Introduction
Torrefaction, a relatively mild pyrolysis reaction under anoxic condition, is of interest in the thermo-chemical conversion of biomass to energy and fuels because of its favorable effects on biomass energy density, feedstock reactivity, and possible elimination of tar precursors. It is a solid state hydrolysis of hemi-cellulose in the biomass using thermal treatment at low temperature. This process produces a solid product (torrefied biomass) that has superior fuel quality for any thermo-chemical conversion processes into fuels and power.

The main objective of this study was to determine the torrefaction reaction kinetics of southern pine wood using Thermal Gravimetric with Mass Spectrometry (TG-MS) analyzer. In this study, a kinetic model of biomass torrefaction was developed in the temperature range of 200-300°C and kinetic mass-loss parameters for the torrefaction of southern pine wood were presented. A simple hemi-cellulose decay model was proposed to predict the torrefaction reaction kinetics. The torrefaction kinetic data will be critical to understand the torrefaction process, to design, develop and simulate the torrefaction reactors commercial scale applications and to investigate the downstream thermo-chemical conversion processes.

Objectives
➢ To postulate a model for mass loss during the torrefaction of pine wood and obtain relevant kinetic parameters.
➢ To study the effect of torrefaction at various holding temperatures on mass loss kinetics and off-gas composition in downstream thermal conversion processes.

Material & Methods
➢ Clean white pine chips ground to 0.25 mm mesh
➢ Powder samples were used at the TG-MS to target temperature at 10°C C/min under nitrogen environment. Samples were held at target temperature for 3 h to obtain mass loss data.
➢ Mass loss data was used to study the torrefaction reaction kinetics.

Downstream Effects of Torrefaction
Integrating torrefaction with combustion, gasification & pyrolysis – Preliminary study
Pine powder samples were initially torrefied at various temperatures and the samples were directly combusted (with air), gasified (with limited oxygen) and pyrolyzed (with nitrogen). The off-gas emission from each conversion processes were monitored using MS with a selective ion monitoring approach.

The analyzed results indicated that no effect on mass loss kinetics data during combustion, gasification, pyrolysis processes were observed. Combustion behavior of torrefied biomass was compared with low sulfur coal. Torrefied and raw pine powder samples were highly reactive compared to coal samples. MS analysis data indicated that significant reduction off-gas concentrations of acetol in gasification and both acetol and acetic acid in pyrolysis was observed.

Conclusions and Future Research
A kinetic model for mass loss during the torrefaction of southern pine was developed. It was found that the mass loss cannot be adequately described as a single step process, and that the kinetic parameters do not follow a typical Arrhenius relationship. More detailed study of the chemical reaction and mass transfer events that occur during torrefaction is required to further understand this process. This will allow for model validation and justification via investigation of the intermediate stages of torrefaction; and will further our understanding of the effects of torrefaction on the downstream conversion processes. Detailed HPLC and NMR studies on torrefied material are forthcoming.