Long-term Research Grant Scheme (LRGS) Sharing The Experience (2012 – 2017)

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Department of Chemical and Environmental Engineering

8 March 2019
1. MOHE has approved RM5.808 million to UPM in 2012 to conduct fundamental research under LRGS on “Enhancing the Productivity and Sustainability of Palm Oil”

2. Objectives of the program:
   - To improve the existing palm oil milling technologies and
   - To increase biomass utilization through fundamental approaches.

3. The program comprises of 5 projects; 3 projects led by UPM and 2 projects by UITM and UTM.

4. The research program focused on industry-based problems, involving major players in palm oil industries in particular SIME DARBY, FELDA (FGV), DOLPHIN ENG AND FIBALOY INTERNATIONAL
LRGS APPLICATION

- Identify research niche area
- Determine scope, projects, project leaders, members
- Identify industry players

- 5 pages (max)
- LRGS_Robiah_concept_sample.docx
- LRGS_ITMA_Robiah_3Jan2012_v7.pptx
- Program.ProposalLRGS_ITMA_2July.docx
1. Executive Summary

2. General Background and Rationale

3. General Objectives
   • Objective for Project 1
   • Objective for Project 2

4. Description of Research Programme and Research Team

5. Methodology

6. Track record of project leaders

7. Expected Results

5 Pages
PROJECT PROGRESS AND MONITORING

- Overall program report
- Individual project report

- LRGS 1st Progress_Program_2013_2019.pptx
- LRGS 2nd Progress_Program_2014_2019.pptx
- LRGS 3rd Progress_Program_2015_2019.pptx
- LRGS 4th Progress_Program_2016_2019.pptx
1. All KPIs for the programme achieved
   i. KPI on students (17 PhD and 33 MS)
   ii. KPI on publication (50 journals and 65 conference papers)

2. 3 journal writing workshops held in 2013, 2014 and 2015.

3. 3 colloquiums held in Dec 2013, Jan 2015, March 2016

4. 5 intensive courses on fundamental issues in palm oil milling processes.

5. 12 workshops organised to monitor the projects progress

6. Licensed two technologies;
   • High Pressure Sterilization has been licensed by Dolphin Eng (2014).
   • A More Efficient Palm Oil Extraction Method has been licensed by Fibaloy International Sdn Bhd (2017)

Video
https://www.youtube.com/watch?v=CLwUjdKOPqg&feature=youtu.be
Terima Kasih | Thank You
ENHANCING PRODUCTIVITY AND SUSTAINABILITY OF PALM OIL MILLING INDUSTRY

- Inefficient milling technology particularly poor oil extraction leads to oil losses.
  - Oil losses in unstripped FFB at 0.4% oil loss/FFB or RM 3.0 million/mill/year
  - 0.7% oil loss/FFB in press fiber and kernel loss, 0.32%/FFB (50% oil in kernel) at or RM 6.8 million/mill/year
  - Oil losses in sludge at 0.32% oil loss/FFB or RM 2.8 million/mill/year
- Major oil losses in palm oil mills occur in the Fibre, Sludge and Steriliser condensate (90% of all oil losses)
- High oil loss and % of broken kernels in press fibre is due to inefficient sterilization, digestion and screw press.
- Formation of emulsions at the oil/water boundary in clarifier leads to more oil loss.
- Oil loss in condensate occurs due to longer than necessary steriliser cycle or due to over ripe fruit.
ENHANCING PRODUCTIVITY AND SUSTAINABILITY OF PALM OIL MILLING INDUSTRY

PROJECT 1

PROJECT 2

PROJECT 3

PROJECT 4

OUR SOLUTION

Improve OER to 22%

PROJECT 5
**RESEARCH DELIVERABLES**

- Improved OER to 22%
- RM12 million/year per mill
- Potential income of **RM5.4 billion/yr**

- Reduced total oil losses to below 1.0%
- Reduced kernel losses to below 5%
- Palm oil milling process with zero discharge

**ENHANCING PRODUCTIVITY AND SUSTAINABILITY OF PALM OIL MILLING INDUSTRY**

- Fully automated oil palm grading /oil quality system
- Improved technology

- 54 publications
- 8 patents
- 15 PhD
- 32 MS
- Trained workers (51 bachelor students)

**ENHANCING PRODUCTIVITY AND SUSTAINABILITY OF PALM OIL MILLING INDUSTRY**
# OVERALL BUDGET - PROJECT

<table>
<thead>
<tr>
<th>Project</th>
<th>Allocation for 1(^{st}) Year (RM)</th>
<th>Allocation for 2(^{nd}) Year (RM)</th>
<th>Allocation for 3(^{rd}) Year (RM)</th>
<th>Allocation for 4(^{th}) Year (RM)</th>
<th>Allocation for 5(^{th}) Year (RM)</th>
<th>Total Allocation (RM)</th>
<th>Balances after 5 Years (RM)</th>
<th>Percent Expenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1</td>
<td>651,224</td>
<td>268,152</td>
<td>237,855</td>
<td>109,248</td>
<td>86,636</td>
<td>1,353,115</td>
<td>46,574.19</td>
<td>96.5%</td>
</tr>
<tr>
<td>Project 2</td>
<td>348,816</td>
<td>304,263</td>
<td>310,840</td>
<td>409,849</td>
<td>244,138</td>
<td>1,617,906</td>
<td>32,644.90</td>
<td>97.9%</td>
</tr>
<tr>
<td>Project 3</td>
<td>275,600</td>
<td>563,500</td>
<td>179,876</td>
<td>65,200</td>
<td>33,299</td>
<td>1,117,475</td>
<td>26,299.32</td>
<td>97.6%</td>
</tr>
<tr>
<td>Project 4</td>
<td>355,760</td>
<td>411,985</td>
<td>394,529</td>
<td>86,803</td>
<td>70,027</td>
<td>1,319,104</td>
<td>1,7777.95</td>
<td>99.9%</td>
</tr>
<tr>
<td>Project 5</td>
<td>112,200</td>
<td>113,200</td>
<td>69,000</td>
<td>59,000</td>
<td>47,000</td>
<td>400,400</td>
<td>0.00</td>
<td>100%</td>
</tr>
<tr>
<td>Total</td>
<td>1,743,600</td>
<td>1,661,100</td>
<td>1,192,100</td>
<td>730,100</td>
<td>481,100</td>
<td>5,808,000</td>
<td>120,920.5</td>
<td>97.9%</td>
</tr>
</tbody>
</table>
RESEARCH ACHIEVEMENT
# PROGRAM

## ENHANCING PRODUCTIVITY AND SUSTAINABILITY OF PALM OIL MILLING INDUSTRY

<table>
<thead>
<tr>
<th>ACHIEVEMENT PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project progress (milestone)</td>
</tr>
<tr>
<td>Percentage</td>
</tr>
</tbody>
</table>

## RESEARCH OUTPUT AND HUMAN CAPITAL DEVELOPMENT

<table>
<thead>
<tr>
<th>Articles/Books</th>
<th>Conference/Proceeding</th>
<th>Intellectual Property</th>
<th>Number of PhD student</th>
<th>Number of Master student</th>
<th>Number of UG student</th>
</tr>
</thead>
<tbody>
<tr>
<td>54 articles 1 book</td>
<td>71</td>
<td>8 (patent pending)</td>
<td>15 (M’sian) 2 (Non-M)</td>
<td>28 (M’sian) 5 (Non-M)</td>
<td>51 (M’sian)</td>
</tr>
</tbody>
</table>
NEW TECHNOLOGIES FROM PROJECT 1

PROJECT 1: Study on Novel and Practical Fruit Grading and Oil Quality Monitoring Technology in Palm Oil Mills

1. Thermal Camera for FFA Determination from FFB at Palm Oil Mill

During the last year we have experimented with different combinations of sensors. From these results, we created models and found that combinations of Sensor 3 (Red Emission, Red Detector), Sensor 2 (DRed Emission), Sensor 2 (FRE Emission), Sensor 4 (Blu Emission), and Sensor 4 (NIR Emission) showed the best combination to distinguish ripeness of fresh fruit bunch with 79.8% over ripe, 69.4% ripe and 93.3% under ripe. Accuracy values to detect free fatty acids increases to 77% with addition of average temperature as sensor. Accuracy of determining oil content and Peroxide Value (PV) was 91.8% and 83.3% respectively after training and testing the samples.
NEW TECHNOLOGIES FROM PROJECT 1

2. FFA Detection System for Crude Palm Oil

**Step 1:** Pipette hydroxylamine into CPO/hexane in glass tube

**Step 2:** Insert tube into 1st slot hole for heating & mixing for t sec. at T °C. Time & temp can be set via buttons.

**Step 3:** Transfer top oil phase from tube in 1st hole and transfer into new tube 2nd slot hole. Add in V₂O₅ solution and run photometer

LCD and buttons provided to run tests, display readings and run calibration and set parameters such as heating temp & time, mixing time etc.

Device comes with internal rechargeable power supply via AC/DC adaptor

2nd improved prototyped
3. Palm Fruit Ripeness Detector

a) A microwave five-port reflectometer for the determination of moisture content in oil palm fruits was developed.

b) The reflectometer was designed to measure both the magnitude and phase of the reflection coefficient of any passive microwave device.

c) The stand-alone reflectometer consists of a PC, a microwave source, diode detectors and an analog to digital converter.

d) All the measurement and data acquisition were done using Agilent VEE graphical programming software. The reflectometer can be used with any reflection based microwave sensor.
Sterilization

Extraction

Separation

Oil losses in unstripped FFB amounts to RM 3.0 million/mill/year (0.4%/FFB)

Oil losses in press fiber and kernel loss, amounts to RM 6.8 million/mill/year (0.7%/FFB)

Oil losses in sludge oil amounts to RM 2.8 million/mill/year (0.32%/FFB)

NEW TECHNOLOGIES FROM PROJECT 2

RM 12 mil per year
In 2014/15 Fibaloy and Dolphin Application Sdn Bhd integrated UPM’s Dr. Azis’s High Pressure Sterilization patent and LRGS research into development of Dolphin’s Robo-REST sterilization system.

**Robo-REST**

- **70 psi, 30 minutes sterilization**
- **40 psi, 30 minutes sterilization**

Kilang Sawit Bukit Kapah, Hulu Terengganu
NEW CPO EXTRACTION TECHNOLOGY

MICRONES is an acronym for Maceration Induced Cell Rupturing Oil Nut Extraction Synthesis

Micrones is designed to work with:
- Conventional sterilisers
- Continuous sterilizers.

60 ton FFB MICRONES System
• Clarification is a process to remove water and sludge from oil.
• Most mills use gravitational clarifier to obtain clarified oil in 3 to 5 hours.
• However, oil loss in sludge is among the highest in mills.
• Our new approach is to apply vacuum during clarification process.
• Lower oil loss in sludge crude palm oil and shorter process time during clarification process are process challenges.
1. Oil Recovery from EFB

Oil loss—portion of oil impregnated onto the surface of EFB due to mechanical processes. Oil mainly located on the spikelet rather than the stalk.

Mechanical processes (conveyor, sterilization, thresher equipment etc.) mainly contribute to the oil transfers from fruit to bunches.

2. Completed Work: EFB Oil recovery system (1st Concept)

3. Completed Work: EFB Oil Recovery (2nd Concept)

NEW TECHNOLOGIES FROM PROJECT 3
Sufficient evidence that; CPO presence mainly free and small droplet size (< 100 um).

\[ \text{Settling Time (sec)} \]
\[ \text{Settling Velocity (m/s)} \]
\[ \text{Particle Sizes (µm)} \]

\[ \text{Oil Recovery (%)} \]
\[ \text{Feed Flow Rate (ml/min)} \]

\[ \text{3. Microbubbles Technique Dissolved Air Floatation Technology} \]
NEW TECHNOLOGIES FROM PROJECT 3

3. Oil Recovery from OPDC

1. Completed work: Green solvent (d-limonene) used to recover oil in OPDC. The OPDC contained approximately 12.55±3.15% (dry). d-limonene successfully recovered 100% of oil with 90% recycling rate.

RCPO content in OPDC’ [% dry basis] 12.55±3.15

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Recovery [%]</th>
<th>Oil Loss [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>d-limonene</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>n-hexane</td>
<td>90</td>
<td>70</td>
</tr>
<tr>
<td>Carotene</td>
<td>75.616</td>
<td>614.67</td>
</tr>
<tr>
<td>C16:0 Palmitic acid</td>
<td>39.22</td>
<td>47.99</td>
</tr>
<tr>
<td>C18:1n9c Oleic acid</td>
<td>31.05</td>
<td>37.36</td>
</tr>
</tbody>
</table>

OEROL PI RANGE INDICATOR

<table>
<thead>
<tr>
<th>OEROL</th>
<th>PI</th>
<th>RANGE</th>
<th>INDICATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>1.00  – 1.72</td>
<td>POOR</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1.73  – 2.26</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2.27  – 2.99</td>
<td>GOOD</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>3.00  – 4.00</td>
<td>EXCELLENT</td>
</tr>
</tbody>
</table>

4. Oil Loss and OER Study

Sub-project 4 progress: Clear indication of sources of oil loss in the mill – evaporation, sterilisation condensate, unstripped fruit bunches, hard bunches, hydrocyclone or claybath effluent, clarification section, empty fruit bunches and decanter cake.

Originality - A new method to representing OER performance which include OER and OIL LOSS DATA

<table>
<thead>
<tr>
<th>OER</th>
<th>Ex</th>
<th>CONTINUOUS STERILIZER SYSTEM (CS)</th>
<th>OIL LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RATING</td>
<td>RANGE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>18.00 – 19.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>19.25 – 20.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>20.50 – 21.74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>21.75 – 23.00</td>
</tr>
</tbody>
</table>

Click on EPI Calculator will display the information need to be input by the user. Each of the variables meaning will be available from the menus. Once all the value are input accordingly, press "Calculate".

"About" page shows the apps version and description. Appears when the users selects it in menu.

This result shown the EPI of palm oil calculated from previous equation. The “Save” button available for saving the data into cloud database. For this purpose, internet connection is needed.

Ultrasonic Assisted Soxhlet Extraction for faster oil
NEW TECHNOLOGIES FROM PROJECT 4

- Hot Compressed Water Extraction (HCWE)
- Green Solvent Extraction & Crystallization
- Air Classifier with Air Disturbance System
- Supercritical Carbon Dioxide Extraction (SC-CO2)
HCWE

SCREW PRESS

<table>
<thead>
<tr>
<th></th>
<th>HCWE</th>
<th>SCREW PRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPO yield</td>
<td>0.70 g-oil/g-dried mesocarp</td>
<td>0.61 g-oil/g-dried mesocarp</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>2204 ppm</td>
<td>1150 ppm</td>
</tr>
<tr>
<td>Carotene</td>
<td>858 ppm</td>
<td>800 ppm</td>
</tr>
</tbody>
</table>

Vitamin E: 600 – 1000 ppm
Carotene: 500 – 700 ppm

HCWE: New technologies from Project 4

Hot Compressed Water Extraction (HCWE)

Palm Pressed Fibre
Oil
De-oil fibre

CPO
PPF-HCWE

<table>
<thead>
<tr>
<th></th>
<th>CPO</th>
<th>PPF-HCWE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin E</td>
<td>11139.39 ppm</td>
<td>600 – 1000 ppm</td>
</tr>
<tr>
<td>Carotene</td>
<td>3866.53 ppm</td>
<td>500 – 700 ppm</td>
</tr>
</tbody>
</table>
NEW TECHNOLOGIES FROM PROJECT 4

Green Solvent Extraction & Crystallization

Oil Palm Mill Biomass & Refinery Waste

- Water resistant
- Gas resistance ideal for MAP (Modified Atmosphere Packaging)
- Biodegradable
- Sustainable resources

Green & Biodegradable Oil Palm Based Coatings

<table>
<thead>
<tr>
<th></th>
<th>GF</th>
<th>BW</th>
<th>CPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFA, %</td>
<td>1.23</td>
<td>25.19</td>
<td>3 - 5</td>
</tr>
<tr>
<td>Kinematic Viscosity (mm²/s)</td>
<td>66.07</td>
<td>77.89</td>
<td>45.34</td>
</tr>
<tr>
<td>Carotene (ppm)</td>
<td>3.3</td>
<td>103.1</td>
<td>474 to 689</td>
</tr>
</tbody>
</table>

A sustainable alternative to Paraffin Wax

NON-FOOD APPLICATIONS

Carbon Dioxide Restriction through Uncoated and Coated EFB Paper
Air Classifier with Air Disturbance System

- Used air disturbance system (injected air pressure to the bottom of separator column)
- 40% efficiency improved
- Reduced air velocity usage
- Reduced separation time more than 80%

**NEW TECHNOLOGIES FROM PROJECT 4**

- Discharge opening
- Nut/kernel/shell
- Mesocarp fiber
- Heater
- Air flow generated by blower
- Sample at the bottom

**Results:**

- Velocity: 3.2 m/s, Setting time: 1 minute, Sample ratio: 60/40, Result: 98.60%
- Velocity: 1.8 m/s, Setting time: 30 seconds, Sample ratio: 60/40, Result: 75.80%
Supercritical Carbon Dioxide Extraction (SC-CO2)

- Low-cost substitute resource of Squalene which is usually found in shark and whale oils

SC-CO2

Mesocarp

Squalene, C_{30}H_{50}

---

NEW TECHNOLOGIES FROM PROJECT 4

![Graph showing the percentage of squalene yield for different methods of extraction.]

- SC-CO2 (16 Mpa, 60 °C & 2 ml/min)
- SC-CO2 (23 Mpa, 45 °C & 5 ml/min)
- SC-CO2 (30 Mpa, 60 °C & 5 ml/min)
- Chloroform Soxhlet Extraction
- Isopropanol Soxhlet Extraction
- PE Soxhlet Extraction
The national average oil extraction rate (OER) in Malaysia since 2009 until 2016 have fluctuated from a low of 20.04% in 2006 to a high of 20.62% in 2014, although there were a tremendous increase in the number of mills (from just 10 in 2010 to 24 in 2015) that have obtained more than 23% OER between 2010-2015. Clearly, changes in OER have a significant impact on the national economy. Changes in OER has a bearing on the economy as such changes can result in higher or lower output of Crude Palm Oil (CPO).

**OER Performance for 2014 and 2015 (MPOB, 2016)**

<table>
<thead>
<tr>
<th>Region</th>
<th>2015 (%)</th>
<th>2014 (%)</th>
<th>Diff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peninsular</td>
<td>20.01</td>
<td>20.19</td>
<td>↑ 0.9</td>
</tr>
<tr>
<td>Malaysia</td>
<td>21.57</td>
<td>21.49</td>
<td>↓ 0.4</td>
</tr>
<tr>
<td>Sabah</td>
<td>20.15</td>
<td>20.43</td>
<td>↑ 1.4</td>
</tr>
<tr>
<td>Sarawak</td>
<td>20.46</td>
<td>20.62</td>
<td>↑ 0.8</td>
</tr>
<tr>
<td>Malaysia</td>
<td>20.46</td>
<td>20.62</td>
<td>↑ 0.8</td>
</tr>
</tbody>
</table>
New prediction of HIRARC for new technologies showed that the technologies is predicted to contribute medium to low risk towards workers.

<table>
<thead>
<tr>
<th>Workstations</th>
<th>Physical</th>
<th>Chemical</th>
<th>Biological</th>
<th>Ergonomic</th>
<th>Psychosocial</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading</td>
<td>18.5</td>
<td>0</td>
<td>15.6</td>
<td>12.2</td>
<td>14.3</td>
<td>15.8</td>
<td>13.8</td>
<td>0</td>
</tr>
<tr>
<td>Ramp</td>
<td>19</td>
<td>0</td>
<td>11.1</td>
<td>9.4</td>
<td>14.3</td>
<td>16.5</td>
<td>7.3</td>
<td>100</td>
</tr>
<tr>
<td>Sterilizer</td>
<td>8.5</td>
<td>0</td>
<td>11.1</td>
<td>10.8</td>
<td>14.3</td>
<td>8.1</td>
<td>16.3</td>
<td>0</td>
</tr>
<tr>
<td>Press</td>
<td>12.7</td>
<td>0</td>
<td>11.1</td>
<td>15.8</td>
<td>14.3</td>
<td>14.4</td>
<td>4.1</td>
<td>0</td>
</tr>
<tr>
<td>Oil room</td>
<td>7.1</td>
<td>4.8</td>
<td>17.8</td>
<td>15.8</td>
<td>14.3</td>
<td>10.8</td>
<td>17.9</td>
<td>0</td>
</tr>
<tr>
<td>Kernel</td>
<td>19.8</td>
<td>71.4</td>
<td>22.2</td>
<td>18</td>
<td>14.3</td>
<td>21.5</td>
<td>20.3</td>
<td>0</td>
</tr>
<tr>
<td>Workshop</td>
<td>14.4</td>
<td>23.8</td>
<td>11.1</td>
<td>18</td>
<td>14.3</td>
<td>12.9</td>
<td>20.3</td>
<td>0</td>
</tr>
<tr>
<td>Total (%)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**PREDICTION OF HIRARC**

![Graph showing the prediction of HIRARC for various workstations and processes.](image-url)
NEW FINDINGS FROM PROJECT 5

**KAP LEVEL**

- Workers good level in knowledge, attitude and perception towards hazard in palm oil mills.
- High stress level (PSI) due to personal noise exposure, work shift and PPE usage.
- MHSI software also developed to estimate the comfort level among palm oil mill works based on environmental factor and drinking water intake per day.

---

**Statistical Model of Stress in Relation with Noise**

- \[ R^2 = 0.335 \]
- \[ \beta_1 = +0.518^{**} \]
- \[ \beta_1 = +0.224^{***} \]
- \[ \beta_1 = +0.009 \]

**MHSI INDEX (MHSI)**

- PSI score = \(-39.308 + 0.570(TWA) + 6.732(\text{Shift}) + 4.838(\text{PPE})\)

---

**DEVELOPMENT OF MALAYSIAN HEAT STRESS INDEX (MHSI)**

**MHSI INDEX CALCULATION**

- **Range**
  - \( <31.5 \)
  - \( 31.5 \text{ to } 37.2 \)
  - \( 37.2 \text{ to } 41.9 \)
  - \( >41.9 \)

- **Degree of Comfort**
  - No Discomfort
  - Discomfort
  - Dangerous

**The assumption of this index as follow:**
- Range of Relative Humidity, % (20-100), Range of WBTIn, °C (29.5-40.0), Drinking Volume should be at least 0.5 litre and Smoking (number of cigarette/day), if non smoker = 0
Economics and Financial Feasibility of New Extraction Technology

i) **OVERALL COST (15 Ton FFB/hr system)**
RM 6,000,000 plus RM 1,920,000 (OPEX for three years)

*Product cost:*
RM 1,020,000 (15 FFB t/hr oil extraction system) to RM 4,080,000 (60 FFB t/hr) /unit

*Selling price:*
RM 1,500,000 (15 FFB t/hr oil extraction system) to RM 6,000,000 (60 FFB t/hr) /unit

ii) **EXPECTED SALES:**

For first year (2021) as shown in the table: RM 58,500,000

1 stand alone 15 FFBt/hr system, 2 upgrade from 15 FFBt/hr to 30 FFB t/hr system, 4 stand alone 30 FFBt/hr system, 2 upgrade from 30 FFBt/hr to 45 FFBt/hr system, 4 stand alone 45 FFBt/hr system, 2 upgrade from 45 FFBt/hr to 60 FFBt/hr system and 3 stand alone 60 FFBt/hr system.

For year 2 (2022): RM 94,500,000

8 stand alone 30 FFBt/hr system, 4 upgrade from 30 FFBt/hr to 45 FFBt/hr system, 5 stand alone 45 FFBt/hr system, 4 upgrade from 45 FFBt/hr to 60 FFBt/hr system and 6 stand alone 60 FFBt/hr system.

iii) **BREAK EVEN POINT**
37 months based on the above projected cash flow table.