Biofuels Production and Development in China

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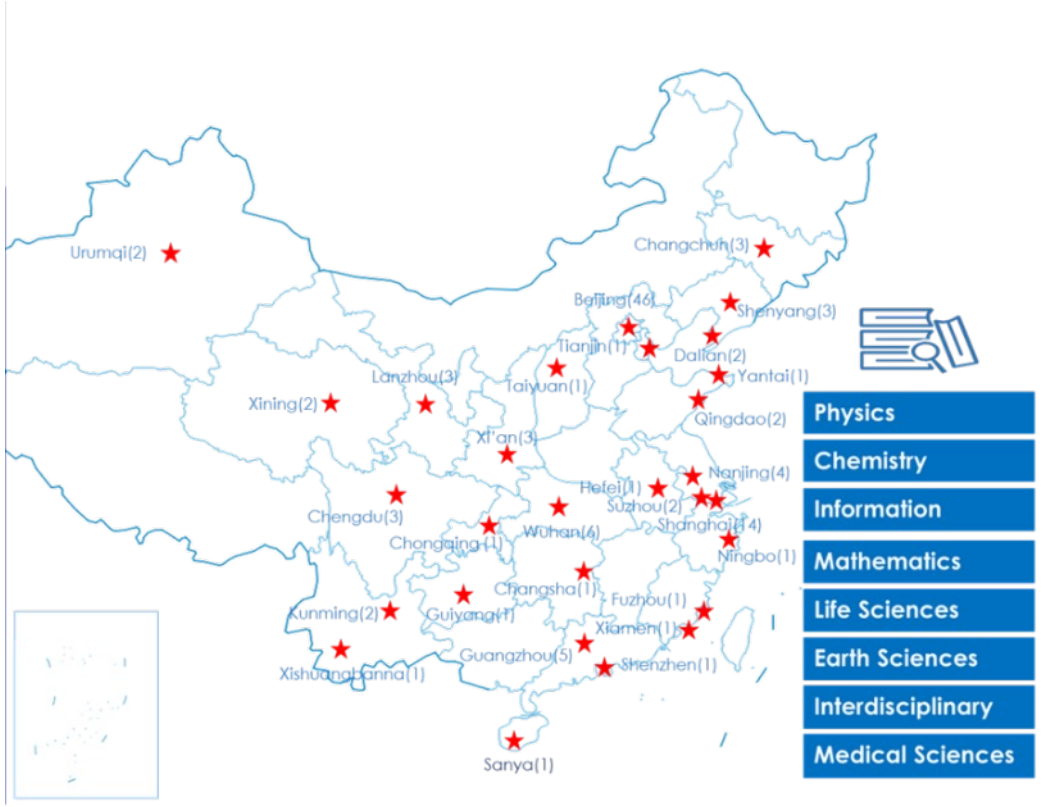
Qingdao Institute of Bioenergy and Bioprocess Technology
Chinese Academy of Sciences

IEA Bioenergy
Technology Collaboration Programme
Task 39

中国科学院
CHINESE ACADEMY OF SCIENCES

Three IN One

1. research & development system
2. a merit-based academic society
3. higher education function



International Outreach Initiative---
9 overseas research organizations

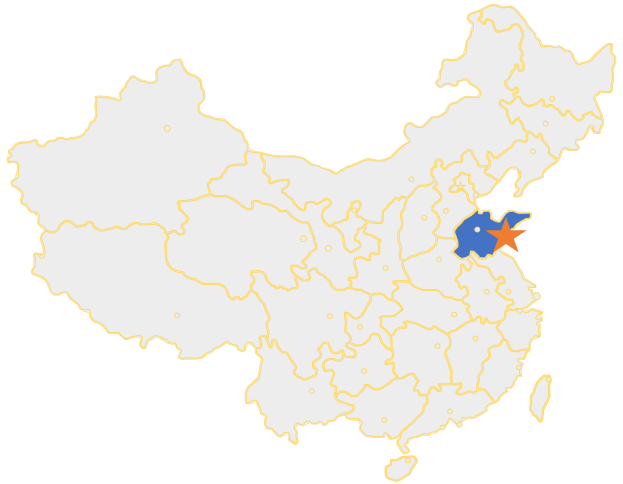
106 *research institutes*

800 *Members*
92 *Foreign Fellows*

3 *Universities*
70,000+ *students*

Qingdao Institute of Bioenergy and Bioprocess Technology, CAS

- Qingdao is located at China east coast in Shandong Province;
- Aim for biofuel R&D since 2006



17/9/2006, QIBEBT co-construction Agreement signed by CAS, Shandong, and Qingdao

Campus and Demonstration Sites

2 campus +
1 demonstration sites

Main Campus

73,260 m^2 area

Pilot Plant

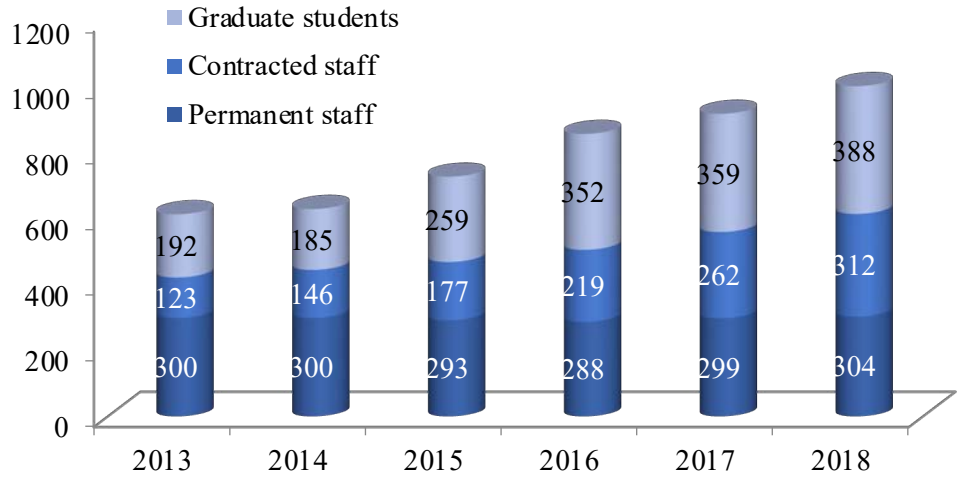
67,000 m^2 area
13 pilot-scale projects

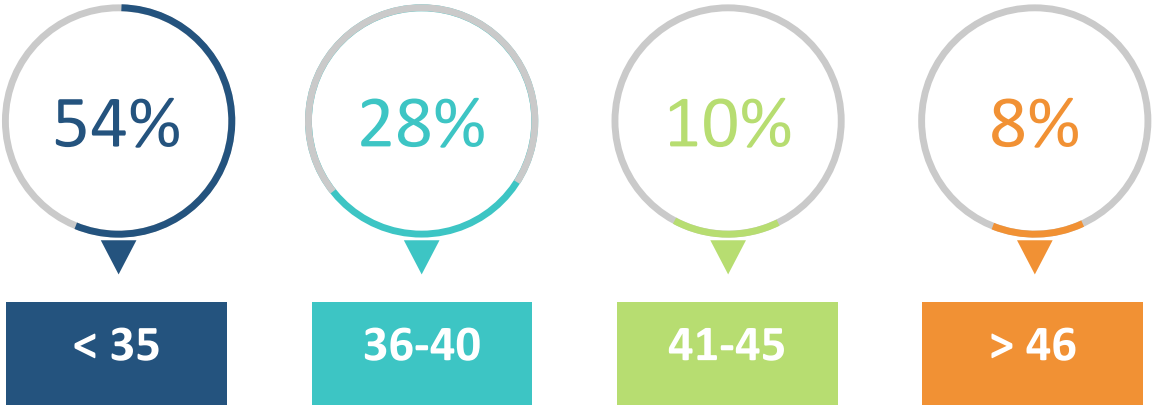
New Campus

100,700 m^2 area

Human Resource

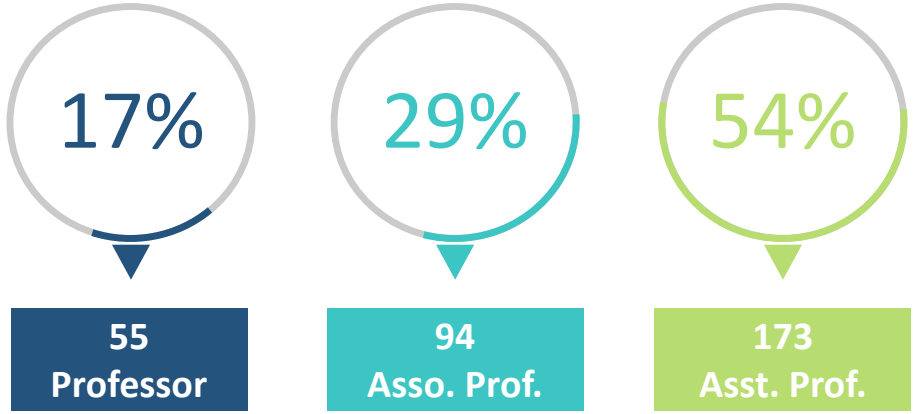
- 1500+ staff and students
- 90% of professors have overseas background
- Average age of full employees is 37





Age of Staff

Average age 37



Research staff

20+ National Talent Award

International Cooperation

Multi-level cooperation with over 70 global and domestic institutes, universities and companies:

- Joint laboratories
- Academic exchange and training
- Collaborative research projects
- Regular seminars and conferences

Research Priorities

新生物

Frontier Biotechnology

- Gene editing technology
- Single-cell analysis technology
- Synthetic biotechnology
- Microbiome technology
- Metabolic engineering
- Featured bio-resources and scale cultivation
- High value biological function products

新能源

Renewable Energy

- Biogas
- Jet fuel and biofuel conversion technologies
- New organic solar cells
- Perovskite solar cells
- Large-capacity advanced physical storage
- High-power high-density advanced chemical storage

新材料

Advanced Materials

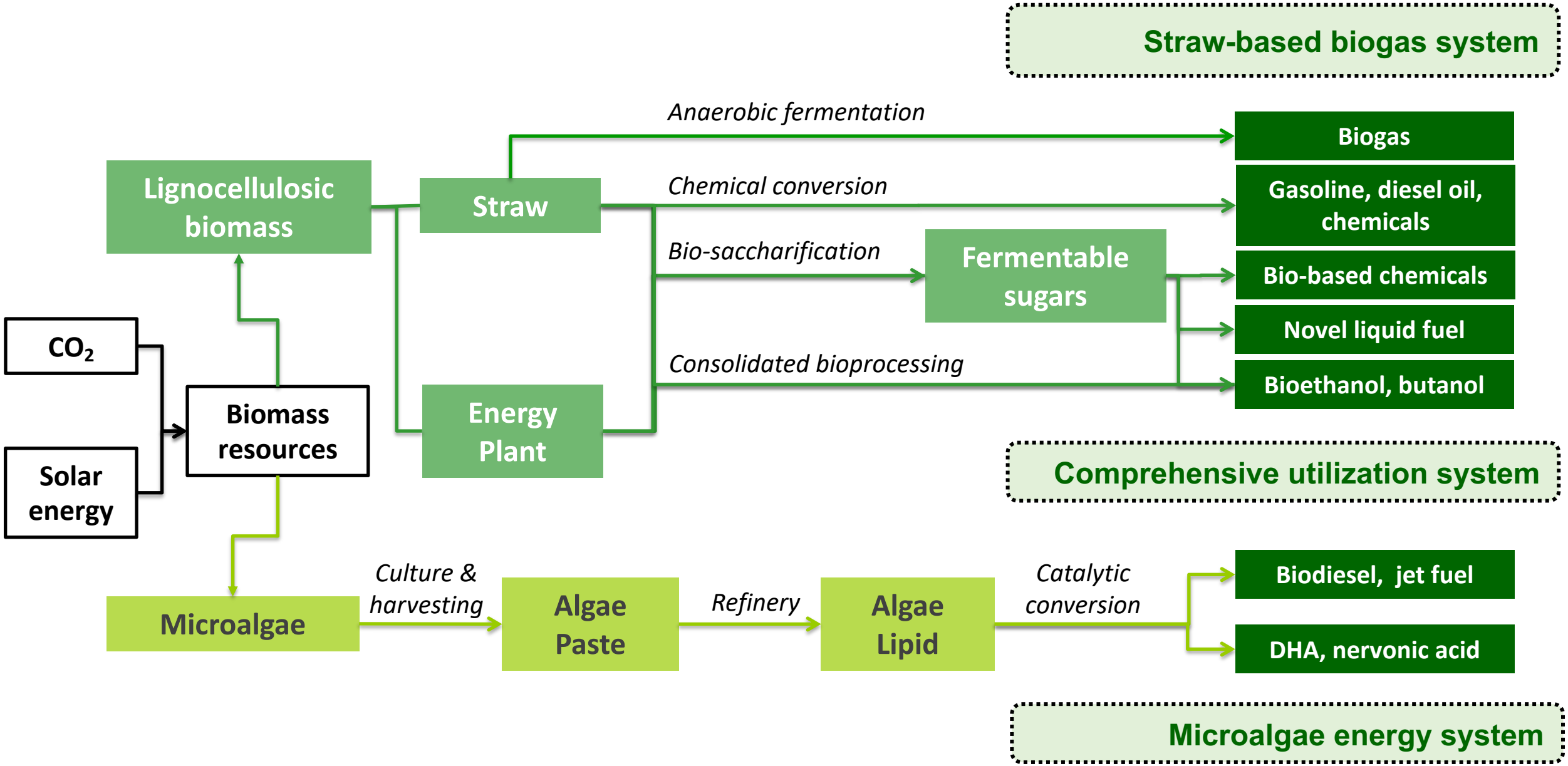
- Biomass-based new materials
- Carbon-based new materials
- Smart bionic new materials
- High-performance membrane materials
- Advanced composite materials

Fundamental Science

Applied Research

Technology Solutions

Bioenergy Solutions at QIBEBT



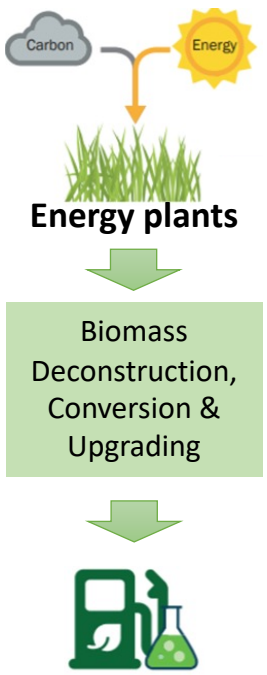
1. Energy plant / microalgae

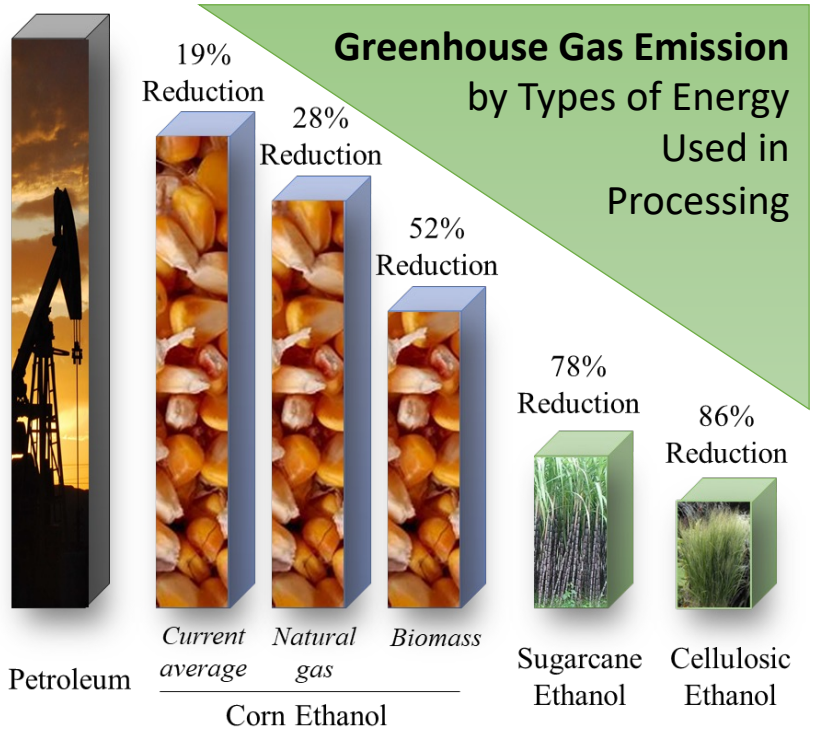

Prof. Xuefeng Lu


Prof. Chunxiang Fu


Prof. Shengjun Li

➢ **Current Commercialization Status**



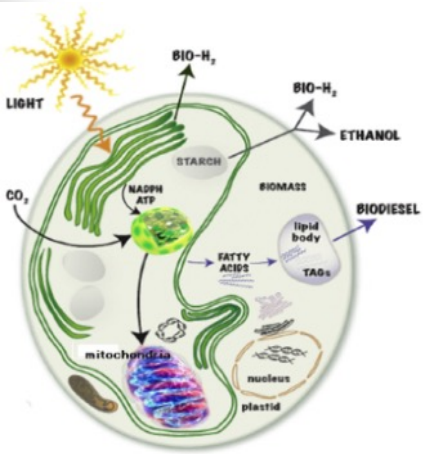


Source: www1.eere.energy.gov/biomass

- Agriculture waste biomass in China: 0.7 billion t/a ≈ 0.35 billion t/a standard coal
- Energy crops including switchgrass, miscanthus, *Arundo donax* L. (**10-30 ton/ha)** are good at storing carbon in soils and can be cultivated on **marginal lands**
- Utilization of energy crops as cellulosic biomass for ethanol production (**30-65 gallons ethanol per dry ton**) **largely reduce the greenhouse gas emission**

1. Energy plant / microalgae

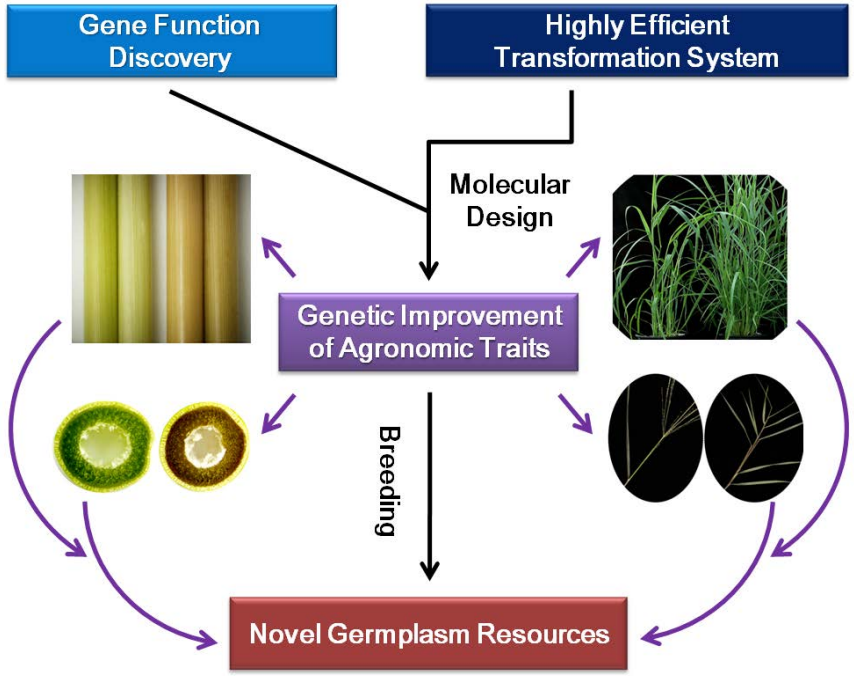
➢ Technical Challenges and R&D



Resistance

Yield

Quality



- Highly efficient **transformation and genome editing** technology system **(>30%)** for energy crop switchgrass
- Rapid platform to characterize **target genes (50-100 genes /person/year)** in switchgrass

2. BioEthanol

Environmental impact

Journal of Cleaner Production 397 (2023) 136492

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

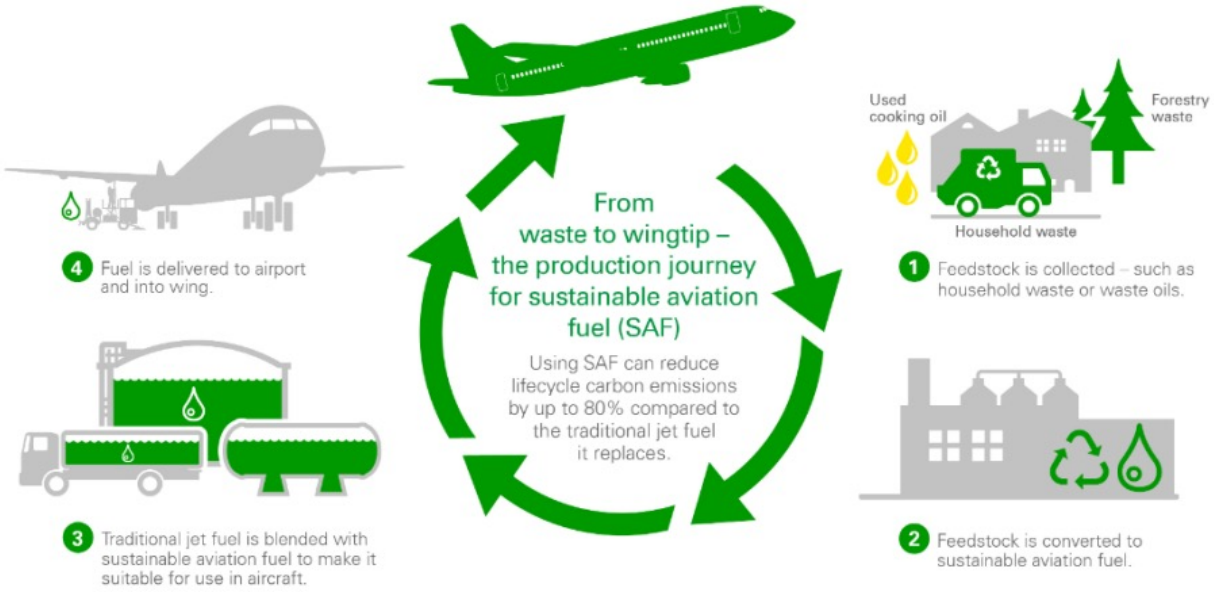
Life cycle assessment of bio-fermentation ethanol production and its influence in China's steeling industry

Lingyun Zhang [a,b], Qun Shen [a,*], Cheng Heng Pang [b], Wei Chao [c], Shuhuan Tong [c], Kien Woh Kow [b], Edward Lester [d], Tao Wu [b], Li Shang [a], Xuehang Song [a], Nannan Sun [a,***], Wei Wei [a,e,**]

[a] CAS Key Laboratory of Low-Carbon Conversion Science & Engineering, Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai, 201210, PR China
[b] Department of Chemical and Environmental Engineering, Faculty of Science and Engineering, University of Nottingham Ningbo China, Ningbo, 315100, PR China
[c] Beijing Shougang LanzaTech Technology Co., Ltd, Beijing, 100000, PR China
[d] Department of Chemical and Environmental Engineering, University of Nottingham, Nottingham, NG7 2RD, UK
[e] School of Physical Science and Technology, ShanghaiTech University, Shanghai, 201210, PR China

LDG-ethanol environmental impact value (0.41) is 22%-25% lower than that of Corn-ethanol (0.53) and Coal-ethanol (0.55)

Ethanol to Sustainable Jet Fuel and Ethylene



China produced 37,470 kilotons ethylene in 2021, consumed 58,320 kiloton, imported 20,850 kilotons

2. BioEthanol

Large Demand: E10 gasoline in China (10 million tons needed)

Table 2. China: Ethanol Production, Supply, and Distribution

Ethanol Used as Fuel and Other Industrial Chemicals (Million Liters)										
Calendar Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Beginning Stocks	0	0	0	0	0	0	0	0	0	0
Fuel Begin Stocks	0	0	0	0	0	0	0	0	0	0
Production	5,795	6,921	7,868	8,071	9,211	9,770	10,740	10,830	10,580	11,850
Fuel Production	2,934	2,951	2,914	2,534	3,041	2,914	4,339	3,801	3,421	3,804
>of which fossil-based synthetic	0	0	0	0	0	0	0	30	30	40
>of which biobased	2,934	2,951	2,914	2,534	3,041	2,914	4,339	3,771	3,391	3,764
>of which biobased cellulosic	25	25	38	40	30	20	0	0	0	0
Imports	0	27	687	890	24	1,035	104	69	824	10
Fuel Imports	0	26	477	871	8	759	0	63	550	5
Exports	40	33	25	34	135	79	21	367	13	10
Fuel Exports	2	2	0	1	3	35	7	21	0	2
Consumption	5,755	6,915	8,530	8,927	9,100	10,726	10,823	10,532	11,391	11,850
Fuel Consumption	2,932	2,975	3,391	3,404	3,046	3,638	4,332	3,843	3,971	3,807
Ending Stocks										
Fuel Ending Stocks										
Refineries Producing First Generation, Bio-based Fuel Ethanol (Million Liters) 1/										
Number of Refineries	6	7	7	10	11	12	14	20	22	22
Nameplate Capacity	3,000	3,200	3,200	3,600	4,200	5,000	5,257	6,578	7,720	7,720
Capacity Use (%)	97%	91%	90%	69%	72%	58%	83%	57%	44%	49%
Refineries Producting Cellulosic Fuel Ethanol (Million Liters) 2/										
Number of Refineries	1	3	3	1	1	1	1	1	1	1
Nameplate Capacity	50	129	129	65	65	65	65	65	65	65
Capacity Use (%)	50%	19%	29%	62%	46%	31%	0%	0%	0%	0%
Co-product Production (1,000 MT)										
DDGs	1,652	1,661	1,640	1,427	1,598	1,536	2,796	2,436	2,279	2,471
Feedstock Use for Fuel Ethanol (1,000 MT)										
Corn Kernals	5,277	5,308	5,241	4,558	5,105	4,542	6,763	5,426	4,229	4,694
Rice Kernals						364	2,170	2,357	3,052	3,199
Cassava (dried chips)	2,203	2,215	2,188	1,902	2,283	2,188	1,303	1,132	1,018	1,469
Wheat	na	na	na	na	387	371	552	480	173	96
Celluloic Biomass	na	na	na	na	na	na	na	na	na	na
Fossil Fuels/Waste Gas	na	na	na	na	na	na	na	na	na	na
Market Penetration (Million Liters)										
Fuel Ethanol Use	2,932	2,975	3,391	3,404	3,046	3,638	4,332	3,843	3,971	3,807
Gasoline Pool 3/	130,017	135,837	157,490	164,502	170,477	182,197	193,853	191,631	211,207	209,357
Blend Rate (%)	2.3%	2.2%	2.2%	2.1%	1.8%	2.0%	2.2%	2.0%	1.9%	1.8%

Notes: f = forecast
Corn kernels: 1 MT = 402 (before 2014) to 417 liters (after 2014)
Rice: 1 MT = 400 liters
Wheat kernels: 1 MT = 393 liters
Sorghum (Sweet) 1 MT = 430 (used in 2014 Baseline)
Cassava (fresh root): 1 MT = 143 to 150 liters (25 to 35% starch content)
Cassava (dried chips): 1 MT = 333 to 400 liters (15 to 65% starch content)
Sources: Post estimates and industry sources

Table 3. China: Production Capacity of China's Fuel Ethanol Licensed producers (2022 estimates)

	Producers	Production Capacity	Feedstock
1	SDIC Jilin Alcohol	887 million liters	Corn
2	Henan Tianguan	887 million liters	Wheat, Corn, Cassava
3	COFCO Biochemical (Anhui)	798 million liters	Corn, Cassava
4	COFCO Bioenergy (Zhaodong)	507 million liters	Corn, Cellulosic
5	SDIC (Zhanjiang)	190 million liters	Cassava
6	Shandong Longlive	65 million liters	Cellulosic
7	COFCO Bioenergy (Guangxi)	253 million liters	Cassava
8	Zonergy (Inner Mongolia)	38 million liters	Sweet Sorghum
9	SDIC (Tieling)	380 million liters	Corn
10	Liaoyuan Jufeng Biochemical	380 million liters	Corn
11	Jilin Boda Biochemistry	507 million liters	Corn
12	Jiangsu Lianhai Biotechnology	152 million liters	Corn
13	Shandong Fu'en Biochemical	152 million liters	Cassava
14	Jiangxi Yufan	127 million liters	Cassava
15	Shougang Lanza Tech	58 million liters	Coal, Waste Residues, Industrial Flue Gases
16	SDIC (Hailun)	380 million liters	Corn
17	Wanli Runda (Baoqing)	380 million liters	Corn
18	Hongzhan (Nehe)	380 million liters	Corn
19	Hongzhan (Huanan)	380 million liters	Corn
20	Ningxia Shougang Lanza Jiyuan	57 million liters	Coal, Waste Residues, Industrial Flue Gases
21	Hongzhan (Bayan)	380 million liters	Corn
22	SDIC (Jidong)	380 million liters	Corn
	TOTAL	**7,720 million liters**	

Source: Post Industry Sources

- Depressed import & export
- Sufficient domestic supply
- Mainly grain-ethanol
- Tax credit phased out

Source: General Administration of Customs of the People's Republic of China

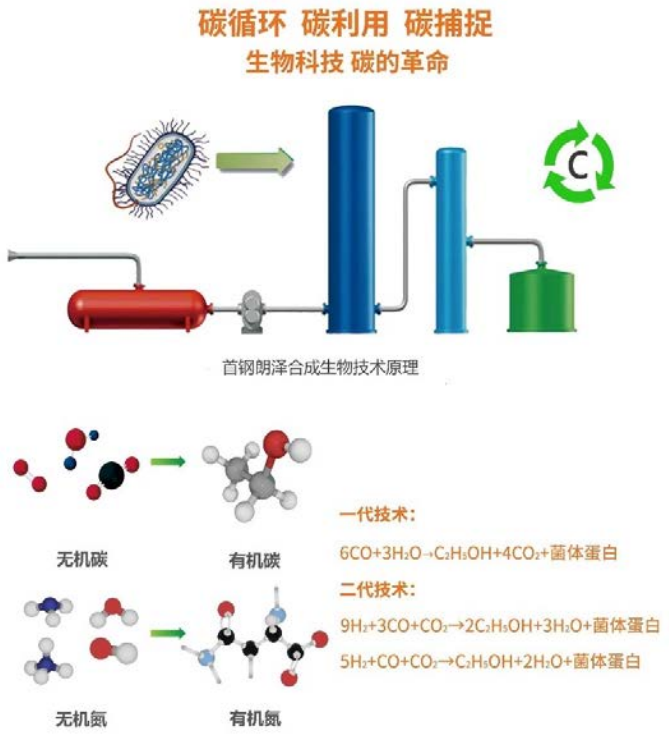
BioEthanol from Industry Flux Gas

Prof. Fuli Li

➢ Current Commercialization Status

Syngas to ethanol

- ✓ 90 billion m^3 steel industry, coal chemical
- ✓ Shougang Lanza Tech: 4 sets of 45,000 t/a
  - ✓ 1 at Caofeidian 2018
  - ✓ 2 sets in Ningxia 2021
  - ✓ 1 in Guizhou 2022)
- ✓ Jupeng & Lu'an Co. : 20,000 t/a (under construction since 2018)



➢ Technical Challenges

Gas-Liquid Mass Transfer, Metabolic Efficiency, Feedback Inhibition, Different industry flux gas or thermal pyrolysis of biomass

➢ Research & Development

- ✓ Strain Modification
- ✓ Medium Optimization
- ✓ Bioreactor Improvement (SinoPec, RongXin Coal Chemical Co.).

BioEthanol from lignocellulose



Prof. Qiu Cui Prof. Ya-Jun Liu Prof. Bin Li

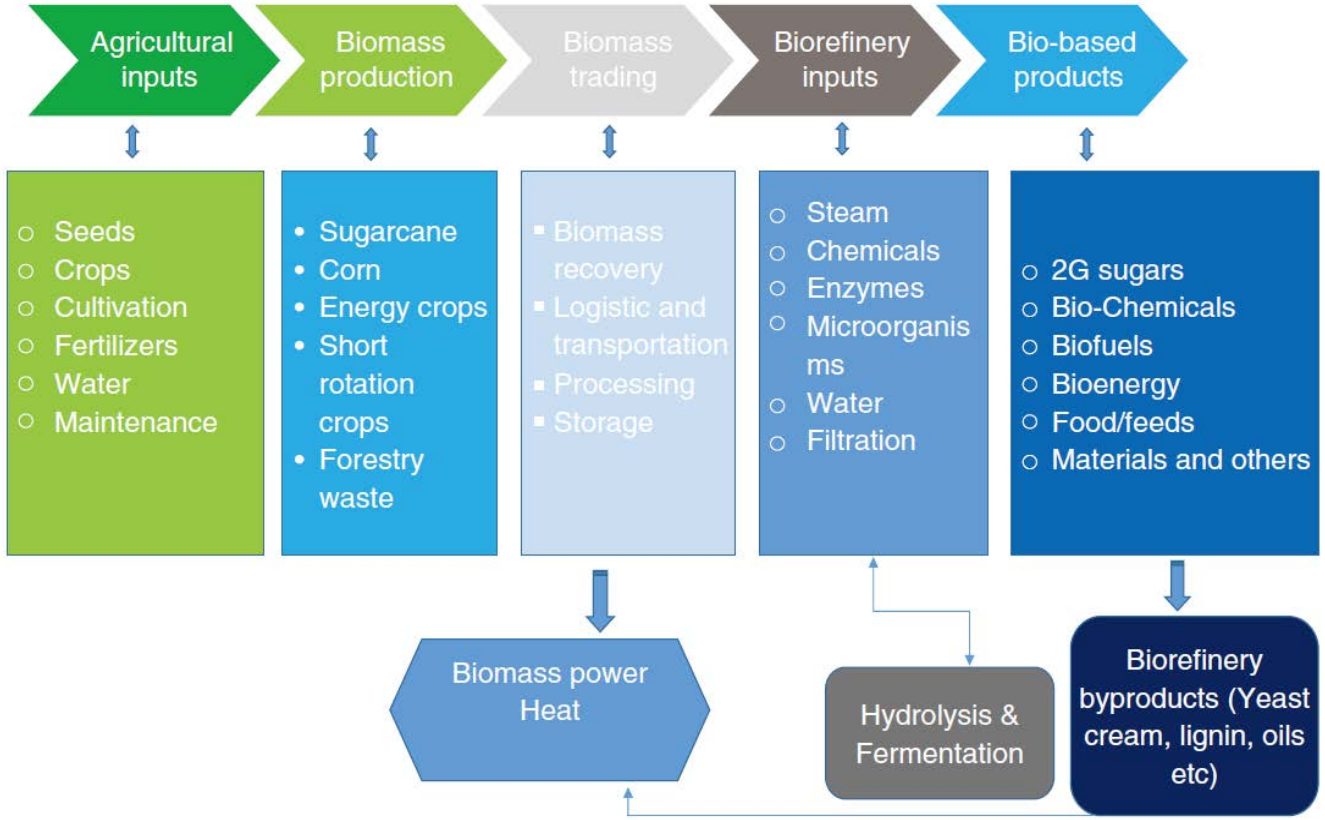
➢ **Current Commercialization Status**

Table 6. China: Suspended or Planned Cellulosic Ethanol Production Capacity (2022 estimates)		
Producers	**Production Capacity**	**Status**
COFCO Biochemical (Zhaodong)	6.3 million liters	Announced in 2006
Jinan Shengquan	25 million liters	Announced in 2012
Shendong Zesheng	25 million liters	Announced in 2012
Xin Tianlong (Jilin's Siping)	n/a	Announced in 2015
Meijie Guozhen (Anhui's Fuyang)	230 million liters	Announced in 2017
Shandong Longlive	65 million liters	Production suspended
SDIC Jilin Alcohol	101 million liters	Planned
COFCO Biochemical (Anhui's Bengfu)	127 million liters	Planned
SDIC Hailun	38 million liters	Planned
Hebei Yigao	304 million liters	In Trial
Source: Post Industry Sources		

- All facilities producing cellulosic ethanol use on-site or off-site produced fungal cellulases for cellulose saccharification.

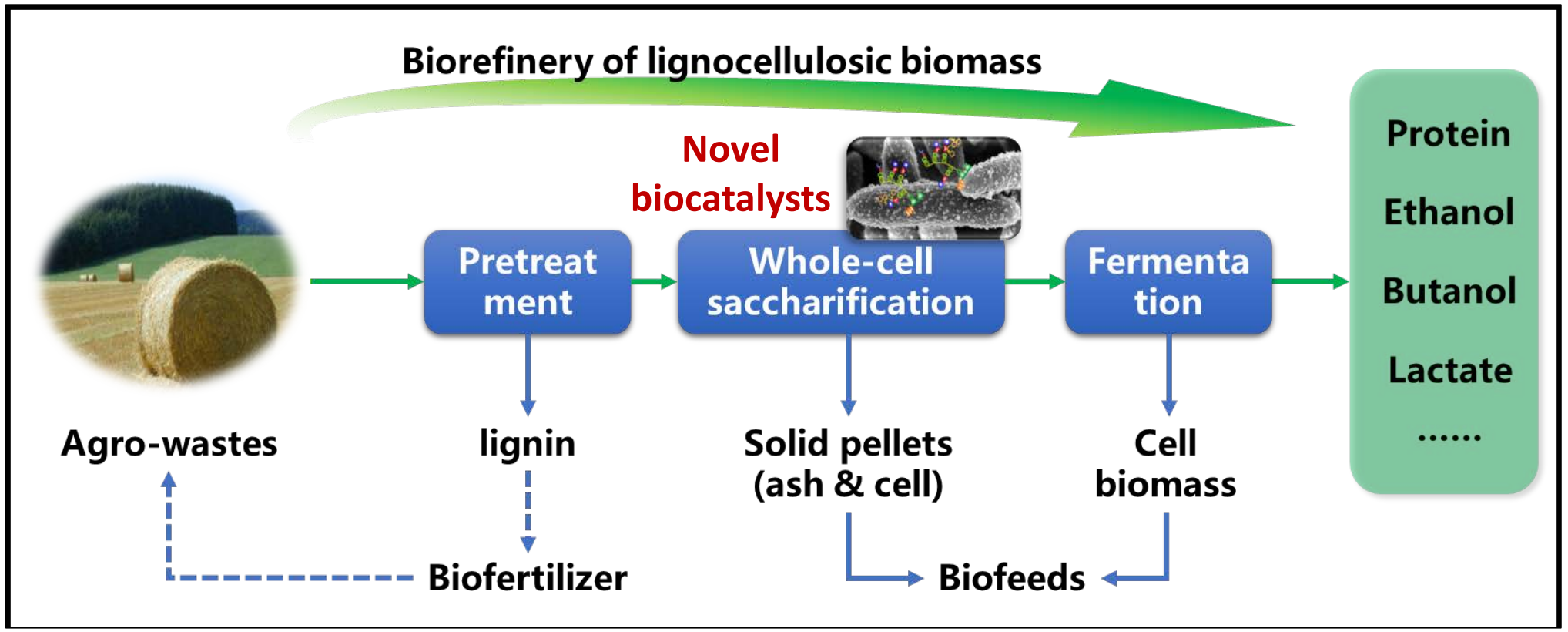
➢ Technical Challenges

- **Feedstock**: collection, high cost of long-distance transport; season-dependent harvest requires large space for storage; quality control
- **Lignocellulose saccharification and comprehensive utilization**: For China, cost-efficient saccharification technology is critical. Lignin utilization is essential for enhancing the value of the whole technology chain.
- **Process cost and cleanliness**: The coupling of pretreatment, saccharification, fermentation, and lignin utilization would reduce the process cost. The recycling of wastewater in a single process or among different processes would enhance cleanliness.



Chandel AK, et al. Comparative analysis of key technologies for cellulosic ethanol production from Brazilian sugarcane bagasse at a commercial scale. **Biofuel Bioprod Biorefin 2019**, 13(4)**:** 994-1014.

Research & Development



QIBEBT has developed novel lignocellulose saccharification technology using thermophilic and cellulosome-producing *Clostridium* strains as the whole-cell biocatalyst.

3. Catalytic Conversion of oil and fat to Biodiesel

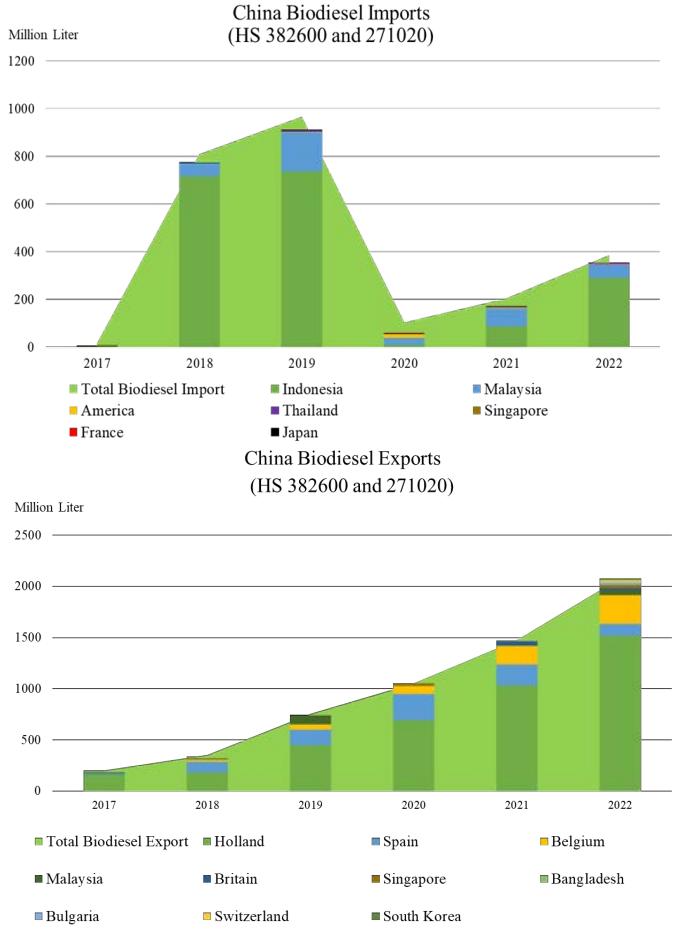
Prof. Xuebing Li Prof. Song Chen

➢ **Current Commercialization Status**

Table 4. China: Biodiesel Production, Supply, and Distribution

Biodiesel (Million Liters)										
Calendar Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022f
Beginning Stocks		0	0	0	0	0	0	0	0	0
Production	1,079	1,133	787	909	1,043	834	939	1,455	1,835	2,430
Imports	895	1,028	33	8	18	853	953	102	204	295
Exports		43	27	76	194	357	752	1,035	1,475	2,125
Consumption	1,974	2,118	793	841	867	1,330	1,140	522	564	600
Ending Stocks										
Production Capacity (Million Liters)										
Number of Biorefineries	53	53	53	48	46	44	40	42	44	46
Nameplate Capacity	4,000	4,000	4,000	2,680	2,680	2,680	2,680	2,726	2,800	4,700
Capacity Use (%)	27.0%	28.3%	19.7%	33.9%	38.9%	31.1%	35.0%	53.4%	65.5%	51.7%
Feedstock Use (1,000 MT)										
UCO	1,055	1,108	771	891	1,022	816	918	1,426	1,798	2,381
Market Penetration (Million Liters)										
Biodiesel, on-road use	324	340	236	273	313	410	430	250	260	276
Diesel Pool , on-road use	133,383	133,365	134,375	130,564	130,538	126,898	135,370	136,149	141,000	139,828
Blend Rate (%)	0.2%	0.3%	0.2%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%	0.2%
Diesel Pool, total 1/										

Note: Fuel pools are defined as fossil fuels plus all "bio-components" (biofuels) blended with fossil diesel.
f = forecast; All PSD data are B100 or B100-equivalent (see statistical info section of Reporting Instructions).
Used cooking oil (UCO):1 MT = 1,043 liters of UCOME (UCO methyl ester)
Source: Post and Industry sources



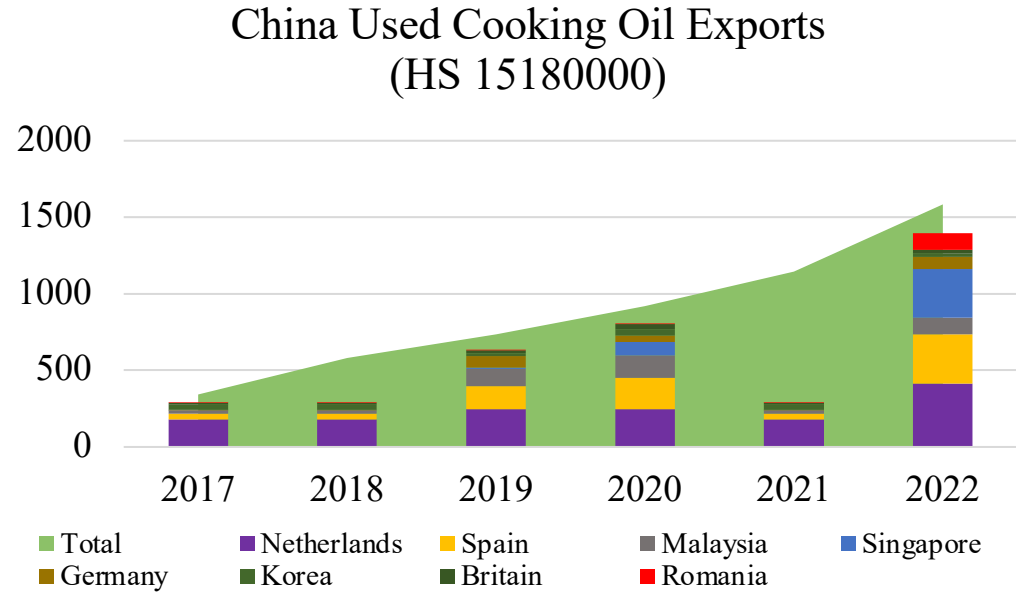
Source: General Administration of Customs of the People's Republic of China

➢ Technical Challenges

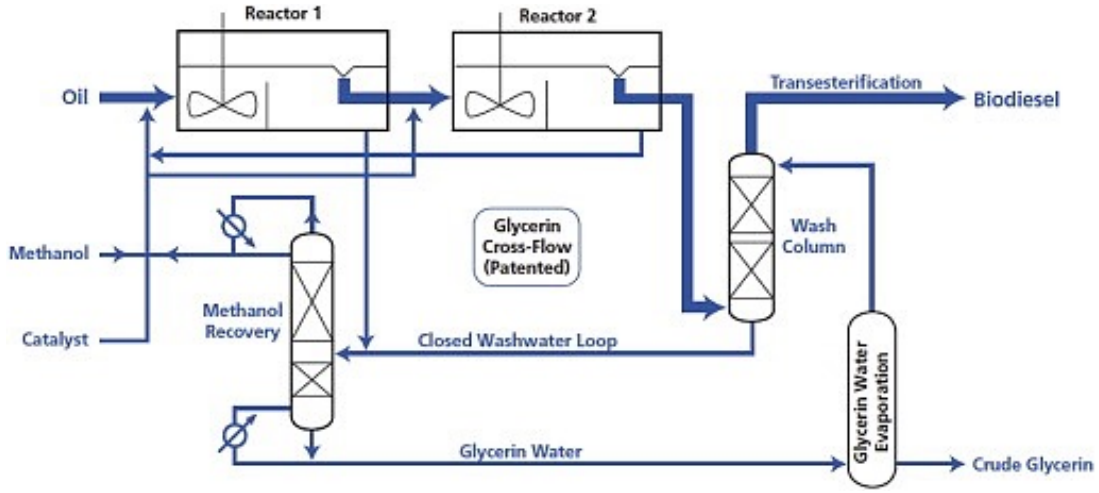
- Corrosivity of Feedstocks and Catalysts
- Impurities in Feedstocks
- Catalyst Life

➢ Research & Development

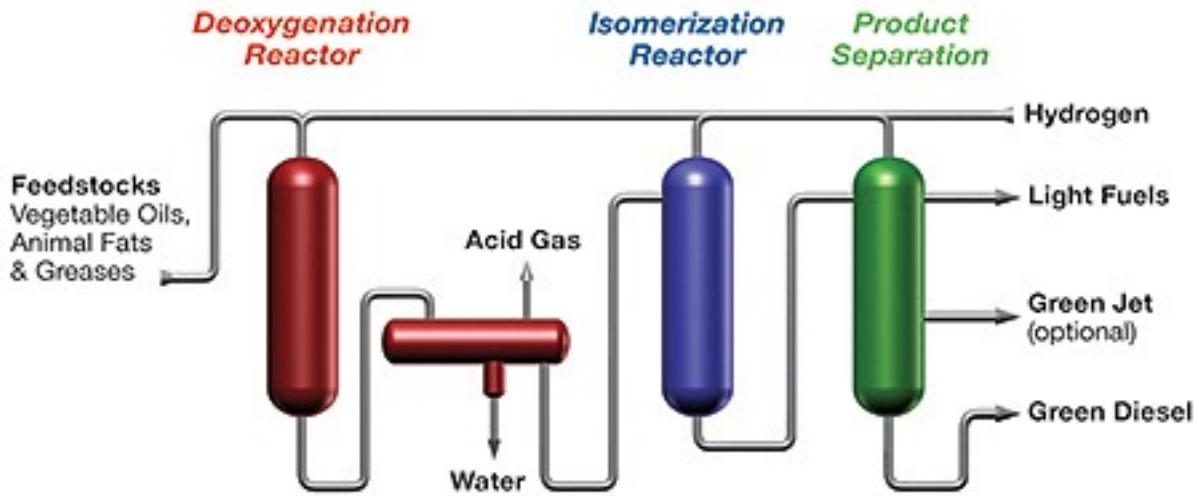
- Catalyst Exploration (Solid acid/base catalysts)
- Process Optimization (Slurry-bed hydrogenation)
- Bioreactor Improvement



Source: General Administration of Customs of the People's Republic of China



Representative: 1st Generation Biodiesel -- Lurgi Process



Representative: 2nd Generation Biodiesel -- Eco-fining Process

[1] *REN21, Renewables 2021 Global Status Repot.*

4. Bio Jet Fuels and Green Methanol

Prof. Jinhu Wu

Prof. Guanghui Wang

- **Current Commercialization Status**
  - ✓ Hydroprocessing of triglyceride (Sinopec, 2022, 100,000 t/a);
  - ✓ Annex A2 (HEFA SPK) fat hydrogenation
  - ✓ Bio Jet Fuel certificate of airworthiness approved by China Civil Aviation Administration
  - ✓ Asia RSB Sustainable Aviation Fuel Certificate Approved by SCS

SCS Global Services does hereby certify that an independent assessment has been conducted on behalf of:

SINOPEC Zhenhai Refining & Chemical Company

Jiaochuan Street, Ningbo, Zhejiang 315207, China

Has demonstrated the operation of a management system that is compliant with the requirements of:

Roundtable on Sustainable Biomaterials

Standard(s): **RSB Global: RSB-STD-01-001 V3.0, RSB-PRO-20-001 V3.2, RSB-PRO-30-001 V3.3, RSB-PRO-50-001 V3.5, RSB-PRO-60-001 V3.3, RSB-STD-01-003-01 V2.3, RSB-STD-01-010 V2.3**

RSB

CB Registration No. 592

The scope of this certificate shall be limited to:

1 Industrial Processor: SAF facility

1 First Collector

[Confidential #] Points of Origin

Input: Used Cooking Oil

Output: Sustainable Aviation Fuel

RESPONSIBLE BIOMATERIALS CERTIFIED SCS GLOBAL SERVICES RSB

This RSB certificate was issued under accreditation by a RSB recognized certification body for compliance with the RSB standards and the RSB certification systems.

Certificate Code: **SCS-RSB/PC-0048**

RSB Participant Code: **2217**

Valid from **6 April 2022 to 5 April 2027**

This RSB certificate is only valid if duly registered in the RSB database(s) of registered RSB certificates and that the validity of this RSB certificate shall be verified in the RSB database(s) of registered RSB certificates. Please see http://rsb.org/certification/participating-operators/. This certificate itself does not constitute evidence that a particular product supplied by the certificate holder is certified to RSB standards. This certificate shall remain the property of SCS, and all copies and reproductions shall be returned to SCS immediately upon request. Products offered, shipped or sold by the certificate holder can only be considered covered by the scope of this certificate when the

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Biomass to High Quality Jet Fuels (B2HQJF)

➢ Technical Challenges

- Raw materials limitation. Raw materials, like Fat, Oil, collected difficultly and expensive
- Composition deficiency. Oil molecules are most chain hydrocarbons
- Maximum addition limitation. Less than 50% in practical applications.

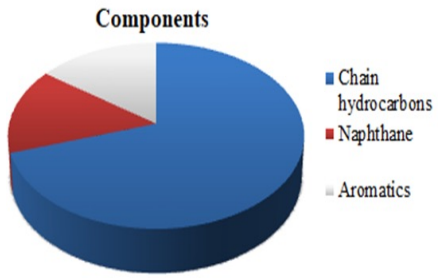
Synthetic blending component in aviation fuels	Main molecules structure in components	Preparation routes /Raw materials	Other detail requirements (wt%)	Blending component addtion limited（v%）
Annex A1 (FT SPK)	Linear hydrocarbons	Fischer- Tropsch Synthesis /coal, woods	Cycloparaffins ≤15%, Aromatics ≤0.5%	**≤50%**
Annex A2 (HEFA SPK)	Linear hydrocarbons	Fat hydrogenation/fat	Cycloparaffins ≤15%, Aromatics ≤0.5%	**≤50%**
Annex A3 (SIP)	Iso-paraffins	Hydrogenation of fermentable sugars/ sugars	Saturated hydrocarbons ≥98%, Aromatics ≤0.5%	**<10%**
Annex A4 (FT SPK/A)	Linear hydrocarbons, Aromatics	Fischer- Tropsch Synthesis, light hydrocarbon aromatic/coal, woods	Cycloparaffins ≤15%, Aromatics ≤20%	**≤50%**
Annex A5 (ATJ-SPK)	Linear hydrocarbons	Alcohols dehydration-oligomerization/Alcohols	Cycloparaffins ≤15%, Aromatics ≤0.5%	**≤50%**

➢ Research & Development in QIBEBT

- A 100 t/a pilot scale system run since April 2023. Producing 1 ton jet fuel may need about 10 tons biomass.
- The obtained oil contained all the components that jet fuel should be needed. It will provide possibilities for 100% bio-jet fuel applications.

Biomass to High Quality Jet Fuel via Gasification-Synthesis Route

Pilot scale system



Components of crude oil

- ➢ Cost reduction
  - ➢ Gasified-synthesis technology expanded the raw material of biomass.
  - ➢ Chemical looping gasification technology did not need the use of air separation.
- ➢ Supplementary component
  - ➢ Two step synthesis technology supplemented the components of the jet fuel (aromatics, cycloalkane, etc.).

Green Methanol

- Green electronic power to methanol & biomass to methanol;
- First methanol powered ship (49.9 kiloton) produced by China State Shipbuilding Co. Lit on June 20, 2022;
- It can reduce 75% CO_2 emission, 15% NOx, 99% sulfur etc.
- Shanghai Harbor supply methanol since 2023

- ✓ Geely Auto & Shuncheng Group: 1st 100 kiloton green methanol plan
- ✓ Will utilize 360 million m^3 of coke oven gas per year, produce 110,000 tons of methanol and 70,000 tons of co-produced Liquid Natural Gas (LNG) annually.
- ✓ Technology transferred from Iceland
- ✓ To power 300 heavy trucks on Feb 21, 2023

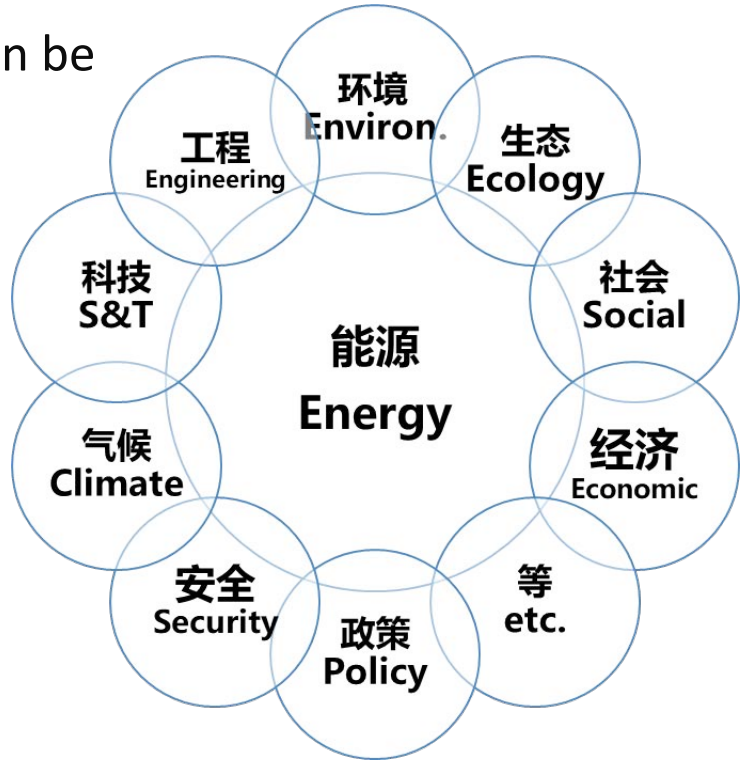
5. Extended Energy Big Data (EEBD)

Prof. Yajun Tian

➢ Innovation Conception

Extended Energy Big Data (EEBD) is a new conception put forward by QIBEBT, it believes that energy is an essential factor of modern society, so with energy as a common core, diverse dimensions such as economy, society, ecology, environment, engineering, science and technology, climate, energy security etc. can be associated, and any disturbance from any dimension can be conducted to others through energy.

By digging the big data based on EEBD principle, much new knowledge can be revealed, it will be helpful for smart development.



➢ Current Status

- Conception of EEBD principle has been developed and issued
- A big data based on EEBD principle has been constructed
- A platform used to manage and dig EEBD has been developed

➢ Research & Development

- A model used for government intelligent decision has been developed
- A new methodology of GIS-LCA was proposed and related standards are being written
- Some cases of smart plants has been built up.

Applied Energy 312 (2022) 118791

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Life cycle assessment and techno-economic analysis of ethanol production via coal and its competitors: A comparative study

Junjie Li [a,b,c,d], Yueling Zhang [e], Yanli Yang [a,b,c], Xiaomei Zhang [a,b,c], Nana Wang [a,b,c], Yonghong Zheng [a,b,c], Yajun Tian [a,b,c,*], Kechang Xie [a,b,c,d]

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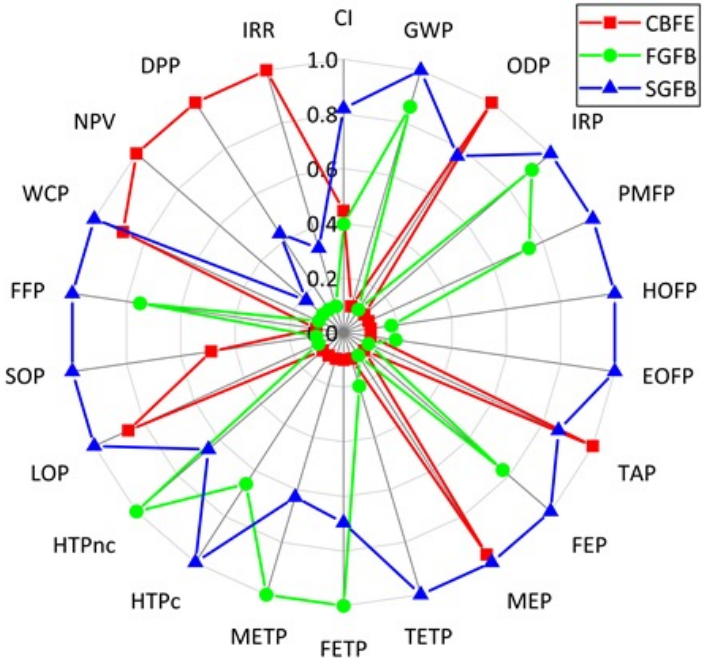

Biofuel Policies Updates in China

Technological support for implementing carbon peak and carbon neutrality strategies (2022-2030).

Develop and promote the technology for the production of **bio-jet fuel, biodiesel, cellulosic ethanol, biogas, and biomass pyrolysis**, as well as the technology for the preparation of biomass-based materials and high-value chemicals, and the key technology for **efficient combustion of low-calorific biomass fuels**.

Bioethanol

"Notice on Strengthening the Daily Supervision of the Production of Biofuel Ethanol and the Use of Ethanol Gasoline"

Strictly control the corn fuel ethanol, strengthen the regulation of the ethanol gasoline market

Biodiesel

On-site meeting on the pilot work of promoting and applying biodiesel

Carry out the promotion and application of biodiesel pilot, promote the further improvement of biodiesel standard system

Green power

Notice on Promoting the Full Coverage of Renewable Energy Green Electricity Certificates and Promoting the Consumption of Renewable Energy Electricity

Revise the green power certificate system, promote the full coverage of green certificate issuance, further expand green certificate trading, and do a good job in connecting with carbon trading.

Biofuel Policies Updates in China

- **Deepen industrial restructuring:**
  - ✓ vigorously develop green and low-carbon industries, build a green manufacturing system.
  - ✓ accelerate the development of biotechnology, new energy, new materials, high-end equipment, green environmental protection
  - ✓ Continuously increasing the proportion of non-fossil energy consumption.
- **Construction of green and low-carbon cities**
  - ✓ Optimize the energy consumption structure of urban construction.
  - ✓ Promote the application of renewable energy, such as solar energy geothermal energy, air source heat pumps, biomass energy

“Green+” upgrading to reduce Carbon emission

The Ministry of Industry and Information Technology, the Ministry of Science and Technology, the Ministry of Finance, and the Civil Aviation Administration of China jointly released the "Guidelines for the Development of Green Aviation Manufacturing Industry (2023-2035)."

- “Green+” upgrading of the civil aviation industry
  - ✓ Enhance the comprehensive lifecycle management of green aviation technologies/pathways
  - ✓ Promote carbon footprint assessment across the entire industry chain
  - ✓ Reduce energy and resource consumption as well as greenhouse gas emissions such as carbon dioxide.
  - ✓ Strengthen the application verification of sustainable aviation fuel on domestically produced civil aircraft and engines.
- Deepen international cooperation in green aviation.
  - ✓ Establish international technology innovation cooperation.
  - ✓ Encourage enterprises to embrace green aviation development
  - ✓ integrate into the international green aviation industry supply chain system
  - ✓ explore international green aviation markets.

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383g
414g
帮TA复活能量
40g
4g
73g
79g
3g
可收取
可收取
还剩 11:03
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一键收
找能量
用道具
留言
送道具
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展开好友动态

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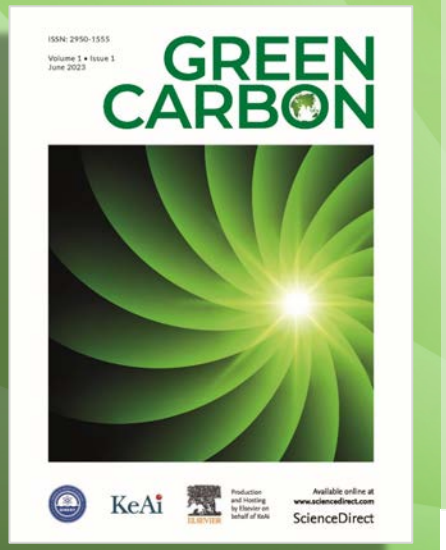

TOPICS:

- Renewable carbon: resources, environment, energy, chemicals and materials
- Green carbon utilization technologies: electrocatalysis, photocatalysis, chemical catalysis, biocatalysis and bio-manufacturing
- Synthetic biology for carbon fixation and conversion
- Electrochemical energy conversion and storage
- Net-zero and negative carbon technology
- Carbon management: carbon footprint and life cycle assessment, carbon simulation and policy
- Artificial intelligence and data science in green carbon research

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