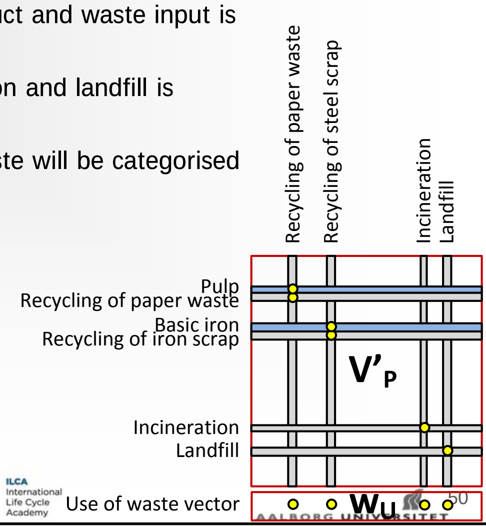


How to create extended PSUTs?

7. Waste rows in physical supply table

Note: Use of waste ($\mathbf{w_U}$) appear in supply table ($\mathbf{V'_P}$)

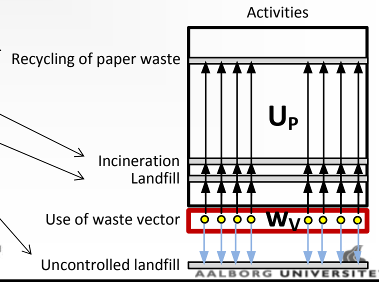
- Ratio between off-diagonal by-product and waste input is known
- Quantity of total waste to incineration and landfill is known/estimated from statistics
- All non-specified (no treatment) waste will be categorised as: ‘Uncontrolled landfill’.



How to create extended PSUTs?

8. Waste rows in the physical use table

- We have calculated total tonage of each waste fraction (**W_V**)
- Under (7) we have specified how much of each fraction is:
  - x tons recycling
  - y tons incin
  - z tons landfill
  - Then the ‘uncontrolled landfill’ will be = total – x – y - z
- Waste treatment mix (**J**) for each fraction can be calculated as:
  - Recycling = x / total
  - Incin. = y / total
  - Landfill = z / total
  - Uncontr. = uncoltr. / total



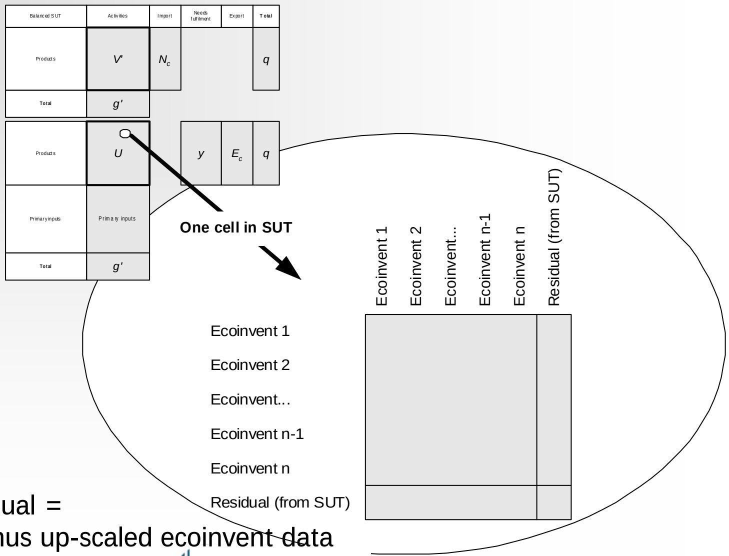
Content of the lecture

Analogy between flow charts and matrix representation of LCI
LCA calculus
Process LCA and IO-LCA
Uses of IO-LCA
Derivation of supply-use tables and IO-table
Trade-linking
Supply use data and Mass flow analysis
Now → Hybrid LCA

Hybrid – what does it mean?

- Hybrid database
  - Monetary units – but detailed via engineering data
  - Hybrid units
  - Process LCI database embedded in SUT
  - IO-database detailed using process data – process and product level
  - IO-database detailed using process data – only process level
- Hybrid LCA data sets
  - Embedded approach
  - Tiered approach

Hybrid LCA; embedded approach



- Original residual =
  SUT data minus up-scaled ecoinvent data

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