



HELSINGIN YLIOPISTO



Energy Positive Farm - ENPOS

13 Monitoring energy use on farms, measurements, bookkeeping, inventories

Scientific background:

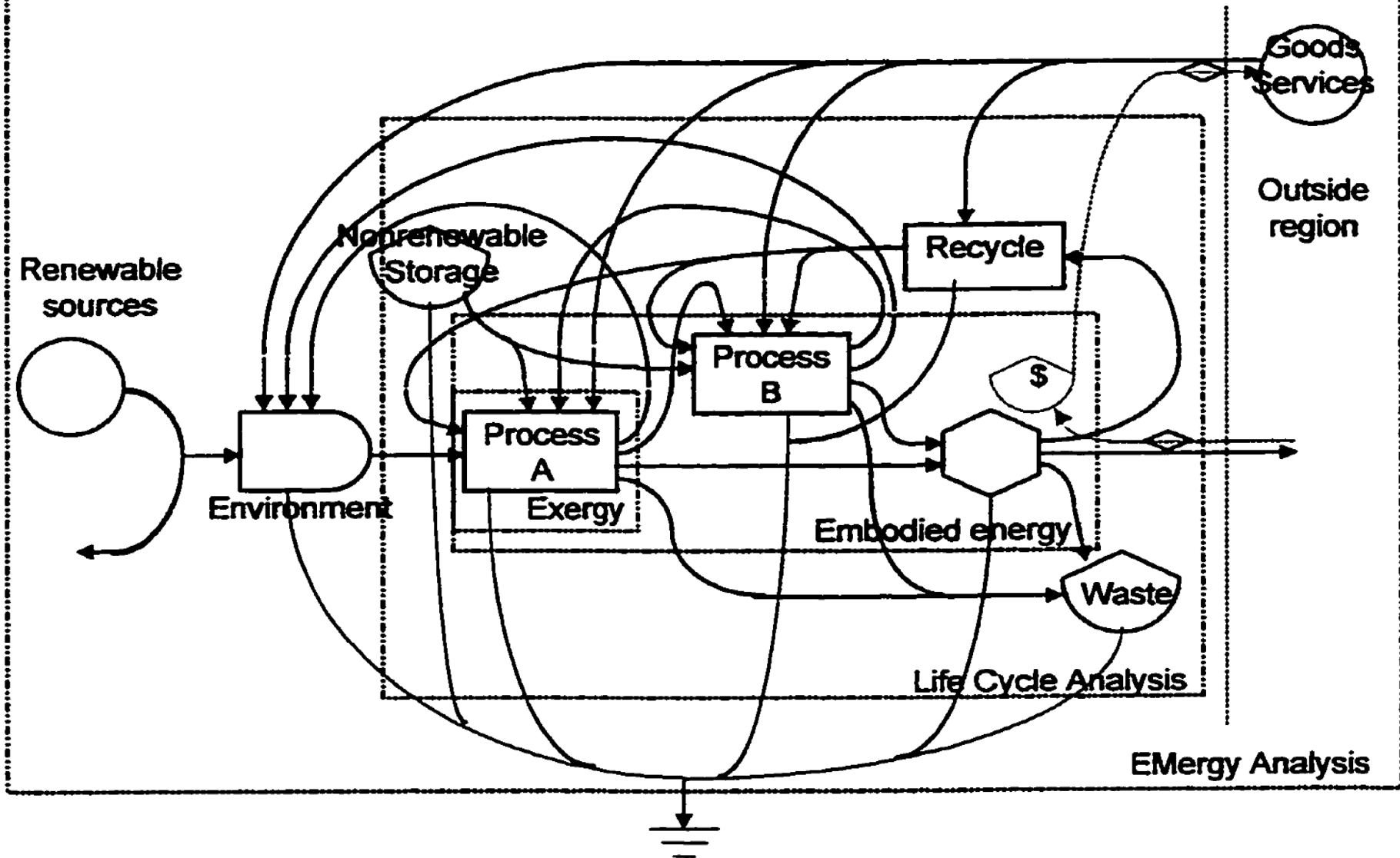
Mulder, K. & Hagens, N. 2008. Energy Return on Investment: Toward a Consistent Framework. *Ambio* 37:74-79.

Hagens, N. & Mulder, K. 2008. A Framework for Energy Alternatives: Net Energy, Liebig's Law and Multi-criteria Analysis. In: Pimentel D. (ed) *Biofuels, Solar and Wind as Renewable Energy Systems: Benefits and Risks*, Springer, Science+Business Media B.V. p. 295-319.

Gangwer, T. Biomass Fuel Cycle Boundaries and Parameters: Current Practice and Proposed Methodology. In: Pimentel D. (ed) *Biofuels, Solar and Wind as Renewable Energy Systems: Benefits and Risks*, Springer, Science+Business Media B.V. p. 231-257.

Winfried Schäfer MTT, 16.2.2010

Methodology comparison



Source: **Buranakarn, V.**, 1998. Evaluation of recycling and reuse of building materials using the emergy analysis method. Ph.D. Dissertation. University of Florida. 279 p. Picture courtesy of Mark Brown

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Methodology comparison

Methods	Level	Coefficients, Currency	Data requirement	Units	Remarks
Exergy, EROI	Process, Activity / operation	1	Actual data, direct energy input and output	GJ GJ/ha GJ/kg	Only direct energy, no energy quality, no labour, no environmental input
Embodied energy, EROI	Farm, Process	Mass or quantity into energy	Actual data, energy and mass input and output	GJ/farm GJ/process GJ/ha	Direct and indirect energy, no energy quality, no labour, no environmental input
LCA	Farm, Process, Time	Mass, nutrient or quantity into energy and /or CO2 equivalents	Actual, average or statistical energy and mass input and output	GJ, kg, nutrient, CO2 eq / Farm Process ha	Direct and indirect energy and environmental input and output no energy quality, no labour,
Emergy analysis	Ecological boundary, Farm, Process, Time	Transformity	Actual, average or statistical energy and mass input and output	Sej Sej/farm Sej/process Sej/ha	Energy, labour, environment, services input included, correction for energy quality

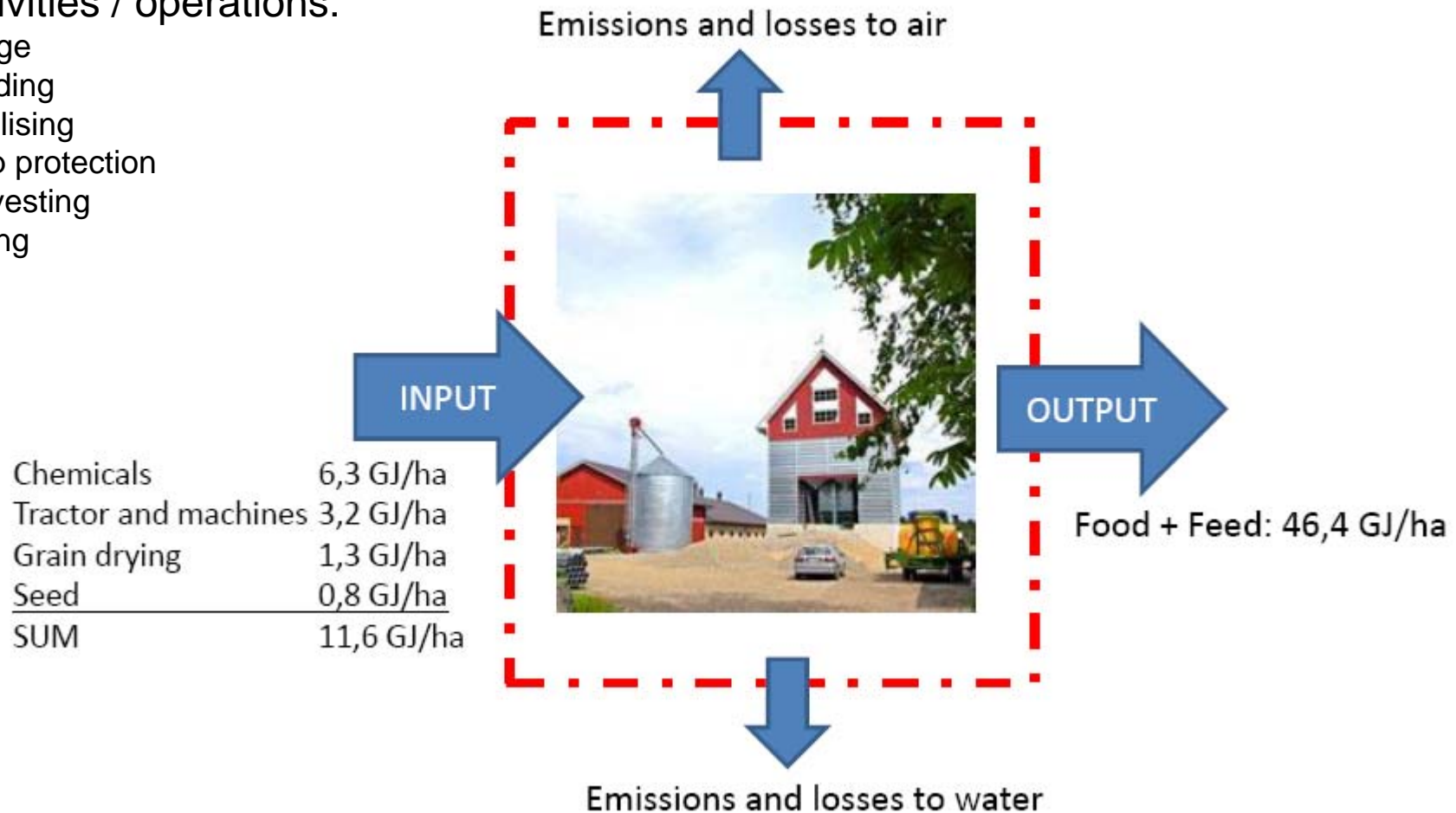
Physical farm boundary as system boundary

Process: Crop production

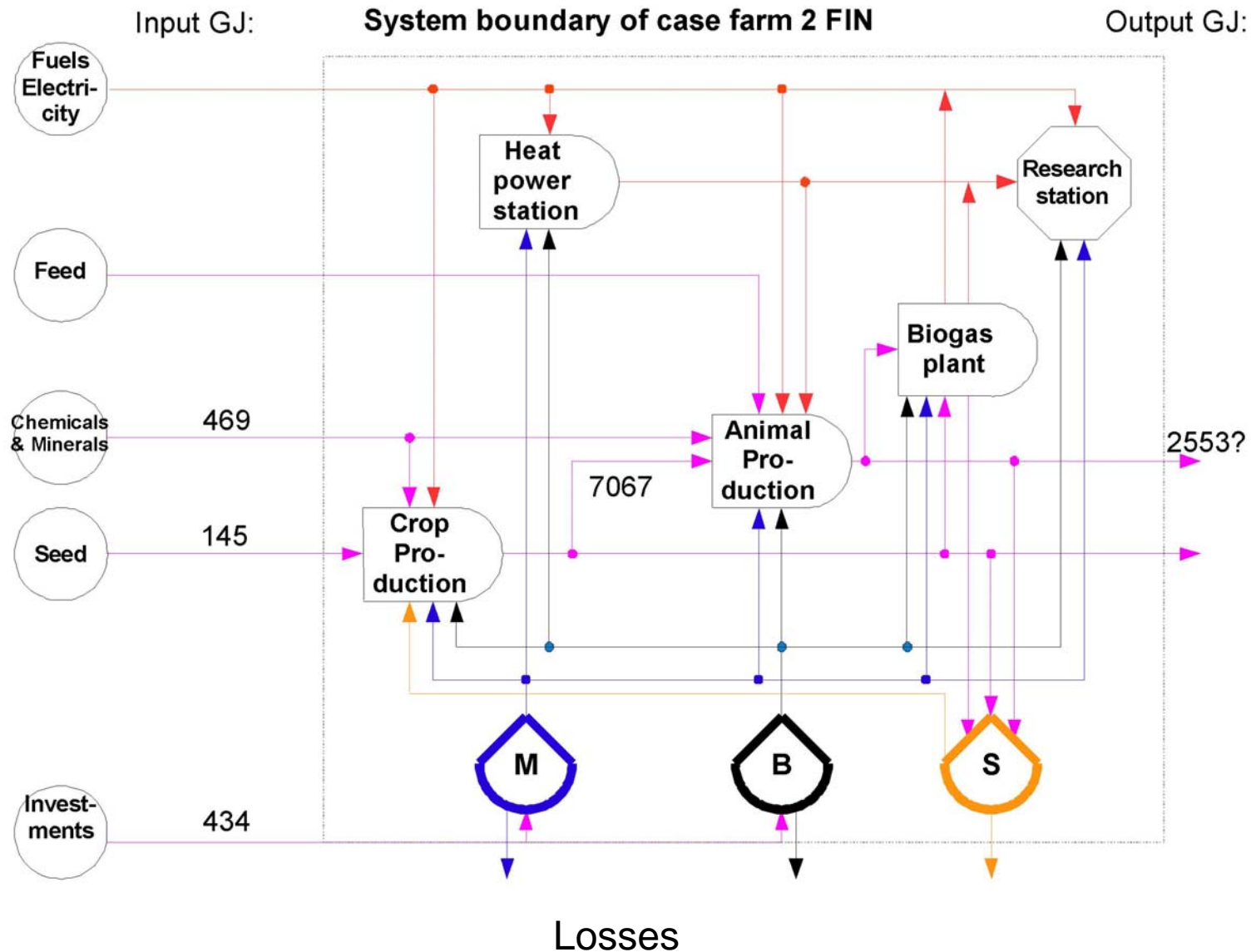
Activities / operations:

- Tillage
- Seeding
- Fertilising
- Crop protection
- Harvesting
- Drying

Energy flows



Processes, stocks and consumer of case farm 2 FIN

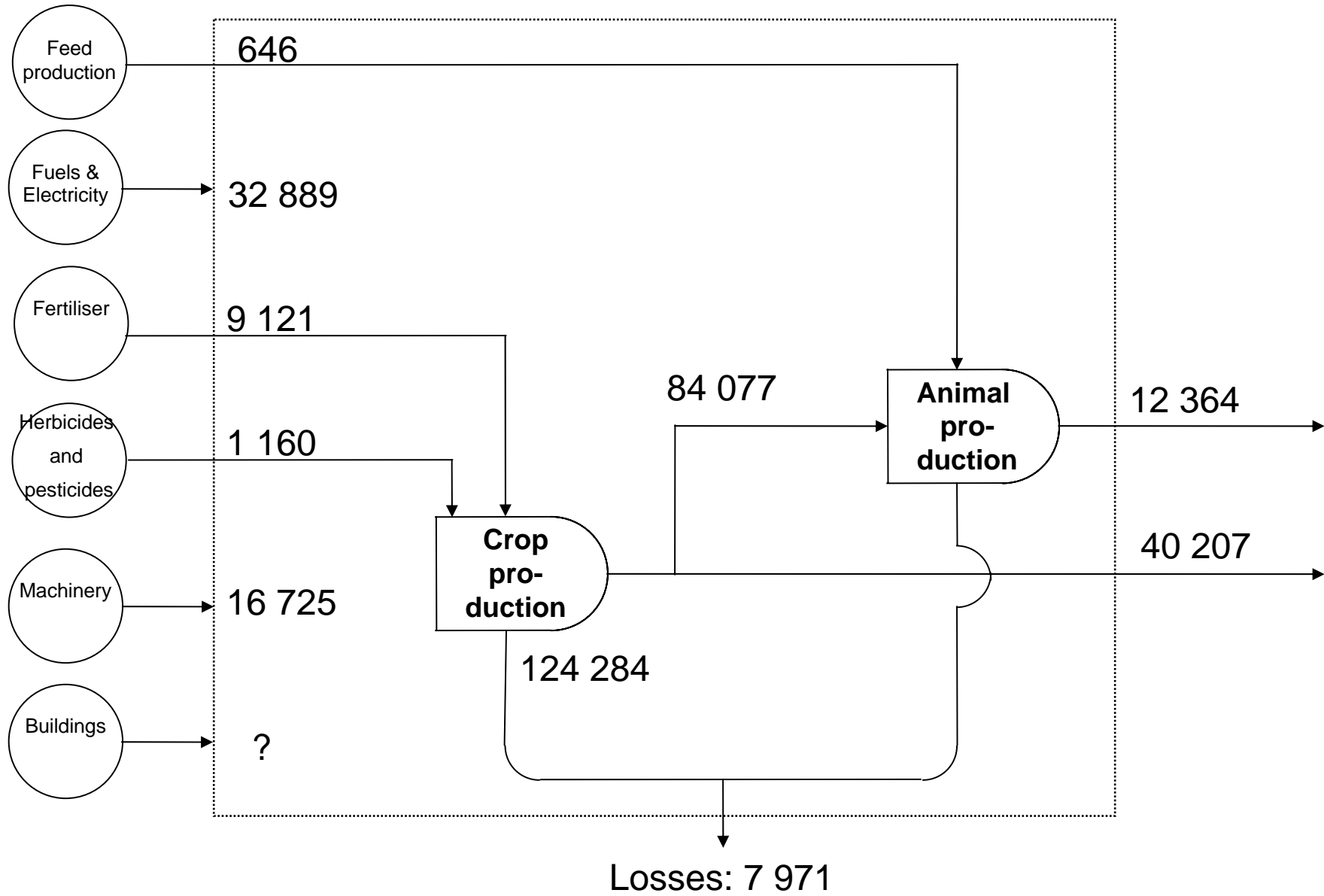


Economic, energy, and environmental accounting

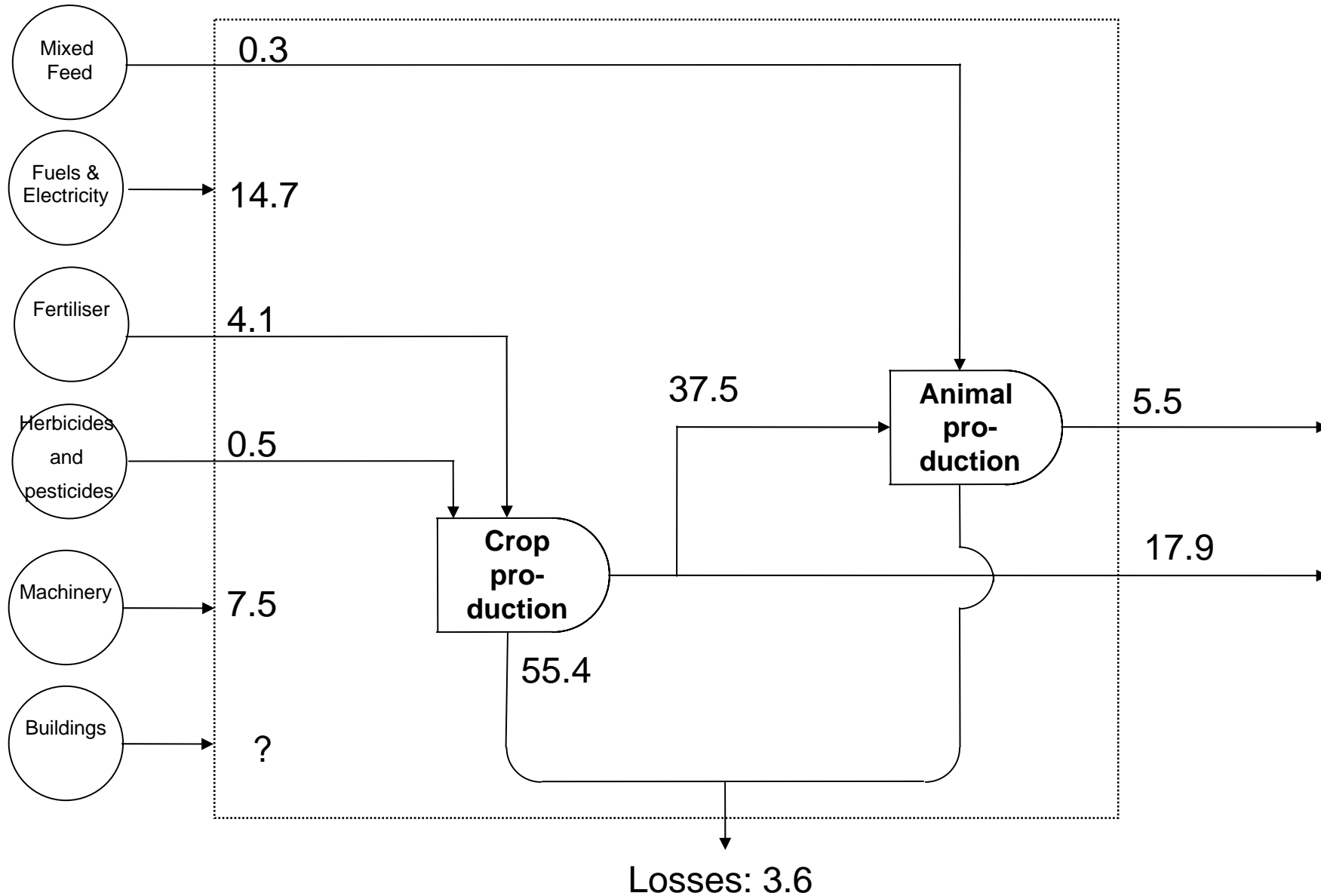
	Book keeping	EROI	LCA
Currency	€, EEK	Conversion factor e.g. GJ/t The scientific challenge of ENPOS	Conversion factor e.g. CO2 eq / GJ
Direct input	Variable cost	Direct energy input, Embedded energy from mass input	Direct energy and material input
Stocks	Fixed cost, depreciation, Investment	Indirect embedded energy depreciation of machinery and buildings	Changes in nutrient stocks, e.g. N, P, K, C content of soil
Output	Income	Direct energy output, Embedded energy from mass output	Emissions
Gain	Profit	EROI	Quantity of emissions

**Energy balance of Finland's agriculture
2001 in TJ**

Input 60 542 **Output** 52 571

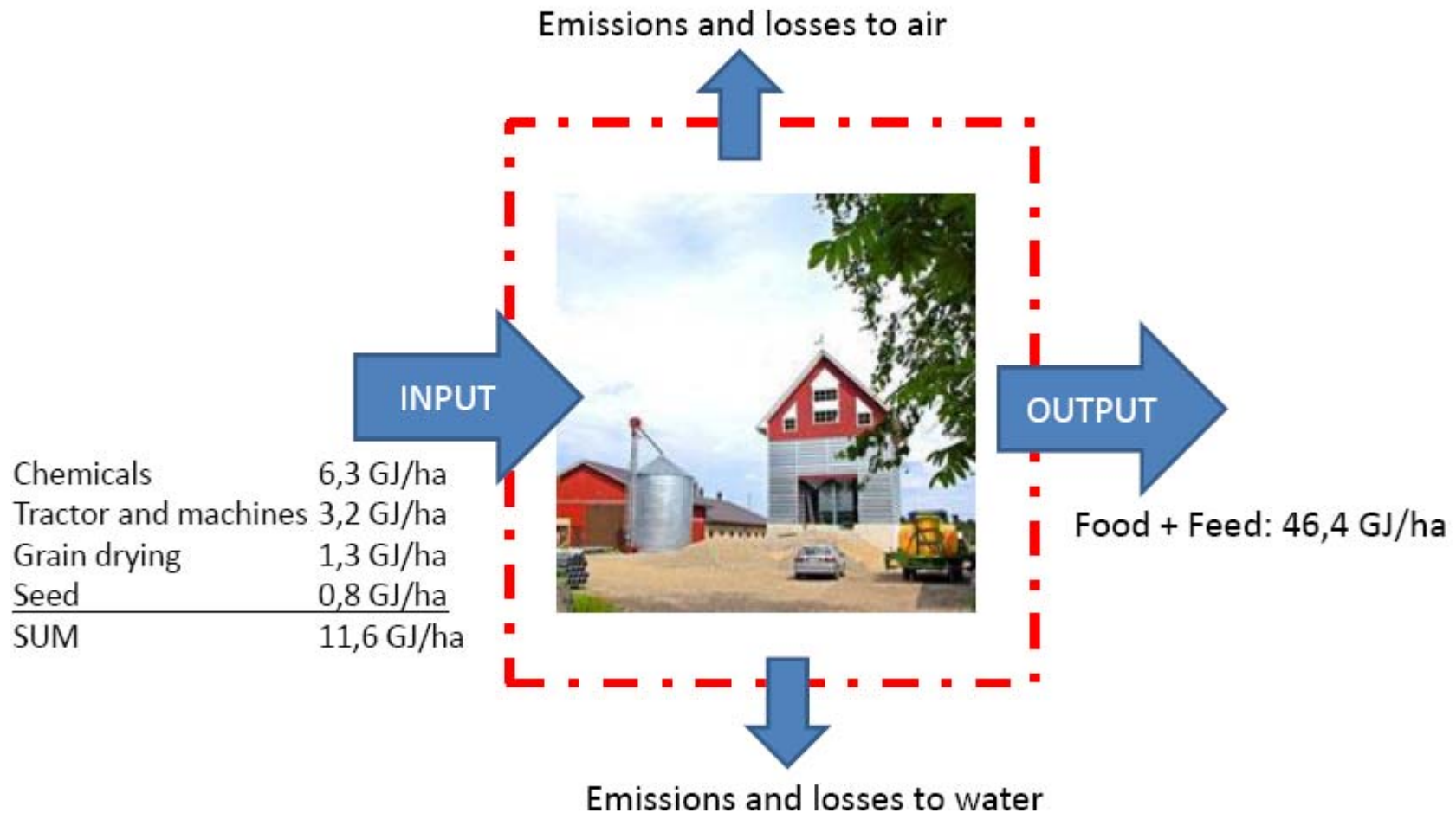


Input 27.0 **Energy balance of Finland's agriculture** (2 243 416 ha) 2001 in GJ/ha **Output** 23.4



For comparison EROI of grain production

Energy flows

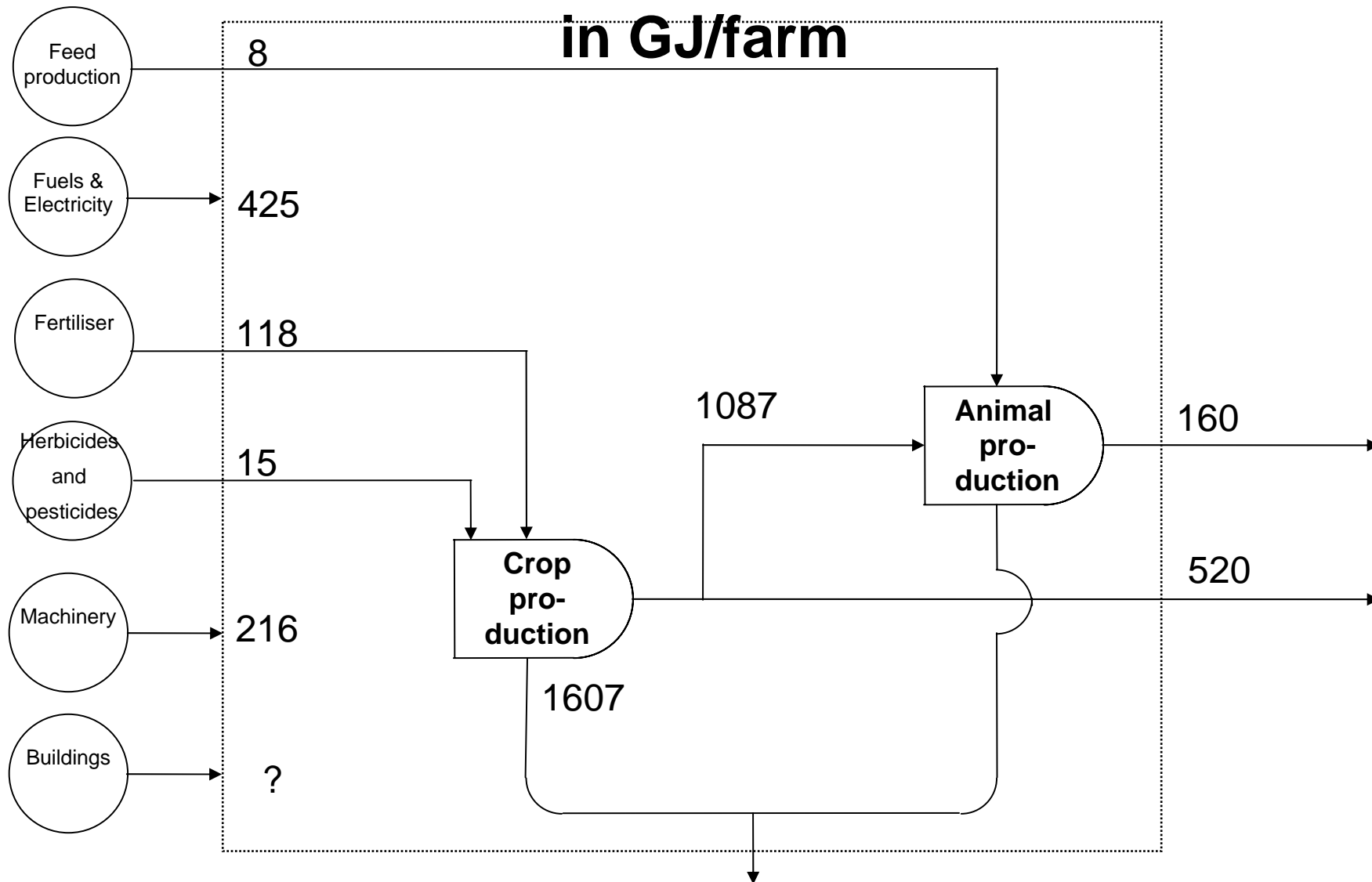


Energy balance of Finland's agriculture (77 320 farms) 2001

Input
783

Output
680

in GJ/farm



Losses: 103

Form input: national level

Note	Process	Direct energy input	Quantity	unit	Conversion factor	GJ	GJ/ha	
1	Farm unspecified	Electric grid power	850	GWh	3 600,00	GJ/GWh	3 060 000	1,36399
2		Electric power from biogas	72	MWh	3,60	GJ/MWh	259	0,00012
3		Heavy fuel oil	74 951	t	40,61	GJ/t	3 043 907	1,35682
4		Diesel and light fuel oil	477 217	t	42,29	GJ/t	20 179 923	8,99518
5		Gasoline	548	TJ	1 000,00	TJ/GJ	548 000	0,24427
6		Natural gas	680	TJ	1 000,00	TJ/GJ	680 000	0,30311
7		Fire wood	4 500	TJ	1 000,00	TJ/GJ	4 500 000	2,00587
8		Peat	470	TJ	1 000,00	TJ/GJ	470 000	0,20950
9		Earth heat	10	TJ	1 000,00	TJ/GJ	10 000	0,00446
10		District heat	110	GWh	3 600,00	GJ/GWh	396 000	0,17652
11		Biogas	200	MWh	3,60	GJ/MWh	720	0,00032
		Total					32 888 809	14,66015

		Fertiliser	Quantity	unit	Conversion factor	GJ	GJ/ha	
12	Crop Production	Nitrogen	165 621	t	50,00	GJ/t	8 281 050	3,69127
13		Phosphorus	21 393	t	12,00	GJ/t	256 716	0,11443
14		Potassium	61 877	t	7,00	GJ/t	433 139	0,19307
15		Lime stone	752	t	0,20	GJ/t	150 400	0,06704
16		Boron	178	t				
17		Copper Manganese Zinc	48	t				
18		Manganese	369	t				
19		Magnesium	5 195	t				
20		Zinc	215	t				
		Total					9 121 305	4,06581

Form notes: national level

Note	Input	Source quantity	Source conversion factor
1	Electric grid power	Statistic Finland 2003, Energiatilasto 2002	
2	Electric power from biogas	Kuittinen et al. 2001	
3	Heavy fuel oil	Statistic Finland 2003, Energiatilasto 2002	
4	Diesel and light fuel oil	Statistic Finland 2003, Energiatilasto 2002	
5	Gasoline	Statistic Finland 2003, Energiatilasto 2002	
6	Natural gas	Statistic Finland 2003, Energiatilasto 2002	
7	Fire wood	Statistic Finland 2003, Energiatilasto 2002	
8	Peat	Statistic Finland 2003, Energiatilasto 2002	
9	Earth heat	Statistic Finland 2003, Energiatilasto 2002	
10	District heat	Statistic Finland 2003, Energiatilasto 2002	
11	Biogas	Statistic Finland 2003, Energiatilasto 2002	
12	Nitrogen		Daalgard et al. 2001
13	Phosphorus		Daalgard et al. 2001
14	Potassium		Daalgard et al. 2001
15	Lime stone		Grönroos, J., Voutilainen, P. 2001. Maata
16	Boron	Statistical Yearbook of Finland 2004, table 124	
17	Copper Manganese Zinc	Statistical Yearbook of Finland 2004, table 124	
18	Manganese	Statistical Yearbook of Finland 2004, table 124	
19	Magnesium	Statistical Yearbook of Finland 2004, table 124	
20	Zinc	Statistical Yearbook of Finland 2004, table 124	

Form farm level: case farm 2 FIN (direct input)

		Direct energy input						
Process/Stocks	Note		Quantity	unit	Conversion factor	unit	MJ	MJ/ha
Farm	1	Electric grid power		kWh	3,60	MJ/kWh	0	0
Farm	2	Electric power from biogas		kWh	3,60	MJ/kWh	0	0
Farm	3	Diesel		l			0	0
Farm	4	Light fuel oil		l			0	0
Farm	5	Gasoline		l			0	0
Farm	6	Lubricants		kg			0	0
Farm	7	Fire wood		l-m3			0	0
Farm	8	Peat		kg			0	0
Farm	9	Wood chips district heating		l-m3			0	0
Farm	10	Biogas substrate		kg			0	0
Farm	11	Gas		kg			0	0
Total			0				0	0
		Seed						
Process	Note		Quantity	unit	Conversion factor		MJ	MJ/ha
Crop Production	12	Seed	7 734	kg	18,70		144 620	997
Total								
		Fertiliser						
Process	Note		Quantity	unit	Conversion factor		MJ	MJ/ha
Crop Production	13	Nitrogen	7 886	kg	50,00	MJ/kg	394 302	2 719
Crop Production	14	Phosphorus	789	kg	12,00	MJ/kg	9 463	65
Crop Production	15	Potassium	4 732	kg	7,00	MJ/kg	33 121	228
Crop Production	16	Lime stone		kg	0,20	MJ/kg	0	223
Crop Production	17	Boron		kg				
Crop Production	18	Copper		kg				
Crop Production	19	Manganese		kg				
Crop Production	20	Magnesium		kg				
Crop Production	21	Zinc		kg				
Total			13 406		69,20		436 886	3 013
		Agrochemicals						
Process	Note		Quantity	unit	Conversion factor		MJ	MJ/ha
Crop Production	22	Seed dressing agent						
Crop Production	23	Fungicides		kg		MJ kg-1	0	0
Crop Production	24	Pesticides	149	kg	216,26	MJ kg-1	32 326	223
Crop Production	25	Herbicides		kg		MJ kg-1	0	0
Crop Production	26	Growth regulators		kg		MJ kg-1	0	0
Total			149		216,26		32 326	223
Total Chemicals & Minerals							469 212	

Form: Farm level case farm 2 FIN (stocks)

Stocks	Note	Machines	Quantity	unit	Conversion factor	MJ	MJ/ha
Crop Production	36	TRAKTORI VALTRA C130 ETUKUORMAAJALLA, REK 333-N	5 270	kg	14,00 MJ/kg	73 780	509
Crop Production	37	TRAKTORI VALTRA VALMET 8450-4, REK.NO 30-TBB	5 410	kg	14,00 MJ/kg	75 740	522
Crop Production	38	GIANT V451X-TRA 45HVKUBOTA D1505T	880	kg	14,00 MJ/kg	12 320	85
Crop Production	39	Väderstad KYLVÖLANNOITIN SUPER-RAPID 300C XL	4 300	kg	14,00 MJ/kg	60 200	415
Crop Production	40	LIETEVAUNU LIVAKKA 14M3 800/50R34 RENK.	5 900	kg	14,00 MJ/kg	82 600	570
Crop Production	41	TARKKUUSSILPPURI JF FCT-1050	2 130	kg	14,00 MJ/kg	29 820	206
Crop Production	42	NIITTOMURSKAIN JF GMS 3200 D	2 400	kg	14,00 MJ/kg	33 600	232
Crop Production	43	JOUSTOPIIKKIÄES MULTIVA OPTIMA S600	3 150	kg	14,00 MJ/kg	44 100	304
Crop Production	44	LANNOITTEENLEVITIN BOGBALLE EXW TREND 4500-02 5	600	kg	14,00 MJ/kg	8 400	58
Crop Production	45	ELHO SIDE CHOPPER VM 240 VESAKKO/KESANTOMURSK	980	kg	14,00 MJ/kg	13 720	95
Crop Production	46	NURMENKORJUUKONE HEGE 212		kg	MJ/kg	0	0
Total			31 020			434 280	2 995
Stocks	Note	Machines	Quantity	unit	Conversion factor	MJ	MJ/ha
Biogas plant	47	Engine and generator		kg	MJ/kg	0	0
Biogas plant	48	Pumping and mixing					
Total			0			0	0
Stocks	Note	Machines	Quantity	unit	Conversion factor	MJ	MJ/ha
Animal production	49	VÄKIREHUKIOSKIT 5 KPL NEDAP RUOKINTA JA PUNNITUS-		kg	MJ/kg		
Animal production	50	LAAKASIILOT		kg	MJ/kg		
Animal production	51	KALUSTEET LEHMILLE		kg	MJ/kg		
Animal production	52	LYPSYASEMA KALANRUTO 2X8 PELLON 115BL		kg	MJ/kg		
Animal production	53	TUOREREHUSUKKULA, SIIRTOVAUNUT, TARVIKKEET		kg	MJ/kg		
Animal production	54	VAAKAKUPIT + TUNNISTUS RIC-JÄRJESTELMÄ 24 KUPPIA		kg	MJ/kg		
Animal production	55	BIOKAASULAITOS MAANINKA		kg	MJ/kg		
Animal production	56	APEREHUVAUNU DUALMIX SUPER UNIFEED MK2		kg	MJ/kg		
Animal production	57	LIETELANTASEPARAATTORI BAUER S 655		kg	MJ/kg		
Animal production	58	ERILLISOSASTON LYPSEKONE, DUPLO 2 PUTKISTO, TYHJIÖLAIT-		kg	MJ/kg		
Animal production	59	RUOKKIJAN KISKON KANNATUSORRET		kg	MJ/kg		
Animal production	60	RUOKINTALAITTEISTON PURKUSPIRAALIT. SPIRAALIT TÄYTTÄVÄT		kg	MJ/kg		
Animal production	61	REHUVAUNU MULTIVA TR170R		kg	MJ/kg		
Animal production	62	KULUNVALVONTA LAITUMELLE		kg	MJ/kg		
Animal production	63	PARSIPETI PROMAT+ETUTYYNY		kg	MJ/kg		
Animal production	64	LANNANPOISTOJÄRJESTELMÄ DISCOVERY MOBILE BARN CLEANE		kg	MJ/kg		
Total			0			0	0
Total Machines				kg	MJ/kg		

Form: Notes farm level case farm 2 FIN

Process/Stocks	Note	Input	Source quantity	Source conversion factor	Value	Min	Max
Farm	1	Electric grid power					
Farm	2	Electric power from biogas					
Farm	3	Diesel					
Farm	4	Light fuel oil					
Farm	5	Gasoline					
Farm	6	Lubricants					
Farm	7	Fire wood					
Farm	8	Peat					
Farm	9	Wood chips district heating					
Farm	10	Biogas substrate					
Farm	11	Gas					
Total							
Process	Note	Seed					
Crop Production	12	Seed					
Total							
Process	Note	Fertiliser					
Crop Production	13	Nitrogen	MTT Maaninka: Summary of selected fertilizers 2009. file:///F:/HY ENPOS/Maaninka/WEBWISU/WebWisu data 13.4.10.ods'				
Crop Production	14	Phosphorus	MTT Maaninka: Summary of selected fertilizers 2009. file:///F:/HY ENPOS/Maaninka/WEBWISU/WebWisu data 13.4.10.ods'				
Crop Production	15	Potassium	MTT Maaninka: Summary of selected fertilizers 2009. file:///F:/HY ENPOS/Maaninka/WEBWISU/WebWisu data 13.4.10.ods'				
Crop Production	16	Lime stone					
Crop Production	17	Boron					
Crop Production	18	Copper					
Crop Production	19	Manganese					
Crop Production	20	Mangnesium					
Crop Production	21	Zinc					
Total							
Process	Note	Agrochemicals					
Crop Production	22	Seed dressing agent					
Crop Production	23	Fungicides					
Crop Production	24	Pesticides	MTT Maaninka: Summary of used plant protection products 2009: file:///F:/HY ENPOS/Maaninka/WEBWISU/WebW				
Crop Production	25	Herbicides					
Crop Production	26	Growth regulators					
Total							
Total Chemicals & Minerals							

Process and activity level monitoring in crop production by book keeping programme, e.g. WEBWISU

Forms of the book keeping program, using accounts (direct energy and material input, time) for
crops (=process),
activities ,
machines.

Use of measuring results were ever possible. Missing data are estimated based on experiences and literature.

Total of all activities per crop
Total of all crops per farm

Total of machines allocated to activities
Total of machines allocated to crops

Currencies: €, EEK, GJ, CO2 eq., N, P, K, C

Summary

1. Top down approach
Farm level input output balance calculation based on book keeping data
2. Bottom up approach
Measuring energy and material input and output on activity level.
Missing data are estimated.
3. Calculating totals of activities and processes
4. Comparison of results of step 1 and step 3
5. Conclusions and energy saving strategies

The scientific challenge of ENPOS: calculation of conversion factors