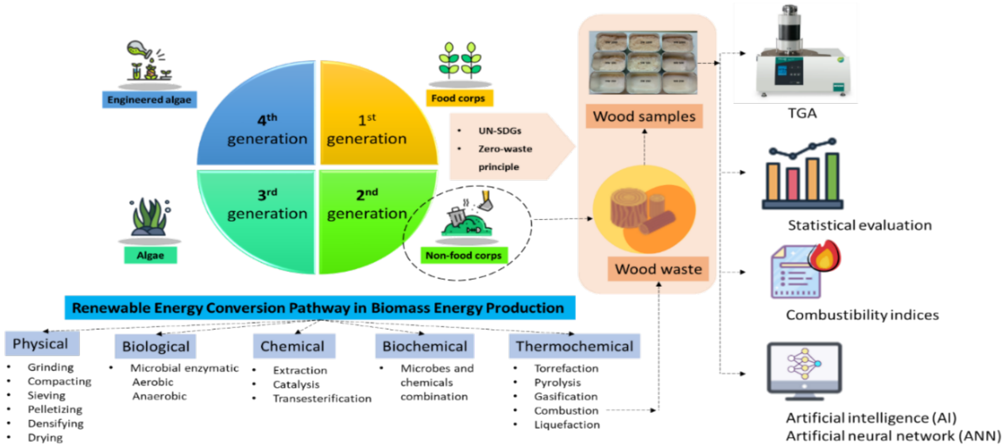
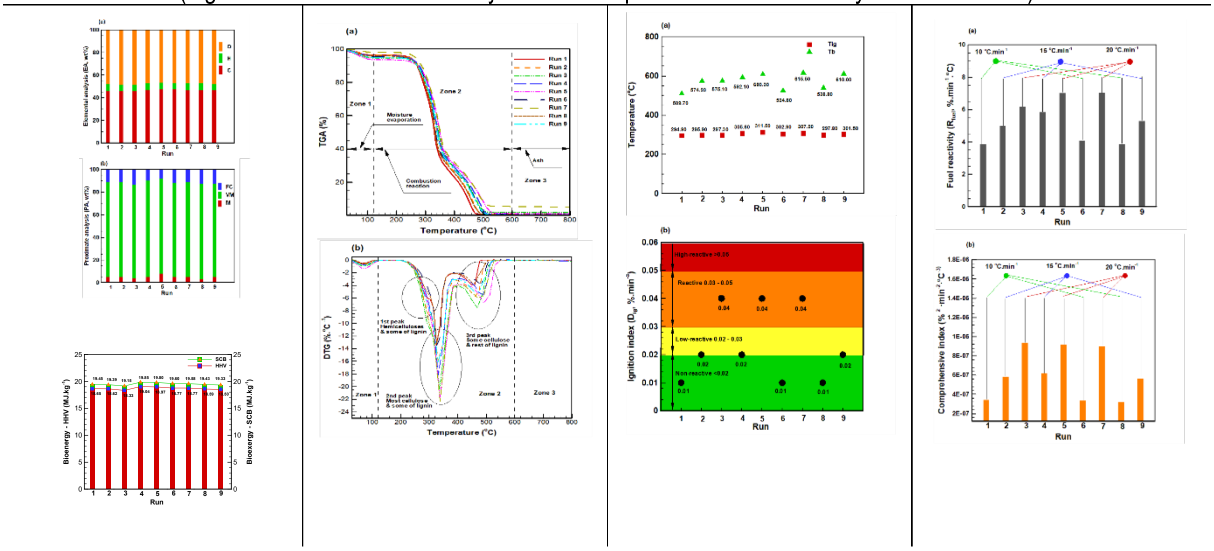
CASAVA-B2



(Fig. 1a. Direct combustion study via TGA coupled with statistical analysis and AI aided.)



(**Fig. 1b**. Characterization, product analyses, and combustibility indexes.)

Comprehensive **A**nalysi**S** of Dec**A**rbonized **V**alorization of Lignocellulosic biomass with **A**rtificial Intelligence-Aided design in **B**iomaterials and **B**iofuels productions

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Thematic action concerned: *WP3*

Context —
Recycled wood waste (hardwood, softwood, woods blend) is thermochemically treated (combustion) and statistically analyzed to understand its potential as renewable energy biomass fuel (biofuel). Bioenergy and bioexergy analyses along with statistical evaluation and an artificial intelligence model are utilized to evaluate the characterization of the wood waste and performance of the combustion process. The quantity and the quality of the recycled wood waste are presented well in the combustion indexes.

Objectives —
Solid wood waste amount in European countries, especially France is considerably huge. In order to convert the wood waste into more valuable added products, the three types of wood waste (hardwood, softwood, and wood blends) have been treated to obtain the potential biofuel. Recycling woody waste into biofuel is considered an effective method that shares the goal of achieving the future United Nations – Sustainable Development Goals (UN-SDGs) affordable and clean energy (SDG7), responsible consumption and production (SDG12), and climate action (SDG13), respectively. Moreover, since the woody biowaste utilized in this study is collected from the wood waste of industrial activities, the ninth goal of industry, infrastructure, and innovation (SDG9) and zero waste principle for managing waste generation is considerably aligned with the goal of the present study.

Approaches —
The wood wastes (hardwood, softwood, and woods blend) are explored for the combustibility thermodegradation behavior via the TGA method integrated with the DoE of the Taguchi orthogonal array approach, which also studies the parameters influence that may occur. The statistical evaluation and artificial intelligence – artificial neural network (AI-ANN) analysis are provided to evaluate the experimental parameter and simulate the model prediction for bioenergy and bioexergy determinations. The approaches used to analyze the wood waste valorization in this study are characterization, combustibility indexes, statistical evaluation, and artificial intelligence model analysis.

Key results —
1. Direct combustion of wood wastes via TGA is investigated aided by statistics-AI.
2. The SCB is identified as typically higher than HHV, SCB/HHV ratio of 1.043-1.046.
3. Combustibility indexes D_{ig} (0.01–0.04) and R_{fuel} (3.82–6.97 $\%\cdot min^{-1}\cdot °C^{-1}$) are detected.
4. Statistical evaluation presents that wood waste type significantly impacts HHV and SCB.
5. ANN model using 1 hidden layer and 5 neurons can predict HHV and SCB with R^2=1.

Main conclusions including key points of discussion —
The bioenergy and bioexergy evaluations show that the SCB values are typically higher than HHV values. The chemical characterization suggests that SW has the highest HHV (18.84 $MJ\cdot kg^{-1}$) and SCB (19.65 $MJ\cdot kg^{-1}$) values due to the highest C-element compared to the woods blend or hardwood. As the amount is meager, insignificant influences are suggested by ash content, H-, and S-elements. The linear correlation indicates that the highest HHV corresponds to the highest SCB. The determination of the SCB/HHV ratio is 1.043-1.046, proving that the estimate of SCB is slightly higher than the HHV. The combustion of the lignocellulosic components is identified in three distinct zones: moisture evaporation (Zone I), combustion reaction (Zone II), and ash remains (Zone III). The TGA/DTG curves obtained, using typical heating rates of 10, 15, and 20 $°C\cdot min^{-1}$, suggest the hemicelluloses are degraded firstly around <275 °C, while cellulose and lignin degradation have more way to undergo in about 275-600 °C. The combustibility indexes (D_{ig}, R_{fuel}, and S_n) of the wood waste show three types of ignition index (D_{ig} = 0.01-0.04) non-reactive, low reactive, and reactive; fuel reactivity rate (R_{fuel}) describes the waste wood has a low to middle reactivity rate of 3.82-6.97 $\%\cdot min^{-1}\cdot °C^{-1}$; and comprehensive combustion index (S_n) suggests that wood waste has a better combustion performance than bituminous coal (> 5×10^{-7} $\%^2\cdot min^{-2}\cdot °C^{-3}$). The statistical evaluation presents that the highest HHV and SCB values are obtained by performing combustion at a heating rate of 15 $°C\cdot min^{-1}$ for a wood waste type of softwood with a 250 µm particle size. The S/N ratio and ANOVA results agree that the wood waste type, particularly for softwood (fir), and particle size denote the most influential parameters. The AI using the artificial neural network (ANN) model indicates that the best-fit quality (R^2=1) is obtained with 1 hidden layer and 5 neuron configurations to predict the HHV and SCB.

Perspectives —
This study investigates the combustion of wood waste and by-products via the thermogravimetry analysis (TGA) method coupled with the Taguchi orthogonal array, statistical evaluation, and artificial intelligence (AI) to predict the bioenergy (higher heating value, HHV) and biomass exergy or bioexergy (specific chemical bioexergy, SCB). Among the three types of wood waste, softwood shows a better combustibility performance and HHV-SCB than hardwood and wood waste for biofuel. This phenomenon shows that the chemical elements (CHONS) have an important role in biofuel characterization. The operational condition adjustment of the thermochemical conversion pathway is essential to utilize biofuel efficiently and effectively. Statistical evaluation provides a better understanding of the validity and accuracy of the data obtained from the experiment. Additionally, by using the AI model to forecast the biofuel using recycled wood waste is achieved. AI usage is essential for optimization and future work of industrialization (scale-up).

Valorization —
Conference:

3. Applied Energy Symposium: Low Carbon Cities and Urban Energy Systems (CUE 2023). Sept. 2-7, 2023. Matsue, Shimane – Japan.
4. The 1st International Conference on The Practical Zero Emissions Technologies and Strategies (PZETS 2023). Dec. 9-12, 2023. Ho Chi Minh City – Vietnam.

Journal publication:

- Bioenergy and bioexergy analyses with artificial intelligence application on combustion of recycled hardwood and softwood wastes via TGA. Applied Energy Journal. Impact factor: 11.20 (SCI, Q1). Status: Required Reviews Completed (5 March 2024)

Leveraging effect of the project—
Collaboration with Pr. WH Chen (HCR), National Cheng Kung University, Tainan, TAIWAN
Emerging collaboration with National Research Center in Indonesia (BRIN)
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