THEORETICAL CALCULATIONS OF ENERGY USAGE AND CARBON EMISSIONS FROM FOOD PROCESSING PLANTS

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ABSTRACT

Theoretical energy usage calculations for the production, under South African conditions, of two hundred different food products have been modified to include the carbon dioxide emissions from each.

The original calculations of energy usage formed part of a database of food processing systems. Each calculation in spreadsheet format involved a flow diagram of the process and a mass and energy balance. Thus the results given were

a The theoretical product yield
b The approximate total energy requirement in kJ kg^{-1}
c The energy requirement, either electrical or thermal, of each stage of the process.

The results have been extended to give an estimate of carbon dioxide emissions from each of the processes. In each case a decision was made as to the sources of energy that would be employed. Variations taken are in line with South African Energy usage norms.

In general, the theoretical results that have been obtained have indicated lower energy use than other surveys and practical tests which are available in the literature. Comparisons are difficult because of variation in the scale of the processes and the process boundaries.

Benchmark energy usages are indicated from these results. In addition each calculation highlights the unit operations within the production sequence which could be addressed to reduce both the energy usage and the carbon emissions.

INTRODUCTION

Work on the development of a database of energy requirements for food processing under typical South African conditions has been reported (Murray and Lagrange,1998; Murray, 2004; Lagrange 2007). This is known as the Eskom Food Processing Enquiry Handling (FOPREH) mass and energy database.

The database has been expanded to include a total of 218 reports each dealing with one food product. The products that have been chosen for analysis fall into the following groupings: berries, brassicae, cereal crops, citrus fruit, cucurbita, dairy, deciduous fruit, field crops, general crops, meat, root crops and subtropical fruit. Some of products have been analysed at more than one capacity or making allowance for more than one set of processing conditions.

These reports have been designed to provide the following information -

a The theoretical product yield
b The approximate total energy requirement in kJ kg^{-1}
c An assessment of which steps in the process are energy intensive and should thus be checked or re-checked during process design

The energy balance for each product includes a calculation in spread sheet format as well as one or more linked summaries.

The mass and energy analysis is intended to reflect typical but small scale processing plants under South African conditions. More than one analysis of a particular product may reflect a different processing method or a different capacity. For instance pasteurised milk has been analysed at five different capacities employing different process methods.

The final output is a flow diagram reflecting:

A mass balance in terms of one kilogram of final product,

Energy inputs in terms of the percentage of the total requirements that will be required at each stage. This is intended to highlight the stages in the process that require large quantities of energy. Energy usage has been divided between electrical energy and energy derived from burning of fuels (listed as *other*),

The total energy requirement (kJ/kg feed and kJ/kg product) and the total power installed for the capacity under consideration.

Output diagrams are given in Figs 1-4. A comparison between some of the spreadsheets and reported energy use and benchmarks is given below. It may be seen on Fig 4 that the thermal energy requirement of the dryer used for production of milk powder takes 23% of the total energy requirement and the thermal energy to the evaporator is more than 35% of the whole. This indicates which areas should be targeted for energy management. An arithmetic mean of the energy use of the products on the database indicates that almost 80% of energy use in the industry is thermal.

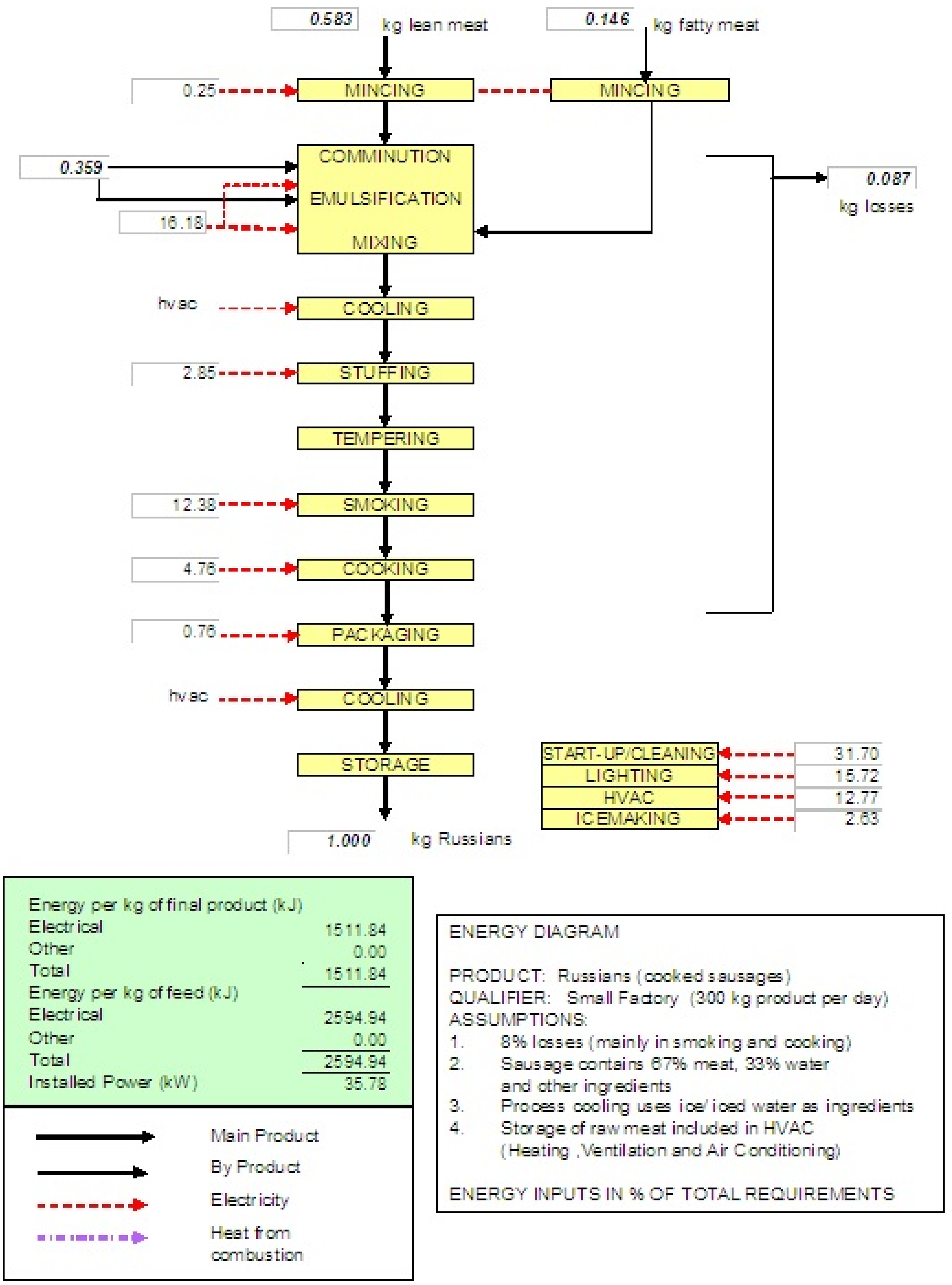

Figure 1 FOPREH energy diagram for cooked sausage. This is the published format. The figures on the diagram itself are linked to the calculation spreadsheet and are expressed in percentages of the total. The figures in the green square give kJ/kg product, kJ/kg feed and installed power.

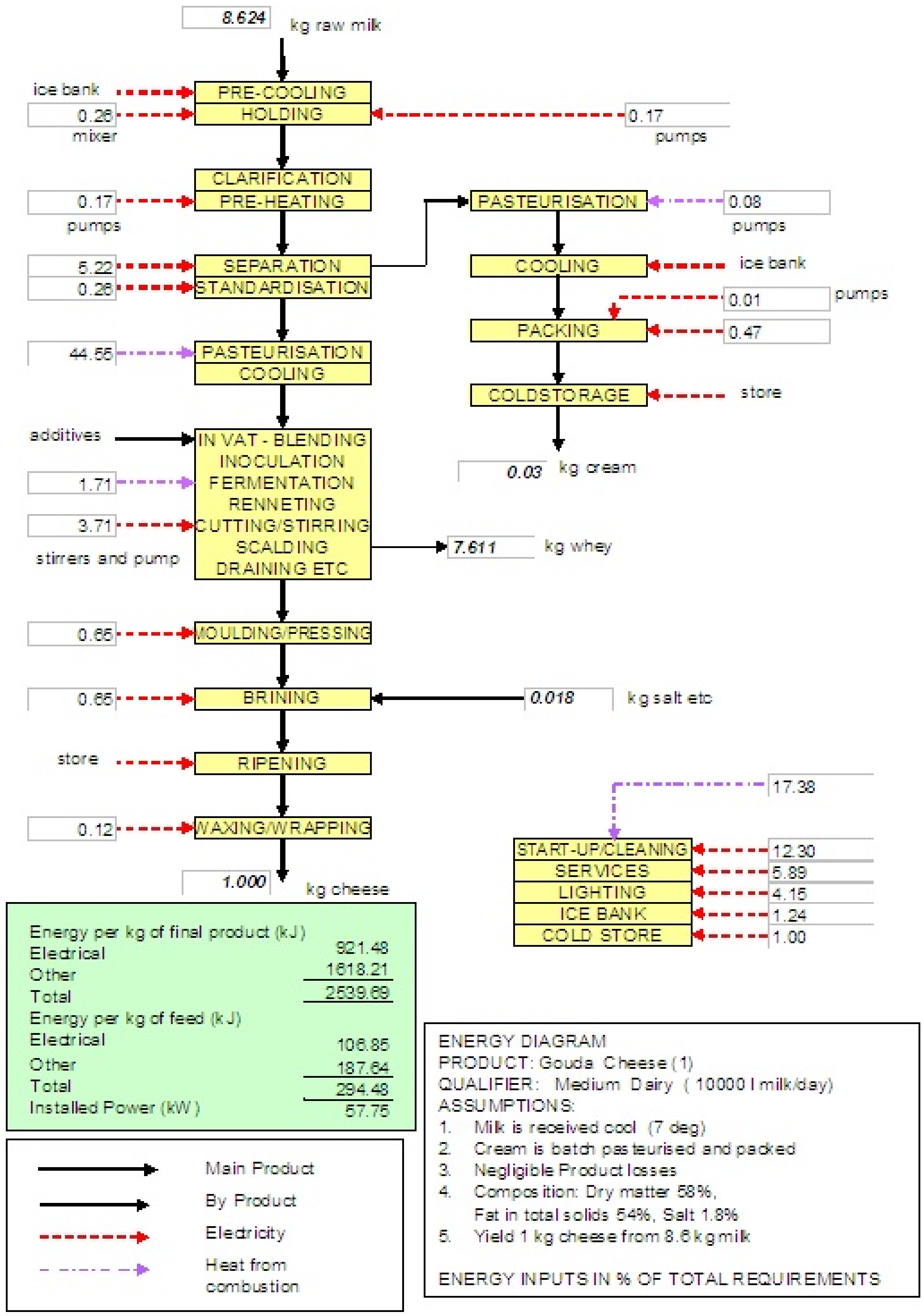

Figure 2 Energy diagram for Gouda Cheese at medium scale.

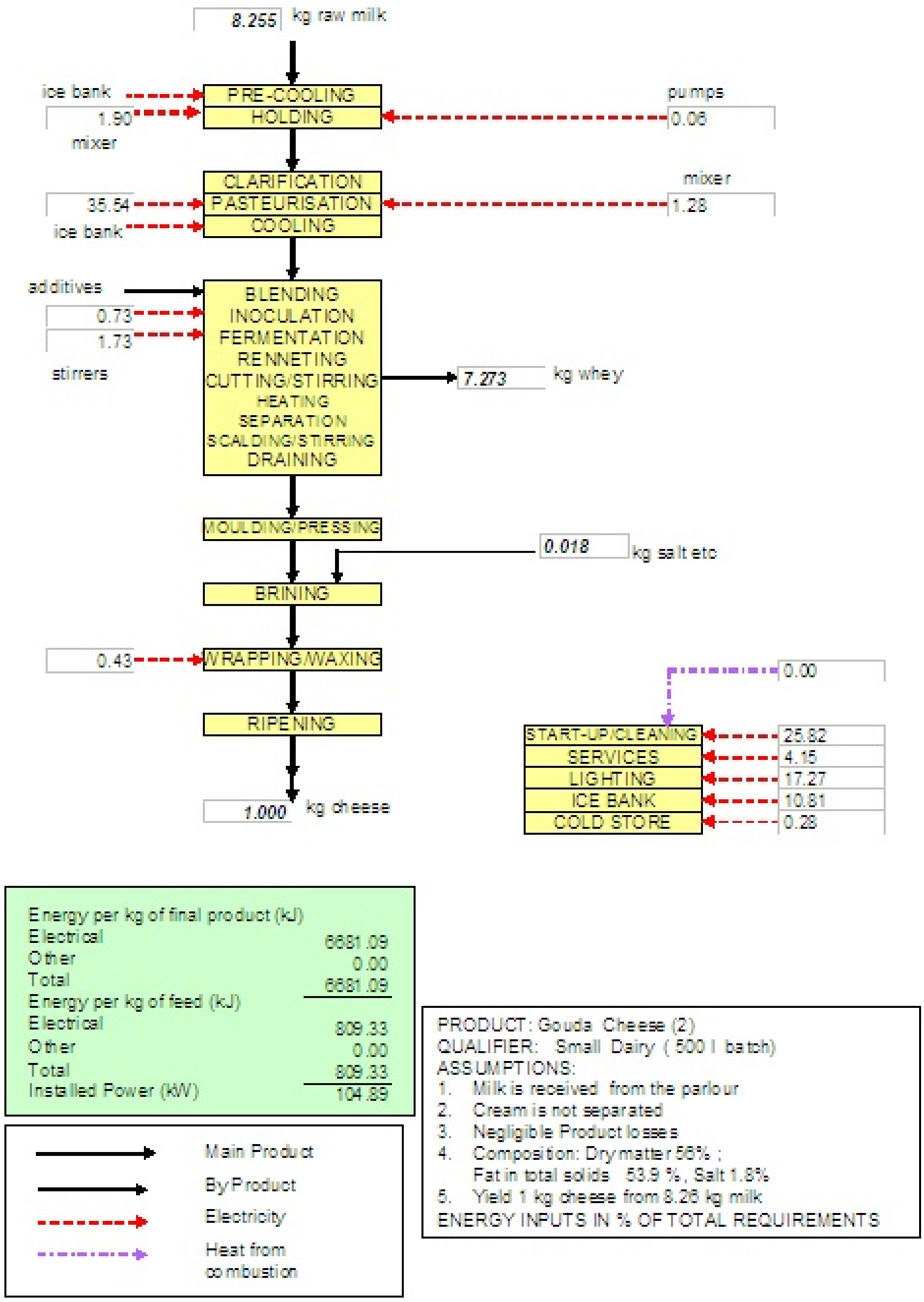

Figure 3 Energy diagram for Gouda Cheese on small scale. It is estimate that the specific energy use will be more than twice that for medium or large scale production..

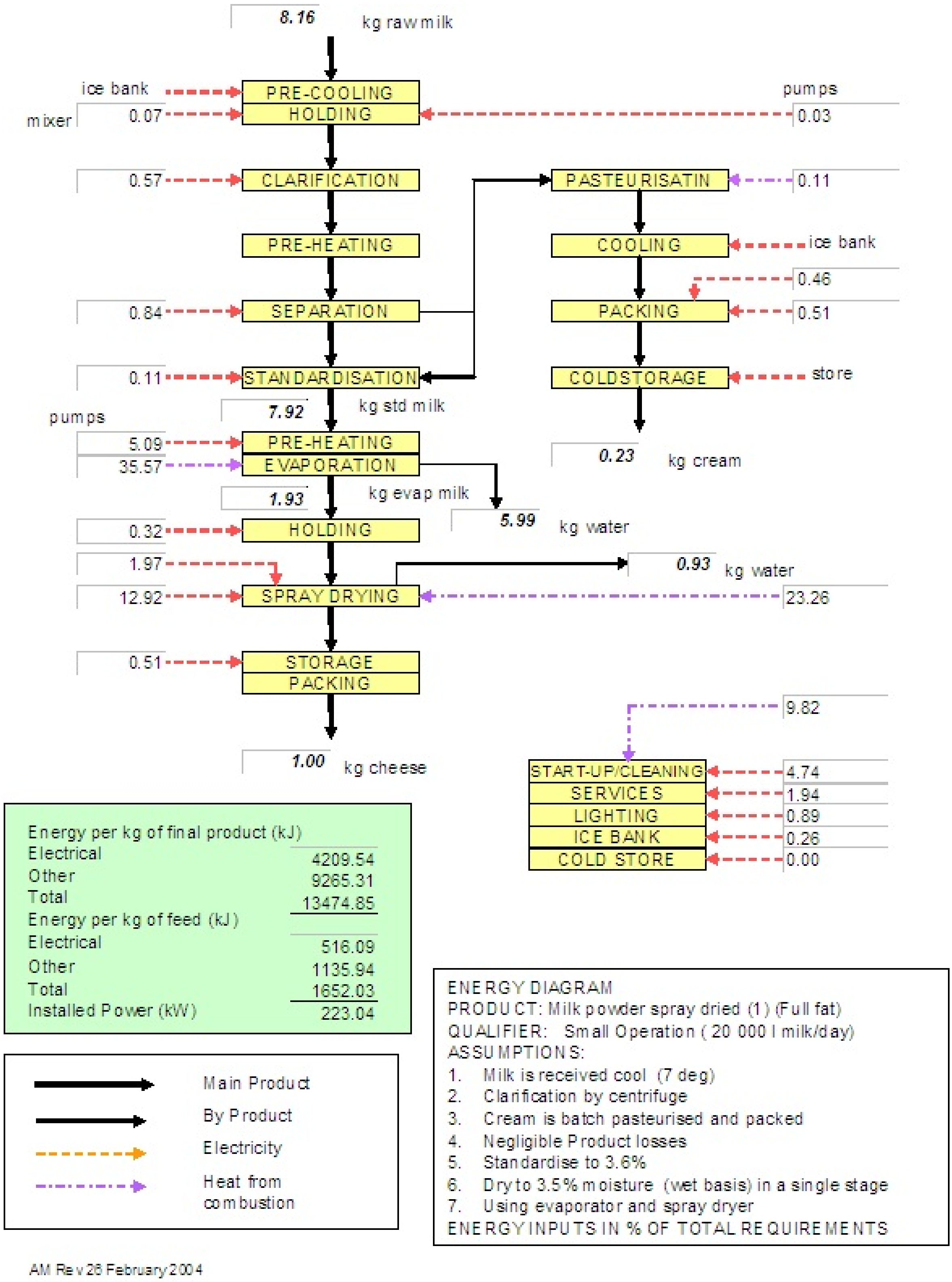

Figure 4 Energy Diagram for Spray dried milk powder. The diagram shows that 23% of the energy use is thermal energy in the dryer and more than 35% represents thermal energy to the evaporator

SPREADSHEET CALCULATIONS

It was found during the production of the calculations that slightly different methods were required depending on the type of product being investigated.

Each calculation, however, commences with a flowsheet, assumptions (Fig 5) and a mass balance in terms of 1 kilogram of final product. The energy calculations for each step in the process follow. Each stage of the process has space for calculating and listing installed power, the electrical energy requirement, the thermal energy requirement and the requirements expressed as percentages of the total (Fig 6). Process calculations are separated from service requirements. Service requirements include boilers, HVAC, lighting and air compressors (Fig 7).

Where literature figures are found to be available for specific heat capacities and other properties these are used. If not, properties are calculated using information regarding the composition fo the product.

Inputs for the various items of equipment are calculated as follows:

Wherever possible heating and cooling have been calculated using standard heat balance equations.

Energy for pumps is calculated using typical flow and pressure drop calculations together with an efficiency factor.

Centrifuges and homogenisers inputs are estimated from commercial data.

Evaporators and dryers, which are major users of energy, are calculated using separate energy balance sheets. Each of these is calculated as a separate balance (Figs 8-10) . Evaporator calculations used in the spread sheets have also been calculated on a stand alone evaporator programme and the figures transferred manually. Information on steam requirements of evaporators are also given in the commercial publications. (APV, 1994)

Heat loads for processing rooms are taken from published data. (Murray,1972).

Refrigeration energy requirements have been based on theoretical COP values together with a factor designed to include the fans, pumps and other equipment used.

Where detailed information is not available for any items of equipment such as mixers, bowl cutters, and filling machines an estimate has been made as follows
$e = 3600\ p/(m_h s)$
where e is the required energy input in kJ kg-1

p is the installed power (kW) (equipment supplier's information)
m_h is the mass flow of final product (kg/hour)
s is a service factor for the machine

The cooling requirement for the evaporator is calculated or taken from the design sheet. Cooling towers used in the food industry in South Africa most often work between 40 and 26°C.
Cooling water (m^3/h) = mass of vapour (kg/hr) x latent heat /14/.4.2/1000.

Boiler pumps and boiler sizing are taken from local commercial data. In this way the electrical input to the boiler is linked to the capacity. In most of the calculation it is assumed that the boiler will be coal fired.

Cold storage and freezer storage are calculated taking the heating requirements, the COP and a factor to cover fans and pumps.. To calculate the load in stores used for long term storage a daily temperature rise in the product (say 3°) is multiplied by the length of storage required and the specific heat of the product.

The lighting installed is estimated according to the size of the plant.

The assumption is made that all sections of the plant run for the start up and cleaning phases. The energy requirement is thus the total energy multiplied by the cleaning hours and divided by the process time. To this is added a hot water usage, the size of which is dependent on the size of the plant.

Examples of different sections of the calculation are given in figs 5 to 11

	B	C	D	E
62	**Basis**			
63	Milk Powder	kg	1.00	
64	Milk	litre/day	20000	
65				
66	Operation	h/day	12	
67	Cleaning	h/day	2	
68				
69	**Properties of milk**			
70	Density	kg/cu m	1030	
71	Fat	%	4.50	
72	SNF	%	8.5	
73				
74	Fat in cream	%	35.00	
75	Fat in std milk	%	3.6	
76				
77	Evap Milk Composition			
78	Solids	%	50.00	
79				
80				
81	Powder composition			
82	Solids (wet basis)	%	3.50	
83				

Figure 5. The assumption section of the spreadsheet for milk powder

	B	C	D	E	F	G	H	I	J	K
1	AGRELEK MASS BALANCE									
2		Units	Value	Power	Elec Input	Steam Input	%	Comments		
3				kW	kJ	kJ				
118	Energy Balance									
119										
120	Precooling									
121	Milk	kg	8.16							
122	Temp in	C	7							
123	Temp out	C	4							
124	Specific heat		3.84							
125	Cooling Reqd	kJR	93.97805066							
126										
127										
128	Mixer		9.41	0.6	9.41		0.07			
129	Pumps		4.08	1.5	4.08		0.03	2 feed pumps		
130										
131										
132	Clarifier	kJ	77.28154609	7.5	77.28		0.57			
133										
134	Preheating									
135	Milk	kg	7.92					Preheating to skimming temperature		
136	Temp in	C	4					and to evaporation temp will take place in		
137	Pasteurize	C	60					the evaporator with a hoding tank.		
138	Heating	kJ	Below					There is no regeneration		
139								Energy recovey from condensate and stea		
140								Preheat	6-30 by condenser wa	
141									30 - 50 by first effect v	
142									50 - 55 condensates	
143									55- 80 by recompress	
144										
145										
146	Skimming									
147	Centrifuge	kJ	113.3462676	11.0	113.35		0.84	(figure from Singh 34.87 kJ/kg)		
148								or from kW installed		113.3463
149										
150	Standardization									
151	Mixer	kJ	14.47344648	1.1	14.47		0.11	(0.1 kW per cu meter for 1/2 hour)		
152								two mixing tanks		
153										
154	Evaporation							Two effevect thermocompression evapora		
155	kg steam/kg evaporation		0.387076791					Temps 85-70-50		
156	steam	kg/hr	488.2065646					2102.11	794.62	0.378011
157	kg steam/kg evap powder prod		2.319656833					figures from computer prog etc		
158	Heat	kJ	4792.674948					Comparison	APV	0.400354
159						4792.67	35.57			
160								From Evap sheet		0.387077
161	Evaporator Pumps	kJ	685.91	40.1	685.91		6.09	Feed, four extract, incl standarisation, Con		

Figure 6 Energy balance for Milk Powder showing column structure

	A	B	C	D	E	F	G	H	I	J
1		AGRELEK MASS BALANCE								
2			Units	Value	Power	Elec Input	Steam Input	%	Comments	
3					kW	kJ	kJ			
215										
216		**TOTAL PROCESS**	kJ		**187.9**	**3162.99**	**7941.69**			
217										
218										
219										
220		**Services**								
221										
222		Boiler Motors	kW	14						1.5
223		Air comp	kW	0.75						
224		Cooling Tower	kW	2.2						
225		Pump kW		2.2						
226				262.0483273	19.15	262.05		1.94		
227										
228		**Lighting**		119.7348754	7	119.73		0.89		
229										
230		**Services plus lighting**			26.15	381.78	0.00			
231										
232		**Sub total**			214.04	3534.78	7941.69			
233										
234		**Ice bank**								
235		Cooling Load		116.120						
236		COP		5.51						
237		Fator		1.67						
238		Electrical input		35.19414851	2.00	35.19		0.26	0.052535969	kW
239										
240										
241		**Cold Store**								
242		Cooling Load	kJR	2.21						
243		COP		5.51						
244		Fator		1.67						
245		Electrical input	J/kg	0.671078288	2.00	0.67		0.00	0.000114784	
246										
247										
248		**Cleaning**								
249		Cleaning/start up hours	hours	2.000					Treat as medium plant	
250		Process time	hours	12.000						
251		Product	kg/hr	210.465						
252		Start up energy electrical	kJ	589.13						
253		Start up energy steam	kJ	1323.62						
254		Hot water	l/day	600						
255		Temp change	C	50						
256		Specific heat	kJ/kg C	4.19						
257		Heat	kJ	49.77074682						
258		Total cleaning/Start up	kJ		5	638.90	1323.62	4.74		
259								9.82		
260										
261										
262										
263		**Total**			**223.04**	**4209.64**	**9265.31**	**100.00**	**13474.85**	
264										
265										
266										
267										
268										

Figure 7 Energy balance. The services section

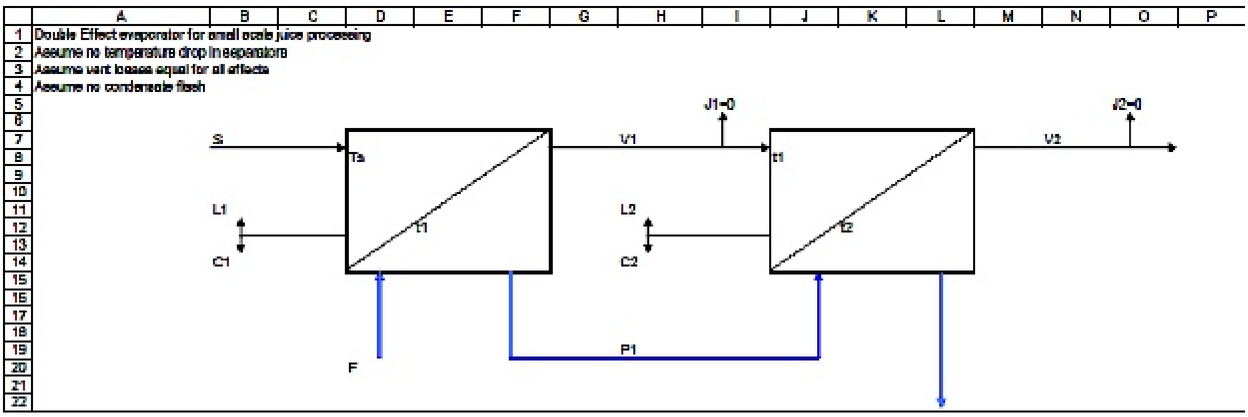

Figure 8 The evaporator diagram showing inputs and outputs

	G	H	I	J	K	L	M	N	O	P	Q
26											
27		C1	C2	P1	P	S	V1	V2			
28		0	0	1	0	0	1	0	7.92		
29		0	0	-1	1	0	0	1	0		
30		0	0	0	1	0	0	0	1.93		
31		1	0	0	0	-0.985	0	0	0		
32		0	1	0	0	0	-0.985	0	-2.05399		
33		-355.9	0	-242.126	0	2646.562	-2626.78	0	-2420.86		
34		-292.98	0	242.1256	-135	0	2587.378	-2592.03	5559.719		
35											
36											
37		0.62897026	0.571796	-0.54201	1.227182	0	0.000457	0.000221	4.057862	C1	
38		0.50557514	0.550538	-0.52186	0.071729	1	2.67E-05	0.000212	2.060592	C2	
39		0.48672575	-0.55892	0.529812	-0.07282	0	-2.7E-05	-0.00022	3.74551	P1	
40		0	0	1	0	0	0	0	1.93	P	
41		0.63854849	0.580503	-0.55027	0.230642	0	0.000464	0.000224	4.119657	S	2.319657
42		0.51327425	0.558922	-0.52981	0.072821	0	2.71E-05	0.000216	4.177246	V1	
43		0.48672575	0.441078	-0.47019	-0.07282	0	-2.7E-05	-0.00022	1.81551	V2	
44											
45											
46						Normal	If vap take off is recompressor				

Figure 9 Part of the evaporator calculation. In the case of the milk powder there are seven simultaneous equations

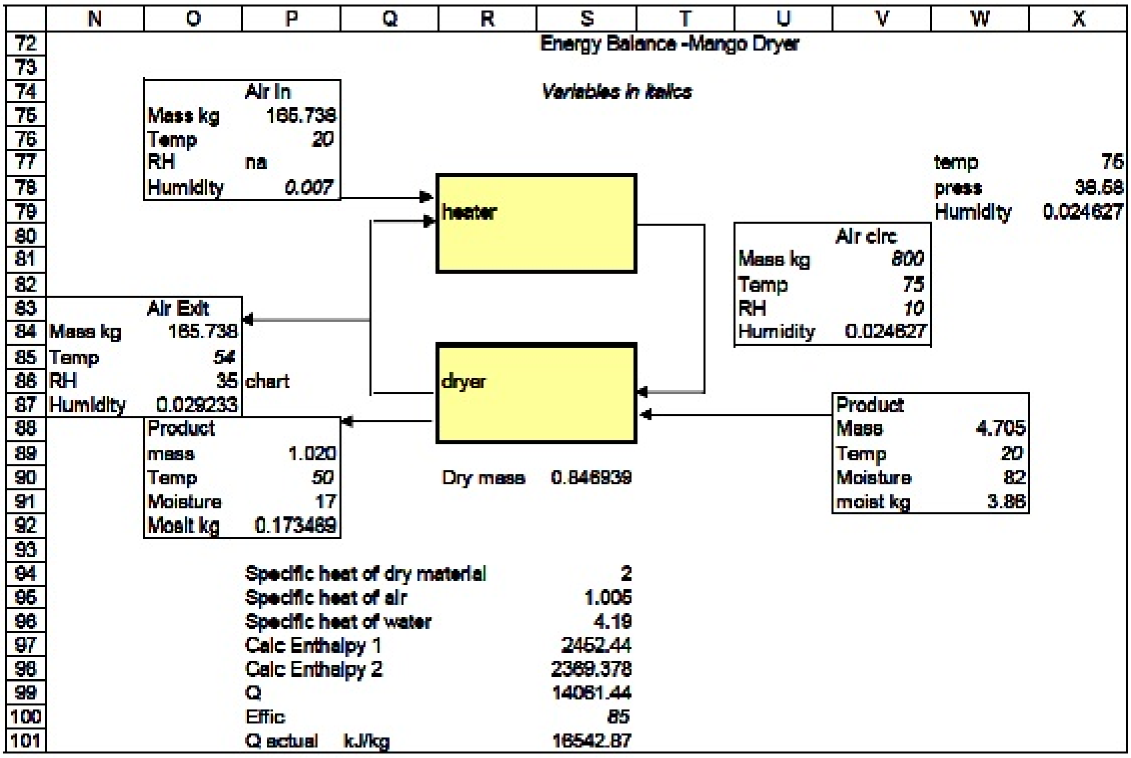

Figure 10 Energy calculations for a dryer for mango slices. The dryer for milk powder will have a similar calculations

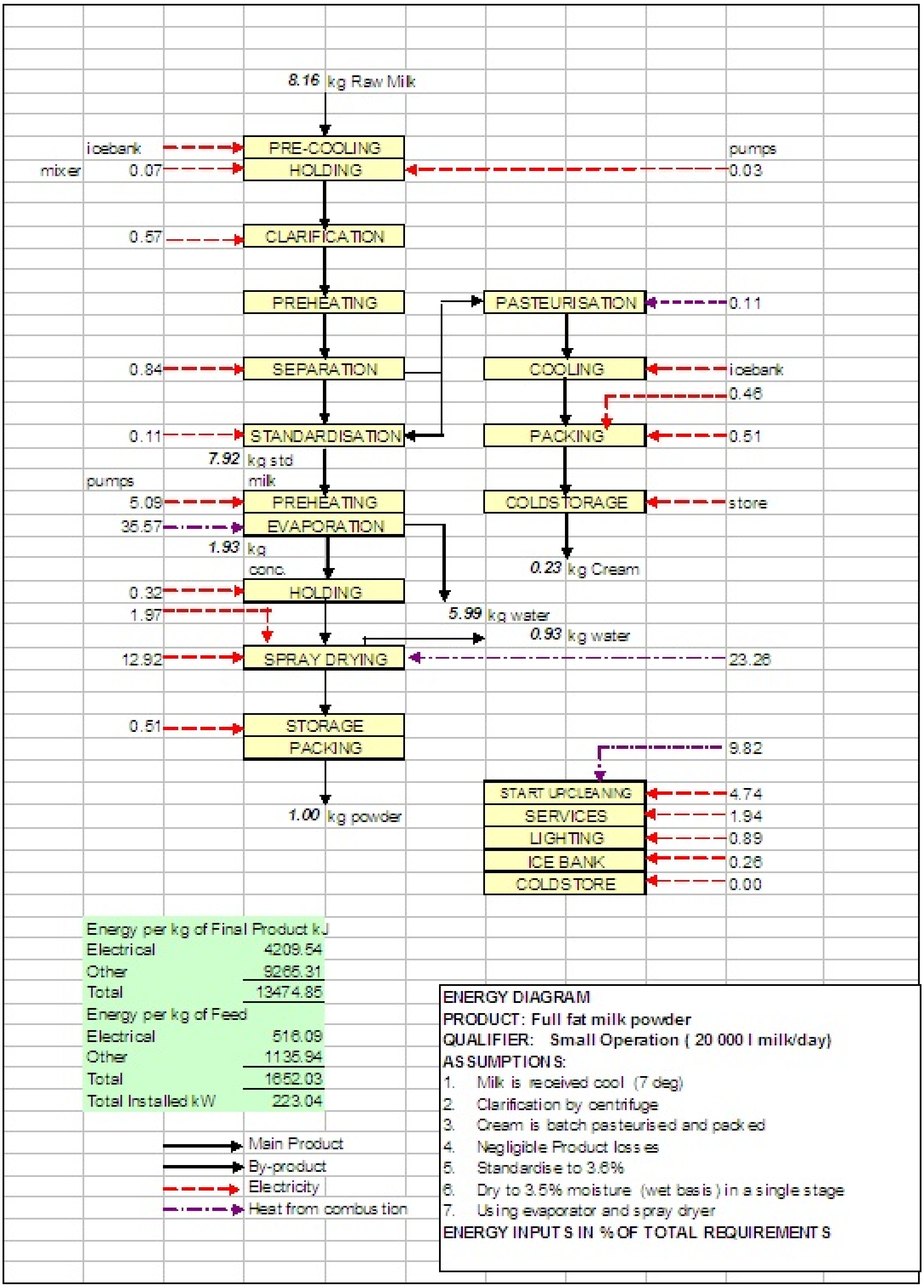

Figure 11 The mass balance diagram for full fat milk powder

COMPARISONS

Comparisons with reported data is difficult because there can be very large differences in the calculated figured depending on the process. Generally good data has been found in the dairy sector (Flapper,2009; IFC,2007). Comparisons are given on Table 1 and Table 2.

Flapper has taken a range of individual dairy plant data from European countries, USA, Canada, Australia and Kenya. His figures are divided into five sections: Fluid Milk, Butter, Cheese, Concentrated Milk and Powder. This is compared with our own (FOPREH) calculations on TABLE 1. Generally, the FOPREH calculations are within the expected range and relatively low as would be expected from theoretical calculations.

TABLE 1 Comparison of Energy Usage Data in Dairy Processing

	Range of energy usage (Data from Flapper,2009) MJ/kg product	Comparative data FOPREH database MJ/kg product
Fluid Milk (including yoghurt)	0.22 - 12.6	0.18 - 0.78
Butter	1.00 - 4.20	2.50 - 3.50
Cheese	1.8 - 64.7	1.1 - 9.1
Concentrated Milk	1.8 -10.8	2.2 - 2.7
Powder	4.6 - 221.4	13.4 - 34

The international finance corporation has released data from European and Scandinavian sources giving individual data as well as benchmarks. With the exception of the figures for ice cream, the FOPREH figures are within the range of the recorded data supplied. Figures quoted for fluid milk in the Canadian dairy industry are of similar magnitude (Wardrop, 1997)

TABLE 2 Comparison of Energy Data in Dairy Processing

	IFC recorded data kWh/L raw milk	IFC Benchmark kWh/L raw milk	FOPREH Data kWh/L raw milk
Milk and Cultured Milk	0.07 - 0.45	0.1 - 0.2	0.05 - 0.22
Cheese and Whey	0.06 -0.82	0.2 -0.3	0.07 - 0.26
Milk Powder, Cheese and Liquid Products	0.18 - 6.47	0.3 -0.4	0.3 - 0.45
Ice Cream		0.8 -1.2 kWh/kg ice cream	0.4 kWh/kg ice cream

TABLE 3 Comparison of Energy Data in Food Processing

	Data listed by Pimentel (1997) kJ/kg product	Comparative Data FOPREH Database kJ/kg product
Fruit and vegetables (canned)	2415	1287-2768
Fruit and vegetables (frozen)	7623	1523-12549
Meat	5065	930-5949
Milk	1487	247-703
Ice cream	3696	1453

Singh (1986) has quoted figures by Adolfson and others. Comparisons with these figures are difficult. Some are included on Table 4

TABLE 4 Comparison of Energy Data in Food Processing

	Energy figures from Singh (1986) kJ/kg product	FOPREH FIGURES kJ/kg product
Canned Vegetables	5187	1399 to 2228
Citrus Concentrate	3873.8 to 8234 depending on whether pulp is dried or not	5569 without pulp drying
Wheat flour	256	189

CARBON EMISSIONS

Carbon Emissions from using the following loadings for typical South African conditions

Inputs from Electricity: 333 gCO_2/MJ
Inputs from Coal: 187 gCO_2/MJ
Inputs from Heavy Furnace Oil/Diesel 77gCO_2/MJ

As a general rule diesel or fuel oil will be burned in smaller plants and coal in the larger facilities in South Africa. The range of emissions calculated were from 35 gCO_2/kg product (Uncooked wheat porridge) to 17239 (dehydrated tomato using a coal fired dryer). The latter reduces to 7974 gCO_2/kg product where oil is the fuel.

For dairy products the range is between 52gCO_2/kg (Amazi, a local fermented beverage) and 5974 for production of whey powder. Where milk is pasteurised in an electric batch pasteuriser the emission is calculated to be 218 g whereas a large dairy using a regenerative pasteuriser will only emit 52g/kg pasteurised milk.

CONCLUSIONS

Due to the wide range of processes and products, benchmarking of energy usage and carbon emissions in the food industry is difficult. However a systematic theoretical calculation of each individual process can be used to assess individual plants or processes.

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APPENDIX A

PRODUCTS IN THE FOPREH ENERGY DATA BASE

Figures in brackets indicate where products have been analysed at more than one capacity.

BERRIES	Blackcurrant juice (2), Blackcurrant juice carbonated (2), Blackcurrant juice concentrate, Blueberry juice, Blueberry juice carbonated, Blueberry juice concentrate (2) Cherry juice (2), Cherry juice carbonated Raspberry juice Red currant juice (2), Red currant juice carbonated (2), Red currant juice concentrated, Strawberry juice (SS), Strawberry nectar
BRASSICAS	Broccoli frozen
CEREAL CROPS	Maize alcohol , Maize bake extruded snacks, Maize flaked cereal, Maize fried extruded snacks, Maize mielie meal, Maize starch Sorghum flour ,Sorghum malt, Sorghum beer Wheat flour, Wheat pasta extruded (2), Wheat pasta fresh noodles, Wheat porridge, Wheat tortillas
CITRUS FRUIT	Grapefruit juice, Grapefruit juice concentrate Lemon juice (2), Lemon juice concentrate (2) Orange fermented beverage, Orange juice concentrate, Orange peel dried (2), Orange pulp frozen, Orange puree
CUCURBIT	Butternut frozen Cucumber Gherkins (2) Pumpkin frozen pieces (2), Pumpkin frozen puree
DAIRY	Butter continuous process, Butter traditional process (2), Butteroil direct process, Butteroil semi-direct process, Cream pasteurised (2), Cream sterilised, Cream UHT, Milk condensed, Milk evaporated Amazi (2), Buttermilk cultured (2), Cheese cheddar (2), Cheese cottage (4), Cheese Feta (2), Cheese Gouda (2), Cheese processed, Cheese Ricotta (2), Cheese spread, Cream soured, Kefir, Yoghurt drinking (2), Yoghurt set, Yoghurt stirred (2), Ice cream, Yoghurt frozen (2) Milk pasteurised (5), Milk sterilised, Milk UHT, (2) Casein acid, Casein rennet, Caseinates roller dried, Caseinates spray dried, Cheese powder, Ice cream powder, Milk powder instant, Milk powder roller dried (2), Milk powder spray dried, Whey powder
DECIDUOUS FRUIT	Apple canned (2), Apple cider (2), Apple frozen, Apple juice clarified (2), Apple juice cloudy (2), Apple pieces

	dehydrated, Apple rings dried Apricot dried, Apricot pieces dehydrated, Grape jam, Grape juice cold pressed, Grape juice concentrate, Grape juice hot pressed,Grape raisins artificial dehydration, Grape seed oil (2) Peach canned, Peach chutney, Peach dried (2), Peach frozen(2),Peach jam (2), Peach nectar, Peach pieces dehydrated, Peach puree (3) Pear dried Plum prune dried
FIELD CROPS	Tomato canned (2), Tomato chutney,Tomato dehydrated, Tomato fruit leather (3), Tomato jam, Tomato juice (2), Tomato paste (3), Tomato puree, Tomato sauce (Ketchup), Tomato sun-dried (SS) (2)
GENERAL CROPS	Olive calimata long method (2), Olive calimata short method Olive California-style, Olive Greek-style (2), Olive oil (2), Olive Spanish-style
MEAT	Meat russians Meat liver spread, Meat tongue canned, Meat tongue cooked, Meat tongue pickled Meat frankfurters, Meat french polony Meat salami Meat fresh sausage, Meat patties fresh, Meat patties frozen (3) Smoked sausages Meat bacon canned (2), Meat bacon sweetcure, Meat bacon wiltshire, Meat corned meat, Meat corned meat canned, Meat ham bone-in, Meat ham cooked, Meat ham deboned, Meat ham dry cured, Meat ham kassler
ROOT CROPS	Asparagus frozen (2), Asparagus pickled (3), Asparagus spears canned, Beetroot pickled, Beetroot pieces dehydrated Carrot canned, Carrot copper penny salad, Carrot frozen (2), Carrot gun-puffed, Carrot juice, Carrot peeled fresh cut, Carrot piccalilli (thick carrot pickle), Carrot pickled, Carrot pieces dehydrated (2), Carrot shredded fresh cut , Carrot sticks fresh cut, Garlic flakes dehydrated, Garlic minced frozen Onion pieces dehydrated Fresh cut peeled potatoes, Frozen hash browns (2), Potato canned, Potato crisps (2), Potato coquette frozen (2), Potato diced frozen (3), Potato flour, Potato french fries frozen (3), Potato mash frozen (2), Potato pieces dehydrated, Potato starch Sweet potato crisps (2), Sweet potato flakes dehydrated, Sweet potato formed frozen, Sweet potato mash canned, Sweet potato

mash frozen, Sweet potato pieces dehydrated, Sweet potato pieces frozen (2), Sweet potato reconstituted chips (2), Sweet potato starch (2)

SUBTROPICAL FRUIT Banana slices dehydrated, Banana solar-dried (2), Banana sun-dried (2)
Grenadilla (passionfruit) juice, Grenadilla juice concentrate (2)
Guava fruit bar, Guava juice clarified, Guava puree (3), Guava puree concentrate
Kiwifruit nectar
Litchi juice, Litchi juice concentrate
Mango dried rolls, Mango juice, Mango puree, Mango puree concentrate, Mango slices dehydrated, Mango sun-dried (2)
Papaya juice, Papaya tunnel-dried (2)
Pineapple juice

APPENDIX B
Selected values of calculated emissions from processing of food products.

Calculated Emissions from selected productions g CO2/kg product produced		Thermal energy form coal	Thermal energy from oil
BERRIES			
Blueberry juice	1000 kg/hr feed. Hot break	178	102
Blueberry juice carbonated	200 kg/hr feed. Hot break and sugar addition	66	56
Blueberry juice concentrate (2)	1000 kg/hr feed. 50 Brix product	2278	1149
	2000 kg/hr feed. 50 Brix product	1412	734
BRASSICAS			
Broccoli frozen	500 kg/hr	732	479
CEREAL CROPS			
Sorghum flour	500 kg/hr sorghum	70	70
Wheat pasta fresh noodles	300 kg wheat flour per batch	397	205
Wheat porridge	1000 kg/hour. Uncooked	35	35
CITRUS FRUIT			
Orange peel dried (2)	6000 kg/hr sun dried byproduct	95	95
	6000 kg/hr tunnel dried byproduct	2452	1091
Orange pulp frozen	10000 kg/hr by product of juice	291	258
CUCURBIT			
Butternut frozen	200 kg/hr Cryogenic freezing	963	510
Cucumber Gherkins (2)	200 kg daily batch. Manual	172	101
	3000 kg/day	180	109
DAIRY			
Milk condensed	30000 l milk/day full fat sweetened	643	429
Milk evaporated	30000 l/day raw milk. Canned product	527	361
Amazi (2)	10000l/day full fat milk	52	33
	500 litre batch	261	261
Cheese Gouda (2)	10000 l /day milk	609	431
	500 l batch	2225	2225
Yoghurt stirred (2)	20000 l/d addition of powder. Full fat	81	60
	500 litre batch	156	110
Milk pasteurised (3 of 5)	1000 l/d no separator or homogeniser. Electric	82	82
	1000 l/d Electric batch pasyeuriser	218	218
	15000 l/d homogenised and standardised	54	49
Milk powder spray dried	20000 l/d milk	3134	2115
DECIDUOUS FRUIT			
Apple canned (2)	500 kg/h apples 55% drained weight	519	270
	500 kg/hr pie apple	734	400
Peach jam (2)	500 kg/hr peaches (fresh)	604	354
	500 kg/hr peaches (frozen)	485	255
Peach nectar	2000 kg/hr nectar	42	35
FIELD CROPS			
Tomato canned (2)	500 kg/hr feed excl sauce	556	280
	50 kg/hr feed excl sauce	694	488
Tomato jam	50 kg/hr tomato	1208	736
GENERAL CROPS			
Olive calamata short method	3000 kg/day bottled.	120	100
MEAT			
Meat russians	300 kg/day product	503	503
Meat ham cooked	40 kg batch	835	835
ROOT CROPS			
Asparagus frozen (2)	500 kg/hr asparagus. Conventional Freeze	548	435
Asparagus spears canned	400 kg/hr asparagus	272	159
Beetroot pickled	500 kg /hr beetroot	267	156
Beetroot pieces dehydrated	3000 kg/hr feed	10535	4611
Carrot frozen (2)	2 ton/h conventional refrigeration	551	391
	2 ton/h cryogenic	386	226
Carrot peeled fresh cut	300 kg/hr product (351 kg feed)	84	84
Potato pieces dehydrated	3000 kg/hr feed	5489	2399
Sweet potato crisps (2)	2000 kg/hr feed	1948	852
	50 kg/hr feed	2885	1903
SUBTROPICAL FRUIT			
Guava puree concentrate	3000 kg/hr guavas	1036	507
Litchi juice concentrate	4000 kg/hr litchis	639	376
Mango puree	2000 kg/hr feed	127	103