Data and calculations to:

Rydberg, T. & Haden, A. C. 2006. Emergy evaluations of Denmark and Danish agriculture: assessing the influence of changing resource availability on the organization of agriculture and society.

Content:

Appendix A Emergy evaluation of Denmark

Table A.1. Emergy evaluation of Denmark, 1936.

Note	Item, units	Data (units/yr)	Transformity (sej/unit)	Ref. for Transform.	Solar Emergy (E20 sej/yr)
RENEWABLE RESOURCES:					
1	Sunlight, J	3.31E+20	1.00E+00	A	3.31
2	Wind, kinetic energy, J	5.77E+14	1.50E+03	A	0.01
3	Rain, chemical, J	2.90E+17	1.82E+04	A	61.50
4	Rain, geopotential, J	2.41E+15	2.79E+04	A	1.06
5	Waves, J	2.57E+17	3.06E+04	A	78.37
6	Tide, J	2.29E+16	1.68E+04	A	3.86
7	Earth cycle, J	4.31E+16	3.44E+04	A	14.81
INDIGENOUS RENEWABLE ENERGY					
8	Agriculture production, J	1.64E+17	2.48E+04	G	40.67
9	Livestock production, J	2.28E+16	3.49E+05	G	79.57
10	Forest extraction, J	1.31E+16	6.60E+03	C	0.86
NONRENEWABLE SOURCES FROM WITHIN SYSTEM:					
11	Coke, J	8.76E+15	4.00E+04	A	3.50
12	Calcium carbonate, g	3.87E+10	1.00E+09	A	0.39
13	Minerals, g	1.04E+12	1.00E+09	A	10.40
14	Top soil, J	6.51E+14	7.40E+04	A	0.48
IMPORTS AND OUTSIDE SOURCES:					
15	Coal, J	1.86E+17	4.00E+04	A	74.26
16	Crude oil, J	1.27E+16	5.40E+04	A	6.83
17	Gas/fuel oil, J	1.20E+16	6.60E+04	A	7.95
18	Oil derived products, J	7.74E+15	6.60E+04	A	5.11
19	Metals, g	5.49E+11	9.20E+08	D	5.05
20	Minerals, g	3.62E+11	1.00E+09	A	3.62
21	Food & agriculture products, J	2.59E+16	2.00E+05	F	51.76
22	Livestock, meat, fish, J	3.66E+14	2.00E+06	F	7.32
23	Fisheries production, J	3.64E+14	1.20E+06	H	4.37
24	Plastics & rubber, g	6.87E+09	3.80E+08	D	0.03
25	Chemicals, g	5.80E+11	3.80E+08	D	2.20
26	Wood, paper, textiles, J	1.11E+16	3.49E+04	G*	3.89
27	Mechanical & transport. equip., g	2.92E+10	6.70E+09	D	1.96
28	Service in imports, USD	3.30E+08	2.58E+13	G	85.20
EXPORTS:					
29	Metals, g	1.20E+11	9.20E+08	D	1.11
30	Minerals, g	6.14E+11	1.00E+09	A	6.14
31	Food & agriculture products, J	4.46E+15	2.00E+05	F	8.92
32	Livestock, meat, fish, J	2.60E+15	2.00E+06	F	51.94
33	Wood, paper,textiles, J	6.80E+14	3.49E+04	D	0.24
34	Chemicals, g	9.76E+10	3.80E+08	D	0.37
35	Plastics & rubber, J	2.71E+10	3.80E+08	D	0.10
36	Mechanical & transport. equip., g	3.43E+08	6.70E+09	D	0.02
37	Service in exports, USD	2.95E+08	2.58E+13	G	75.96

Notes to A.1. Emergy evaluation of Denmark, 1936.
The codes listed in the import and export sections refer to the trade category codes used in the Danish statistical abstracts.

RENEWABLE RESOURCES:

1 SOLAR ENERGY:
Total area = 1.12E+11 m2. Cont. Shelf Area = 6.86E+10 m2 at 200 m depth (WRI, 1994), Land area = 4.31E+10 m2 (Statistics Denmark, 1999a). Insolation = 3.70E+03 MJ/m2/yr (Mean value; The Royal Danish Geographic Institute, 1986). Albedo = 0.20 [% given as decimal]. Solar Energy Received, J = 1.12E+11 [m2, area incl. shelf] x 3.70E+03 [MJ/m2/yr, avg. insolation] x (1-0.20) [1-albedo] x 1E6 [J/MJ] =

3.31E+20 J/yr

2 WIND ENERGY:
Surface wind is 60% of the wind speed at 1000m; i.e. 40% of the wind speed is absorbed. Average wind speed at ground = 7.0 m/s (* estimate from Statistics Denmark, 1971a; 1937) Energy = 1000 [m, height of boundary layer] x 1.23 [kg/m3, density of air] x 43100000000 [m2, area] x (0.4 [40%] x 7.0 [m/s, wind speed] / 0.6 [60% of wind speed absorbed at ground])2/2 = 5.77E+14 J/yr

3 RAIN, CHEMICAL POTENTIAL ENERGY:
Cont. Shelf Area = 6.86E+10 m2 at 200 m depth (WRI, 1994), Land area = 4.31E+10 m2 (Statistics Denmark, 1971a). Precipitation rate, 1936 = 0.66 m/yr (Statistics Denmark, 1937). Evapotranspiration rate = 0.35 m/yr (47% of rainfall * estimate from Lagerberg et al. (1999). Energy (land), J = 4.31E+10 [m2,area] x 0.66 [m/yr, rainfall] x 0.47 [evapotranspiration] x 1000 [kg/m3] x 4.94E+03 [J/kg Gibbs no.] = 7.68E+16 J/yr. Energy (shelf), J = 6.86E+10 [m2 ,area] x 0.76 [m/yr, rainfall] x1000 [kg/m3] x 4.94E+03 [J/kg Gibbs no.] = 2.61E+17 J/yr. Total energy, J = 2.90E+17 J/yr

4 RAIN, GEOPOTENTIAL ENERGY:
Energy, J = 4.31E+10 [m2 land area, (Statistics Denmark, 1937)] x 0.39 [% runoff rate, given as decimal] x 0.66 [m/yr, precipitation rate, (Statistics Denmark, 1937)] x 30 [m, mean elevation] x 1000 [kg/m3, density of water] x 9.8 [m/s2, gravity] = 2.41E+15 J/yr

5 WAVE ENERGY:
Length of shoreline = 3379000 m (WRI, 1994). Wave energy = 3379000 [m, shore length] x 1/8 x 1025 [kg/m2, density] x 9.8 [m/s2, gravity] x 0.52 [m, height squared] x (9.8 x 6)1/2 [m, mean shoaling depth, (Lagerberg et al., 1999)] x 31.54 E6 [sec/yr] = 2.57E+17 J/yr

6 TIDAL ENERGY:
50% of tidal energy is assumed to be absorbed by shelf. Energy, J = 6.86E+10 [m2, area of shelf] x 0.5 [50%] x 7.06E+02 [tides/y, estimation of 2 tides/day in 365 days] x 0.312 [m, mean tidal range2] x 1.01E+03 [kg/m3, density of seawater] x 9.8m/s2 [gravity] = 2.29E+16 J/yr

7 EARTH CYCLE:
Energy , J = 4.31E+10 [m2, land area] x 1.00E+06 [J/m2, heat flow, estimate from Odum, (1996)] = 4.31E+16 J/yr

INDIGENOUS RENEWABLE ENERGY:

8 AGRICULTURAL PRODUCTION:
See agriculture analysis, 1936, for energy calculations.

9 LIVESTOCK PRODUCTION:
See agriculture analysis, 1936, for energy calculations.

10 FOREST EXTRACTION
2.05E+06 m3 Harvest (Statistics Denmark, 1937). Energy, J = 2.05E+06 [m3] x 0.53E+06 [g/m3, density of wood, (Tsoumis, 1991)] x 0.8 [80% dry material, given as decimal] x 3.6 [Cal/g] x 4186 [J/Cal] = 1.31E+16 J/yr

NONRENEWABLE RESOURCE USE FROM WITHIN DENMARK:

11 COKE
Consumption = 3.02E+05 Tn/yr (Mitchell, 1998). Energy, J = 3.02E+05 [Tn/yr] x 2.9E+10 [J/Tn] = 8.76E+15 J/yr

12 CALCIUM CARBONATE:
Consumption = 3.87E+04 Tn/yr (Statistics Denmark, 1937). Mass(g) = 3.87E+04 [Tn/yr] x 1E6 [g/Tn] = 3.87E+10 g/yr

13 MINERALS:
Production = 1.04E+06 Tn/yr (Statistics Denmark, 1937) Codes V,X. Mass (g) = 1.04E+06 [Tn/yr] x 1E6 [g/Tn] = 1.04E+12 g/yr

14 TOPSOIL:
Energy, J = 6.51E+14 [J/yr, (Schjønning, 1995)] see 1936 agriculture analysis for energy calculations.

IMPORTS OF OUTSIDE ENERGY SOURCES:

15 COAL:
Imports = 5.84E+06 Tn/yr (Statistics Denmark, 1937), Code V: Coal, coke, and briquettes. Energy, J = 5.84E+06 [Tn/yr] x 3.18 E10 [J/Tn] = 1.86E+17 J/yr

16 CRUDE OIL:
Imports = 2.84E+05 Tn/yr (Statistics Denmark, 1937), Code N: Petroleum/Gasoline. Energy, J = 2.84E+05 [Tn/yr] x 7.3 [bbl/Tn] x 6.1 E9 [J/barrel] = 1.27E+16 J/yr

17 GAS/FUEL OIL:

Imports = 2.84E+05 Tn/yr (Statistics Denmark, 1937), Code N, Fuel oil, duty-free. Energy, J = 7.61E+06 [Tn/yr] x 6.9 [bbl/Tn] x 5.83 E6 [Btu/bbl] x 1054 [J/Btu] = 3.23E+17 J/yr

18 OIL DERIVED PRODUCTS:
Imports = 1.97E+05 Tn/yr (Statistics Denmark, 1937), Code N: lamp oil, lubric. oil, asphalt. Energy, J = 1.97E+05 [Tn/yr] x 6.4 [bbl/Tn] x 5.83 E6 [Btu/bbl] x 1054 [J/Btu] = 7.74E+15 J/yr

19 METALS:
Imports = 5.49E+05 Tn/yr (Statistics Denmark, 1937), Codes; Y, Z. Mass (g) = 5.49E+05 [Tn/yr] x 1E+6 [g/Tn] = 5.49E+11 g/yr

20 MINERALS:
Imports = 3.62E+05 Tn/yr (Statistics Denmark, 1937), Codes V,X. Mass (g) = 3.62E+05 [Tn/yr] x 1E+6 [g/Tn] = 3.62E+11 g/yr

21 FOOD and AGRICULTURAL PRODUCTS:
Imports = 2.21E+06 Tn/yr (Statistics Denmark, 1937), Codes; C,D,E,F,G, some of N,R,T. Energy, J = 2.21E+06 [Tn/yr] x 1E+6 [g/Tn] x 3.5 [Kcal/g] x 4186 [J/Kcal] x 0.8 [80% dry matter] = 2.59E+16 J/yr

22 LIVESTOCK, MEAT, FISH:
Imports = 7.95E+04 Tn/yr (Statistics Denmark, 1937), Codes; A,B. Energy, J = 7.95E+04 [Tn/yr] x 1E+6 [g/Tn] x 5 [Kcal/g] x 4186 [J/Kcal] x 0.22 [22% protein by weight] = 3.66E+14 J/yr

23 FISHERIES PRODUCTION:
Fish Catch = 8.70E+04 Tn/yr, data for 1935 (Mitchell, 1998). Energy, J = 8.70E+04 [Tn/yr] x 1E+06 [g/Tn] x 5 [Cal/g] x 0.2 [20% protein content by weight] x 4186 [J/Cal] = 3.64E+14 J/yr

24 PLASTICS & RUBBER:
Imports = 6.87E+03 Tn/yr (Statistics Denmark, 1937), Codes; O, some of N. Mass (g) = 6.87E+03 [Tn/yr] x 1E+6 [g/Tn] = 6.87E+09 g/yr

25 CHEMICALS:
Imports = 5.80E+05 Tn/yr (Statistics Denmark, 1937), Code U. Mass (g) = 5.80E+05 [Tn/yr] x 1E+6 [g/Tn] = 5.80E+11 g/yr

26 WOOD, PAPER, TEXTILES,LEATHER:
Imports = 7.43E+05 Tn/yr (Statistics Denmark, 1937), [Mix of imports approx. 60% wood, 35% paper, 5%, leather and textiles] Codes H,I,J,K,L,M,P,Q,S. Energy, J = 7.43E+05 [Tn/yr] x 1E+6 [g/Tn] x 1.5E+4 [J/g] = 1.11E+16 J/yr

27 MACHINERY, TRANSPORTATION, EQUIPMENT:
Imports = 2.92E+04 Tn/yr (Statistics Denmark, 1937), Code Æ. Mass (g) = 2.92E+04 [Tn/yr] x 1E+6 [g/Tn] = 2.92E+10 g/yr

28 IMPORTED SERVICES:
USD Dollar value = 3.30E+08 USD (Statistics Denmark, 1937) [Main trading partners, Germany, Sweden, UK, Netherlands, USA, Italy, and France, in terms of economic value.]

EXPORTS OF ENERGY, MATERIALS AND SERVICES:

29 METALS:
Exports = 1.20E+05 Tn/yr (Statistics Denmark, 1937), Codes; Y, Z. Mass (g) = 1.20E+05 [Tn/yr] x 1E+6 [g/Tn] = 1.20E+11 g/yr

30 MINERALS:
Exports = 6.14E+05 Tn/yr (Statistics Denmark, 1937), Codes V,X. Mass (g) = 6.14E+05 [Tn/yr] x 1E+6 [g/Tn] = 6.14E+11 g/yr

31 FOOD and AGRICULTURAL PRODUCTS:
Exports = 3.81E+05 Tn/yr (Statistics Denmark, 1937) Codes; C,D,E,F,G,R,T, some of N. Energy, J = 5.89E+06 [Tn/yr] x 1E+6 [g/Tn] x 3.5 [Kcal/g] x 4186 [J/Kcal] x 0.8 [80% dry matter] = 4.46E+15 J/yr

32 LIVESTOCK, MEAT, FISH:
Exports = 5.64E+05 Tn/yr (Statistics Denmark, 1937), Codes, 01,02,03,04,05. Energy, J = 5.64E+05 [Tn/yr] x 1E+6 [g/Tn] x 5 [Kcal/g] x 4186 [J/Kcal] x 0.22 [22% protein by weight] = 2.60E+15 J/yr

33 WOOD, PAPER, TEXTILES,LEATHER:
Exports = 5.64E+04 Tn/yr (Statistics Denmark, 1937), Codes H,I,J,K,L,M,P,Q,S. Energy, J = 5.64E+04 [Tn/yr] x 1E+6 [g/Tn] x 1.5E+4 [J/g] = 6.80E+14 J/yr

34 CHEMICALS:
Exports = 9.76E+04 Tn/yr (Statistics Denmark, 1937), Code U. Mass (g) = 9.76E+04 [Tn/yr] x 1E+6 [g/Tn] = 9.76E+10 g/yr

35 PLASTICS & RUBBER:
Exports = 3.43E+02 Tn/yr (Statistics Denmark, 1937), Code; O. Mass (g) = 3.43E+02 [Tn/yr] x 1E+6 [g/Tn] = 3.43E+08 g/yr

36 MACHINERY, TRANSPORTATION, EQUIPMENT:

Exports = 2.71E+04 Tn/yr (Statistics Denmark, 1937), Code AE. Mass (g) = 2.71E+04 [Tn/yr] x 1E+6 [g/Tn] = 2.71E+10 g/yr

37 SERVICES IN EXPORTS:

USD Dollar Value = 2.95E+08 USD (Statistics Denmark, 1937)

Table A.2. Emergy evaluation of Denmark, 1970.

Note	Item, unit	Data (units/year)	Transformity (sej/unit)	Ref. for Transform.	Solar Emergy (E20 sej/yr)
RENEWABLE RESOURCES:					
1	Sunlight, J	3.31E+20	1.00E+00	A	3.31
2	Wind, kinetic energy, J	5.77E+14	1.50E+03	A	0.01
3	Rain, chemical, J	3.34E+17	1.82E+04	A	61.50
4	Rain, geopotential, J	3.67E+15	2.79E+04	A	1.06
5	Waves, J	2.57E+17	3.06E+04	A	78.37
6	Tide, J	2.29E+16	1.68E+04	A	3.86
7	Earth cycle, J	4.31E+16	3.44E+04	A	14.81
INDIGENOUS RENEWABLE ENERGY:					
8	Renewable energy, J	1.51E+15	6.60E+03	A	0.10
9	Agriculture production, J	2.14E+17	4.66E+04	G	99.72
10	Livestock production, J	3.63E+16	4.02E+05	G	145.93
11	Forest extraction, J	1.21E+16	6.60E+03	C	0.80
NONRENEWABLE SOURCES FROM WITHIN SYSTEM:					
12	Oil, J	8.91E+15	5.40E+04	A	4.81
13	Coal, J	2.90E+15	4.00E+04	A	1.16
14	Metals, g	5.41E+09	1.00E+09	A	0.05
15	Minerals, g	2.28E+12	1.00E+09	A	22.78
16	Top soil, J	1.21E+15	7.40E+04	A	0.90
IMPORTS AND OUTSIDE SOURCES:					
17	Coal, J	1.07E+17	4.00E+04	A	42.88
18	Crude oil, J	4.51E+17	5.40E+04	A	243.39
19	Gas/fuel oil, J	3.23E+17	6.60E+04	A	212.95
20	Oil derived products, J	1.40E+17	6.60E+04	A	92.64
21	Metals, g	1.86E+12	9.20E+08	D	17.10
22	Minerals, g	2.43E+12	1.00E+09	A	24.27
23	Food & agriculture products, J	2.84E+16	2.00E+05	F	56.85
24	Livestock, meat, fish, J	1.87E+15	2.00E+06	F	37.33
25	Fisheries production, J	5.19E+15	1.20E+06	H	62.30
26	Plastics & rubber, g	3.33E+11	3.80E+08	D	1.27
27	Chemicals, g	1.71E+12	3.80E+08	D	6.50
28	Wood, paper, textiles, J	2.94E+16	3.49E+04	G*	10.25
29	Mechanical & transport. equip., g	7.62E+11	6.70E+09	D	51.06
30	Service in imports, USD	4.38E+09	9.58E+12	A	420.04
31	Tourism, USD	2.60E+08	9.58E+12	A	24.94
EXPORTS:					
32	Coal	6.68E+11	5.30E+04	A	0.00
33	Crude oil	8.02E+11	5.40E+04	A	0.00
34	Gas/fuel oil, J	3.55E+16	6.60E+04	A	23.41
35	Oil derived products, J	4.13E+16	6.60E+04	A	27.24
36	Metals, g	4.03E+11	9.20E+08	D	3.71
37	Minerals, g	3.97E+12	1.00E+09	A	39.71
38	Food & agriculture products, J	1.91E+16	2.00E+05	F	38.11
39	Livestock, meat, fish, J	6.80E+15	2.00E+06	F	135.95
40	Wood, paper, textiles, J	1.01E+16	3.49E+04	D	3.52
41	Chemicals, g	2.67E+11	3.80E+08	D	1.02
42	Mechanical & transport. equip., g	5.30E+11	6.70E+09	D	35.52
43	Plastics & rubber, g	7.98E+10	3.80E+08	D	0.30
44	Service in exports, USD	3.29E+09	9.58E+12	G	315.10

Footnotes to Table A.2. Emergy evaluation of Denmark, 1970.
The codes listed in the import and export sections refer to the trade category codes used in the Danish statistical abstracts.

RENEWABLE RESOURCES:

1 SOLAR ENERGY:
Total area = 1.12E+11 m2. Cont. Shelf Area = 6.86E+10 m2 at 200 m depth (WRI, 1994), Land area = 4.31E+10 m2 (Statistics Denmark, 1999a). Insolation = 3.70E+03 MJ/m2/yr (The Royal Danish Geographic Institute, 1986). Albedo = 0.20 [% given as decimal]. Solar Energy Received, J = 1.12E+11 [m2, area incl. shelf] x 3.70E+03 [MJ/m2/yr, avg. insolation] x (1-0.20) [1-albedo] x 1E6 [J/MJ] = 3.31E+20 J/yr

2 WIND ENERGY:
Surface wind is 60% of the wind speed at 1000m; i.e. 40% of the wind speed is absorbed. Average wind speed at ground = 7.0 m/s (Statistics Denmark, 1971a). Energy = 1000 [m, height of boundary layer] x 1.23 [kg/m3, density of air] x 43100000000 [m2, area] x (0.4 [40%] x 7.0 [m/s, wind speed] / 0.6 [60% of wind speed absorbed at ground])2/2 = 5.77E+14 J/yr

3 RAIN, CHEMICAL POTENTIAL ENERGY:
Cont. Shelf Area = 6.86E+10 m2 at 200 m depth (WRI, 1994), Land area = 4.31E+10 m2 (Statistics Denmark, 1971a). Precipitation rate, 1999 = 0.76 m/yr (Statistics Denmark, 1971a). Evapotranspiration rate = 0.35 m/yr (47% of rainfall * estimate from Lagerberg et al. (1999)). Energy (land), J = 4.31E+10 [m2,area] x 0.76 [m/yr, rainfall] x 0.47 [evapotranspiration] x 1000 [kg/m3] x 4.94E+03 [J/kg Gibbs no.] = 7.68E+16 J/yr. Energy (shelf), J = 6.86E+10 [m2 ,area] x 0.76 [m/yr, rainfall] x 1000 [kg/m3] x 4.94E+03 [J/kg Gibbs no.] = 2.61E+17 J/yr. Total energy, J = 3.34E+17 J/yr

4 RAIN, GEOPOTENTIAL ENERGY:
Energy, J = 4.31E+10 [m2 land area, (Statistics Denmark, 1971a)] x 0.39 [% runoff rate, given as decimal] x 0.76 [m/yr, precipitation rate, (Statistics Denmark, 1971a)] x 30 [m, mean elevation] x 1000 [kg/m3, density of water] x 9.8 [m/s2, gravity] = 3.67E+15 J/yr

5 WAVE ENERGY:
Length of shoreline = 3379000 m (WRI, 1994)
Wave energy = 3379000 [m, shore length] x 1/8 x 1025 [kg/m2, density] x 9.8 [m/s2, gravity] x 0.52 [m, height squared] x (9.8 x 6)1/2 [m, mean shoaling depth, (Lagerberg et al., 1999)] x 31.54 E6 [sec/yr] = 2.57E+17 J/yr

6 TIDAL ENERGY:
50% of tidal energy is assumed to be absorbed by shelf. Energy, J = 6.86E+10 [m2, area of shelf] x 0.5 [50%] x 7.06E+02 [tides/y, estm. of 2 tides/day in 365 days] x 0.312 [m, mean tidal range2] x 1.01E+03 [kg/m3, density of seawater] x 9.8m/s2 [gravity] = 2.29E+16 J/yr

7 EARTH CYCLE:
Energy, J = 4.31E+10 [m2, land area] x 1.00E+06 [J/m2, heat flow, estimate from Odum (1996)] = 4.31E+16 J/yr

INDIGENOUS RENEWABLE ENERGY:

8 RENEWABLE ENERGY:
Consumption = 100000 Tn/yr [mostly forestry waste] (Statistics Denmark, 1971a). Energy, J = 1E+05 [Tn, forest waste] x 1E+06 [g/Tn] x 3.6 [Cal/g] x 4186 [J/Cal] = 1.51E+15 J/yr

9 AGRICULTURAL PRODUCTION:
See agriculture analysis, 1970, for energy calculations.

10 LIVESTOCK PRODUCTION:
See agriculture analysis, 1970, for energy calculations.

11 FOREST EXTRACTION
1.90E+06 m3 Harvest (Statistics Denmark, 1971b). Energy, J = 1.90E+06 [m3] x 0.53E+06 [g/m3, density of wood, (Tsoumis, 1991)] x 0.8 [80% dry material, given as decimal] x 3.6 [Cal/g] x 4186 [J/Cal] = 1.21E+16 J/yr

NONRENEWABLE RESOURCE USE FROM WITHIN DENMARK:

12 CRUDE OIL, production
Production = 2.00E+05 Tn (Statistics Denmark, 1971a). Energy, J = 2.00E+05 [Tn] x 7.3 [bbl/Tn] x 6.1 E9 [J/bbl] = 8.91E+15 J/yr

13 COAL
Production = 1.00E+05 Tn/yr (Mitchell, 1998). Energy, J = 1.00E+05 [Tn/yr] x 2.9E+10 [J/Tn] = 2.90E+15 J/yr

14 METALS: (Au,Ag,Pb,Cu,Zn,Fe,Mn,Mo)
Production = 5.41E+05 Tn/yr (Statistics Denmark, 1971a). Mass(g) = 5.41E+05 [Tn/yr] x 1E6 [g/MT] = 5.41E+09 g/yr

15 MINERALS:

Production = 2.28E+06 Tn/yr Data from 1968 (Statistics Denmark, 1971a). Mass (g) = 2.28E+06 [Tn/yr] x 1E6 [g/Tn] = 2.28E+12 g/yr

16 TOPSOIL:
Energy, J = 1.21E+15 [J/yr, (Schjønning, 1995)] see 1970 agriculture analysis for energy calculations

IMPORTS OF OUTSIDE ENERGY SOURCES:

17 COAL:
Imports = 3.37E+06 Tn/yr (Statistics Denmark, 1971a), Code 27.01.11-20. Energy, J = 3.37E+06 [Tn/yr] x 3.18 E10 [J/Tn] = 1.07E+17 J/yr

18 CRUDE OIL:
Imports = 1.01E+07 Tn/yr (Statistics Denmark, 1971a), Code 27.09. Energy, J = 1.01E+07 [Tn/yr] x 7.3 [bbl/Tn] x 6.1 E9 [J/barrel] = 4.51E+17 J/yr

19 GAS/FUEL OIL:
Imports = 7.61E+06 Tn/yr (Statistics Denmark, 1971a), Codes 27.51.2, 27.55.2. Energy, J = 7.61E+06 [Tn/yr] x 6.9 [bbl/Tn] x 5.83 E6 [Btu/bbl] x 1054 [J/Btu] = 3.23E+17 J/yr

20 OIL DERIVED PRODUCTS:
Imports = 3.57E+06 Tn/yr (Statistics Denmark, 1971a), Code 27, all excluding 27.01.11-20, 27.09, 27.51.2, 27.55.2. Energy, J = 3.57E+06 [Tn/yr] x 6.4 [bbl/Tn] x 5.83 E6 [Btu/bbl] x 1054 [J/Btu] = 1.40E+17 J/yr

21 METALS:
Imports = 1.86E+06 Tn/yr (Statistics Denmark, 1971a), Codes 73,74,75,76,77,78,79,80,81,82, 83. Mass (g) = 1.86E+06 [Tn/yr] x 1E+6 [g/Tn] = 1.86E+12 g/yr

22 MINERALS:
Imports = 2.43E+06 Tn/yr (Statistics Denmark, 1971a), Codes 25,26,68. Mass (g) = 2.43E+06 [Tn/yr] x 1E+6 [g/Tn] = 2.43E+12 g/yr

23 FOOD and AGRICULTURAL PRODUCTS:
Imports = 2.43E+06Tn/yr (Statistics Denmark, 1971a), Codes 6,7,8,9,10,11,12,13,14,17,18, 19,20,21,22,23,24. Energy, J = 2.43E+06 [Tn/yr] x 1E+6 [g/Tn] x 3.5 [Kcal/g] x 4186 [J/Kcal] x 0.8 [80% dry matter] = 2.84E+16 J/yr

24 LIVESTOCK, MEAT, FISH:
Imports = 4.05E+05 Tn/yr (Statistics Denmark, 1971a), Codes 2,3,4,5,15,16. Energy, J = 4.05E+05 [Tn/yr] x 1E+6 [g/Tn] x 5 [Kcal/g] x 4186 [J/Kcal] x 0.22 [22% protein by weight] = 1.87E+15 J/yr

25 FISHERIES PRODUCTION:
Fish Catch = 1.24E+06 Tn/yr. Data for 1969 (Statistics Denmark, 1971a). Energy, J = 1.24E+06 [Tn/yr] x 1E+06 [g/Tn] x 5 [Cal/g] x 0.2 [20% protein content by weight] x 4186 [J/Cal] = 5.19E+15 J/yr

26 PLASTICS & RUBBER:
Imports = 3.33E+05 Tn/yr (Statistics Denmark, 1971a), Codes 39, 40. Mass (g) = 3.33E+05 [Tn/yr] x 1E+6 [g/Tn] = 3.33E+11 g/yr

27 CHEMICALS:
Imports = 1.71E+06 Tn/yr (Statistics Denmark, 1971a), Codes 28,29,30,31,32,33,34,35,36,37, 38. Mass (g) = 3.05E+06 [Tn/yr] x 1E+6 [g/Tn] = 1.71E+12 g/yr

28 WOOD, PAPER, TEXTILES,LEATHER:
Imports = 1.96E+06 Tn/yr (Statistics Denmark, 1971a), [Mix of imports approx. 60% wood, 35% paper, 5%, leather and textiles] Codes 41,42,43,44,45,46,47,48,49,50,51,52,53,54,55, 56,57,58,59,60,61,62,63,64,65,66,67,94. Energy, J = 1.96E+06 [Tn/yr] x 1E+6 [g/Tn] x 1.5E+4 [J/g] = 2.94E+16 J/yr

29 MACHINERY, TRANSPORTATION, EQUIPMENT:
Imports = 7.62E+05 Tn/yr (Statistics Denmark, 1971a), Codes, 84,85,86,87,88,89,90,91,92,93. Mass (g) = 1.70E+06 [Tn/yr] x 1E+6 [g/Tn] = 7.62E+11 g/yr

30 IMPORTED SERVICES:
USD Dollar value = 4.38E+09USD (Statistics Denmark, 1971a) [Main trading partners, Germany, Sweden, UK, Netherlands, USA, Italy, France in terms of economic value. Sej/$ of trading partners (Switz, Japan, Spain, Netherland, W. Germ., USA) from Odum (1996)]

31 TOURISM :
Dollar Value = 2.60E+08 USD (Statistics Denmark, 1971a)

EXPORTS OF ENERGY, MATERIALS AND SERVICES:

32 COAL:
Exports = 2.10E+01 Tn/yr (Statistics Denmark, 1971a) Code 27.01.11-20. Energy, J = 2.10E+01 [Tn/yr] x 3.18E+10 [J/Tn] = 6.68E+11 J/yr

33 CRUDE OIL:
Exports = 1.80E+01 Tn/yr (Statistics Denmark, 1971a) Code 27.09. Energy, J = 1.80E+01 [Tn] x 7.3 [bbl/Tn] x 6.1E+09 [J/bbl] = 8.02E+11

34 GAS/FUEL OIL:
Exports = 8.37E+05 Tn/yr (Statistics Denmark, 1971a) Codes 27.51.2, 27.55.2. Energy, J = 8.37E+05 [Tn] x 6.4 [bbl/Tn] x 5.83 E6 [Btu/barrel] x 1054 [J/Btu] = 3.55E+16 J/y

35 OIL DERIVED PRODUCTS:
Exports = 1.05E+06 Tn/yr (Statistics Denmark, 1971a) Code 27, all excluding 27.01.11-20, 27.09, 27.51.2, 27.55.2. Energy, J = 1.05E+06 [Tn] x 6.4 [bbl/Tn] x 5.83 E6 [Btu/barrel] x 1054 [J/Btu] = 4.13E+16 J/y

36 METALS:
Exports = 4.03E+05 Tn/yr (Statistics Denmark, 1971a), Codes, 73,74,75,76,77,78,79,80,81,82, 83. Mass (g) = 4.03E+05 [Tn/yr] x 1E+6 [g/Tn] = 4.03E+11 g/yr

37 MINERALS:
Exports = 3.97E+06 Tn/yr (Statistics Denmark, 1971a), Codes, 25,26,68. Mass (g) = 3.97E+06 [Tn/yr] x 1E+6 [g/Tn] = 3.97E+12 g/yr

38 FOOD and AGRICULTURAL PRODUCTS:
Exports = 1.63E+06 Tn/yr (Statistics Denmark, 1971a) Codes 06,07,08,09,10,11,12,13,14,17, 18,19,20,21,22,23,24. Energy, J = 5.89E+06 [Tn/yr] x 1E+6 [g/Tn] x 3.5 [Kcal/g] x 4186 [J/Kcal] x 0.8 [80% dry matter] = 1.91E+16 J/yr

39 LIVESTOCK, MEAT, FISH:
Exports = 1.48E+06 Tn/yr (Statistics Denmark, 1971a), Codes, 01,02,03,04,05. Energy, J = 1.48E+06 [Tn/yr] x 1E+6 [g/Tn] x 5 [Kcal/g] x 4186 [J/Kcal] x 0.22 [22% protein by weight] = 6.80E+15 J/yr

40 WOOD, PAPER, TEXTILES,LEATHER:
Exports = 8.35E+05 Tn/yr (Statistics Denmark, 1971a), Codes 41,42,43,44,45,46,47,48,49,50, 51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,94. Energy, J = 8.35E+05 [Tn/yr] x 1E+6 [g/Tn] x 1.5E+4 [J/g] = 1.01E+16 J/yr

41 CHEMICALS:
Exports = 2.67E+05 Tn/yr (Statistics Denmark, 1971a), Codes 28,29,30,31,32,33,34,35,36,37, 38. Mass (g) = 2.67E+05 [Tn/yr] x 1E+6 [g/Tn] = 2.67E+11 g/yr

42 MACHINERY, TRANSPORTATION, EQUIPMENT:
Exports = 5.30E+05 Tn/yr (Statistics Denmark, 1971a), Codes, 84,85,86,87,88,89,90,91,92,93 Mass (g) = 5.30E+05 [Tn/yr] x 1E+6 [g/Tn] = 5.30E+11 g/yr

43 PLASTICS & RUBBER:
Exports = 7.98E+04 Tn/yr (Statistics Denmark, 1971a), Codes 39, 40. Mass (g) = 7.98E+04 [Tn/yr] x 1E+6 [g/Tn] = 7.98E+10 g/yr

44 SERVICES IN EXPORTS:
USD Dollar Value = 3.29E+09 USD (Statistics Denmark, 1971a)

Table A.3. Emergy evaluation of Denmark, 1999.

Note	Item	Raw Units	Transformity (sej/unit)	Ref. for Transf.	Solar Emergy (E20 sej/yr)
	RENEWABLE RESOURCES:				
1	Sunlight, J	3.31E+20	1.00E+00	A	3.31
2	Wind, kinetic energy, J	6.80E+14	1.50E+03	A	0.01
3	Rain, chemical, J	3.38E+17	1.82E+04	A	61.47
4	Rain, geopotential, J	3.77E+15	2.79E+04	A	1.05
5	Waves, J	2.57E+17	3.06E+04	A	78.37
6	Tide, J	2.29E+16	1.68E+04	A	3.86
7	Earth cycle, J	4.31E+16	3.44E+04	A	14.81
	INDIGENOUS RENEWABLE ENERGY				
8	Renewable electricity, J	8.10E+16	1.35E+05	A	109.61
9	Agriculture production, J	2.36E+17	3.31E+04	G	78.12
10	Livestock production, J	4.56E+16	2.58E+05	G	117.65
11	Forest extraction, J	1.10E+16	6.60E+03	C	0.72
	NONRENEWABLE SOURCES FROM WITHIN SYSTEM:				
12	Natural gas, production, J	2.78E+17	4.80E+04	A	133.23
13	Natural gas, consumption, J	1.55E+17	4.80E+04	A	74.44
14	Oil, production, J	6.65E+17	5.40E+04	A	359.27
15	Oil, consumption, J	4.98E+17	5.40E+04	A	268.79
16	Calcium carbonate, g	3.34E+12	1.00E+09	A	33.43
17	Minerals, g	4.45E+13	1.00E+09	A	445.15
18	Top soil, J	3.19E+15	7.40E+04	A	2.36
	IMPORTS AND OUTSIDE SOURCES:				
19	Coal, J	2.28E+17	4.00E+04	A	91.32
20	Crude oil, J	4.51E+17	5.40E+04	A	243.39
21	Oil derived products, J	2.14E+17	6.60E+04	A	141.17
22	Metals, g	3.25E+12	9.20E+08	D	29.90
23	Minerals, g	6.39E+12	1.00E+09	A	63.95
24	Food & agriculture products, J	6.99E+16	2.00E+05	F	139.79
25	Livestock, meat, fish, J	6.74E+15	2.00E+06	F	134.81
26	Fisheries production, J	5.71E+15	1.20E+06	H	68.53
27	Plastics & rubber, g	1.02E+12	3.80E+08	D	3.87
28	Chemicals, g	3.05E+12	3.80E+08	D	11.59
29	Wood, paper, textiles, J	7.24E+16	4.40E+04	G*	31.87
30	Mechanical & transport. equip., g	1.70E+12	6.70E+09	D	113.67
31	Service in imports, USD	4.45E+10	1.95E+12	G	868.56
32	Tourism, USD	3.07E+09	1.67E+12	G	51.17
	EXPORTS:				
33	Coal, J	6.42E+15	4.00E+04	A	2.57
34	Crude Oil, J	4.02E+17	5.40E+04	A	216.85
35	Oil derived products, J	1.87E+17	6.60E+04	A	123.11
36	Natural Gas, J	1.10E+17	4.80E+04	A	52.77
37	Metals, g	2.74E+12	9.20E+08	D	25.22
38	Minerals, g	4.97E+12	1.00E+09	A	49.66
39	Food & agriculture products, J	6.91E+16	2.00E+05	F	138.19
40	Livestock, meat, fish, J	1.41E+16	2.00E+06	F	281.82
41	Wood, paper, textiles, J	2.74E+16	4.40E+04	G*	12.06
42	Chemicals, g	1.43E+13	3.80E+08	D	54.51
43	Mech. & trans. equip., g	1.57E+12	6.70E+09	D	105.50
44	Plastics & rubber, g	2.13E+11	3.80E+08	D	0.81
45	Service in exports, USD	4.95E+10	1.67E+12	G	825.11

Footnotes to Table A.3. Emergy evaluation of Denmark, 1999.
The codes listed in the import and export sections refer to the trade category codes used in the Danish statistical abstracts.

RENEWABLE RESOURCES:

1 SOLAR ENERGY:
Total area = 1.12E+11 m2. Cont. Shelf Area = 6.86E+10 m2 at 200 m depth (WRI, 1994), Land area = 4.31E+10 m2 (Statistics Denmark, 1999a). Insolation = 3.70E+03 MJ/m2/yr (The Royal Danish Geographic Institute, 1986). Albedo = 0.20 [% given as decimal]. Solar Energy Received, J = 1.12E+11 [m2, area incl. shelf] x 3.70E+03 [MJ/m2/yr, avg. insolation] x (1-0.20) [1-albedo] x 1E6 [J/MJ] = 3.31E+20 J/yr

2 WIND ENERGY:
Surface wind is 60% of the wind speed at 1000m; i.e. 40% of the wind speed is absorbed. Average wind speed at ground = 7.6 m/s (*Data for 1998, (Statistics Denmark, 1999a)). Energy = 1000 [m, height of boundary layer] x 1.23 [kg/m3, density of air] x 43100000000 [m2, area] x (0.4 [40%] x 7.6 [m/s, wind speed] / 0.6 [60% of wind speed absorbed at ground])2/2 = 6.80E+14 J/yr

3 RAIN, CHEMICAL POTENTIAL ENERGY:
Cont. Shelf Area = 6.86E+10 m2 at 200 m depth (WRI, 1994), Land area = 4.31E+10 m2 (Statistics Denmark, 1999a). Precipitation rate, 1999 = 0.77 m/yr (Statistics Denmark, 1999a). Evapotranspiration rate = 0.35 m/yr (47% of rainfall * estimate from Lagerberg et al. (1999)). Energy (land), J = 4.31E+10 [m2,area] x 0.77 [m/yr, rainfall] x 0.47 [evapotranspiration] x 1000 [kg/m3] x 4.94E+03 [J/kg Gibbs no.] = 7.68E+16 J/yr. Energy (shelf), J = 6.86E+10 [m2 ,area] x 0.77 [m/yr, rainfall] x 1000 [kg/m3] x 4.94E+03 [J/kg Gibbs no.] = 2.61E+17 J/yr. Total energy, J = 3.38E+17 J/yr

4 RAIN, GEOPOTENTIAL ENERGY:
Energy, J = 4.31E+10 [m2 land area, (Statistics Denmark, 1999a)] x 0.39 [% runoff rate, given as decimal] x 0.77 [m/yr, precipitation rate, (Statistics Denmark, 1999a)] x 30 [m, mean elevation] x 1000 [kg/m3, density of water] x 9.8 [m/s2, gravity] = 3.77E+15 J/yr

5 WAVE ENERGY:
Length of shoreline = 3379000 m (WRI, 1994). Wave energy = 3379000 [m, shore length] x 1/8 x 1025 [kg/m2, density] x 9.8 [m/s2, gravity] x 0.52 [m, height squared] x (9.8 x 6)1/2 [m, mean shoaling depth (Lagerberg et al., 1999)] x 31.54 E6 [sec/yr] = 2.57E+17 J/yr

6 TIDAL ENERGY:
50% of tidal energy is assumed to be absorbed by shelf. Energy, J = 6.86E+10 [m2, area of shelf] x 0.5 [50%] x 7.06E+02 [tides/y, estm. of 2 tides/day in 365 days] x 0.312 [m, mean tidal range2] x 1.01E+03 [kg/m3, density of seawater] x 9.8m/s2 [gravity] = 2.29E+16 J/yr

7 EARTH CYCLE:
Energy, J = 4.31E+10 [m2, land area] x 1.00E+06 [J/m2, heat flow, estimate from Odum (1996)] = 4.31E+16 J/yr

INDIGENOUS RENEWABLE ENERGY:

8 RENEWABLE ENERGY:
Energy, J = 8.10E+16 J/yr [Mostly straw, wind and waste combustion (Statistics Denmark, 2001)]

9 AGRICULTURAL PRODUCTION:
See agriculture analysis, 1999, for energy calculations

10 LIVESTOCK PRODUCTION:
See agriculture analysis, 1999, for energy calculations.

11 FOREST EXTRACTION
1.72E+06 m3 Harvest (Statistics Denmark, 1999b). Energy, J = 1.72E+06 [m3] x 0.53E+06 [g/m3, density of wood, (Tsoumis, 1991)] x 0.8 [80% dry material, given as decimal] x 3.6 [Cal/g] x 4186 [J/Cal] = 1.10E+16 J/yr

NONRENEWABLE RESOURCE USE FROM WITHIN DENMARK:

12 NATURAL GAS, production
Production = 7.45E+09 m3/yr. 1997 figures (Statistics Denmark, 1999a). Energy, J = 7.45E+09 [m3/yr] x 35.31 [m3/ft3] x 1.055E+6 [J/ft3] = 2.78E+17 J/yr

13 NATURAL GAS, consumption
Consumption = 4.16E+09 m3/yr *1997 figures (Statistics Denmark, 1999a). Energy, J = 4.16E+09 [m3/yr] x 35.31 [m3/ft3] x 1.055E+6 [J/ft3] = 1.55E+17 J/yr

14 CRUDE OIL, production
Production = 1.49E+07 Tn (Statistics Denmark, 2001). Energy, J = 1.49E+07 [Tn] x 7.3 [bbl/Tn] x 6.1 E9 [J/bbl] = 6.65E+17 J/yr

15 CRUDE OIL, consumption
Consumption = 1.12E+07 Tn, (Statistics Denmark, 2001). Energy, J = 1.12E+07 [Tn] x 7.3 [bbl/Tn] x 6.1 E9 [J/bbl] = 4.98E+17 J/yr

16 CALCIUM CARBONATE:

Production = 3.34E+06 Tn/yr (Statistics Denmark, 2001). Mass (g) = 3.34E+06 [Tn/yr] x 1E6 [g/Tn] = 3.34E+12 g/yr

17 MINERALS:
Production = 4.45E+07 Tn/yr production after subtracting calcium carb. (Statistics Denmark, 2001). Mass (g) = 4.45E+07 [Tn/yr] x 1E6 [g/Tn] = 4.45E+13 g/yr

18 TOPSOIL:
Energy, J = 3.19E+15 [J/yr, (Schjønning, 1995)] see 1999 agriculture analysis for energy calculations

IMPORTS OF OUTSIDE ENERGY SOURCES:

19 COAL:
Imports = 7.18E+06 Tn/yr (Statistics Denmark, 2001). Energy, J = 7.18E+06 [Tn/yr] x 3.18 E10 [J/Tn] = 2.28E+17 J/yr

20 CRUDE OIL:
Imports = 5.30E+06 Tn/yr (Statistics Denmark, 2001). Energy, J = 5.30E+06 [Tn/yr, (Statistics Denmark, 2001)] x 7.3 [bbl/Tn] x 6.1 E9 [J/barrel] = 2.36E+17 J/yr

21 OIL DERIVED PRODUCTS:
Imports = 5.44E+06 Tn/yr (Statistics Denmark, 1999c), SITC Code 334. Energy, J = 5.44E+06 [Tn/yr] x 6.4 [bbl/Tn] x 5.83 E6 [Btu/bbl] x 1054 [J/Btu] = 2.14E+17 J/yr

22 METALS:
Imports = 3.25E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 28,67,68,69. Mass (g) = 3.25E+06 [Tn/yr] x 1E+6 [g/Tn] = 3.25E+12 g/yr

23 MINERALS :
Imports = 6.39E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 27,66. Mass (g) = 6.39E+06 [Tn/yr] x 1E+6 [g/Tn] = 6.39E+12 g/yr

24 FOOD and AGRICULTURAL PRODUCTS:
Imports = 5.96E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 04,05,06,07,08,09,10,11, 12,292,421,422. Energy, J = 5.96E+06 [Tn/yr] x 1E+6 [g/Tn] x 3.5 [Kcal/g] x 4186 [J/Kcal] x 0.8 [80% dry matter] = 6.99E+16 J/yr

25 LIVESTOCK, MEAT, FISH:
Imports = 1.46E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 00,01,02,03,291,411, 431. Energy, J = 1.46E+06 [Tn/yr] x 1E+6 [g/Tn] x 5 [Kcal/g] x 4186 [J/Kcal] x 0.22 [22% protein by weight] = 6.74E+15 J/yr

26 FISHERIES PRODUCTION:
1.36E+06 Tn. Total catch landed in Denmark from international waters *data for 1998 (Statistics Denmark, 1999a). Energy, J = 1.36E+06 [Tn] x 1E+06 [g/MT] x 5 [Cal/g] x .2 [20% protein content, as decimal] x 4186 [J/Cal] = 5.71E+15 J/yr

27 PLASTICS & RUBBER:
Imports = 1.02E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 231,232,57,58,62. Mass (g) = 1.02E+06 [Tn/yr] x 1E+6 [g/Tn] = 1.02E+12 g/yr

28 CHEMICALS:
Imports = 3.05E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 51,52,53,54,55,56,59 Mass (g) = 3.05E+06 [Tn/yr] x 1E+6 [g/Tn] = 3.05E+12 g/yr

29 WOOD, PAPER, TEXTILES,LEATHER:
Imports = 4.83E+06 Tn/yr (Statistics Denmark, 1999c), [Mix of imports approx. 60% wood, 35% paper, 5%, leather and textiles] SITC Codes 21,24,25,26,61,63,64,65,81,82,83,84,85 Energy, J = 4.83E+06 [Tn/yr] x 1E+6 [g/Tn] x 1.5E+4 [J/g] = 7.24E+16 J/yr

30 MACHINERY, TRANSPORTATION, EQUIPMENT:
Imports = 1.70E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 71,72,73,74,75,76,77,78, 79,87,88,89. Mass (g) = 1.70E+06 [Tn/yr] x 1E+6 [g/Tn] = 1.70E+12 g/yr

31 IMPORTED SERVICES:
USD Dollar value = 4.45E+10 USD (Statistics Denmark, 1999c) [Main trading partners, Germany, Sweden, UK, Netherlands, USA, Italy, France in terms of economic value. Sej/$ of trading partners (Switz, Japan, Spain, Netherland, W. Germ., USA) from Odum (1996)]

32 TOURISM :
Dollar Value = 3.07E+09 USD (Statistics Denmark, 1999c) [Sej/$ of trading partners (Switz, Japan, Spain, Netherland, W. Germ., USA) from Odum (1996)]

EXPORTS OF ENERGY, MATERIALS AND SERVICES:

33 COAL:
Exports = 2.02E+05 Tn/yr (Statistics Denmark, 2001). Energy, J = 2.02E+05 [Tn/yr] x 3.18E+10 [J/Tn] =

6.42E+15 J/yr

34 CRUDE OIL:
Exports = 9.02E+06 Tn/yr (Statistics Denmark, 2001). Energy, J = 9.02E+06 [Tn] x 7.3 [bbl/Tn] x 6.1E+09 [J/bbl] = 4.02E+17 J/yr

35 OIL DERIVED PRODUCTS:
Exports = 4.74E+06 Tn/yr (Statistics Denmark, 2001). Energy, J = 4.74E+06 [Tn] x 6.4 [bbl/Tn] x 5.83 E6 [Btu/barrel] x 1054 [J/Btu] = 1.87E+17 J/yr

36 NATURAL GAS:
Exports = 2.95E+09 m3/yr (Statistics Denmark, 1999c). Energy, J = 2.95E+09 [m3/yr] x 35.31 [ft3/m3] x 1.055E+6 [J/ft3] = 1.10E+17 J/yr

37 METALS:
Exports = 2.74E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 28,67,68,69. Mass (g) = 2.74E+06 [Tn/yr] x 1E+6 [g/Tn] = 2.74E+12 g/yr

38 MINERALS:
Exports = 4.97E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 27,66. Mass (g) = 4.97E+06 [Tn/yr] x 1E+6 [g/Tn] = 4.97E+12 g/yr

39 FOOD and AGRICULTURAL PRODUCTS:
Exports = 5.89E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 04,05,06,07,08,09,10,11, 12,292,421,422. Energy, J = 5.89E+06 [Tn/yr] x 1E+6 [g/Tn] x 3.5 [Kcal/g] x 4186 [J/Kcal] x 0.8 [80% dry matter] = 6.91E+16 J/yr

40 LIVESTOCK, MEAT, FISH:
Exports = 3.06E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 00,01,02,03,291,411,431. Energy, J = 1.46E+06 [Tn/yr] x 1E+6 [g/Tn] x 5 [Kcal/g] x 4186 [J/Kcal] x 0.22 [22% protein by weight] = 1.41E+16 J/yr

41 WOOD, PAPER, TEXTILES,LEATHER:
Exports = 2.27E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 21,24,25,26,61,63,64,65, 81,82,83,84,85. Energy, J = 2.27E+06 [Tn/yr] x 1E+6 [g/Tn] x 1.5E+4 [J/g] = 2.74E+16 J/yr

42 CHEMICALS:
Exports = 1.43E+07 Tn/yr (Statistics Denmark, 1999c), SITC Codes 51,52,53,54,55,56,59. Mass (g) = 3.05E+06 [Tn/yr] x 1E+6 [g/Tn] = 1.43E+13 g/yr

43 MACHINERY, TRANSPORTATION, EQUIPMENT:
Imports = 1.57E+06 Tn/yr (Statistics Denmark, 1999c), SITC Codes 71,72,73,74,75,76,77,78, 79,87,88,89. Mass (g) = 1.57E+06 [Tn/yr] x 1E+6 [g/Tn] = 1.57E+12 g/yr

44 PLASTICS & RUBBER:
Imports = 2.13E+05 Tn/yr (Statistics Denmark, 1999c), SITC Codes 231,232,57,58,62. Mass (g) = 1.02E+06 [Tn/yr] x 1E+6 [g/Tn] = 2.13E+11 g/yr

45 SERVICES IN EXPORTS:
USD Dollar Value = 4.95E+10 USD (Statistics Denmark, 1999c)

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Appendix B - Emergy Evaluations of Danish Agriculture

Table B.1. Emergy evaluation of Danish agriculture, 1936.

Note	Item, units	Data (units/yr)	Unit Solar EMERGY (sej/unit)	Ref. for Transform.	Solar EMERGY (E20 sej/yr)
RENEWABLE RESOURCES (R)					
1	Sun, J	8.42E+19	1	A	0.84
2	Wind, J	3.54E+14	1.50E+03	A	0.01
3	Rain, J	7.83E+16	1.82E+04	A	14.25
4	Earth cycle, J	3.25E+16	3.40E+04	E	11.05
NONRENEWABLE STORAGES (N)					
5	Net topsoil loss, J	6.51E+14	7.38E+04	A	0.48
Goods for livestock production (F1)					
6	Imported feed, cereals, J	1.17E+16	6.80E+04	D	7.93
7	Imported feed, concentrates, J	1.52E+16	8.00E+04	F	12.13
Commercial energy (F2)					
8	Fuel, J	9.75E+14	6.60E+04	A	0.64
9	Electricity, J	1.30E+15	1.60E+05	A	2.08
Goods for crop production (F3)					
10	Potash, g K	3.25E+10	1.10E+09	A	0.36
11	Phosphate, g P	6.53E+10	1.78E+10	A	11.63
12	Nitrogen, g N	3.19E+10	3.80E+09	A	1.21
Farm assets (F4)					
13	Mechanical equipment, g	2.21E+10	6.70E+09	D	1.48
14	Buildings, USD	2.12E+07	2.22E+13	G	3.81
LABor and serviceS (L+S)					
15	Labor (L), USD	1.51E+08	1.80E+13	G	27.17
16	Services (S), USD	2.51E+08	1.80E+13	G	45.24
CROP YIELD, J					
17	Energy in crop production, J	1.97E+17			
LIVESTOCK YIELD, J					
18	Energy in livestock production, J	2.28E+16			

Footnotes to Table B.1. Emergy analysis of Danish agriculture, 1936.

RENEWABLE RESOURCES:

1 SOLAR ENERGY:
Energy received on land, J = 32,500,000,000 [m2, total land area in agriculture (Statistics Denmark, 1968a)] x 3.70E+03 [MJ/m2/yr, avg. insolation (The Royal Danish Geographic Institute, 1986)] x 1-0.30 [1-albedo] x 1+E6 [J/MJ] = 8.42E+19 J/yr

2 WIND ENERGY:
Surface wind is 60% of the wind speed at 1000m; i.e. 40% of the wind speed is absorbed. Average wind speed at ground = 7.0 m/s (* estimate from Statistics Denmark, 1971a, 1937) Energy received on land, J = 1000 [m, height of boundary layer] x 1.23 [kg/m3, density of air] x 32500000000 [m2, area] x (0.4 [40%] x 7.0 [m/s, wind speed] / 0.6 [60% of wind speed absorbed at ground])2/2 = 4.35E+14 J/yr

3 RAIN, EVAPOSTRANSPIRATION:
Energy, J = (768 [mm/yr, precipitation (Statistics Denmark, 1937)] x 16250000000 [m2, farmed area in permanent pasture] x 0.77% [evapotranspiration rate]) + (768 [mm/yr, precipitation (Statistics Denmark, 1937)] x 16250000000 [m2, farmed area in spring cereals] x 0.5% [evapotranspiration rate]) x .001 [m/mm] x 1+E6 [g/m3] x 4.94 [J/g, Gibbs free energy] = 7.83E+16 J/yr

4 EARTH CYCLE:
Energy, J = 32500000000 [m2, land area] x 1.00E+06 [J/m2, heat flow, estimate from Odum (1996)] = 3.25E+16 J/yr

NONRENEWABLE STORAGES (N):

5 TOPSOIL LOSS:
Net topsoil loss, J = (6.22E+04 [g/ha/yr, erosion rate of grass and hay (Hansen & Nielsen, 1995)] x 1.29E+06 [ha, farmed area grass and hay (Statistics Denmark, 1968a)] + 7.62E+05 [g/ha/yr, erosion rate

of cereals and pulses (using values of topsoil loss from spring cereals (Hansen & Nielsen, 1995)] x 1.35E+06 [ha, farmed area cereals and pulses (Statistics Denmark, 1968a)] = 1.11E+12 [g/yr, total loss of topsoil] x .026 [% organic matter in soil given as decimal (Sibbesen, 1995; Schjønning, 1995)] = 2.88E+10 [g/org matter/yr] x 5.4 [kcal/g] x 4186 [J/kcal] = 6.52E+14 J/yr

Goods for livestock production (F1):

6 IMPORTED CEREALS:
Imported cereals (mostly wheat, rye and corn) = 8.52E+11 [g, national figure, all may not go to livestock (Statistics Denmark, 1937)] x 3.27 [kcal/g, energy content (Francis, 2000)] = 2.79E+12 kcal x 4186 [J/kcal] = 1.17E+16 J

7 IMPORTED FEEDS:
Imported feed concentrates, by digestible crude protein (all data from Statistics Denmark, 1968b)
Total energy, J = 24000 [J/g] x (2.03E+11 [g, cereals and pulses] + 1.30E+10 [g, bran, fodder meal] + 2.71E+11 [g, oil-cakes] + 1.00E+10 [g, meat and bone meal, fish meal, etc.] + 1.35E+11 [g, milk and milk powder, etc.]) = 1.52E+16 J

Commercial energy (F2):

8 FUEL:
Total energy, J = 3.00E+08 [J/ha/yr, combines petrol, kerosene and diesel (Schroll, 1994)] x 3250000 [ha, land in agriculture (Statistics Denmark, 1968a)] = 9.75E+14 J

9 ELECTRICITY:
Total energy, J = 4.00E+08 [J/ha/yr (Schroll, 1994)] x 3250000 [ha, land in agriculture (Statistics Denmark, 1968a)] = 1.30E+15 J

Goods for crop production (F3):

10 POTASH, g K
Total use (purchased) = 3.25E+10 g/yr [tonnage used x percent raw nutrient (Statistics Denmark, 1968a)]

11 PHOSPHATE, g P
Total use (purchased) = 6.53E+10 g/yr [tonnage used x percent raw nutrient (Statistics Denmark, 1968a)]

12 NITROGEN, g N
Total use (purchased) = 3.19E+10 g/yr [tonnage used x percent raw nutrient (Statistics Denmark, 1968a)]

Farm assets (F4):

13 Mechanical equipment:
Mechanical equipment (g, steel, all data from Statistics Denmark, 1937; Odal, 1990)=
Mobile power machines
Total mass (kg) = 6.65E+03 [Tractors, assuming 43.5 avg. hp] x 2.50E+03 [kg, steel/tractor (Odal, 1990)] + 1.27E+03 [Steam engine tractors, (Statistics Denmark, 1937)] x 2.50E+03 [kg, steel/tractor, estimate] = 1.98E+07 kg/steel
Fixed power machines
Total mass (kg) = 7.36E+04 [electric motors] x 1.00E+02 [kg, steel/machine, estimate] + 3.48E+04 [internal combustion engines] x 3.00E+02 [kg, steel/machine, estimate] + 1.26E+04 [windmills, farm work] x 5.00E+01 [kg, steel/machine, estimate] + 2.93E+03 [windmills, water pump] x 5.00E+01 [kg, steel/machine, estimate] = 1.86E+07 kg/steel
Field machines
1.12E+05 [Seed drills (for grain)] x 2.20E+02 [kg, steel/machine, estimate] + 1.59E+04 [Broadcast seeders] x 2.20E+02 [kg, steel/machine, estimate] + 1.16E+05 [Mowing machines] x 2.20E+02 [kg, steel/machine, estimate] + 1.06E+04 [Hay rakes] x 1.50E+02 [kg, steel/machine, estimate] + 8.23E+04 [Reaper-binder/harvesters] x 8.00E+02 [kg, steel/machine, estimate] + 2.63E+03 [Potato planters] x 2.20E+02 [kg, steel/machine, estimate] + 7.14E+03 [Potato harvester] x 1.50E+02 [kg, steel/machine, estimate] + 2.00E+04 [Root crop (turnip/beet) harvesters] x 1.50E+02 [kg, steel/machine, estimate] + 8.91E+03 [Fertilizer spreaders] x 2.20E+02 [kg, steel/machine, estimate] + 3.08E+03 [Copper sulfate spreaders (by horse power)] x 2.20E+02 [kg, steel/machine, estimate] + 5.51E+03 [Liquid manure spreaders] x 2.20E+02 [kg, steel/machine, estimate] = 1.30E+08 kg/steel
Machines in Stalls and Barns
1.39E+04 [Large self-cleaning threshing machines w/ roller] x 1.00E+03 [kg, steel/machine, estimate] + 2.97E+04 [Double cleaning threshing machines w/o roller] x 1.00E+03 [kg, steel/machine, estimate] +

6.54E+04 [Smaller single-cleaning threshing machines] x 5.00E+02 [kg, steel/machine, estimate] + 3.32E+04 [Threshing machines without cleaner] x 5.00E+02 [kg, steel/machine, estimate] + 2.93E+04 [Straw presses w/ binder] x 8.00E+02 [kg, steel/machine, estimate] + 1.45E+04 [Straw presses w/o binder] x 8.00E+02 [kg, steel/machine, estimate] + 8.61E+04 [Grinding mills] x 1.50E+02 [kg, steel/machine, estimate] + 1.40E+05 [Chaff cutter] x 1.50E+02 [kg, steel/machine, estimate] + 2.20E+03 [Root crop washers] x 1.50E+02 [kg, steel/machine, estimate] + 3.36E+03 [Root crop dryers] x 1.50E+02 [kg, steel/machine, estimate] + 3.64E+03 [Milking Machines] x 1.50E+02 [kg, steel/machine, estimate] = 1.62E+08 kg/steel
Total mass (g) = 3.39E+08 x 1000 [g/kg] = 3.39E+11 g
3.39E+11 g / 15 [yrs, depreciation rate] = 2.21E+10 g/yr

14 BUILDINGS, value USD:
880 [DKK, value/ha (Statistics Denmark, 1937)] x 3.25E+06 [ha (Statistics Denmark, 1937)] = 2,860,000,000 [DKK, total value] / 4.5 [DKK/USD exchange rate (Statistics Denmark, 1937)] = 636,000,000 USD / 30 [depreciation rate, 30 years] = 2.12E+07 USD, yearly contribution

LABOR AND SERVICES (S+L):

15 Labor (L) = 6.80E+8 [DKK/yr, total labor cost] / 4.5 [DKK/USD] = 1.51E+08 USD

16 Services (S) = 5.57E+02 [DKK/ha/yr, total production value] x 3250000 [ha] / 4.5 [DKK/USD] = 4.02E+08 [USD]. 4.02E+08 [USD] - 1.51E+08 [USD] = 2.51E+08 USD

CROP PRODUCTION:

17 Data for crop production from (Statistics Denmark, 1968a)
Total production, J = (3.13E+11 [g, spring wheat] + 2.02E+11 [g, rye] + 6.48E+11 [g, mixed grains] + 9.17E+11 [g, spring barley] + 8.54E+11 [g, oats]) x 16000 [J/g, (Schroll, 1994)]) + (7.67E+09 [g, pulses] x 0.83 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (4.06E+12 [g, straw] x 15 [kJ/g, (Duke, 1983)] x 1000 [J/kJ]) + (1.31E+12 [g, potatoes] x 0.7 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (1.47E+12 [g, sugar beets] x 0.67 [kcal/g (Ulgiati et al., 1994)] x 4186 [J/kcal]) + (1.08E+12 [g, fodder beets and sugar beets for feed] x 2.09E+03 [J/g (Schroll, 1994)]) + (1.20E+13 [g, swedes] x 2.09E+03 [J/g (Schroll, 1994)]) + (8.48E+11 [g, turnips] x 2.09E+03 [J/g (Schroll, 1994)]) + (9.37E+12 [g, mangolds] x 2.09E+03 [J/g (Schroll, 1994)]) + (1.31E+11 [g, carrots] x 2.09E+03 [J/g (Schroll, 1994)]) + (3.44E+11 [g, beet tops] x 0.45 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (8.12E+12 [g, grass, green fodder and aftermath] x 3.82E+03 [J/g (Schroll, 1994)]) = 1.97E+17 J

LIVESTOCK PRODUCTION:

18 Data for livestock production from (Statistics Denmark, 1968b)
Total production, J = (1.78E+11 [g, beef and veal] x 2.52 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (3.47E+11 [g, pork] x 3.81 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (2.57E+10 [g, poultry] x 2.30 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (3.30E+09 [g, horse meat] x 2.52 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + 2.90E+09 [g, mutton and lamb] x 3.78 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + (5.21E+12 [g, milk] x 0.66 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + (1.15E+11 [g, eggs] x 1.47 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) = 2.28E+16 J

Table B.2. Emergy evaluation of Danish agriculture, 1970.

Note	Item, units	Data (units/yr)	Unit Solar EMERGY (sej/unit)	Ref. for Transform.	Solar EMERGY (E20 sej/yr)
RENEWABLE RESOURCES (R)					
1	Sun, J	7.62E+19	1	A	0.76
2	Wind, J	3.54E+14	1.50E+03	A	0.01
3	Rain, J	1.03E+17	1.82E+04	A	11.98
4	Earth cycle, J	2.94E+16	3.40E+04	E	10.00
NONRENEWABLE STORAGES (N)					
5	Net topsoil loss, J	1.21E+15	7.38E+04	A	0.89
Goods for livestock production (F1)					
6	Imported feed, cereals, J	8.43E+15	6.80E+04	D	5.73
7	Imported feed, concentrates, J	1.19E+16	8.00E+04	F	9.52
Commercial energy (F2)					
8	Fuel (petrol, kerosene, diesel), J	1.12E+16	6.60E+04	A	7.38
9	Electricity, J	8.82E+15	1.60E+05	A	14.12
Goods for crop production (F3)					
10	Potash, g K	1.52E+11	1.10E+09	A	1.67
11	Phosphate, g P	5.54E+10	1.78E+10	A	9.86
12	Nitrogen, g N	2.71E+11	3.80E+09	A	10.28
13	Pesticides, g	5.88E+09	1.50E+10	B	0.88
Farm assets (F4)					
14	Mechanical equipment, g	8.32E+10	6.70E+09	D	5.57
15	Buildings, USD	9.89E+07	7.96E+12	G	7.88
LABOR AND SERVICES (L+S)					
16	Labor (L), USD	7.75E+08	7.96E+12	G	61.65
17	Services (S), USD	1.24E+09	7.96E+12	G	98.74
CROP YIELD					
18	Energy in crop production, J	2.15E+17			
LIVESTOCK YIELD					
19	Energy in livestock production, J	3.63E+16			

Footnotes to Table B.2. Emergy evaluation of Danish agriculture, 1970.

RENEWABLE RESOURCES (R):

1 SOLAR ENERGY:
Energy received on land, J = 29,413,160,000 [m2, total land area in agriculture (Statistics Denmark, 1972)] x 3.70E+03 [MJ/m2/yr, avg. insolation (The Royal Danish Geographic Institute, 1986)] x 1-0.30 [1-albedo] x 1+E6 [J/MJ] = 7.62E+19 J/yr

2 WIND ENERGY:
Surface wind is 60% of the wind speed at 1000m; i.e. 40% of the wind speed is absorbed. Average wind speed at ground = 7.0 m/s (* estimate from Statistics Denmark, 1971a, 1937) Energy received on land, J = 1000 [m, height of boundary layer] x 1.23 [kg/m3, density of air] x 29413160000 [m2, area] x (0.4 [40%] x 7.0 [m/s, wind speed] / 0.6 [60% of wind speed absorbed at ground])2/2 = 3.54E+14 J/yr

3 RAIN, CHEMICAL POTENTIAL ENERGY:
Energy, J = (768 [mm/yr, precipitation (Statistics Denmark, 1972)] x 9,803,406,228 [m2, farmed area in permanent pasture] x 0.77% [evapotranspiration rate]) + (768 [mm/yr, precipitation (Statistics Denmark, 1937)] x 19,606,812,456 [m2, farmed area in spring cereals] x 0.5% [evapotranspiration rate]) x .001 [m/mm] x 1+E6 [g/m3] x 4.94 [J/g, Gibbs free energy] = 6.58E+16 J/yr

4 EARTH CYCLE:
Energy, J = 29413160000 [m2, land area] x 1.00E+06 [J/m2, heat flow, estimate from Odum (1996)] = 2.94E+16 J/yr

NONRENEWABLE STORAGES (N):

5 TOPSOIL LOSS:
Net topsoil loss = (erosion rate) x (farmed area) = (total mass of topsoil lost) x (% organic). Energy loss = (loss of organic matter)x(5.4 kcal/g)x(4186 J/kcal)Net topsoil loss, J = 6.22E+04 [g/ha/yr, erosion rate of grass and hay (Hansen & Nielsen, 1995)] x 8.00E+05 [ha, farmed area grass and hay (Statistics

Denmark, 1972)] + 7.62E+05 [g/ha/yr, erosion rate of cereals and pulses (using values of topsoil loss from spring cereals from Hansen & Nielsen, 1995)] x 1.62E+06 [ha, farmed area cereals and pulses (Statistics Denmark, 1972)] + 6.38E+06 [g/ha/yr, erosion rate of winter cereals from Hansen & Nielsen (1995)] x 1.22E+05 [ha, farmed area cereals and pulses (Statistics Denmark, 1972)] = 2.06E+12 [g/yr, total loss of topsoil] x .026 [% organic matter in soil given as decimal (Sibbesen, 1995; Schjønning, 1995)] = 5.35E+10 [g, org matter/yr] x 5.4 [kcal/g] x 4186 [J/kcal] = 1.21E+15 J/yr

Goods for livestock production (F1):

6 IMPORTED CEREALS:
Imported cereals = 6.16E+11 [g, (Statistics Denmark, 1972)] x 3.27 [kcal/g, energy content (Francis, 2000)] = 2.01E+12 kcal x 4186 [J/kcal] = 8.43E+15, J

7 IMPORTED FEEDS:
Imported feed concentrates, by digestible crude protein (all data from Statistics Denmark, 1972)
Total energy, J = 24000 [J/g, protein (Brandt-Williams, 2001)] x (3.90E+10 [g, cereals and pulses] + 1.10E+10 [g, bran, fodder meal] + 3.75E+11 [g, oil-cakes] + 5.10E+10 [g, Mash, draff, yeast and molasses] + 1.20E+10 [g, meat and bone meal, fish meal, etc.] + 8.00E+09 [g, milk and milk powder, etc.]) = 1.19E+16 J

Commercial energy (F2):

8 FUEL:
Total energy, J = 3.80E+9 [J/ha/yr, combines petrol, kerosene and diesel (Schroll, 1994)] x 2941316 [ha, land in agriculture (Statistics Denmark, 1972)] = 1.12E+16 J

9 ELECTRICITY:
Total energy, J = 3.00E+09 [J/ha/yr (Schroll, 1994)] x 2941316 [ha, land in agriculture (Statistics Denmark, 1968a)] = 8.82E+15 J

Goods for crop production (F3):

10 POTASH, g K
Total use = 1.52E+11 [g/yr, raw nutrient (Statistics Denmark, 1972)]

11 PHOSPHATE, g P
Total use = 5.54E+10 [g/yr, raw nutrient (Statistics Denmark, 1972)]

12 NITROGEN, g N
Total use (purchased) = 2.71E+11 g/yr [g/yr, raw nutrient (Statistics Denmark, 1972)]

13 PESTICIDES, g active substance (includes pesticides, fungicides, herbicides)
Total use (g) = 2 [kg/ha, active substance (Schroll, 1994)] x 2941316 [ha] x 1000 [g/kg] = 5.88E+09 g/yr

Farm assets (F4):

14 Mechanical equipment:
= ((1.75E+05 [tractors] x 4.70E+03 [kg steel/tractor]) + (4.22E+04 [Combined and automatic harvesters] x 6.95E+03 [kg steel/combine]) + (5.34E+04 [forage harvesters] x 2.50E+03 [kg steel/harvester]) x 1000 [g/kg])/15 [yrs, depreciation rate] = 8.32E+10 g/yr

15 BUILDINGS, value USD:
Maintenance on buildings, 1969= 742,000,000 [DKK, (Statistics Denmark, 1972)] / 7.5 DKK/USD = 9.89E+07 USD

LABOR AND SERVICES (S+L):

16 Labor (L) = 1,975 [DKK/ha, labor cost (Statistics Denmark, 1972)] * 2941316 [ha] / 7.5 [DKK/USD] = 7.75E+08 USD

17 Services (S) = 5138 [DKK/ha, total production value (Statistics Denmark, 1972)] x 2941316 [ha, (Statistics Denmark, 1972)] / 7.5 [DKK/USD] = 2.01E+09 USD.
2.01E+09 USD - 7.75E+08 USD [labor cost] = 1.24E+09 USD

CROP PRODUCTION:

18 Data for crop production from (Statistics Denmark, 1972)
Total production, J = (3.85E+11 [g, winter wheat] + 1.27E+11 [g, spring wheat] + 1.34E+11 [g, rye] + 1.42E+11 [g, mixed grains] + 4.81E+12 [g, spring barley] + 6.31E+11 [g, oats]) x 16000 [J/g, (Schroll, 1994)]) + (9.30E+10 [g, pulses] x 0.83 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (4.34E+12 [g, straw] x 15 [kJ/g, (Duke, 1983)] x 1000 [J/kJ]) + (1.03E+12 [g, potatoes] x 0.7 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (1.89E+12 [g, sugar beets] x 0.67 [kcal/g (Ulgiati et al., 1994)] x 4186

[J/kcal]) + (1.10E+13 [g, fodder roots, swedes] x 2.09E+03 [J/g (Schroll, 1994)]) + (3.05E+10 [g, seeds for sowing] x 3.27 [kcal/g (Francis, 2000)] x 4186 [J/kcal]) + (2.87E+10 [g, seeds for industrial use] x 5.77 [kcal/g (Appelqvist & Ohlson, 1973)] x 4186 [J/kcal]) + (4.64E+11 [g, beet tops] x 0.45 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (4.19E+12 [g, grass, green fodder and aftermath] x 3.82E+03 [J/g (Schroll, 1994)]) = 2.15E+17 J

LIVESTOCK PRODUCTION:

19 Data for livestock production from (Statistics Denmark, 1972)
Total production, J = (2.34E+11 [g, beef and veal] x 2.52 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (7.97E+11 [g, pork] x 3.81 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (8.04E+10 [g, poultry] x 2.30 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (1.80E+09 [g, horse meat] x 2.52 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + 1.90E+09 [g, mutton and lamb] x 3.78 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + (7.16E+12 [g, milk] x 0.66 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + (7.93E+10 [g, eggs] x 1.47 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) = 3.63E+16 J

Table B.3. Emergy evaluation of Danish Agriculture, 1999.

Note	Item	Data (units/yr)	Unit Solar EMERGY (sej/unit)	Ref. for Transf.	Solar EMERGY (E20 sej/yr)
RENEWABLE RESOURCES (R)					
1	Sun, J	6.85E+19	1	A	0.68
2	Wind, J	3.54E+14	1.50E+03	A	0.01
3	Rain, J	6.25E+16	1.82E+04	A	11.38
4	Earth cycle, J	2.64E+16	3.40E+04	E	8.99
NONRENEWABLE STORAGES (N)					
5	Net Topsoil Loss, J	3.19E+15	7.38E+04	A	2.36
Goods for livestock production (F1)					
6	Imported feed, cereals, J	5.08E+14	6.80E+04	D	0.35
7	Imported feed, concentrates, J	2.47E+16	8.00E+04	F	19.76
Commercial energy (F2)					
8	Diesel, J	2.17E+16	6.60E+04	A	14.34
9	Coal, J	1.59E+15	4.00E+04	A	0.64
10	Motor gasoline, J	9.42E+13	6.60E+04	A	0.06
11	Fuel oil, J	2.75E+15	6.60E+04	A	1.82
12	Natural gas, J	4.08E+15	4.80E+04	A	1.96
13	Electricity, J	6.05E+15	1.60E+05	A	9.68
Goods for crop production (F3)					
14	Potash, g K	8.09E+10	1.10E+09	A	0.89
15	Phosphate, g P	2.03E+10	1.78E+10	A	3.61
16	Nitrogen, g N	2.63E+11	3.80E+09	A	9.98
17	Pesticides, g	3.62E+09	1.50E+10	B	0.54
Farm assets (F4)					
18	Mechanical equipment, G	4.35E+10	6.70E+09	D	2.91
19	Buildings, USD	7.77E+07	1.56E+12	G	1.21
LABOR AND SERVICES (L+S)					
20	Labor (L), USD	1.77E+09	1.56E+12	G	27.62
20	Services (S), USD	5.51E+09	1.56E+12	G	85.98
CROP YIELD, J					
21	Crop production, J	2.26E+17			
LIVESTOCK YIELD, J					
22	Livestock production, J	4.56E+16			

Footnotes to Table B.3. Emergy evaluation of Danish agriculture, 1999.

RENEWABLE RESOURCES (R):

1 SOLAR ENERGY:
Energy received on land, J = 26,440,000,000 [m2, total land area in agriculture (Statistics Denmark, 1999a)] x 3.70E+03 [MJ/m2/yr, avg. insolation (The Royal Danish Geographic Institute, 1986)] x 1-0.30 [1-albedo] x 1+E6 [J/MJ] = 6.85E+19 J/yr

2 WIND ENERGY:
Surface wind is 60% of the wind speed at 1000m; i.e. 40% of the wind speed is absorbed. Average wind speed at ground = 7.0 m/s (* estimate from Statistics Denmark 1999, 1971a, 1937) Energy received on land, J = 1000 [m, height of boundary layer] x 1.23 [kg/m3, density of air] x 29413160000 [m2, area] x (0.4 [40%] x 7.0 [m/s, wind speed] / 0.6 [60% of wind speed absorbed at ground])2/2 = 3.54E+14 J/yr

3 RAIN, CHEMICAL POTENTIAL ENERGY:
Energy, J = (768 [mm/yr, precipitation (Statistics Denmark, 1972)] x 8,804,520,000 [m2, farmed area in permanent pasture] x 0.77% [evapotranspiration rate]) + (768 [mm/yr, precipitation (Statistics Denmark, 1937)] x 8,804,520,000 [m2, farmed area in spring cereals] x 0.5% [evapotranspiration rate]) + (768 [mm/yr, precipitation (Statistics Denmark, 1937)] x 8,804,520,000 [m2, farmed area in winter cereals] x 0.6% [evapotranspiration rate]) x .001 [m/mm] x 1+E6 [g/m3] x 4.94 [J/g, Gibbs free energy] = 6.25E+16 J/yr

4 EARTH CYCLE:
Energy, J = 26440000000 [m2, land area] x 1.00E+06 [J/m2, heat flow, estimate from Odum, 1996] = 2.64E+16 J/yr

NONRENEWABLE STORAGES (N):

5 TOPSOIL LOSS:

Net energy loss from topsoil, J = 6.22E+04 [g/ha/yr, erosion rate of grass and hay (Hansen & Nielsen, 1995)] x 7.56E+05 [ha, farmed area grass and hay (Statistics Denmark, 1999b)] + 7.62E+05 [g/ha/yr, erosion rate of cereals and pulses (using values of topsoil loss from spring cereals from Hansen & Nielsen (1995))] x 6.86E+05 [ha, farmed area spring cereals (Statistics Denmark, 1999b)] + 6.38E+06 [g/ha/yr, erosion rate of winter cereals from Hansen & Nielsen (1995)] x 7.62E+05 [ha, farmed area cereals and pulses (Statistics Denmark, 1972)] = 5.43E+12 [g/yr, total loss of topsoil] x .026 [% organic matter in soil given as decimal (Sibbesen, 1995; Schjønning, 1995)] = 1.41E+11 [g, org matter/yr] x 5.4 [kcal/g] x 4186 [J/kcal] = 3.19E+15 J/yr

Goods for livestock production (F1):

6 IMPORTED CEREALS:

Imported cereals = 3.71E+10 [g, (Statistics Denmark, 1999b)] x 3.27 [kcal/g, energy content (Francis, 2000)] = 2.01E+12 kcal x 4186 [J/kcal] = 5.08E+14, J

7 IMPORTED FEEDS:

Imported feed concentrates, by digestible crude protein (all data from Statistics Denmark, 1999b)
Total energy, J = 24000 [J/g, protein (Brandt-Williams, 2001)] x (3.80E+10 [g, cereals and pulses] + 1.50E+10 [g, bran, fodder meal] + 7.41E+11 [g, oil-cakes] + 5.10E+10 [g, Mash, draff, yeast and molasses] + 2.00E+09 [g, Lucerne meal] + 1.82E+11 [g, meat and bone meal, fish meal, etc.] + 1.00E+09 [g, milk and milk powder, etc.]) = 2.47E+16 J

Commercial energy (F2):

8 DIESEL:

Total energy content, J = 468000000 [kg/yr, (Statistics Denmark, 1999a)] x 1.2 [l/kg] x 3.87E+07 [J/l (United States Department of Energy, 2001)] = 2.17E+16 J

9 COAL:

Total energy content, J = 5.00E+04 [Tn/yr, (Statistics Denmark, 1999a)] x 3.18E+10 [J/Tn (Odum, 1996)] = 1.59E+15 J

10 GASOLINE:

Total energy content = 2.00E+03 [Tn/yr, (Statistics Denmark, 1999a)] x 4.71E+10 [J/Tn, (United States Department of Energy, 2001)] = 9.42E+13 J

11 FUEL OIL, J

Total energy content, J = 2.75E+15 J (Statistics Denmark, 1999a)

12 NATURAL GAS:

Total energy content, J = 4.082E+15 J (Statistics Denmark, 1999a)

13 ELECTRICITY:

Total energy use, J = 1.68E+09 [kWh/yr, (Statistics Denmark, 1999a)] x 3.6E6 [J/kWh] = 6.05E+15 J

Goods for crop production (F3):

14 POTASH, g K

Total use = 8.09E+10 [g/yr, raw nutrient (Statistics Denmark, 1999b)]

15 PHOSPHATE, g P

Total use = 2.03E+10 [g/yr, raw nutrient (Statistics Denmark, 1999b)]

16 NITROGEN, g N

Total use = 2.63E+11 g/yr [g/yr, raw nutrient (Statistics Denmark, 1999b)]

17 PESTICIDES, g active substance (includes pesticides, fungicides, herbicides)

Total use (g) = 3.62E+09 [g/yr, data from 1998]

Farm assets (F4):

18 Mechanical equipment:

Mechanical equipment, g (data from Statistics Denmark, 1999a; Odal, 1990)
= ((3.05E+04 [tractors under 54 hp (assume 43.5 avg.)] x 2.50E+03 [kg steel/tractor]) + (4.76E+04 [tractors, 54-80 hp (assume 67 avg.)] x 3.20E+03 [kg steel/tractor]) + (4.45E+04 [tractors, 81-134 hp (assume 107.5 avg.)] x 4.70E+03 [kg steel/tractor]) + (6.74E+03 [tractors, 135 hp and over (assume 162.5 avg.)] x 6.95E+03 [kg steel/tractor]) + (2.42E+04 [Combined and automatic harvesters] x 6.95E+03 [kg steel/tractor]) x 1000 [g/kg])/15 [yrs, depreciation rate] = 4.35E+10 g/yr

19 BUILDINGS, value USD:

Maintenance on buildings = (9.40E+03 [DKK/farm, maintenance expenditure] x 57841 [farms])/7

[DKK/USD] = 7.77E+07 USD

SERVICES and LABOR (S):

20 Labor (L) = (48700 [DKK, per farm] x 57831 [farms]) / 7 [DKK/USD]) + (811000 [gross income per farm] - 645400 [total operating cost per farm])*57831 [farms]) / 7 [DKK/USD]) = 1.77E+09 USD

21 Services (S) = 50,972,000,000 [DKK, total production value] / 7 [DKK/USD] = 7.28E+09 USD
7.28E+09 USD - 1.77E+09 USD [labor cost] = 5.51E+09 USD

CROP PRODUCTION:

22 Data for crop production from (Statistics Denmark, 1999b)
Total production, J = (4.43E+12 [g, winter wheat] + 3.78E+10 [g, spring wheat] + 2.48E+11 [g, rye] + 2.51E+11 [g, triticale] + 2.79E+12 [g, spring barley] + 8.84E+11 [g, winter barley] + 1.30E+11 [g, oats]) x 16000 [J/g, (Schroll, 1994)]) + (1.93E+11 [g, pulses] x 0.83 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (3.61E+12 [g, straw] x 15 [kJ/g, (Duke, 1983)] x 1000 [J/kJ]) + (1.50E+12 [g, potatoes] x 0.7 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (3.55E+12 [g, sugar beets] x 0.67 [kcal/g (Ulgiati et al., 1994)] x 4186 [J/kcal]) + (1.50E+12 [g, fodder roots, swedes] x 2.09E+03 [J/g (Schroll, 1994)]) + (8.64E+10 [g, seeds for sowing] x 3.27 [kcal/g (Francis, 2000)] x 4186 [J/kcal]) + (5.12E+09 [g, seeds for industrial use] x 5.77 [kcal/g (Appelqvist & Ohlson, 1973)] x 4186 [J/kcal]) + (3.44E+11 [g, beet tops] x 0.45 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (2.15E+13 [g, grass, green fodder and aftermath] x 3.82E+03 [J/g (Schroll, 1994)]) + (3.49E+11 [g, winter rape] x 5.77 [kcal/g (Appelqvist & Ohlson, 1973)] x 4186 [J/kcal]) + (6.26E+10 [g, winter rape] x 5.77 [kcal/g (Appelqvist & Ohlson, 1973)] x 4186 [J/kcal]) = 2.26E+17 J

LIVESTOCK PRODUCTION:

23 Data for livestock production from (Statistics Denmark, 1999b)
Total production, J = (1.73E+11 [g, beef and veal] x 2.52 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (1.78E+12 [g, pork] x 3.81 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (2.05E+11 [g, poultry] x 2.30 [kcal/g (Holland et al., 1993)] x 4186 [J/kcal]) + (1.40E+09 [g, horse meat] x 2.52 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + 1.50E+09 [g, mutton and lamb] x 3.78 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + (4.66E+12 [g, milk] x 0.66 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) + (7.82E+10 [g, eggs] x 1.47 [kcal/g (Holland et al., 1993) x 4186 [J/kcal]) = 4.56E+16 J

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