TNB RESEARCH

Innovate With The End In Mind

2017 IERE-TNB PUTRAJAYA WORKSHOP
"Technologies reshaping the electricity supply industries"

Enhancement of Post-combustion Carbon Capture via Adsorption Technology

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21st November 2017

Overview

1	TNB Research
2	Scenario of power generation and CO2 emission in Malaysia
3	Approaches in reducing CO2 emission
4	TNBR program on CCU
5	Research project
6	Research findings
7	Way forward

TNB Research

TNBR is streamlining the aspiration, values and enablers to align with TNB Re-Imagining

- One of the leading & largest R&D company in Malaysia
- Subsidiary of TNB since 1993
- Non-profit driven centre for electricity and environmental research
- Specialize in energy & environmental sector

Awarded R&D Status by MIDA since 1997

Collaboration to obtain governmental incentives

OUR PEOPLE

Technical Expert : 8
Doctorate : 11
Researchers : 84
TNBR QATS: 80

OUR SERVICES

Applied Research

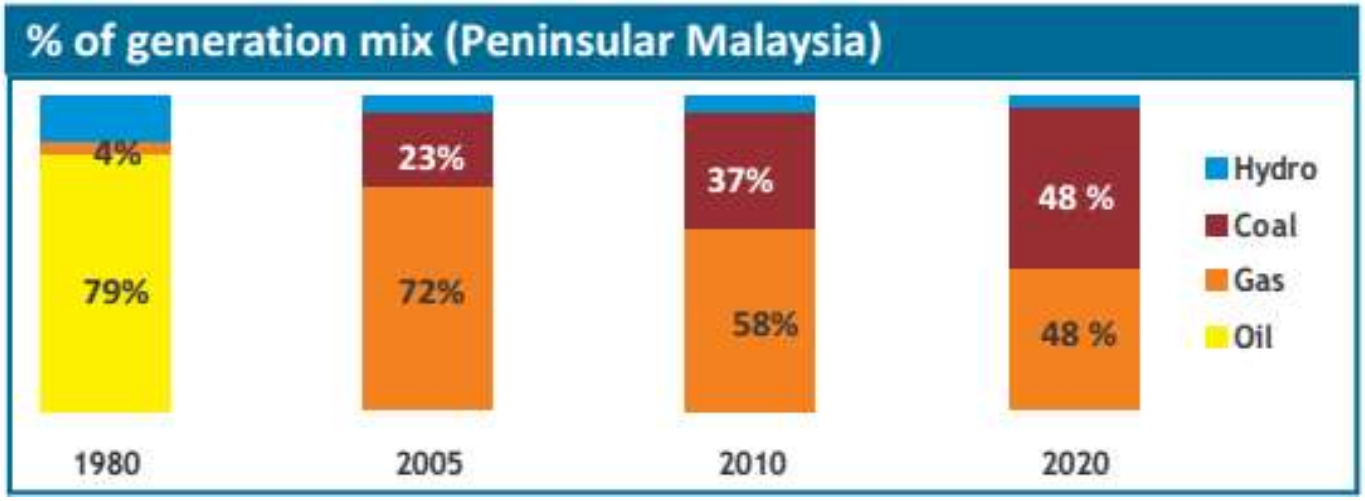
- Power Delivery
- Power Generation
- Environmental Management
- Strategic Research

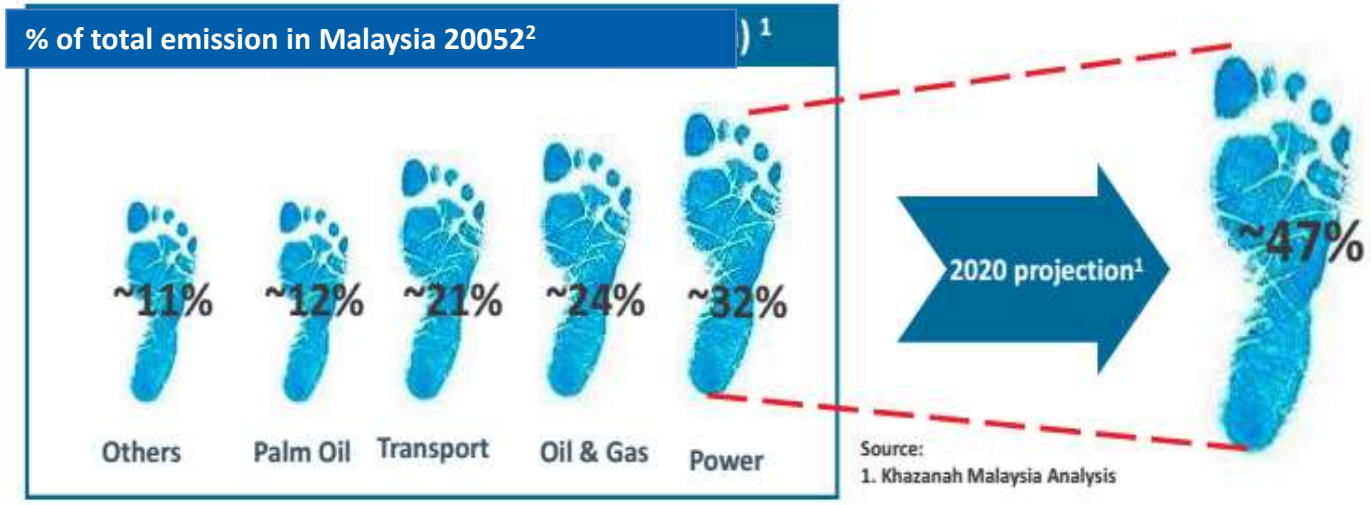
Advanced Research

- Low Carbon Power Generation Technology
- Emission & Waste Management Technology
- Smart Grid Technology
- Green Energy Technology

Scenario of power generation and CO_2 emission in Malaysia

In COP 21, Paris 2015, Malaysia has committed to reduce greenhouse gas emissions intensity by 45% by 2030.Utility sector can become an easy target for any future directives on CO2



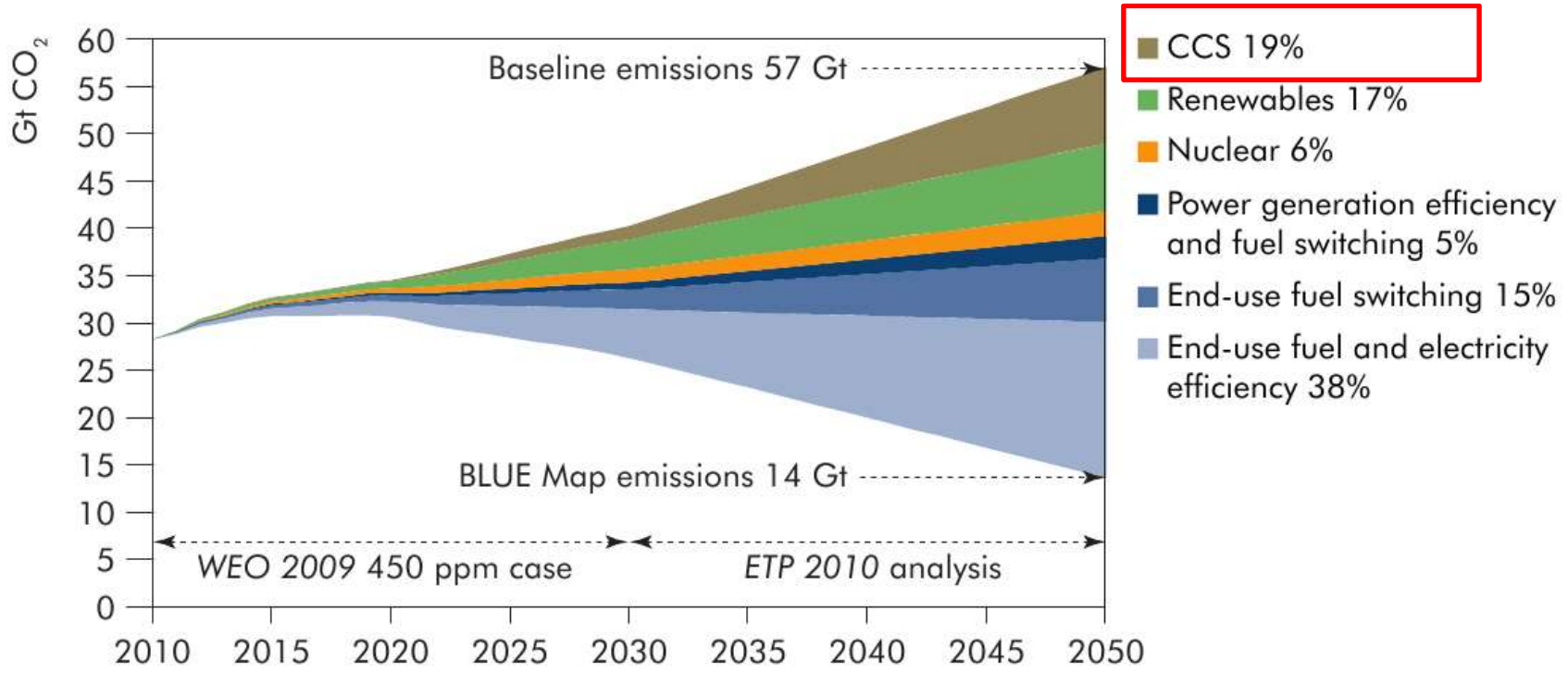


Source:

- [1]Peninsular Malaysia Electricity Supply Industry Outlook, 2013.
- [2] Khazanah Malaysia Analysis.

Approaches in reducing CO_2 emission

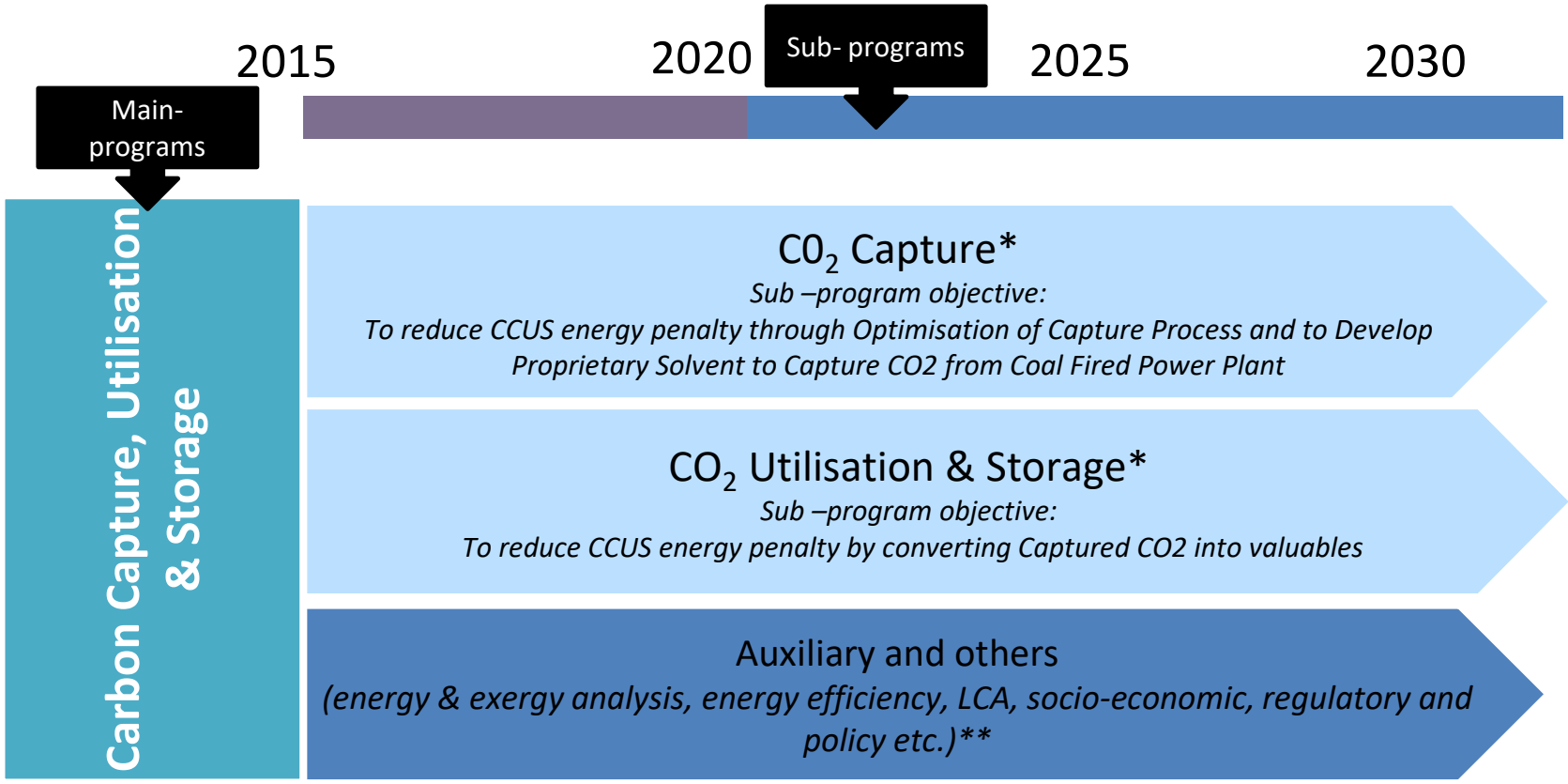
Lowest cost pathways in reducing CO2 emission→CCUS contributes 19% of total CO2 emission reductions required by 2050, against a business-as-usual scenario



Source:
IEA, Energy Technology Policy , 2010.

TNBR program on CCU

Program Objective: To develop an Integrated Carbon Capture , Utilization and Storage pilot plant and to position TNBR as referral on national CCUS Research and Development.

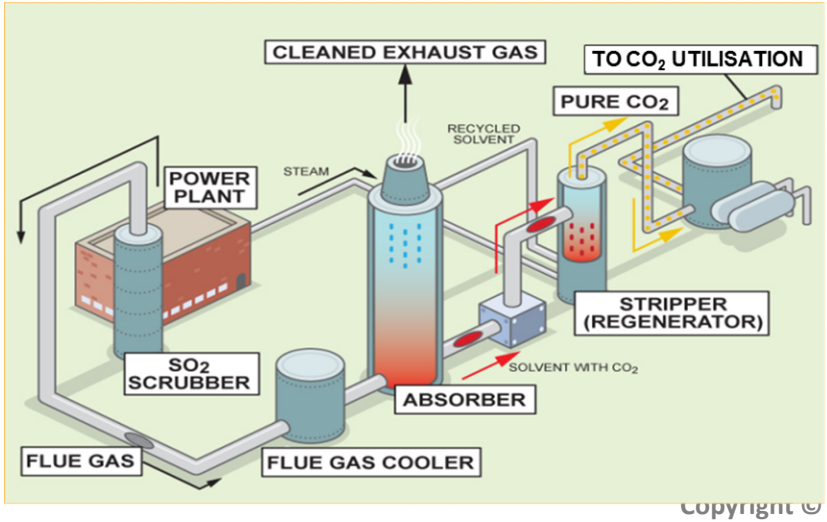


* TNBR main focus on the CCUS will be on CO2 Capture and CO2 Utilisation.

** TNBR will be part of the team member in joint collaboration with other RI and Universities on research in auxiliary and other technologies to support our main sub-program.

TNBR program on CCU

Concept of TNBR CCU approach – CO_2 from thermal power plant flue gas is separated from other gases. The gas is concentrated for further use.



Existing Power Plant

Energy & Exergy Analysis and Process Optimization

Coal fired power plant

Steam/ Excess heat

Excess heat recovery

Recovery technology

Flue gas

Retrofit Power Plant with CO_2 Capture

Integrated CO_2 Capture

Flue gas pretreatment

Absorption/ Adsorption

Regeneration

Steam/ Excess heat

Integrate CO2 Capture with CO2 Utilisation

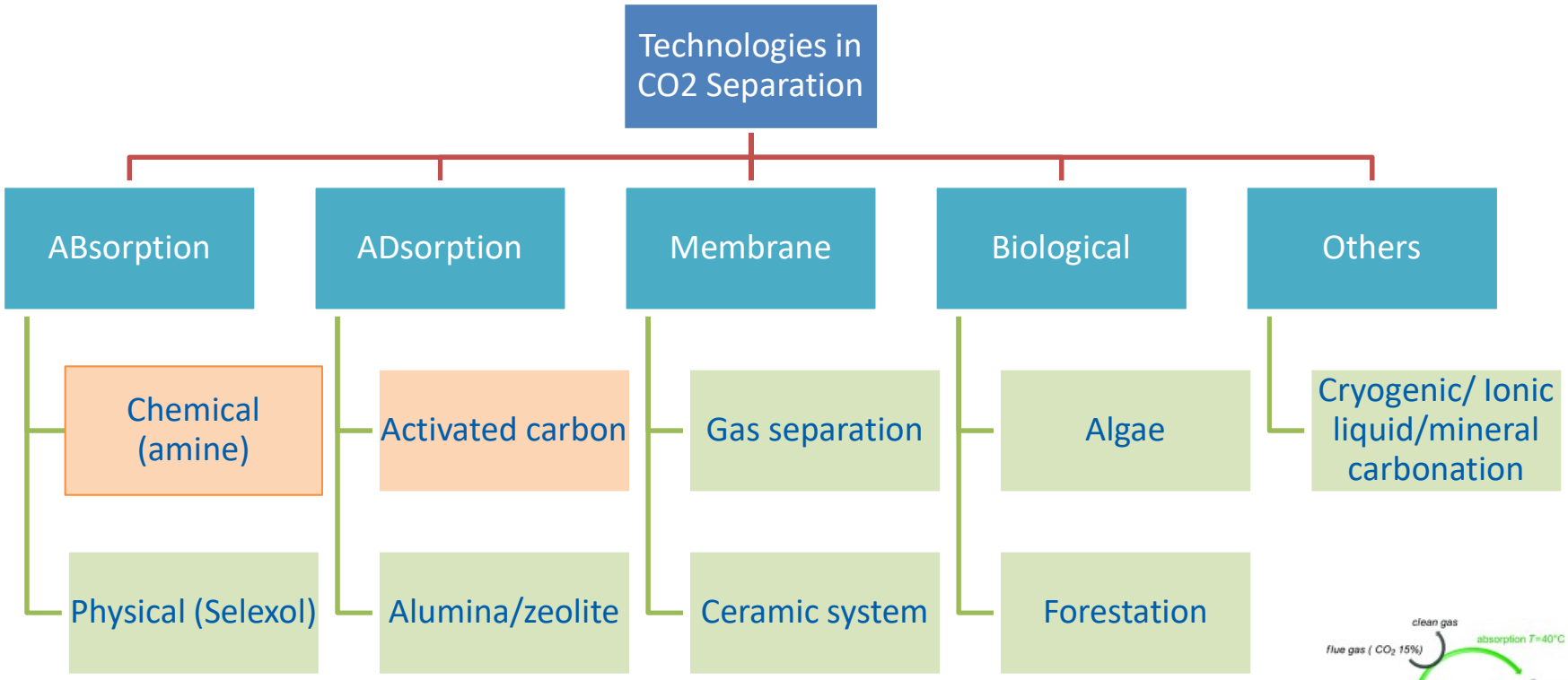
CO2 Utilization

1. Methanation
2. Microalgae Growth

CO_2

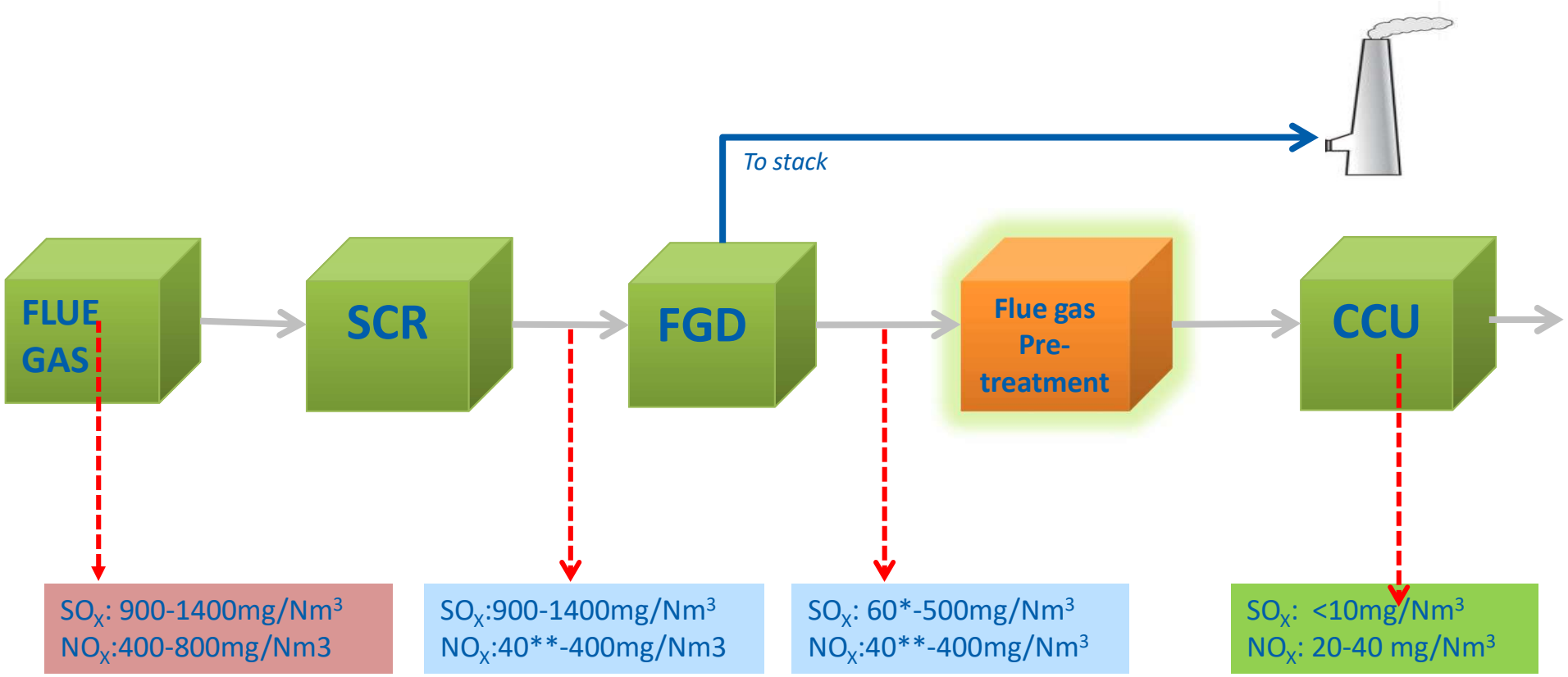
CO_2 Capture Technology

The two most dominant technologies for CO2 capture/separation for power industries are Absorption and Adsorption technologies.



Motivation

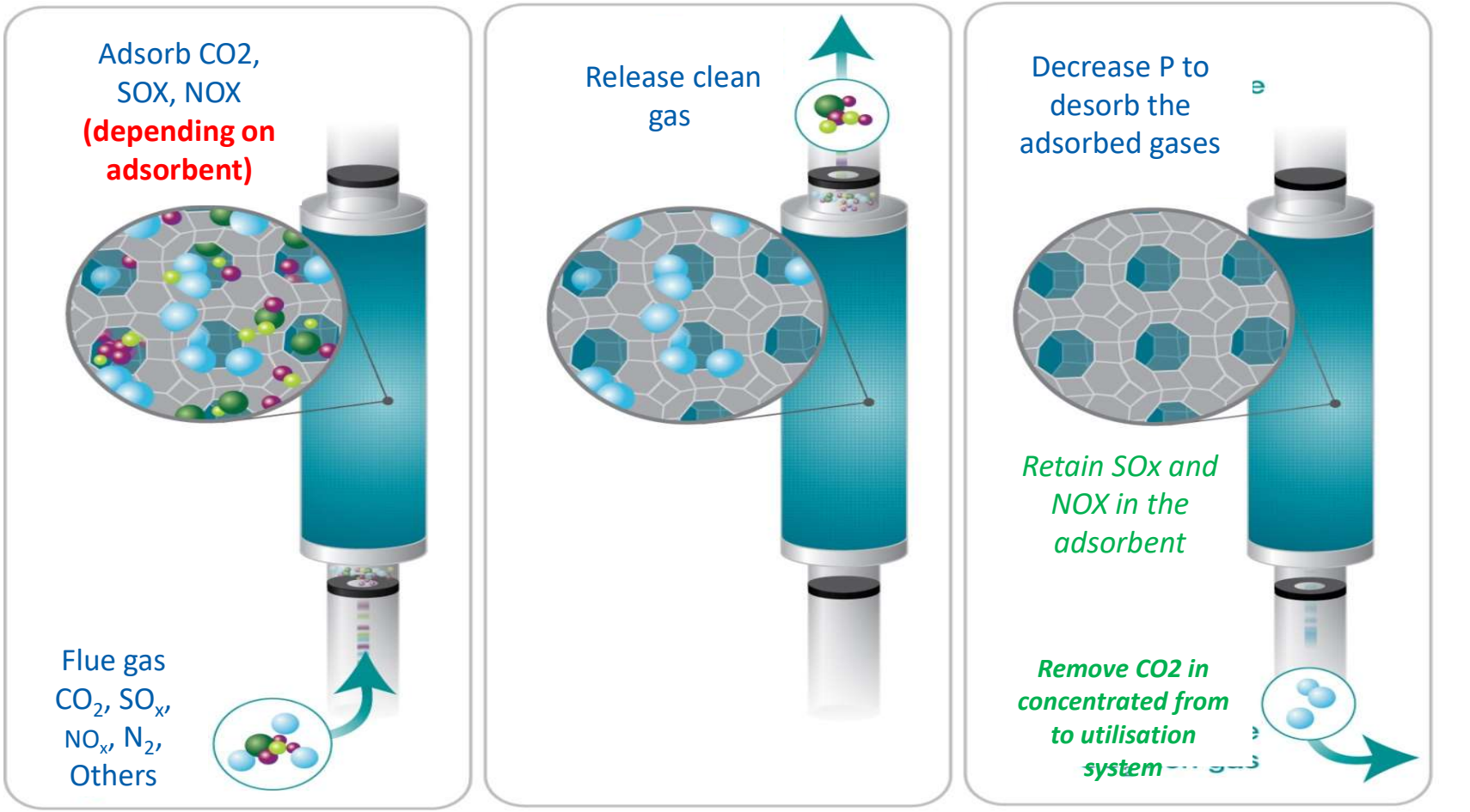
In a coal fired power plant, the levels of SO_x and NO_x from flue gas are not sufficient to allow the gas to be used immediately in the CO_2 capture system. Therefore ,it is essential to have a pre-treatment system before the carbon capture and utilisation (CCU) system.



**state of the art dry FGD at ultra supercritical (USC) coal fired power plants*
***state of the art SCR technology*

Project Background

Adsorption process can be used to pretreat the flue gas➔ remove SOx and NOx.



Research gap

Research gap To determine the suitable carbon material to capture both SOx and NOx simultaneously and selectively over CO2 from the flue gas stream to enhance the CCU system

Carbon base material preparation

Palm kernel shell

Coconut shell

Ground to a desired size

Activation process

Impregnation with metal oxides

BaO

CuO

MgO

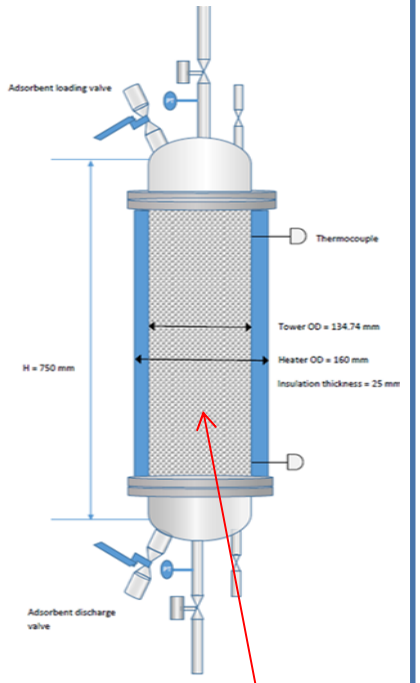
TiO_2

CeO_2

Metal oxides selection

Impregnation of activated carbon with metal oxide

Adsorption testing and analysis for selective removal of NOx and SOx over CO2 in a flue gas stream



Impregnated activated carbon

Results and discussions

Criteria for preferred adsorbent: ☑High yield ☑ High BET surface area ☑ Large pore volume

Carbon source	Activation method	Process	Yield (%)	BET surface area (m^2/g)	Pore volume (cm^3)
Palm kernel shell (PKS) 	Physical	Raw material screening and grinding → Devolatilisation 300C at 30 min, then 800C. → Activation using steam at 800C for 1 hour → Activated carbon	22	584	0.26
	Chemical	Raw material screening and grinding → Soaked with $ZnCl_2$ (24h) → Activation at 550°C, 1hr → Activated carbon	44	1,223	0.70
Coconut shell (CS) 	Physical	Raw material screening and grinding → Devolatilisation 300C at 30 min, then 800C. → Activation using steam at 800C for 1 hour → Activated carbon	24	1,011	0.45
	Chemical	Raw material screening and grinding → Soaked with $ZnCl_2$ (24h) → Activation at 550°C, 1hr → Activated carbon	45	953	0.43

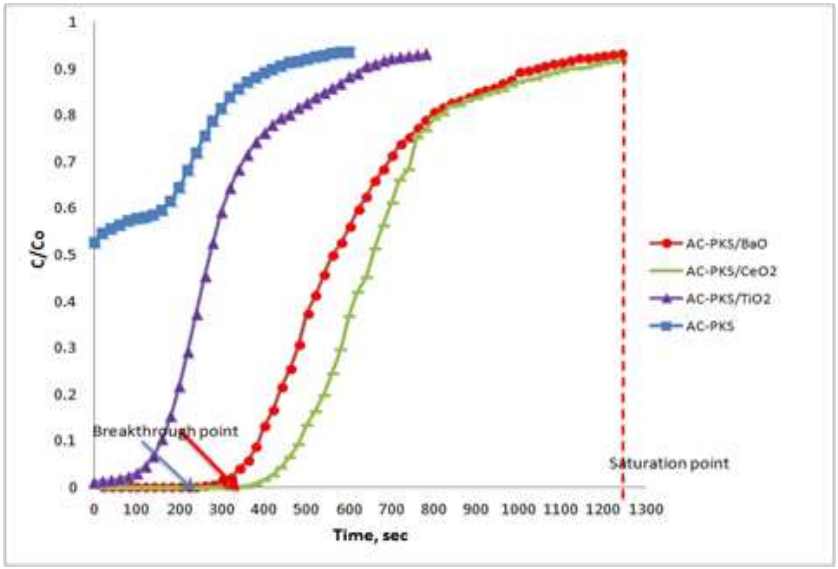
- Chemical activated AC are better since it produces higher yield due to the lower temperature process.
- PKS is better adsorbent since it possess a higher surface area and larger pore volume.

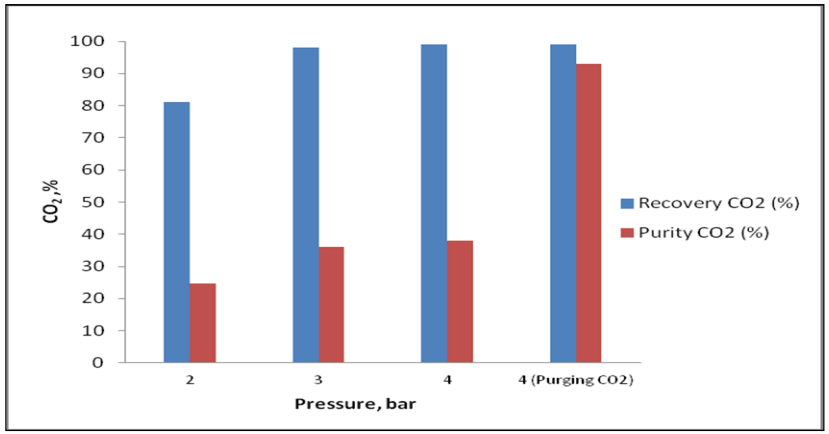
CONCLUSION → Chemical activated PKS was selected as activated carbon base to be impregnated with metal oxides (BaO, TiO2, CeO2, CuO, MgO) due to its **high yield, high surface area and large pore volume**

Research findings

The impregnated AC was used in the in the VPSA system to evaluate for the breakthrough curve and effect of pressure and the CO_2 recovery and purity.

- The impregnated activated carbon with metal oxide is capable to simultaneously removes SOx and NOx and selectively over CO_2.
- The impregnated activated carbon can recover 95% of captured CO_2 and retained SO_X and NO_X in the adsorbent during the desorption process.
- This impregnated activated carbon can be regenerated which can prolong the adsorbent lifetime.





Way Forward

Our end in mind : Carbon Capture and Utilisation Pilot Plant

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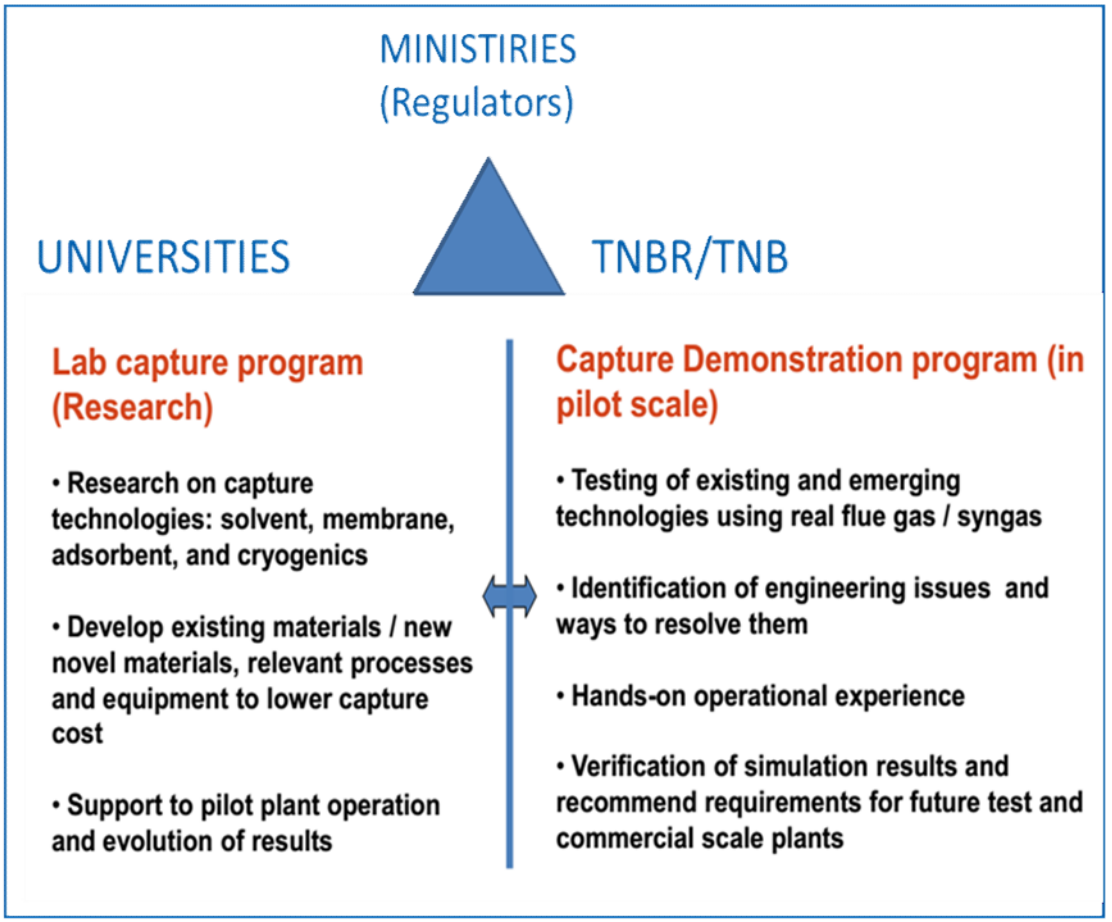
TNBR Capability:

Pilot Plant design and development:-

1. CO2 capture/gas cleaning system using amine absorption
2. Solubility test rig
3. Vacuum pressure Swing adsorption system
4. Methanation pilot plant

Areas of potential collaboration:-

1. Catalyst development for methanation
2. Renewable hydrogen production
3. Amine disposal
4. Adsorbent development from coal fired power plant waste
5. CCU energy & exergy analysis, energy efficiency, LCA, socio-economic, regulatory and policy etc



Our capability

25 m3 vacumm/temperature swing adsorption system.

Patented adsorbent (PI 2017700352)

THANK YOU

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