

沼气工程的作用

WHY BIOGAS MATTERS?

AGRICULTURAL BIO-WASTES IN A GREAT CYCLE

董仁杰

DONG Renjie

rjdong@cau.edu.cn

+86 13601387967

中国农业大学教授，工学院农业农村碳中和研究中心主任

国际标准化组织沼气工程标委会主席

国家生物燃气高效制备及综合利用技术研发（实验）中心理事

国家级生物质能科学与技术国际联合研究中心主任；农业部可再生能源清洁化利用重点实验室常务副主任

Chairman, Technical Committee 255 (Biogas), International Standard Organization

Director, National Center for International Research of BioEnergy Science and Technology (iBEST)

Executive Director, MoA Key Lab of Clean Production and Utilization of Renewable Energy (CPURE)

Professor and Head, Research Center of Carbon Neutralization in Agriculture, College of Engineering, China Agricultural University (CNA)

Member of Board of Directors, State R&D Center for Efficient Production and Comprehensive Utilization of Biobased Gaseous Fuels (BGFuels)





内容

CONTENT

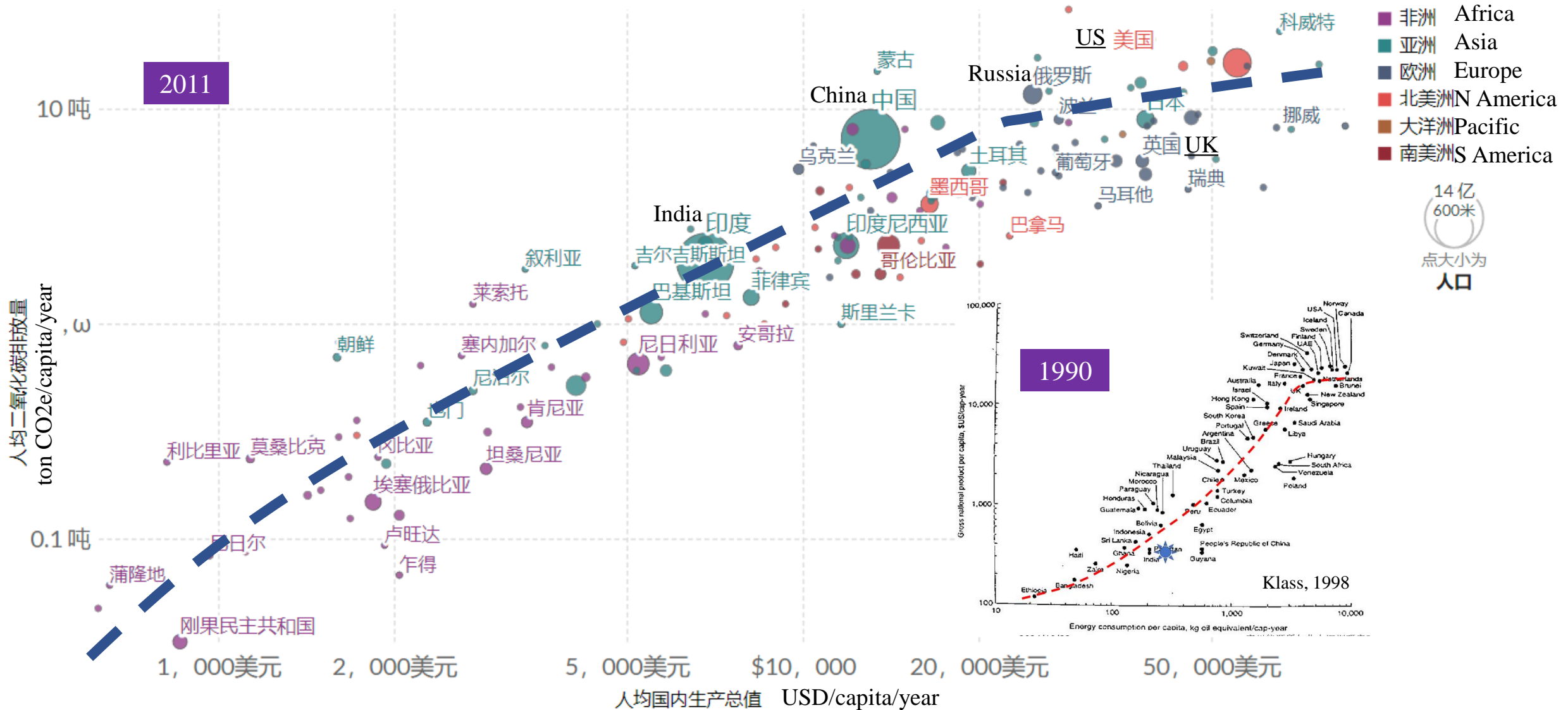
1. 能源和环境是社会发展的基础
2. 大循环中的沼气工程
3. 沼气工程的五大作用
4. 沼气工程面临的挑战
5. 合作倡议
6. 中国农业大学

1. ENERGY AND ECOLOGY: FUNDAMENTALS FOR DEVELOPMENT
2. BIOGAS IN THE GREAT CYCLE
3. FIVE ROLES OF BIOGAS ENGINEERING
4. CHALLENGES FOR BIOGAS INDUSTRY
5. CALL FOR COOPERATION
6. CHINA AGRICULTURAL UNIVERSITY



1. 能源和环境是社会发展的基础

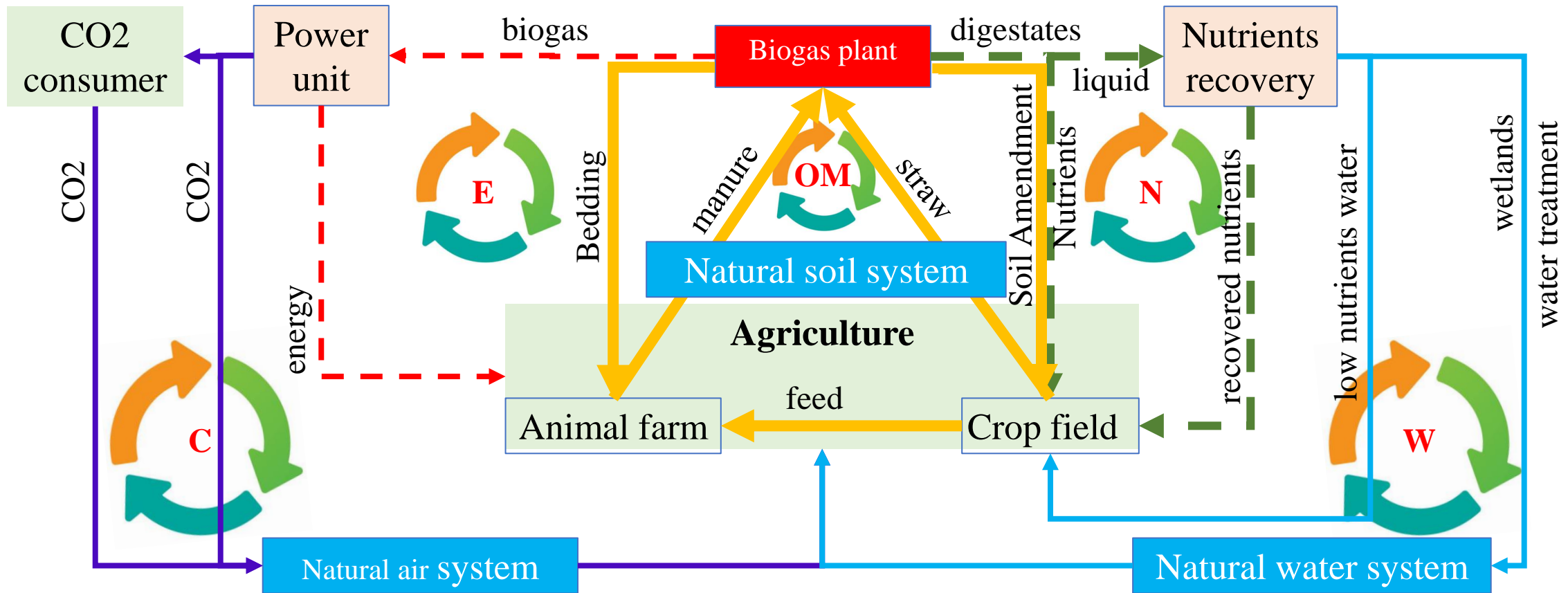
ENERGY AND ECOLOGY: FUNDAMENTALS FOR DEVELOPMENT





2. 大循环中的沼气工程

BIOGAS IN THE GREAT CYCLE



NEWCOM Great Cycles: Nutrients, Energy, Water, Carbon, Organic Matter)

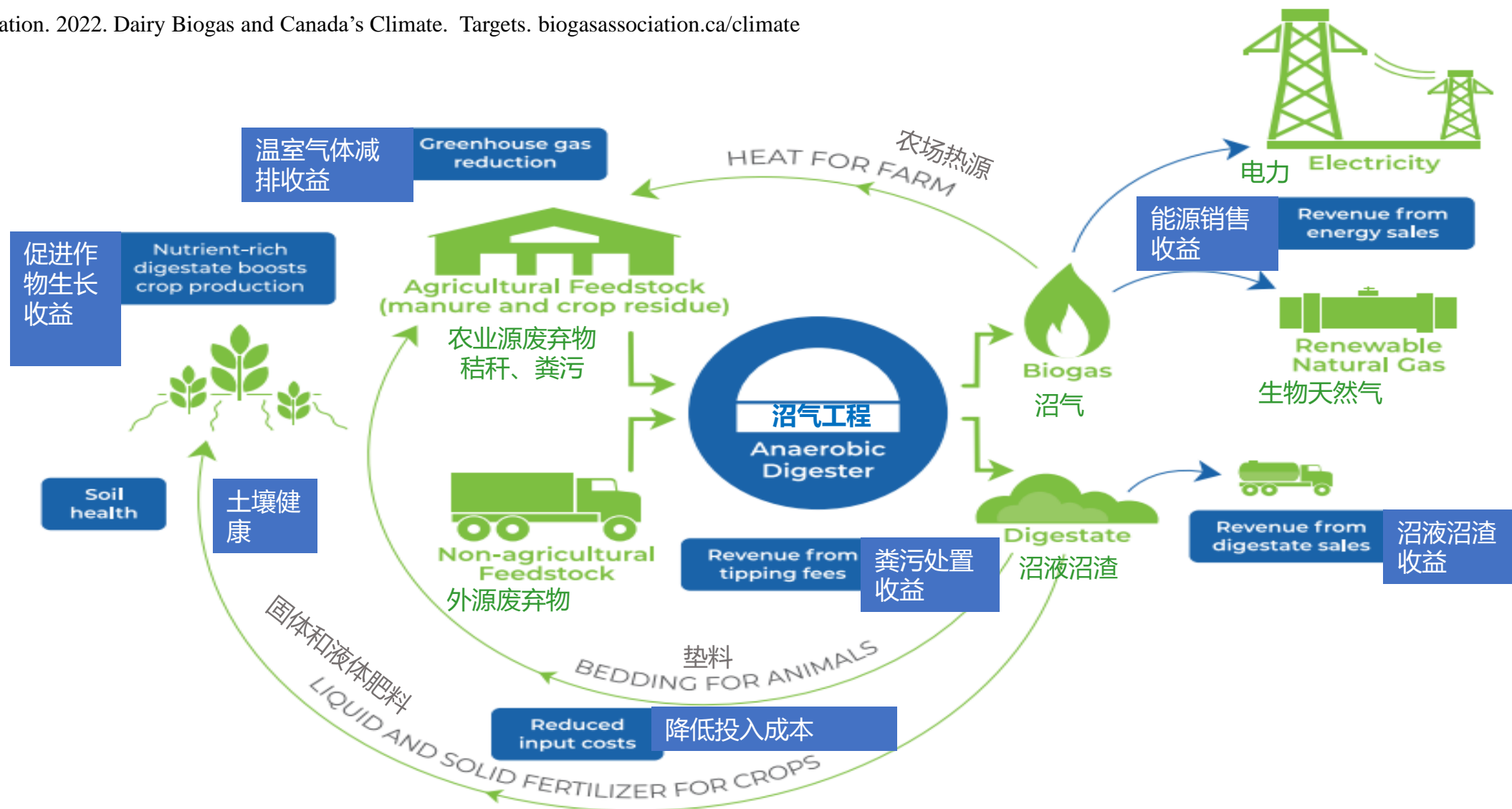
→ **Greenhouse Gases Emission Reduction/Sequestration**



加拿大奶牛养殖场沼气工程

CANADIAN DAIRY BIOGAS

Canadian Biogas Association. 2022. Dairy Biogas and Canada's Climate. Targets. biogasassociation.ca/climate



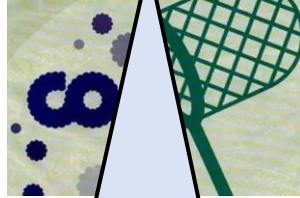


3. 沼气的五大作用

FIVE ROLES OF BIOGAS ENGINEERING

⑤

减排价值
Emission Mitigation



负排放
Negative emission

BGCCS

BioGas with Carbon Capture and Sequestration

②

能源替代
Energy substitution

能源价值
Renewable Energy

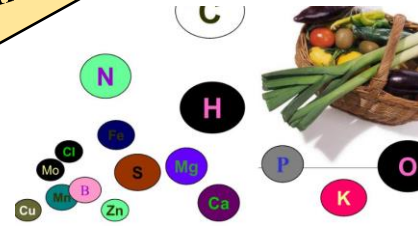


③

肥料价值
Fertilizers

能源替代
Energy substitution

养分
Nutrients



①

避免排放
Avoidance

环境保护价值
Clean Environment

废弃物处理
Bio-waste treatment

稳定化有机质
Stabilized organic matter

④

耕地质量提升
Soil Improvement

土壤固碳
Soil Carbon Storage

沼气工程
Biogas

能源
Biogas



沼气工程保留了所有养分并创造了植物激素

NUTRIENTS REMAINED AND HORMONES PRODUCED

畜禽粪中大量元素和微量元素的含量(干重计算)

Contents of major elements and trace elements in livestock and poultry manure (DM based)

养分 Nutrient	牛粪 Cow dung	猪粪 Pig manure	羊粪 Sheep manure	鸡粪 Chicken manure
全氮 TN (%)	1.73	2.91	2.23	2.82
全磷 TP (%)	0.83	1.33	0.78	1.22
全钾 TK (%)	0.74	1	0.78	1.4
全硼 B (mg/kg)	22.8	21.7	30.8	24
全锌 Zn (mg/kg)	187	199	146	130
全锰 Mn (mg/kg)	355	261	172	143
全钼 Mo (mg/kg)	3.7	<3.0	3.4	4.2
全铁 Fe (mg/kg)	1952	1845	1921	1901
全铜 Cu (mg/kg)	16.7	50	23	13
有机质 OM (%)	73.6	77	60.2	68.9

孙曦, 等. 有机肥料在植物营养和提高土壤肥力的作用, 发表在Current Progress in Soil Research in People's Republic of China, 197-206, 1986.

类别 type	种类 Acids	猪粪发酵沼液 Pig manure digestate	猪粪 Pig manure
必需氨基酸 Essential amino acids	苏氨酸 threonine	3	—
	缬氨酸 valine	66.4	53.5
	蛋氨酸 methionine	36.5	44.3
	苯丙氨酸 phenylalanine	65.2	33.15
	赖氨酸 lysine	88.3	55.62
	精氨酸 arginine	76.5	47.8
	亮氨酸 leucine	3.6	11.18
	异亮氨酸 isoleucine	7.2	—
	组氨酸 histidine	16.2	—
	合计 Sub total	362.9	245.55
非必需氨基酸 Non-essential amino acids	天门冬氨酸 Aspartic acid	110.3	99.68
	丝氨酸 serine	71.8	62.5
	甘氨酸 glycine	11	—
	丙氨酸 alanine	150.1	230.5
	谷氨酸 glutamate	86	65
	合计 Sub-total	429.2	457.68

沼液沼渣植物激素
Plant hormones of
raw manures and
liquid digestate
(mg/L)

植物激素 Phytohormones	鸡粪 Chicken manure		牛粪 Cow dung		猪粪 Pig manure	
	原料 Raw material	沼液沼渣 Biogas slurry	原料 Raw material	沼液沼渣 Biogas slurry	原料 Raw material	沼液沼渣 Biogas slurry
Gibberellin acid (GA ₃)	1.45 ± 0.65	44.83 ± 1.68	3.06 ± 0.67	38.53 ± 1.40	4.25 ± 0.26	16.37 ± 2.16
Indoleacetic Acid (IAA)	4.44 ± 0.03	36.84 ± 4.32	7.05 ± 0.92	17.38 ± 2.31	4.37 ± 0.02	21.17 ± 2.02
Abscisic acid (ABA)	6.45 ± 0.15	13.23 ± 2.82	7.24 ± 0.28	23.53 ± 2.27	8.79 ± 0.37	35.59 ± 3.42



中国农业生物固体废弃物的沼气潜力, 十亿M3

CHINA SUBSTANCES 100MT, AND BIOGAS, BCM

来源Source	2020		2025		2030		2060	
	原料 feed	产沼气 biogas	原料 feed	产沼气 biogas	原料 feed	产沼气 biogas	原料 feed	产沼气 biogas
畜禽粪便 Animal Manure	2790	23.4	3395	142.6	3701	353.9	3320	896.4
作物秸秆 Crop Residues	860	2.41	900	368.4	950	1282.5	900	1795.5
果蔬垃圾 Fruit and Vegetable Waste	250	0.2	260	1.92	280	10.56	250	80
农村生活垃圾 Rural Household Waste	163	0.42	160	2.96	140	14.41	80	45.1
餐厨垃圾 Food Waste	75	16.8	80	27	90	85	90	166
厨余垃圾 Kitchen Waste	121	6.4	140	63	160	149	190	342
污泥 Municipal Sludge	47	2.0	70	6	100	15	90	28
填埋垃圾 Landfill Waste	100	164.2	140	126	160	79	190	37
轻工行业废水 Light Industrial Wastewater	4556	228	5000	300	5530	331	6710	537
非轻工行业废水 Other Industrial Wastewater	1981	39.6	2410	49	2870	57	3110	63
沼气产量 Total biogas, bcm		48.343		108.688		237.737		399
可提纯天然气 Biogas based Methane, bcm 总计		29.006		65.213		142.64		239.4
农业农村 Rural/Agricultural Biowaste		1.586		30.953		99.682		169.0
占2020年天然气用量 (333.989) % of 2020 NG consumption		8.68		19.53		42.71		71.68
占2020年天然气进口量 (139.7) % of 2020 NG importation		20.76		46.68		102.11		171.37

中国农业农村商品能源消费约为2~2.5亿吨标准煤, 折合1600~2000亿方天然气

China agricultural and rural energy consumption is 200~250 million tons of standard coal, equivalent to 160~200 bcm natural gas



沼液还田同时也是灌溉、沼液净化 WATER WITH DIGESTATES FIELD APPLICATION, OR DIGESTATES FILTRATION FOR WATER DISCHARGE



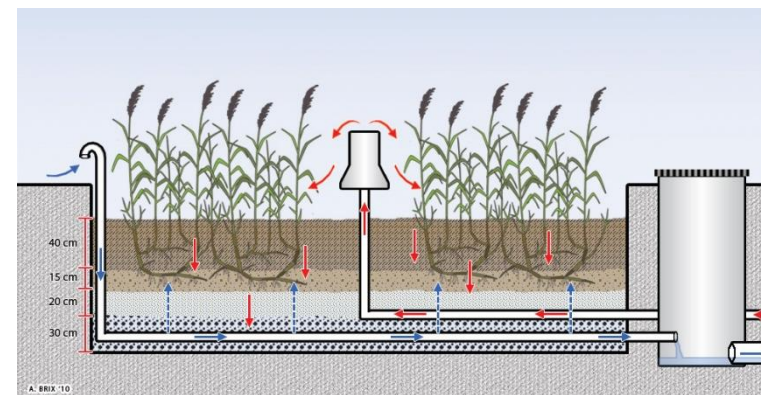
中国广西沼液农用
Digestates slurry field application, Guangxi

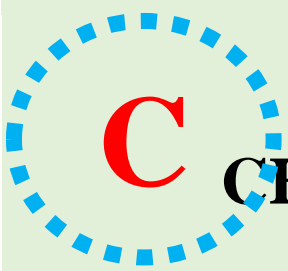


中国山东，沼液农田贮存池
Digestates slurry field storage, Shandong



美国康奈尔沼液敞口贮存
Digestates slurry open storage, Cornell

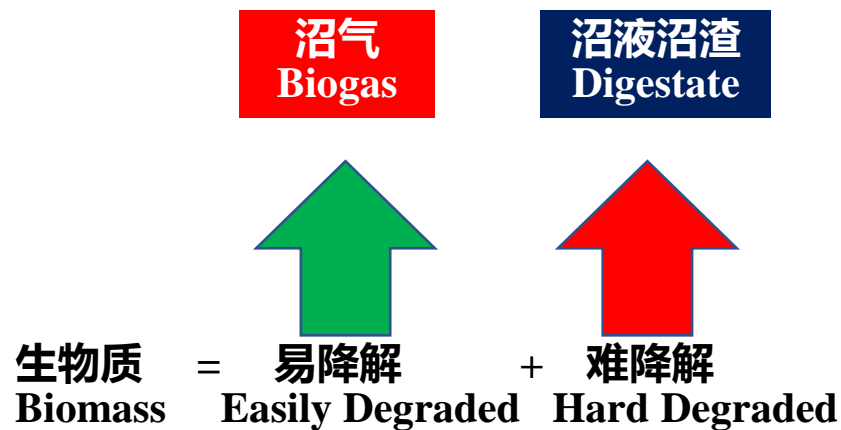




奶牛养殖和水稻种植的甲烷减排潜力

CH4 EMISSION REDUCTION IN DAIRY AND PADDY RICE PRODUCTION

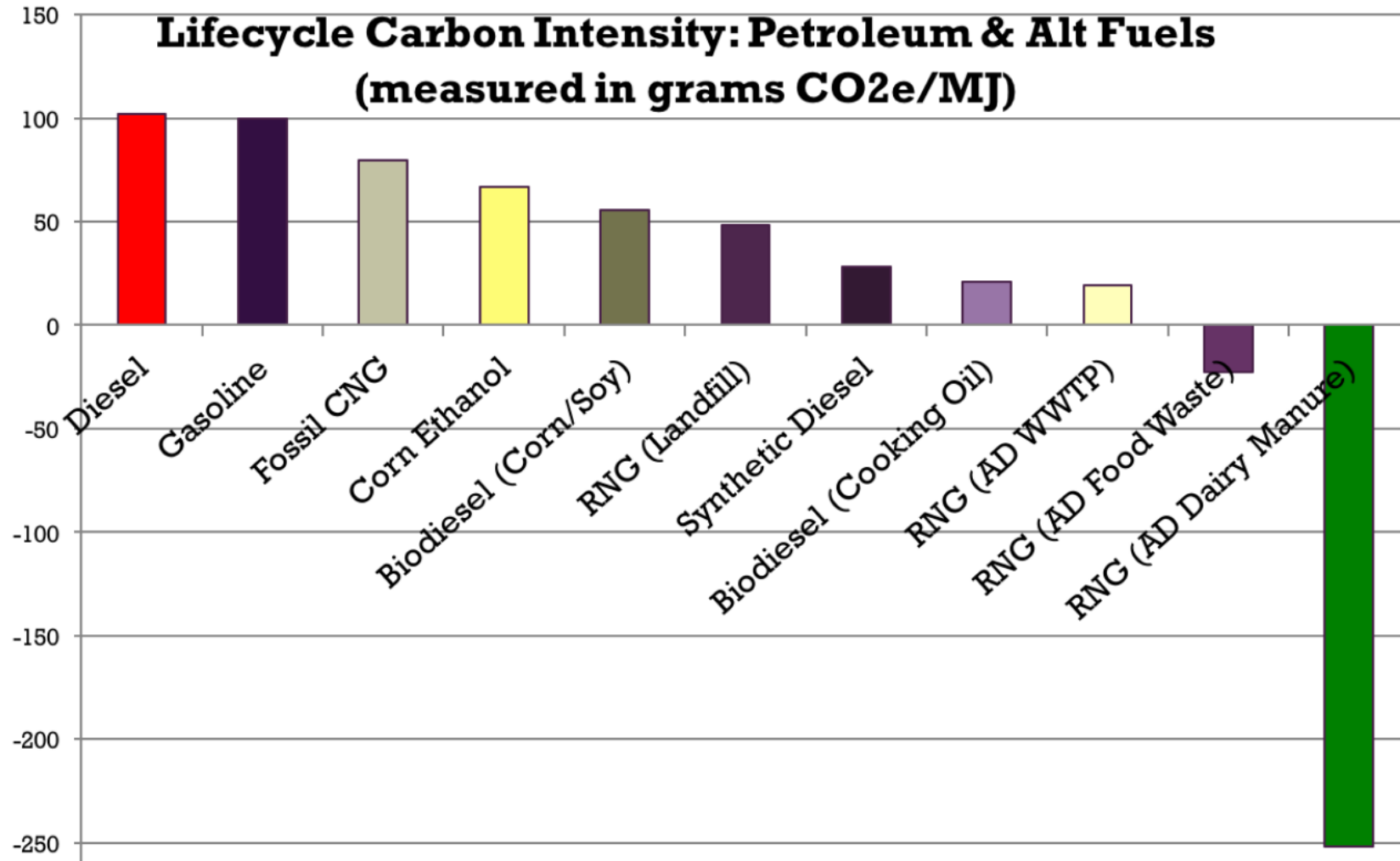
- 利用沼气工程处理奶牛粪污，1头泌乳牛/年甲烷减排量约197kg CH₄/(a·head)。
- Annual methane emission reduction per head of milking cow is about 197 kg CH₄/(a·head) by AD treatment of the manure.



- 双季稻田可实现稻田甲烷减排量约213 kg CH₄/(a·ha)；单季稻田甲烷减排量约81 kg CH₄/(a·ha)。
- The methane emission reduction in double-cropping rice field is about 213 kg CH₄/(a·ha), while in single season rice field is about 81 kg CH₄/(a·ha).



加利福尼亚州低碳燃料全生命周期排放 CARB LCFS PATHWAY DATA 2018

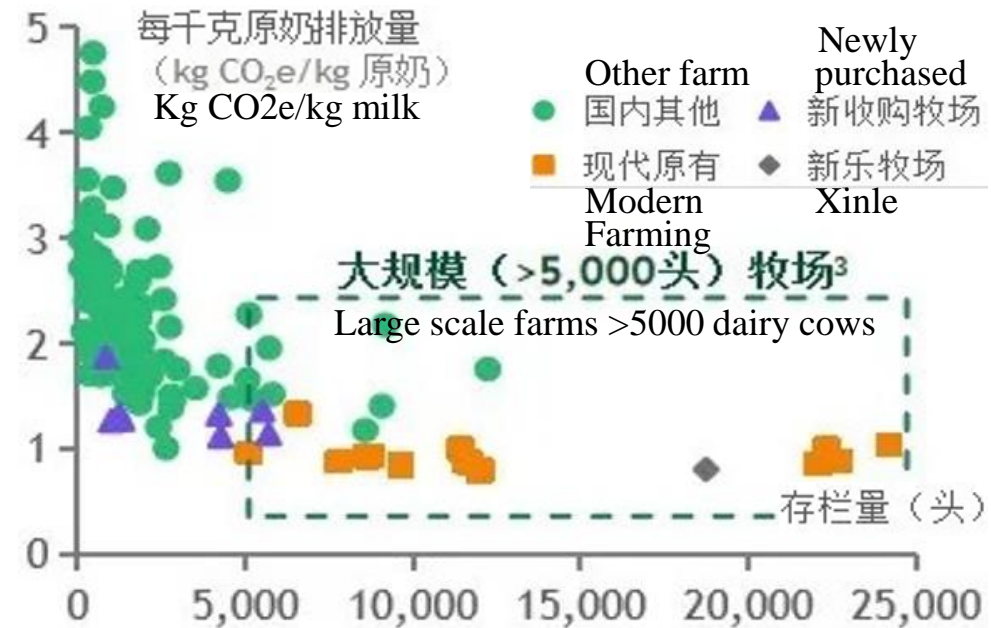
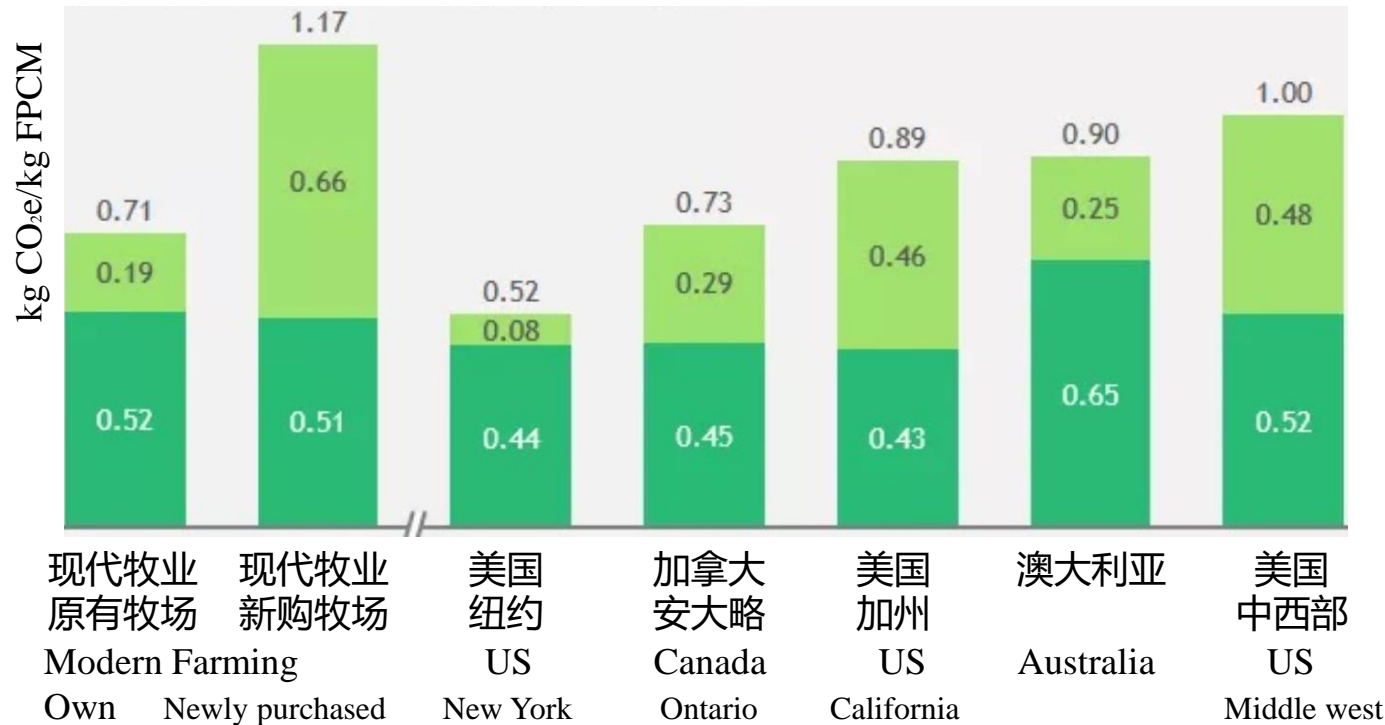




中国现代牧业

MODERN FARMING OF CHINA

- 牛粪沼气年替代30%常规能源。年平均碳足迹每千克标准奶1.95 kg CO₂e (0.82~5.09) , 南方偏高、北方偏低。排放源是饲料生产与加工 (31.8%)、肠道发酵 (30.0%)、粪便管理 (20.8%)、能源 (9.7%)、运输 (7.7%) 和还田 (7.2%)。
- The annual average carbon footprint of milk is 1.95 (0.82 to 5.09) kg CO₂e/kg fat and protein corrected milk (FPCM), higher in South and lower in North China. Emission sources are feed (31.8%), enteric fermentation (30.0%), manure management (20.8%), energy consumption (9.7%), transport (7.7%) and manure field application (7.2%).

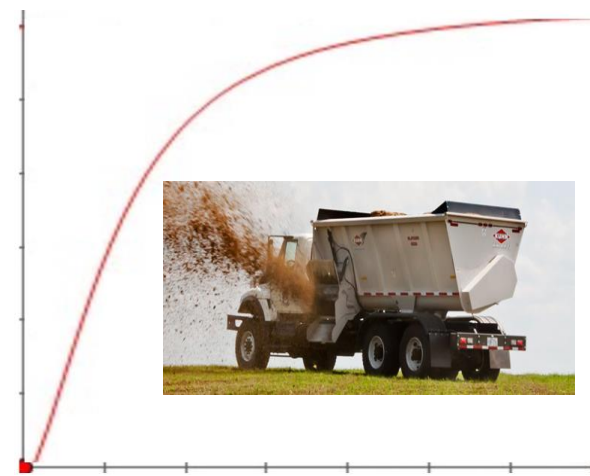
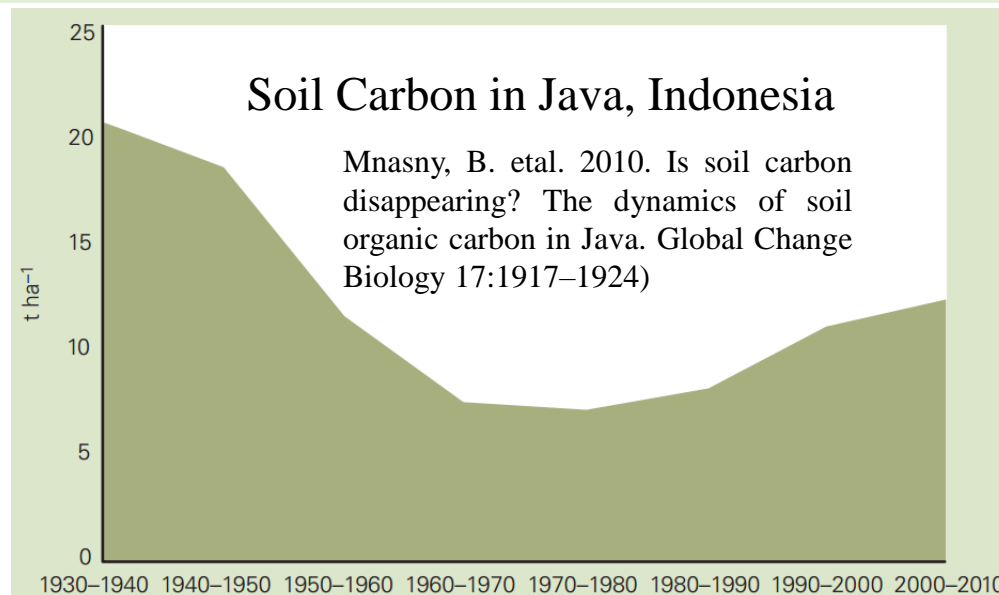




耕地质量提升和黑土地，附带土壤碳汇

SOIL IMPROVEMENT AND INCIDENTAL CARBON-TO-SOIL

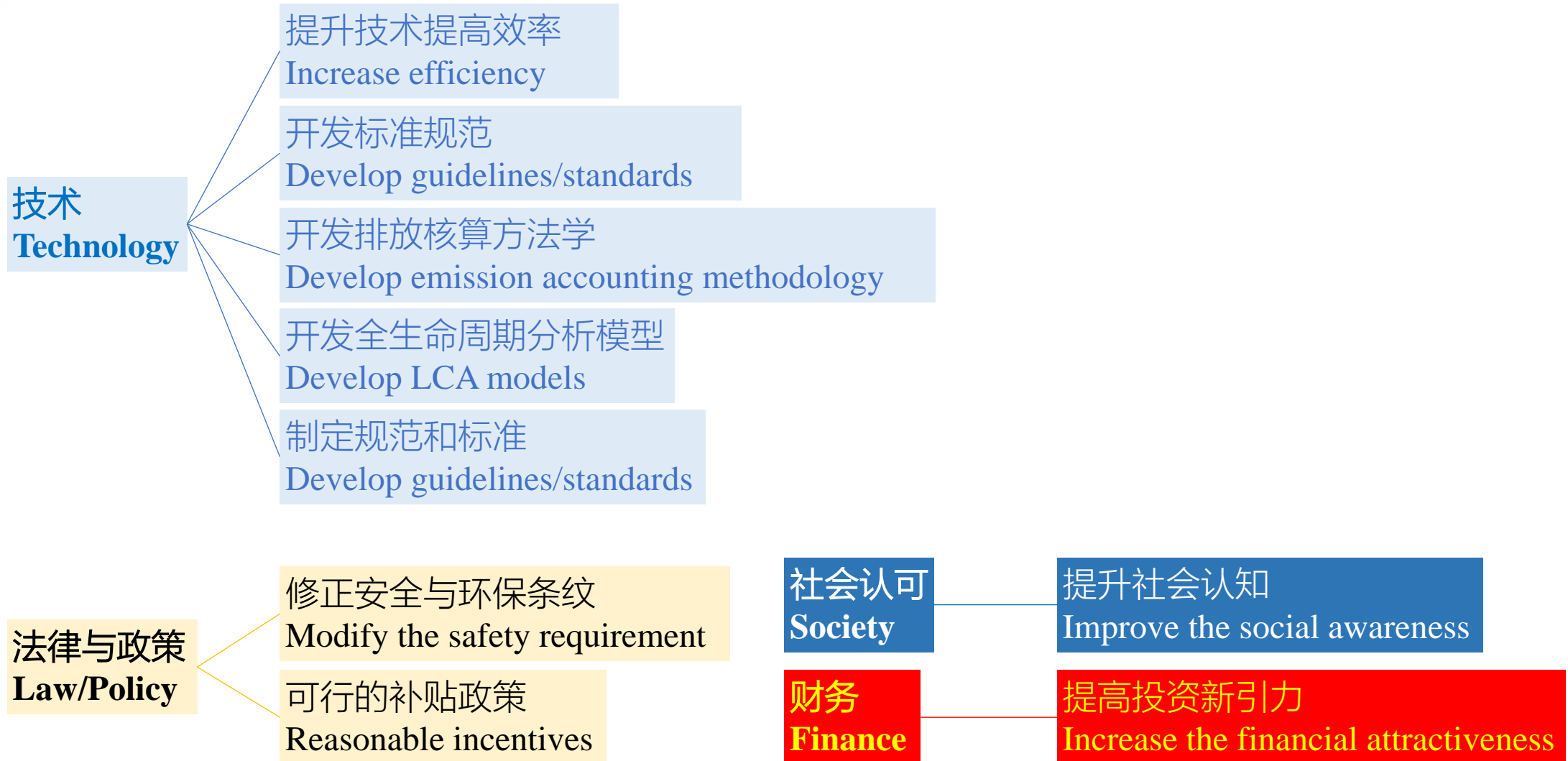
沼渣含有有机质30%~50%，腐殖酸10%~25%
Organic content 30-50% in the digestates; Humic acids 10~25%





4. 沼气工程面临的挑战

CHALLENGES FOR BIOGAS INDUSTRY





5. 合作倡议

CALL FOR COOPERATION

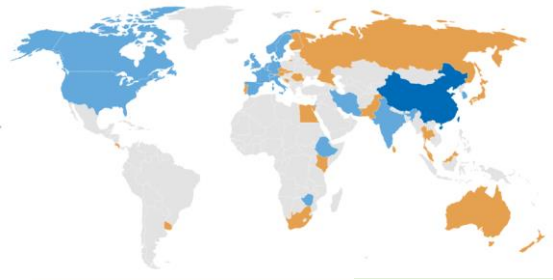
- ◆ 养殖场粪污治理与甲烷排放评估
- ◆ 跨国沼气认证
- ◆ 建设沼气技术国际标准
- ◆ 参访中国沼气工程
- ◆ 共同发表学术成果

- ◆ **Manure Methane Emission Accounting**
- ◆ **Int'l Biogas Accreditation**
- ◆ **Int'l Standards through ISO TC 255**
- ◆ **Welcome to Visit China on Biogas**
- ◆ **Joint Publications on *Agriculture***



Agricultural Biomass Generation and Utilization: Progress, Challenges and Prospects

- ❑ Guest Editors: Prof. Dr. Renjie Dong; Prof. Dr. Walter Stinner
 - ❑ Website: https://www.mdpi.com/journal/agriculture/special_issues/7PD58JIBV1
 - ❑ Deadline for manuscript submissions: 25 March 2025
- ❑ Agricultural biomass generation, properties and characteristics;
 - ❑ Solid biofuels and utilization;
 - ❑ Anaerobic digestion and digestates valorization;
 - ❑ Composting;
 - ❑ Manure acidification;
 - ❑ Biochar; Hydrothermal carbonization;
 - ❑ Field application of manure, compost, and biogas digestates;
 - ❑ Value-added utilization of agricultural biomass (feed, insect protein, single-cell protein, etc.);
 - ❑ GHG emissions accounting and reduction;
 - ❑ Technical–social–economic analyses.



TC 255 会员国

COUNTRY MEMBERS IN ISO/TC 255

Liaisons: 5

1. ISO/TC 275: Sludge recovery, recycling, treatment and disposal;
2. ISO/TC 193: Natural gas;
3. ISO/TC 22SC/41: Specific aspects for gaseous fuels;
4. European Biogas Association
5. ISO/TC 301: Energy management and energy savings

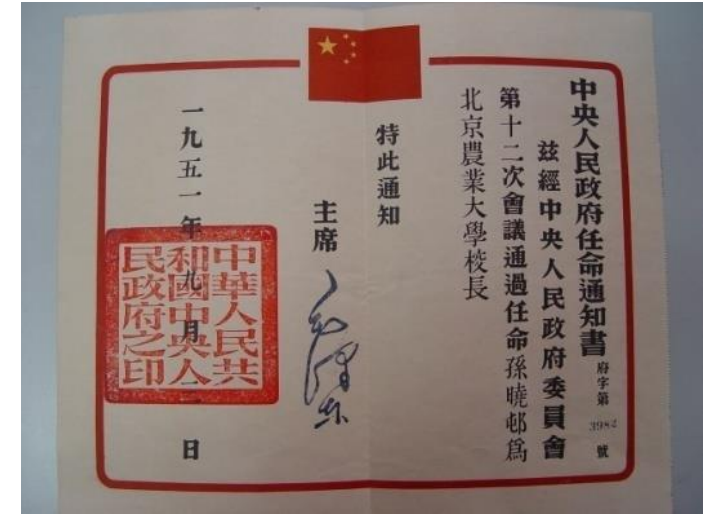
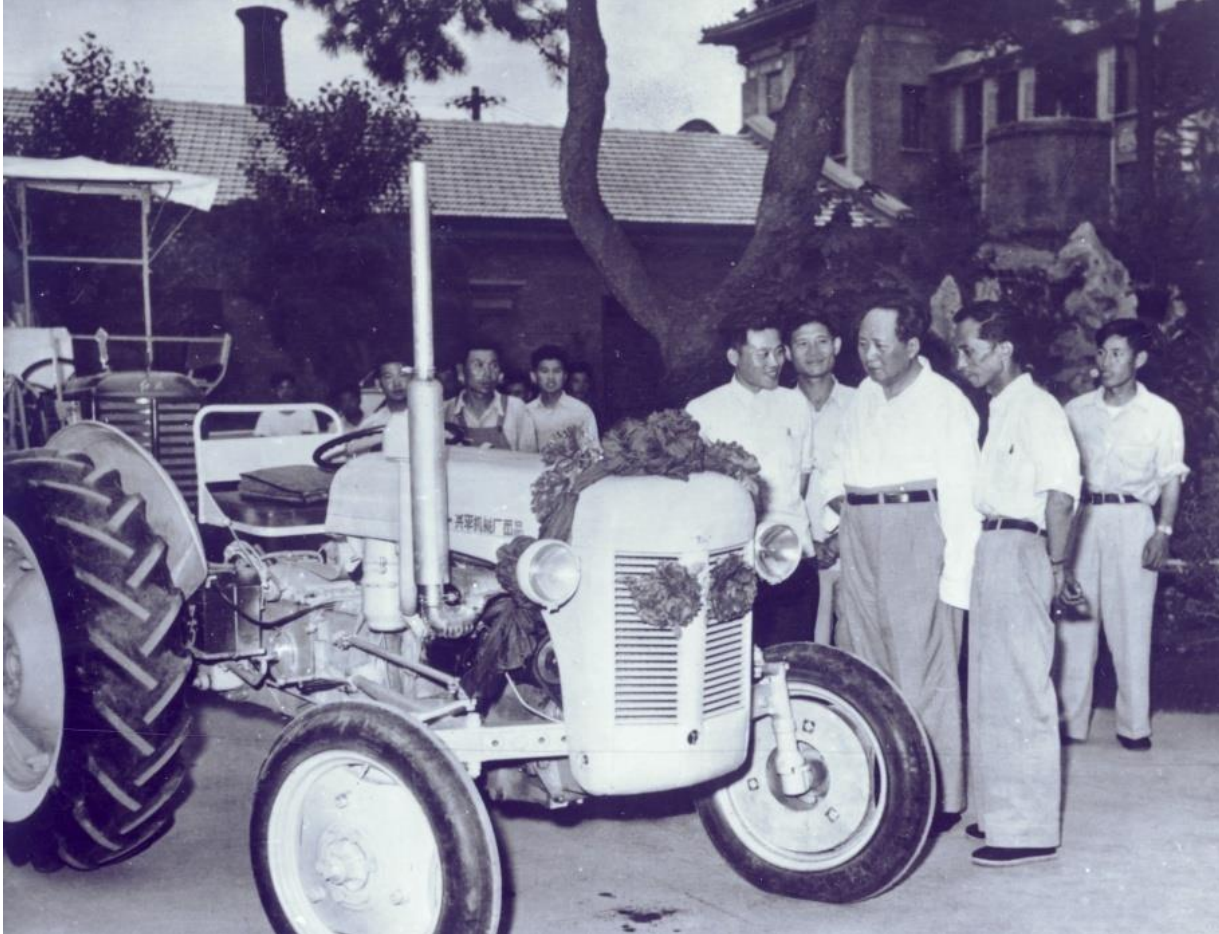
More countries
More experts
More standards

P member 21	ACRONYM	WGs	O member 22	ACRONYM
Belgium	NBN		Australia	SA
Canada	SCC	6	Austria	ASI
China	SAC	1; 4; 6	Bosnia and Herzegovina	ISBIH
Denmark	DS	1; 4; 6	Costa Rica	INTECO
France	AFNOR	1; 4; 6	Czech Republic	UNMZ
Germany	DIN	1; 4	Egypt	EOS
India	BIS		Finland	SFS
Iran, Islamic Republic of	INSO	6	Japan	JISC
Ireland	NSAI		Kenya	KEBS
Israel	SII	1	Luxembourg	ILNAS
Italy	UNI	1	Malaysia	DSM
Korea, Republic of	KATS	1; 4; 6	New Zealand	NZSO
Netherlands	NEN	1; 4; 6	Pakistan	PSQCA
Norway	SN		Portugal	IPQ
Spain	UNE		Romania	ASRO
Sweden	SIS		Russian Federation	GOST R
Switzerland	SNV		Slovakia	UNMS SR
United Kingdom	BSI	1	South Africa	SABS
United States	ANSI	1; 4; 6	Sri Lanka	SLSI
Zimbabwe	SAZ		Thailand	TISI
Uganda	UNBS		Uruguay	UNIT
			Ethiopia	IES



6. 中国农业大学

CHINA AGRICULTURAL UNIVERSITY



始建于1905年京师大学堂农科大学；1949年9月新中国成立前决定建设北京农业大学，1951年由中央人民政府任命校长。

Established from 1905, as College of Agriculture, Imperial University of Peking;

Beijing Agricultural University has been established just before new China was set up in 1949. The university President was Assigned by Chairman MAO in 1951.



生物能源环境科学与技术研究室

THE BEST-BIOENERGY AND ENVIRONMENT S&T LAB

农业部可再生能源清洁化利用技术重点实验室

(中国农业大学)

Key Laboratory of Clean Production and Utilization of Renewable Energy, Ministry of Agriculture, P. R. China

中华人民共和国农业部

二〇一一年

国家能源生物燃气高效制备及综合利用
技术研究(实验)中心

(中国农业大学)

State R&D Center for Efficient Production and Comprehensive Utilization of Biobased Gaseous Fuels

生物质能科学与技术
国家级国际联合研究中心
National Center for International Research of
BioEnergy Science and Technology



中华人民共和国科学技术部
Ministry of Science & Technology of China



微生物处理与分析实验室
Microbial treatment and analyses



大型仪器分析实验室
Large facility Lab



化学分析实验室
Chemical Analyses



厌氧发酵实验室
Anaerobic Experiments Lab



大循环

GREAT CYCLE SINCE 2013

Sweden



Poland



Ireland



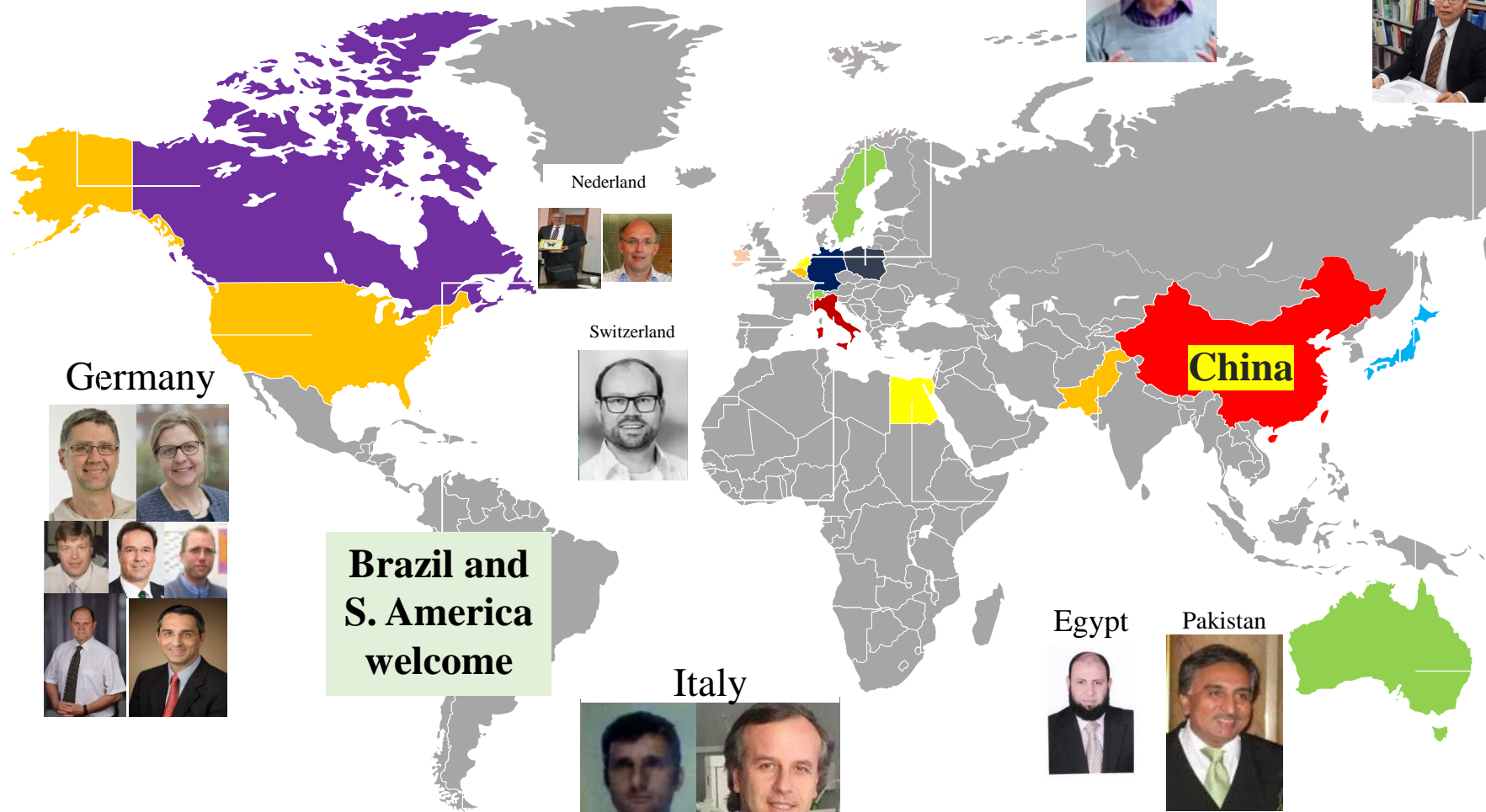
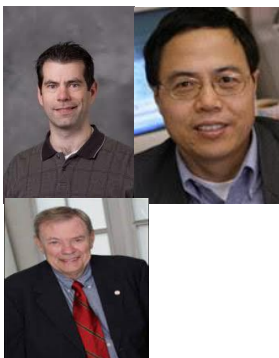
Japan



Canada



USA



Nederland



Switzerland



Germany



Brazil and S. America welcome

Italy



Egypt



Pakistan



Australia



Initiator
Renjie DONG
Beijing, China



大循环国际年会

GREAT CYCLE ANNUAL CONFERENCE

2008
FREPCD

Animal Manure Treatment and Utilization

Biogas Symposium

Bioenergy and Nutrient Recovery



Stuttgart

Prevention and Control of
Organic Pollution in Agriculture
and Rural Areas

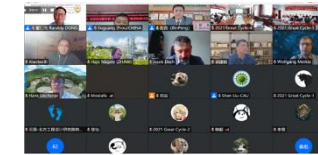
Biogas Technology to Mitigate Methane
Emission from Agriculture



Yantai



Agricultural and Rural
Carbon Neutralization
Contribution of Biogas



2013

2014

2015

2016

2017

2018

2019

2020

2021

2022

2023

2024



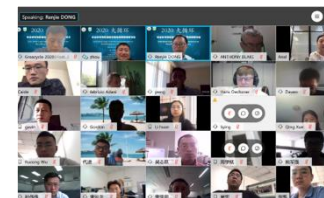
Bioenergy Environment S&T



Renewable Energy in
Developing Countries



Agricultural Soil and Water
Organic Pollution Prevention
and Control



Rural Biowaste-to-Resource



**Methane
Mitigation**

Biogas Engineering Technologies to Mitigate Methane Emissions from Agricultural Sources



谢谢大家

Thank You!



+86 13601387967

rjdong@cau.edu.cn

