Thermo-Disintegration Waste to Resource (TDWR) system as a decentralised, flexible, and value-adding waste management strategy for a zero waste sustainable city

G. Lisak[1,3], A.W.K. Law[2,3], W.P. Chan[1], L.Y. Ge[1], A. Veksha[1], W.Q. Chen[1], X. Yang[1], S.C. Wong[1], Z. Tsakadze[1], C.W. Low[1], R. Aryal[1], C.J.L. Foo[1], K. Zhao[1], C.W. Mao[1], J.L. Guo[1], G. Soon[2], H.L. Trinh[2], R. Silva[1], H.M. Ong[1]

[1]Resource Recovery Programme, Nanyang Environment and Water Research Institute, Nanyang Technological University, 1 Cleantech Loop, Clean Tech One, 637141, Singapore
[2]Environmental Sensing Modelling and AI Machine Learning Programme, Nanyang Environment and Water Research Institute, Nanyang Technological University, 1 Cleantech Loop, Clean Tech One, 637141, Singapore
[3]School of Civil and Environmental Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798, Singapore
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Presenting author email: g.lisak@ntu.edu.sg

Year 2019 was designated as the Year Towards Zero Waste for Singapore to build a national consciousness to care and protect the environment. The following years to come saw a growing emphasis on the importance for Singapore to become a sustainable, resource-efficient, and climate-resilient nation. In February 2021, the Singapore Green Plan was announced that charts concrete targets over the next 10 years; plans include reducing waste sent to our only Semakau landfill per capita per day by 20% by 2026, with the goal of reaching to 30% by 2030. To achieve this goal, one of the most important aspects is to explore effective value-adding to waste management strategies, develop flexible and complementary decentralised approaches, maximize creation and retention of the waste to resource in a circular economy. Today, municipal solid waste (MSW) and most of the non-recyclable wastes are currently incinerated in Singapore for energy recovery. The ash residues generated, and the non-combustible wastes are disposed of at the Semakau Landfill, which is estimated to be full by Year 2035 at current landfilling rates.

Additionally, various types of specialized waste streams, including food wastes, plastics, tires, sewage sludge oil sludge, and medical wastes are generated on a daily basis in this modern city (Chan and Wang, 2016), which presents significant and complicated challenges on effective management and value creation (instead of destruction, through incineration and landfilling) from these waste materials. This gave rise for an opportunity for a unique Thermo-Disintegration Waste to Resource (TDWR) system from Bluefield Renewable Energy Pte Ltd (BRE) and complementary innovative technologies (Zhao et al., 2021) from Nanyang Technological University (NTU) to jointly harness the energy and valuable resources from these challenging waste streams by converting the wastes into high quality char (Muhammad et al., 2022) and syngas, through the first-of-its-kind exploration in Singapore for effective decentralised waste management in a city (as shown in **Fig. 1**).

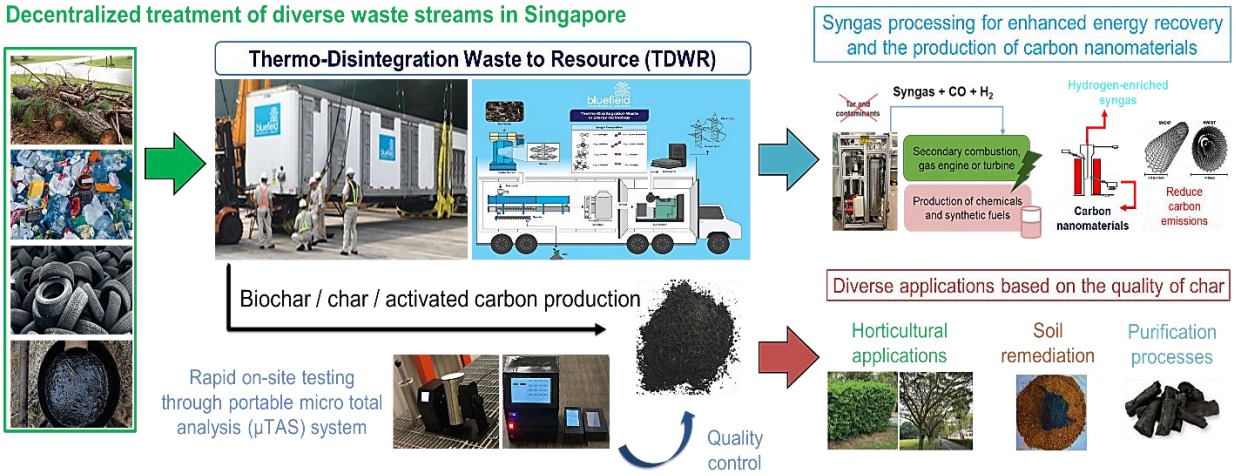

Fig. 1 Decentralised treatment of diverse waste streams through Thermo-Disintegration Waste to Resource (TDWR) system and upcycling of the by-products generated to value-added products.

By decentralising the management and adding values into wastes through an environmentally friendly treatment method, the capacity and flexibility of Singapore's waste industry will be improved to address unexpected

disrupting scenarios, to survive in the rapid changing waste management landscape, and to significantly reduce the need for waste disposal at the landfill; prolonging the life of Singapore's only landfill site – Pulau Semakau. Through this research project, substantial improvement of the technology are performed by NTU and BRE to optimise the system operation, deployment flexibility and product quality. The optimised products will provide Singapore with the opportunity to be an export hub for char and activated carbon as well as to build its reputation into a leading zero waste circular economy smart city hub.

The proposed novel rapid pyrolysis technology, TDWR, is capable to convert raw wastes to green energy and resources. The TDWR system is a containerized, mobile, modular, stackable and scalable system. It is capable of decentralise waste management and processing diverse waste streams at high temperatures (650°C-1000°C), and generating char and syngas (as shown in **Fig. 2**), which can be applied directly or upgraded (Chan et al., 2019) for many applications ranging from green renewable energy, chemicals synthesis, horticultural application and the production of carbon nanomaterials (Veksha et al., 2017). In this project, TDWR system will be upgraded and optimised to further extend this garden city into a high-tech char generating city, exporting biochar to agricultural industries and modified char, activated carbon (Shen et al., 2024) and carbon nanomaterials for chemicals and manufacturing industries, worldwide.

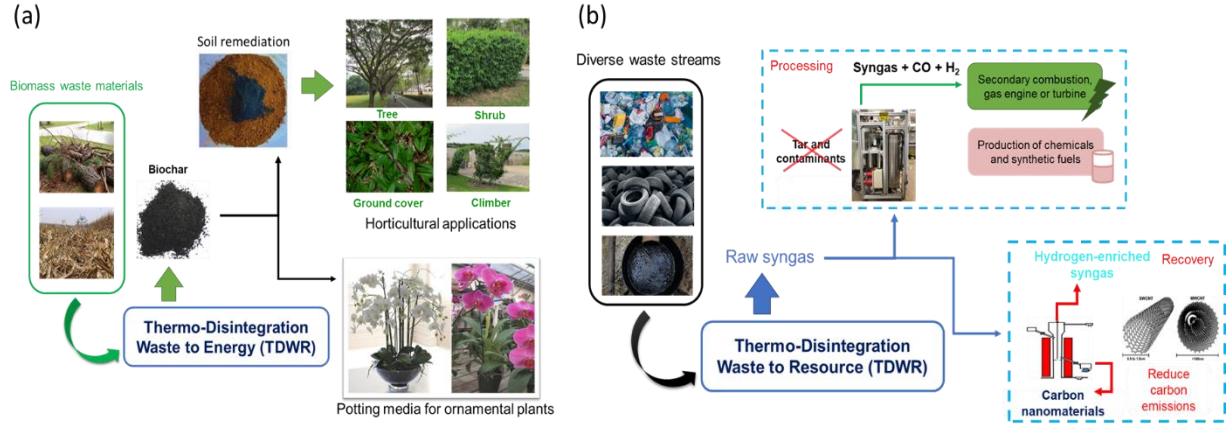

Fig. 2 (a) From biomass waste materials to high quality biochar. (b) Syngas processing and resource recovery.

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