天津商業大學 TIANJIN UNIVERSITY OF COMMERCE

天津大學 Tianjin University

Actual deployment of gasification （China updates）

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II. Gasification development in China

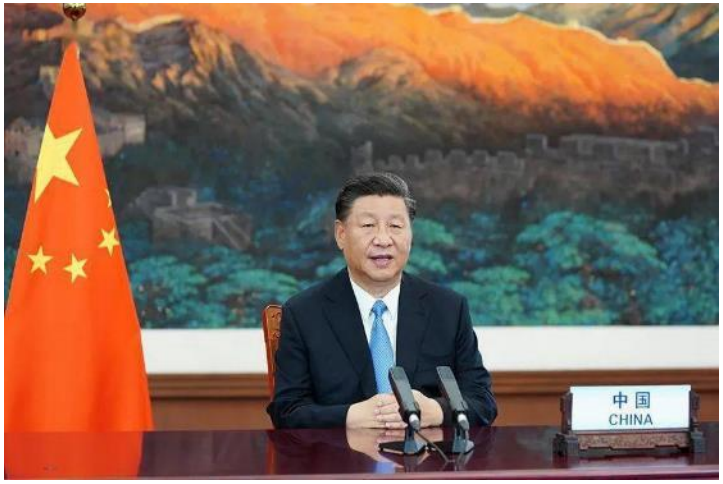
III. Actual demonstrations in China

IV. Future perspectives

V. Gasification in TJU and TJUC

I. Background

Carbon net zero emission



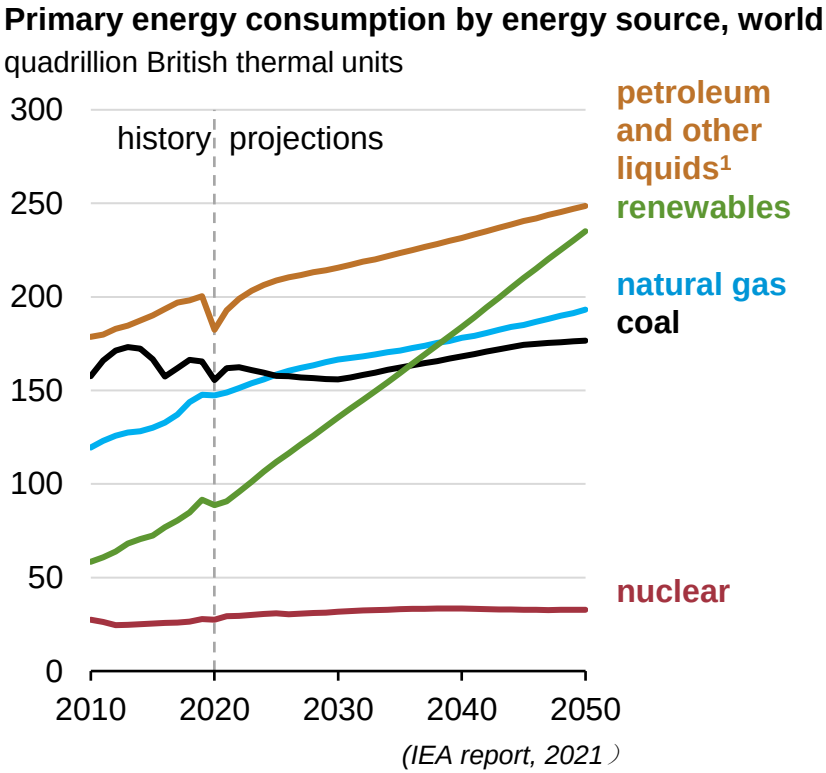
22/09/2022
General debate of the 75th session of the United Nations General Assembly
"China will enhance national independent contribution, adopt more effective policies and measures, strive to reach the peak of carbon dioxide emissions by 2030, and strive to achieve carbon neutrality by 2060."

12/12/2020
Climate Ambition Summit
"By 2030, China's carbon dioxide emissions per unit of GDP will drop by more than 65% compared with 2005. Non fossil energy will account for about 25% of primary energy consumption."

I. Background

Clean energy shortage vs. Renewable biomass energy

Economic growth is definitely needed, driving the continuous increase of energy consumption, causing energy supply risk and even crisis.



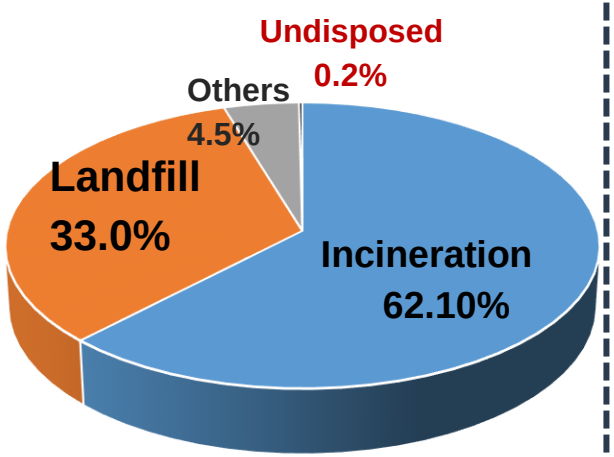
- In 2020, China's total carbon emissions were 11.3 billion tons, including 9.9 billion tons in the energy sector, accounting for 88%;
- Biomass is a renewable energy resource, which can be converted into any form of fuel, including solid, liquid and gas. Its inedibility, relatively rapid growth ability and abundant availability make it a potential energy source for sustainable energy production.

I. Background

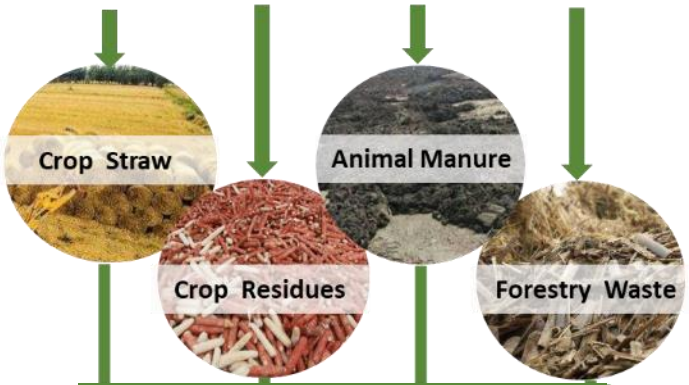
Large amount of biomass/wastes are currently still not be well used and even treated in rural area.

Municipal Solid Waste

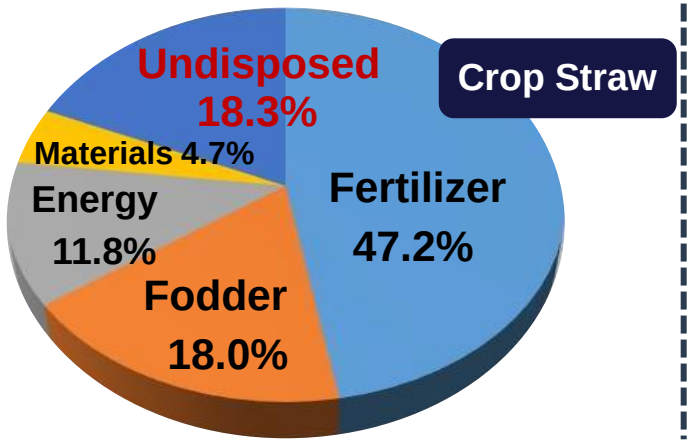
2.35 billion tons in 2020



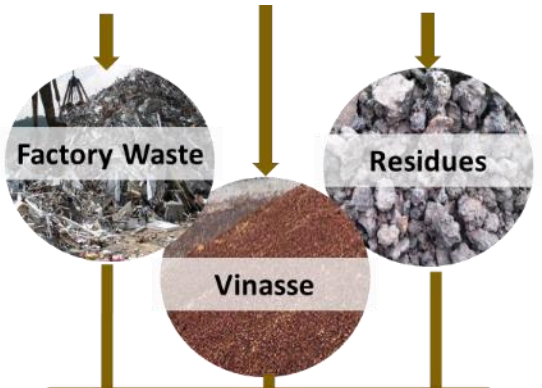
Agricultural & forest residues



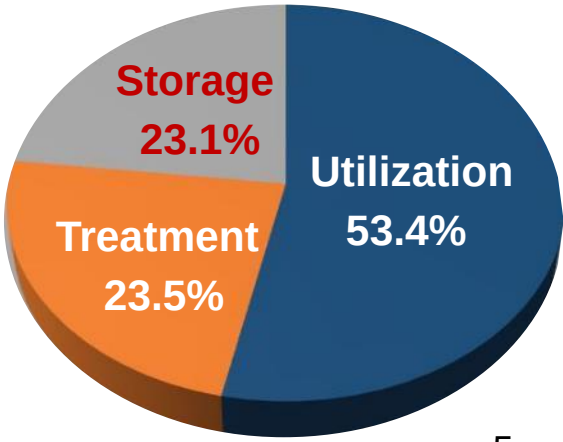
3.04 billion tons in 2020



Industrial Solid Waste



0.65 billion tons in 2020



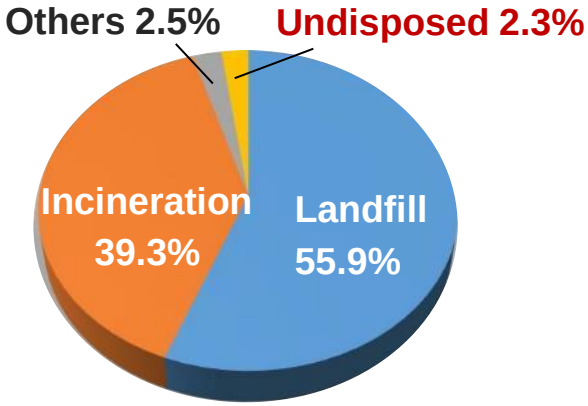
(China Statistical Yearbook, 2020)

I. Background

Classifications and characteristics of typical biomass in China

Bio-wastes

- **High Moisture Content**
- **High organic matter content**
- **Rich in nutrients**
- **Heavy metals and other polluting risk**



- Biomass is huge in total, diverse in variety, complex in nature, and has great potential for resource utilization.

I. Background

Technologies and products for biomass utilization

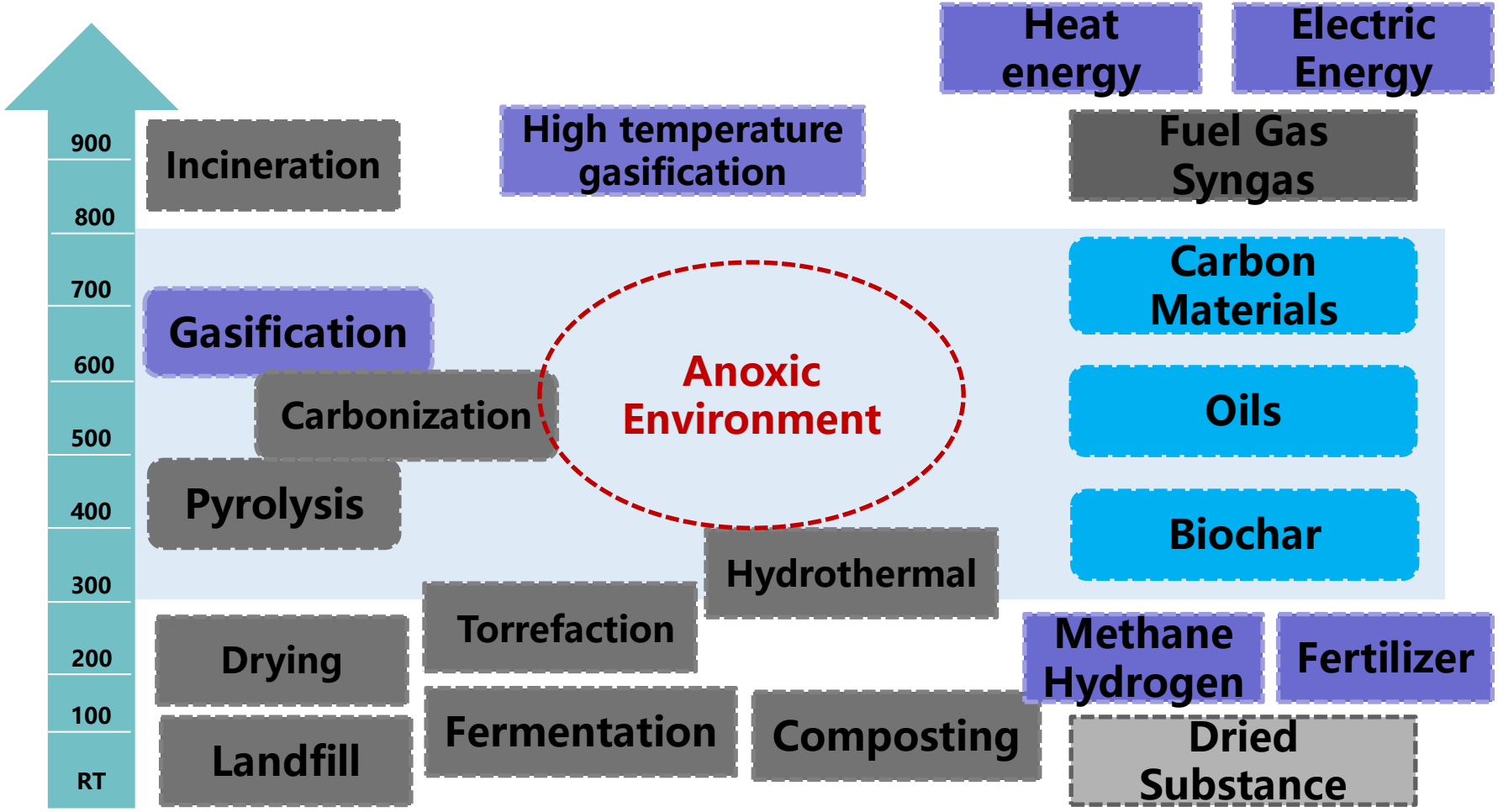


Diagram of technologies and products under Temperature-pressure response

I. Background

Gasification is a re-growing interest in China

---Demand of gas is continuously growing

- Gas shortage of 50% annually
- Clean heating growing
- Growing carbon reduction in industrial sector for metallurgy and steel making
- A promising solution of treating and utilizing wastes

Biomass/ wastes gasification

substituting for natural gas

rural-urban heating

syngas for chemical synthesis and conversion

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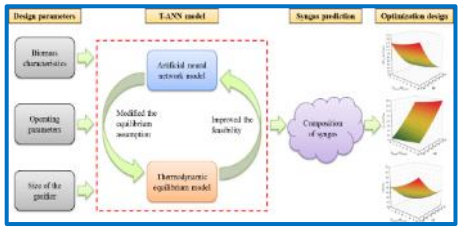
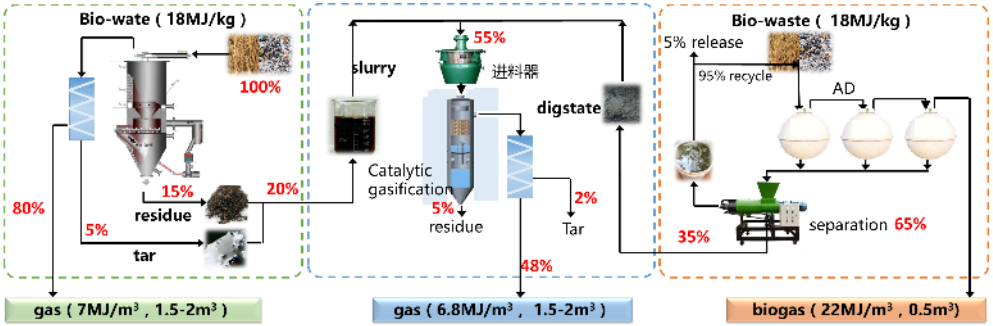
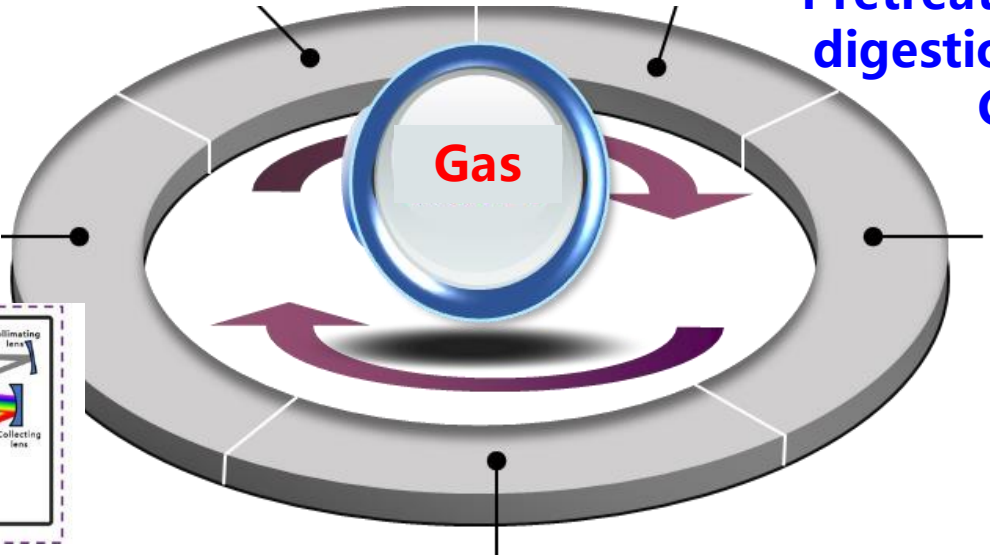
2.1 Gasification for fuel gas production



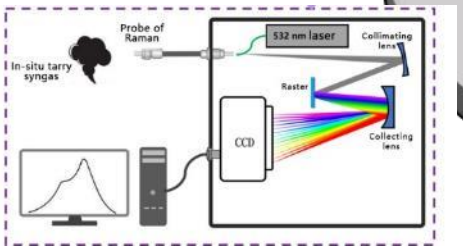
Reverse design of gasifier

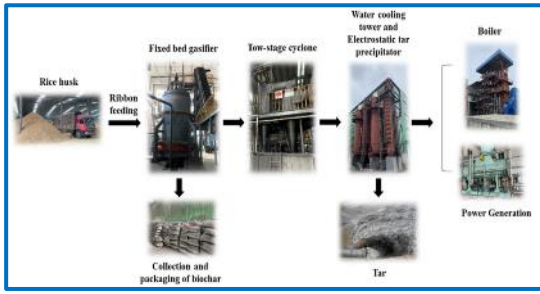


Pretreatment of anaerobic digestion integrated with Gasification



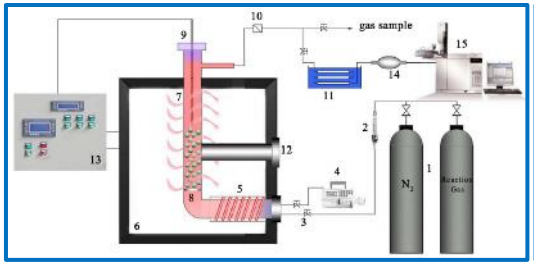
Tar online monitoring

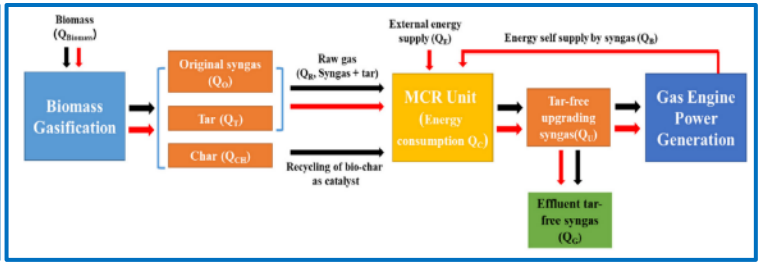




Process control and optimization

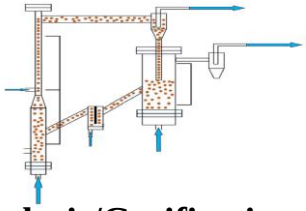
Microwave catalytic/reforming of tar





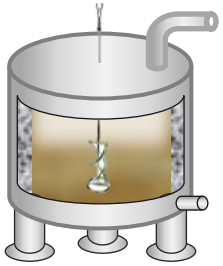
2.2 Gasification for fuel production (bio-ethanol)

Biomass



Pyrolysis/Gasification

Syngas

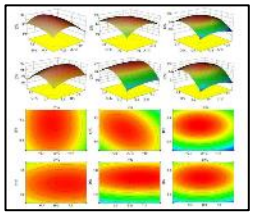


Fermentation

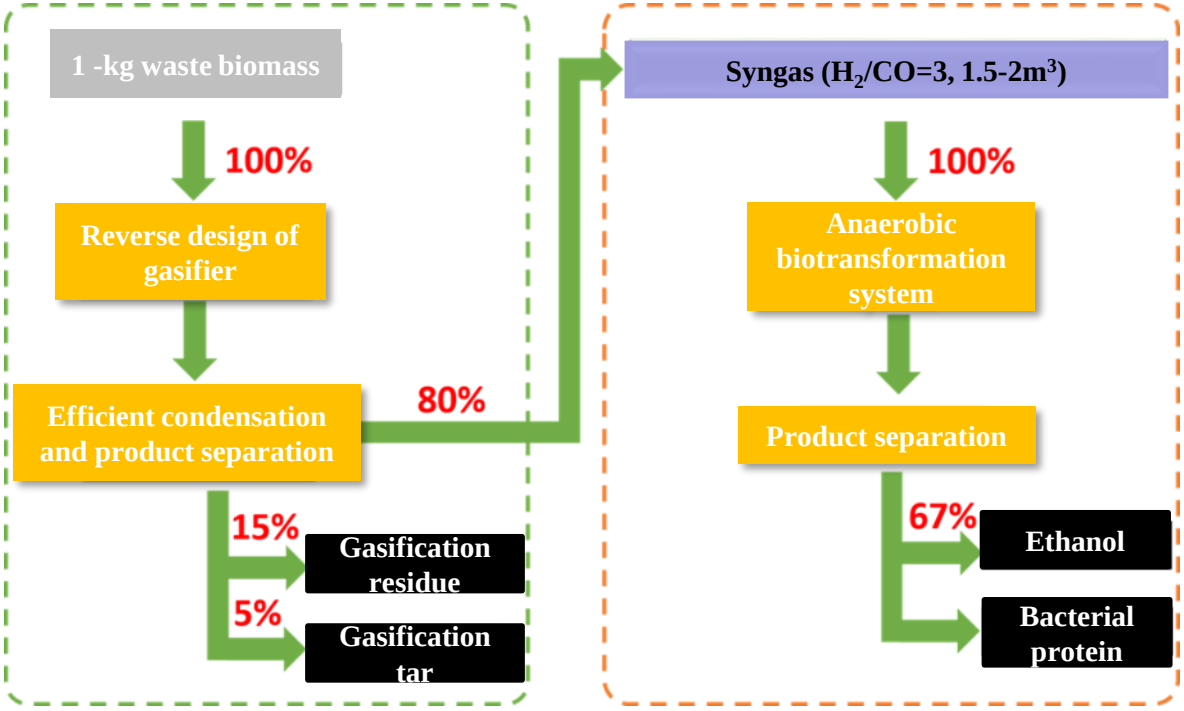
Fischer–Tropsch process

Bio-ethanol

Gasoline/diesel /bio-jet fuel



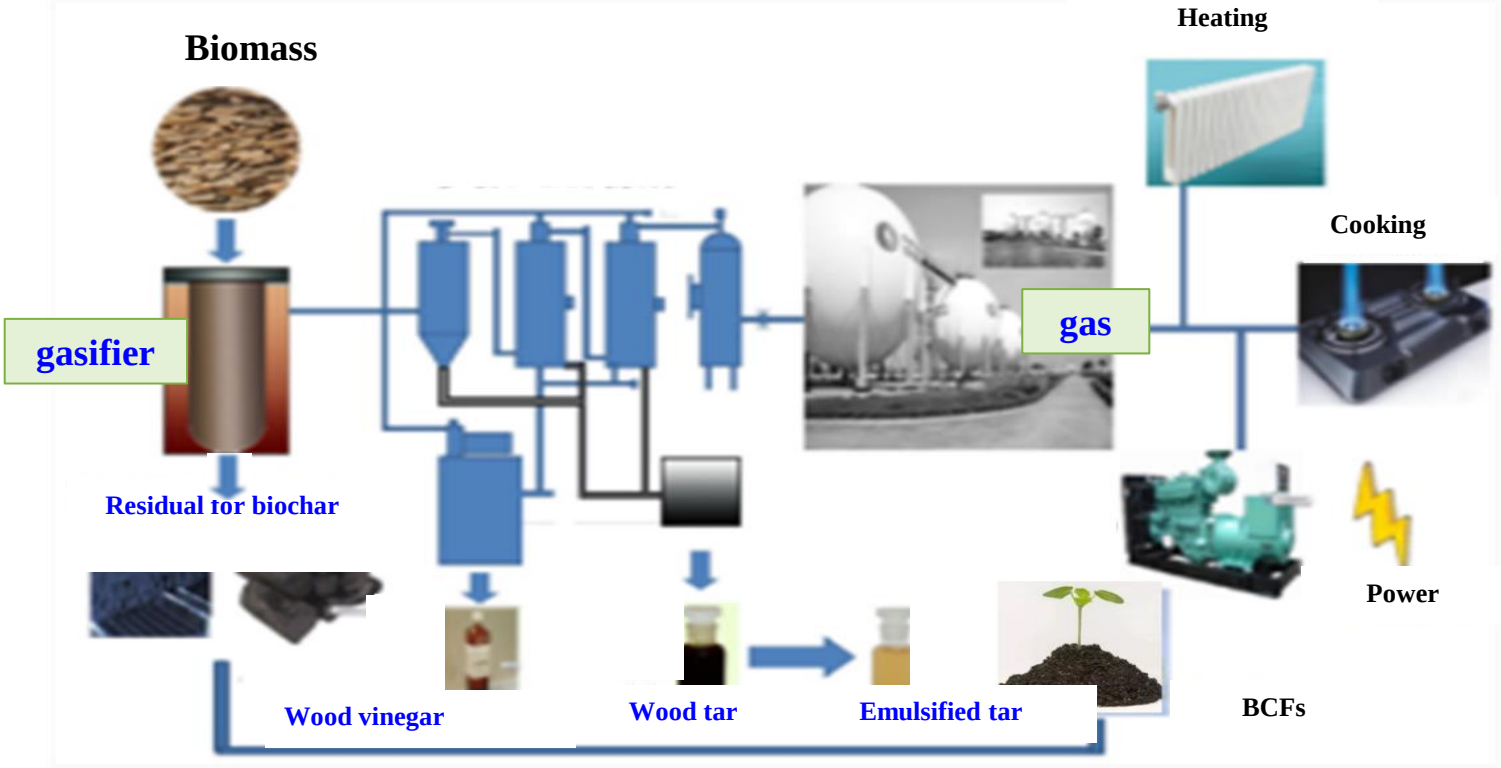
Evaluation simulation and system reverse design



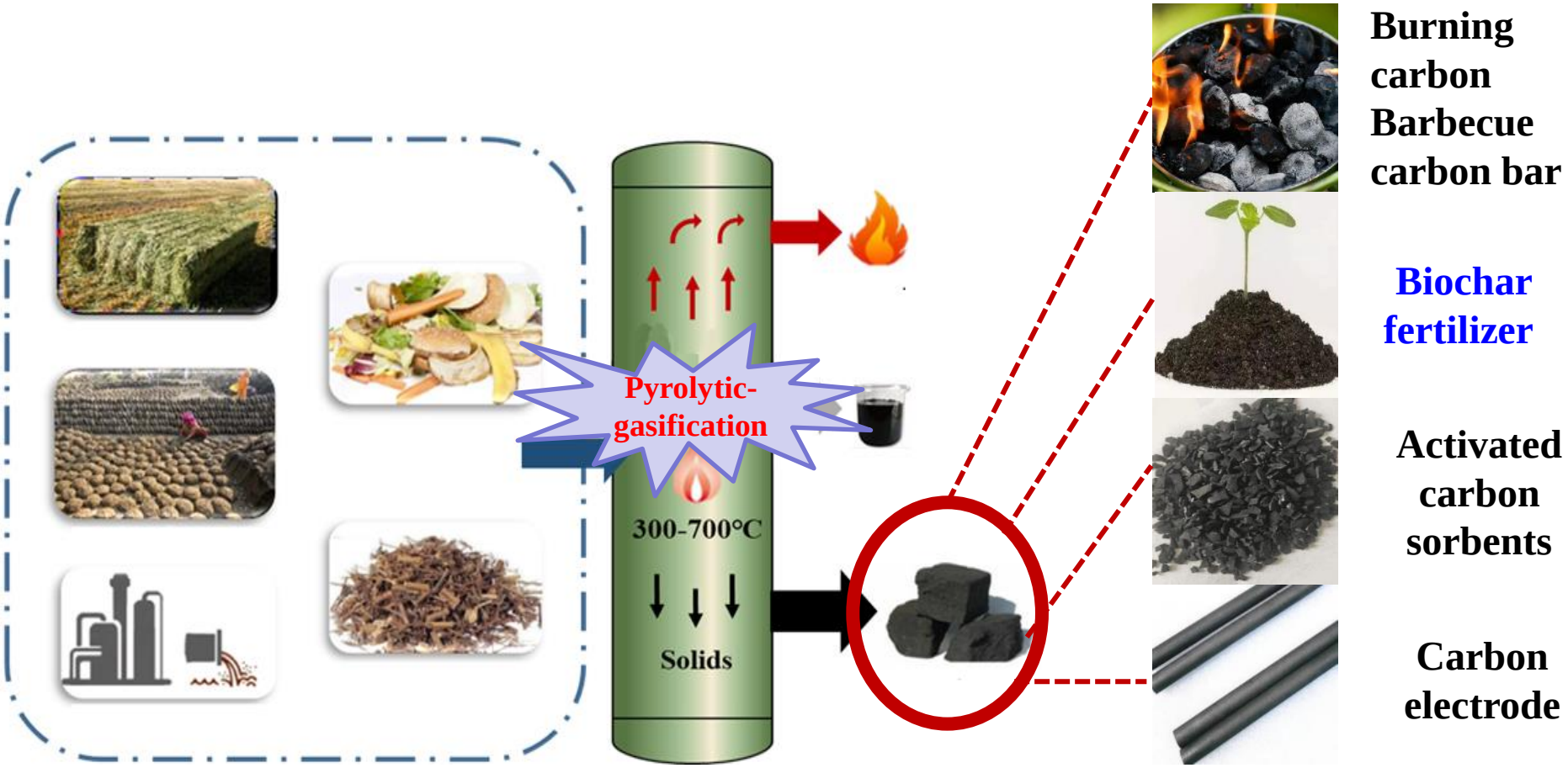
- The maximum output of bioethanol per ton of biomass raw materials is 0.54 tons;
- The cost per ton is less than 3000 yuan

2.3 Gasification for poly-generation

- ❑ Combined heat and power
- ❑ SNG, heat and power
- ❑ Others
- ❑ Biofuels, heat and power
- ❑ Hydrogen and heat



2.4 Gasification for carbon-based products



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3.0 General Information

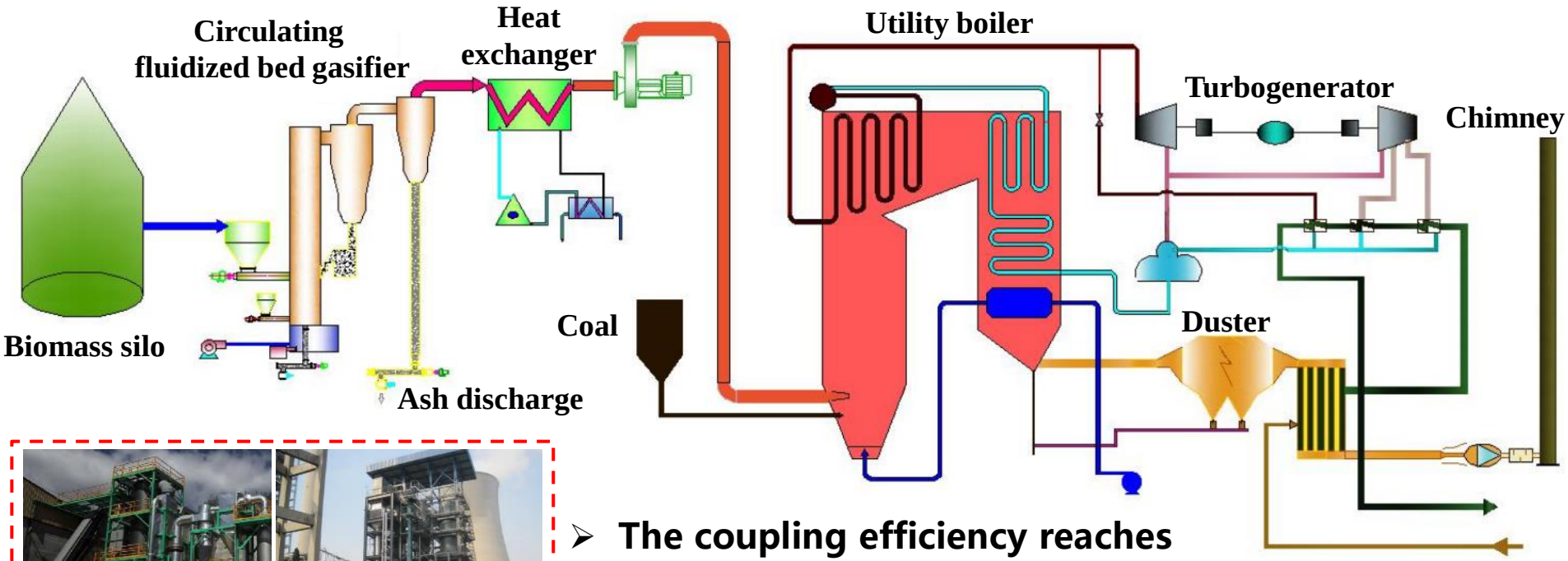
❑ **In total, 84 biomass gasification plants are running in China, and more than 20 plants are under construction presently**

Representative gasification plants in China

No.	Location	Company	Description
1	Jingmen, Hubei	Debo Bio-energy technology., Ltd.	• **Rice husk** gasification coupled with coal combustion for power generation (10.8 MW). • **CFB** with the feedstock of 8 t/h. • Bio-char is utilized as a fertilizer.
2	Anji, Zhejiang	Debo Bio-energy technology., Ltd.	• **Bamboo** gasification for poly-generation of steam and bio-char. • **CFB** (7 t/h) + steam boiler (10 t/h). • Char is sold for production of activated carbon.
3	Heze, Shandong	Baichuan Tongchuang Energy., Ltd.	• **Chinese medical residue** (as received, 150 t/d) gasification producing heat and steam. • **CFB** (10 t/h) + combustion of syngas + heat recovery boiler • The steam and heat are recycled to medicine production process.
4	Jingning, Zhejiang	Litian Environmental technology., Ltd	• **MSW** gasification • Four **Fixed bed gasifiers** (200 t/d in total) • Gasified gas is combusted and clean treatment of MSW is achieved.

3.1 Traditional gasification

3.1.1 Coal-fired power generation coupled with biomass gasification



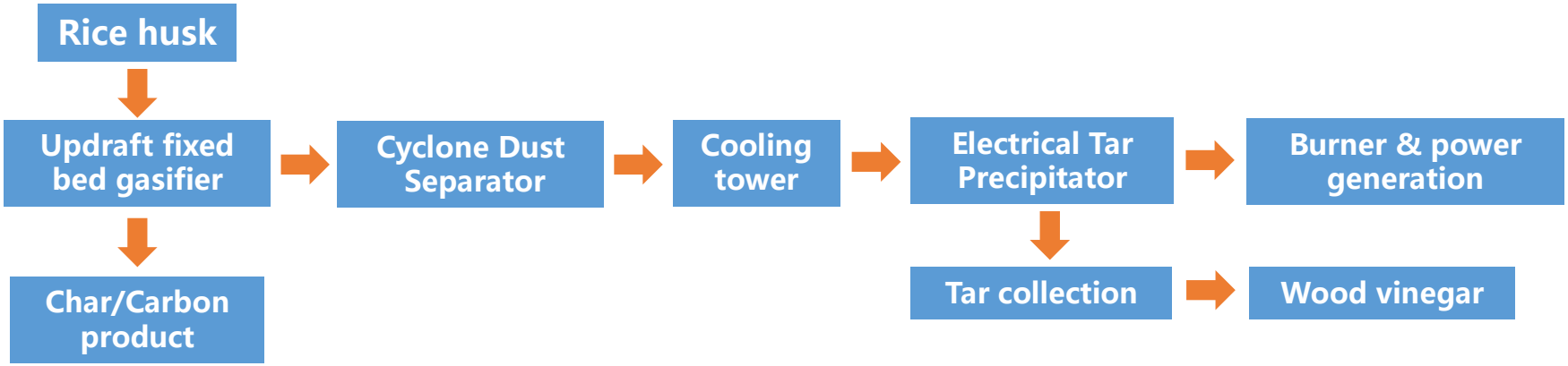
- **The coupling efficiency reaches 40%;**
- **Reduce coal-fired power generation duration;**
- **Redundant load can be more effective.**

Location
Hefei, Anhui Province in China

Scale
Biomass treating capability 30 t/h

3.1 Traditional gasification

3.1.2 Biomass gasification for co-generation of electricity & bio-char



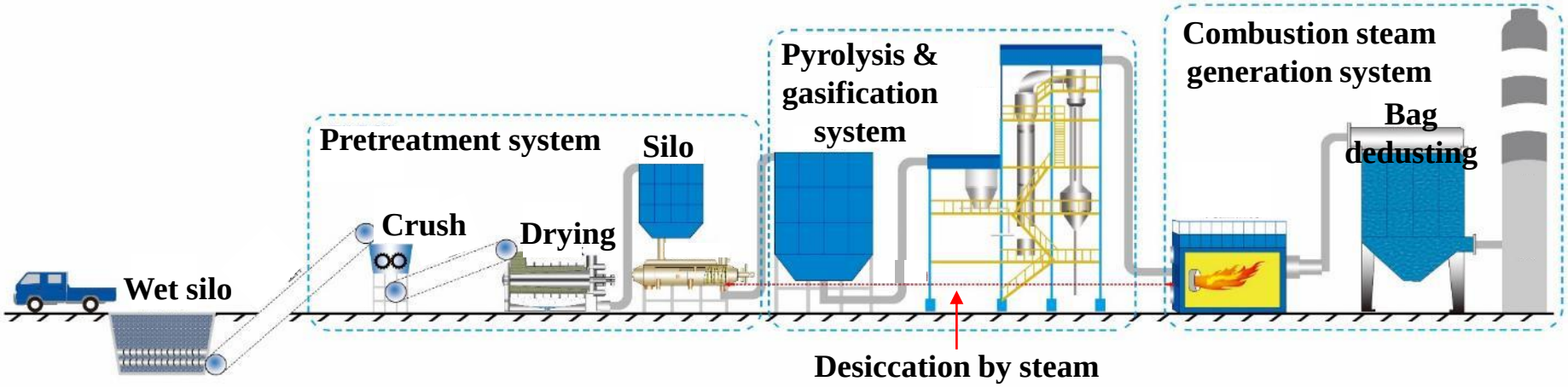
Location
Yingshang, Anhui Province in China

Products
Initial Tar yield: 3-4 g/Nm^3
Char yield: 40 t/d

Scale
Rice husk treating capability 150 t/d

3.2 Gasification of industrial bio-wastes

3.2.1 Gasification of Chinese herb/medicine residue



(a) Overview of the pilot plant

The gasification & combustion sections

The crushing & drying sections

Location
Heze, Shandong Province in China

Feedstock
Various herb residue with moisture of 75 wt% (raw) → 20 wt%

Scale
Herb residue treating capability 250 t/d

3.2 Gasification of industrial bio-wastes

3.2.2 Gasification of brewing waste

Distiller's grains

Anaerobic fermentation

Separation

Biogas residue

Biogas slurry

Biogas

Biogas residue gasification

Aqueous phase reforming

Location
Maotai, Guizhou Province in China

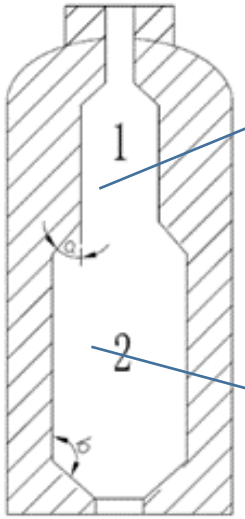
Scale
Distiller's grains treating capability 110 Kt/a
Biogas residue yield: 22500 t/a

Effect expectation:

- **Potential energy of biogas residue: 4.37*10^8 MJ;**
- **Potential energy of gas: 3.02*10^8 MJ.**

3.2 Gasification of industrial wastes

3.2.3 Gasification of solid waste slurry



First reaction zone

$C+O_2 \rightarrow CO_2$

$2C+O_2 \rightarrow 2CO$

$VM+O_2 \rightarrow CO_2+H_2O$

Second reaction zone

$C+CO_2 \rightarrow 2CO$

$C+H_2O \rightarrow CO+H_2$

$CO+H_2O \rightarrow CO_2+H_2$

Multi-stage gasifier

Location

Zhenjiang, Jiangsu Province in China

Scale

hazardous waste mixture treating capability 150 kt/a

Feedstock

- ✓ hazardous waste mixture
- ✓ bituminous coal
- ✓ organic industrial wastewater

Different hazardous waste

Analyzing

Data

Unqualified

Database

Scheme output

Qualified

Compatibility scheme

Production system

3.3 Gasification of municipal solid waste

3.3.1 Traditional direct gasification of MSW

Raw MSW → Screening / Manual sorting → Pre-treated MSW → Gasification → Syngas combustion → Purification → Emission monitoring

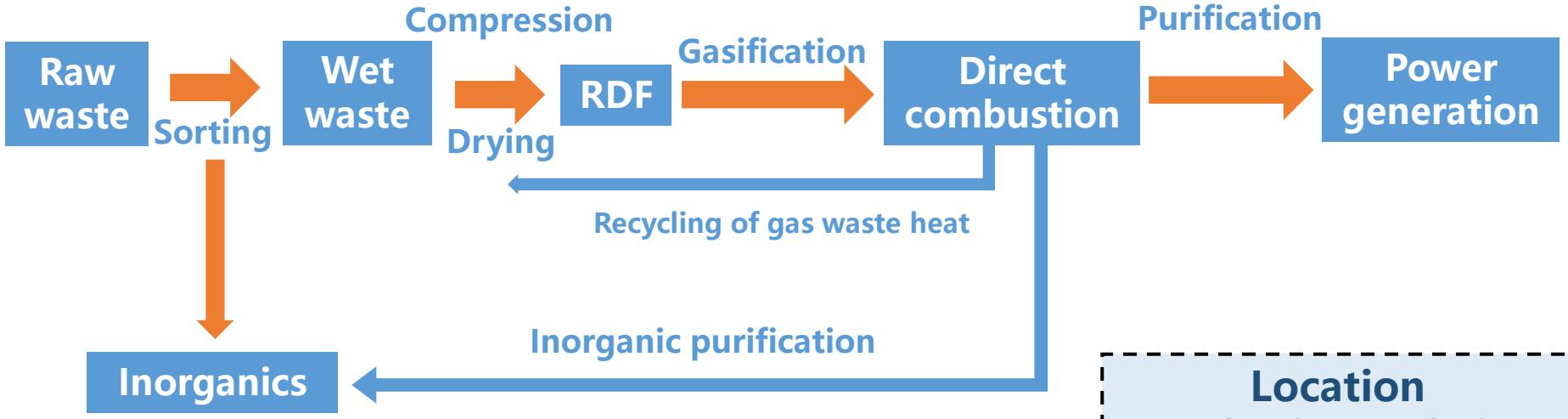
Location
Jingning, Zhejiang Province in China

Scale
MSW disposal capability 200 t/d

Feedstock
MSW with moisture below 30 wt.% (raw), the content of inorganics is reduced by manual sorting

3.3 Gasification of municipal solid waste

3.3.2 Gasification of MSW and energy feedback for pre-treatment of MSW



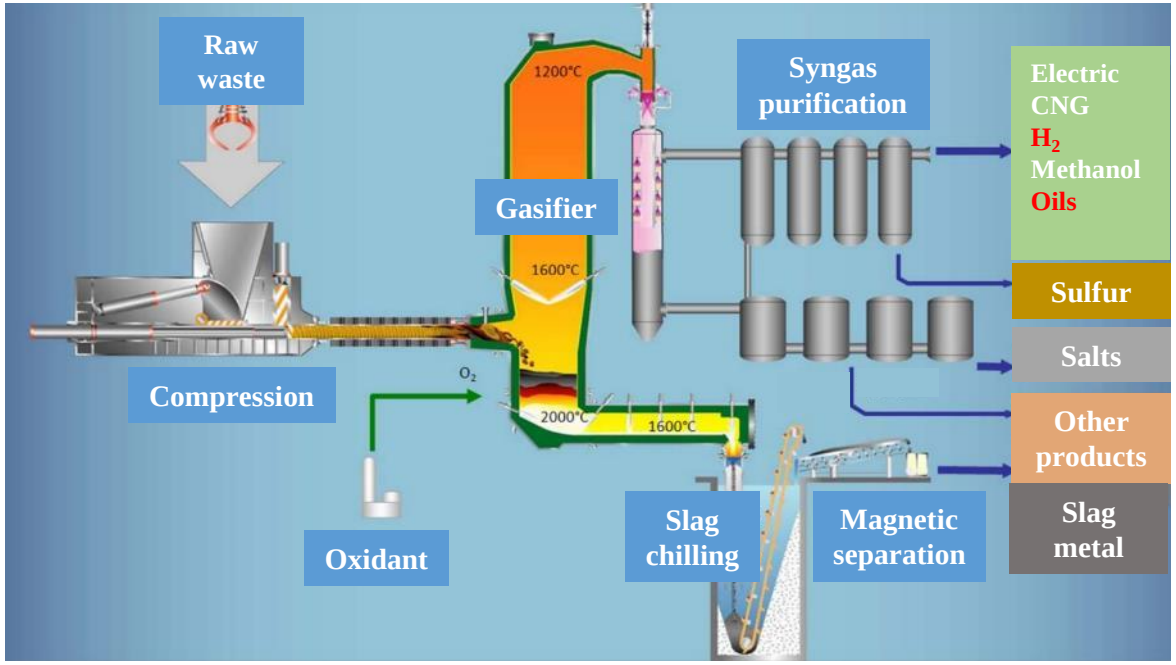
Location
Shexian, Hebei Province in China

Feedstock
MSW with moisture 60 wt.% (raw)

Scale
MSW treating capability 60 t/d

3.3 Gasification of municipal solid waste

3.3.3 High-temperature gasification of MSW



Location
Fangshan, Beijing in China

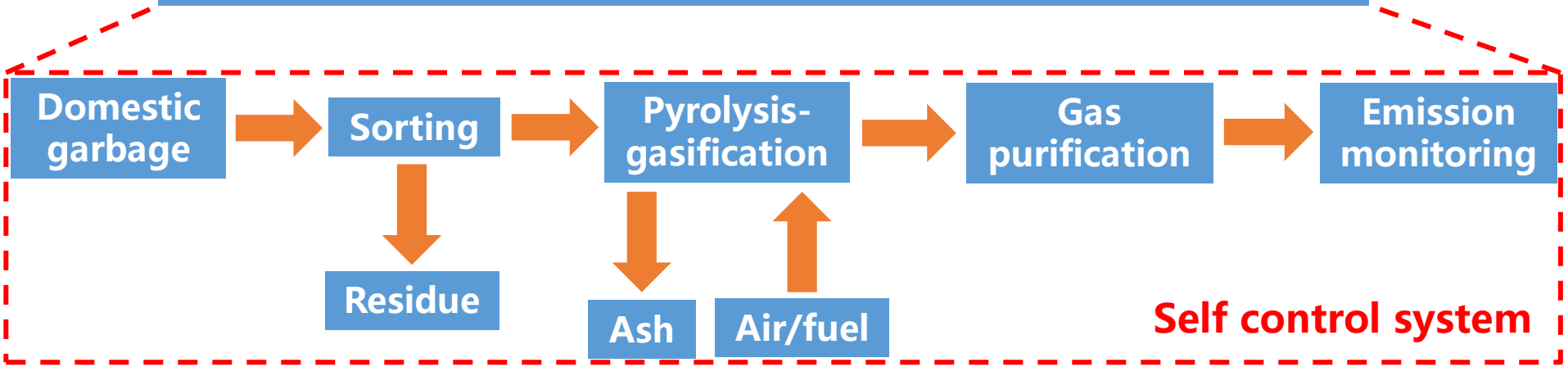
Products
hydrogen

Scale
MSW disposal treating
2 t/d

3.4 Mobile/small-scale waste gasification

3.4.1 Fixed small-scale gasification-combustion of rural garbage

Intelligent continuous treatment system for domestic waste



3.4 Mobile/small-scale waste gasification


Location	Scale
Maduo, Qinghai Province in China	5 t/d



Location	Scale
Gangcha, Qinghai Province in China	10 t/d



Location	Scale
Qinghai Province, China	3-5 t/d



Location	Scale
Zaduo, Qinghai Province in China	20 t/d



Location	Scale
Boxing, Shandong Province in China	10 t/d



Location	Scale
Qinghai Province, China	3-5 t/d

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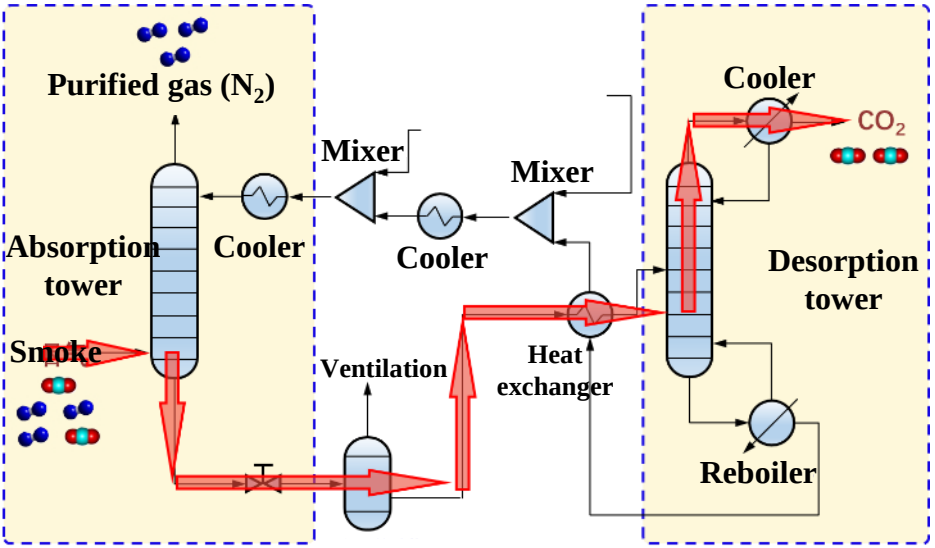
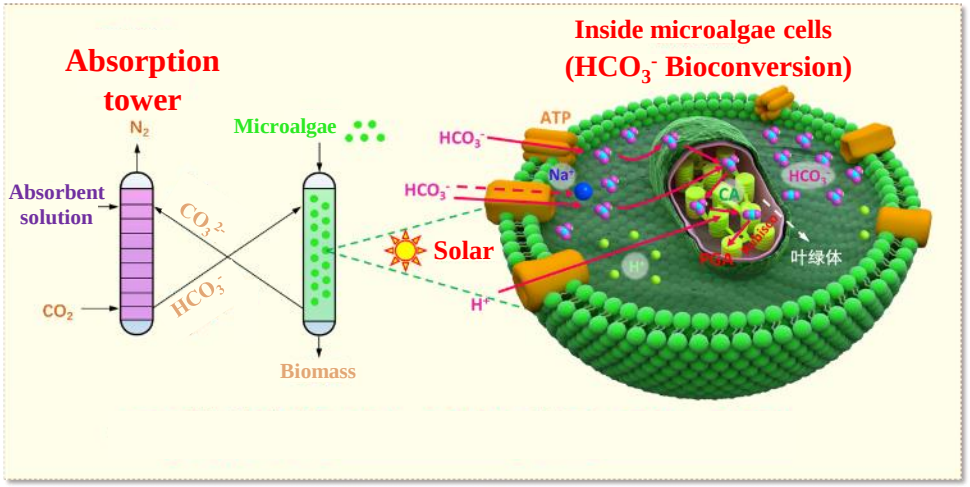
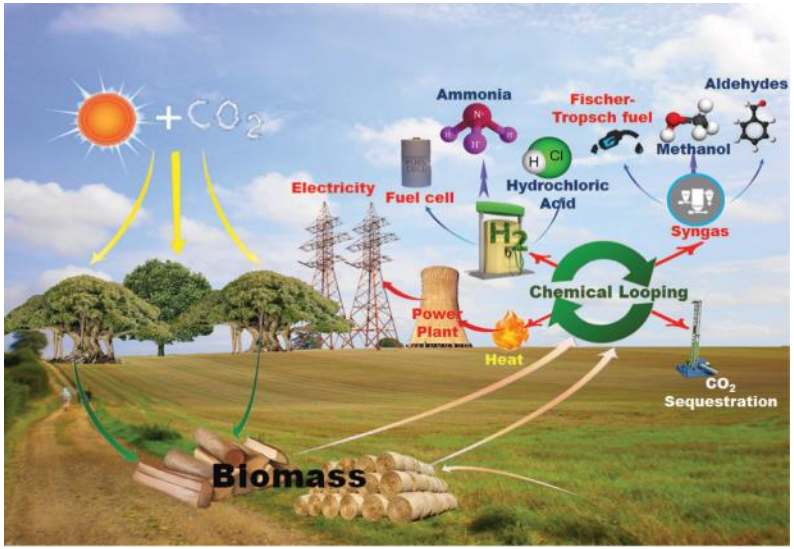
4.1 Biomass gasification with CCS



CO_2 chemical absorption technology



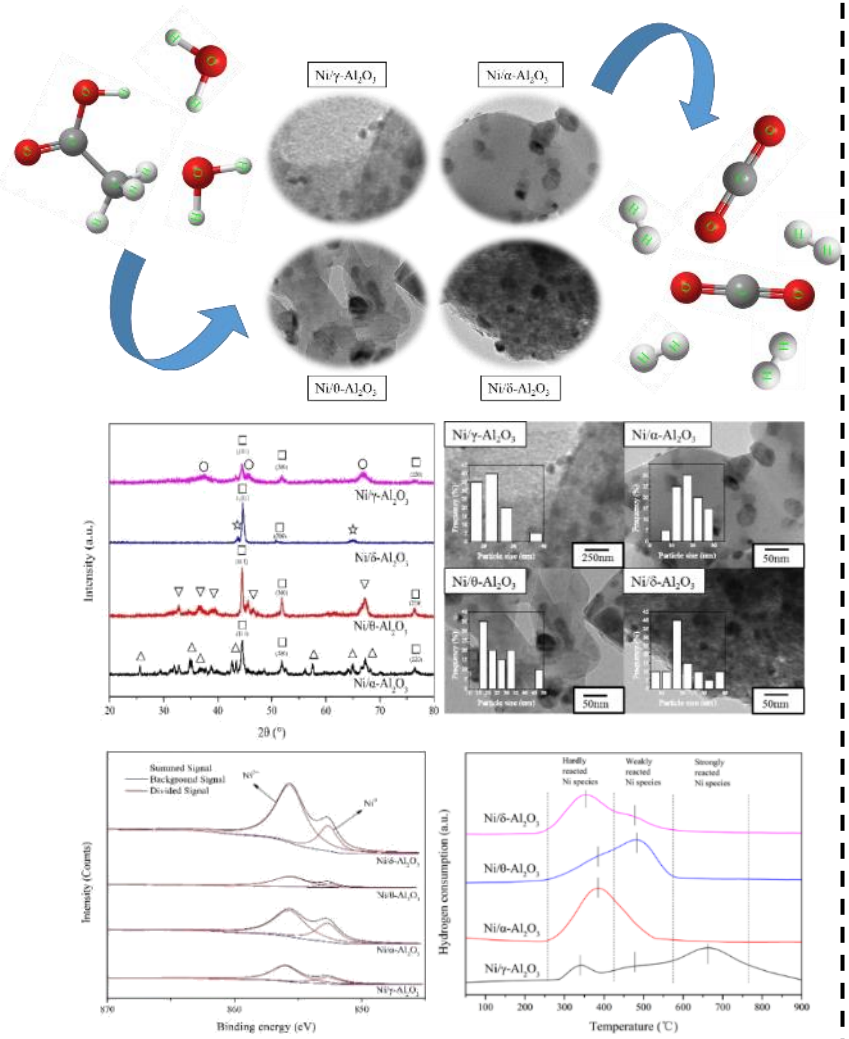
CO_2 chemical absorption coupled with biotransformation technology



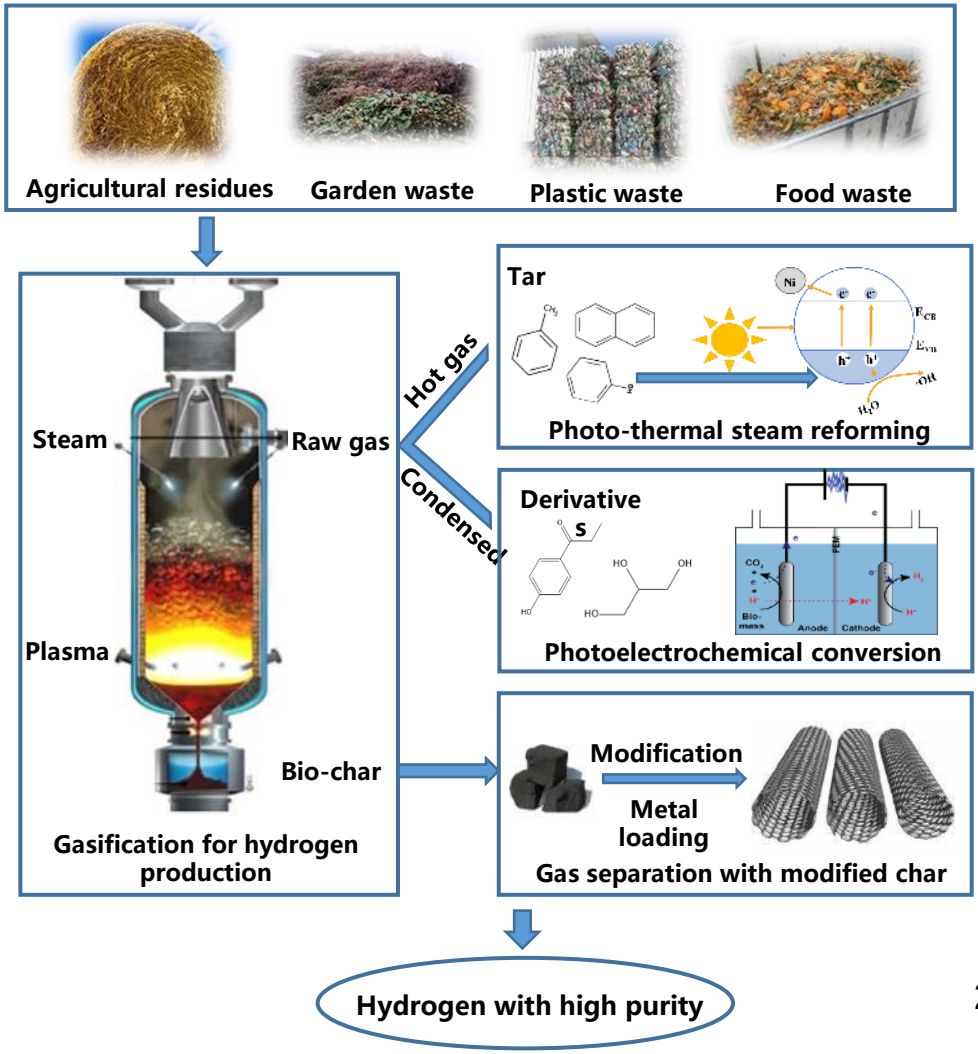
Chemical looping gasification technology

4.2 Biomass to hydrogen

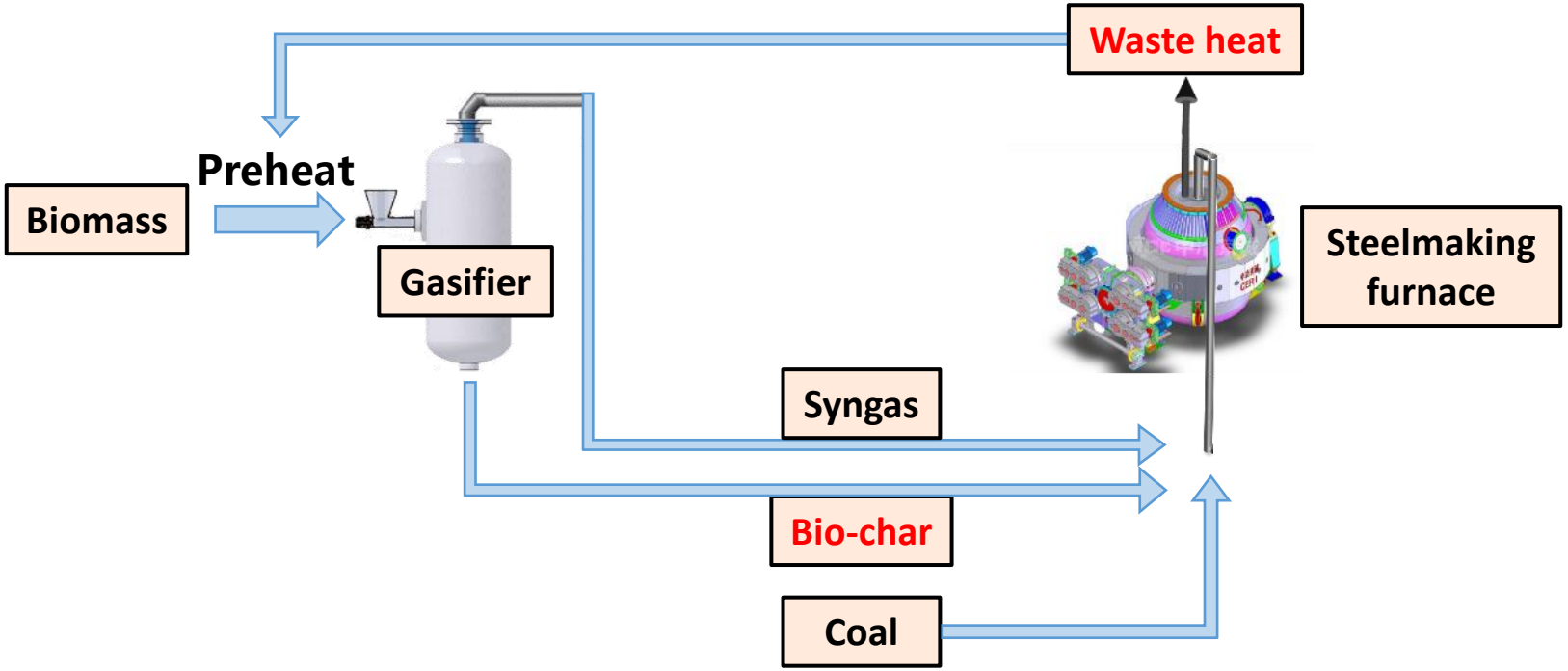
Bio-oil (acetic acid) catalytic reforming for H_2 production



Bio-waste gasification-tar reforming for H_2 production

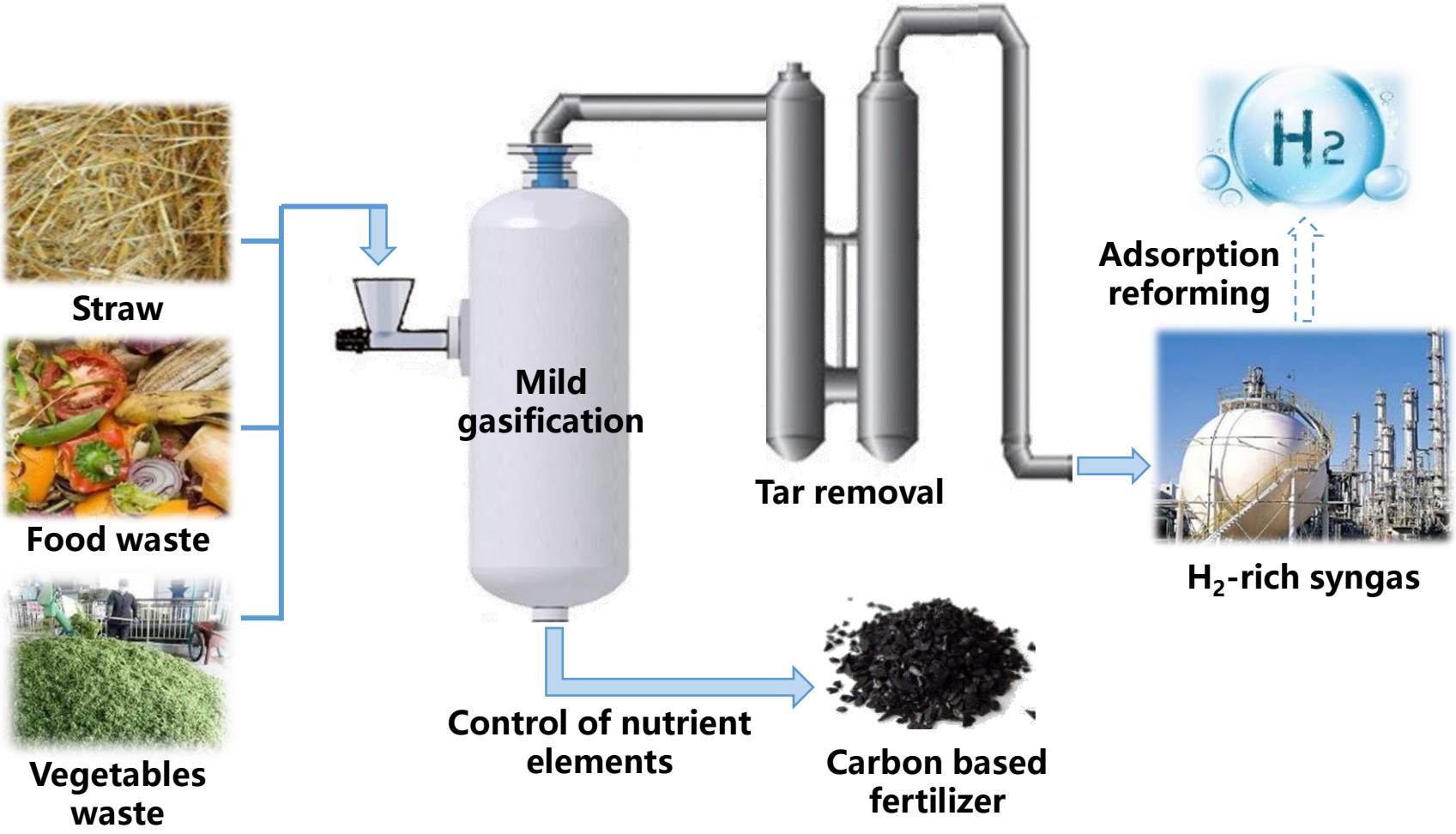


4.3 Bio-char applied in steel industry for carbon reduction



- Bio-char obtained from biomass gasification/pyrolysis can be utilized in steel industry to **partially replace coal.**
- The waste heat from steel industry can be recycled and **provides heat for bio-char production**.

4.4 Poly-generation of H_2 and carbon based fertilizer



- Smart control of the gasification degree to achieve the **balance between energy elements** (C/H/O) and **nutrients elements** (K/N/P) during gasification.
- New efficient method to remove tar and converts it into hydrogen.

4.5 Gasification of landfill excavation waste

Treatment of stale waste based on pyrolysis and gasification technology

Separation

60%

40%

Humus soil

Loose soil with more pores, large SSA and rich in nutrients

Land greening, planting and cultivation (Mature technology)

Combustible components

Chlorine pollution release
Heavy metal enrichment
High management cost
Poor economy

Burn

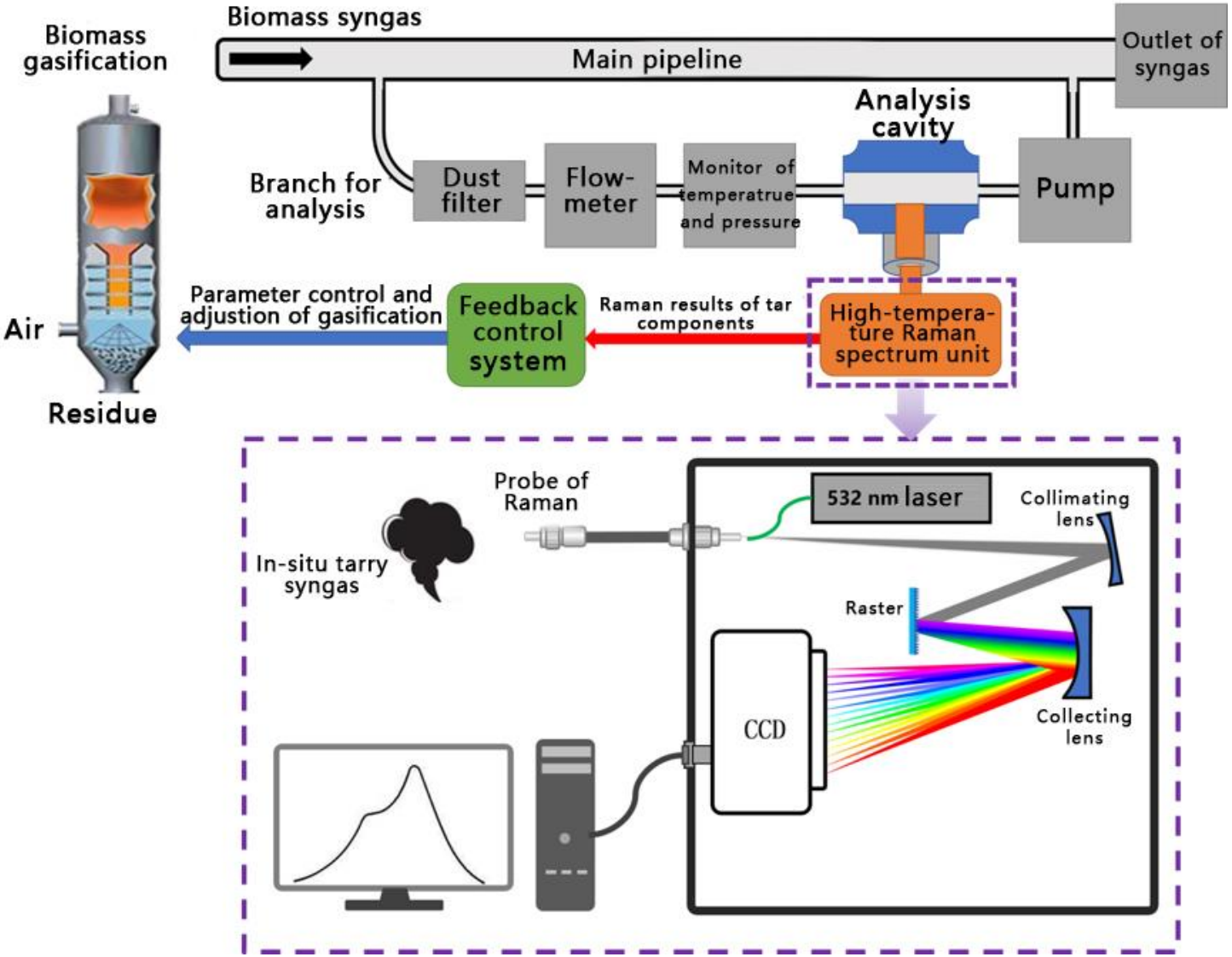
Gasification

Safe and simple pollutant control
High feasibility of full components

Stale waste

Low water content
(< 20%)
High calorific value
(> 15MJ/kg)

4.6 On-line measurement of gasification tar



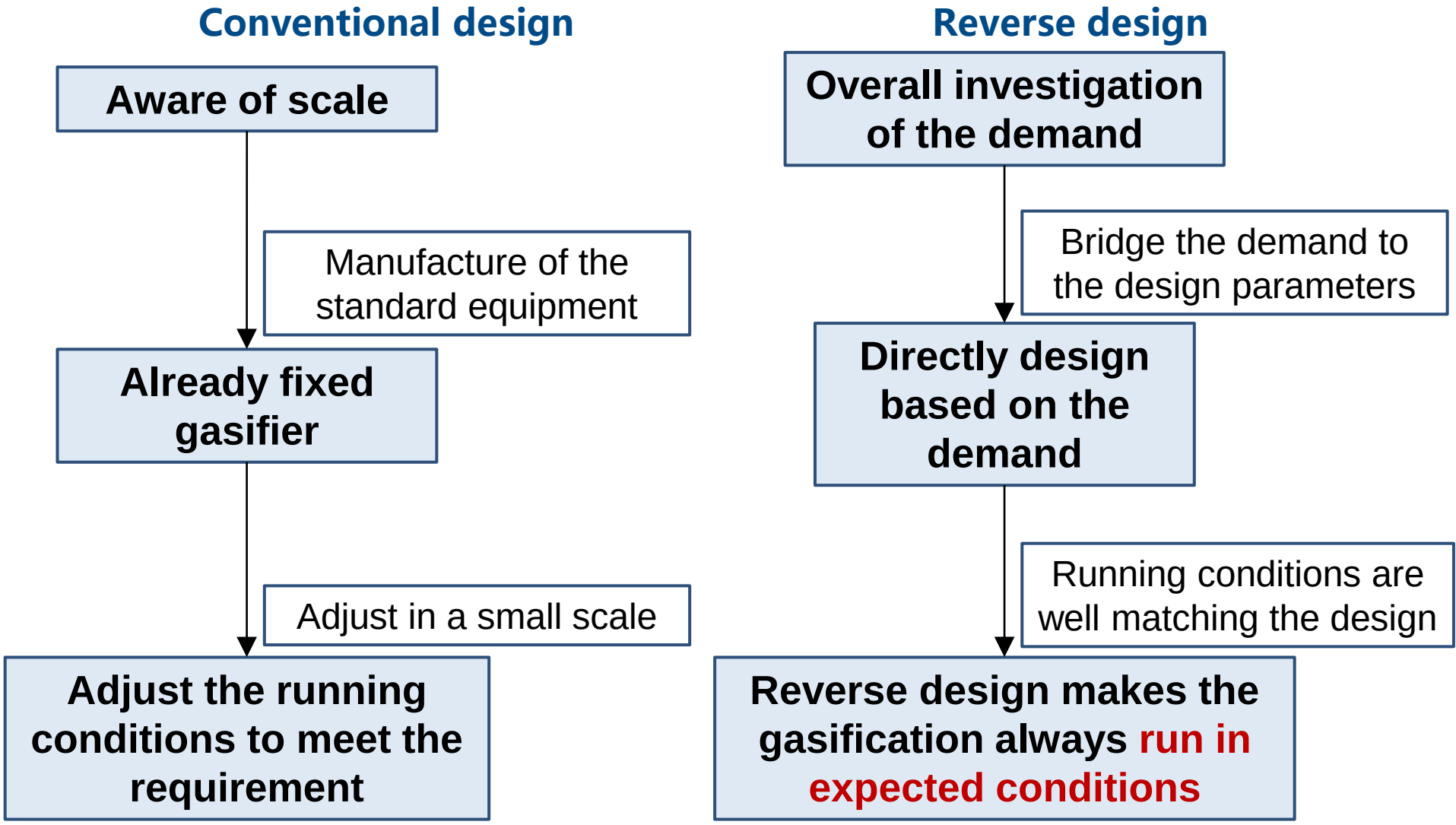
Scheme of on-line optical measurement of tar

4.7 Small-scale gasification

Small-scale gasification plant in village

- It is urgently needed to develop small-scale gasification especially in village due to the limitation of collection and transportation of feedstock.
- The cost of gas cleaning is high which lowers the quality of syngas and limits the application.

4.8 Advanced design of gasification



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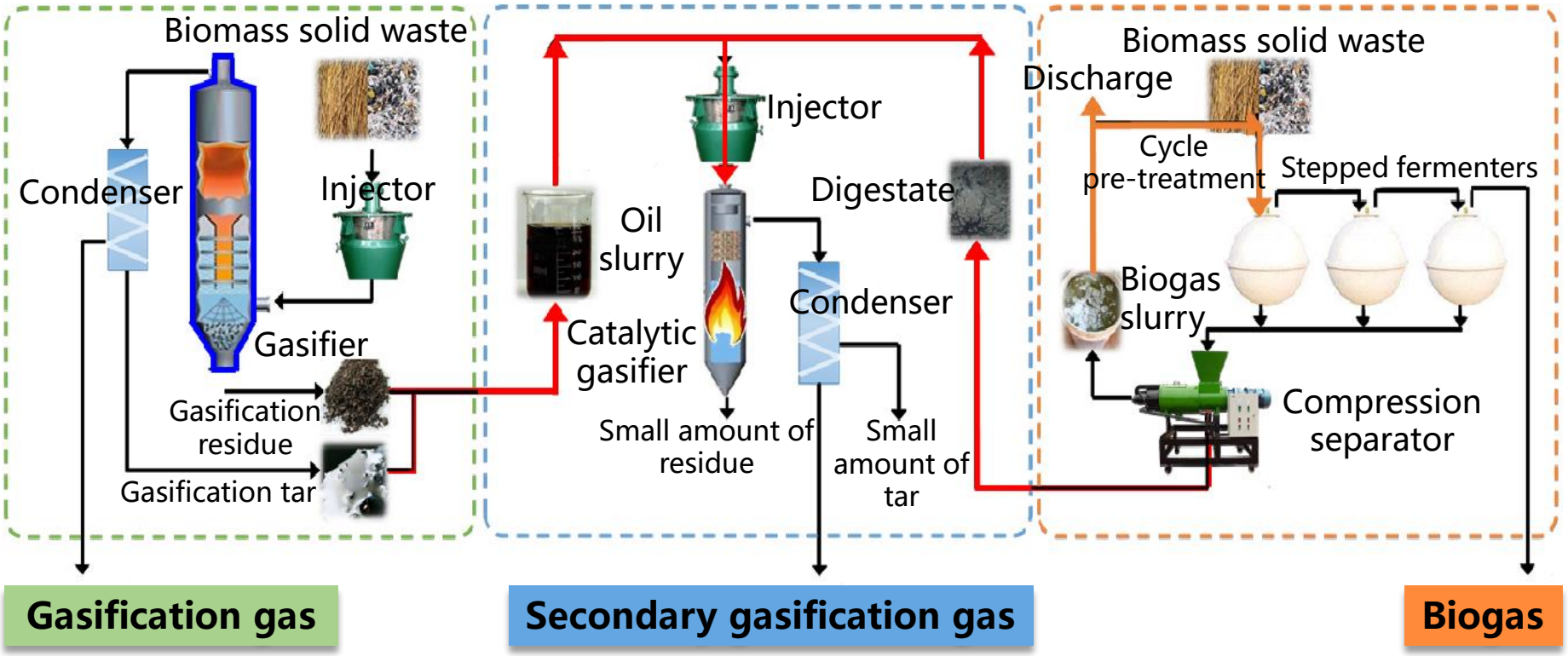
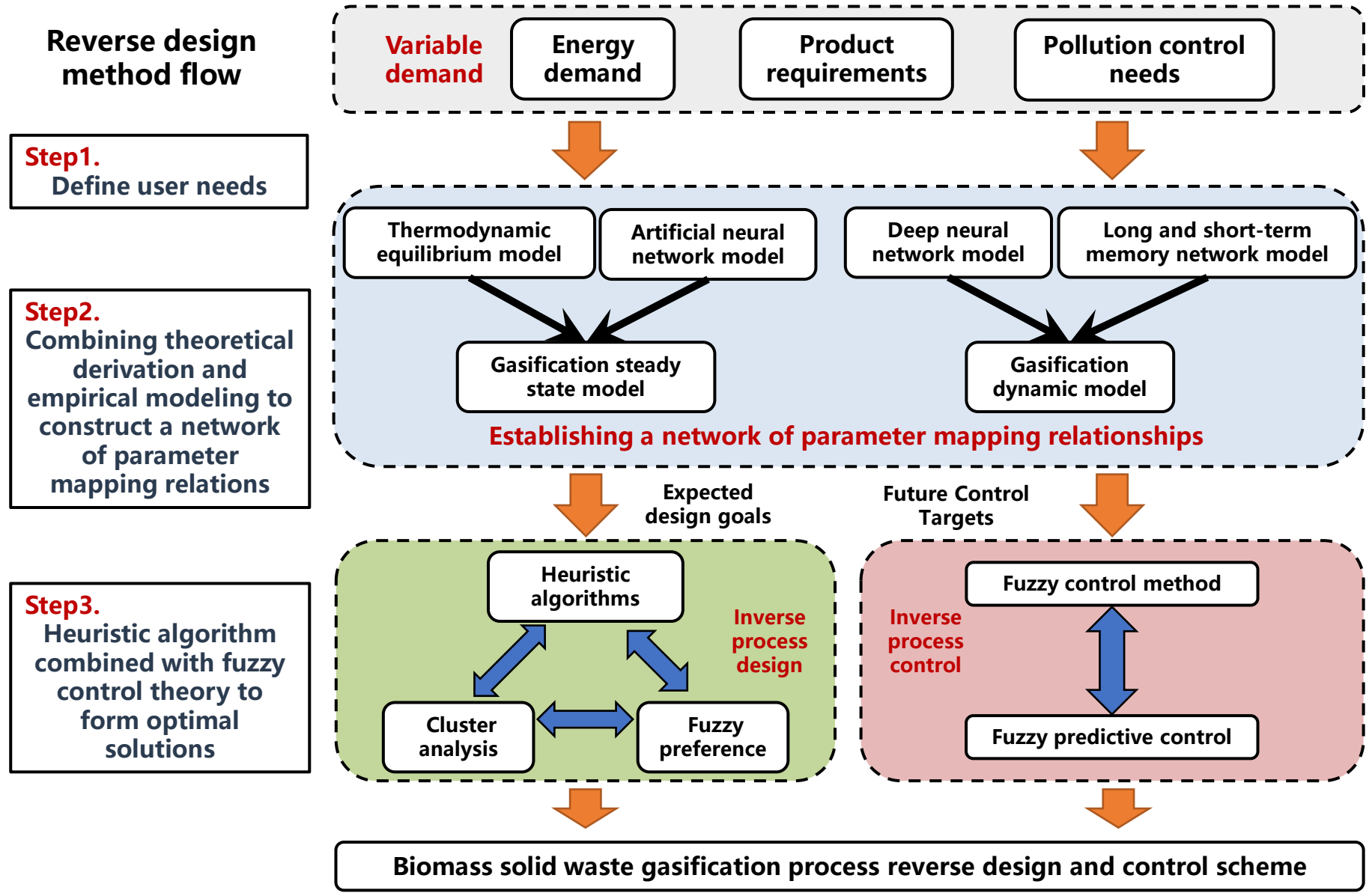
5.1 New-type clean gasification for mutiple biowaste

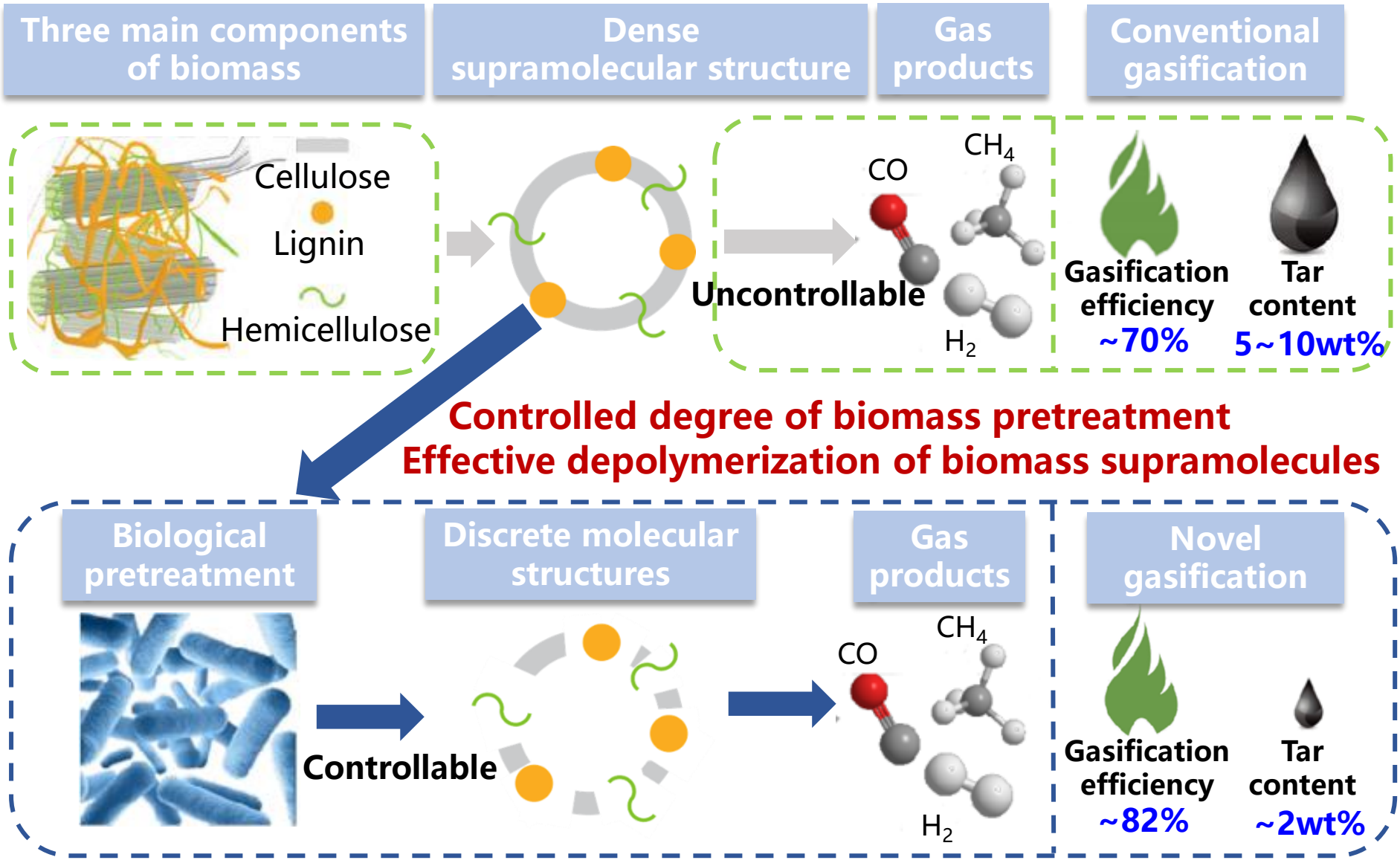
Secondary gasification technology for tar and other by-products



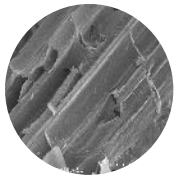
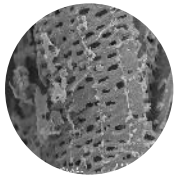
5.2 Innovative design of gasification: Reverse design



5.3 Bio-thermal coupling technology



5.3 Bio-thermal coupling technology

	Morphology	structure	Heating Value (MJ/Nm^3)	Fuel gas efficiency (%)
Traditional gasification	 1 kg straw		<6	~65
Anaerobic Digestion	 0.66kg AD for 28d → 0.27m^3 biogas		20.80	45.77
Coupling technology	 0.69kg AD for 14d → 0.2m^3 biogas		6.83	85.03

The total fuel gas production efficiency reaches 85%

Research Team

Guanyi Chen Vice president and professor of Tianjin University of Commerce

- **Distinguished professors of Changjiang Scholars, leading talents of the 10000 person plan, and leading talents of ecological and environmental protection**
- **National outstanding scientific and technological workers enjoy the special government allowance of the State Council**
- **Baosteel excellent teachers and the first batch of Tianjin outstanding talents**

He is mainly engaged in research on **biomass waste energy conversion**. He presided over key projects of the National Natural Science Foundation, projects/topics of the Ministry of science and technology, EU projects, etc. Now he is a member of the overall expert group of the key special project of the national key R & D plan "technological innovation in green livable villages and towns", the convener of the biomass gas environment and safety group of TC 255 Committee of ISO international organization for standardization, the director of Tianjin Key Laboratory of biomass waste utilization, and the president of Tianjin Institute of sustainable development.

Beibei Yan Professor of Tianjin University

- **Winner of National Science Fund for Outstanding Young Scholars**
- **Winner of Tianjin Youth Science and Technology Award and Tianjin outstanding youth fund**
- **Young leading talents and young scientific and technological talents in Tianjin**
- **Secretary of the Council of national solid waste energy industry technology innovation strategic alliance**

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Member of Tianjin University of Commerce

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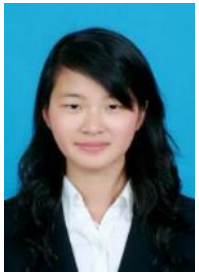

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professor

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Research Team

Academic achievement: more than 450 papers; 41 patents (including Japan, USA, Australia patents); 6 software registrations; 1 international standard and 9 books.