



TNB RESEARCH

*Energizing Research, Enlivening Innovation*

# Biomass Value Chain in Energy Transition Journey

**Presenter**

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# Outline:

**1.0 EMISSION  
REDUCTION  
TARGET**

**2.0 BIOMASS  
VALUE CHAIN IN  
ENERGY  
TRANSITION  
JOURNEY**

**3.0 CASE STUDY**

# 1.0 Global & National Target on Emission Reduction

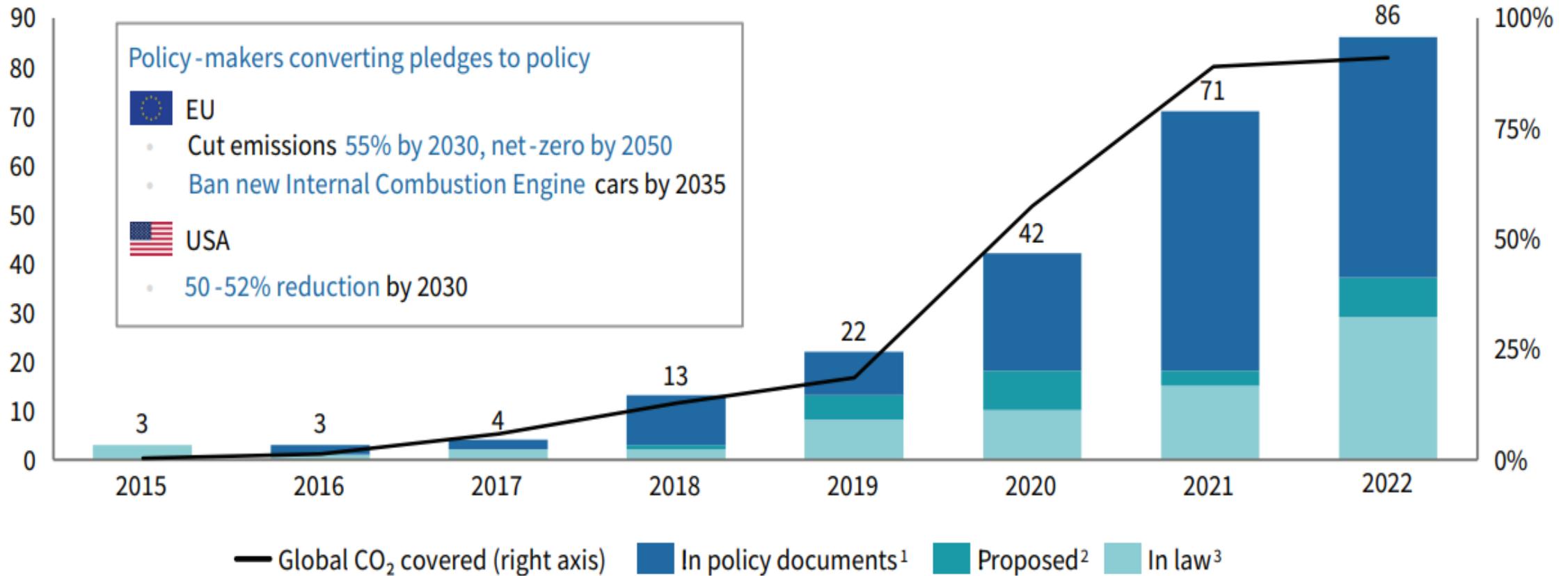
- Intergovernmental Panel on Climate Change (IPCC) with 195 member countries estimated that global annual Greenhouse Gas emissions to be reduced to 45% by 2030 (compared to 2010 levels) to limit global average temperature increase to 1.5 °C in reducing the impacts of climate change.
- Today, it is at 1.1 °C above preindustrial levels.
- Malaysia made a commitment to reduce the intensity of carbon emissions of 45% reduction compared to per unit of GDP in 2005 by 2030.
- According to Malaysia 3<sup>rd</sup> Biennial update report to the United Nations Framework Convention on Climate Change (UNFCCC), total GHG emissions for 2016 were 316,833 Gg CO<sub>2</sub> eq for emissions without (land use, land use change and forestry) LULUCF and 75,488 Gg CO<sub>2</sub> eq with LULUCF in 2016.
- The energy sector remained as the largest contributor of emissions that accounted for 79.4% of the total emissions. In terms of gaseous, CO<sub>2</sub> emissions amounted to 80% of the total GHG emissions.

Source: UN Climate Change News, 26 October 2022, 3<sup>rd</sup> Biennial update report to UNFCCC, SEDA - MyRER strategic framework

# Global Emissions % reduction through policy and law

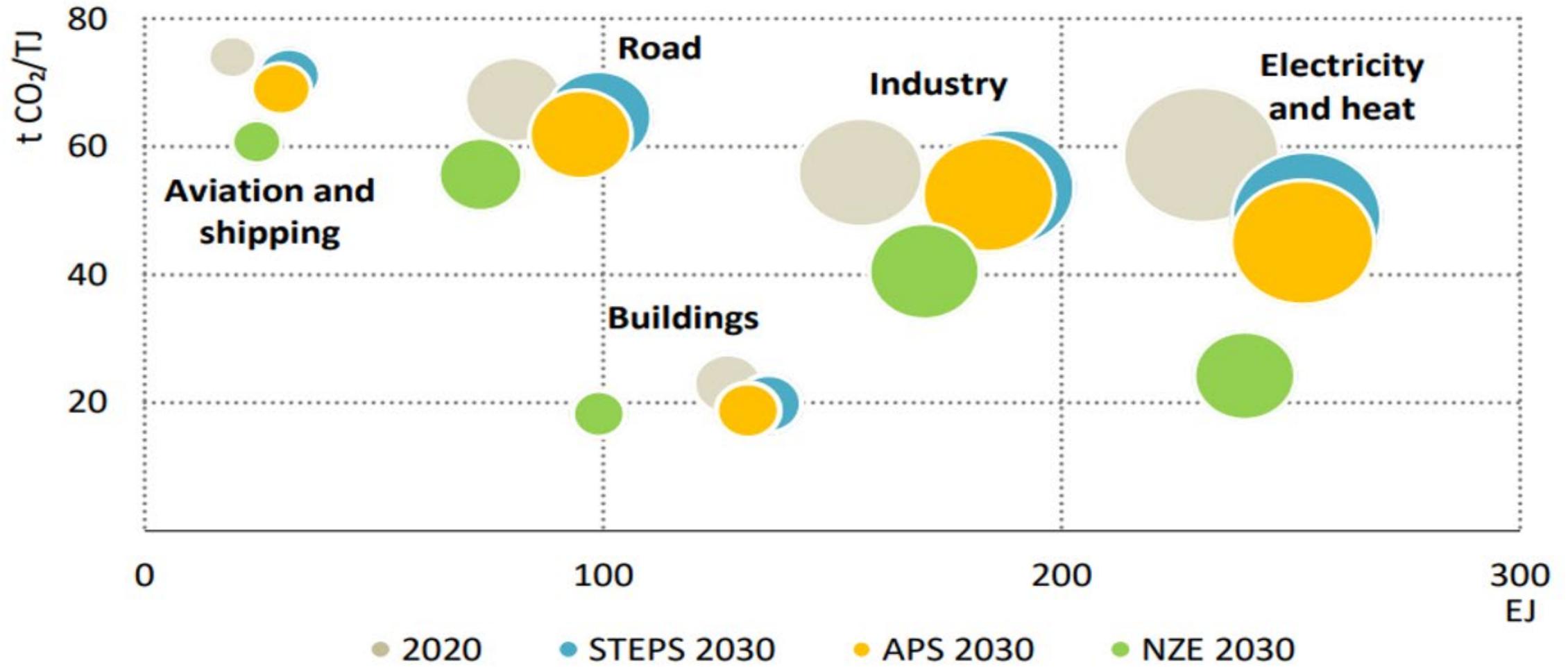
## Net-zero pledges cover 88% of global emissions

Countries (#)



Source: National Energy Transition Roadmap

# Transition to NZE 2030

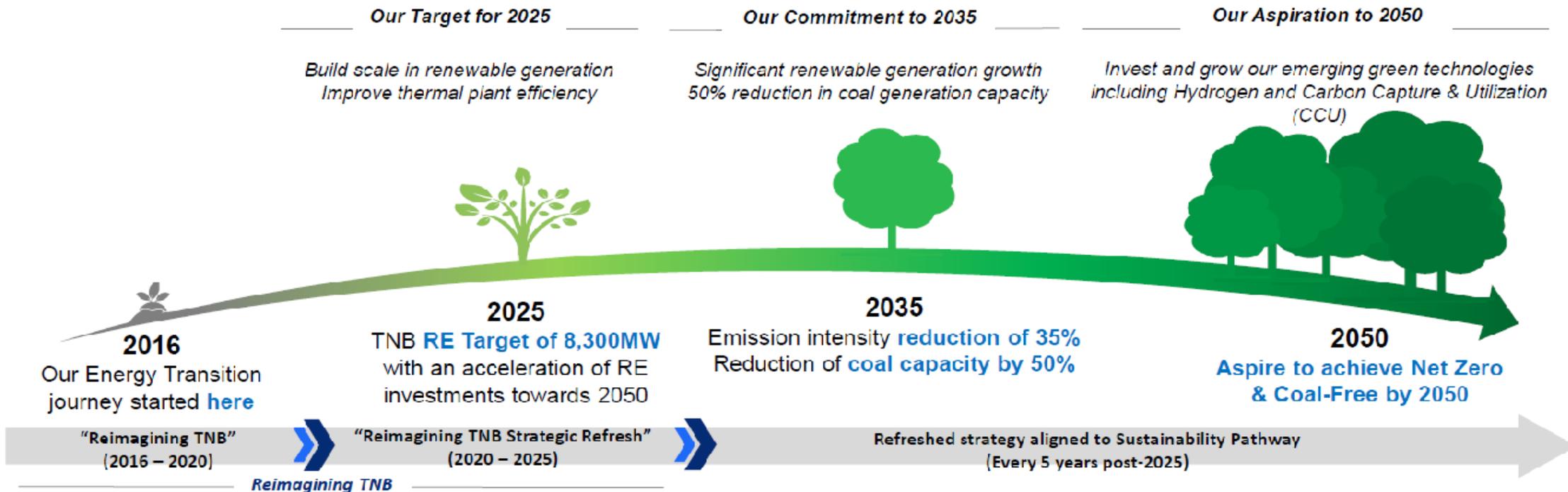


Source: IEA World Energy Outlook 2021 \* STEPS Stated Policies Scenario, \* APS (Announced Pledges Scenarios)

# TNB Sustainability Pathway

**We believe that our sustainability pathway towards 2050 will open new growth opportunities whilst remaining true to our core role**

**Target of 8.3GW RE by 2025**  
**Commitment of 35% reduction of our emission intensity by 2035**  
**Aspire to achieve Net Zero emissions by 2050**



 **Our journey for the next 5 years is still guided by Reimagining TNB – the medium term goals to 2025 still remain**

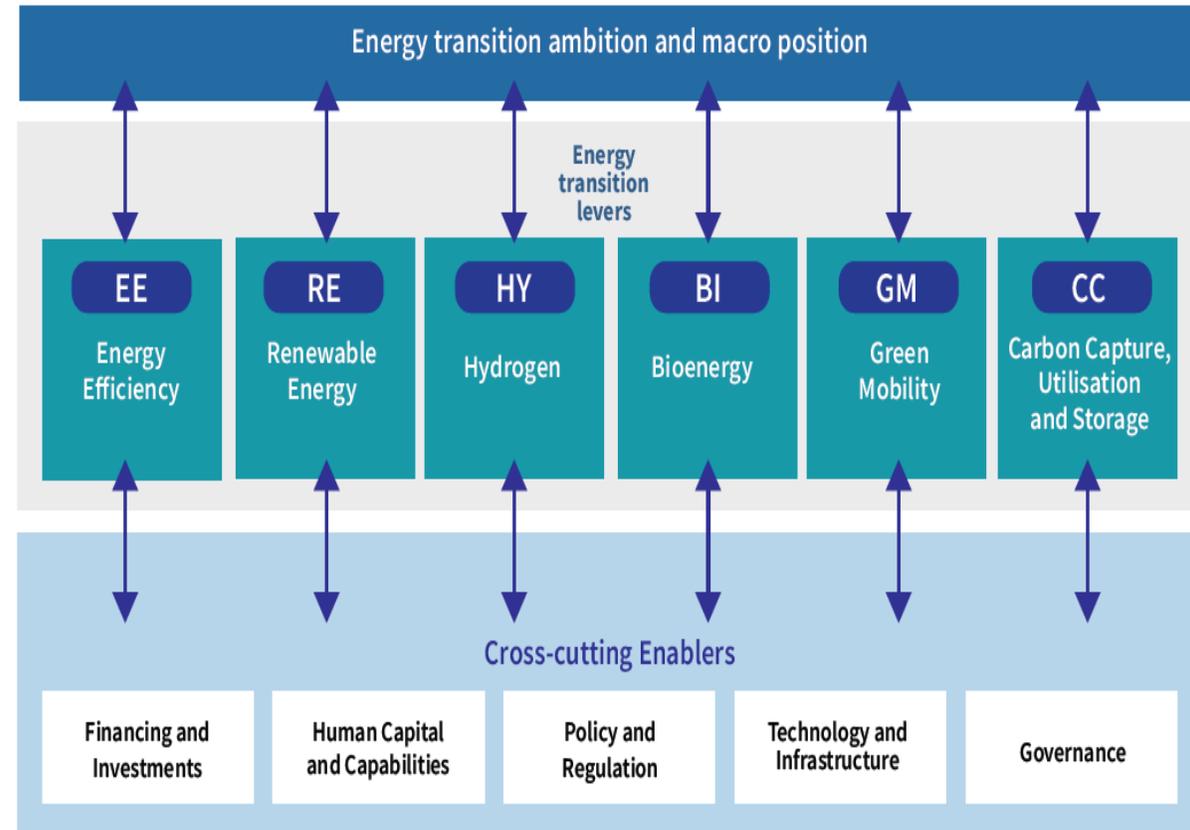
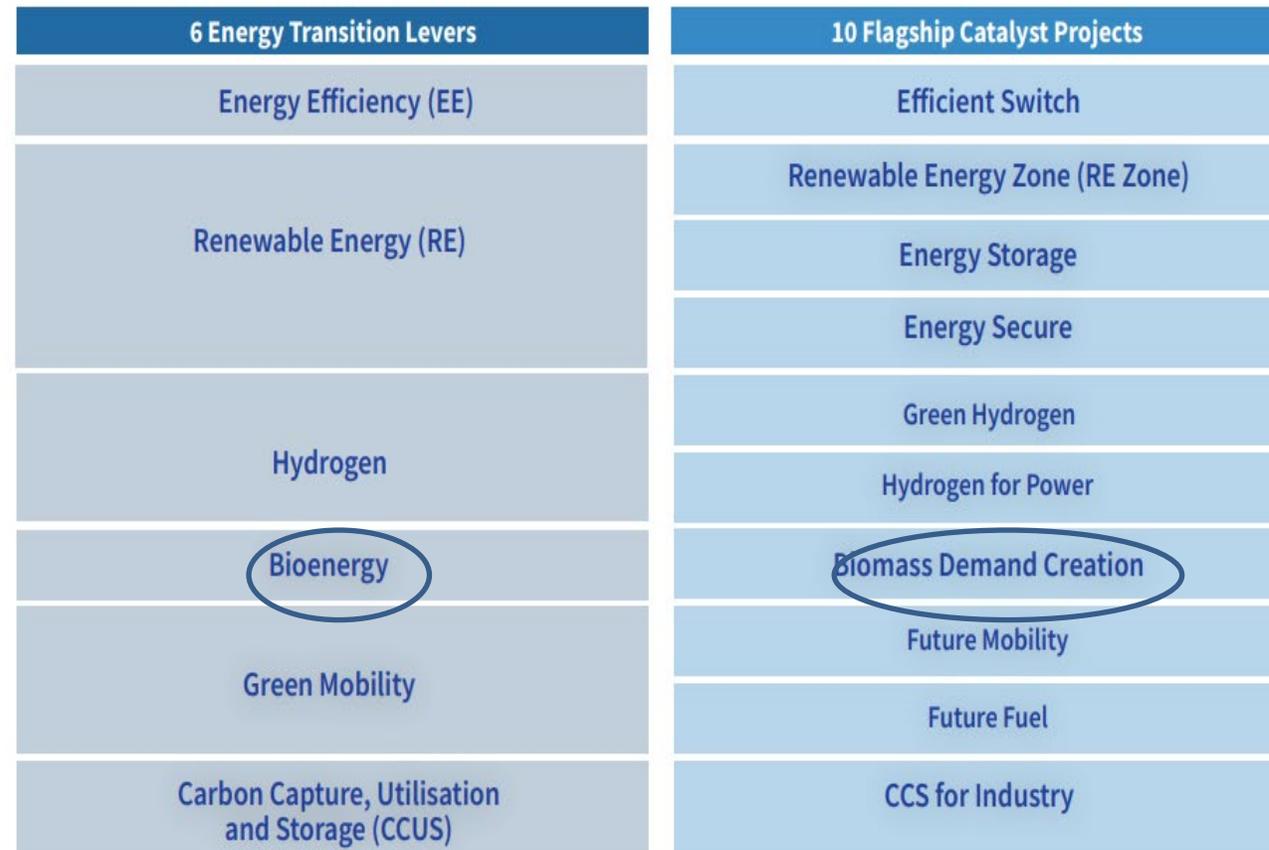
# NETR aims to **accelerate energy transition** to clean energy to achieve net zero GHG by 2050 in addition to **National Energy Policy 2022-2040** to transform energy landscape of Malaysia

## NETR Part 1

## NETR Part 2

Identify flagship catalyst projects and initiatives

Establish low-carbon pathway, energy mix and emission target reduction for the energy sector



## Selected targets on Low Carbon Nation Aspiration 2040 compared to 2018

Selected Targets		2018	Low Carbon Nation Aspiration 2040
 1. Percentage of urban public transport modal share	● ●	20%	50%
 2. Percentage of electric vehicle (EV) share	●	<1%	38%
 3. Alternative fuel standard for heavy transport	●	B5	B30
 4. Percentage of Liquefied Natural Gas (LNG) as alternative fuel for marine transport	●	0%	25%
 5. Percentage of industrial and commercial energy efficiency savings	● ● ●	<1%	11%
 6. Percentage of residential energy efficiency savings	● ● ●	<1%	10%
 7. Total installed capacity of RE	● ● ●	7,597 MW	18,431 MW
 8. Percentage of coal in installed capacity	● ● ●	31.4%	18.6%
 9. Percentage of RE in TPES	● ● ●	7.2%	17%

Legend: ● Energy security ● Energy affordability ● Environmental sustainability

Source: National Energy Policy 2022-2040 [EPU], TPES Total Primary Energy Supply

# Biomass Conversion to Fuel

## Thermochemical

- Lignocellulosic Feedstock:-
- **Pyrolysis: Bio-oils** hydrotreating to liquid fuels/zeolites **upgrading to liquid fuels**
- **Gasification:** supercritical water, steam to **syngas** to **Hydrogen** via water gas shift, to **alcohols** via catalysed alcohols synthesis or via Fisher Tropsch to alkanes
- **Liquefaction**
- **Combustion**
- Reaction Conditions: Higher temperatures and Pressures
- Shorter residence time

## Biological

- Feedstock : **Cellulose** derived **sugars ie glucose, Hemicellulose** contains hexoses (mannose, galactose) and pentoses (xyloses and arabinose)
- **Fermentation: Alcohol**
- Dehydration: **Aromatics**
- Aqueous phase processing: **Hydrogen, Alkanes, Furans**
- Lignin upgrading: Aromatics, Alkanes
- Reaction conditions: Atmospheric and at lower temperature
- Longer residence time

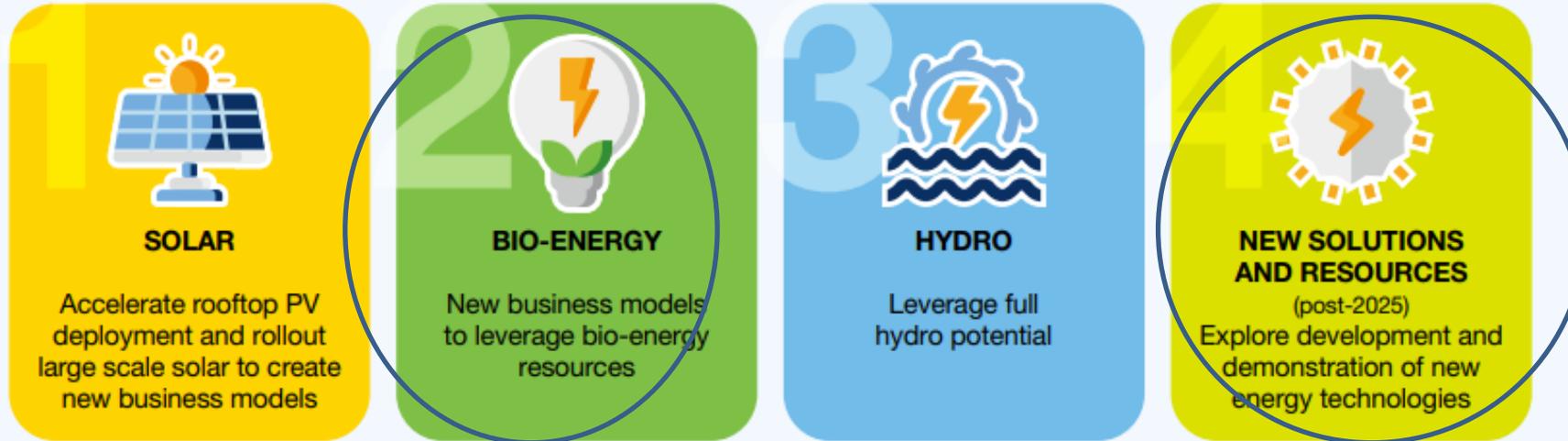


- Each routes can produce **fuels, chemicals, materials and clean gas** and **residues from sugar platform can be utilised for combined heat and power**

# Vision

## Pathway Towards Low Carbon Energy System

Technology specific pillars



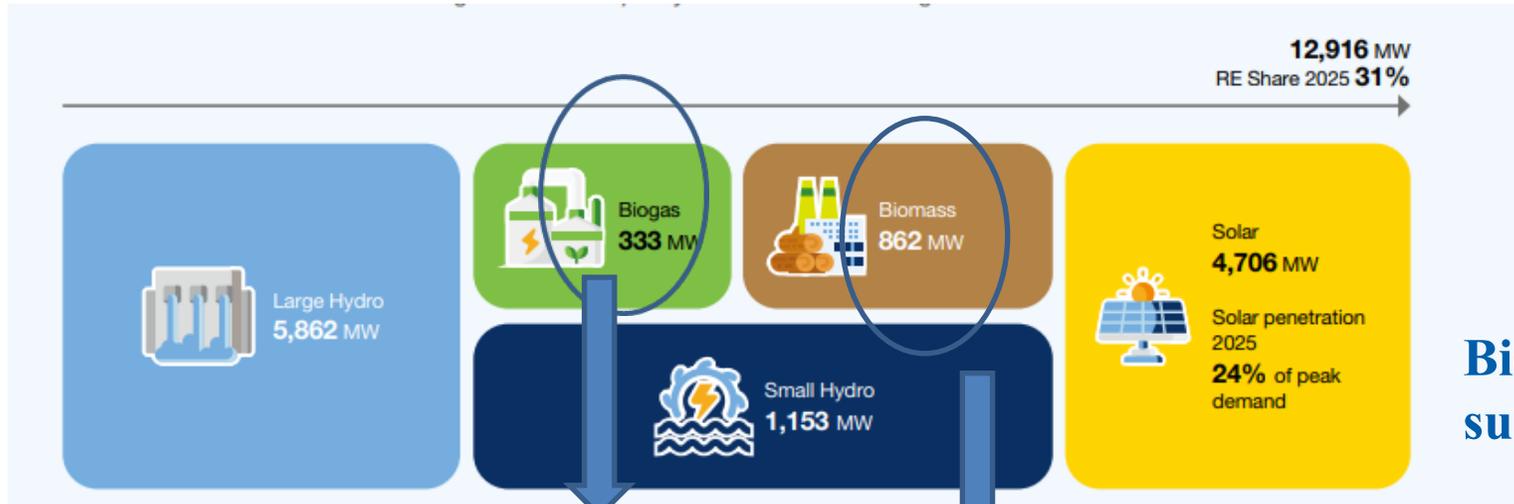
Enabling initiatives



- 5.1 Leverage future-proofing electricity market for RE opportunities
- 5.2 Improve access to financing
- 5.3 Shape human capital & infrastructure
- 5.4 Increase system flexibility

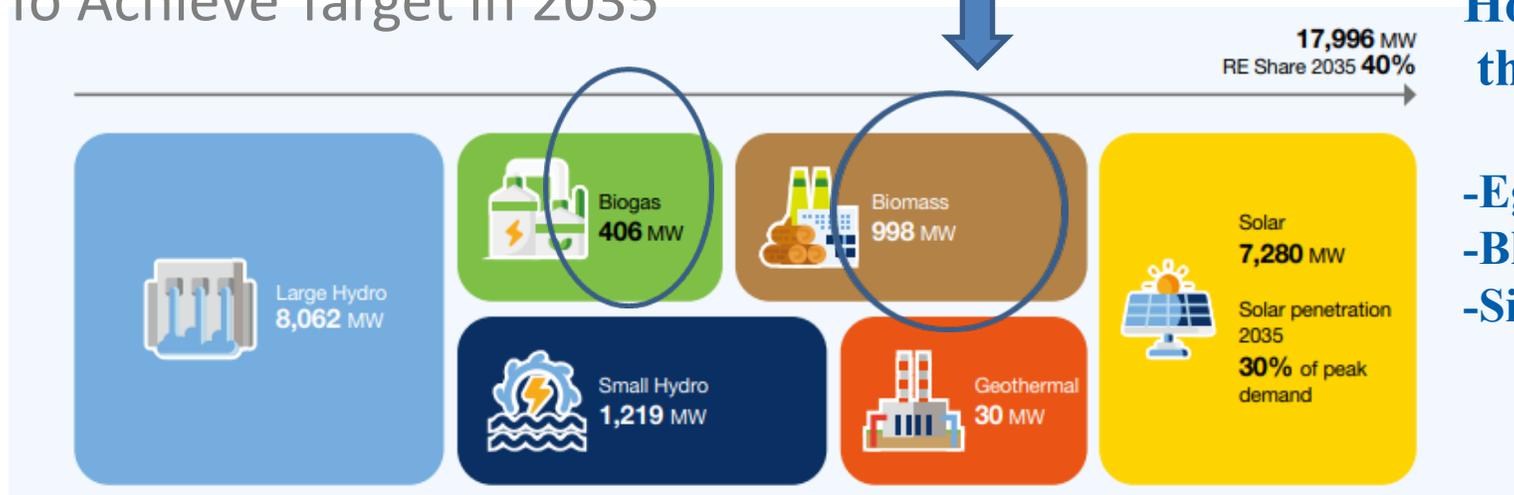
# RENEWABLE ENERGY CAPACITY MIX

To Achieve Target in 2025



**Biomass contributes 10% of world energy supply (IEA 2016)**

To Achieve Target in 2035



**How biomass can contribute to the renewable energy capacity mix?**

- Eg. Biogas /
- Blended solid biomass fuel
- Single biomass fuel straight burn

# National Biomass Action Plan 2023-2030

## Biomass Resources

\* HARVESTING 1TON OF FRESH OIL PALM FRUIT~ REMOVAL OF 1900KG OF FRONDS.

PROCESSING 1 TON FFB ~ 200 KG EFB, ~70 KG PALM SHELLS, ~220 KG FIBRE

BIO MASS  
ECONOMIC OPPORTUNITY MAPPING

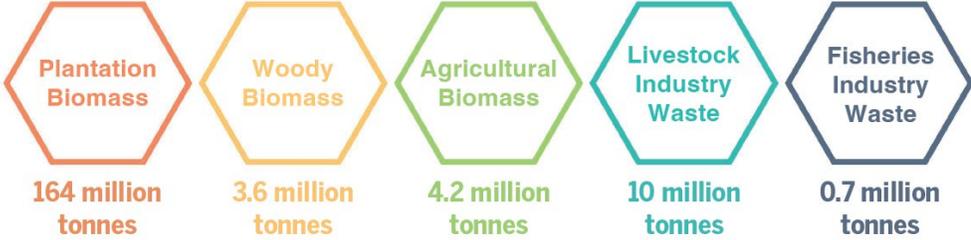


**Estimated Biomass Quantities for Year 2022**  
**182.6 million tonnes**

## PLANTATION BIOMASS

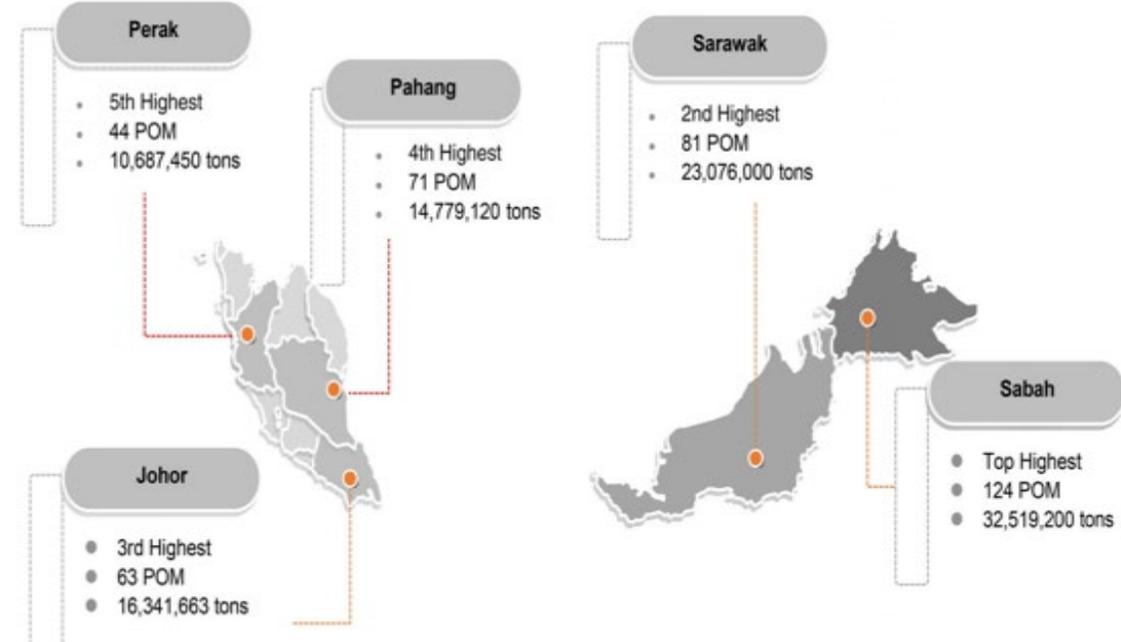
**89.8%**

**164 MILLION TONNES**



Palm Oil Mills Fresh Fruit Bunch Production: 94,814,456 tonnes	Empty Fruit Bunch (EFB) Mesocarp Fibres (MF) Palm Kernel Shells (PKS) Palm Kernel Cake (PKC) Palm Oil Mill Effluent (POME)	7,300,713 tonnes 7,679,023 tonnes 4,427,835 tonnes 2,465,176 tonnes 63,525,686 tonnes
Cocoa Processing Factories: 537 tonnes	Oil Palm Fronds (OPF) Oil Palm Trunks (OPT) Cocoa Bean Shell Cocoa Hob & Pulp	59,593,762 tonnes 10,548,826 tonnes 49 tonnes 364 tonnes
Kenaf Planted Area: 1,500 hectares	Kenaf Shoot	3,000 tonnes
Sago Planted Areas: 33,928 hectares	Sago Palm Frond	53,564 tonnes
Palm Sagu Mill Production: 133,911 tonnes	Sago Bark Sago Hampas Sago Waste Water	147,302 tonnes 147,302 tonnes 8,034,660 tonnes

# OPERATIONAL CAPACITY OF MALAYSIA PALM OIL SECTORS (tons/year)

Sector	No	Operational Capacity	No	Operational Capacity	No	Operational Capacity
	Peninsular Malaysia	Peninsular Malaysia	Sabah	Sabah	Sarawak	Sarawak
FFB Mills	242	58,155,680	*124	*32,519,200	*81	*23,076,000
PK Crushers	26	4,397,500	12	2,072,200	4	697,200
<b>MALAYSIA</b>	<b>457 FFB Mills</b> <b>Operational Capacity = 116,811,750 (ton/yr)</b>	<b>42 PK Crushers</b> <b>Operational Capacity = 7,166,900(ton/yr)</b>				

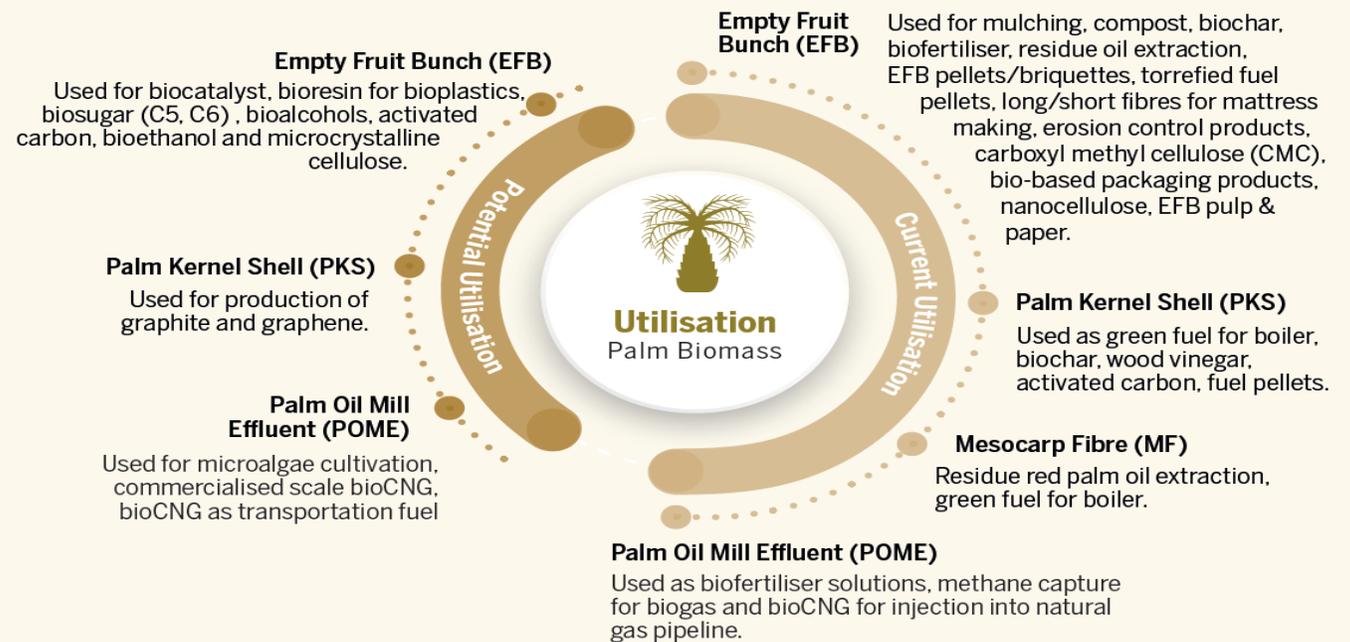
Source: (i) \*M,F,MA Zamri et al (2022) Energy & Environment (ii) MPOB 2020

# Oil Palm Biomass Utilisation and Business Models

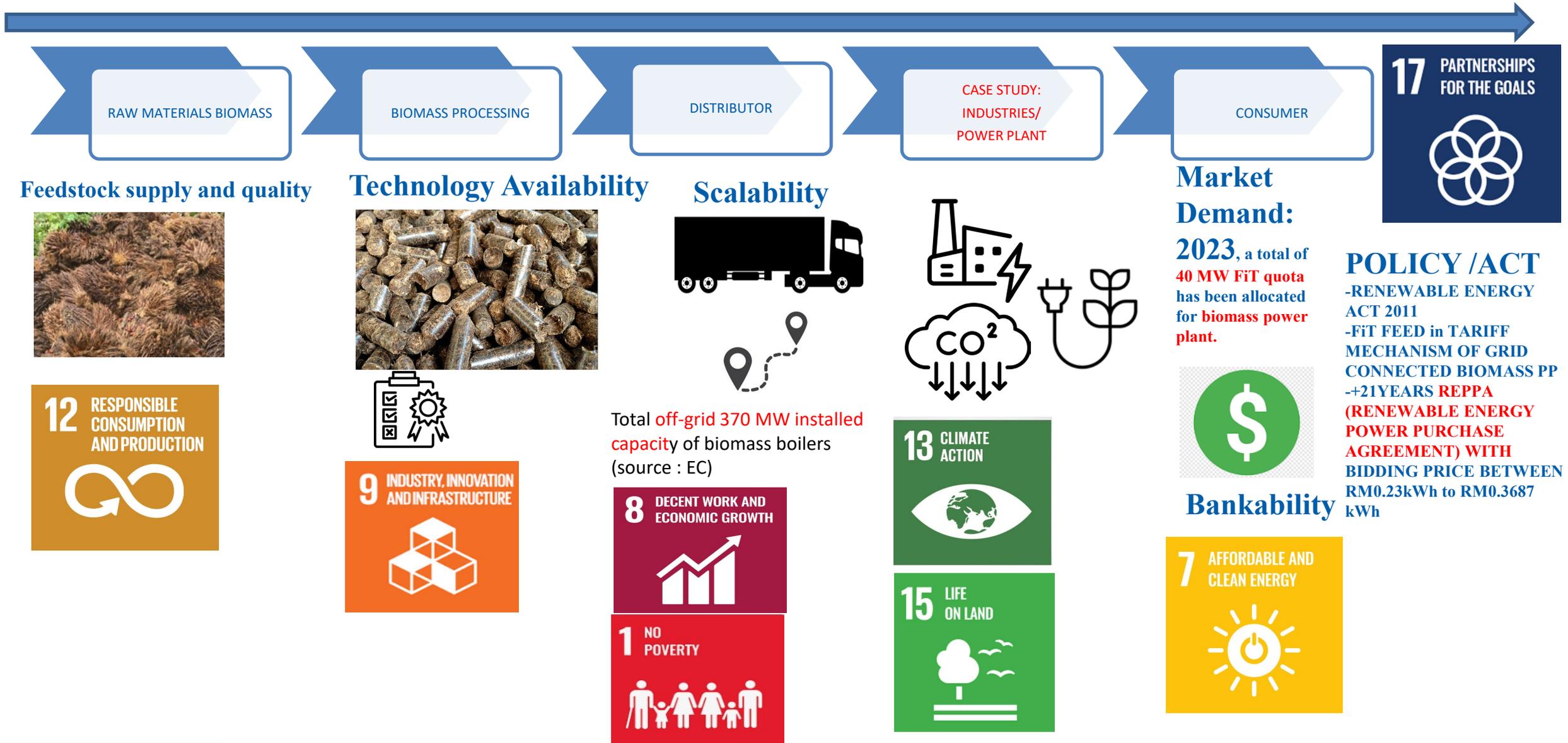
## 14 Biomass Business Models

Wood Pellets ▲	Empty Fruit Bunches (EFB) Pellets ▲	Grid-connected Biomass Power Plant ▲	Fuel Switching from Fossil Fuel to Biomass Fuel ▲
OPT Products - OPT Pellets, OPT Plywood, Palm Wood, Blockboard ▲		Activated Carbon & Reactivated Carbon ▲	Biodegradable Packaging Products using Rice Straw ▲
Animal Feeds ▲	Compost, Biofertiliser, Biopesticide ▲	Palm Kernel Shell-based Graphite and Graphene ▲	Biodegradable Erosion Control Product ▲
Biochar from Animal Manure ▲	Fish Waste Booster Liquid Biofertiliser & Fish Meal ▲	Specialty Biochemical and Biopolymers ▲	

▲ Bioenergy	▲ Eco-product
▲ Bio-agriculture	▲ Biochemical



# Biomass Value Chain in Energy Transition Journey

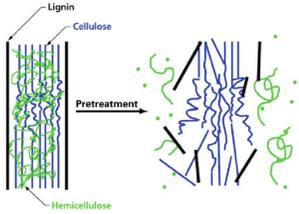


Malaysia has achieved 1,063,528 (tCO<sub>2</sub>) emission reduction based on the 1868 GWh renewable energy generated from the biomass power plants between the year 2012 – 2020.

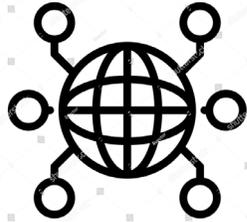
Biomass			
Year	Cumulating RE Installed Capacity (MW)	RE Generated (GWh)	Annual GHG Emission Reduction (tCO <sub>2</sub> )
2012	52.3	104.54	57,852
2013	50.4	220.55	119,904
2014	55.9	200.16	109,413
2015	76.7	246.73	145,884
2016	87.90	248.48	137,636
2017	95.55	247.21	143,008
2018	70.65	226.09	131,313
2019	70.65	225.22	131,670
2020	70.65	149.32	86,848
<b>Total</b>		<b>1868.30</b>	<b>1,063,528</b>

Source: SEDA Malaysia

# CHALLENGES



**Feedstock – homogeneities, stability of supply infrastructure for collection**



**Technology readiness at large scale >500MW; Accessibility to technology**



**Integration throughout the value chain, partnership**



**Skilled workforce/AI/ML**



**Infrastructure for collection, security of supply; blending share in grid**



**Awareness of bioenergy potential**

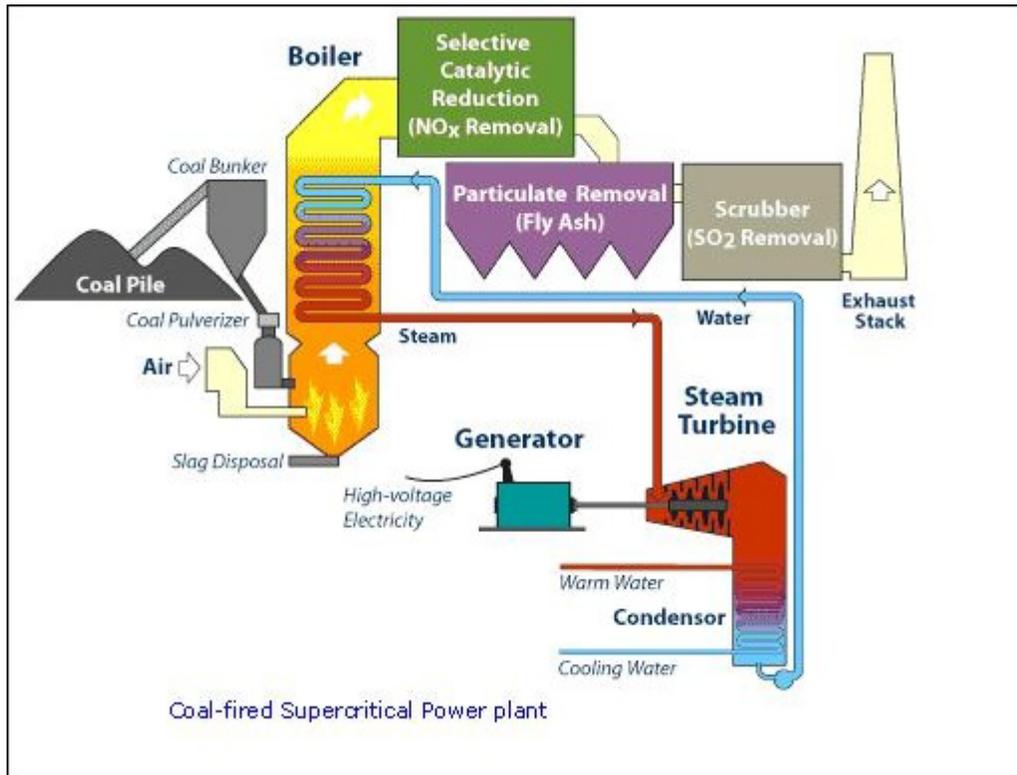


**Fuel Price, Investment(bankability), Market (local, regional, global)**



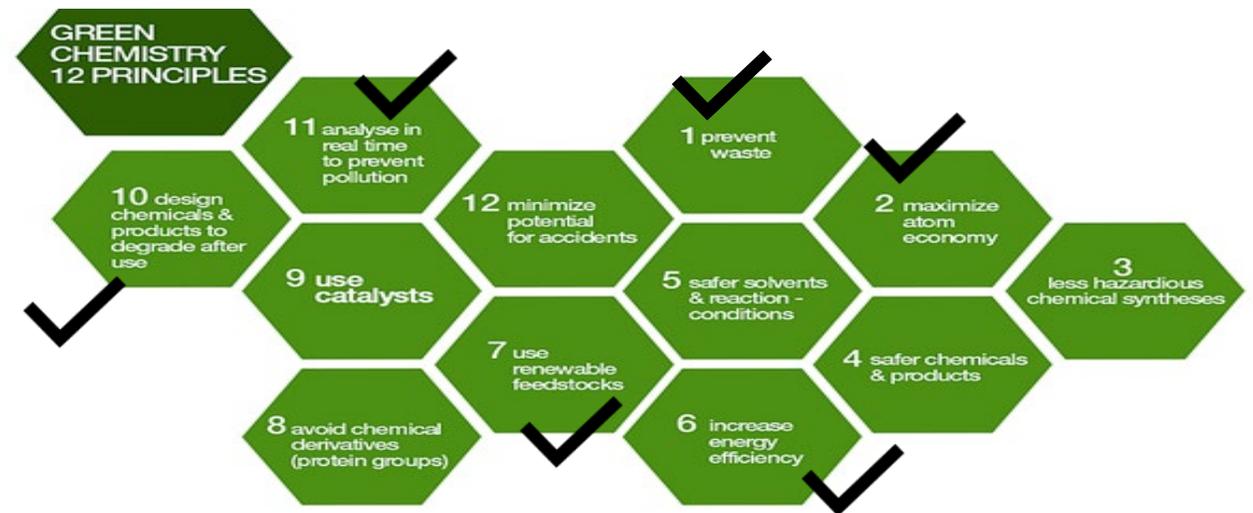
**Certification Standards palm /biomass energy pellets**

# Example Industry Application



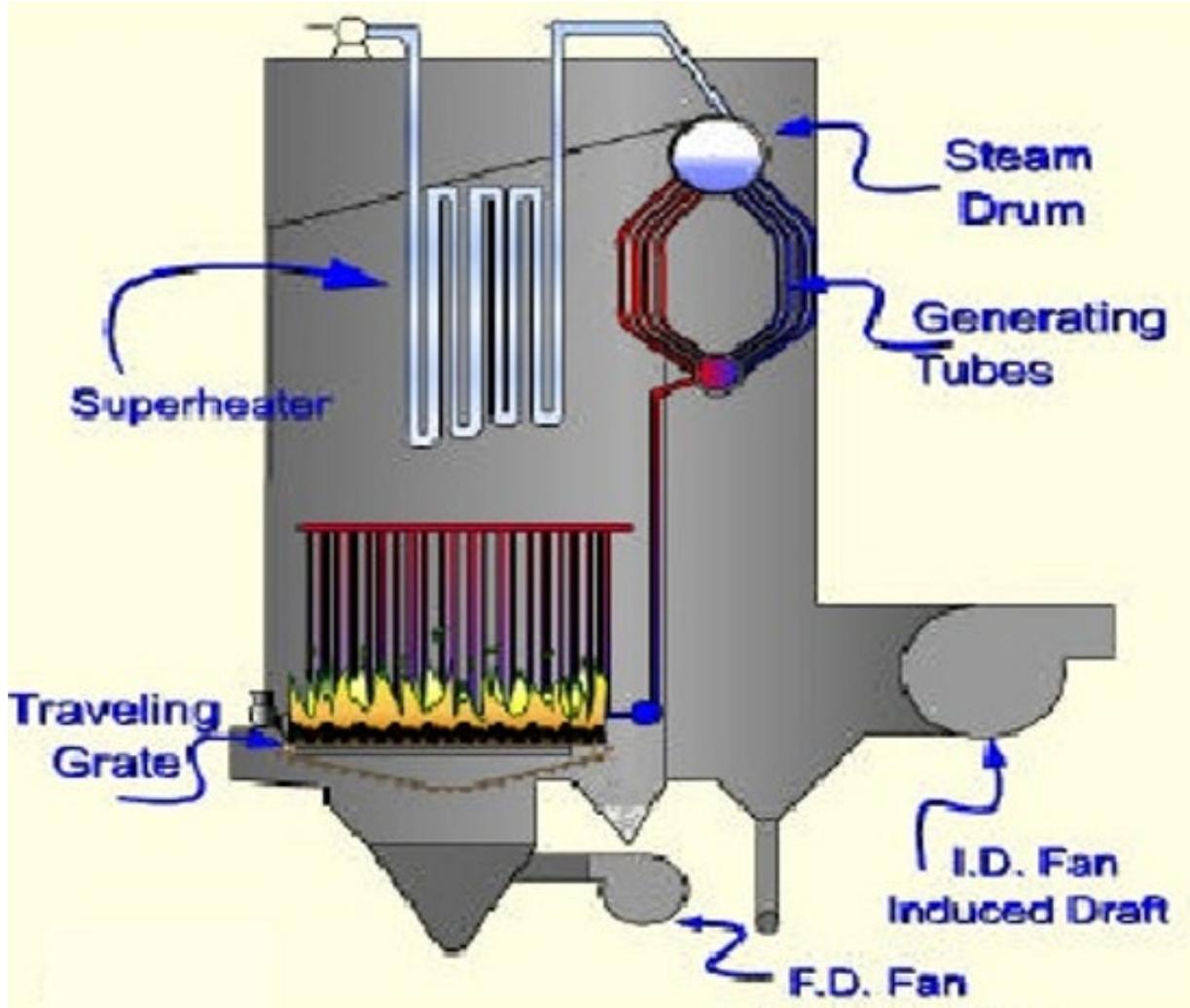
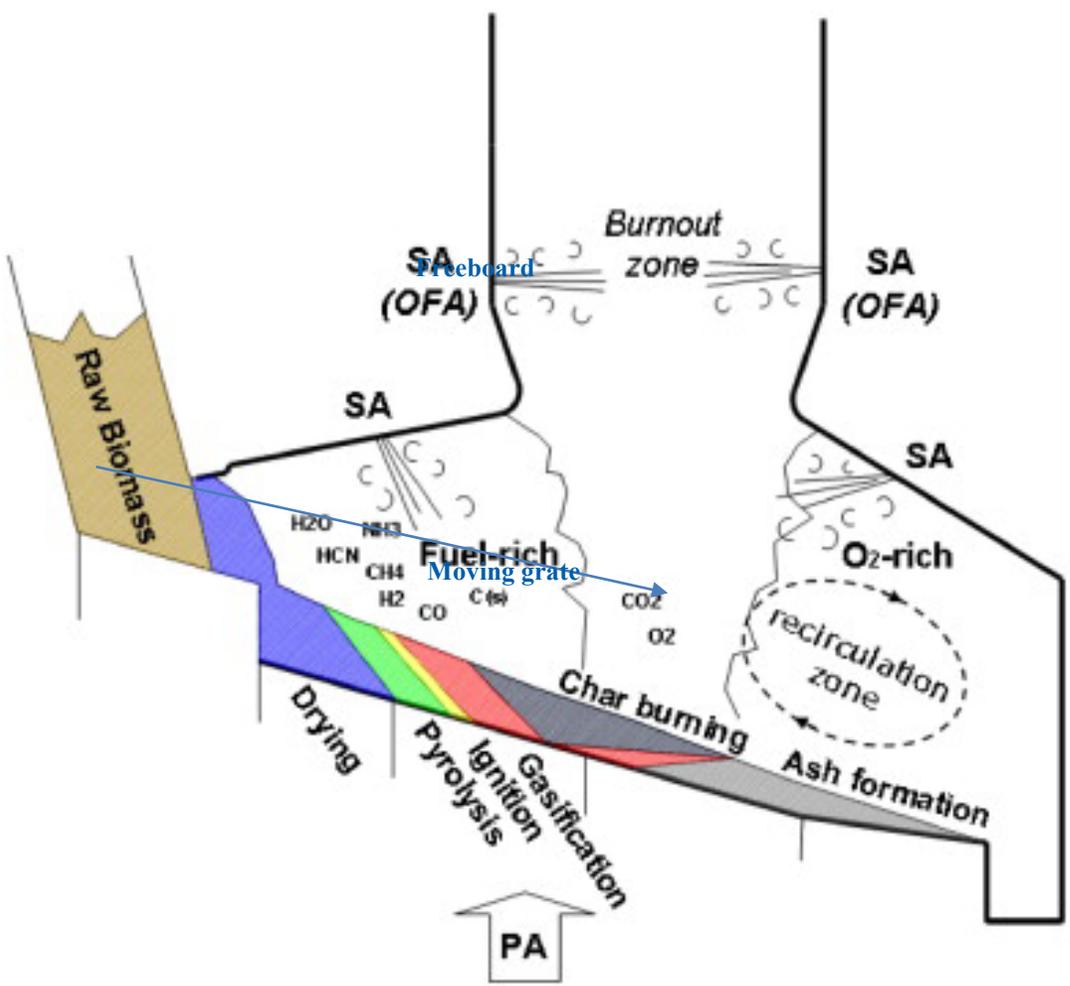
## Key parameters:

- Particle size; size reduction and drying
- Types of coal/biomass
- Equivalence ratio,  $\lambda = (A/B)$  actual oxygen supplied to the combustion process to that required (A/B) stoichiometrically
- Gasifier /Boiler design



# EXAMPLES OF BIOMASS FURNACES

## GRATE FURNACE WITH SPREADER FEEDING SYSTEM



Source: Chungen Yin [2008] Progress in Energy

# PALM PELLETS CHARACTERISTICS

**Optimum biomass quality** is crucial to improve combustion efficiency and to avoid microbial degradation



**Palm Pellet**

**Moisture <10%**

**Ash <6%**

**CV> 4000kCal / kg**

**Bulk density >600 kg/m<sup>3</sup>**



**Palm Kernel Shell**

**Moisture ±25%**

**Iodine absorption number: 200mg/g**

**Ash ±3%**

**Fixed Carbon >80%**

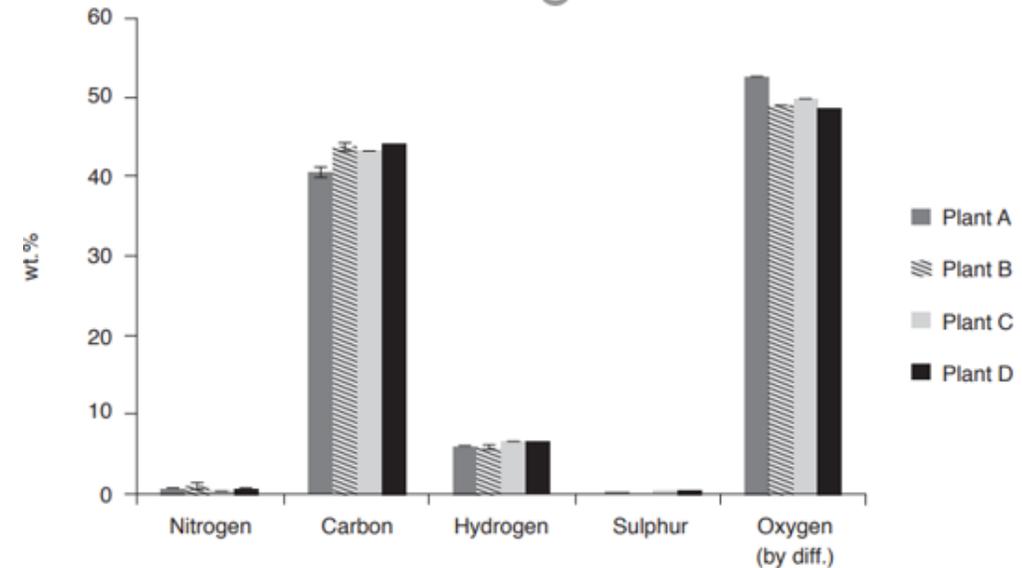
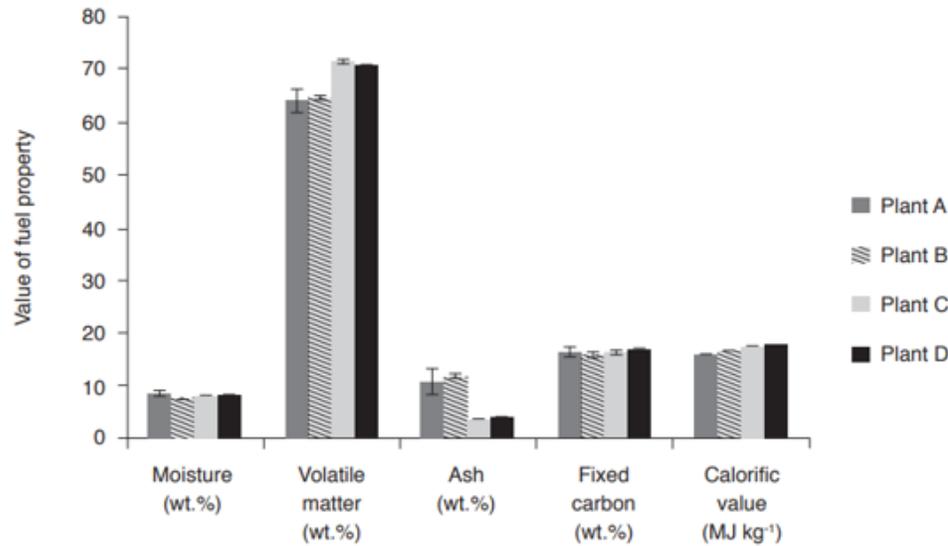
**CV>6500kCal/kg**

- **Compacted EFB** to reduce moisture , increase bulk and energy density and feedstock uniformity
- **Size reduction**
- **Acceptable size distribution and grindability**
- **Optimum biomass quality is crucial to improve combustion efficiency and to avoid microbial degradation**

# EFB PELLETS QUALITIES

PROPERTIES	STANDARD
Diameter and length	EN 14127
Calorific value	ASTM D5865
Proximate analysis	ASTM5142
Ultimate analysis	ASTM D5373
Elemental analyser	AAS,SEM EDX,
Specific density	ASTM D792-08
Bulk density	EN 1097-3
Durability	EN 14961-2

EFB PELLETS PROPERTIES(AVE)	STANDARD EN 1461-2 (wood-min spec)	ISO 17225-6 (non-wood)
Moisture (wt%)	≤10.0	≤10.0
Volatile Matter(wt%)	-	-
Ash(wt%)	≤0.3	≤10.0
Calculated Fixed Carbon(wt%)	-	-
Calorific Value(MJ/kg)	Min Value to be stated	≥16.0



Source: Nasrin et al (2017) Journal of Oil Palm Research

# ELEMENTAL COMPOSITIONS

Element (wt%)	EFB Pellet (Ave)	EN 14961-2 (Wood)	ISO-17225-6 (Non Wood)	Wood Pellet	
C	42.99 + 1.68	-	-	-	
H	6.19 + 0.36	-	-	-	
N	0.64+0.30	≤1.0	≤2.0	-	
S	0.08+0.06	≤0.05	≤0.05	-	
O	50.11+1.80	-	-		
P	0.09+0.03	-	-		
K	1.59+0.18	-	-	0.007+0.08	
Ca	0.43+0.15	-	-	0.11+0.14	
Mg	0.16+0.05	-	-	0.02+0.002	
Cl	0.6+0.3	≤0.03	≤0.5	0.004+0.005	

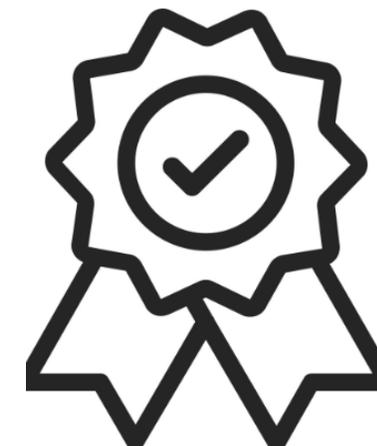
Source Chandrasekaran et al 2012

# SILICA COMPOSITIONS IN UNTREATED OPMF AND TREATED WITH SUPER HEATED STEAM TREATMENT

Sample	Treatment		
	Temp (+2degC)	Time (h)	Silica(ppm)
1	0	0	224.8
6	210	1	203.9
9	230	2	198.3
10	230	3	93.4



## Quality vs Cost





**Energizing Research, Enlivening Innovation**

# Case Study : Computational Modelling of Oil Palm Wastes Co-firing in a Utility Boiler Model

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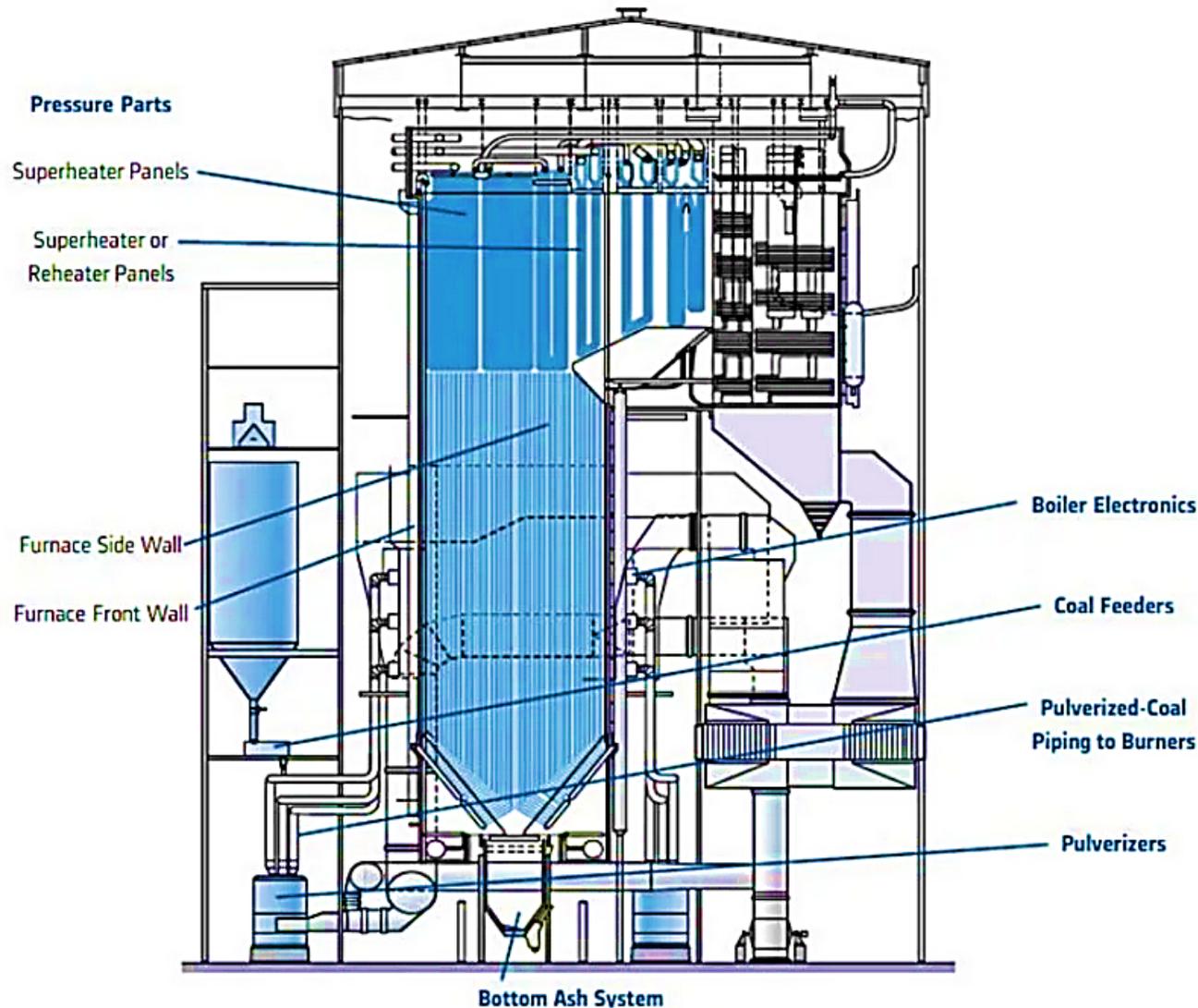
**Tn. Hj. Ismail Shariff**

Head  
(*Sr. Manager*)

Generation Unit

# Introduction of a coal-fired boiler

## Key design aspects



### → In-furnace blending (co-firing)

One or more **pulverisers** (mills) utilise **different** types of **fuel**

Different types of solid fuels **mix** and **burn** in the **furnace**

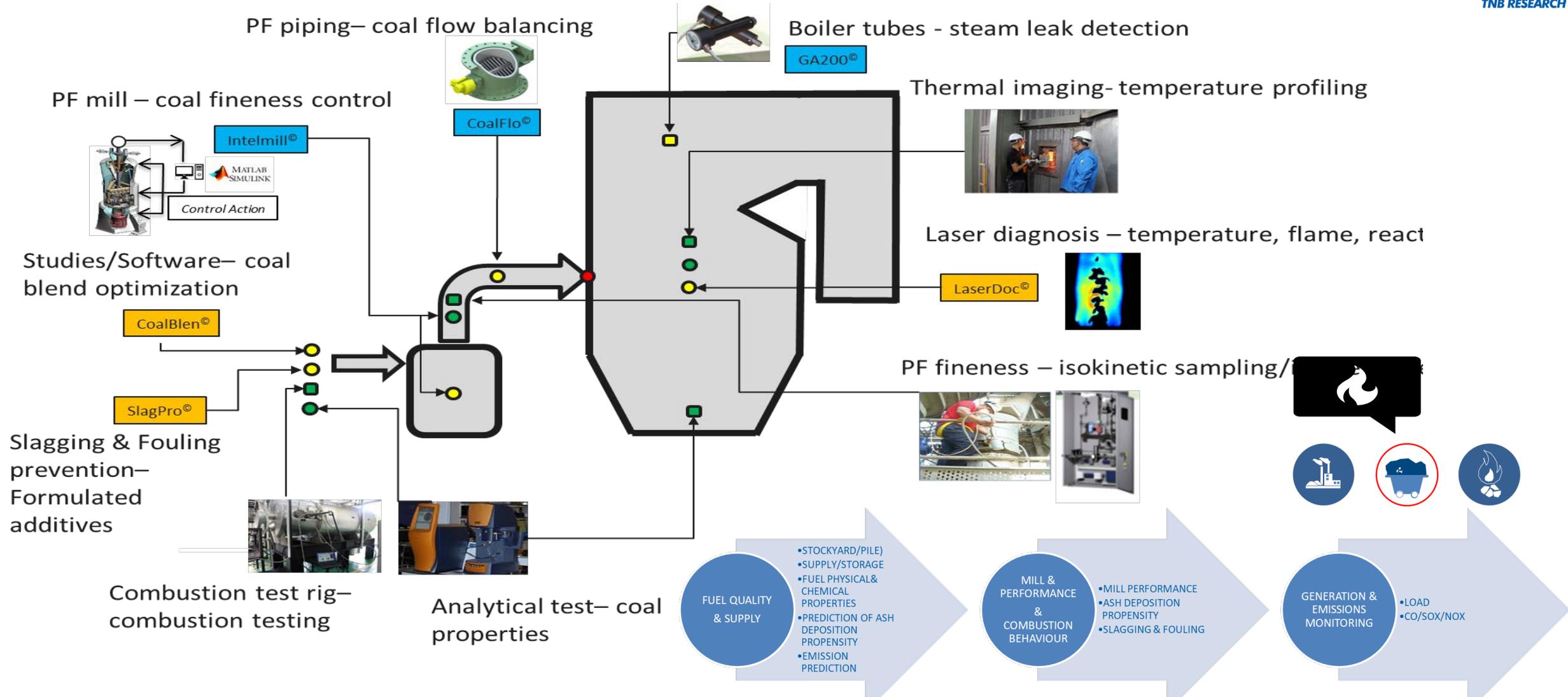
### Out-of-furnace blending

Different types of solid fuels are **blended** in **stockpiles/bins/conveyors**

In the furnace, **pre-mixed solid fuels** are burned

Source - <https://integratedglobal.com/industries/pulverized-coal-fired-boilers-2/>

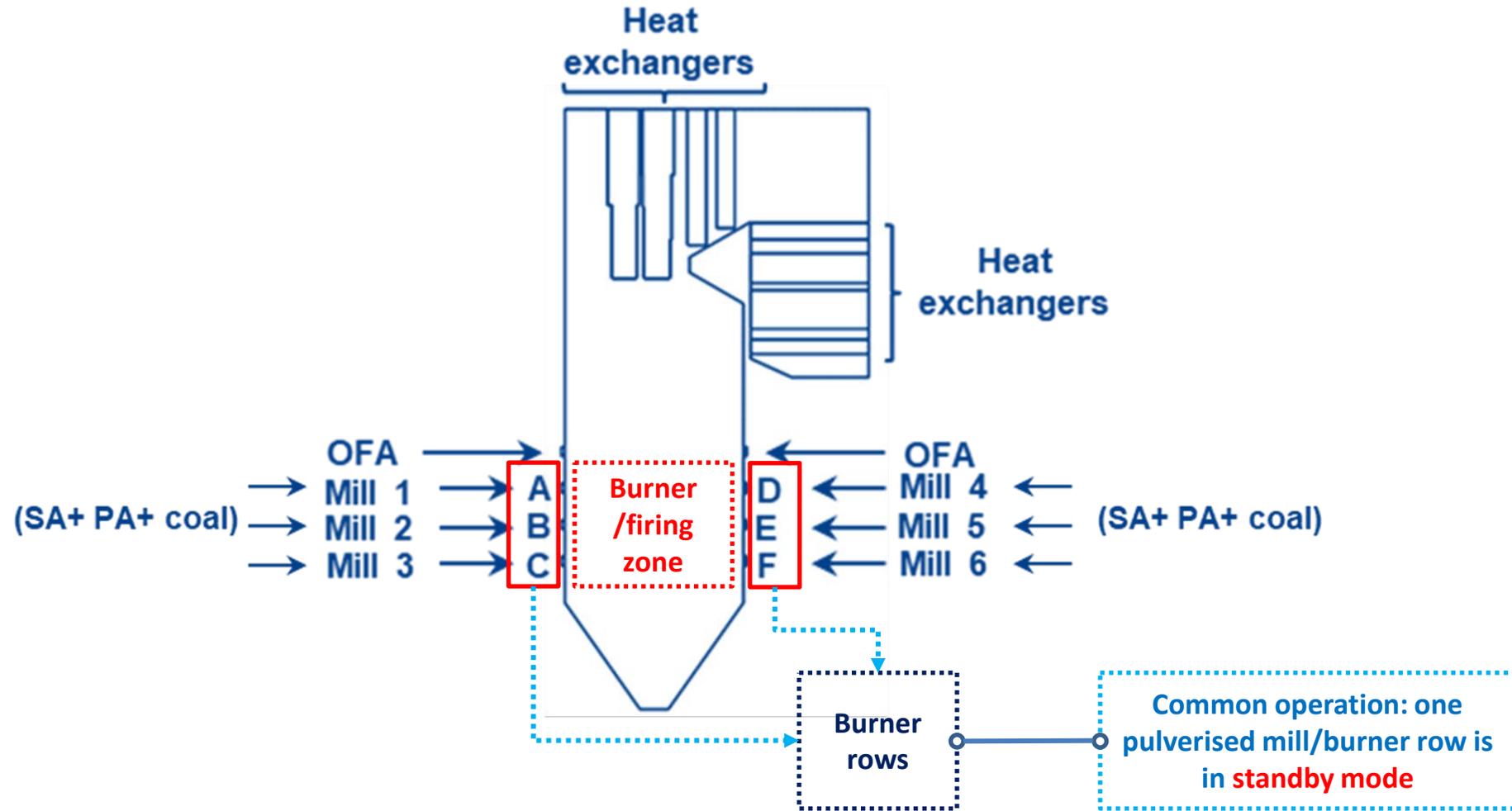
# What are the impact of biomass introduction in coal fired boilers?



Typically Biomass composition: C=43-51%, Hydrogen= (4-6%), Oxygen(34-48%) & Trace amount of N,S, and Cl, inorganic element e.g Ca, and Mg.(increase ash melting point), **K and P (lower Ash melting point)**

# Boiler Model

Overview of boiler model information (one of thermal power plants in Malaysia)



OFA: Over-fire air  
SA: Secondary air  
PA: Primary air

# Characterisation of Coal and Oil Palm Wastes

EFB: Empty fruit bunches, PKS: Palm kernel shell, and PMF: Palm mesocarp fibres

Fuel	Proximate analysis, wt. %, db. (VM-Volatile matter, FC-Fixed carbon, <b>AC-Ash content</b> )			Ultimate analysis, wt. %, db. (C-Carbon, H-Hydrogen, N-Nitrogen, O-Oxygen, S-Sulphur)					GCV- Gross Calorific Value, db. (kcal/kg)
	VM	FC	AC	C	H	N	O	S	
Coal (bit)	25.39	59.49	15.08	73.68	4.53	1.65	4.57	0.50	6678
EFB	78.46	17.28	4.26	44.07	5.52	0.41	45.73	0.46	5067
PKS	80.86	16.77	2.37	49.13	5.42	0.48	42.45	0.41	4852
PMF	79.75	14.85	5.40	45.51	5.03	0.54	43.61	0.42	4876

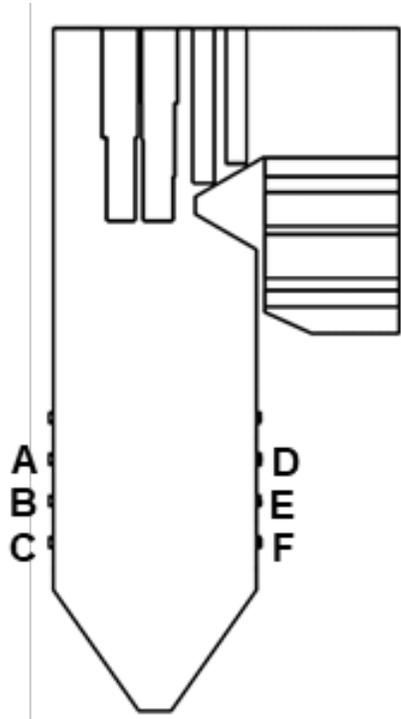
GCV: Gross Calorific Value  
db: Dry-basis  
bit: bituminous

Low risk of slagging & fouling (ash deposition in the utility boiler).

Lower than the **fuel rejection limit** of the coal-fired power plant.

# Simulation cases (co-firing)

EFB: Empty fruit bunches, PKS: Palm kernel shell, and PMF: Palm Mesocarp Fibres



Case	Fuel type for the burner row						Capacity (MW)
	A (20 cal.%)	B (20 cal.%)	C (20 cal.%)	D	E (20 cal.%)	F (20 cal.%)	
Baseline	Coal (bit)	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	500
B1-EFB	EFB	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	
B2-PKS	PKS	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	
B3-PMF	PMF	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	

Important assumption in the computational assessment:

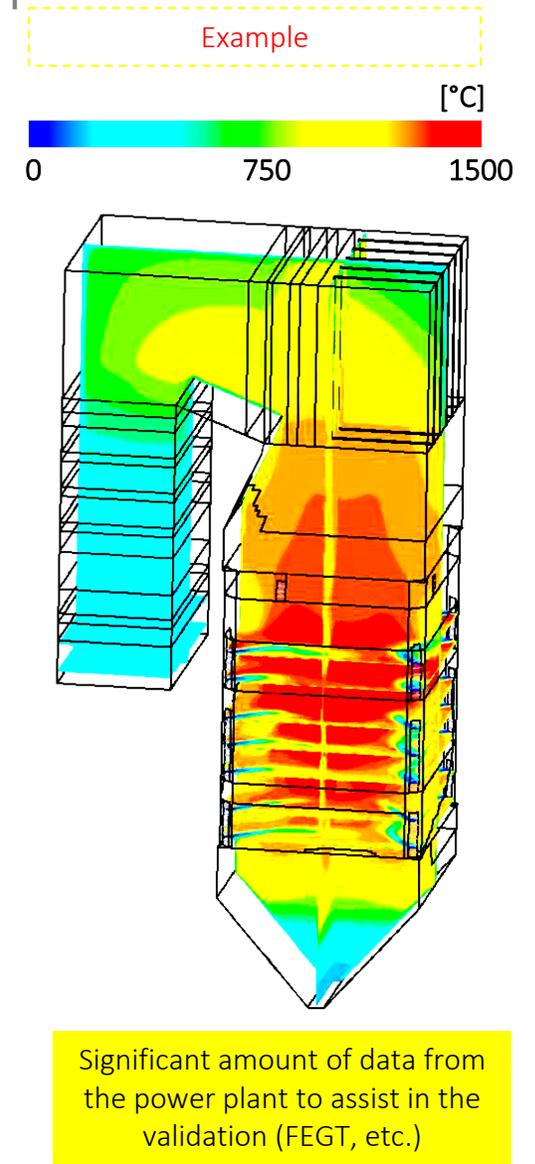
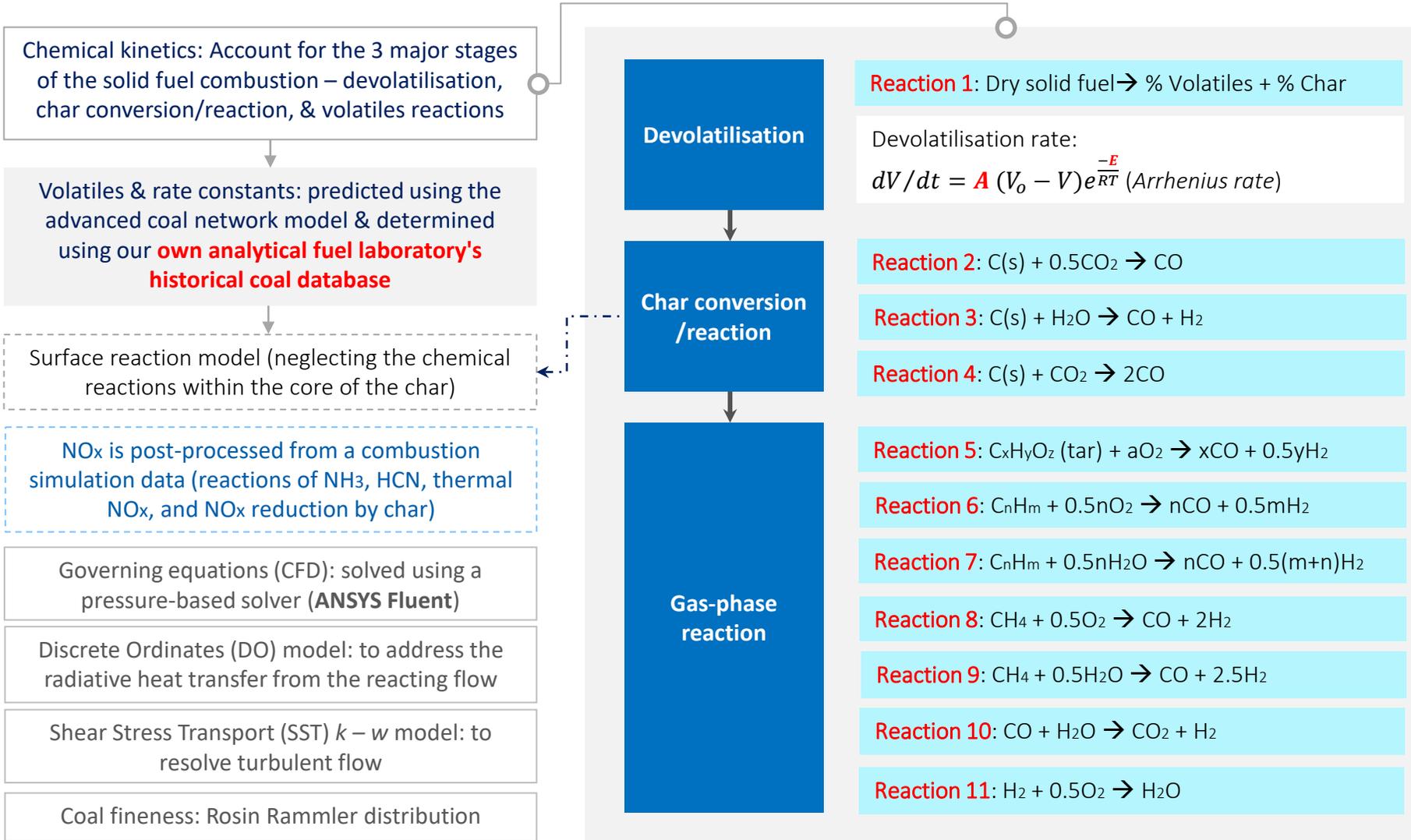
**The fineness of OPWs is assumed to be in the range of 75 μm, as required by the power plant.**

(i) Average **38t/hr per mill of coal**  
 Assume 5 mills (one standby)= 190tonne/hr.  
 For a day= 190 t/hr \*24 = **4560 t ( Single Coal)**

(ii) Say for **20 cal% OPWs**: 80 cal % coal, need approx. 41t/hr for OPWs  
 Thus In a day 24\*41 t/hr= **984 t OPWs**

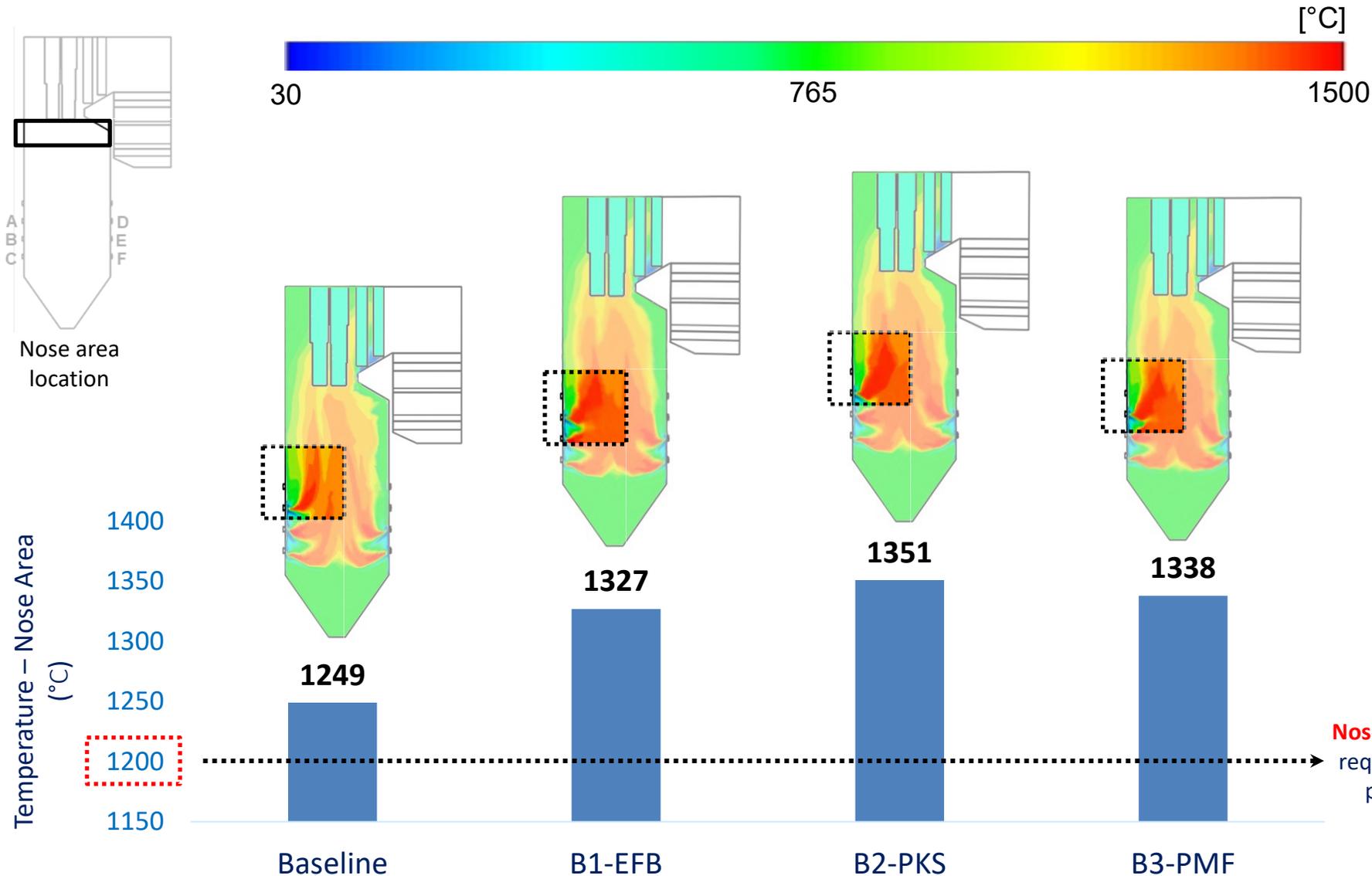
# Numerical setup

TNB Research's validated solid fuel combustion models (overview): Enable combustion optimization and identifying operational limitations



# Results and Discussion

Predicted temperature



This utility boiler has been designed to burn **bituminous coal** (low VM).

OPWs with a **high VM** generate **larger combustion zones** in the furnace [Aziz2016].

To **avoid slagging** and **fouling**, the nose area temperature must not **exceed** the initial deformation temperature (**IDT**) of the **fuel blends**.

Proposed to co-fire OPWs in a **boiler** designed to burn **sub-bituminous coal** (higher VM).

Nose area temperature required by the power plant understudy

# Results and Discussion

## Predicted unburned carbon (UBC)

**Excessive UBC** in fly ash is **undesirable** from the **standpoint** of **power plant** operation. It represents a noticeable **fuel loss**, **lowering** overall **plant efficiency**.

The **concrete** industry is the **largest market** for **fly ash** (additive for cement). According to **ASTM standard 618**, one of the criteria for such an application is that the UBC or **LOI limit** must be **<6%**.

Power plant places a lot of importance on **UBC amount** because it **affects** their **profits** – UBC levels above the LOI limit **reduced plant efficiency**, and **fly ash could not** be **sold** to the **concrete** industry.

Case	UBC from CFD (%)	UBC limit from the power plant (%)
Baseline	<b>3.52</b>	
B1-EFB	<b>2.03 (↓)</b>	<b>&lt; 6%</b>
B2-PKS	<b>1.97 (↓)</b>	
B3-PMF	<b>1.94 (↓)</b>	

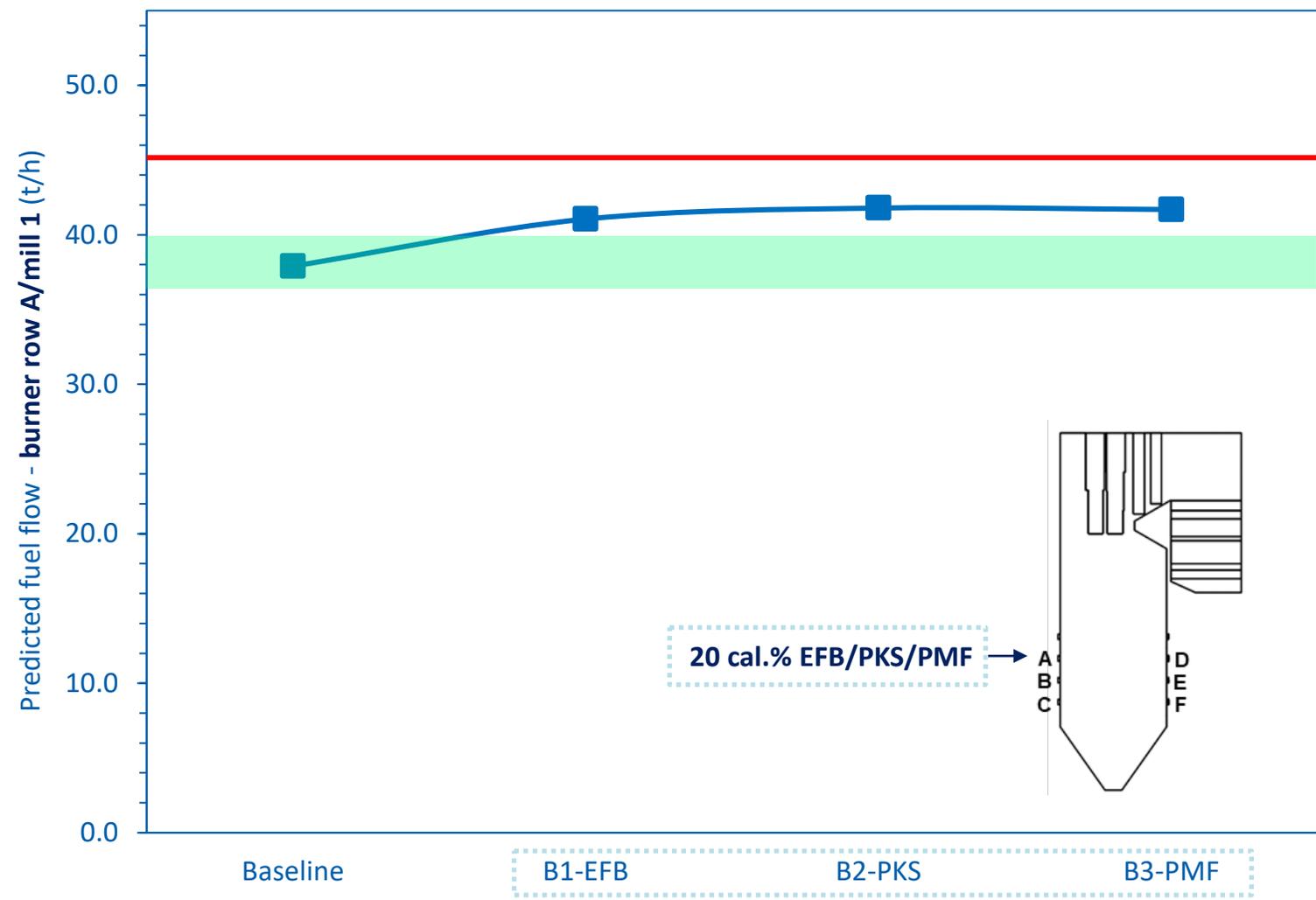
**UBC levels** are **reduced** when **co-firing** with **OPWs** because the OPWs-coal blends contain less FC than the pure coal blend.

$$\text{UBC from CFD}(\%) = \frac{\text{Unburned char at the boiler outlet}}{\text{Char (FC) content of the fuel blend from the proximate analysis}}$$

**LOI: loss on ignition** – Indicator to determine the permitted concentration range of UBC in fly ash based on the national standard.

# Results and Discussion

## OPWs fuel flow and mill capacity



**Maximum fuel flow per mill** (burner row A)

**Normal operation** from the power plant understudy (burner row A)

The **fuel flow** of **OPWs** needed to **maintain** the **heat content** of the fuel blend and **achieve** the required **load/power** from the **boiler**.

- 20 cal.% OPWs: Injected into burner **row A** (mill 1).
- Lower calorific values of OPWs: **Slightly higher flowrate** is needed to maintain the heat content of the fuel blend & achieve the required load/power from the boiler.
- Predicted flowrate for OPWs:
  - **Exceeded** the **normal operation** (37 to 40 t/h).
  - **Lower** than the **maximum fuel flow** per mill.

# Results and Discussion

Predicted carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), and nitrogen oxides (NO<sub>x</sub>)

Case	CO from CFD (mg/m <sup>3</sup> )	CO limit from the power plant (mg/m <sup>3</sup> )
Baseline	<b>197.35</b>	<b>&lt; 200</b>
B1-EFB	<b>149.41 (↓)</b>	
B2-PKS	<b>147.86 (↓)</b>	
B3-PMF	<b>147.11 (↓)</b>	

Case	CO <sub>2</sub> from CFD (%)	CO <sub>2</sub> limit from the power plant (%)
Baseline	<b>14.05</b>	<b>N/A</b>
B1-EFB	<b>9.53 (↓)</b>	
B2-PKS	<b>8.82 (↓)</b>	
B3-PMF	<b>8.45 (↓)</b>	

Case	NO <sub>x</sub> from CFD (mg/m <sup>3</sup> )	NO <sub>x</sub> limit from the power plant (mg/m <sup>3</sup> )
Baseline	<b>574</b>	<b>&lt; 600</b>
B1-EFB	<b>671 (↑)</b>	
B2-PKS	<b>695 (↑)</b>	
B3-PMF	<b>673 (↑)</b>	

**OPWs** have **lower FC** than coal, resulting in **lower CO and CO<sub>2</sub> emissions** when coal is co-fired with POWs.

Although **OPWs** contain **less N** than the **baseline coal**, **OPW co-firing cases** are observed to produce **more NO<sub>x</sub>** than the baseline coal case due to the **higher flame temperature generated, longer residence time** results in an **increase in thermal NO<sub>x</sub> - Zeldovich mechanism** [Aziz2016].

The detailed ash composition is unknown, for the combined ash in the fuel, thus the influence of ash composition on the NO<sub>x</sub> formation is not considered in the computational assessment.



***Energizing Research, Enlivening Innovation***

# Computational Modelling of Agricultural Wastes Co-firing in a Utility Boiler Model

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# Characterisation of Coal and Agricultural Wastes (AWs)

←————— AWs —————→

Codename	AW1	AW2	AW3	AW4	AW5	AW6
	SAGO BIOMASS	SB Hydrochar MW 200	SB Hydrochar MW 250	SB Hydrochar CONV 200	SB Hydrochar CONV 250	SB Hydrochar CONV 300
Moisture	13.88	10.00	9.58	9.48	6.90	13.00
VM <sup>a</sup>	74.58	66.90	63.00	76.40	79.40	65.80
Ash <sup>a</sup>	3.64	1.00	1.00	1.20	2.40	1.00
FC <sup>ac</sup>	7.90	22.10	26.42	12.92	11.30	20.20
Carbon <sup>b</sup>	37.60	52.94	48.70	45.82	47.06	47.00
Hydrogen <sup>b</sup>	6.67	4.13	5.92	5.42	5.01	3.21
Nitrogen <sup>b</sup>	0.00	1.00	0.60	0.85	0.55	0.91
Sulfur <sup>b</sup>	0.00	0.00	0.00	0.00	0.00	0.00
Oxygen <sup>c</sup>	55.73	41.93	55.22	47.91	47.33	48.88

<sup>a</sup>Results expressed as a percentage of dry matter  
<sup>b</sup>Results expressed as a percentage of dry matter free of ashes  
<sup>c</sup>Calculated by difference  
 MW: Microwave MARS; CONV: Conventional Heating  
 C: Carbon; H: Hidrogen; N: Nitrogen; O: Oxygen; S: Sulfur

## Characterisation of Coal and Palm Oil Wastes (POWs)

EFB: Empty fruit bunches, PKS: Palm kernel shell, and PMF: Palm mesocarp fibres

Fuel	Proximate analysis, wt. %, db.			Ultimate analysis, wt. %, db.					GCV: Gross Calorific Value, db. (kcal/kg)
	VM	FC	AC	C	H	N	O	S	
Coal (bit)	25.39	59.49	15.08	73.68	4.53	1.65	4.57	0.50	6678
EFB	78.46	17.28	4.26	44.07	5.52	0.41	45.73	0.46	5067
PKS	80.86	16.77	2.37	49.13	5.42	0.48	42.45	0.41	4852
PMF	79.75	14.85	5.40	45.51	5.03	0.54	43.61	0.42	4876

GCV: Gross Calorific Value  
 db: Dry-basis  
 bit: bituminous

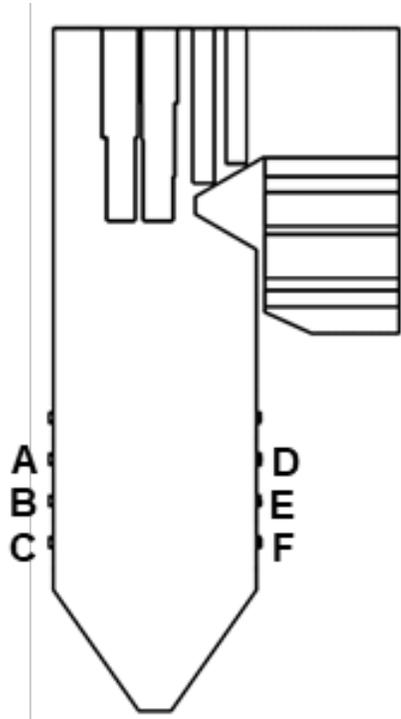
Low risk of slagging & fouling (ash deposition in the utility boiler).  
 Lower than the fuel rejection limit of the coal-fired power plant.

**Low risk of slagging & fouling (ash deposition in the utility boiler).**

**Lower than the fuel rejection limit of the coal-fired power plant.**

Coal: Bituminous (bit) coal (FC:59.49, VM: 23.58, Carbon: 73.68), db (dry basis)

# Simulation cases (co-firing)



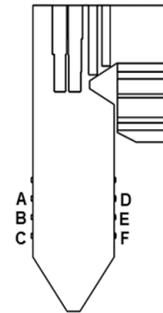
Case	Fuel type for the burner row						Capacity (MW)
	A (20 cal.%)	B (20 cal.%)	C (20 cal.%)	D	E (20 cal.%)	F (20 cal.%)	
Coal-AWs co-firing	AW	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	500

Important assumption in the computational assessment:

The fineness of AWs is assumed to be in the range of 75  $\mu\text{m}$ , as required by the power plant.

## Simulation cases (co-firing)

EFB: Empty fruit bunches, PKS: Palm kernel shell, and PMF: Palm mesocarp fibres



Case	Fuel type for the burner row						Capacity (MW)
	A (20 cal.%)	B (20 cal.%)	C (20 cal.%)	D	E (20 cal.%)	F (20 cal.%)	
Baseline	Coal (bit)	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	500
B1-EFB	EFB	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	
B2-PKS	PKS	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	
B3-PMF	PMF	Coal (bit)	Coal (bit)	Standby	Coal (bit)	Coal (bit)	

Important assumption in the computational assessment:

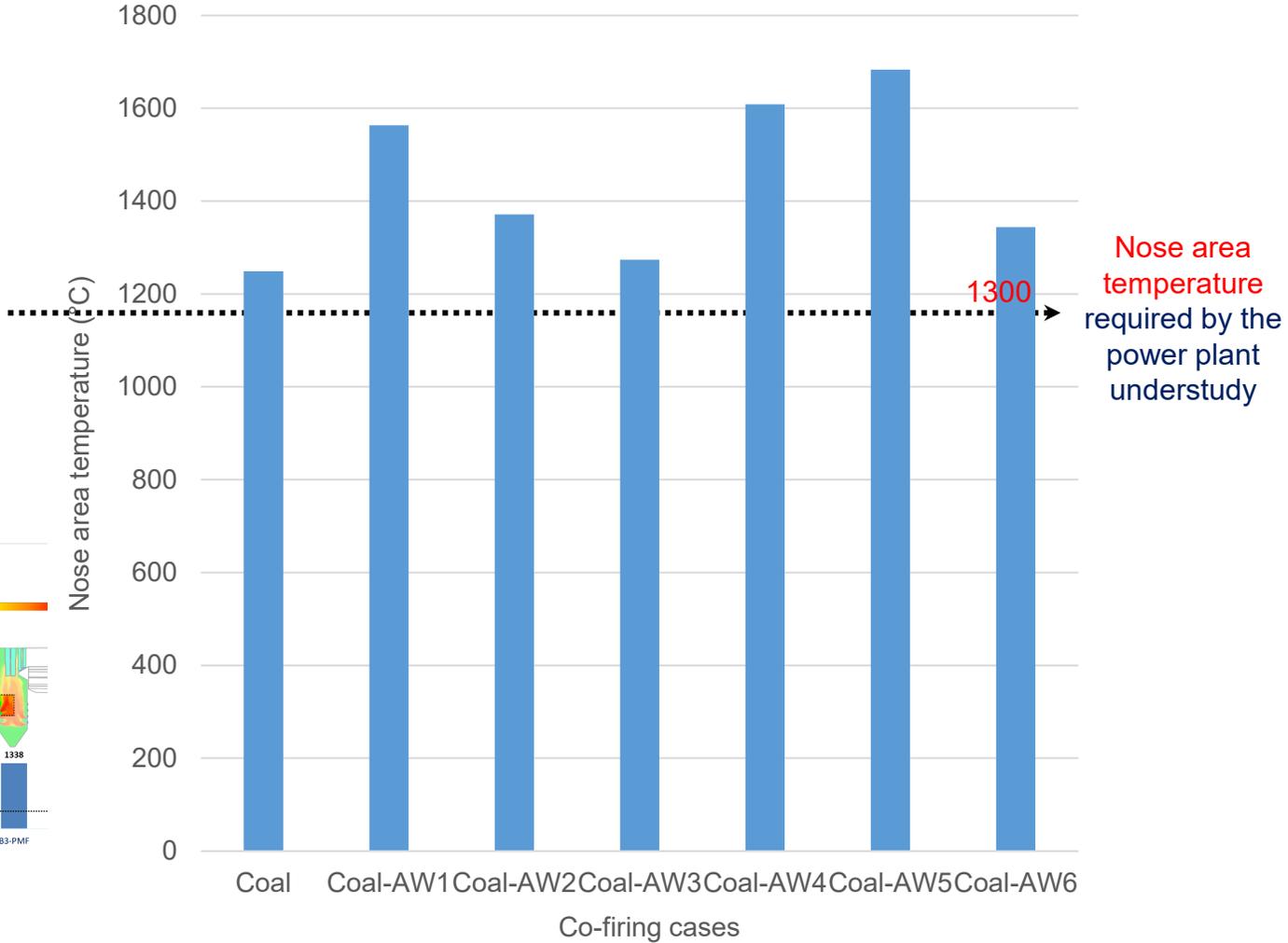
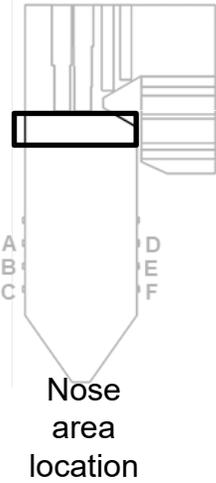
The fineness of POWs is assumed to be in the range of 75  $\mu\text{m}$ , as required by the power plant.

(i) Average 38t/hr per mill of coal  
Assume 5 mills (one standby)= 190tonne/hr.  
For a day= 190 t/hr \* 24 = 4560 t/hr ( Single Coal)

(ii) Say for 20 cal% POWs: 80 cal % coal, need approx. 41t/hr for POWs  
Thus in a day 24\*4 t/hr= 984 t POWs

# Results and Discussion

- Predicted temperature

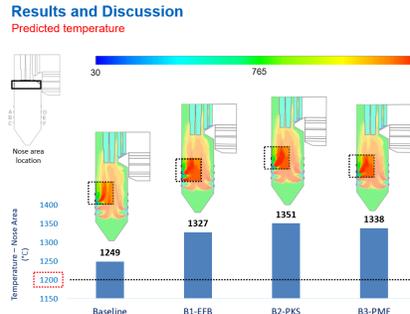


This utility boiler has been designed to burn bituminous coal (low VM).

AWs with a high VM generate larger combustion zones in the furnace [Aziz2016].

To avoid slagging and fouling, the nose area temperature must not exceed the initial deformation temperature (IDT) of the fuel blends.

Proposed to co-fire AWs in a boiler designed to burn sub-bituminous coal (higher VM).



# Results and Discussion

- Predicted unburned carbon (UBC)

**Excessive UBC** in fly ash is **undesirable** from the **standpoint** of **power plant** operation. It represents a noticeable **fuel loss**, **lowering** overall **plant efficiency**.

The **concrete** industry is the **largest market** for **fly ash** (additive for cement). According to **ASTM standard 618**, one of the criteria for such an application is that the UBC or **LOI limit** must be **<6%**.

Power plant places a lot of importance on **UBC amount** because it **affects** their **profits** – UBC levels above the LOI limit **reduced plant efficiency**, and **fly ash could not** be **sold** to the **concrete** industry.

Case	UBC from CFD (%)	UBC limit from the power plant (%)
Coal	<b>3.52</b>	
Coal-AW1	<b>2.07</b>	
Coal-AW2	<b>2.83</b>	
Coal-AW3	<b>2.58</b>	<b>&lt; 6%</b>
Coal-AW4	<b>2.41</b>	
Coal-AW5	<b>2.48</b>	
Coal-AW6	<b>2.48</b>	

**UBC levels** are **reduced** when **co-firing** with **AWs** because AWs-coal blends contain less FC than the pure coal blend.

$$\text{UBC from CFD (\%)} = \frac{\text{Unburned char at the boiler outlet}}{\text{Char (FC) content of the fuel blend from the proximate analysis}}$$

Case	UBC from CFD (%)	UBC limit from the power plant (%)
Baseline	<b>3.52</b>	
B1-EFB	<b>2.03 (↓)</b>	
B2-PKS	<b>1.97 (↓)</b>	<b>&lt; 6%</b>
B3-PMF	<b>1.94 (↓)</b>	

**LOI: loss on ignition** – Indicator to determine the permitted concentration range of UBC in fly ash based on the national standard.

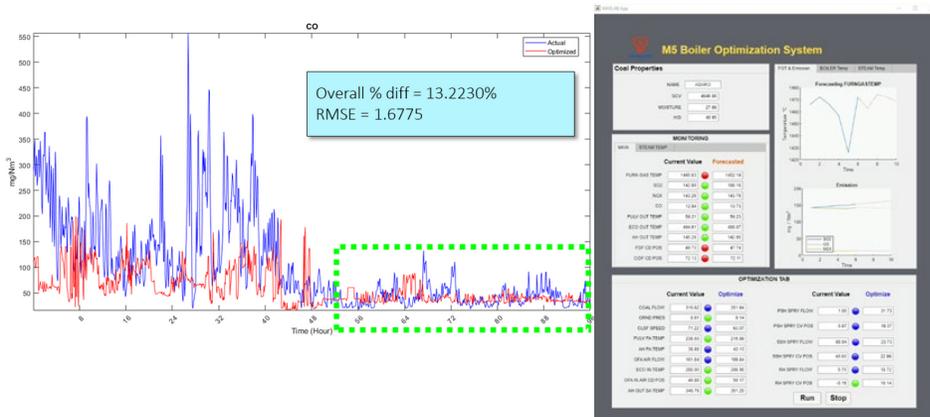
**LOI: loss on ignition** – Indicator to determine the permitted concentration range of UBC in fly ash based on the national standard.

# Conclusions and Recommendations

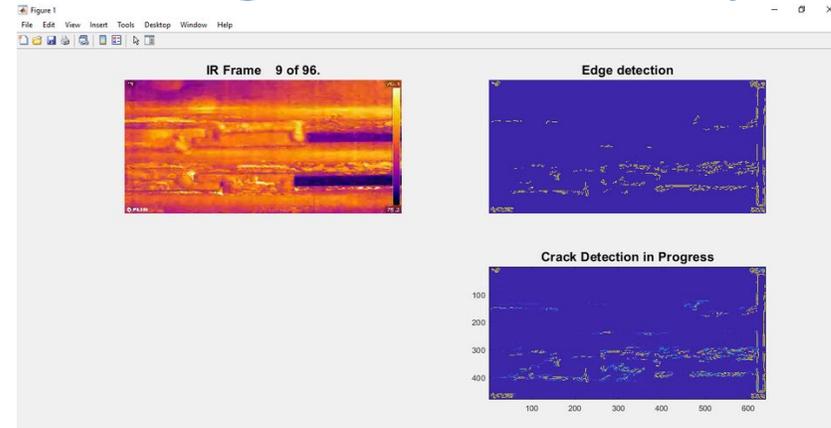
- Based on the CFD data

Parameter	Result	Recommendation	Impact
Slagging and fouling propensity	<b>Low</b> (low ash content of AWs)	N/A	N/A
Combustion temperature	<b>High</b> (higher flame temperature from AW co-firing cases – higher VM)	<ul style="list-style-type: none"><li>Proposed to co-fire AWs in a boiler designed to burn sub-bituminous coal (higher VM).</li></ul>	
UBC levels	<b>Low</b> (low FC content of AWs)	N/A	N/A

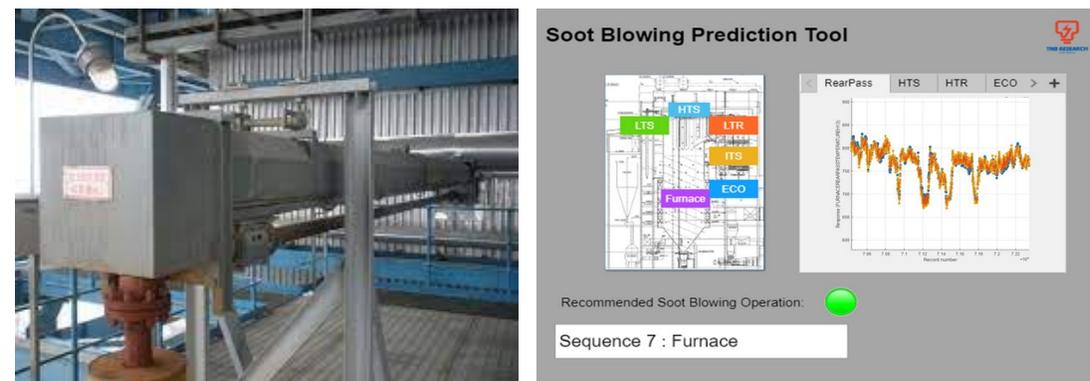
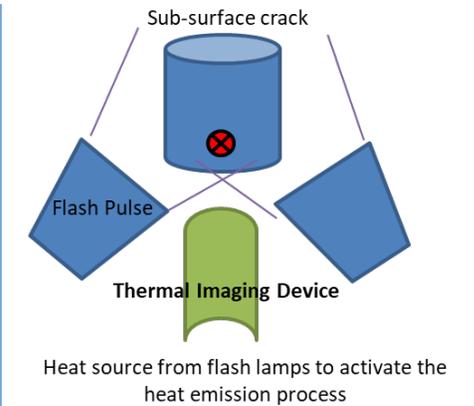
# Other Innovative Tools: Artificial Intelligence, Machine Learning & Data Analytics



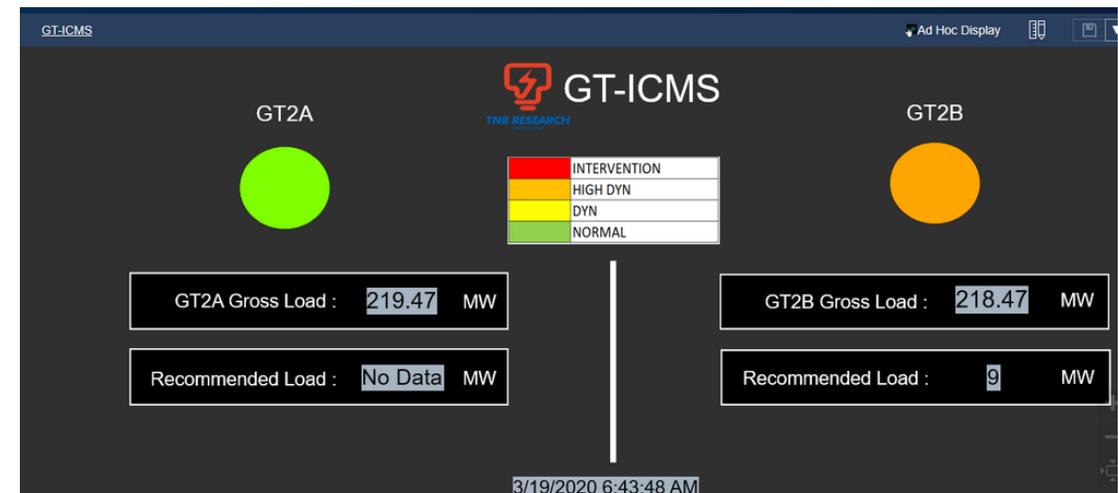
Combustion performance monitoring, prediction and optimization tool



Crack Detection System with Smart Algorithm

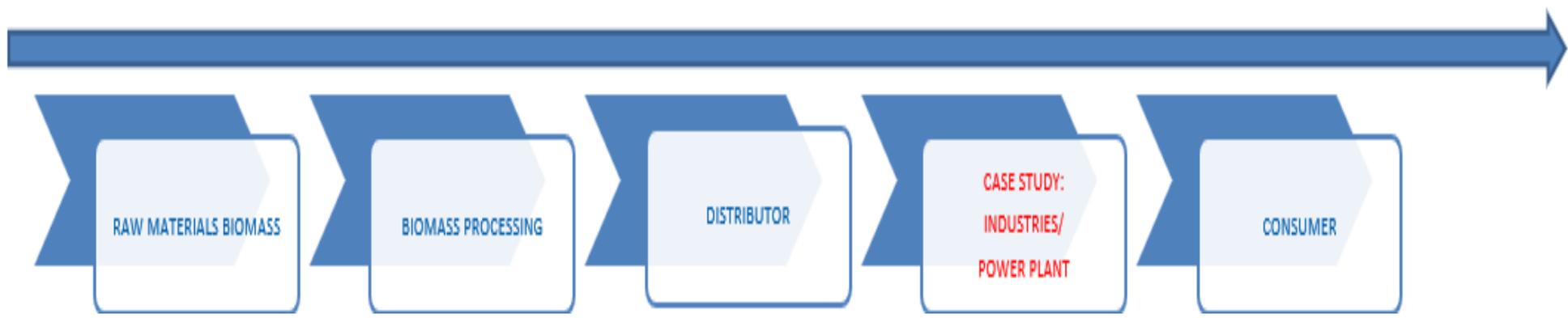


Soot blowing optimization tool



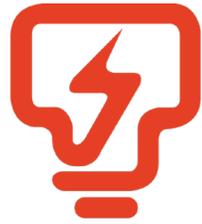
Anomaly Detection of Gas Turbine with Machine Learning

# CONCLUSION



Source: <https://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry/principles/12-principles-of-green-chemistry.html>

Source : <http://www.un.org/sustainabledevelopment/sustainable-development-goals/>

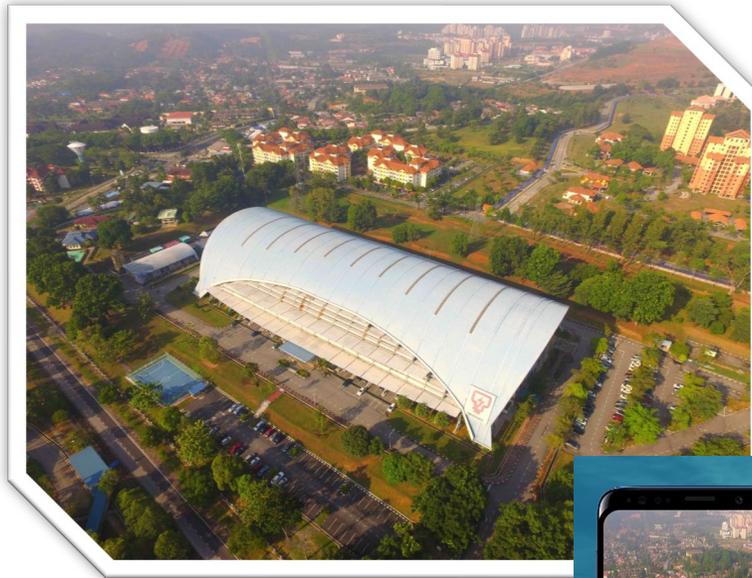


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# Thank You

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