Energy Conversion Engineering and Fluidization Technology

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In Japan, we use ~0.66 t of natural gas, ~1.1 kL of oil, and ~1.4 t of coal per year per capita, resulting in the CO_2 emission of ~8.3 t per year (i.e., ~13000 L per day) per capita (as of 2020). Considering resource depletion and climate change, great increase in utilization of renewable energy and value addition of carbonaceous resource utilization are strongly required. In our group, we have conducted the following research topics:

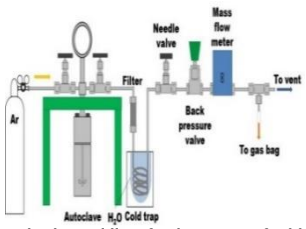
Topic 1: Development of reactors for thermochemical conversion of carbonaceous resources (pyrolysis, gasification, liquefaction, and esterification)

Topic 2: Process development for biochemicals and biofuels production

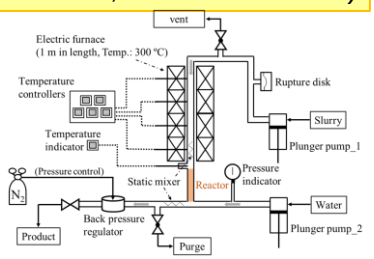
Topic 3: Reaction kinetics and hydrodynamics of fluidized beds

Topic 4: Development of value added thermal and biomass power plants

Development of reactors for thermochemical conversion of carbonaceous resources (pyrolysis, gasification, liquefaction, and esterification)



Hydrothermal liquefaction reactor for bio-oil production and nutrients recovery from biomass, small-scale batch reactor for chemicals production from biomass

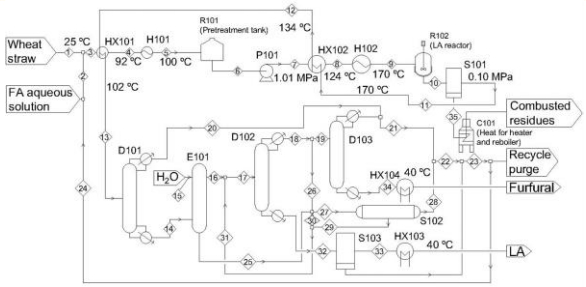


A newly developed reactor for flash hydrolysis of wet biomass

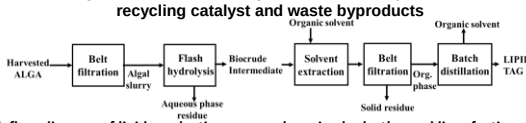
R. Usami, K. Fujii, C. Fushimi, *ACS Omega*, 5, 6684-6696, 2020
C. Fushimi, C. Tachibana, R. Usami, *Int. J. Sus. Biomass Bioenergy* 1, 1-5, 2018 and
C. Tachibana, C. Fushimi, Poster Award, 13th Biomass Science Symposium (JIE) 2018
C. Fushimi, M. Yazaki, R. Tomita, *J. Taiwan Inst. Chem. Eng.* 90, 68-78, 2018
C. Fushimi and A. Umeda, *Energy & Fuels*, 30, 7916-7922, 2016
C. Fushimi, M. Kakimura, R. Tomita, A. Umeda, T. Tanaka, *Fuel Processing Technology* 148, 282-288, 2016
S. Krerkkaiwan, C. Fushimi et al., *Fuel Processing Technology*, 115, 11-18, 2013

We have developed novel reactors for thermochemical conversion of coal and woody/algal biomass. We have also studied efficient bio-oil production process with nutrients recovery from biomass, which is essential for future sustainable large-scale biomass utilization system. We have also carried out experiments on chemicals production from biomass by using a small-scale batch reactor.

Process development for biochemicals and biofuels production



Process flow diagram of Levulinic acid production from lignocellulose biomass by recycling catalyst and waste byproducts

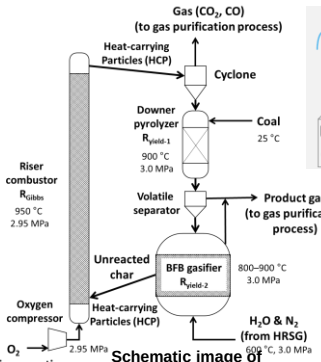


Block flow diagram of lipid production process by using hydrothermal liquefaction of algae

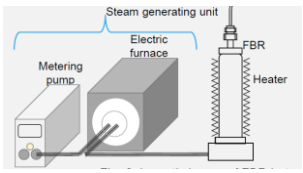
R. Ukawa-Sato, N. Hirano, C. Fushimi, *Chem. Eng. Res. Des.*, 192C, 389-401, 2023
R. Ukawa-Sato, G. Guan, C. Fushimi, *J. Chem. Eng. Jpn.* 54, 620-629, 2021
K. Fujii, C. Fushimi, Excellent paper award , 8th Asian Conf. on Biomass Science (1st ranking) 2021
M. Yazaki, C. Fushimi, *Energy Fuels* 34, 9632-9642, 2020
M. Yazaki, C. Fushimi, Poster Award, 15th Biomass Science Symposium (JIE) 2019
R. Sato et al., APCChE 2019, Research Proposal on SDGs from Youth, Impact Award

We have developed total system for biochemical and biofuels production from woody, algal and waste biomass so that we can greatly reduce total CO_2 emission and cost. We design a biorefinery process from the view point of Green Chemistry, waste recycling. We also carry our technoeconomic analysis of the developed process.

Reaction kinetics and hydrodynamics of fluidized beds



Schematic image of circulating fluidized bed gasifier

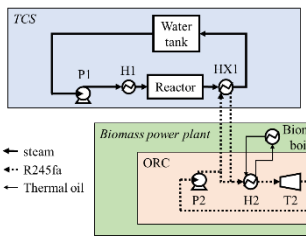


A bubbling fluidized bed reactor

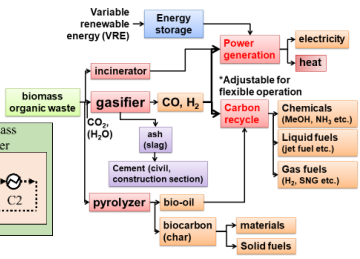
C. Fushimi, K. Yato et al., *KONA Powder and Particle J.* 38, 94-109, 2021
Chihiro Fushimi FY. 2019 Japan Institute of Energy, Academic Promotion Award, 2020
Y. Furusawa et al., *Fuel Processing Technology* 193, 304-316, 2019
W. Lian et al. *Chemical Engineering Science* 205, 259-268, 2019
S. Thangavel et al. *J. Chemical Engineering of Japan* 51, 342-348, 2018
H. Taguchi, Poster Award, 23rd Symposium on Fluidization and Particle Processing (SCEJ) 2017
C. Fushimi et al., *Fuel Processing Technology* 167, 136-145, 2017
Z. Zhao et al., *Powder Technology* 321, 336-346, 2017
M. Kobayashi, Poster Award, 22nd Symposium on Fluidization and Particle Processing (SCEJ) 2016
C. Fushimi et al., *Advanced Powder Technology*, 25, 379-388, 2014

Fluidization technology is widely used for continuous particle processing in industry. We have designed and developed conventional fluidized bed reactors and a novel downer pyrolyzer, and analyzed hydrodynamic behaviors and reaction kinetics of various fluidized beds. We have also investigated the temperature change and heat transfer rate of a bubbling fluidized bed reactor.

Development of value added thermal and biomass power plants



Biomass power plant integrated with a fluidized bed thermal storage unit for flexible operation



Valorization of biomass utilization integrated with variable renewable energy and energy storage system for flexible operation

Uchino, T., T. Yasui, C. Fushimi, *J. Energy Storage*, 61C, 106720 (14 pages), 2023
Murakoshi, R. and C. Fushimi, *J. Energy Storage*, 55B, 105586 (16 pages), 2022
T. Uchino, T. Yasui, C. Fushimi, *Energy Conversion Management*, 243, 114366 (11 pages), 2021
T. Uchino, C. Fushimi, *Chem. Eng. J.* 419, 129571 (12 pages), 2021
C. Fushimi, *Energy Fuels* 35, 3715-3730, 2021
W. Yonamine, S. Thangavel, H. Ohashi, C. Fushimi, *Energy Conv. Management* 174, 552-564, 2018
R. Hoya, C. Fushimi, *Fuel Processing Technology* 164, 80-91, 2017

To greatly reduce CO_2 emission from power generation sector, we study further improvement of thermal efficiency of thermal and biomass power plants. We also try to add new values of these plants during non-steady state operation by combining variable renewable energy for stable operation of the future power grid systems.