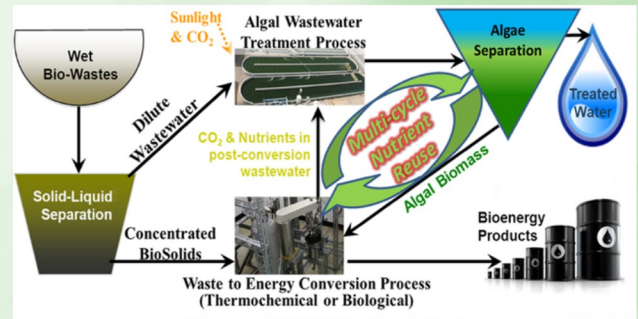


# Laboratory of Environment-Enhancing Energy, China Agricultural University

Environmental pollution and energy recovery are two main topics in the world. Biomass (e.g., agriculture cornstalk, energy crop, animal waste and algae) has the potential to produce clean and renewable fuels through new advanced technologies.

The Environment-Enhancing Energy (E<sup>2</sup>-Energy) group is an innovative research team which is affiliated to the College of Water Resources and Civil Engineering at China Agricultural University (CAU) and which focuses on producing bio-energy, promoting environmental protection and realizing sustainable development of natural resources. The concept of the E<sup>2</sup>-Energy paradigm was initially raised by Professor Yuanhui Zhang. The E<sup>2</sup>-Energy system specifically aims at producing renewable biofuels and chemicals with economical viability and environmental sustainability, while achieving net-zero carbon emissions, nutrient cycling, and maximizing resource utilization and environmental protection. According to Professor Zhang's blueprint, the purpose of E<sup>2</sup>-Energy technology is to produce hydrocarbon fuels and chemicals from bio-waste (including those generated from animals, humans and bioprocessing equipment) and algae, and at the same time to capture carbon, reuse nutrients and clean wastewater.



Environment-Enhancing Energy concept

Petroleum is formed from biomass buried underneath the ground, which is then subjected to thermochemical conversion processes over geological time. Mimicking this natural process, the E<sup>2</sup>-E system focuses on hydrothermal liquefaction of biomass into crude oil and algal production using recycled nutrients in the wastewater. The E<sup>2</sup>-Energy paradigm is split into three distinct parts: First, volatile organic solids in the bio-waste are separated and converted into biocrude oil via hydrothermal liquefaction (HTL); Second, algae is grown in the resulting wastewater to remove excess nutrients and capture carbon dioxide; Finally, the algae is fed back to the HTL reactor, as a sole feedstock or as an additive, to be converted into additional biocrude oil. This synergistic process is extremely advantageous because it brings two rivals - "Energy Production" and "Environmental Protection" - together to complement rather than to compete. It simultaneously improves water quality, captures carbon dioxide and increases biofuel yields.



**Yuanhui Zhang, PhD, PE**  
Innoventor Professor in  
Engineering at UIUC  
Professor at CAU



Liu Zhidan



Lu Haifeng



Duan Na

The E<sup>2</sup>-Energy group is led by professor Yuanhui Zhang and consists of several young potential professors and a myriad of passionate PhD and postgraduate students. The E<sup>2</sup>-Energy group was founded in 2010 and now has had a key laboratory facility at the Ministry of Agriculture in China which is equipped with advanced instruments to ensure the capability of carrying out a series of frontier scientific

studies in the field of agricultural engineering.

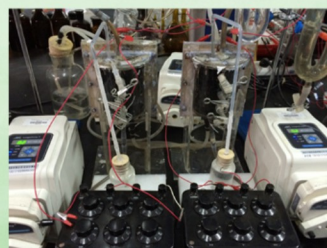
Since 2010, the E<sup>2</sup>-Energy group has been working on the following research areas: 1. Thermochemical conversion of biomass, especially hydrothermal liquefaction (HTL) technology; 2. Bioconversion technology, including biomass gasification and bio-waste anaerobic digestion; 3. Microalgal and photosynthetic bacterial cultivation technologies, which integrates into wastewater treatment and bio-waste nutrients recovery. In addition, some interesting attempts were made aimed at discovering microbial fuel cells (MFC). The E<sup>2</sup>-Energy group has successfully converted bio-waste including animal and human waste, food processing waste and algae into crude oil using thermochemical conversion much similar to mother-nature's petroleum-formation, but in a few minutes rather than geological years.



HTL reactor system



Algae cultivation



Microbial electrochemical tech



Biohythane/biogas system

## E<sup>2</sup>-Energy group's platform

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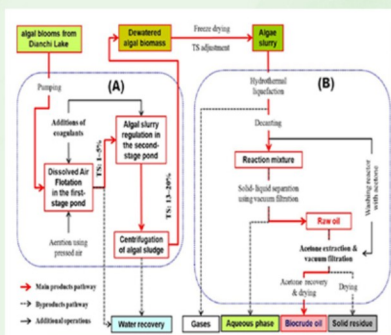
# Research Achievements and Impact of E<sup>2</sup>-Energy Laboratory, CAU

There are 24 students in the team now, 10 PhD candidates and 14 master students. Two PhD and eight master students have previously graduated. The research conducted by the Laboratory of Environment-Enhancing Energy (E<sup>2</sup>-Energy) has been supported by many funding agencies, including the National Natural Science Foundation of China, the National Key Research and Development Program of China, the Bill & Melinda Gates Foundation, the Beijing Youth Top-notch Talents Program, etc. Over 50 papers have been published in peer-reviewed journals, such as *Renew Sust Energy Rev*, *Biotech Biofuel*, *Biores Tech*, *J Cleaner Product*, *Int J Hydrogen Energy*.

Research Progress:

1. Simultaneous production of biocrude oil and recovery of nutrients and metals from biowaste via HTL and development of a continuous HTL reactor for large-scale biowaste treatment;
2. Continuous production of biohythane from hydrothermal liquefied cornstalk biomass via two-stage high-rate anaerobic reactors;
3. Algae cultivation in wastewater (post-HTL wastewater, biogas slurry) for nutrient recovery;
4. Microbial electrolysis to treat hydrothermal liquefied wastewater from cornstalk and recover hydrogen.

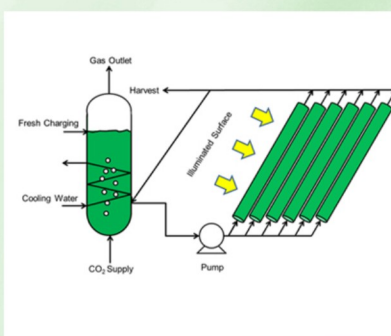
In 2013, the former member of the Standing Committee of the Political Bureau of the CPC Central Committee Song Ping inspected the Laboratory of E<sup>2</sup>-Energy, accompanied by Party Secretary Qu Zhenyuan and Principal Ke Bingsheng of China Agricultural University. Song Ping wrote the inscription for the Lab: "Save the sunlight, and make great efforts to solve the problem of food and energy for the future."



Hydrothermal liquefaction



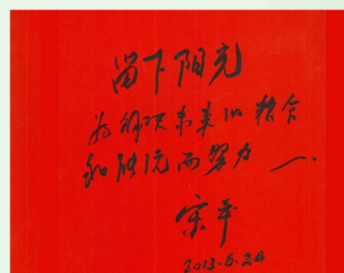
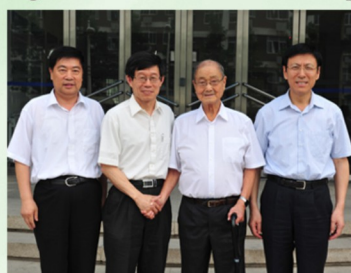
Anaerobic fermentation



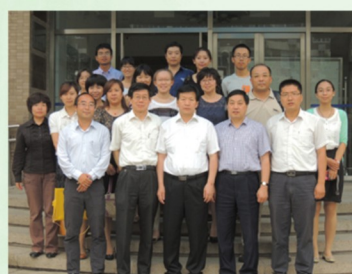
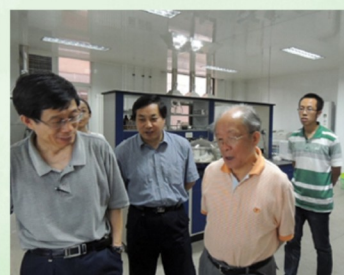
Algae cultivation



Microbial electrochemical tech



Experts inspection and international communications



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