The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

Centre of Sustainable Palm Oil Research

The Biomass Complex in Palm Oil Industry

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The University of Nottingham, Malaysia

Denny K. S. Ng, PhD, MIChemE

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- Qualifications:
  - BEng (Chemical) (Hons.) (UTM)
  - PhD (University of Nottingham)
- Employment History:
  - Professor of Process Design and Integrated Biorefinery (since 2015)
    Associate Professor, University of Nottingham (2012 - 2015)
  - Assistant Professor , University of Nottingham (2009 – 2012)
  - Post-doctoral Research Associate, Texas A&M University, US (2008)
- Areas of research:
  - Process synthesis & design.
  - Resource conservation via process integration techniques
  - Biomass processing and integrated biorefineries.
  - Energy management
  - Carbon-constrained energy planning

Outline of Presentation

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- Palm Oil Industry
- Potential, Policy and Challenges
- Foodsteps of Palm Oil-based Biorefinery
  - First Generation
- REGEN System to transform Palm Oil Mill into Palm-based Biorefinery
- Conclusions

Palm Oil Industry

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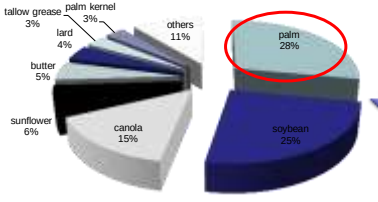
World Consumption for Major Fats and Oils - 2015



Palm Oil Production by Country - 2015 (Metric tonnes)

(IHS, 2016) & (GlobalPalmOilProduction, 2016)

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Oil Palm Planted Area by State (Dec 2014) – Hectares (MPOB, 2015)

State	Mature	%	Immature	%	Total	%
Johore	651,242	88.8	82,225	11.2	733,467	13.6
Kedah	80,767	93.7	5,415	6.3	86,182	1.6
Kelantan	99,783	68.9	44,979	31.1	144,762	2.7
Malacca	49,501	93.7	3,348	6.3	52,849	1.0
Negeri Sembilan	142,503	84.1	26,865	15.9	169,368	3.1
Pahang	623,269	86.6	96,344	13.4	719,613	13.3
Perak	348,794	89.6	40,370	10.4	389,164	7.2
Perlis	189	64.1	106	35.9	295	0.0
Penang	13,309	93.7	895	6.3	14,204	0.3
Selangor	126,805	91.6	11,677	8.4	138,482	2.6
Terengganu	139,410	82.5	29,538	17.5	168,948	3.1
Peninsular Malaysia	2,275,572	91.6	341,762	8.4	2,617,334	48.5
Sabah	1,355,541	89.7	155,969	10.3	1,511,510	28.0
Sarawak	1,058,208	83.8	205,183	16.2	1,263,391	23.5
Sabah & Sarawak	2,413,749	87.0	361,152	13.0	2,774,901	51.5
MALAYSIA	4,689,321	87.0	702,914	13.0	5,392,235	100.0

Palm Oil Industry

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Palm Oil Industry

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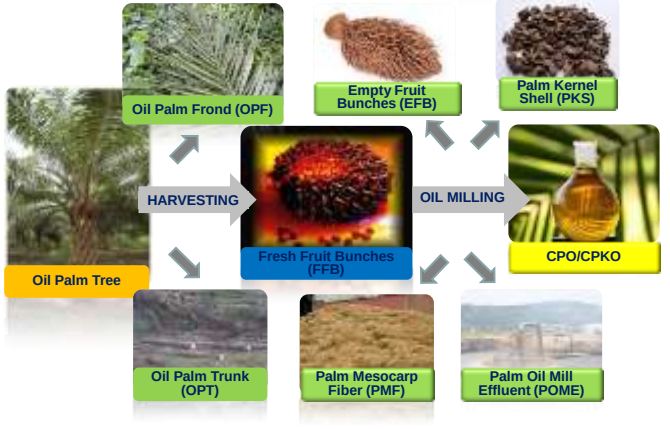

Palm Oil Milling Process

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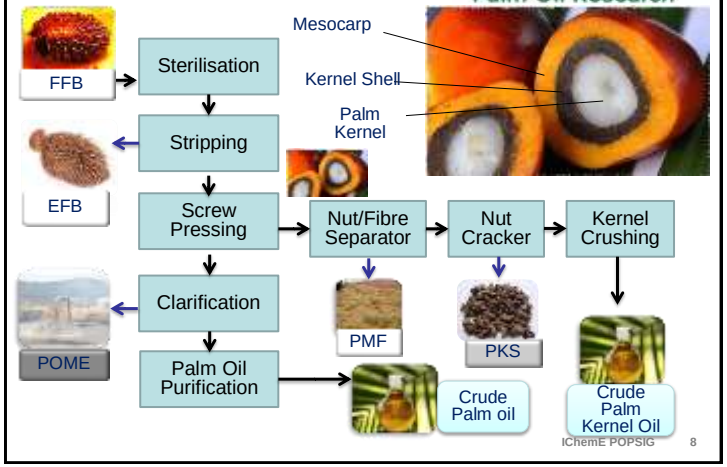

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Crude Palm Oil Production (MPOB, 2015)

Months	Crude Palm Oil	
	2013	2014
JANUARY	1,602,493	1,508,980
FEBRUARY	1,296,824	1,275,812
MARCH	1,325,101	1,497,142
APRIL	1,366,544	1,555,777
MAY	1,384,330	1,656,957
JUNE	1,416,826	1,569,684
JULY	1,674,852	1,665,661
AUGUST	1,735,284	2,031,677
SEPTEMBER	1,912,175	1,896,901
OCTOBER	1,972,278	1,892,994
NOVEMBER	1,861,084	1,750,567
DECEMBER	1,668,668	1,364,884
TOTAL	19,216,459	19,667,016

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Potential of palm oil biomass

Biomass available from Palm Oil Industry	% from FFB*	Quantity (million tonnes)
Empty Fruit Brunch (EFB)	23	21.24
Mesocarp Fibre	13	12.00
Palm Kernel Shell	6	5.54
Palm Oil Mill Effluent (POME)	60	55.40

*Based on 92.33 million tonnes FFB proceed in 2014

Palm-based Biomass

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Biomass	Ultimate Analysis (wt %)				LHV (MJ/kg)	Molecular Formula
	C	H	N	O*		
Shell	53.78	7.20	0.00	36.30	22.14	$CH_{1.69}O_{0.54}$
Fiber	50.27	7.07	0.42	36.28	20.64	$CH_{1.61}O_{0.51}$
EFB	48.79	7.33	0.00	40.18	18.96	$CH_{1.80}O_{0.62}$

Potential of Palm-based Biomass

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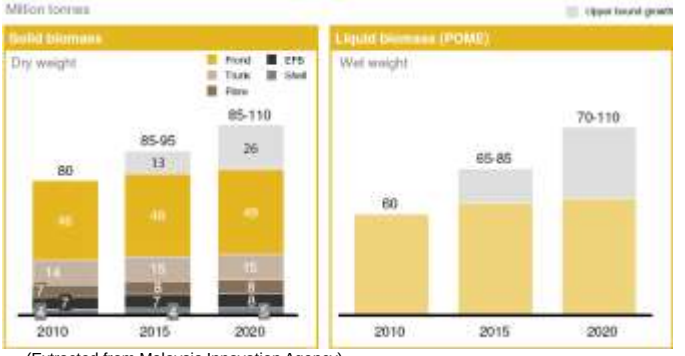
- By 2020, solid biomass will increase to 85-110 million tonnes, POME to 70-110 million tonnes



(Extracted from Malaysia Innovation Agency)

Assessing the best uses of Malaysia's palm oil biomass

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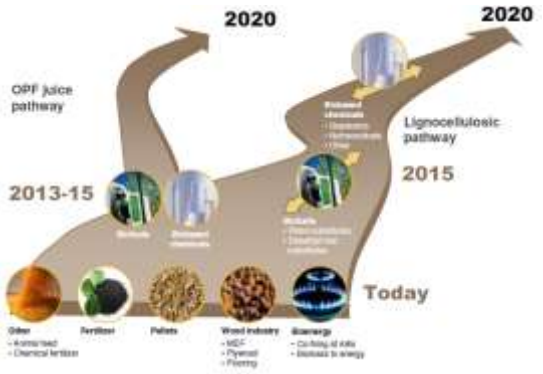

(Extracted from Malaysia Innovation Agency)

National Biomass Strategy 2020

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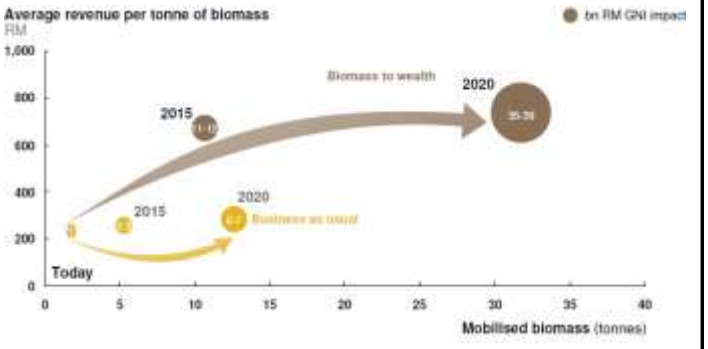

(Extracted from Malaysia Innovation Agency)

National Biomass Strategy 2020

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- Assessing the best uses of Malaysia's palm oil biomass
  - Downstream technologies of today and tomorrow
  - Additional value creation: **Biomass to wealth**
    - Pellets
    - Biofuels
    - Biobased chemicals
- Costing the mobilisation of biomass to create more value from oil palm
- Capturing the **RM 30 billion** opportunity

(Agensi Inovasi Malaysia)

Technical Challenges

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- **Feedstocks:** Production, Supply Chain
- **Capacity, Efficiency:** Requires proven results
- **Equipment design:** Adaption from other industries (e.g., wood)
- **Technology:** Large number of possible pathways

Non-technical Challenges

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- **Use of land:** Effect of large areas of monoculture
- **Economic:** Investment, cost of production, taxation policies, subsidies
- **Company policy/strategy:** "wait and see"
- **Working environment and culture:** Operators are not trained to handle new technology

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Recent research on palm oil-based biomass utilisation (Ng & Ng, 2013)

Category	Technology	Value Added Product
Physical	Densification	Palm briquette
		Palm pellet
		Hybrid plywood
		MDF
Biological	Anaerobic Digestion	Biogas
	Fermentation	Bioethanol
		Biopolymer
		Compost
Thermochemical	Gasification	Syngas
	Pyrolysis	Bio-oil
	Torrefaction	Torrefied biomass
	Liquefaction	Bio-oil

Palm Oil-based Biorefinery

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- Processing facility that transform oil palm biomass into any value-added products.
  - Biofuels
  - Biomaterials
  - Specialty chemicals
  - Pharmaceuticals

Platforms of Biorefinery (NREL)

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- **Sugar-lignin** platform
  - Fermentation, hydrolysis, etc.
- **Thermochemical** platform
  - Gasification, pyrolysis, etc.
- **Biogas** platform
  - Anaerobic Digestion
- **Carbon-rich chains** platform
  - Biodiesel
- **Plant product** platform
  - Oil extraction from algae

Integrated Biorefinery

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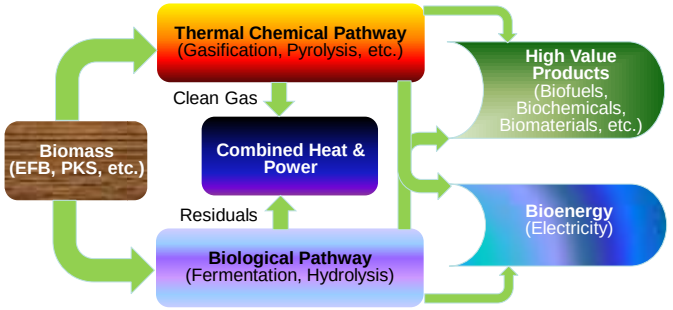

Integrated Biorefinery

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- **Various processing systems** (e.g. fermentation, gasification, pyrolysis, hydrolysis etc.)
- Focus on the use of **non-food crop** as feedstocks, e.g. EFB, OPF, OPT, etc.;
- Multiple feedstock, multiple products, minimum waste
- Have multiple levels of process integration
  - **Material** and **energy** recovery

Footsteps of Palm Oil-based Biorefinery

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- Biomaterials
  - Dried Long Fibre
  - Palm Briquette
  - Palm Pellet
  - Bio-Organic Compost
- Bioenergy
  - Direct heat & power generation via biomass boiler
  - Biogas from POME
  - Electricity

Integrated Waste Recovery & Regeneration System (REGEN System)

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IChemE

eureka synergy

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Together with Eureka Synergy Sdn Bhd –

Highly Recommended for
Sustainable Technology Award 2015

Shortlisted for
Palm Oil Industry Award 2015

IChemE ADVANCING CHEMICAL ENGINEERING WORLDWIDE

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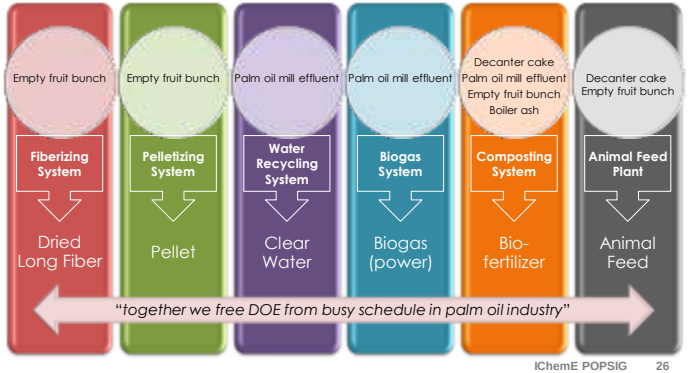
Waste/Biomass → value-added products & power



Nottingham Greentech

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Bioreactor for Biogas Production from Palm Oil Mill Effluent (POME)

Nottingham Greentech

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Bioreactor for Biogas Production from Palm Oil Mill Effluent (POME)

Pilot Scale Research

The most promising solution for water pollution and energy problems faced by the palm oil industries.

- 60% SMALLER FOOTPRINT
- 10% MORE BIOGAS
- HIGHER METHANE PURITY
- LOWER H2S CONCENTRATION
- MEETING BOD 20PPM

Nottingham Greentech

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IAAB Pilot Plant

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Pump House 1 & Pump House 2

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Discharge and Transfer Sump

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CESPOR Office and Lab

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SCADA System

POME Treatment

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Expected Performance

Parameter	Treated Effluent	Recovered water	DOE Std. (2006)	Drinking Water Std.	Unit
pH	6.8-7	7-8	5-9	6.5-9	
BOD	15-22	<6	20	6[a]	mg/L
COD	200 - 250	<10	Nil	10[a]	mg/L
TSS	50-100		400		mg/L
Turbidity	Nil	<5		5	NTU
O&G	ND	ND	50	0.3	mg/L
TN			100		mg/L
Color	--	<15		15	TCU
TDS				1000	mg/L

[a]based on raw water

POME Treatment

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Expected Performance

Raw POME

Anaerobically treated POME

Treated POME via IAAB System

Average COD: 650 mg/L
Average BOD: 28 mg/L
Average TSS : 200 mg/L

[a]based on raw water

POME Treatment

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Expected Performance Final treated POME via Polishing System

Recovered water from treated POME

Average COD: <10 mg/L
Average BOD: <6 mg/L
Average Turbidity : <5 mg/L

Treated POME

POME
to
Clear Water
Quality

Biogas Generation

Expected Performance

Parameter	Raw Biogas	Gas Engine allowance	Flaring system	Unit
Moisture Content	51 (30-100) or 4-8	10 or 1	saturated	g/m^3 %v/v
Temperature	40	5	--	^oC
Methane	60-62 35[a]	50	10-50[b]	%
H_2S	40 -700 10000[a]	4000	--	ppm
Biogas Production @STP	1200 800[a]	--	--	m3/hr

[a]event of failure; [b]<10% needs burner adjustment

Power Generation System

Product	Power
Capacity (60 t/h FFB)	2200 kW
Market price (as of October 2014)	RM 0.4169 per kW

Fiberizing System

Product	Palm dried long fiber	Palm short fiber[2]
Bulk density	300 kg/m^3	--
Fiber length	40 - 45 mm	25 – 30 mm
Moisture content	15 % - 35 %	15 % - 35 %
Market price[1] (as of May 2014)	RM 500 per tonne	RM 200 per tonne

[1]The market price quoted is freight-on-board (FOB) price, after utility cost excluding wear and tear.
[2] Palm short fiber is to be recover to pelletizing system for pellet production.

Fiber Mat System

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Product	Fibre Mat
GSM	1000 g/m^2
Moisture content	< 15%
Market price[1] (as of May 2014)	+/- RM 2000 per tonne

[1]The market price quoted is freight-on-board (FOB) price, after utility cost excluding wear and tear.

Pelletizing System

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Product	Palm pellet
Density	650 kg/m^3
Heating value	4300 kcal/kg
Moisture content	< 10.5%

[1]The market price quoted is freight-on-board (FOB) price, after utility cost excluding wear and tear.

Biofertiliser System

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Product	Biofertiliser
C/N Ratio	< 20
Organic Matter	> 35 %
Moisture content	< 30 %
Total NPK	> 5 %
Market price[1] (as of Oct 2014)	RM 600 per tonne

[1]The market price quoted is freight-on-board (FOB) price, after utility cost excluding wear and tear.

Conclusions

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- Palm oil mill in Malaysia
  - Focusing on First Generation Biorefinery/Biogas system only
  - Development of biorefinery still highly depends on market force
- REGEN System – Nottingham Green Technologies Sdn Bhd
  - Eliminate all solid and liquid wastes
  - Upgrade the biomass into value-added products

Acknowledgment

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- University of Nottingham New Researcher Fund (NRF 5021/A2RL32)
- Eureka Synergy Sdn. Bhd., Malaysia
- Havys Oil Mill Sdn. Bhd., Malaysia
- Ministry of Higher Education, Malaysia
  - LRGS Grant (Enhancing Productivity and Sustainability of Palm Oil Milling Industry)
  - LRGS Grant (Future Biorefineries: Unlocking the Potential of Fine Chemicals and Value Added Byproducts)

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