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# PROCEEDINGS OF INTERNATIONAL SEMINAR ON CHEMICAL ENGINEERING

in conjunction with

## Seminar Teknik Kimia Soehadi Rekwardojo (STKSR) 2016



FOOD



ENERGY



WATER

27-28 October 2016  
Institut Teknologi Bandung, Indonesia

Organized by:



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**Department of Chemical Engineering**  
Faculty of Industrial Technology  
Institut Teknologi Bandung

# **PROCEEDING**

**International Seminar on Chemical Engineering  
in conjunction with  
Seminar Teknik Kimia Soehadi Reksowardojo (STKSR)  
2016**

*“Sustainable Food, Energy, and Water”*

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**27-28 October 2016  
West and East Hall  
Institut Teknologi Bandung  
Jl. Ganesha 10 Bandung INDONESIA**

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*Organized by*

**Department of Chemical Engineering  
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## MESSAGE



First of all, deep gratitude is dedicated to Allah the Almighty which gives His blessing to the Chemical Engineering Institut Teknologi Bandung which this year evenly becomes 75 years old. The journey of 75 years for Chemical Engineering ITB as the oldest Chemical Engineering program in Indonesia and one of the oldest program in ITB is a long journey with all the hurdles which creates the Chemical Engineering ITB becomes a reputable program.

We gladly overcome the presence of “75 Tahun Teknik Kimia untuk Indonesia” book, as a track record of the contributions of Chemical Engineering ITB and its alumni in advancing Indonesian society. The family of Chemical Engineering ITB and its alumni have been proven to be able to build a strong connectivity among the higher education, Science and technology development, and industrial escalation especially in chemical industry. Therefore, the contribution of Chemical Engineering ITB is unquestionably substantial in showing the objective of Indonesian society to achieve food independency and energy sovereignty. It is highly expected that this book can pass those ideas to the society, especially the young generation which will advance the development of Chemical industry in Indonesia.

We would like to congratulate anew this 75th year Commemoration of Chemical Engineering Higher Education in Indonesia. We hope that the family of Chemical Engineering ITB can be continuously actively contribute in generating intellectual works which are affluent in advantages, as a contribution to the Indonesian society. Especially for the alumni of Chemical Engineering ITB, we hope that can keep the good relation with the alma mater, also to keep working, accomplishing, and being the “energy” for ITB to keep carrying on the credence of the higher education.

Bandung, October 2016

**Prof.Dr.Ir. Kadarsah Suryadi, DEA.**

**Rector of Institut Teknologi Bandung (ITB)**

## MESSAGE



Assalamu'alaikum Warahmatullahi Wabarakatuh

Warm Greetings for us all

Ladies and Gentlemen,

Chemical Engineering program in ITB cooperates with Chemical Engineering ITB alumni foundation and the alumni themselves are conducting series of events which consist of the Education Seminar about Chemical Engineering dedicated to High School teachers and students, especially for Science program, on October 26<sup>th</sup> 2016 and the International Seminar on Chemical Engineering in Conjunction with Seminar Teknik Kimia Soehadi Reksowardojo 2016 on 27-28 October 2016.

The seminar this year is focusing on the topic of Energy, Food and Water. Those three topics were chosen in relation to the scarcity of these three aspects which are starting to give impacts and need a special attention. The chemical engineering bachelors can be involved much in those three sectors, and so the academia, practitioners and the government in order to harness this moment to share knowledge for the sake of advancement of Republik Indonesia.

For the participants who are actively involved and the invited speakers, the sponsors and Institut Teknologi Bandung who already gave us permission to utilize the facilities, we express our deep gratitude.

Hopefully this seminar can give benefits for us all.

Wassalam

**Dr.Ir. Irwan Noezar, MS**

**Chairman of 75<sup>th</sup> year Commemoration of Chemical Engineering**

**Higher Education in Indonesia**

## MESSAGE



Dear Colleagues,

On behalf of the Organizing Committee of the International Seminar on Chemical Engineering, I am honorable to welcome you all to Institut Teknologi Bandung, Bandung, Indonesia. This year, Department of Chemical Engineering – Institut Teknologi Bandung is celebrating the 75<sup>th</sup> year of Chemical Engineering Education in Indonesia. One of the main events is holding this Seminar in conjunction with Seminar Teknik Kimia - Soehadi Reksowardojo (STKSR) 2016 with the topic of ‘Sustainable Energy, Food and Water’. Globally and at national level as well, we are aware of the challenges to meet the needs of energy, food and water for all

in sustainable ways.

Those topics will be addressed by leading engineers/scientists from 9 countries, either in plenary lectures or parallel sessions. In each session, an invited speaker will address a certain topic with a depth insight and ample of time to discuss the issue with the participants, hopefully they will learn more from an expert in the field.

We have also prepared several social functions, so that delegates may meet one another and experience the Indonesian culture with Bandung pleasant weather and warm hospitality. Finally, the committee is most grateful to all sponsors and ChemEng-ITB Alumni for providing funds. I also thank all International/Technical Committee members, all the plenary and invited speakers and all oral/poster presenters for their kind efforts and contributions in making this conference a success.

Thank you

**Prof. Tjandra Setiadi, Ph.D.**

**Chairman of STKSR 2016**





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## GENERAL PROGRAM

### Day 1: Thursday, October 27<sup>th</sup> 2016

| TIME          | PROGRAM   |           |
|---------------|---|-----------|
|               | WEST HALL   | EAST HALL |
| 07.30 – 08.00 | Registration  |           |
| 08.00 – 09.05 | <p>Opening Ceremony of Commemoration of 75 Years Higher Education of Chemical Engineering in Indonesia</p> <ul style="list-style-type: none"> <li>• Safety Induction: Dr. Hary Devianto</li> <li>• Report presentation from Programme Advisor: Assoc. Prof. Irwan Noezar</li> <li>• POKJA Presentation</li> </ul> |           |
| 09.05 – 09.15 | Referral of POKJA document to Rector of Institut Teknologi Bandung  |           |
| 09.15 – 09.30 | Opening and Welcoming Speech by Rector of Institut Teknologi Bandung: Prof. Dr. Ir. Kadarsah Suryadi, DEA.  |           |
| 09.30 – 10.00 | Photo session and coffee break  |           |
| 10.00 – 10.15 | <p>Opening ceremony of STKSR 2016:<br/> Prof. Tjandra Setiadi</p>   |           |
|               | <p><b>Keynote 1: Prof. Koichi Fujie.</b><br/> <b>Yokohama National University,</b><br/> <b>Japan.</b></p> <p>“ <b>Design and Evaluation of Biomass Residue Recycle System for Sustainable Crop Cultivation based on Material Flow Analysis</b> ”</p>  |           |
| 10.45 – 11.15 | <p><b>Keynote 2: Prof. Hamdani Saidi</b><br/> <b>Universiti Teknologi Malaysia,</b><br/> <b>Malaysia</b></p>  |           |

| TIME          | PROGRAM  |               |               |               |
|---------------|--|---------------|---------------|---------------|
|               | WEST HALL  | EAST HALL     |               |               |
|               | <b>“ Renewable Energy – Emerging opportunities for Chemical Engineers ”</b>  |               |               |               |
| 11.15 – 11.45 | <b>Keynote 3: Prof. Johan Sanders<br/>Wageningen University, The Netherlands<br/>“ Small Scale Biorefineries for Food and Non Food Application ”</b> |               |               |               |
| 11.45 – 12.15 | Flash Poster Presentation  |               |               |               |
| 12.15 – 13.30 | LUNCH BREAK  |               |               |               |
|               | <b>PARALEL I : 1<sup>st</sup> SESSION</b>  |               |               |               |
|               | <b>ROOM 1</b>  | <b>ROOM 2</b> | <b>ROOM 3</b> | <b>ROOM 4</b> |
| 13.30 – 13.50 | E06*   | F06           | W11*          | O12*          |
| 13.50 – 14.05 | E01  | F05           | W10           | O01           |
| 14.05 – 14.20 | E05  | F03           | W05           | O02           |
| 14.20 – 14.35 | E07  | F16           | W08           | O05           |
| 14.35 – 14.50 | E20  |               | W03           | O07           |
| 15.00 – 15.30 | Coffee Break   |               |               |               |
|               | <b>PARALLEL I: 2<sup>nd</sup> SESSION</b>  |               |               |               |
|               | <b>ROOM 1</b>  | <b>ROOM 2</b> | <b>ROOM 3</b> | <b>ROOM 4</b> |
| 15.30 – 15.50 | E03*   | F29           | E43*          | W13*          |
| 15.50 – 16.05 | E08  | F08           | E31           | O10           |
| 16.05 – 16.20 | E10  | F10           | E34           | O11           |
| 16.20 – 16.35 | E11  | F13           | E38           | O13           |
| 16.35 – 16.50 | E14  | F14           | E39           |               |
| 19.00 – 21.00 | <b>GALA DINNER</b>   |               |               |               |

**Day 2: Friday, October 28<sup>th</sup> 2016**

| TIME          | PROGRAM   |                                     |        |        |
|---------------|---|-------------------------------------|--------|--------|
|               | WEST HALL   | EAST HALL                           |        |        |
|               | POSTER SCORING SESSION  | PARALEL II: 1 <sup>ST</sup> SESSION |        |        |
|               |   | ROOM 2                              | ROOM 3 | ROOM 4 |
| 08.30 – 08.50 |   | F20                                 | W12*   | E35*   |
| 08.50 – 09.05 | F01 F02 F04 F09 F11 F12 F15 F18<br>F23 F24 E04 E09 E13 E15 E17<br>E19 E21 E23 E24 E25 E32 E33<br>E36 E37 W04 W06 W07 O03 O04<br>O06 O08 O09                     | F21                                 | W01    | E16    |
| 09.05 – 09.20 |   | F22                                 | W02    | E22    |
| 09.20 – 09.35 |   | F17                                 |        | E26    |
| 09.35 – 09.50 |   | F19                                 |        | E12    |
| 10.00 – 10.15 | Coffee Break  |                                     |        |        |
|               |   | PARALEL II: 2 <sup>ND</sup> SESSION |        |        |
|               |   | ROOM 2                              | ROOM 3 | ROOM 4 |
| 10.15 – 10.35 |   | F26                                 | E02*   | E44*   |
| 10.35 – 10.50 |   | F25                                 | E40    | E27    |
| 10.50 – 11.05 |   | F30                                 | E18    | E28    |
| 11.05 – 11.20 |   | F07                                 | E46    | E30    |
| 11.20 – 13.30 | LUNCH BREAK   |                                     |        |        |
| 13.30 – 14.00 | <b>Keynote 4: Prof. Sebastien Rauch</b><br><b>Chalmers University, Sweden</b><br><b>“ Wastewater – Still one of the most important engineering challenges ”</b> |                                     |        |        |
| 14.00 – 14.30 | <b>Keynote 5: Prof. Subagjo</b><br><b>Institut Teknologi Bandung, Indonesia</b><br><b>“ Catalysts for Liquid Biofuel Production ”</b>                           |                                     |        |        |
| 14.30 – 15.00 | <b>Keynote 6: Prof. H.J. (Erik) Heeres</b><br><b>University of Groningen, the Netherlands</b>   |                                     |        |        |

| TIME          | PROGRAM   |           |
|---------------|---|-----------|
|               | WEST HALL   | EAST HALL |
|               | <b>“ Biorefineries: from biomass to green energy, biofuels and biobased chemicals.”</b>                                   |           |
| 15.00 – 16.00 | Studium Generale by Indonesian Minister of National Development Planning:<br>Prof. Bambang Permadi Soemantri Brodjonegoro |           |
| 16.00 – 16.30 | Closing remarks<br>Award announcement: best presenter, best paper, best poster, and young scientist award                 |           |
| 16.30 – 17.00 | Coffee Break  |           |

## WASTE TREATMENT AND UTILIZATION IN INDONESIAN PALM OIL INDUSTRY



Udin Hasanudin<sup>1</sup>, Julfi R. Amelia<sup>2</sup>, Agus Haryanto<sup>3</sup>, Ryo Murakami<sup>4</sup>, and Koichi Fujie<sup>4</sup>

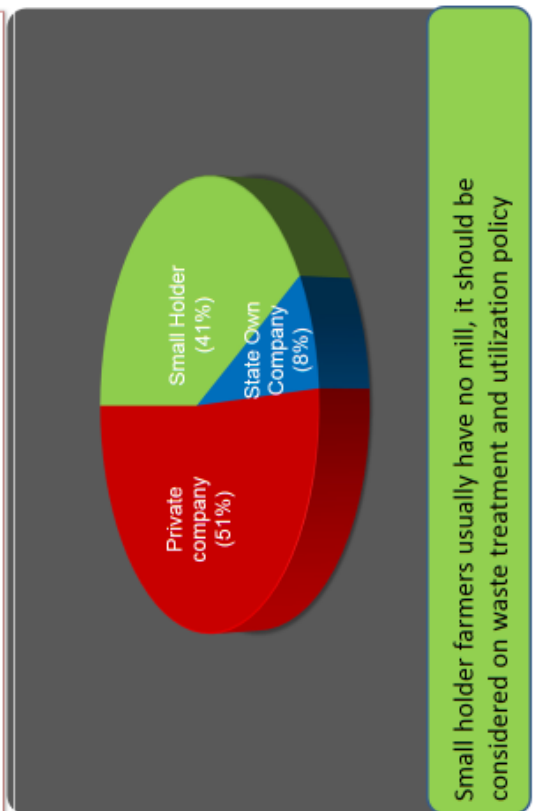
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<sup>4</sup>Graduate School of Environment and Information Sciences, Yokohama National University.

## Owner of Oil Palm Plantation in Indonesia



Small holder farmers usually have no mill, it should be considered on waste treatment and utilization policy

ISChE – STKSR 2016, ITB Bandung, 27-28 October 2016

## Indonesia CPO Production

**2013:**  
27.64 Million tons.

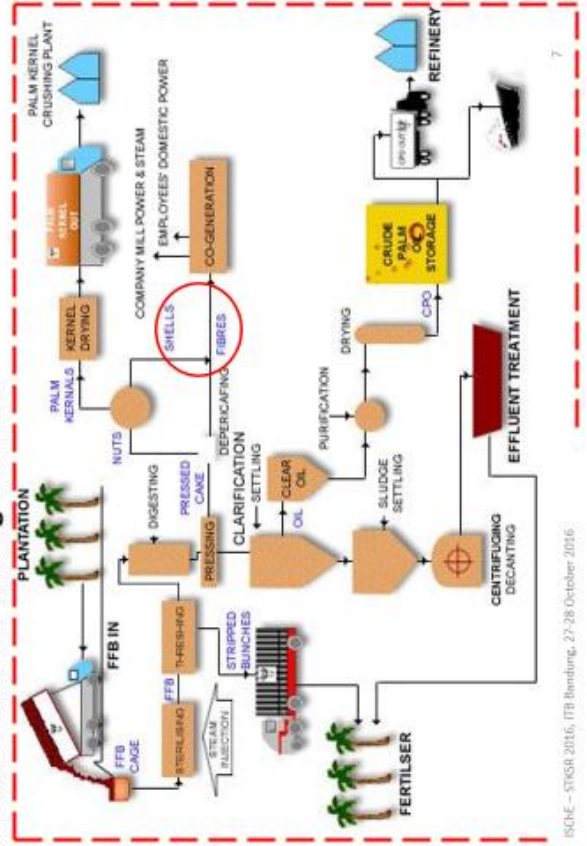
**2015:**  
32.36 Million tons.

**2020 was estimated**  
43.93 Million tons (GAPKI 2014).

**Number of Palm Oil Mills more than 750 unit (some of mills have no plantation)**

ISChE – STKSR 2016, ITB Bandung, 27-28 October 2016

## Crude Palm Oil Milling Process



ISChE – STKSR 2016, ITB Bandung, 27-28 October 2016

## Estimation of Waste Potential from Indonesian Palm Oil Mills

| Type of Waste                           | Waste Production |       |        |
|---|------------------|-------|--------|
|   | 2013             | 2015  | 2020   |
| POME (10 <sup>6</sup> m <sup>3</sup> )  | 84,12            | 98,49 | 133,70 |
| Mesocarp Fiber (10 <sup>6</sup> Ton)    | 14,42            | 16,88 | 22,92  |
| Palm Kernel Shell (10 <sup>6</sup> Ton) | 6,01             | 7,03  | 9,55   |
| EFB (10 <sup>6</sup> Ton)               | 24,03            | 28,14 | 38,20  |
| Boiler Ash (10 <sup>6</sup> Ton)        | 3,00             | 3,52  | 4,78   |

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## Waste Treatment and Utilization Approach

- *minimization of waste,*
- *total utilization of resources, and*
- *increase of total productivity*

**AGROINDUSTRY** **ZERO WASTE**

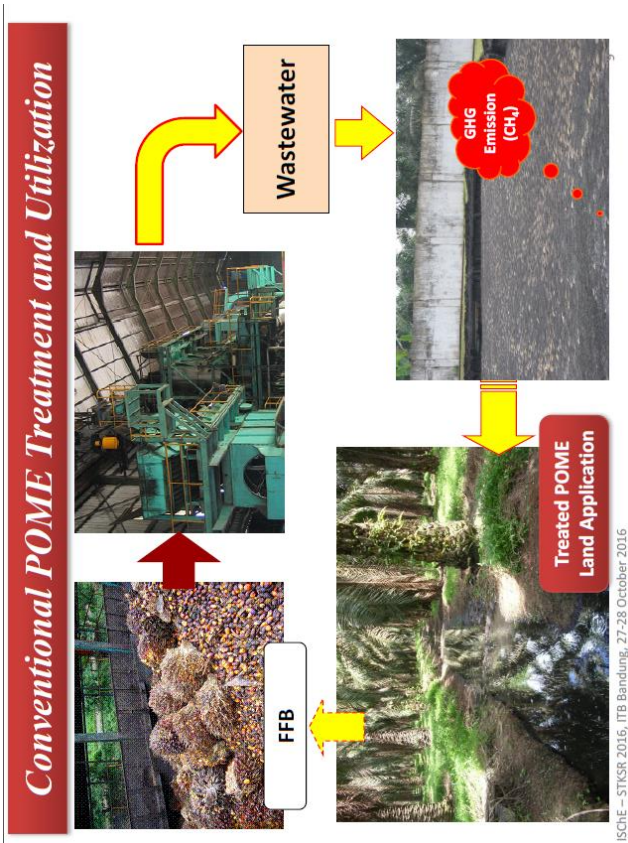
**COMMONS PRACTICES OF  
 WASTE TREATMENT AND UTILIZATION  
 IN INDOONESIAN PALM OIL INDUSTRIES**

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**REQUIREMENT FOR  
 LAND APPLICATION OF TREATED POME**

Decree of Minister of Environment No. 28 and 29, 2003.

- BOD max. 5000 mg/l
- pH 6-9
- prohibited to apply in peat land
- Soil permeability > 1,5 cm/h and < 15 cm/h
- Water table > 2 m
- Conducted a research in the LA area before applying the treated POME

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**What the impact of Treated POME Land Application to the soil environment ?**

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## Nutrient Content in Each Stage of POME Treatment

| Stage of Treatment               | BOD (mg/L)  | N (mg/L) | P (mg/L) | K (mg/L) | Mg (mg/L) |
|----------------------------------|-------------|----------|----------|----------|-----------|
| <b>Fresh POME</b>                | 25.000      | 950      | 150      | 1.960    | 345       |
| <b>After Anaerobic Treatment</b> |             |          |          |          |           |
| - Mixed                          | 1.300       | 900      | 120      | 1.800    | 300       |
| - Liquid                         | 450         | 450      | 70       | 1.200    | 180       |
| - Slurry                         | 190         | 320      | 40       | 1.495    | 260       |
| - Sediment                       | 1.000-3.000 | 3.350    | 1.180    | 1.390    | 1.510     |
| <b>After Aerobic Treatment</b>   |             |          |          |          |           |
| - Liquid                         | 100         | 50       | 12       | 2.300    | 540       |
| - Sediment                       | 150-300     | 1.495    | 460      | 2.380    | 1.000     |

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## The Important of Land Application

- Wastewater (POME) = 0,6-1 m<sup>3</sup>/ton of FFB
- **COD fresh POME = 40.000-100.000 mg/l**
- Effluent standard in palm oil industry:

| Parameters            | Max. Concentration (mg/l)                | Max. Pollution Load (Kg/Ton CPO) |
|-----------------------|--|----------------------------------|
| BOD <sub>5</sub>      | 100                                      | 0,25                             |
| COD                   | 350                                      | 0,88                             |
| TSS                   | 250                                      | 0,63                             |
| Fats and Oils         | 2,5                                      | 0,063                            |
| Nitrogen Total (as N) | 50                                       | 0,125                            |
| pH                    | 6-9                                      |                                  |
| Max. Flow rate        | 2,5 m <sup>3</sup> per ton product (CPO) |                                  |

**Very costly if the objective POME treatment is only for fulfilling the effluent standard**

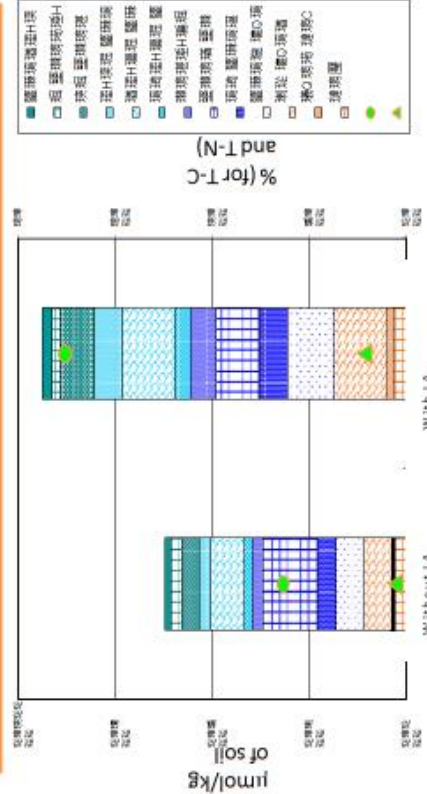
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Land Application is related with SOIL QUALITY and PRODUCTIVITY as main indicators of SUSTAINABILITY in agricultural sectors

**Soil Quality Indicator:**  
 GBEP : considered Soil Organic Carbon  
 ISCC : soil erosion, soil organic matters, soil structure  
 RSPO : soil fertility → optimal and sustained yield  
**SOIL QUALITY has integrated meaning**

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## Microbial Quinone Content, Quinone species, Carbon and Nitrogen content in the Soils

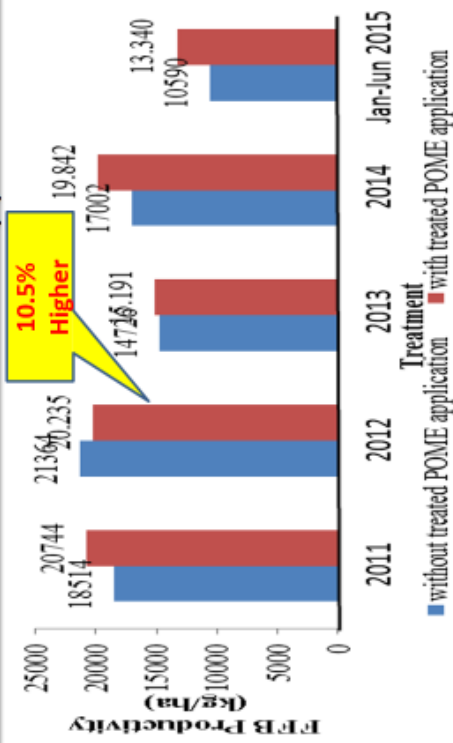


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DQ: 11.752 11.493



### FFB productivity in the block with and without treated POME Application

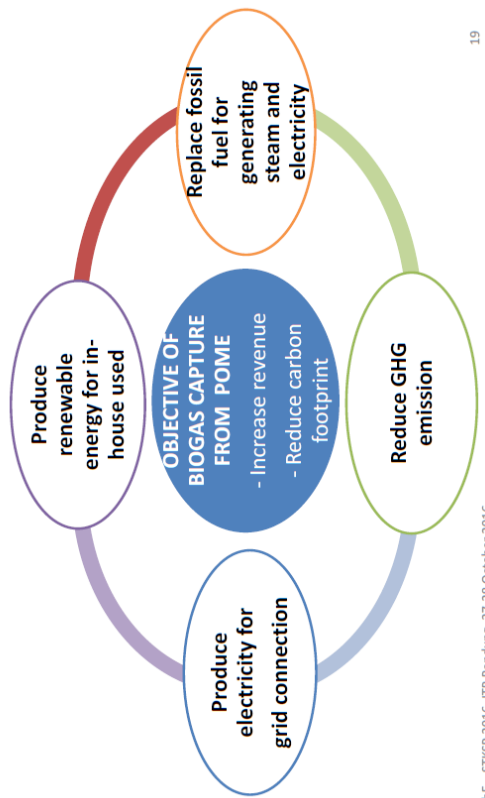


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### Methane Capture dan Land Application

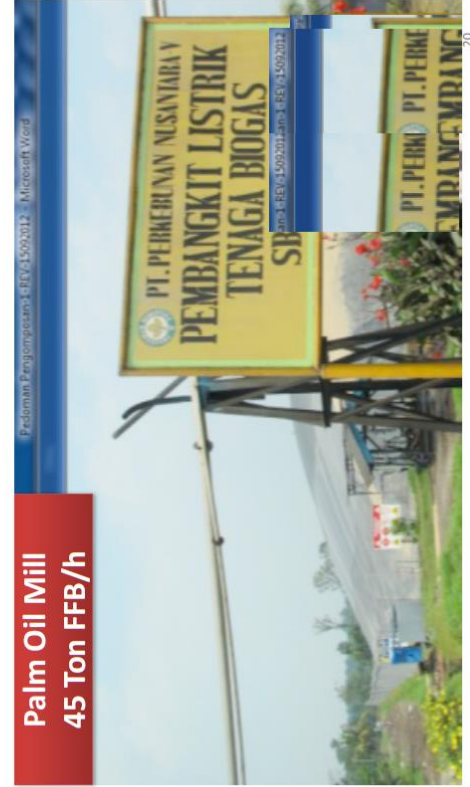
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### The Objective of Methane Capture



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### Biogas Production from POME Cover In Ground Anaerobic Reactor (CIGAR)



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### Estimation of GHG emission potential from POME

| Parameter                                      | Unit   | Value         |               |
|--|--|---------------|---------------|
|  |  | Min           | Max           |
| COD of fresh POME                              | mg/l   | <b>43,375</b> | <b>60,400</b> |
| COD of treated POME                            | mg/l   | 5,500         | 9,000         |
| POME production                                | m <sup>3</sup> /ton FFB                        | 0.55          | 0.65          |
| COD removal                                    | kg/ton FFB                                     | 20.83         | 33.41         |
| IPCC default value <sup>*)</sup>               | kg CH <sub>4</sub> /kg COD removal             | 0.25          |               |
| CH <sub>4</sub> production                     | kg/ton FFB                                     | 5.21          | 8.35          |
| IPCC default value <sup>*)</sup>               | m <sup>3</sup> CH <sub>4</sub> /kg COD removal | 0.35          |               |
| CH <sub>4</sub> production potential           | m <sup>3</sup> CH <sub>4</sub> /ton FFB        | 7.29          | 11.69         |
| GWP potential of CH <sub>4</sub> <sup>*)</sup> | kg CO <sub>2</sub> e/ kg CH <sub>4</sub>       | 21            |               |
| GWP potential                                  | kg CO <sub>2</sub> e/ton FFB                   | <b>109.41</b> | <b>175.35</b> |

<sup>\*)</sup> IPCC, 2006

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Based on methane production potential, the energy production from POME is estimated about:

**25.3-40.6 kWh/ton FFB.**

Using this value, palm oil mill with 45 ton FFB/hour or 900 ton FFB per day has a potential to generate

**0.95 to 1.55 MWh/day**

**Energy Consumption in Palm Oil Mill: 17 kWh/ton FFB**

Based on CPO production at 2015, the potential of energy production from POME in Indonesia is estimated more than **750 MW**.



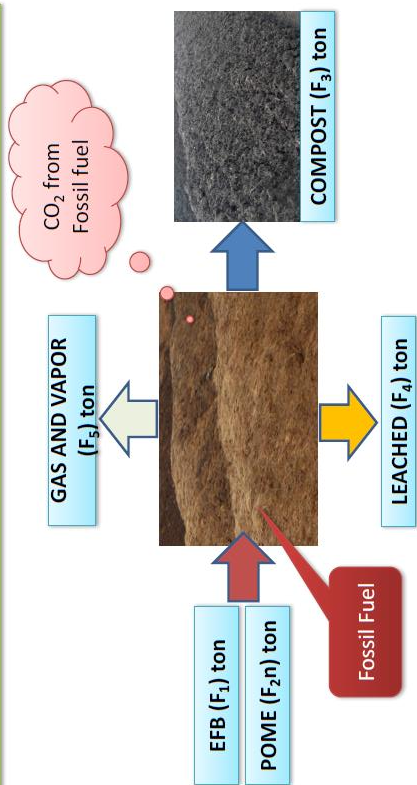
**Co-Composting EFB and POME**

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**ESTIMATION OF GHG EMISSION FROM CO-COMPOSTING OF EFB AND POME USING CARBON BALANCE**



$$F5.C5 = F1.C1 + F2.C2(n) - F3.C3 + F4.C4$$

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- Compost is important to maintain soil carbon and improving soil structure
- In between reversal period, it has potential to occur anaerobic condition. Methane will release during this period

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**Summary of calculation for GHG emission**

|  | Unit                        | 30 days | 70 days |
|--|-----------------------------|---------|---------|
| Baseline emission value ( $E_0$ )                    | kgCO <sub>2e</sub> /ton FFB | 301.48  | 301.48  |
| Fraction of POME used for composting ( $X$ )         | %                           | 43.18   | 78.04   |
| Methane emission from composting pile ( $E_C$ )      | kgCO <sub>2e</sub> /ton FFB | 13.98   | 42.72   |
| Fuel emission for composting process ( $E_F$ )       | kgCO <sub>2e</sub> /ton FFB | 0.30    | 0.70    |
| Greenhouse gas mission reduction (GHG <sub>R</sub> ) | kgCO <sub>2e</sub> /ton FFB | 115.89  | 191.86  |
|  | %                           | 38.44   | 63.64   |

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## Compost Application



**Carbon and Nutrients from EFB and POME are returned to the plantation**

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## Conventional POME Treatment dan Land Application

GHG emission from POME

Land application reduce water pollution and increase soil fertility and productivity

EFB mulching has several problems: high moisture, Oryctes pest disease, but increase C-organic and nutrients content in the soil

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## IS IT SUSTAINABLE ?

## Methane Capture and Land Application

Reduce GHG emission

Produce renewable energy for in-house used

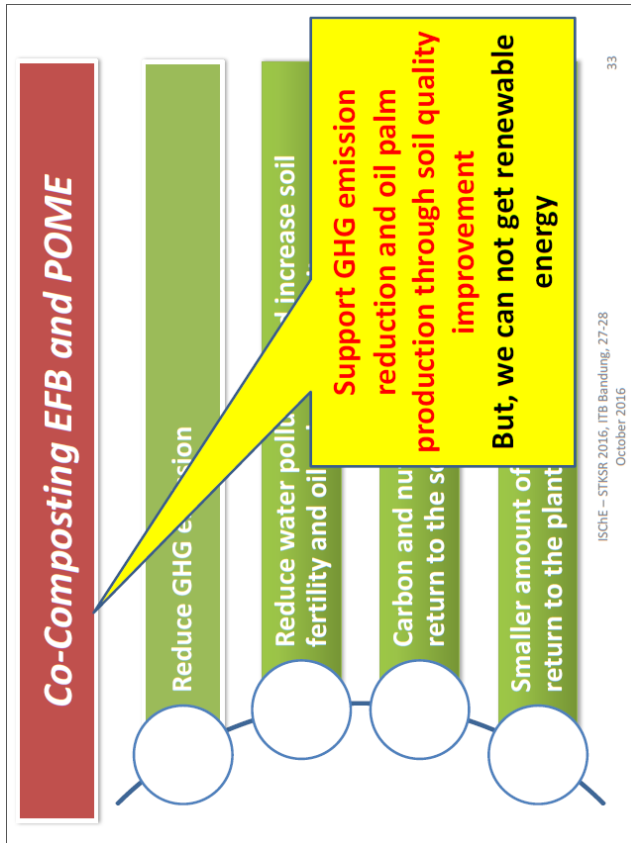
Produce electricity for grid connection

Replace fossil fuel for generation steam and electricity

Land application reduce water pollution and increase soil fertility and productivity

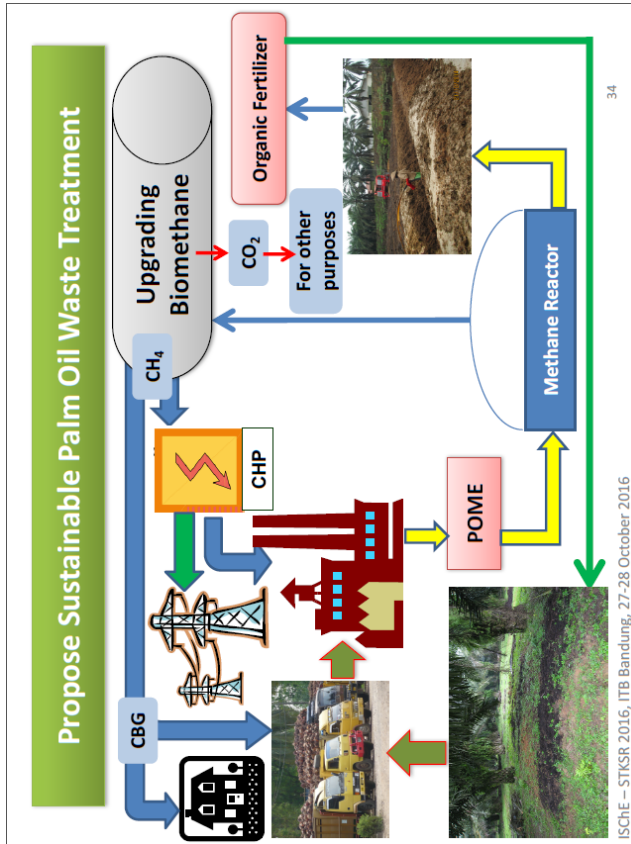
EFB mulching has several problems: high moisture, Oryctes pest disease, but increase C-organic and nutrients content in the soil

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**CONCLUSIONS**

- Palm Oil Mill WASTE treatment has potential to support the sustainability of palm oil industry
- Sustainable Palm Oil Mill WASTE treatment has potential to:
  - ✓ Produce Renewable energy and increase energy diversity,
  - ✓ Reduce GHGs emission
  - ✓ Reduce environmental pollution
  - ✓ Improve soil quality
  - ✓ Increase oil palm productivity
  - ✓ Create new jobs in bioenergy and other sectors



**Sawit Indonesia More Sustainable Than Ever**

**Thank you for your kind attention**