

# Theoretical Energy Calculations for Food Processing under South African Conditions

**A. Murray**

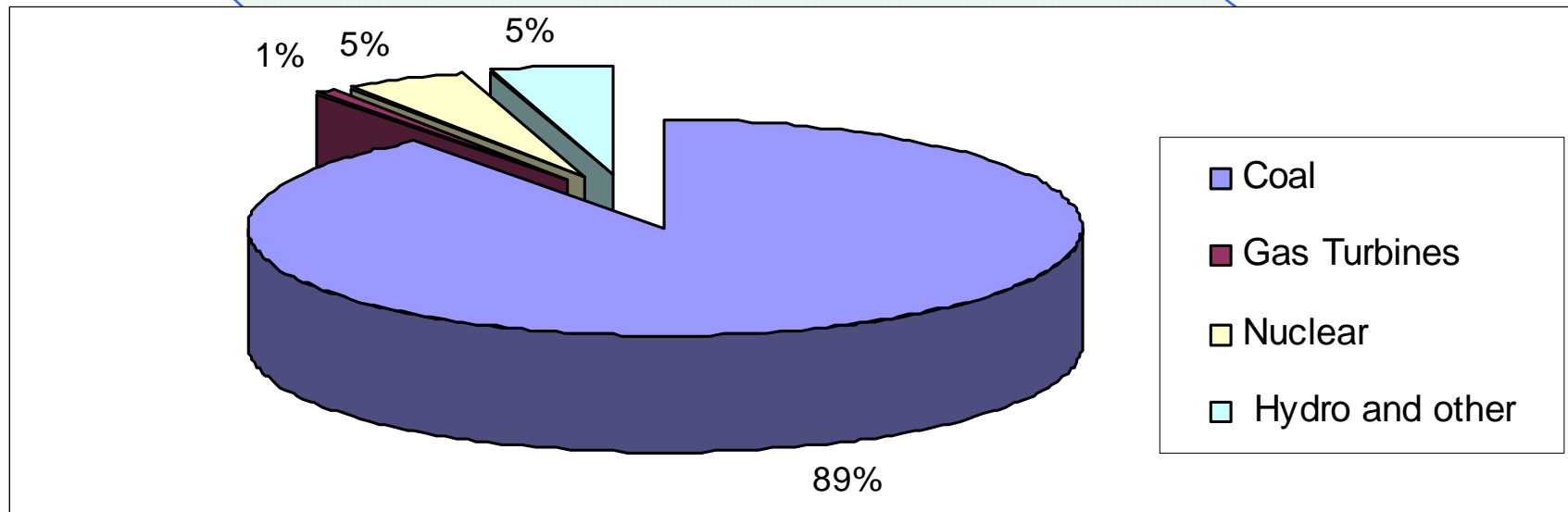
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Presentation for ICEF11

**ESKOM**



**Installed 42 000 MW**

# South African Electrical Energy

- Presently Installed 42 000 MW of which 89% is from Thermal Coal fired generators
- In construction 8 400 MW of Coal fired generators to come on stream 2013 - 2016. Also a number of smaller installations.
- Expected that demand will exceed supply in 2012-13

# FOPREH DATABASE

Food Processing Enquiry Handling System

- A database giving methods of production for a number of agri products under local conditions
- Including theoretical energy calculations for
  - 218 Food Products on
  - 309 Spreadsheets
- berries, cereal crops, citrus fruit, dairy, deciduous fruit, field crops, meat, root crops and subtropical fruit.

# FOPREH DATABASE

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

Energy inputs taken at the factory gate, not primary energy.

# Assumptions

PRODUCT: Set Yoghurt (1) (Full Fat )

QUALIFIER: Medium Dairy ( 20 000 l milk/day)

ASSUMPTIONS:

1. Milk is received cool (7 deg)
2. Clarification by filter/strainer
3. Cream is batch pasteurised and packed
4. Negligible Product losses
5. Composition. Fat 3.5% SNF content 11.6%  
(addition of APPROX 3% Powder) Fruit etc 0

ENERGY INPUTS IN kJ/kg YOGHURT PRODUCED  
(UNFLAVOURED)

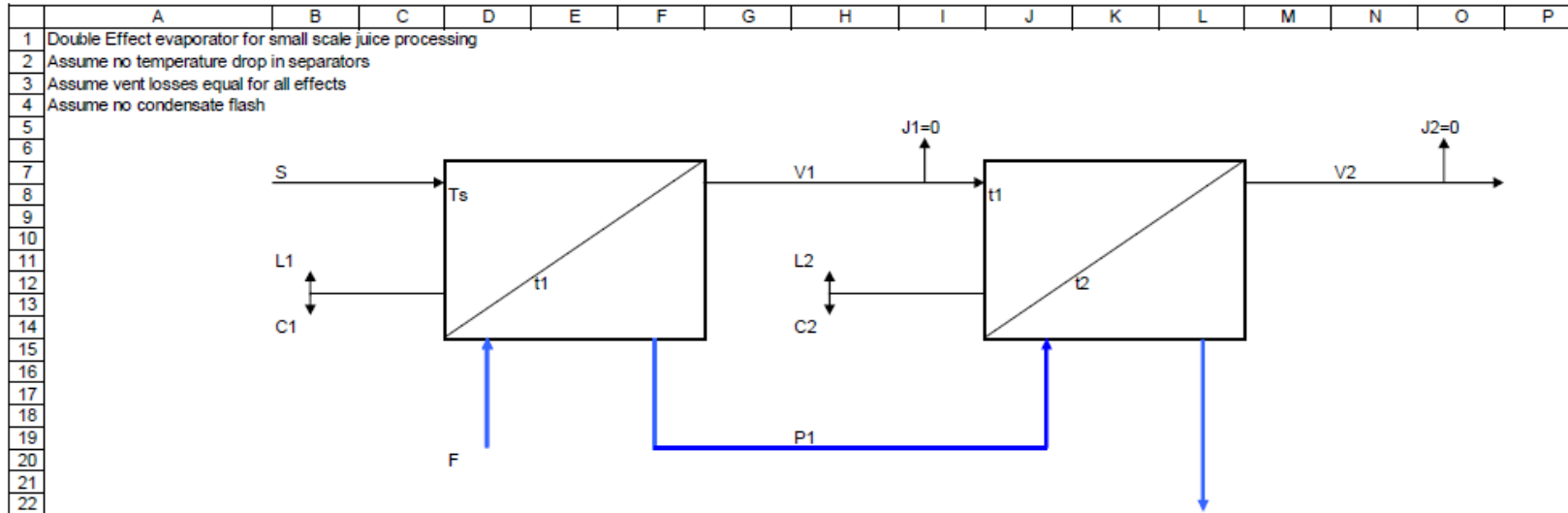
# Mass Balance

	A	B	C	D
2			Units	Value
3				
79		<b>Assumptions</b>		
80		Fruit in yoghurt	%	0
81		Fat in milk (fm)	%	4.5
82		SNF in milk (sm)	%	8.5
83		Fat in Cream (fc)	%	35
84		Fat in skim powder	assumed nil	
85		SNF in skim powder (sp)	%	97
86		Fat in yoghurt (fy)	%	3.5
87		SNF in yoghurt (sy)	%	11.6
88				
89		<b>Calculations</b>		
90		Fruit		0
91		Yoghurt before mixing fruit (Y)	kg	1.00
92		SNF in cream (sc)	%	5.785340314
93		Raw Milk	kg	0.99356713
94		Cream	kg	0.027744345
95		Powder	kg	0.034177215
96		Standard Milk	kg	0.97
97		Milk	kg/hr	20600.00
98		Cream	kg/hr	575.23
99		Powder	kg/hr	708.61
100		Fruit	kg/hr	0.00
101		Yoghurt	kg/hr	20733.3751
102		Standard milk	kg/hr	20024.78608

# METHODS 1

- Heating and Cooling - standard heat balance equations.
- Energy for pumps - flow and pressure drop calculations and efficiency factor.
- Centrifuge and homogenisers - estimated from commercial data.
- Evaporators and dryers- separate energy balance sheets and commercial data
- Heat loads for processing rooms - published data
- Refrigeration energy requirements - theoretical COP values together with a factor for fans and pumps

# Evaporator



	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	1.93	P
41			0.63854849	0.580503	-0.55027	0.230642	0	0.000464	0.000224	4.119657	S
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											2.319657

# Dryer

	N	O	P	Q	R	S	T	U	V	W	X
72	Energy Balance -Mango Dryer										
73	<i>Variables in italics</i>										
74			Air in								
75	Mass kg	165.738									
76	Temp	20									
77	RH	na							temp	75	
78	Humidity	0.007							press	38.58	
79									Humidity	0.024627	
80											
81											
82											
83											
84	Mass kg	165.738									
85	Temp	54									
86	RH	35									
87	Humidity	0.029233									
88											
89	mass	1.020									
90	Temp	50									
91	Moisture	17									
92	Mosit kg	0.173469									
93											
94											
95											
96											
97											
98											
99											
100											
101											

83	Air Exit										
84	Mass kg	165.738									
85	Temp	54									
86	RH	35									
87	Humidity	0.029233									
88	Product										
89	mass	1.020									
90	Temp	50									
91	Moisture	17									
92	Mosit kg	0.173469									
93											
94											
95											
96											
97											
98											
99											
100											
101											

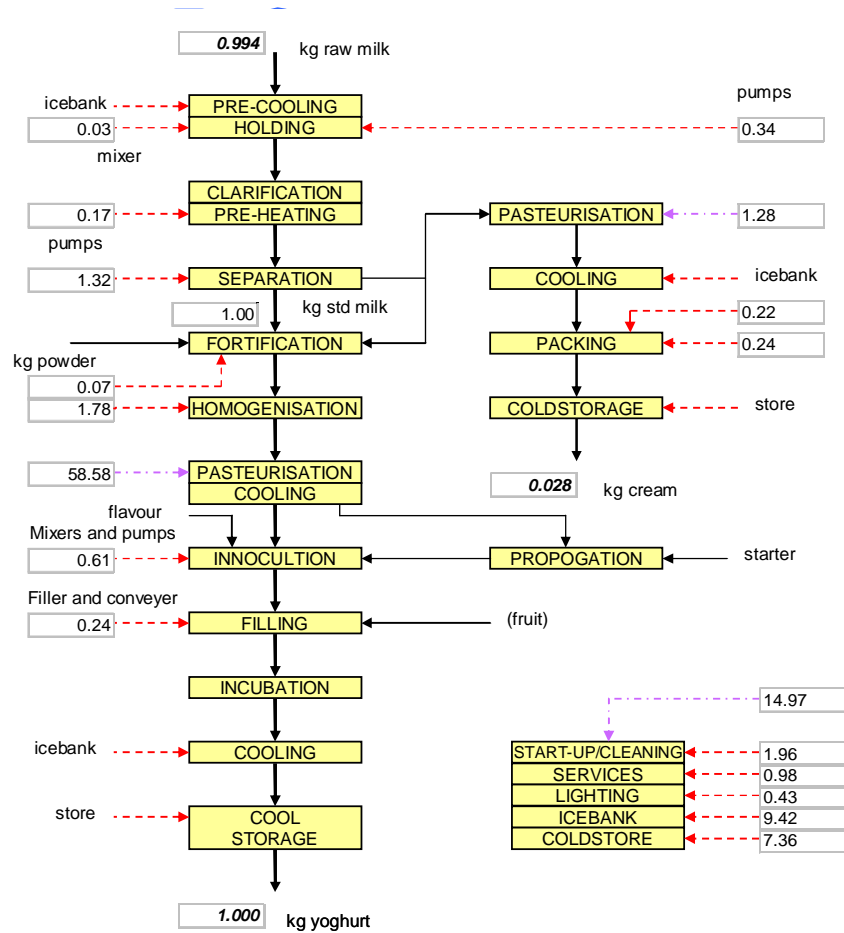
94											
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101											

# METHODS 2

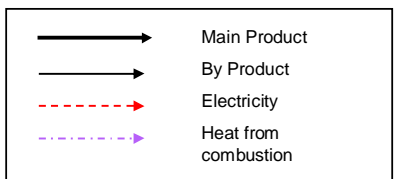
- Mixers, bowl cutters, and filling machines etc - an estimate based on the kW rating of commercially available plant and an estimated service factor.
- Cooling water - 14°C temperature rise and cooling tower requirements from commercial data.
- Boiler pumps and boiler sizing - taken from local commercial data. Boiler would be coal fired.
- Long term cold storage and freezer storage - taking the requirements, the COP and a factor to cover fans and pumps together with expected daily temperature rise.
- Lighting installed - estimated according to the size of the plant

# Energy Balance

	A	B	C	D	E	F	G	H	I
1		AGRELEK MASS BALANCE							
2			Units	Value	Power	Elec Input	Steam Input	%	Comments
133		Pasteurise							
134		Flow	kg	0.97					
135		specific heat		3.90					
136		temp in	C	4					
137		Past temp	C	90					
138		Regen	%	58					
139		temp out of regen	C	53.88					
140		temp back out of regen	C	40.12					
141		cooled temp	C	40.12					
142		heat load	kJ/kg	136.0535241					
143		efficiency	%	80					
144		Heatng reqd	kJ/kg	170.0669051			170.07	58.58	
145									
146		Innoculation							
147		Starter tank mixer		0.0954982	0.55	0.10		0.03	one tank
148		Holding tanks		0.1909964	1.1	0.19		0.07	two tanks
149		Pumps		1.490350895	6.8	1.49		0.51	threee (incl flavour)
150									
151									
152		Filler	kJ	0.173633091	1.0	0.17		0.06	
153		Conveyers etc		0.520899272	3	0.52		0.18	(incl cooler conveyers)



Energy per kg of final product (kJ)	
Electrical	73.05
Other	217.24
<b>Total</b>	<b>290.29</b>
Energy per kg of feed (kJ)	
Electrical	218.65
Other	218.65
<b>Total</b>	<b>292.17</b>
Installed Power (kW)	150.89



**ENERGY DIAGRAM**  
 PRODUCT: Set Yoghurt (1) (Full Fat)  
 QUALIFIER: Medium Dairy ( 20 000 l milk/day)  
 ASSUMPTIONS:  
 1. Milk is received cool (7 deg)  
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 5. Composition: Fat 3.5% , SNF content 11.6% (addition of approx 3% Powder), Fruit etc 0

**ENERGY INPUTS IN % OF TOTAL REQUIREMENTS**

# FOPREH – selected results

	Scale of Operation	SEC in kJkg <sup>-1</sup>		
		Electrical	Thermal	Total
Meat (cooked sausage)	300 kg/day product	1512	0	1512
Milk powder spray dried	20000 l/d milk	4210	9265	13475
Cheese Gouda (1)	10000 l /day milk	921	1618	2540
Cheese Gouda (2)	500 l batch	6681	0	6681
Milk evaporated	30000 l/day raw milk. Canned product	736	1508	2244
Grape juice cold pressed	5000 kg/hr grapes, Hot fill into bottles	297	681	978
Grape juice concentrate	8000 kg/hr grapes	500	4943	5444
Asparagus spears canned	400 kg/hr asparagus	238	1029	1267
Blueberry juice	1000 kg/hr feed. Hot break	148	690	838
Wheat pasta fresh noodles	300 kg wheat flour per batch	214	1741	1955
Orange pulp frozen	10000 kg/hr by product of juice	705	300	1005
Tomato chutney	50 kg/hr tomato	641	2521	3162
Guava puree concentrate	3000 kg/hr guavas	413	4803	5216

# Dairy Industry

	<b>FOPREH Data (kWh/L raw milk)</b>	<b>IFC recorded data (kWh/L raw milk)</b>	<b>IFC Benchmark</b>	<b>CIPEC Benchmark (kWh/L raw milk)</b>
<b>Milk and Cultured Milk</b>	<b>0.05 - 0.22</b>	<b>0.07 - 0.45</b>	<b>0.1 - 0.2</b>	<b>0.12</b>
<b>Cheese and Whey</b>	<b>0.07 - 0.26</b>	<b>0.06 - 0.82</b>	<b>0.2 - 0.3</b>	
<b>Milk Powder, Cheese and Liquid Products</b>	<b>0.3 - 0.45</b>	<b>0.18 - 6.47</b>	<b>0.3 - 0.4</b>	
<b>Ice Cream</b>	<b>0.4 kWh/kg ice cream</b>		<b>0.8 - 1.2 kWh/kg ice cream</b>	

# Comparative Dairy Results

<b>Category</b>	<b>Range of energy usage (Data adapted from Flapper [ 5] MJ/kg product</b>	<b>Comparative data FOPREH database MJ/kg product</b>
<b>Fluid Milk (including yoghurt)</b>	<b>0.22 - 12.6</b>	<b>0.18 - 0.78</b>
<b>Butter</b>	<b>1.00 - 4.20</b>	<b>2.50 - 3.50</b>
<b>Cheese</b>	<b>1.8 - 64.7</b>	<b>1.1 - 9.1</b>
<b>Concentrated Milk</b>	<b>1.8 -10.8</b>	<b>2.2 - 2.7</b>
<b>Powder</b>	<b>4.6 - 221.4</b>	<b>13.4 - 34</b>

## Conclusion

- The research provides data that has not been published elsewhere and which might be used for benchmarking
- Where comparative data is available particularly in dairy processing sector the data seems to give reasonable results
- The results provide a focus for optimizing specific stages in a process

# Acknowledgements

- ESKOM
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- SAAFoST

Thank you for your attention and  
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