Innovating on energy-efficient technologies

Leveraging multidisciplinary resources, researchers at Zhejiang University are leading with transformative technologies to ENHANCE RESOURCE RECYCLING AND ENERGY EFFICIENCY.

Demonstration project of a 1,000MW coal-fired power plant with ultra-low emission technology (First prize, State Technological Invention Award)

Global consensus on the future
of energy supply is all about low-carbon, diversified sources. Observing the latest trends, and catering to growing energy demands, while protecting the environment, ZJU's College of Energy Engineering (CEE) has been advancing the frontiers of energy engineering through innovation. Under the leadership of its dean, Xiang Gao, it promotes technological transfer for real-world applications.

Multi-stage coal conversion

The key to CEE's clean coal use strategy is to increase efficiency by using novel coal conversion technologies. Their new staged conversion method combines pyrolysis, gasification and combustion processes to achieve gas, tar, steam and electricity co-generation. The coal is first pyrolyzed to produce tar and gas, which can be converted into high-value chemical products, substitute natural gas, or liquid fuel. The resultant char can be burned directly in a combustor to produce steam for power generation. The utilization rate may be increased on a large scale with significantly reduced pollutant emissions.

A collaborative innovation centre on power poly-generation with staged conversion technology was established to promote academia-industry collaboration in this field, and was selected for the national '2011 plan'. With its R&D platforms, the centre developed key technologies for poly-generation through staged coal conversion system. Their work successfully addresses national demand for cleaner power from coal. A 150MW demonstration plant has been jointly constructed with an industry collaborator for power co-generation with synthetic natural gas (SNG) and liquid fuel.

Holistic management of waste to make clean energy

A team at ZJU's State Key Laboratory of Clean Energy Utilization (SKLCEU) has been searching for ways to efficiently process solid waste with minimum pollution. They found that garbage collected from Chinese households is mostly kitchen waste, with high water and alkali metal content, and low heating value. To enable stable combustion of these materials, they have developed a circulating fluidized bed boiler, in which solid waste is quickly heated, and anything not burned is recycled for combustion. This process ensures high rates of heat and mass transfer, and efficient burning.

Researchers also invented an inhibitor, and degradation technologies to minimize the generation of dioxins in the process, enabling ultra-low emissions of this pollutant. As well as lowering pollution, through these technologies, up to 80% of energy derived from waste processing can be recycled.

Minimizing air pollution

For ultra-low emission of pollutants from coal-fired utilities, researchers have devised an effective approach that efficiently removes sulphur dioxide, nitrogen oxides, particulate matters, mercury, and other pollutants simultaneously. This can reduce emission levels from coal-fired plants to that comparable with gas combustion. The technology works in complex combustion processes, offering ultra-low emission solutions for different furnaces, with varying unit capacities and loads.

CEE's technique has been used to reduce emissions from industrial boilers, and has seen broad applications in the iron and steel, and marine industries.

Further work uses ozone to remove flue gas pollutants. Taking advantage of ozone's oxidizing ability, researchers turned low-solubility pollutants into dissolvable chemicals.

They have also led or participated in developing more than 30 national and industrial standards. Such innovation promotes the development of clean electric power, and informs policy-making in China.

Efficient energy storage

Building energy storage and conversion devices or systems through plasma processes is also a focus. Plasma's high reactivity offers a unique non-equilibrium environment for advanced nanofabrication. Optimizing this process, advanced functional materials have been developed for energy use.

Based on nanoscale heat and mass transfer mechanisms, and interfacial thermodynamic theories, materials developed at CEE achieved impressive energy storage and conversion. Their supercapacitors have ultra-high energy storage power density, excellent speed, and ultrafast solar-thermal response. The roll-to-roll processes allow for large-scale plasma-assisted fabrication of nanomaterials, promising for broad applications.

They also explore technologies that store the Sun's energy as chemical energy. In thermochemical storage systems, energy can be retrieved in reverse chemical reactions using metal oxide pairs. However, these oxides have poor reversibility. The CEE team proposed a method to tune their reaction characteristics without disrupting performance.

Molten salt is also studied as a low-cost, long-life alternative for thermal energy storage. In a pilot project, researchers established a 1 MW molten salt heat storage unit, based on efficient heat transfer technologies.

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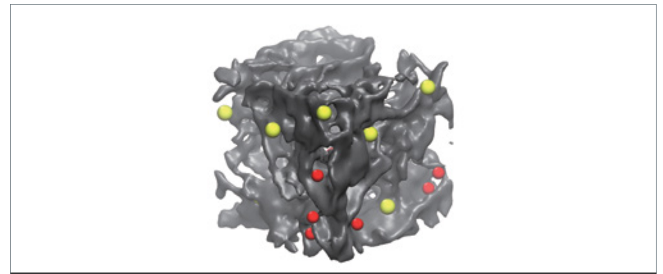
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Hydrogen generation and storage

To support large-scale generation of hydrogen, another clean fuel, the CEE team harnesses the sulphur-iodine thermochemical cycle to split water, using solar energy, nuclear energy, and industrial waste heat. Their closed system boasts great thermal efficiency. They also developed a highly active catalyst for hydrogen iodide decomposition and a hydrogen generation experiment platform, preparing for large-scale industrial use.

Hydrogen storage, however, typically needs pressurized vessels which are difficult to prepare. To ensure safety and efficiency, they invented a 140 MPa device for *in-situ* testing for hydrogen embrittlement. Based on a thin liner technique, they developed multi-layered high-pressure hydrogen storage vessels, which have been used in refuelling stations across China. Their 98MPa steel vessel, with a volume of $1m^3$, is the world's largest of its kind.

Energy-saving gas supply

Another research area is high-quality, stable gas supply. Standard cryogenic air separation systems, while capable of producing high-purity gases, use a great deal of energy. CEE researchers studied physical mechanisms, key components and system integration of large-scale cryogenic air separation systems. They proposed a magnetic-driven approach for enhancing cryogenic distillation, a core process in air separation. To improve the air compressor, a major energy drain, they developed a solution using combined organic Rankine and vapour compression refrigeration cycles for recovering the wasted compression heat. The method may save up to 5% of the total compression energy consumption, showing good potential, and already seeing industrial applications.

Synchronizing growth

To build a sustainable future, CEE's five dedicated research institutes are exploring frontier fields. Their high-fidelity numerical models and computational methods enable multidisciplinary exploration of multi-scale coupling mechanisms.

Advanced optical techniques for smart energy system diagnostics — for example spectroscopy, light scattering, and imaging — are capable of measuring fuel flow field, combustion temperature and other properties non-intrusively. These data can achieve optimal system operation in combination with other techniques such as big data and artificial intelligence.

They developed a thermoacoustic engine to initiate oscillation at near-ambient temperatures, essential for low grade heat recovery. The engine's acoustic power allows pulse tube refrigerators to achieve temperatures as low as 40K, promising for use in liquefying natural gas or coalbed methane. To optimise design and control of multi-source power systems for vehicles and vessels, CEE developed energy-saving systems, intelligent network technologies, and techniques to improve safety, reliability and comfort. ■

Rapid development

Since 1978, CEE has become China's centre for innovation in energy sciences and technologies, and a hub for international exchange.

- **Five** research institutes, covering Thermal Power Engineering, Process Equipment, Refrigeration and Cryogenics, Power Machinery & Vehicle Engineering, and Thermal Science & Power Systems
- **Six** national-level and **eight** provincial-level research platforms
- **14** State Scientific and Technological Progress Awards, **seven** State Technological Invention Awards, and **one** State Natural Science Award
- Undertaken **100-plus** national-level key research projects
- Published **300-plus** articles in SCI journals annually for the past three years
- Awarded more than **125** patents annually in the past three years
- **14** international joint research centres and **11** joint centres with industries

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