Biochar
The Science and the Opportunities

Jiuan Jing Chew (JJ)

School of Engineering & Science, Swinburne University of Technology Sarawak Campus

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JJ Chew

jchew@swinburne.edu.my | +60 16 855 9251 | https://www.linkedin.com/in/jiuan-jing-chew/

Education:

- 2016: PhD, Chemical Engineering, Monash
- 2007: BEng (Honours), Chemical, Curtin

Job experience:

- Lecturer, Swinburne University (2014-present)
- Engineer, Perunding Najna (2017-2020)
- Process Engineer, Sanmina-SCI (2007-2010)

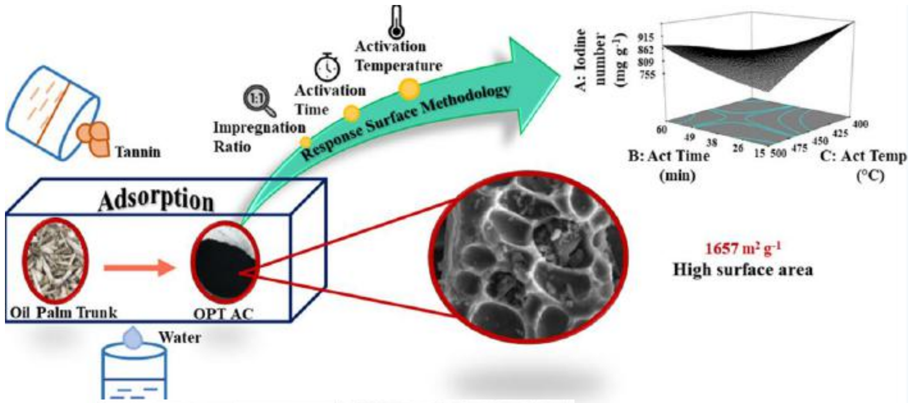
Recent Achievements:

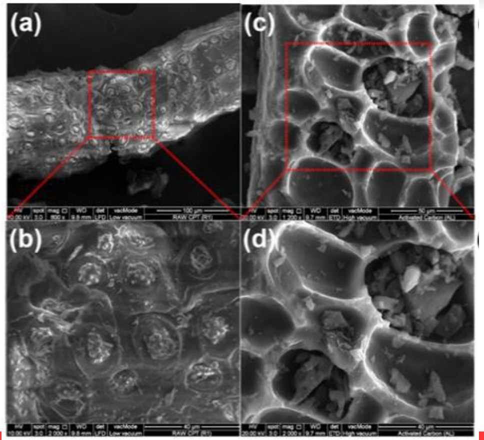
- Young Woman Researcher, 8th Venus International Women Awards 2023
- Vice-Chancellor's One Swinburne Award 2022
- Vice-Chancellor's Accountable Award 2022
- Swinburne Publication Award 2019-2022

People and technology working together to **build a better world**.

Research Brief

My research covers biomass conversion for energy production and value-added products such as biochar. I use thermochemical processes such as torrefaction, pyrolysis as well as gasification to enhance the properties of the biomass and optimize the process conditions to suit targeted application. I have extensive experience in the material characterisation. In addition, I am currently involved in the catalyst development process to enhance biodiesel fuel and also hydrochar synthesis.





Selected Publications:

- Terry, L.M., Wee, M.X.J., Chew, J.J., Khaerudini, D.S., Darsono, N., Aqsha, A., Saptoro, A. and Sunarso, J., 2023. Catalytic co-pyrolysis of oil palm trunk and polypropylene with Ni–Mo/TiO2 and Ni/Al2O3: oil composition and mechanism. Environmental Research, 224, p.115550.
- Lai, J.Y., Ngu, L.H., Chew, J.J. and Khaerudini, D.S., 2022. Parametric Study of Concurrent Activation and Surface Modification (CAM) Process for Palm Kernel Shell Derived Activated Carbon. Chemical Engineering Transactions, 97, pp.415-420.
- Soh, M., Khaerudini, D.S., Chew, J.J. and Sunarso, J., 2021. Wet torrefaction of empty fruit bunches (EFB) and oil palm trunks (OPT): Efects of process parameters on their physicochemical and structural properties. South African Journal of Chemical Engineering, 35(1), pp.126-136.
- Lim, A., Chew, J.J., Ngu, L.H., Ismadji, S., Khaerudini, D.S. and Sunarso, J., 2020. Synthesis, characterization, adsorption isotherm, and kinetic study of oil palm trunk-derived activated carbon for tannin removal from aqueous solution. ACS omega, 5(44), pp.28673-28683.
- Chew, J.J., Soh, M., Sunarso, J., Yong, S.T., Doshi, V. and Bhattacharya, S., 2020. Gasification of torrefied oil palm biomass in a fixed-bed reactor: Effects of gasifying agents on product characteristics. Journal of the Energy Institute, 93(2), pp.711-722.

Our Shared Challenges

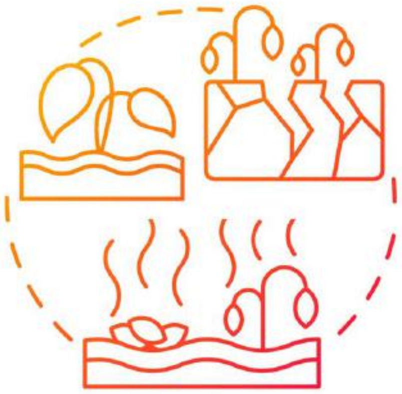
There is only one earth

Food brings us together..

farmers, traders, food manufacturers, retailers and many more

CLIMATE CHANGE

LAND DEGRADATION



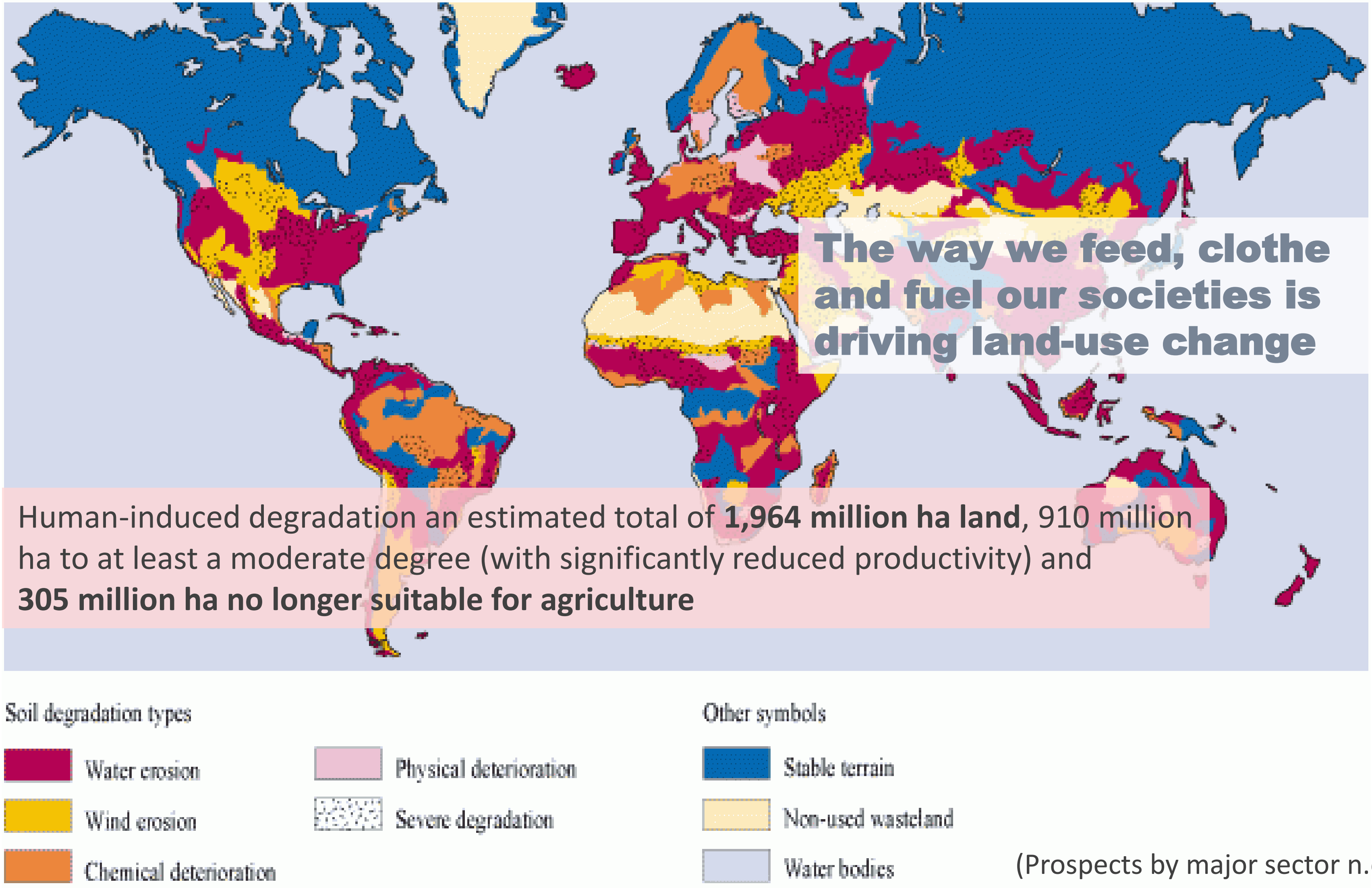
BIOMASS MANAGEMENT

…farm to fork…

...not far from the biggest challenges

Global Land Degradation

Process of testing and experimentation



The way we feed, clothe and fuel our societies is driving land-use change

Human-induced degradation an estimated total of **1,964 million ha land**, 910 million ha to at least a moderate degree (with significantly reduced productivity) and **305 million ha no longer suitable for agriculture**

(Prospects by major sector n.d.)

Healthy Soil

Healthy food production

1. Sustainable land use mitigates risks for businesses
2. Sustainable land use creates business opportunities and resilient jobs
3. Sustainable land can help companies’ with climate commitments

(Why businesses must take bold action on sustainable land use n.d.)

Biochar

Carbon-rich material

"Biochar is a fine-grained charcoal high in o[illegible] to de[illegible]is of plant and waste feedstock's. As a soil amendment, biochar creates a recalcitrant so[illegible]e, s[illegible]c carbon di[illegible]ecalcitrant soil carbon stocks. The enhanced nutrient and moisture retention capacity of biochar-amended soil not only reduces the total fertilizer requirements, but also the climate and environmental impact of croplands."
(International Biochar Initiative Scientific Advisory Committee)

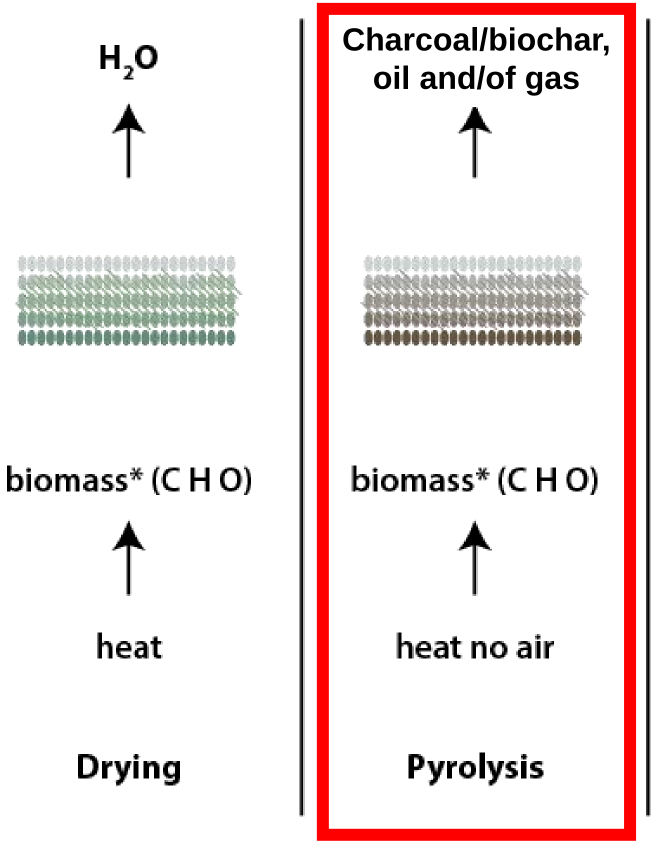
Charcoal from plant and waste made under high temperature & minimal O_2

Sequesters C for generations when placed in soil and is C negative since active C is inactivated

(Woods 2004)

Pyrolysis

- Converts compound by changing its structure
- Elevated temperatures - 400°C to 800°C
- Absence of air



* Biomass is a combination of C, H, and O ($CH_{1.4}O_{0.6}$)

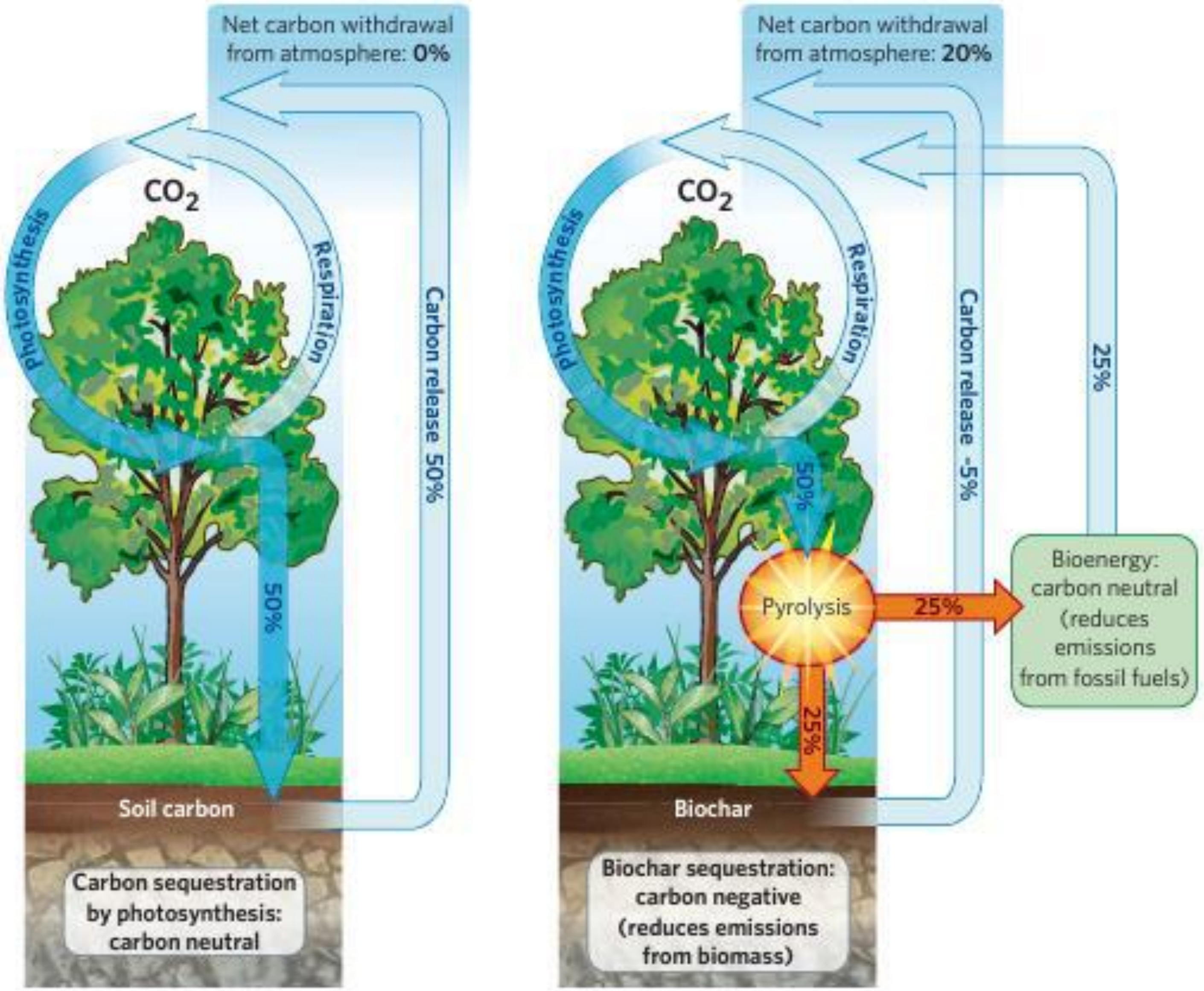
(Waste gasification process n.d.)

(Biomass pyrolysis plant: Quick & Cost-effective carbonization 2021)

(Airex energy completes $38M funding for que. biochar project n.d.)

(Continuous CharMaker CPP n.d.)

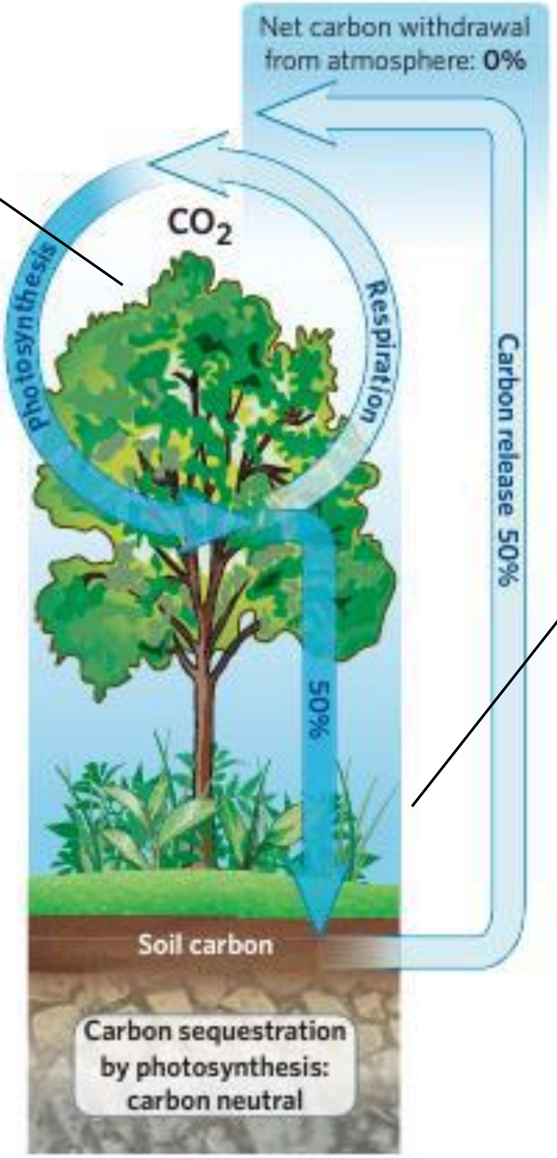
Environmental Benefits



(Lehmann 2007)

Environmental Benefits

Plant growth uptakes CO_2 naturally. CO_2 from the atmosphere to synthesise tissue (plant biomass).
As long as biomass is growing it accumulates carbon.

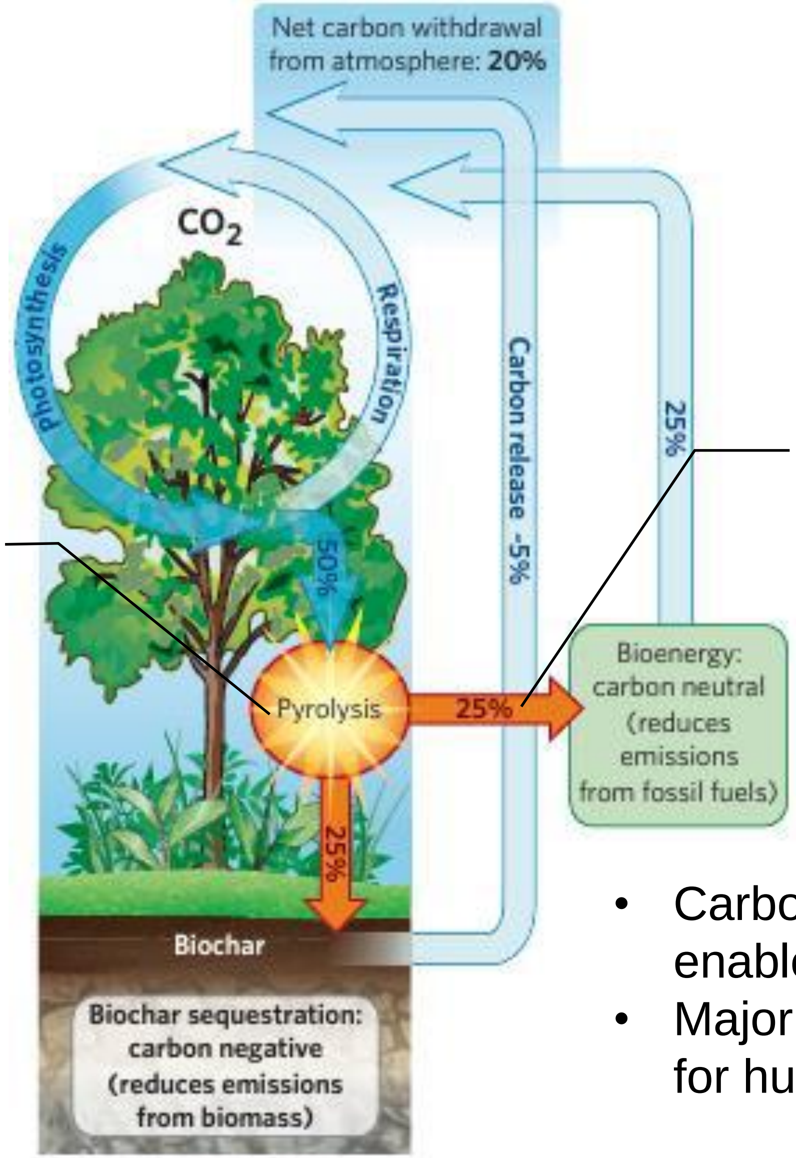


During decomposition of dead biomass and humus, half of the carbon is released as CO_2. In undisturbed ecosystems the accumulation and **release of CO_2 is in equilibrium**.

(Lehmann 2007)

Environmental Benefits

Pyrolysis can transfer 50% of the carbon stored in plant tissue from the active to an inactive carbon pool.



The remaining 50% of carbon (volatiles) can be used to produces energy and fuels.

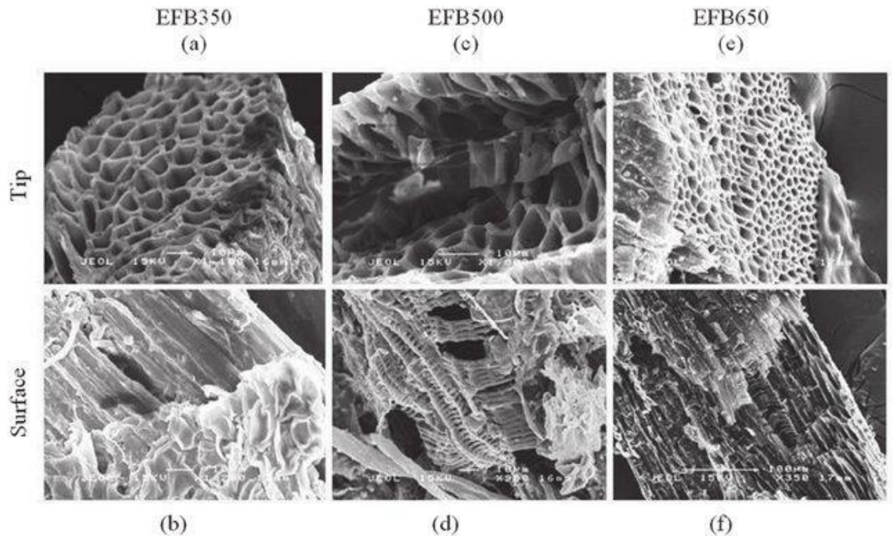
- Carbon negative energy generation enabled if re-growing resources are used.
- Majority of the C locked in biochar is stable for hundreds to thousands of years.

(Lehmann 2007)

Biochar in Agriculture

Benefits of biochar adaptation

Biochar is highly porous, containing a network of pores and channels of varying sizes.



(Claoston et al. 2014)

- **Improve soil aeration & form stable soil aggregates**
- **Reduce soil erosion**
- **Promote water retention**
- **Improve nutrient retention and reduce nutrient leaching**
- **Improved root growth**
- **Temperature regulation** (dark color)
- **Carbon sequestration**
- **pH regulation** (source & process condition)

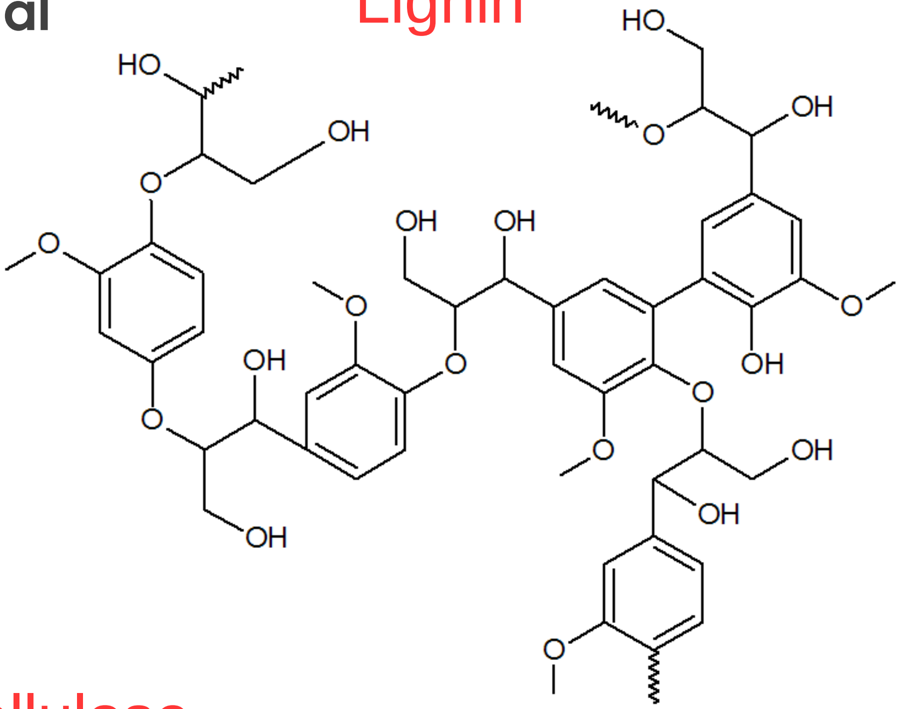
If so…

…what's the wait?

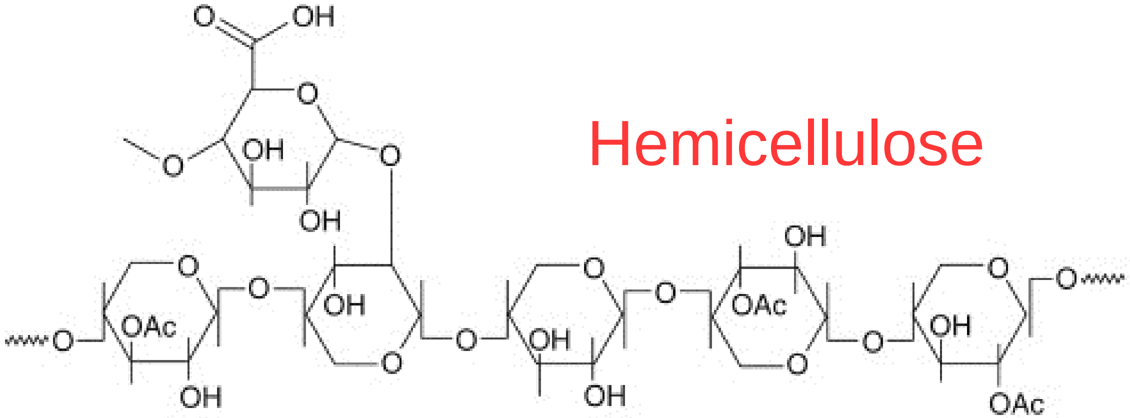
Biomass

are not equal

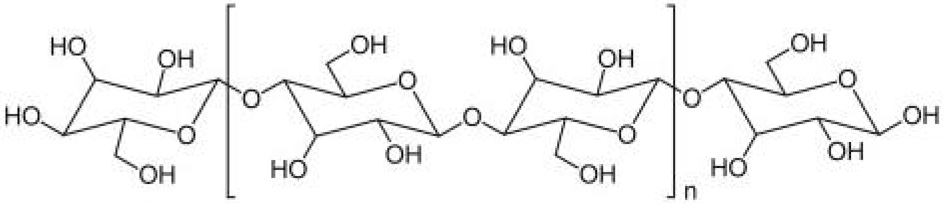
Lignin



Hemicellulose



Cellulose



Biochar

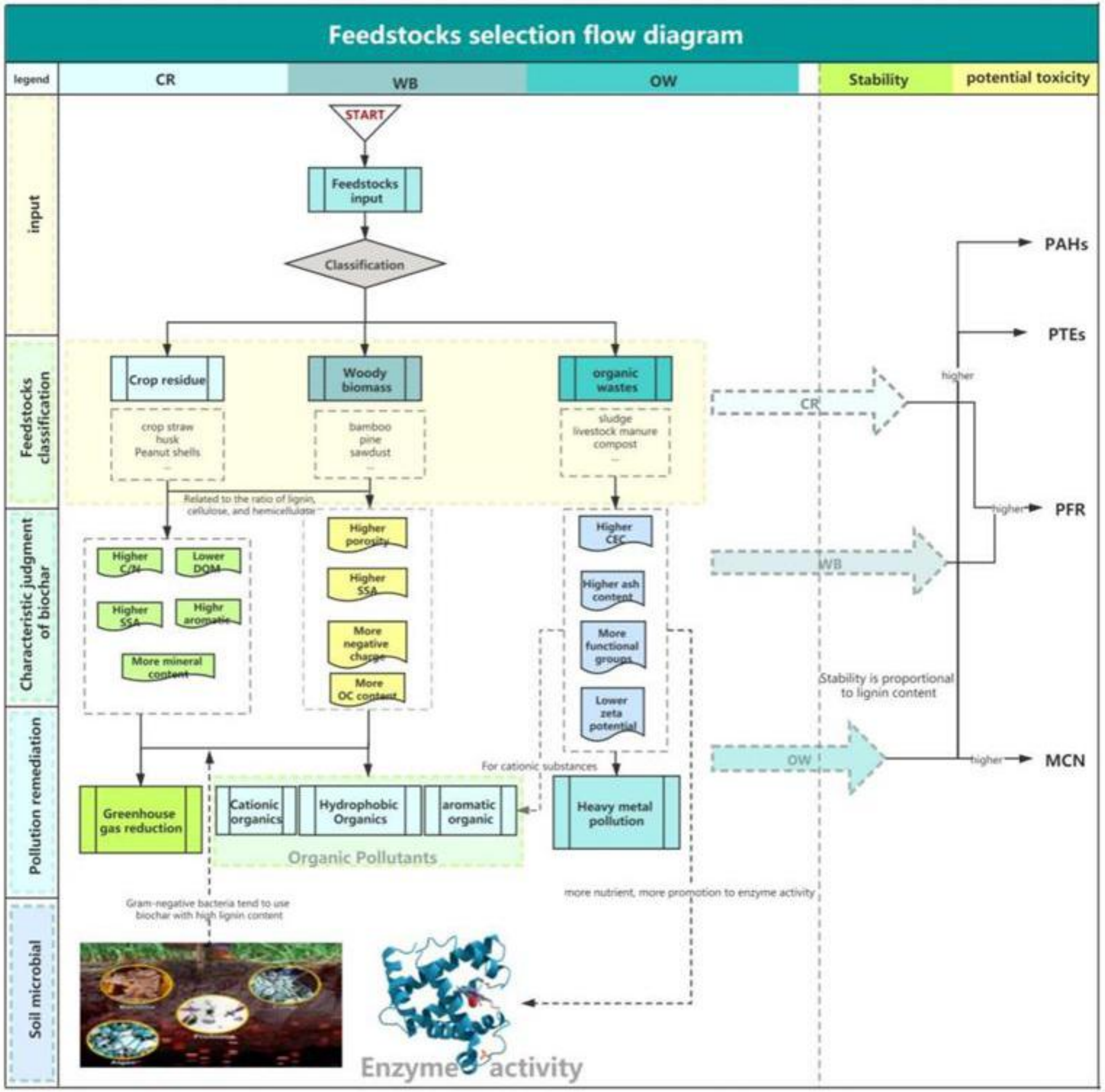
Not all the biochar has the same performance

Crop residues

Woody biomass

Organic wastes

(Ji et al.2022)



Biochar at Work

Frongoch metal mine – contaminant removal

Problem

- Soil polluted by heavy metals including lead, copper and zinc
- Vast areas of saturated soil – local water course pollution – reduced aquatic life

Solution

- Soil remediation by biochar (TerrAffix-Mine) reduced mobility and bioaccumulation of heavy metals from the contaminated soils

Abandoned Frongoch metal mine in 2020

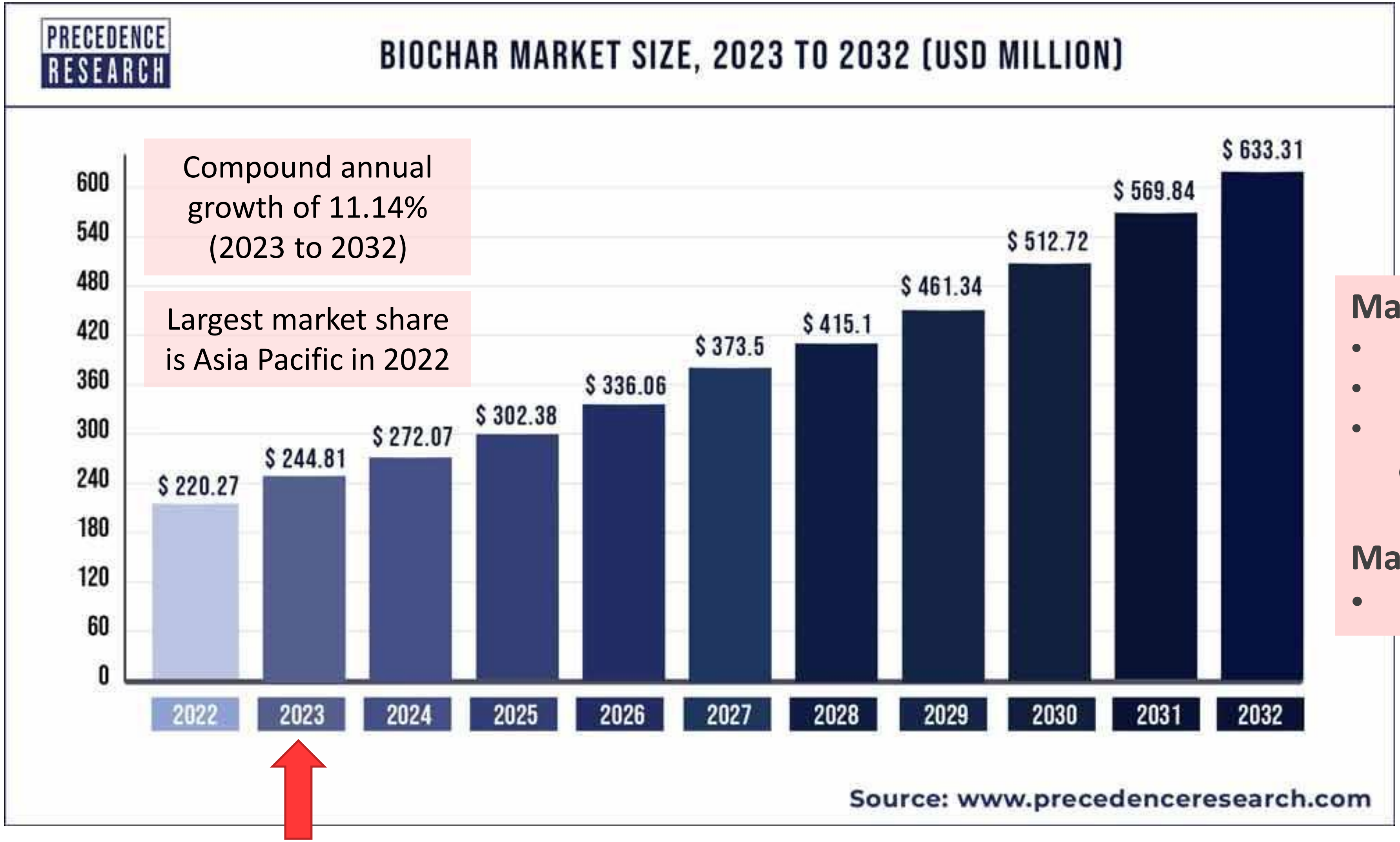
Wetland area from impermeable capping of mine waste

Frongoch Trials grassed up 22 days after seeding

(Mafiana 2021)

(WeDigJames 2018)

Opportunities



Compound annual growth of 11.14% (2023 to 2032)

Largest market share is Asia Pacific in 2022

Market drivers

- Rising gov. investment in agri sector
- Rising env. concerns
- Increase awareness for organic yet env friendly products

Market opportunity

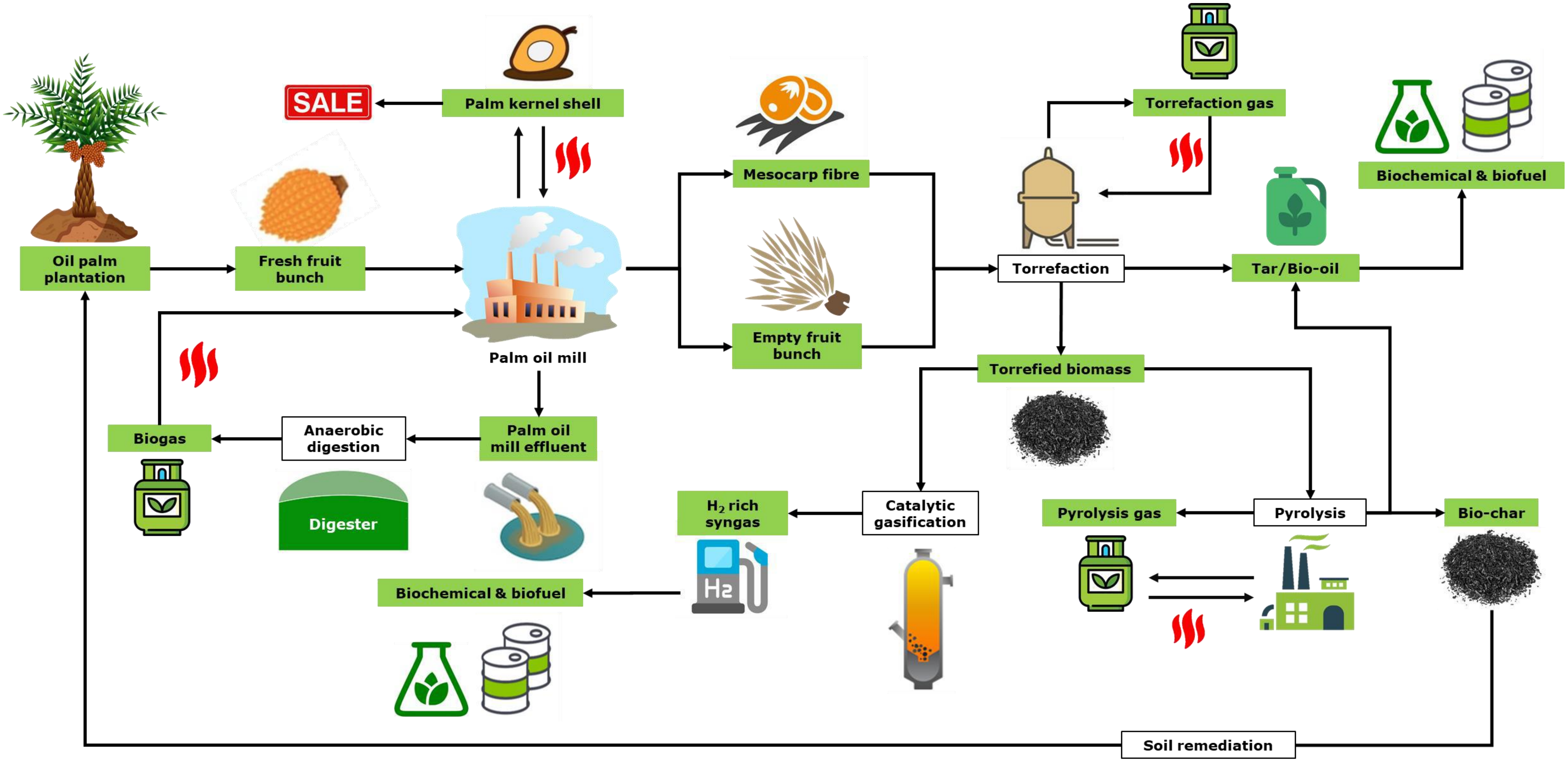
- Emphasis on soil improvement

(Biochar market n.d.)

Key takeaway

Oil palm biomass can become

- **Soil amendment –** hold water and nutrients, inc pH, red fertilizer needs
- **Water quality enhancer** – mitigate N and P runoff, holds heavy metals
- **Climate change mitigation** –minimize CO_2, N_2O, and CH_4 emissions
- **Energy** - process heat, bio-oil, and gases



(Terry et al 2022)

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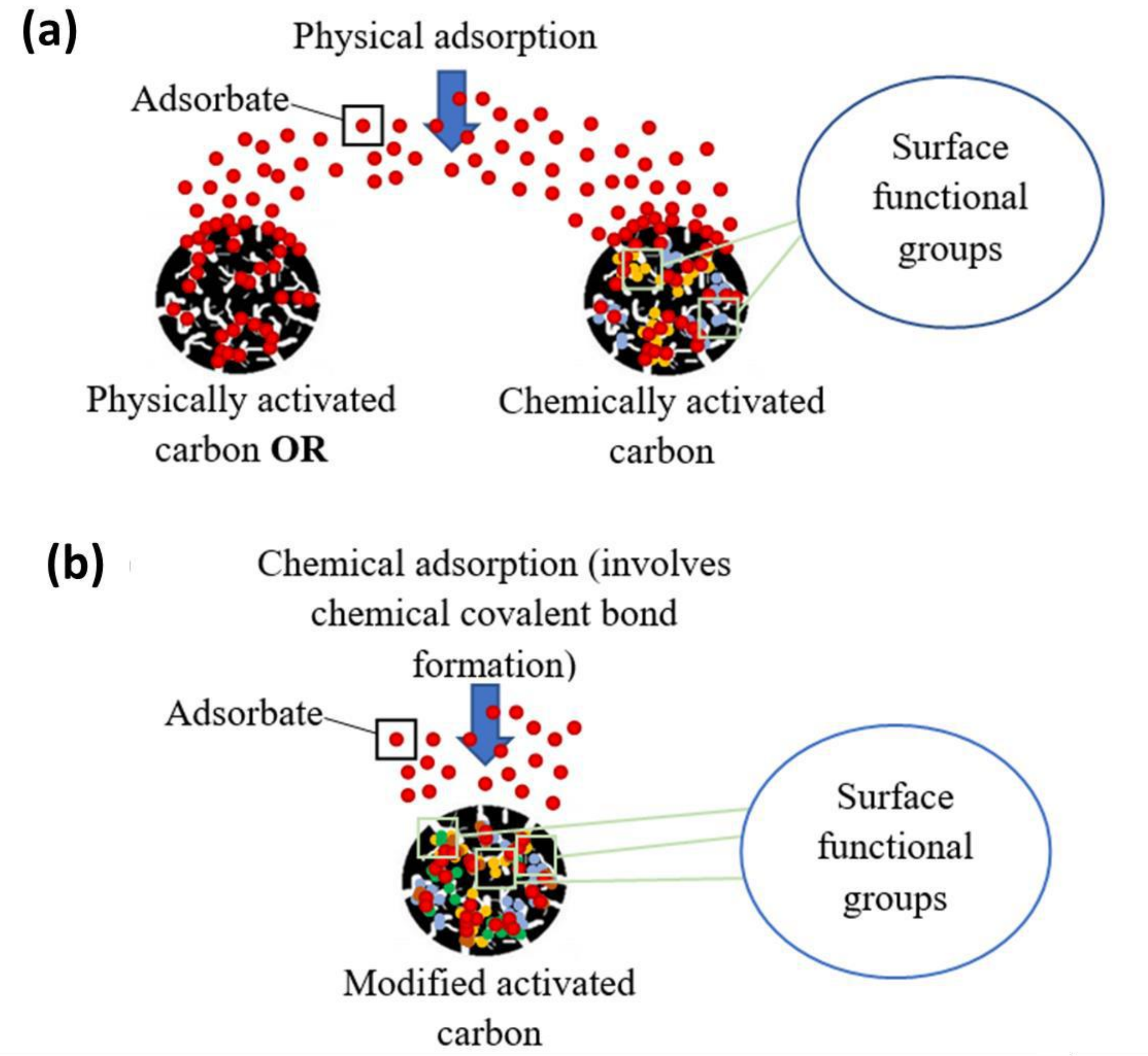
THANK YOU

JJ Chew
jchew@swinburne.edu.my | +60 16 855 9251
9 August 2023

Activated carbon on CCU

Adsorption

- One of the promising CO_2 capture method.
- Preferential adsorbate bonding onto adsorbent surface.
- Involves two types of adsorption that are physical adsorption (a) and chemical adsorption (b).



Reference: Fellinger 2017; Kiener et al. 2019; Rehman et al. 2019; Samer 2015; Spigarelli & Kawatra 2013.

CO_2 Adsorption Performance of Oil Palm-Derived AC

Unmodified Oil Palm-Derived AC

Oil palm part	Adsorption temperature (°C)	Adsorption pressure (bar)	CO_2 adsorption (mmol g^{-1})
Empty fruit bunch	30	1	0.38 – 0.57
Empty fruit bunch	0 - 50	1	0.30 – 5.23
Palm kernel shell	20	4	0.54 – 0.71
Palm shell	0 and 25	1	1.90 – 6.30
Palm shell	25	0.48	1.33

Surface modified Palm kernel shell-derived AC

Types of chemical incorporated	Adsorption temperature (°C)	Adsorption pressure (bar)	CO_2 adsorption (mmol g^{-1})
Polyethyleneimine (PEI)	25	1	0.71 – 2.28
2-amino-2-methyl-1-propanol (AMP)	25	1	0.77
Mono-ethanolamine (MEA)	25-70	1	1.11 - 2.50
Diethanolamine (DEA)	40-70	1	1.60-2.80
Nickel nitrate hexahydrate ($Ni(NO_3)_2 \cdot 6H_2O$)	30	1	0.81 - 0.97
Magnesium oxide (MgO)	20	4	0.38
Copper oxide (CuO)	20	4	0.89
Cerium oxide (CeO_2)	20	4	0.71 and 1.41
Titanium oxide (TiO_2)	20	4	0.71 and 0.78
Barium oxide (BaO)	20	4	1.43 and 1.37

References: Nasri et al. 2015; Ello et al. 2013; Hidayu & Muda 2016; Hidayu & Muda 2017; Parshetti et al. 2015; Ahmad 2009; Aroua et al. 2008; Khalil et al. 2012; Kongnoo et al. 2016; Younas et al. 2016.

Catalytic wet torrefaction

Jiuan Jing Chew, Jaka Sunarso, How Bing Shen

Project title: Reaction mechanism of acid-based catalytic wet torrefaction on oil palm trunks (OPT) and empty fruit bunches (EFB)

Highlights:

- ❑ Wet torrefaction of OPT and EFB under different operating conditions (i.e., temperature, residence time, catalyst type, and catalyst concentration)
- ❑ Evaluate the best catalyst for wet torrefaction of OPT and EFB
- ❑ Evaluate the effect of different catalyst on the reaction mechanisms and vapour pressure during wet torrefaction of OPT and EFB

Related grants: Ministry of High Education Malaysia, Fundamental Research Grant Scheme [Grant number: FRGS/1/2020/TK0/SWIN/03/1] - MYR 147,744

External partners:

- ❑ Prof. Suzana binti Yusup (UTP, Malaysia)
- ❑ Dr. Loh Soh Kheang (MPOB, Malaysia)
- ❑ Dr. Deni Shidqi Khaerudini (LIPI, Indonesia)

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Catalytic bio-oil production

Jiuan Jing Chew, Jaka Sunarso

Project title: Bio-oil production *via* catalytic co-pyrolysis of oil palm trunk and PP

Masters student: Liza Melia Anak Terry

Related grant: Indonesian Ministry of Research, Technology, and Higher Education Research Grant – IDR10,000,000

Related scholarship: Yayasan Sarawak Tun Taib Scholarship

Highlights:

- ❑ Identify the optimum temperature and ratio of feedstocks (oil palm trunk to LDPE) to enhance bio-oil yield and quality
- ❑ Optimise the bio-oil yield and quality with the use of catalyst (Nickel Molybdenum supported with Titanium oxide)

External partner: Dr. Aqsha (Bandung Institute of Technology, Indonesia)

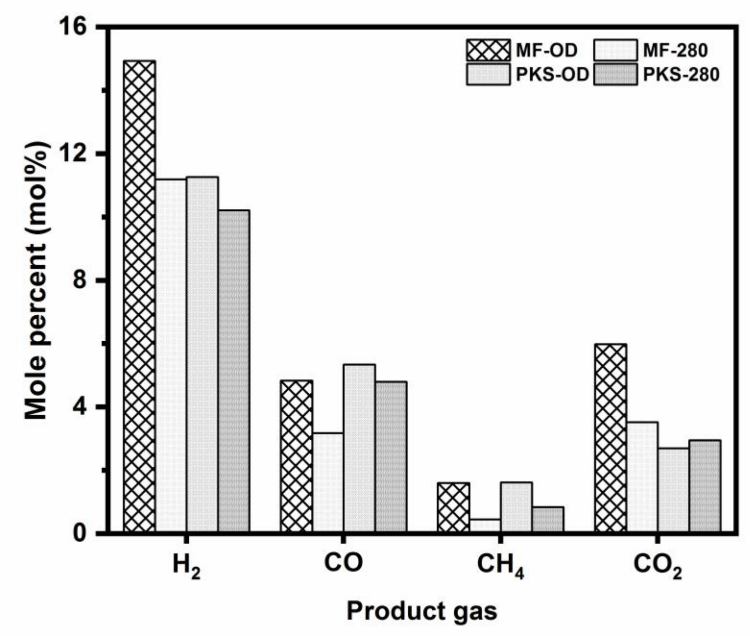
Gasification of torrefied oil palm biomass

Jiuan Jing Chew, Jaka Sunarso

Project title: An experimental study on torrefaction and gasification of oil palm biomass

Highlights:

- Properties of torrefied oil palm biomass under different conditions
- Steam and CO_2 gasification of torrefied oil palm biomass
- Gasification syngas distribution and gasification characteristics of torrefied oil palm biomass



Key publications

Chew et al., Gasification of torrefied oil palm biomass in a fixed-bed reactor: Effects of gasifying agents on product characteristics, Journal of the Energy Institute, 93 (2020) 711-722.

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Gasification of torrefied oil palm biomass

Jiuan Jing Chew, Jaka Sunarso

Related grants: Monash Seed Grant (MYR30,000) and Monash HDR Scholarship

Key publications

Chew et al., Gasification of torrefied oil palm biomass in a fixed-bed reactor: Effects of gasifying agents on product characteristics, Journal of the Energy Institute, 93 (2020) 711-722.

External partners:

- ❑ Dr. Siek-Ting Yong (Monash University, Malaysia)
- ❑ Dr. Veena Doshi (Taylor's University, Malaysia)
- ❑ Prof. Sankar Bhattacharya (Monash University, Australia)