#### Rudianto Amirta Prof. Dr.Agr.Sc

Dekan Fakultas Kehutanan Universitas Mulawarman, Indonesia Jl. Penajam, Gunung Kelua, Samarinda, Kalimantan Timur, INDONESIA 76119 Tel.+62-813-47747651 Email: ramirta@fahutan.unmul.ac.id Energy sustainability innovation: searching for an appropriate biomass plant species for sustainability energy production in the future





## **Outline Presentasi:**

Indonesian National Policy on New Renewable Energy
 Global issue on biomass feedstock production
 Potential biomass energy from lowland community forest
 Potential biomass energy from plantation forest







# Jokowi reveals Indonesian policy in the field of economic and energy transition

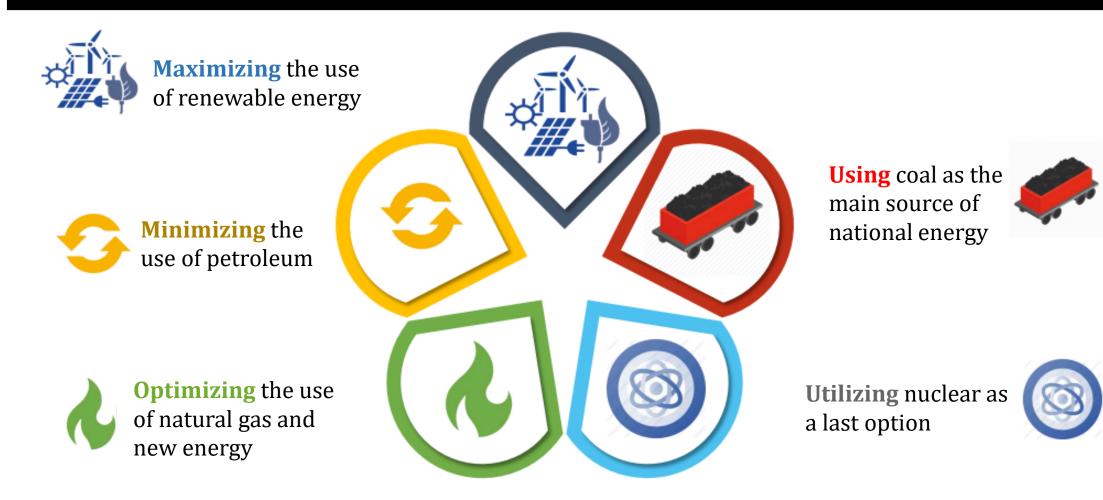
It the energy sector, Indonesia also continues to move forward with the development of the electric car ecosystem and the construction of the largest solar power plant in Southeast Asia. Apart from that, Indonesia is also utilizing new renewable energy, including **biofuel/bioenergy**, as well as developing clean energy-based industries, including the construction of the largest green industrial area in the world in North Kalimantan.





#### **PRIORITY FOR NATIONAL ENERGY DEVELOPMENT**

Based on national energy policy



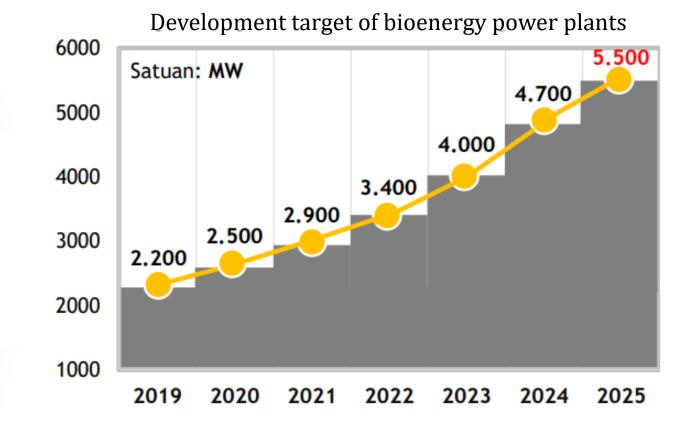


## **Development of bioenergy power plants**

(Programs and national target)

Bioenergy power plant development program

- Biomass power plant
- Biogas power plant
- Natural oil power plant
- Municipal waste power plant





## **Domestic Biomass Energy Needs**







The State Electricity Company (PLN), which initiated corporate action through the co-firing method, explained that to meet the need for 1% cofiring at PLTUs in Indonesia, biomass of 17,470 tons per day or 5 million tons of wood pellets per year is needed.

Indonesia's wood pellet production capacity ±1.1-1.2 million tons/year ±25 million tons of wood pellets are needed (5% Cofiring at PLTU)

**IDR 25 T** 



## **Currently there are three types of steam power plants in Indonesia** (**PLTU**):

- □ 43 PC (Pulverized Coal) type PLTUs with a total capacity of 15,620 MW require a mixture of 1-5% biomass
- 38 types of CFB (Circulating Fluidized Bed) with a total capacity of 2,435 MW requiring 1-5% biomass
- □ Meanwhile, 23 types of STOKER with a capacity of 220 MW use



## **Global issue on biomass feedstock production**

Recently, much attention has been focused on identifying suitable biomass species, which can provide highenergy outputs, to replace conventional fossil fuel energy sources. **Short Rotation Coppice (SRC)** or **Short Rotation Woody Crops (SRWC)** is one option for increasing the supply of woody biomass. Shorter rotation cycles allow higher planting densities and thus, higher biomass yields per unit land area (Dillen et al., 2013; Ghaley and Porter, 2014).

#### **SRC planting process**



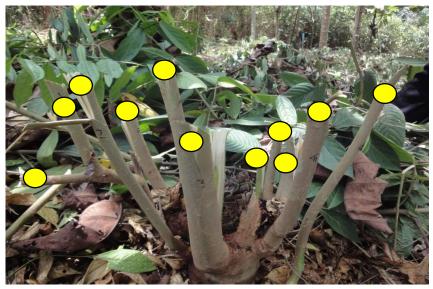






## What is short rotation coppice (SRC)?

Some fast growing tree species can be cut down to a low stump (or stool) when they are dormant in winter and go on to produce many new stems in the following growing season (in European forest). The woody shrub plant species such as Willow, Salix, Poplar, Black Locust and also Acacia and Eucalyptus trees were commonly used on SRC system in Denmark, Germany, Poland, Italy, New Zealand and others European countries (Sims et al. 2001; Sims and Venturi 2004; Fiala and Bacenetti 2012; Dillen et al. 2013; Ghaley and Porter 2014; Hauk et al. 2014; Haverkamp and Musshoff 2014; Krzyzaniak et al. 2015).



Symplocos – East Kalimantan



Willow - UK



## How about SRC/SRWC development in EK (Indonesia)

How about SRC/SRWC in Indonesia? In general speaking, there is no information available for SRC/SRWC and the woody plant species used for the energy-electricity production in Indonesia as far. In Indonesia we only knew and have a conventional concept of the forest plantation for the wood construction and pulp and paper production as well.



Google images



## Evaluation of biomass energy potential from lowland community forest in East Kalimantan, Indonesia: a preliminary study







#### Forest plant species (wood biomass)

Thirty one samples of tropical plant species consists of tree and wood shrub with diameter about 2-10 cm and their leaves and branches were collected from community forest located at Telaga Village, East Kutai District, East Kalimantan Province, Indonesia. The leaves of plant samples were identified at the Laboratory of Forest Dendrology, Faculty of Forestry, Mulawarman University

#### **Physico-chemical and energy potency**

Analysis of forest plant species The physico-chemical and energy potency analysis of forest plant species were performed according to the American Society for Testing and Material (ASTM)



## **Diversity of plant species**

No.	Plant species		Plant	<b>T</b> 1 <b>T</b>	
	Latin Name	Local Name	Category	Local Use	Revegetation
1	C. glaucan	Bengalon	Tree	Construction	Natural
2	Prunus sp.	Tembelas	Tree	Construction	Natural
3	L. splendens	Kacang	Tree	Construction	Natural
4	M. sericea	Telenggawi	Tree	Construction	Natural
5	P. azurea	Mutun	Tree	Construction	Natural
6	A. cadamba	Jabon	Tree	Construction	Artificial
7	M. gigantea	Serkong	Tree	Fire wood	Natural
8	M. tanarius	Mahang	Tree	Fire wood	Natural
9	G. arborea	Gmelina	Tree	Pulp and paper	Artificial
10	A. mangium	Akasia	Tree	Pulp and paper	Artificial
11	P. falcataria	Sengon	Tree	Pulp and paper	Artificial
12	A. saman	Trembesi	Tree	Fire wood	Artificial
13	F. racemosa	Kopi-kopian	Shrub	Fire wood	Natural
14	V. trifolia	Vitex	Shrub	Fire wood	Natural
15	V. amygdalina	Sambung Nyawa	Shrub	Herbal tea	Artificial
16	M. malabathricum	Karamunting	Shrub	Herbal tea	Natural
17	G. sepium	Gamal	Shrub	Fire wood	Artificial
18	P. aduncum	Sirih hutan	Shrub	-	Natural
19	H. capitata	Kayu wangi	Shrub	Herbal tea	Natural
20	A. clypearia	Kelayung	Shrub	-	Natural
21	B. tementosa	Berduri	Shrub	Fire wood	Natural
22	C. calothyrsus	Kaliandra	Shrub	Fire wood	Artificial
23	V. arborea	Hamirung	Shrub	Fire wood	Natural
24	Nauclea sp	Bengkal	Shrub	Fire wood	Natural
25	B. purpurea	Kupu-kupu	Shrub	-	Artificial
26	V. pinnata	Laban	Shrub	Fire wood	Natural
27	Timonius sp	Sebulu	Shrub	Fire wood	Natural
28	S. fasciculata	Simplocos	Shrub	-	Natural
29	F. septica	Awar awar	Shrub	Fire wood	Natural
30	H. populneus	Homalantus	Shrub	Fire wood	Natural
31	T. orientalis	Kalamboto	Shrub	Fire wood	Natural

#### **Table-1.** Plant species collected from the sampling plots located at community forest of Telaga Village, East Kutai





**Figure 2**. Leave shape variations of plant species collected from the community forest of Telaga Villlage, East Kutai District, East Kalimantan, Indonesia



## Wood density of woody biomass

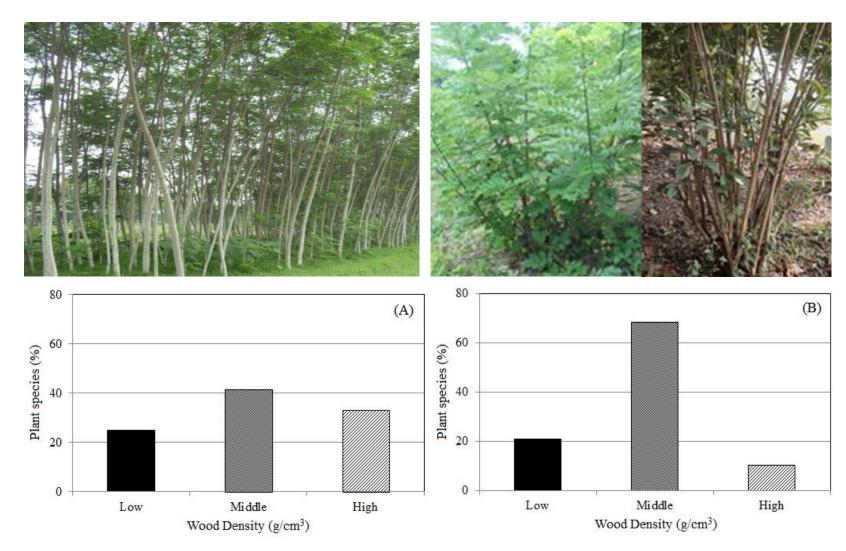
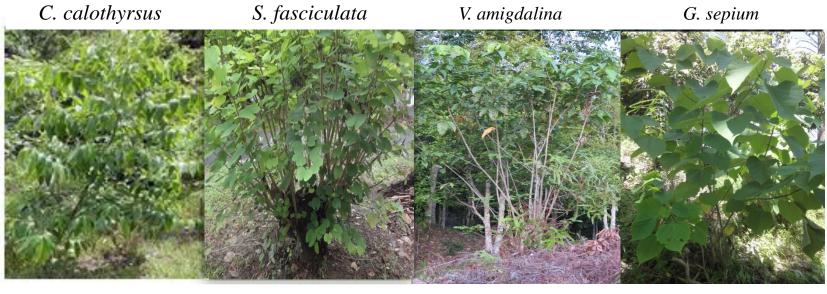


Figure 3. Wood density among (A) trees and (B) wood shrubs plant species collected from the community forest of Telaga Village, East Kutai, Indonesia



## Potential SRC – Biomass Energy Plant Species





P. aduncum

B. purpurea

V. pinnata

G. arborea



## Potential SRC – Biomass Energy Plant Species

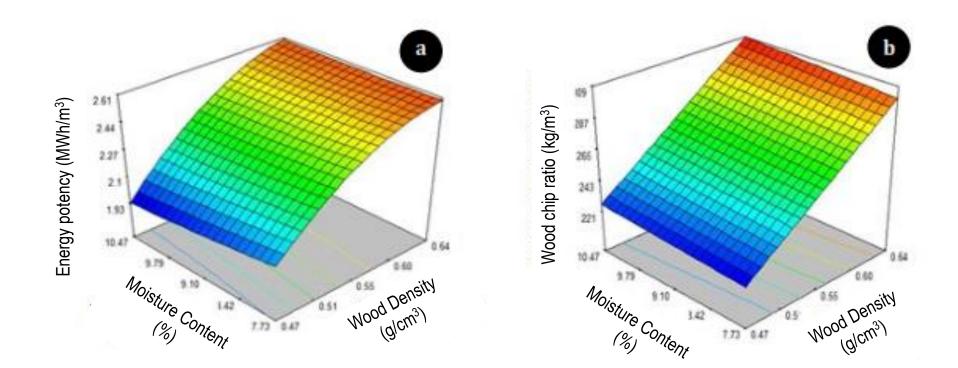
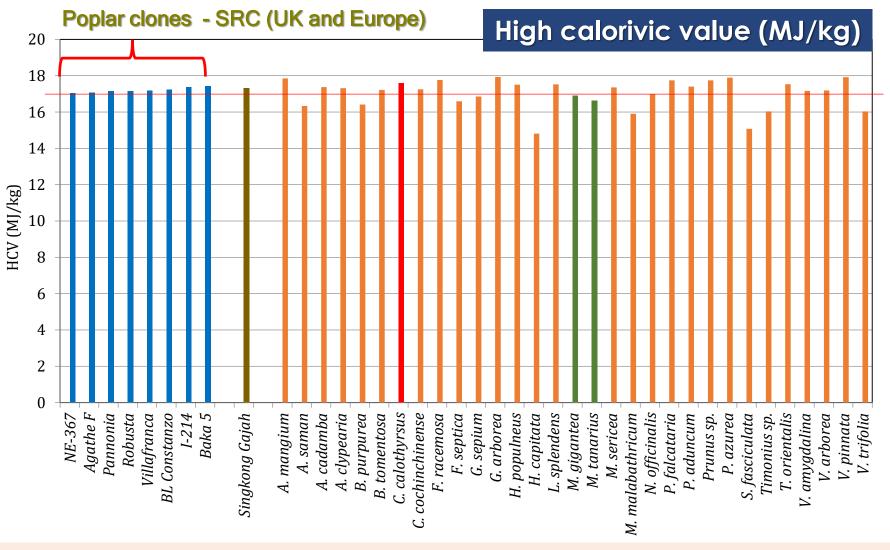


Figure 4. Surface response analysis of short rotation coppice (SRC) plant spesies from tropical lowland community forest in East Kalimantan, Indonesia



#### Energy potency of Tropical Wood to SRC-Poplar



Amirta R, Yuliansyah, Angi EM, Ananto BR, Setiyono B, Haqiqi MT, Septiana HA, Lodong M, Oktavianto RN. 2016. Plant diversity and energy potency of community forest in East Kalimantan, Indonesia: Searching for fast growing wood species for energy production. Nusantara Bioscience 8: 22-30.



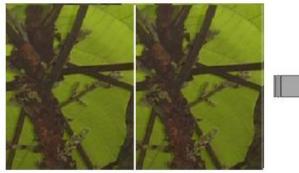


Fig. Macaranga tanarius

- *M. gigantea* and *M. tanarius* have been used as firewood species by local people in East and North Kalimantan Provinces, instead of the higher density wood species such as *Vitex pinnata, Nephelium lappaceum, Blumeodendron kurzii* and *Dipterocarpus* sp. (Yuliansyah et al. 2012).
- The dried root and fresh leaves of *Macaranga* was also used to cover wounds to prevent inflammation, as an emetic agent, antipyretic, antioxidant and antitussive in Thailand and Malaysia (Chulaborn et al. 2002; Lim et al. 2009).
- The bioactive compound *of M. tanarius* was reported effective to be used as an antidiabetic (Puteri and Kawabata 2010).
- Macaranga was also traditionally used by Dayak people in East Kalimantan as the natural plant indicator to determine the end of the recovery period of forest land after ground fire or shifting cultivation activities (Slik et al. 2003, 2005).

### Tropical Forest Resources – Macaranga

## Growth ability of Macaranga



Flower buds



Flower ♀

Flower &



Flower of fall



Young fruit

Flower Q developing to young fruit

**Fig.** Developmental stages of *Macaranga gigantea* flowers and fruits

Susanto D, Ruchyat D, Sutisna M, Amirta R.. 2016. Flowering, fruiting, seed germination and seedling growth of Macaranga gigantea. Biodiversitas, 17 (1): 192-199.



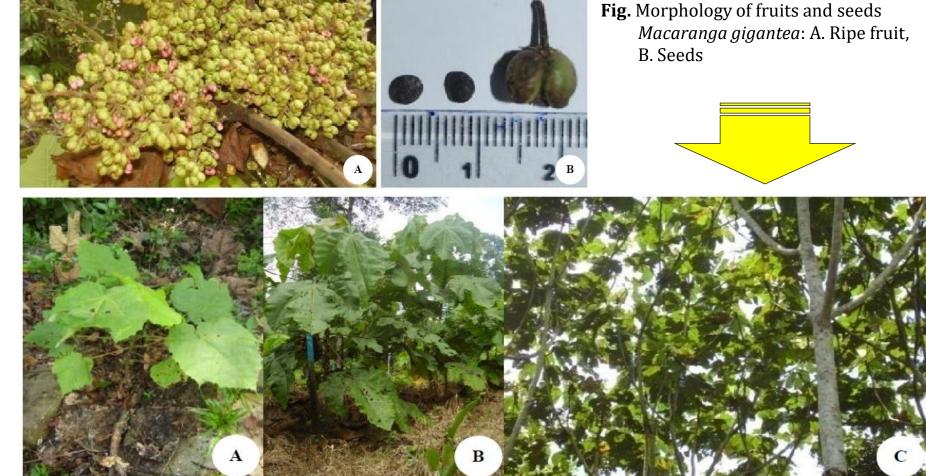
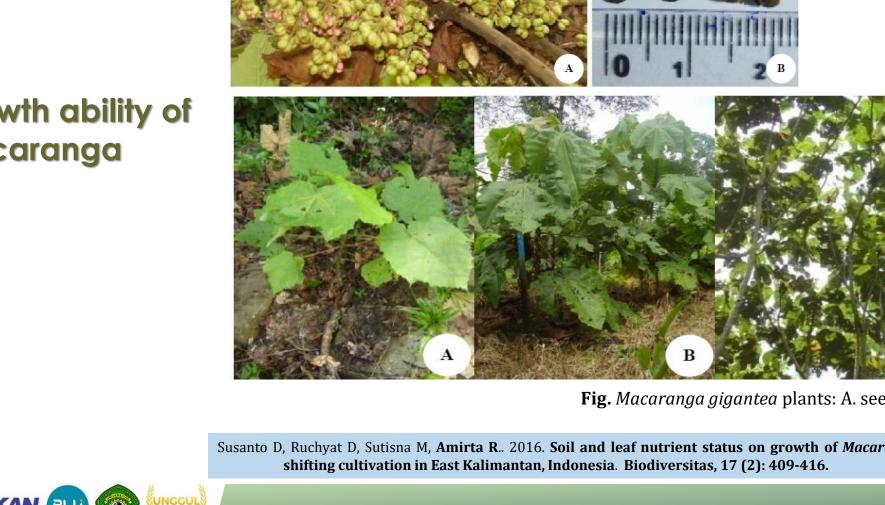


Fig. Macaranga gigantea plants: A. seedling, B. sapling, C. mature trees

Susanto D, Ruchyat D, Sutisna M, Amirta R. 2016. Soil and leaf nutrient status on growth of Macaranga gigantea in secondary forest after shifting cultivation in East Kalimantan, Indonesia. Biodiversitas, 17 (2): 409-416.

## Growth ability of Macaranga





Fast Growing Pioneer Woody Biomass

## Pioneer species in tropical forest ecosystem with very fast growing ability

**Fig.** Description of fast growing ability of *M. gigantea.* (A) 1<sup>st</sup> year, (B) 2<sup>nd</sup> year, (C) 3<sup>rd</sup> year

Gowth indicators	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year
Plant density (g/cm <sup>3</sup> )	-	$0.30 \pm 0.05$	$0.33 \pm 0.07$
Plant diameter (cm)	$3.41 \pm 0.53$	$9.70 \pm 0.25$	$11.50 \pm 2.10$
Plant high (m)	$1.76 \pm 0.34$	7.51 ± 1.60	$9.00 \pm 1.70$
Plant biomass (kg/ha dry wood biomass)	1,297	17,154	26,119

Amirta R, Mukhdlor A, Mujiati D, Septia E, Supriadi, Susanto D. 2016. Suitability and availability analysis of tropical forest wood species for ethanol production: a case study in East Kalimantan. Biodiversitas, 17 (2): 544-552.





**Fig.** Growth comparasion between poplar (Left: 4 years plant - German) and Macaranga (3 years – Samarinda, Indonesia)







East Kalimantan has abundant resources of biomass:

- Forest plantation of *Eucalyptus*. *Acacia Falcataria*. etc.
- Palm oil plantation



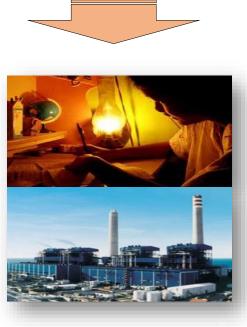


*Eucalyptus* is the major species used widely in the plantation forest of Indonesia (for fiber production to supply pulp and paper industries)

# Evaluation of biomass energy potential from plantation forest of *Eucalyptus pellita*

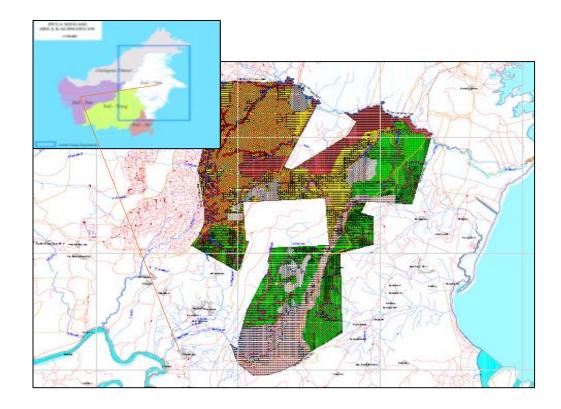
#### **Research purpose**

Therefore herein this paper the potential of biomass energy production from plantation forest in East Kalimantan. Indonesia particularly that located at district Sebulu and Sei Mao managed by Sumalindo Hutani Jaya Ltd (Sinar Mas Group) was analyzed toward supplying the green electricity for rural and remote area









#### **Research Location**

Plantation forest of *Eucalyptus pellita* (EP). located at Site Sebulu and Sei Mao, Kutai Kertanegara – East Kutai, East Kalimanta,. Indonesia (PT. Sumalindo Hutani Jaya Ltd – Sinar Mas Group)

#### **Evaluation:**

The evaluation was focused on:

- The growth rate and total biomass production of main species planted, *E. pell*ita (EP) in different ages of plant.
- The proximate, ultimate & conversion ratio of log to chip and also energy potential from the plantation forest were also studied.





Plant Ages (year)	High (m)	Diameter (cm)	Plant Density (n/ha)	Volume (m <sup>3</sup> /ha)
1	6.48	5.13	1146	11.65
2	12.12	8.62	1085	58.30
3	14.93	10.25	1019	95.40
4	16.58	11.18	947	116.94
5	17.65	11.77	862	125.77

## Growth rate and biomass potency of *E. pellita*

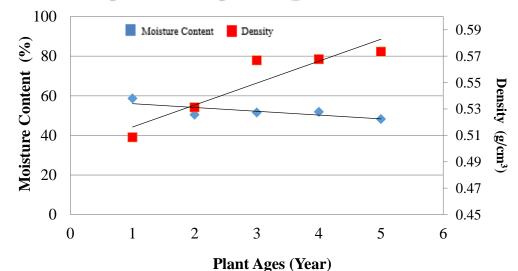




#### Growth rate and biomass potency of E. pellita

Plant Ages	Wood I	Density	Rasio Solid-Chip	Volume per Ha	<b>Biomass Potency</b>
(Year)	g/cm <sup>3</sup>	kg/m <sup>3</sup>	(m <sup>3</sup> /ton)	(m <sup>3</sup> /ha)	(ton/Ha)
1	0.51	508.52	4.75	11.65	5.92
2	0.53	531.25	4.61	58.30	30.97
3	0.57	566.83	4.34	95.40	54.08
4	0.57	567.73	4.34	116.94	66.39
5	0.57	573.40	4.33	125.77	72.12

#### Relationship between plant ages. moisture content and density of *E. pellita*



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#### Wood components of *E. pellita*

Plant Ages (Year)	Lignin (%)	Holocellulose (%)	Cellulose (%)
1	$25.35\pm0.42$	$68.54 \pm 1.13$	$41.86 \pm 1.24$
2	$28.12 \pm 1.15$	$66.60\pm0.88$	$40.08\pm0.04$
3	$28.47\pm0.94$	$66.84\pm0.79$	$40.37\pm0.21$
4	$28.87\pm0.31$	$66.02 \pm 1.23$	$39.79\pm0.25$
5	$29.90\pm0.78$	$67.49\pm0.15$	$37.70\pm0.46$

#### Proximate data of *E. pellita*

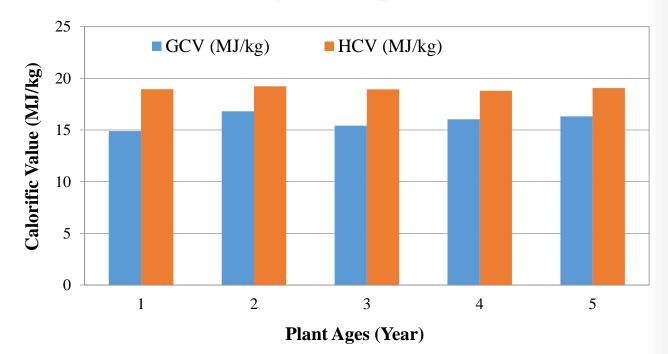
Plant Ages		Proximat Data	
(Year)	Volatile Matter (%)	Fixed Carbon (%)	Ash (%)
1	81.89	17.48	0.63
2	80.58	18.85	0.57
3	82.24	17.27	0.49
4	83.07	16.51	0.42
5	82.10	17.71	0.19

#### Ultimate data of *E. pellita*

Diant A gog (Voon)		<b>Ultimate Data</b>	
Plant Ages (Year)	Carbon (%)	Hydrogen (%)	Oxygen (%)
1	48.39	5.99	44.29
2	48.67	5.98	44.03
3	48.42	6.00	44.40
4	48.32	6.01	44.56
5	48.64	6.01	44.46



## Potential energy of *E. pellita*







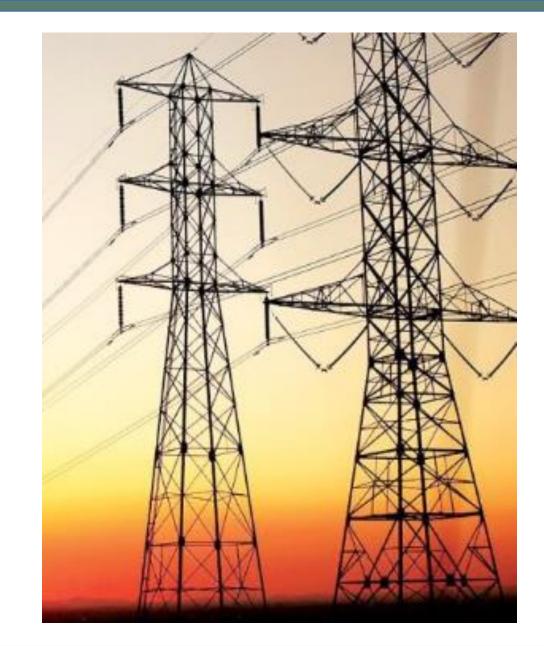
**Annual biomass production** 745,296 tons

**20% of annual biomass production** 149,059 tons

**Equal to** 2,864,918 GJ of energy

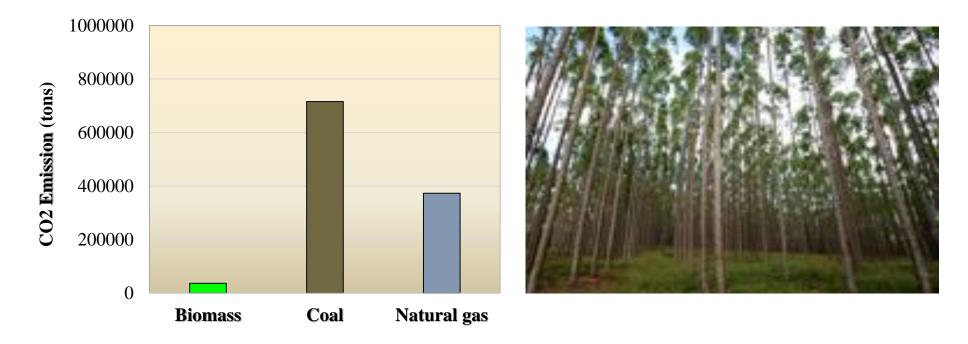
Power plant efficiency ratio 25% 8000 hours per year of operation

**Potential electricity supply** 24.87 MW





## **Comparasion of CO<sub>2</sub> emission**



#### **Potential CO<sub>2</sub> emission reduction on prdoction of** $\pm$ 795,810 MWe



## Conclusions

- We found the biomass production was linearly increased due to increase of plant ages (maturity) to reached 11.65 m<sup>3</sup>/ha. 58.30 m<sup>3</sup>/ha. 95.40 m<sup>3</sup>/ha. 116.94 m<sup>3</sup>/ha and 125.77 m<sup>3</sup>/ha for 1-5 years of plantation. respectively
- 2. The biomass production was equal to 5.92-72.12 tons/ha of dry material with the range of higher calorific value (HCV) was 18.79-19.22 GJ/ton.
- 3. 745.296 tons of biomass potentially produced annually. which is 20% of them could be used as energy feedstocks (equal to 149.059 tons of biomass or 2.864.918 GJ of energy).
- 4. If this energy potential is applied at a power plant with efficiency ratio of 25% and 8000 hours per year of operation. this has potential of 24.87 MW of electricity.
- 5. This fact was not only good for the sustainable production of biomass and green electricity supply issues but also link with the significant  $CO_2$  emission reduction potential (±716.229 ton  $CO_{2e}$ ) that could be achieved from replacement of coal power plant to biomass in this area.

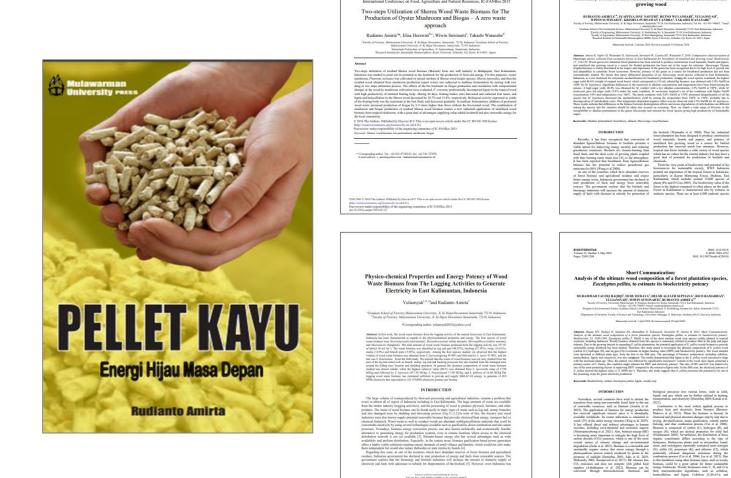




45 KW electricity for 100 houses @ 450 watt power and 115 KW heat power for chilling and drying

MASTERPLAN PERCEPATAN DAN PERLUASAN PEMBANGUNAN EKONOMI INDONESIA 2011-2025





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INTRODUCTION biological processes into various forms, such as solid,	1	Keywork: Electricity, fast-growing, native species, secondary for	rest, woody hierans		Krywards: monaus, teennock, green energy, pain averary, visamp-pear	kirod .
Strengther, and provide matter burger of the strength of the		INTRODUCTION The explaintion of fixed fields has significantly inverse the demonstration of automatic scattering and the	the consistent is addressing a standing large data of the data of		<b>LYEODETED</b> and the second sec	and of COs, relational time the attractional structure of the structure of
promute of analytic Domaining 2010. Mate at 2019; Oktober 2010 and		significant challings on how to might change that and colore those harmful GHC effects (Karmakar et al 2020, Rengel and Graph 2020). The United Nations (UN), through the Climate Action Summit in New York in 2029 has set a global plan to achieve net-zeros remissions by 2059 (Matzer and Malapo 2021). Therefore, many contribu-	Forties of the 2017/F weeks oriented in receive white the forest in allow one of the premising forderacks to prevalue clean energy because it 2017, Lee et al. 2013, Stoce almost all remote zeros in hadronic arc cuvered by foreste with limited transportation access, the approach to using its himmass will be adaptate to survey the cleansity.		with decrease in arbeidy available for permittion of the bel- biestenergy and befored. (Withoutber 4), 2003). Biosenergy was also developed to replace family fails in energy Un- poderisition is noted to decrease permittions. In this production is noted to decrease permittion of the term of the interpretation of the second second second second does not cause and near the distribution of the term The important idea believes the first distribution of the does not cause and near the distribution of the distribu- tion of the second second (COA) emissions from bioenergy were considered to be zone based on the fast that the	ans productivity and its withshifty in be used as the s energy feedatock is important not only for the inshifts supply of biomass-based energy for the manify, but also for conserving and managing the mp-pent forest itself.

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## **POME** biogas potency in East Kalimantan

Parameter	Unit	Value
CPO production	Tonnes	5,221,016
POME generated <sup>a</sup>	m <sup>3</sup>	15,663,048
COD level in POME <sup>b</sup>	mg/L	798,815
COD converted <sup>c</sup>	Tonnes	639,052
CH <sub>4</sub> produced <sup>d</sup>	Tonnes	159,763
Energy rate <sup>e</sup>	MJ	7,988,154,480
	MWh	2,218,932
Diesel equivalent <sup>f</sup>	L	227,297,817
Electricity generated <sup>9</sup>	MWh	887,573
Power plant capacity (gas engine) <sup>g</sup>	MW	111

<sup>a</sup>Assume that 3m<sup>3</sup> POME generated per tonne CPO produced.; <sup>b</sup>COD of POME based on mean value given by Malaysia Palm Oil Board (MPOB); <sup>c</sup>Assume that digester efficiency is 80%.; <sup>d</sup>Theoretical methane conversion factoris 0.25 kg CH<sub>4</sub> per kg COD [66]. <sup>e</sup>Calorific value of CH<sub>4</sub> is 50MJ/kg. <sup>f</sup>Calorific value of disselis35.144MJ/L.; <sup>g</sup>Assume the gas engine operating 8000 hr/yr and with efficiency of 40%. (Ji et al., 2013)

