EGEDA
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APEC
Asia-Pacific
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IRENA
International Renewable Energy Agency

Exercise 4. Measurement and estimation

Kraft pulp and palm oil

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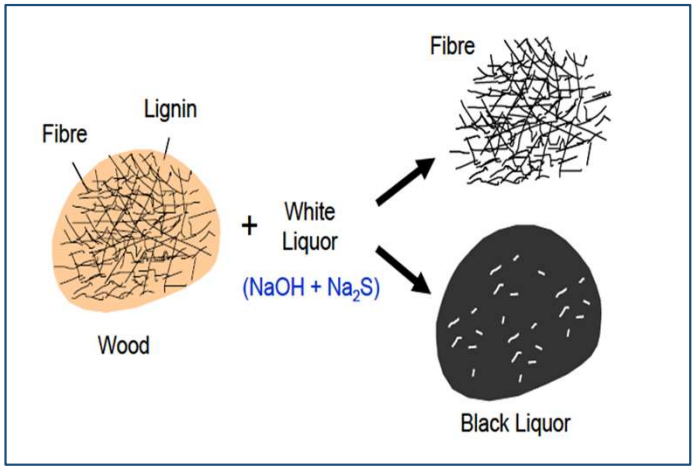
Outline of presentation

1. Kraft pulp processing
2. Estimating energy use from kraft pulp processing
3. Palm oil processing
4. Estimating energy use from palm oil processing

Kraft pulp processing

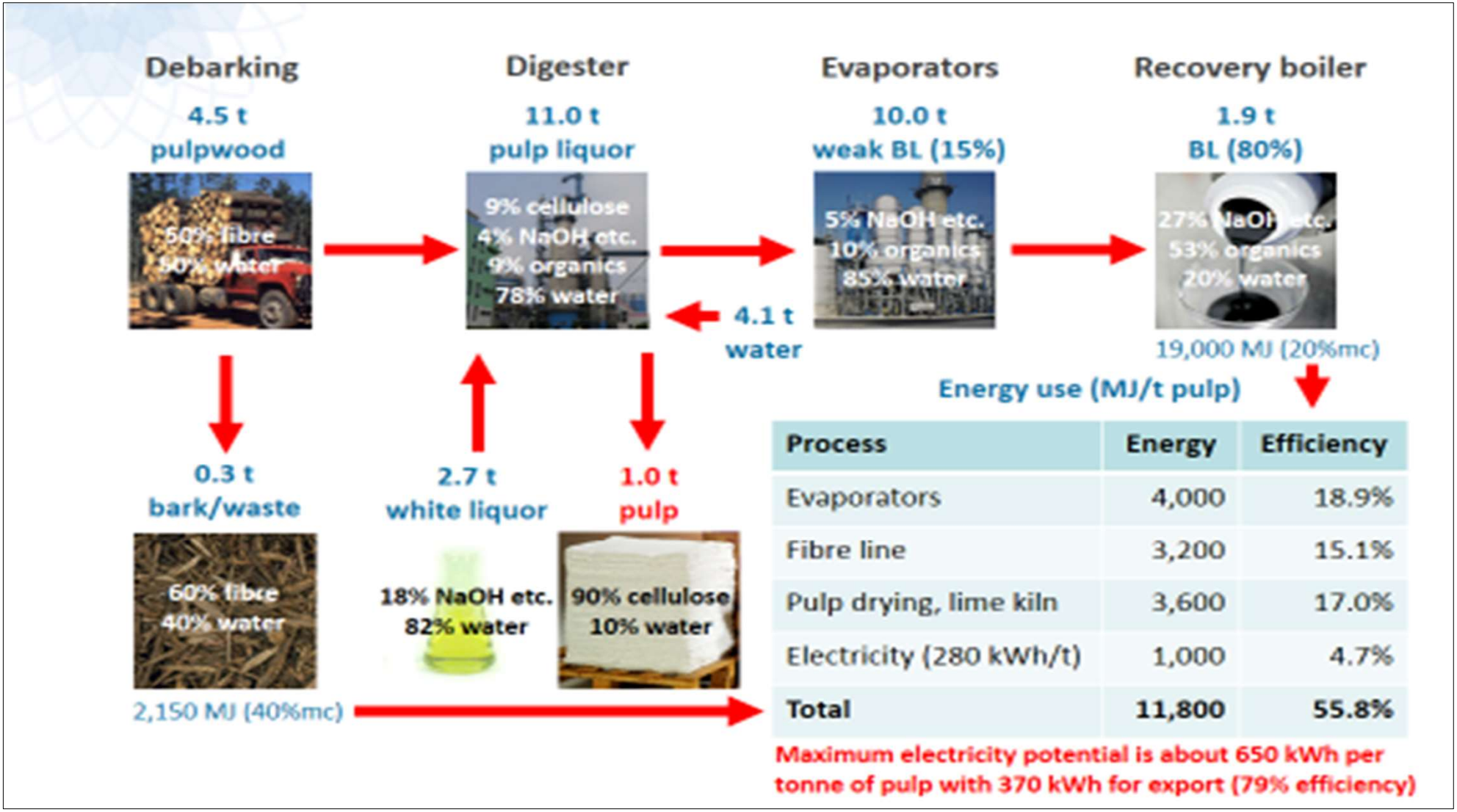
- Half of the wood is dissolved, and together with the spent pulping chemicals forms a liquid steam called weak black liquor (Na_2S).
- The weak black liquor is separated from the pulp by washing and is sent to the kraft recovery system, where the inorganic pulping chemicals are recovered for reuse, while the dissolved organics are used as a fuel to make steam and power.



Source : Tran and Vakkilainen

Kraft pulp processing

Kraft pulp mass/energy flow



Process	Energy	Efficiency
Evaporators	4,000	18.9%
Fibre line	3,200	15.1%
Pulp drying, lime kiln	3,600	17.0%
Electricity (280 kWh/t)	1,000	4.7%
Total	**11,800**	**55.8%**

Maximum electricity potential is about 650 kWh per tonne of pulp with 370 kWh for export (79% efficiency)

Source: IRENA

Illustration

Indonesia

- Wood pulp production (excluding mechanical wood pulp) in 2018

= 8,402,335 tonnes

Find:

1. Electricity own use (GWh)
2. Heat/mechanical energy use (TJ)
3. Total energy use (TJ)
4. Max electricity potential (GWh)
5. Black liquor produced (TJ)

Notes:

- 280 kWh of electricity is produced per tonne of pulp;
- Heat/mechanical use = energy used from evaporators to pulp drying;
- Estimated total energy use for processing = 11,800 MJ/t
- Maximum electricity potential is at 370 kWh/tonne
- Black liquor recovered = 19,000 MJ/t

Solution

Calculation for 1-5

- Electricity own use
  - = 8,402,335 x 280)/10^6
  - =2,353 GWh=8,470 TJ
- Heat/mechanical energy use
  - = (8,402,335 x 10,800)/10^6
  - = 90,745 TJ (Table 3)
- Total energy use
  - = (8,402,335 x 11,800)/10^6 = 99,148 TJ
- Max electricity potential
  - = (8,402,335 x 650)/10^6
  - = 5,462 GWh=19,661 TJ
- Black liquor produced
  - = 19,000MJ*8,402,335
  - = 159,644 TJ (Table 1)

Other computation

- BL for electricity
  - = 159,644 TJ-90,745 TJ
  - = 68,899 TJ
- Thermal efficiency
  - = 68,899 TJ/19,661 TJ = 29%
- BL used for electricity
  - = 8,470 TJ /29%
  - = 29,680 TJ (Table 2)
- Total BL consumption
  - = 92,745 TJ+ 29,680 TJ = 120,425 TJ
- Unused BL
  - = 159,899 TJ- 120,425 TJ
  - = 39, 220 TJ (Stat diff)

Answer sheet

Supply (Table 1)

		Black liquor
		TJ
		T
Production[1]	(+) 1	159,644
Imports	(+) 2	
Exports	(-) 3	
Stock change (opening-closing)	(+) 4	
Gross inland deliveries (calculated)	**(=) 5**	**159,644**
Statistical difference	6	39,220
Gross inland deliveries (observed)	**7**	**120,425**

Transformation (Table 2)

		Black liquor
		TJ
		T
TOTAL TRANSFORMATION SECTOR	1	**29,680**
Main Activity Producers	2	0
Electricity Plants	3	
CHP Plants	4	
Heat Plants	5	
District Cooling Plants	6	
Autoproducers	7	29,680
Electricity Plants	8	
of Which off-grid	9	
CHP Plants	10	29,680
of Which off-grid	11	
Heat Plants	12	
of Which off-grid	13	
District Cooling Plants	14	
Biofuels Processing[2]	15	
Charcoal Production	16	
Not Elsewhere Specified	17	
TOTAL ENERGY SECTOR	18	
Electricity, CHP and Heat Plants	19	
Biofuels Processing	20	
Not Elsewhere Specified	21	

Final consumption (Table 3)

		Black liquor
		TJ
		T
FINAL CONSUMPTION	1	**90,745**
TOTAL INDUSTRY SECTOR	2	90,745
Iron and steel	3	
Chemical and petrochemical	4	
Non-ferrous metals	5	
Non-metallic minerals	6	
Transport equipment	7	
Machinery	8	
Mining and quarrying	9	
Food, beverages and tobacco	10	
Pulp, paper and print	11	90,745
Wood and wood products	12	
Construction	13	
Textile and leather	14	
Not elsewhere specified	15	
TOTAL TRANSPORT SECTOR	16	0
Domestic air transport	17	
Road	18	
Rail	19	
Inland waterways	20	
Pipeline transport	21	
Not elsewhere specified	22	
TOTAL OTHER SECTOR	23	0
Commercial and public services	24	
Residential	25	
Agriculture	26	
Fishing	27	
Not elsewhere specified	28	

From the data collected, there will be stat diff of 39,220 TJ

3.1a Hands-on exercise

Kraft pulp processing

Estimate BL, energy use

Pulpwood production (tonnes)

Economy	2018
AUS	1,520,000
CDA	9,789,000
CHL	5,053,000
PRC	11,082,201
HKC	15,000
INA	8,402,335
JPN	8.264,000
ROK	499,000
MAS	131,000

Economy	2018
MEX	125,000
NZ	765,423
PE	59,000 (1993)
PHL	147,000 (2011)
RUS	6,508,000
CT	370,201
THA	1,065,000
US	47,856,642
VN	250,000

Source: FAO

No data for BD; PNG; SGP

Palm oil processing

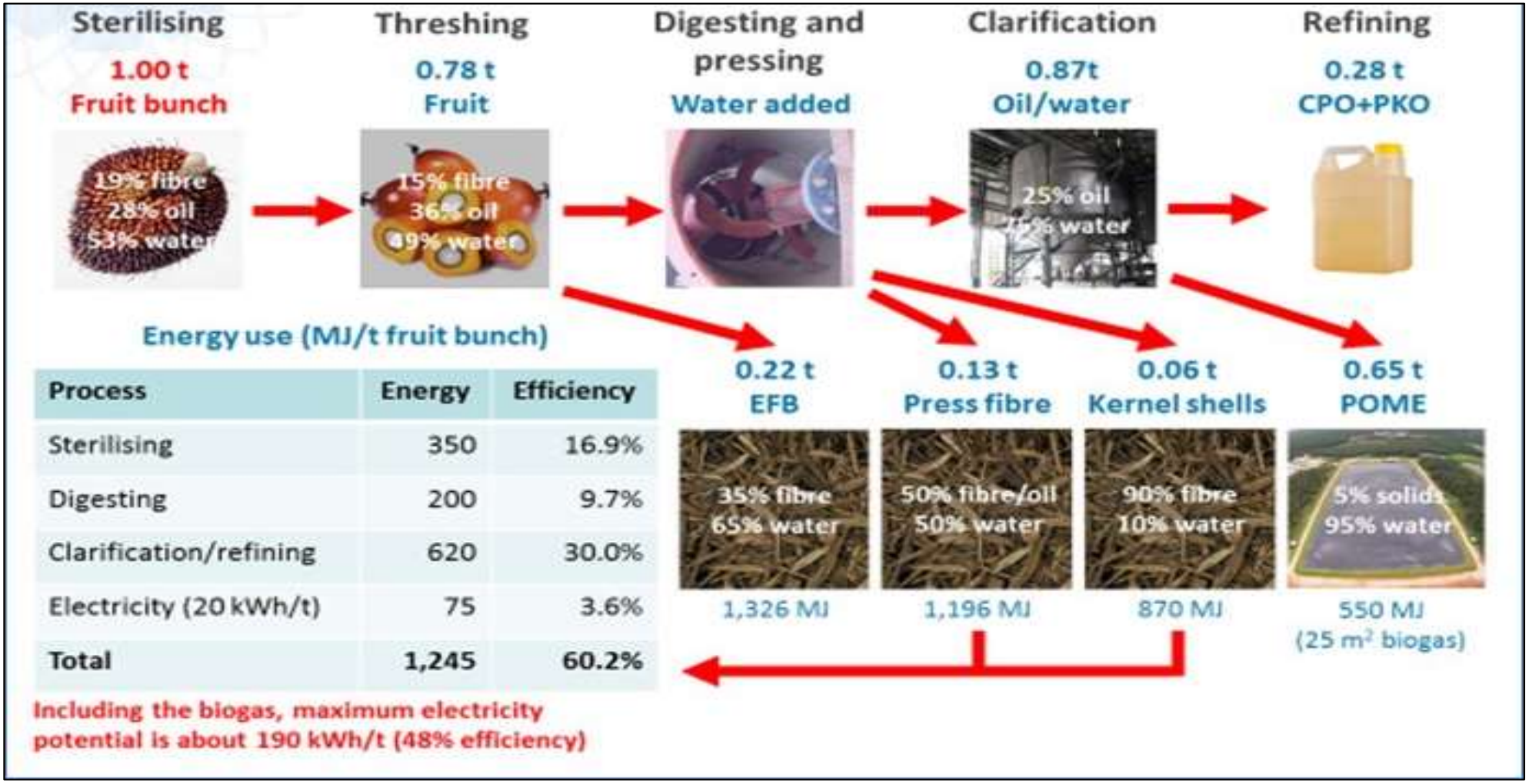
- Palm oil is a vegetable oil derived from the fruit of the palm tree. It is an important and efficient type of oil which is used as a raw material for both food and non-food industries.
- Oil palm is grown as a plantation crop in most countries with high rainfall (in tropical climates within 10° of the equator.
- A palm oil mill produces crude palm oil (palm fruit) and kernels (seeds), as primary products and biomass as secondary product.

Source : WIkipedia

Biomass products include empty fruit bunch (EFB), press fibre, kernel shells and palm oil mill effluent (POME)

Palm oil processing

Pal oil mass/energy flow



Process	Energy	Efficiency
Sterilising	350	16.9%
Digesting	200	9.7%
Clarification/refining	620	30.0%
Electricity (20 kWh/t)	75	3.6%
Total	**1,245**	**60.2%**

Including the biogas, maximum electricity potential is about 190 kWh/t (48% efficiency)

Source: IRENA

Illustration

Palm production of PNG

- Oil palm production in 2018

  = 2,496,325 tonnes

Find:

1. Electricity own use (GWh)
2. Heat/mechanical energy use (TJ)
3. Total energy requirement (TJ)
4. Max electricity potential (GWh)
5. Biomass and biogas produced (TJ)

Notes:

- 20 kWh of electricity is produced per tonne of oil palm;
- Heat/mechanical use = energy used from fruit bunch processing;
- Estimated total energy use for processing = 1,245 MJ/t
- Maximum electricity potential is at 190 kWh/tonne
- POME per t of oil palm = 500 MJ/t

Solution

Estimation for biomass

- Electricity own use

  = (2,496,325 x 20)/ 10^6

  = 50 GWh = 180 TJ

- Heat/mechanical energy use

  = (2,496,325 x (350+200+620))/ 10^6 = 2,921 TJ (Table 1)

- Max electricity potential

  = (2,496,325 x 190) / 10^6

  = 474 GWh = 1,707 TJ

Estimation for biogas

- Own use of biogas for electricity

  = (180/.48) = 374 TJ (0.48 is efficiency)

- Biogas used for electricity

  = 374 TJ (Table 1 and 2)

- Total energy requirement

  = 2,921 TJ (Table 3)+ 374 TJ

  = 3,216 TJ

Answer sheet (questionnaire)

Supply and consumption		Other vegetal and agricultural waste	Other biogases from anaerobic fermentation
2017		**TJ**	**TJ**
Production	(+)	2,921	374
Imports	(+)		
Exports	(-)		
Stock changes	(+)		
International Bunkers	(-)		
Domestic supply	(=)	**2,921**	**374**
Transfers			
Statistical Differences		**0**	**0**
Power plants			
CHP plants			374
Commercial heat plants			
Charcoal production			
Biomass pellet and briquette production			
Other transformation			
Energy sector and own use		0	0
Distribution losses			
Total final consumption			
Industry sector		2,921	0
Transport sector			
of which road transport			
Commercial and public services			
Residential			
of which traditional uses			
Other			
Net calorific value (MJ/t)			

Electricity Production
(in MWh)
49,927

3.1b Hands-on exercise

Oil palm processing

Estimate biomass and biogas

Oil palm production (tonnes)

Economy	Production
China	672,760
Indonesia	115,267,491
Malaysia	98,419,400
Mexico	983,676
PNG	2,496,325
Peru	921,001
Philippines	500,466
Thailand	15,400,000

Source : FAOSTAT

Oil palm production is mostly common in topical economies; no production data from AUS; BD; CDA; CHL; HKC; JPN; ROK; NZ; RUS; SGP; CT; US and VN

Solution