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Choice of sewage sludge thermochemical disposal methods from multi- perspective analysis

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CHOICE OF SEWAGE SLUDGE THERMOCHEMICAL DISPOSAL METHOD FROM MULTI-PERSPECTIVE ANALYSIS

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Content

- Thermal chemical treatment of sewage sludge
- Flow diagrams of three typical thermal chemical conversion technologies
- Comparison of investment & operation of the three technologies
- LCA results
- Results of questionnaire survey
- Conclusion

Sewage sludge, a byproduct discharged from a wastewater treatment plant

Thermal-chemical treatment of sewage sludge is necessary in China due to the following reasons:

1. Huge generation of sewage sludge(SS) [1]

- **Waste water treatment plant ≥3000 plants in operation**
- **Waste water ＞ 36,000,000,000 m^3/a**
- **Sewage sludge generation（80% MC） ＞ 22,000,000t/a**

2. Pollution related to sewage sludge

- **Highly contaminated with：organics, pathogen and toxic materials**
- **High soil & sand content; cannot be easily disposed through biotechnologies**

3. Thermal chemical treatment technologies [2,3]

- **Incineration**
- **Gasification**
- **Pyrolysis**

these three technologies can kill the pathogen, destroy the toxic materials and greatly reduce the volume of SS…

SS Thermal-chemical treatment experiences in China[4,5]

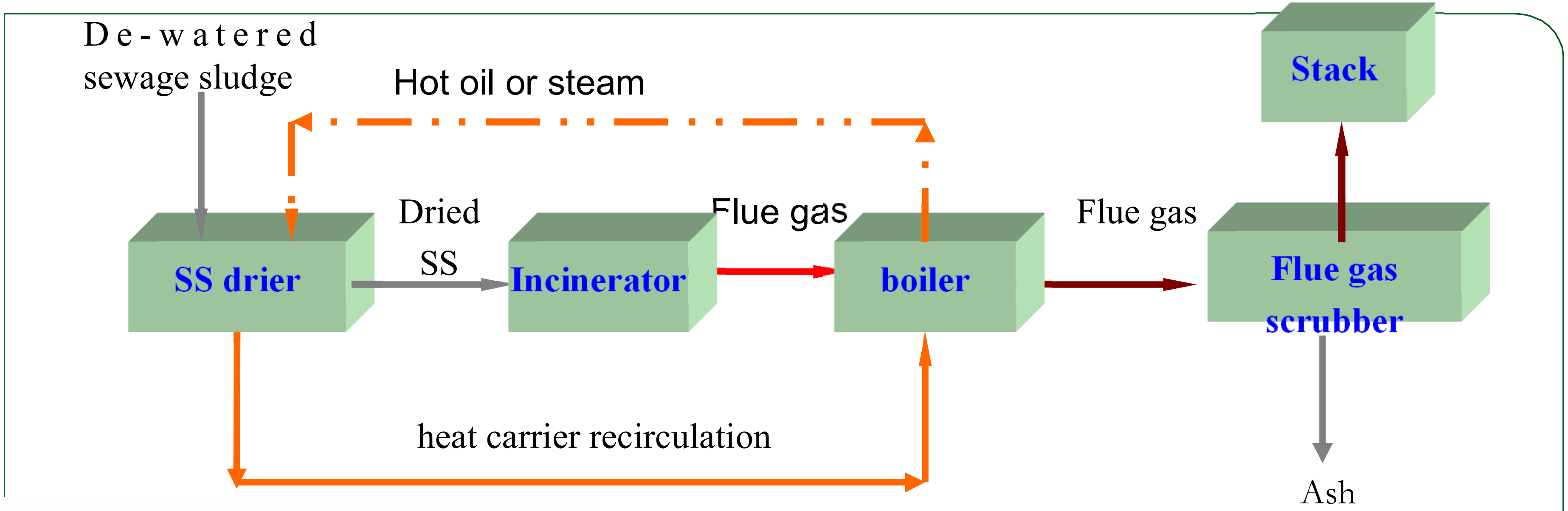
Technology	Capacity (t/d, 80%MC)	Investiment (10^4 Yuan)	Operation cost (Yuan/t)	Location
Bubbling fluidized bed Incineration (SS alone)	180	8000	Planned :280 Actually:400	Shanghai
	800	48000	473.8 - 584	Shenzhen
Circulating fluidized bed Incineration (SS with MSW or coal)	500 + 1000 (MSW)	55000		Shaoxing
	200 (70% MC) + 1200 Coal (designed for 400t/d SS)	8050	170-300 (depending on tipping fee)	Nanjing
Spray dry +Rotary kiln incineration (SS alone)	360	10000		Xiaoshan
Cement kiln incineration	500	17500	252	Beijing
Gasification *	50	1088.56	~400	Xinxiang
Pyrolysis (traditional)	200	4500	400	Yiwu (stopped)
Pyrolysis (Volatile reforming)	30 (≦30%MC)	627	200	Chongqing (just start)

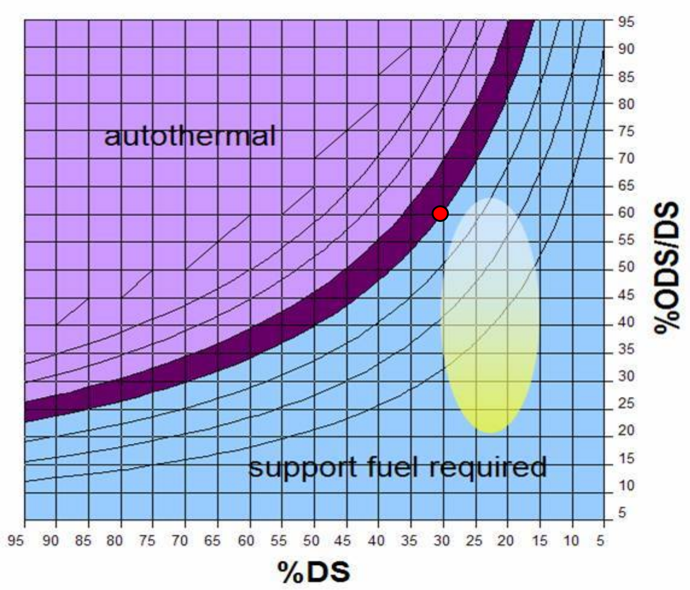
- For all of three technologies, the sewage sludge (SS) should be dried before thermal chemical treatment;
- For incineration, flue gas scrubbing is rigidly required;
- For gasification and pyrolysis, syngas can be burnt first and flue gas scrubbing is followed afterwards; or the syngas can be washed first and then burnt in boiler or gas engine.

* MC: moisture content

Content

2.1 Incineration system





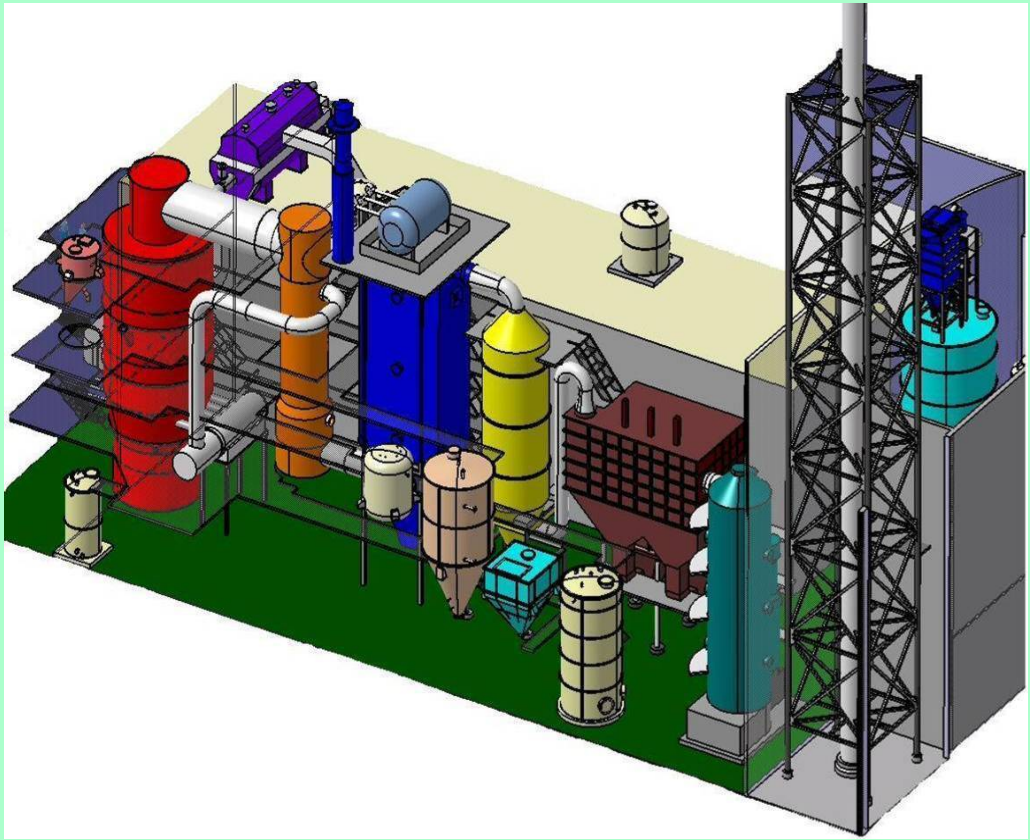
Adiabatic temperature calculated by the following formula:

$$t_a = \left(LHV \left(1 - \frac{q_g + q_{ash}}{100 - q_s} \right) + Q_k + Q_{oil} \right) \cdot \varphi \Big/ \left(V_y C_{pj} \right) \geq t_t$$

Adiabatic temperature t_a should reach its threshold value around 1050 °C for autocombustion.

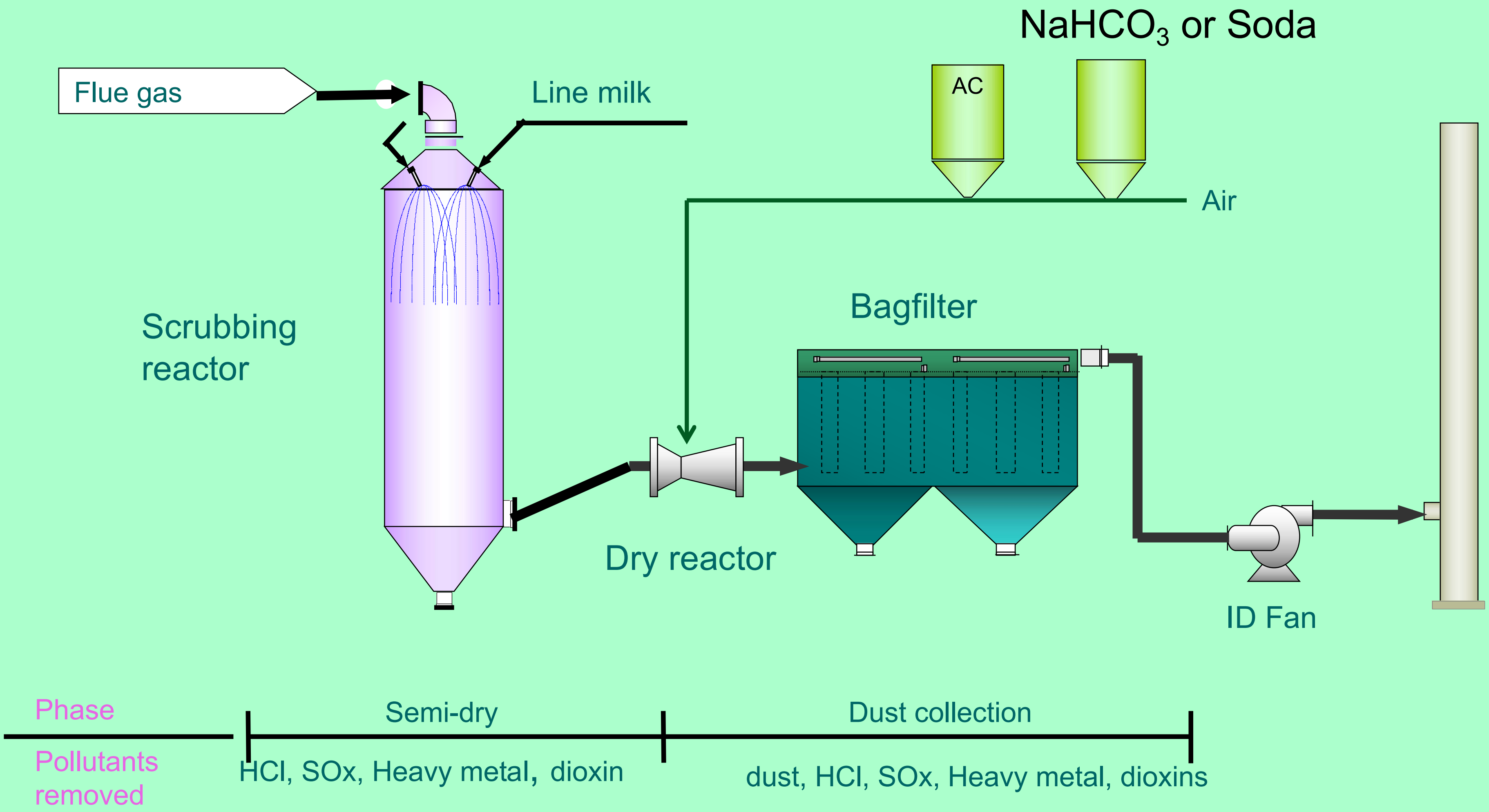
SS can be burnt in the coal-fired boilers, MSW incinerators and incinerated independently. For comparison, the commonly used fluidized-bed drying & incineration alone is adopted here:

SS receiving and storage → Drying → Incineration → Boiling for heat recovery → Flue gas scrubbing system → Ash collection & disposal

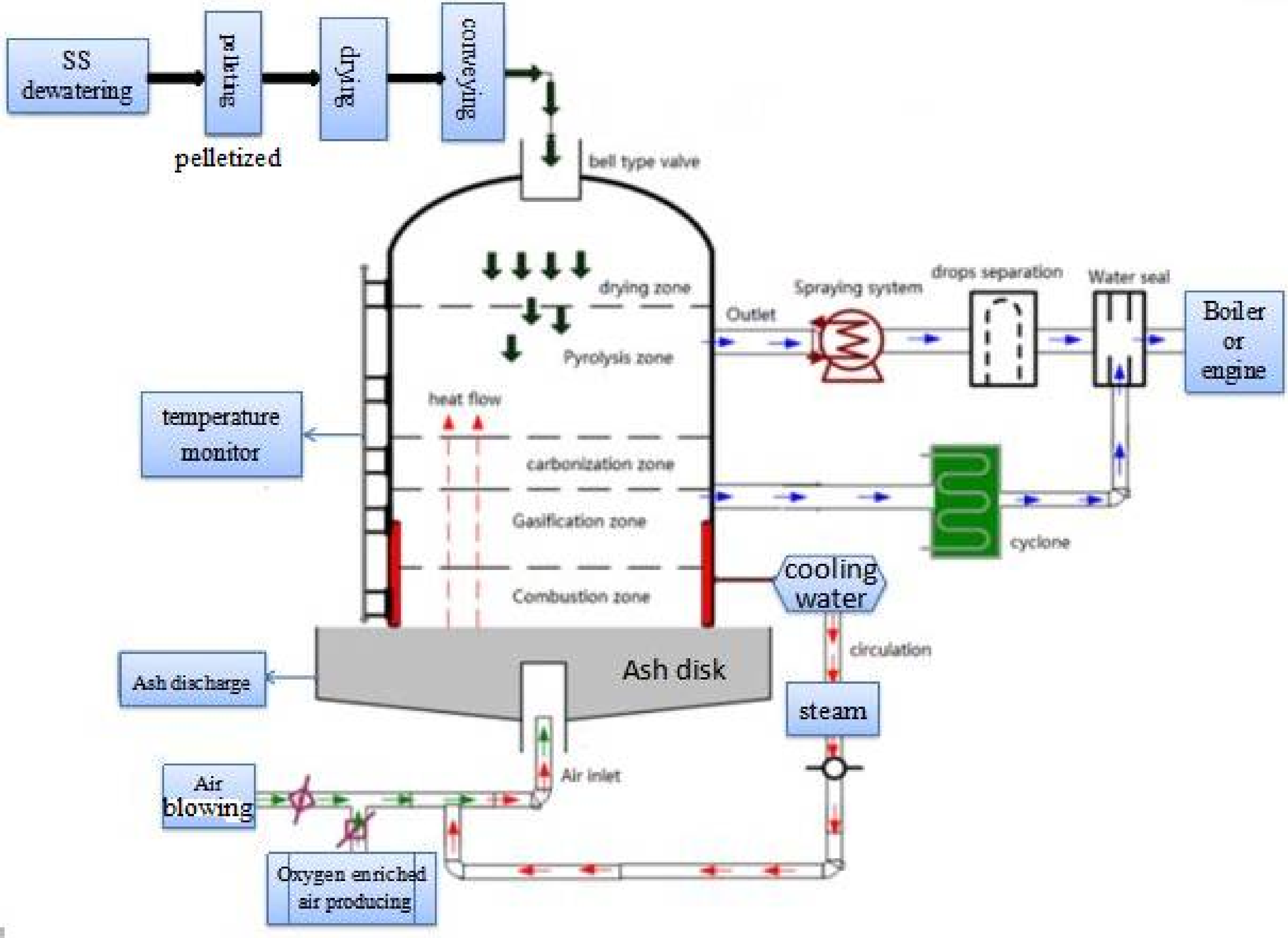


<Technical Specification for Fluidized-bed Drying and Incineration for Sewage Sludge> (CECS250-2008) should be followed to run fluidized-bed drying and incineration.

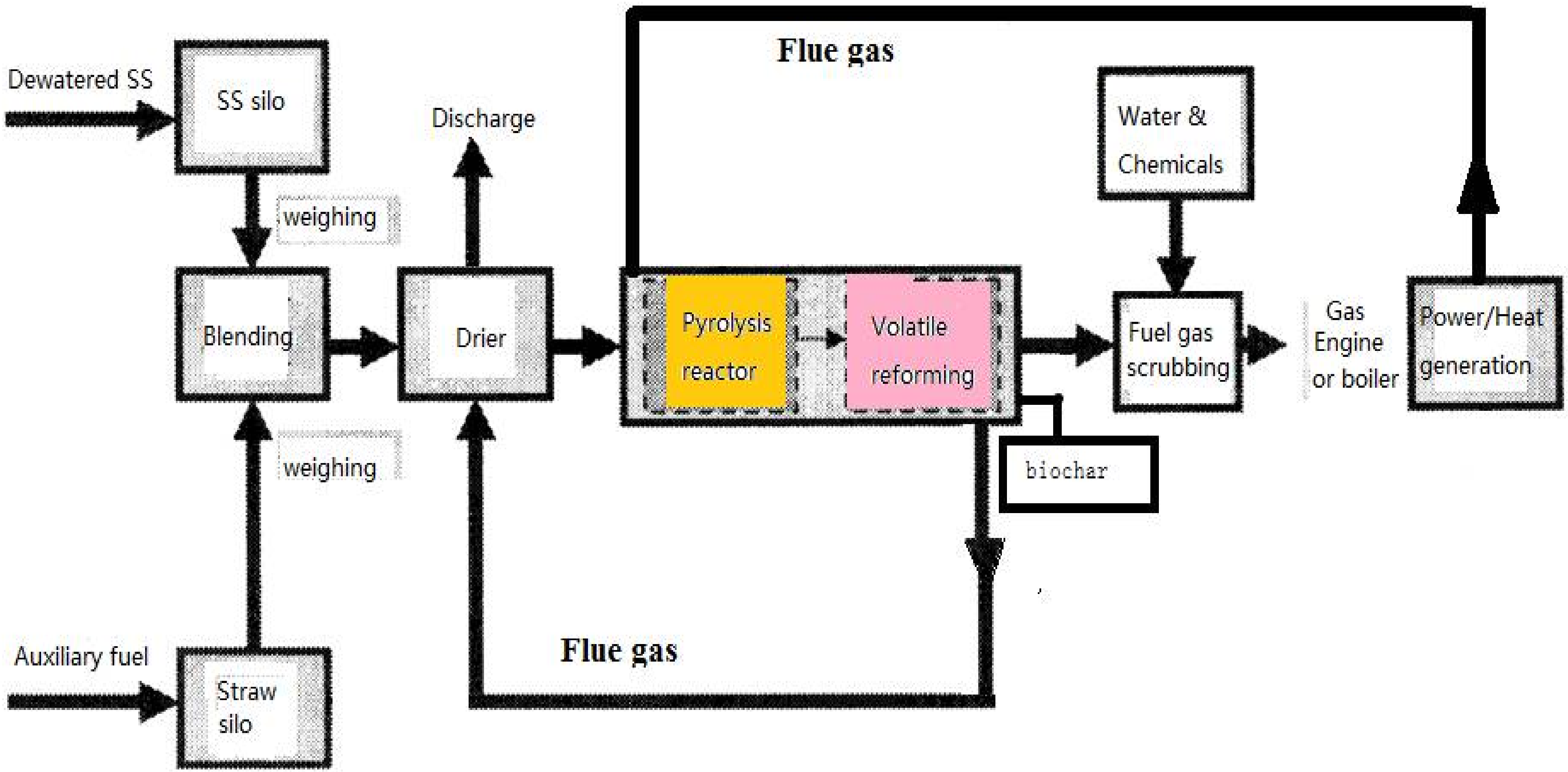
Semi-dry flue gas scrubbing system is adopted in the LCI analysis



2.2 SS gasification



2.3 SS pyrolysis & volatile reforming system



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3.1 LCI analysis of the three technologies

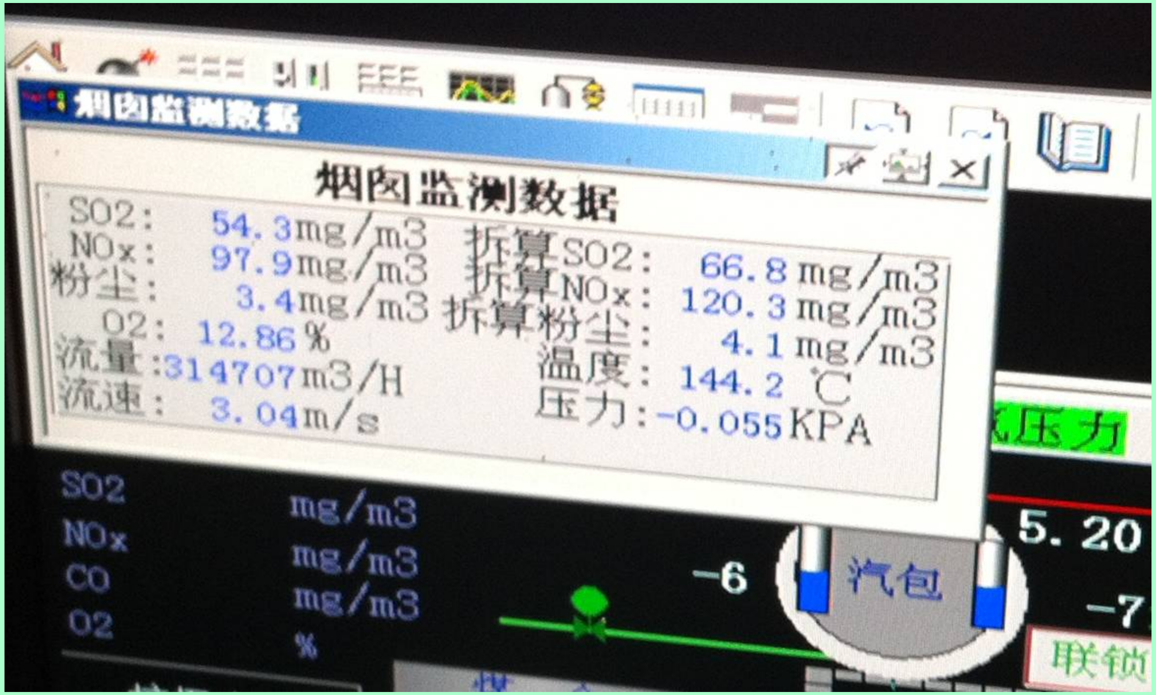
- When do the comparison, the averaged LHV of SS is adopted: 11.85 MJ/kg (db) [6]
- When the initial moisture content (MC) is 80%, this kind of sewage sludge has a very low net calorific value (0.37MJ/kg);
- To support the heat the thermal chemical conversion, auxiliary fuel is needed, as shown in the following table:

Table 3.1 Operation & investment comparison[7]

Inventory	Incineration	Gasification	Pyrolysis
Electricity consumption (kWh/t)	27.56 -82	32.82-64.15	35.07-48.56
Energy conversion efficiency	⩾99%	65% (air gasifying)	0.63-0.796 (volatile reformed)
Thermal energy recovery efficiency	73%	85%	81.50%
water consumption (t/t)	0.54-0.60	0.684	0.5-0.65
Auxilary fuel required (kg/t)	38 (coal with LHV of 23 kJ/g)	55 (coal with LHV of 23MJ/kg)	54 (straw with LHV of 13.4MJ/kg)
Investment(10^4 yuan/(t.d))	25.4 - 50	21.77 - 35.62	20.9-40
Activated carbon (kg/t)	0.07-0.2	0.05-0.12	0.04-0.06
Na_2CO_3 (kg/t)	2.56-3.45	2.20-2.89	1.65-2.00

Emissions from different thermal chemical processes

- CEMS monitoring



♣ The semi-dry system adopted

- Lime +$NaHCO_3$ spray
- Bagfilter was adopted
- Activated carbon was used

Dioxin emissions from SS fluidized-bed incinerator

(TEQ ng/Nm^3 at O_2 = 11%)

Case 1	Case 2	Averaged
0.06914[8]	0.04376 [9]	0.05645

Emissions from different thermal chemical processes

Technologies	Source of data	NOx		HCl	SO_2, NH_3	CO_2
		Direction combustion	Syngas washed before combustion			
gasification	[Lab data]	725.2 g/t	639 g/ t	69.7 g/t	198.6 g/t; 1.65 g/t	305.7 kg/t (db)
pyrolysis	[Data from Chong qing]	---	608.6 g/t	58.0 g/t	103.7 g/t 1.70 g/t	260 g/t
Incineration	([Data from Shanghai and [8])	697.89	----	139.4 g/t	387.5 g/t	305.7 kg/t (db)

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4 LCA assessment

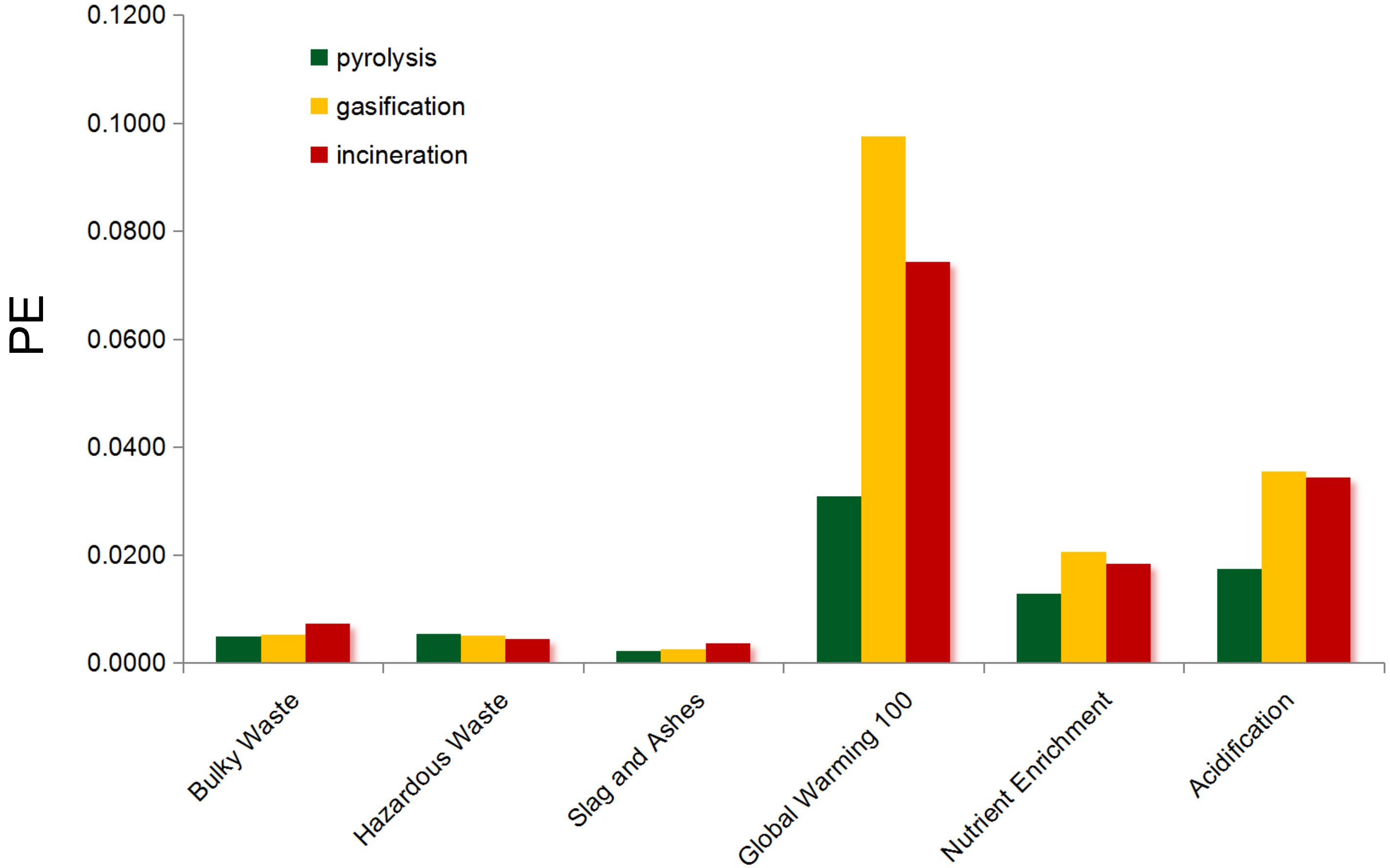
- When the LCA is carried out for the SS with averaged LHV of 11.85 MJ/kg (db) and the initial moisture content (MC) of 80%;
- The heat generated in the process is mainly used for evaporating the moisture in SS instead of supporting power & heat to external users.

- EDIP methodology [10] has been adopted to perform the LCA of the three technologies and the framework of EASEWASTE [11] is used to organize the results.

- According to EDIP methodology the catalogries of enviromental impact include: GW100, AC, NE, HTs, HTw, SA, BW, HW, OD etc

4.2 Comparison of three technologies

- It can be see that all of impact categories have positive values due to the high moisture of SS



- Gasification corresponds to the highest enviromental impacts due to the fact that gasification efficiency is low when air gasification is adopted;
- Pyrolysis is of most advantage if properly designed.

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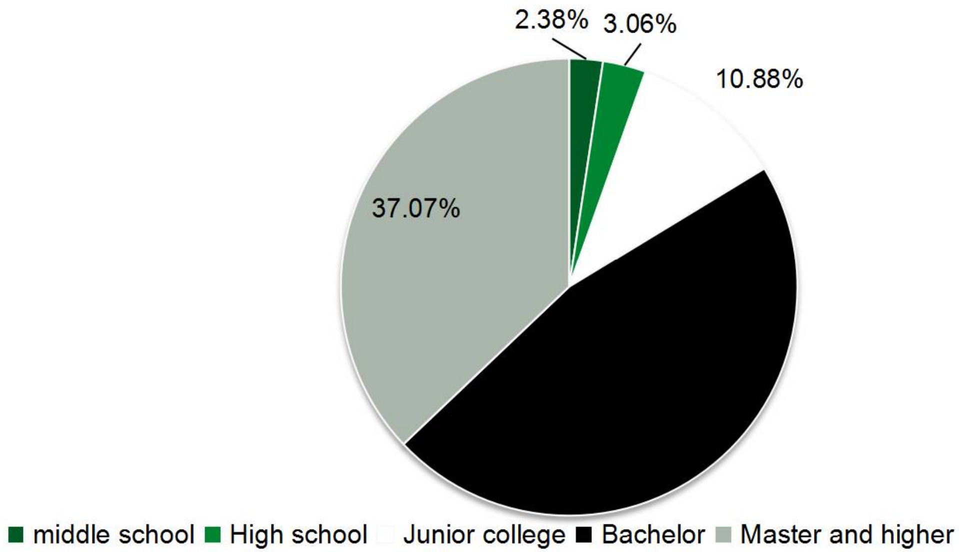
5.Results of questionnaire survey

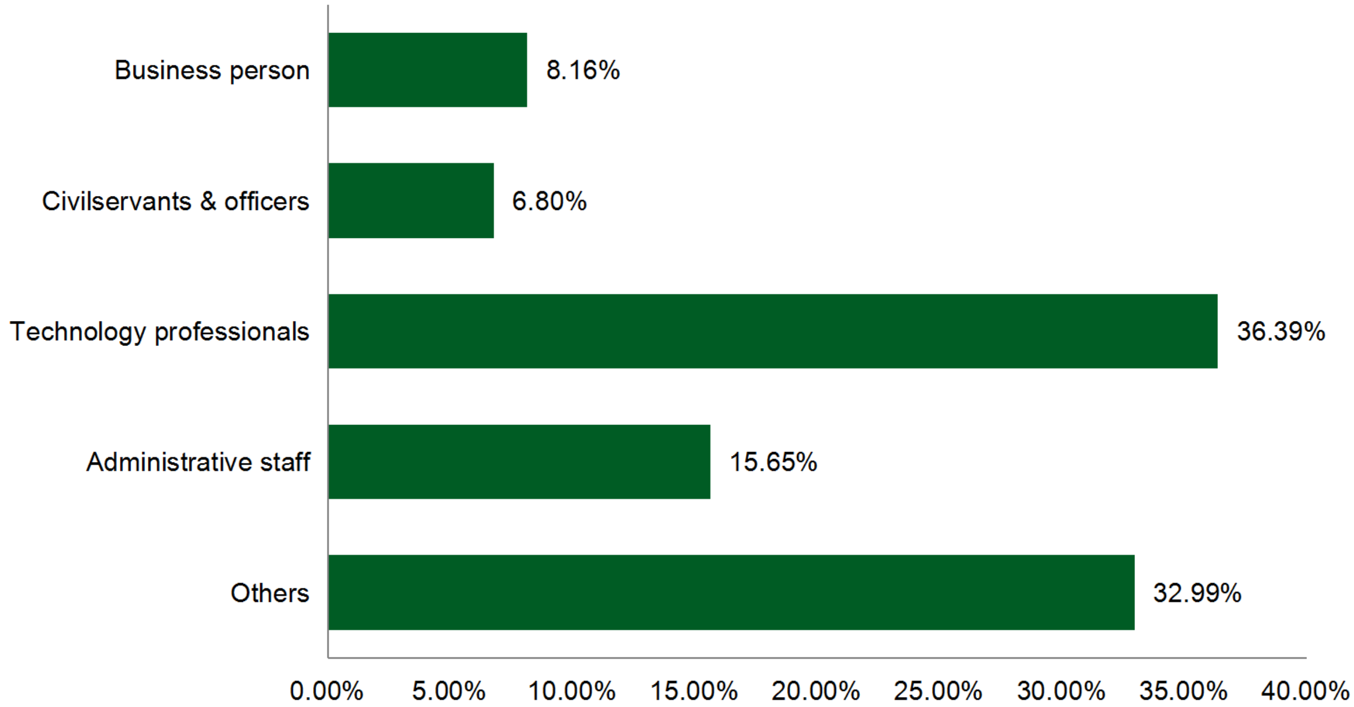
● questionnaire survey is carried out and 281 answers have been received.

Most of the people are highly educated



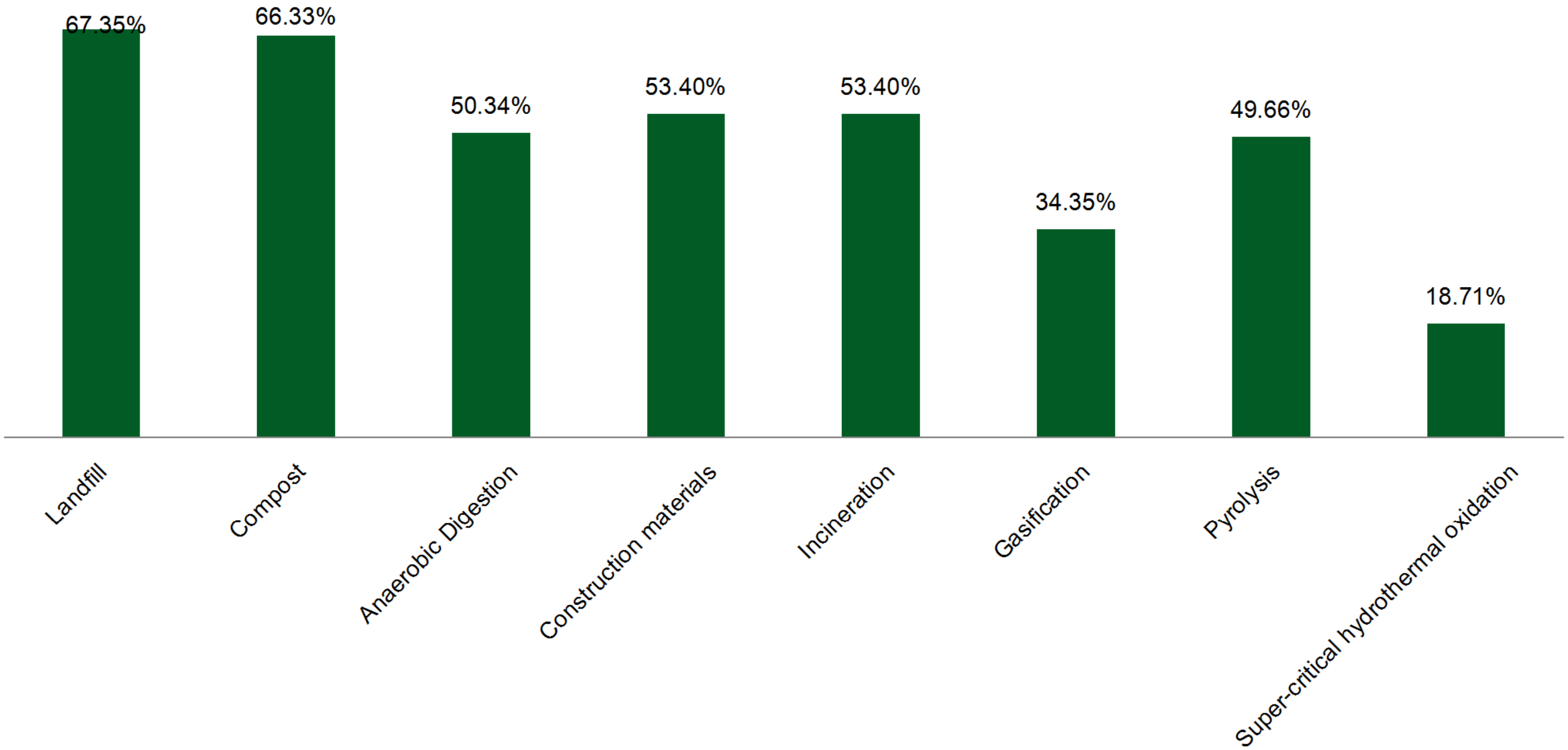
Degree of people who taking part in the survey

About the person who taking part in the survey

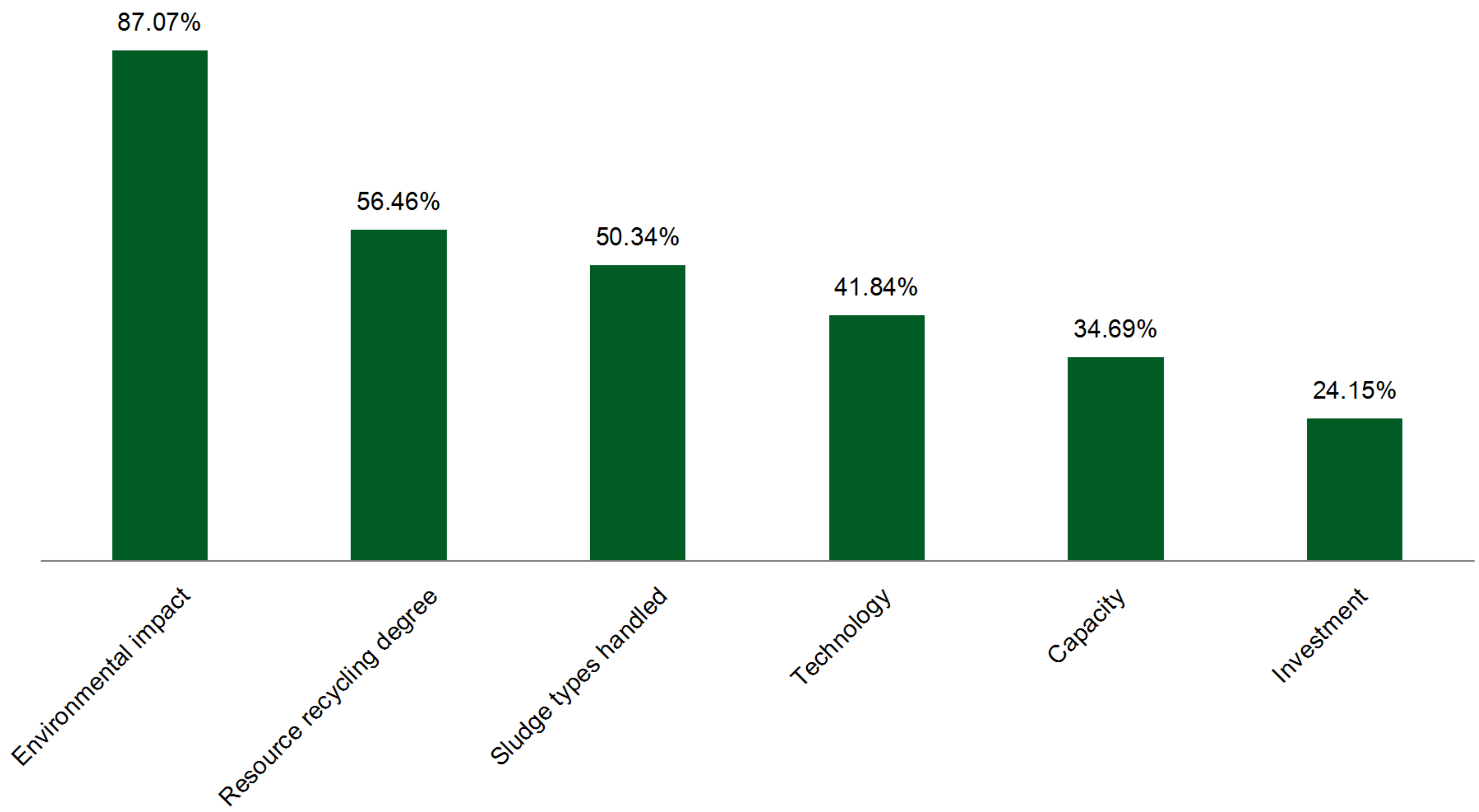


Career of the people who taking part in the survey

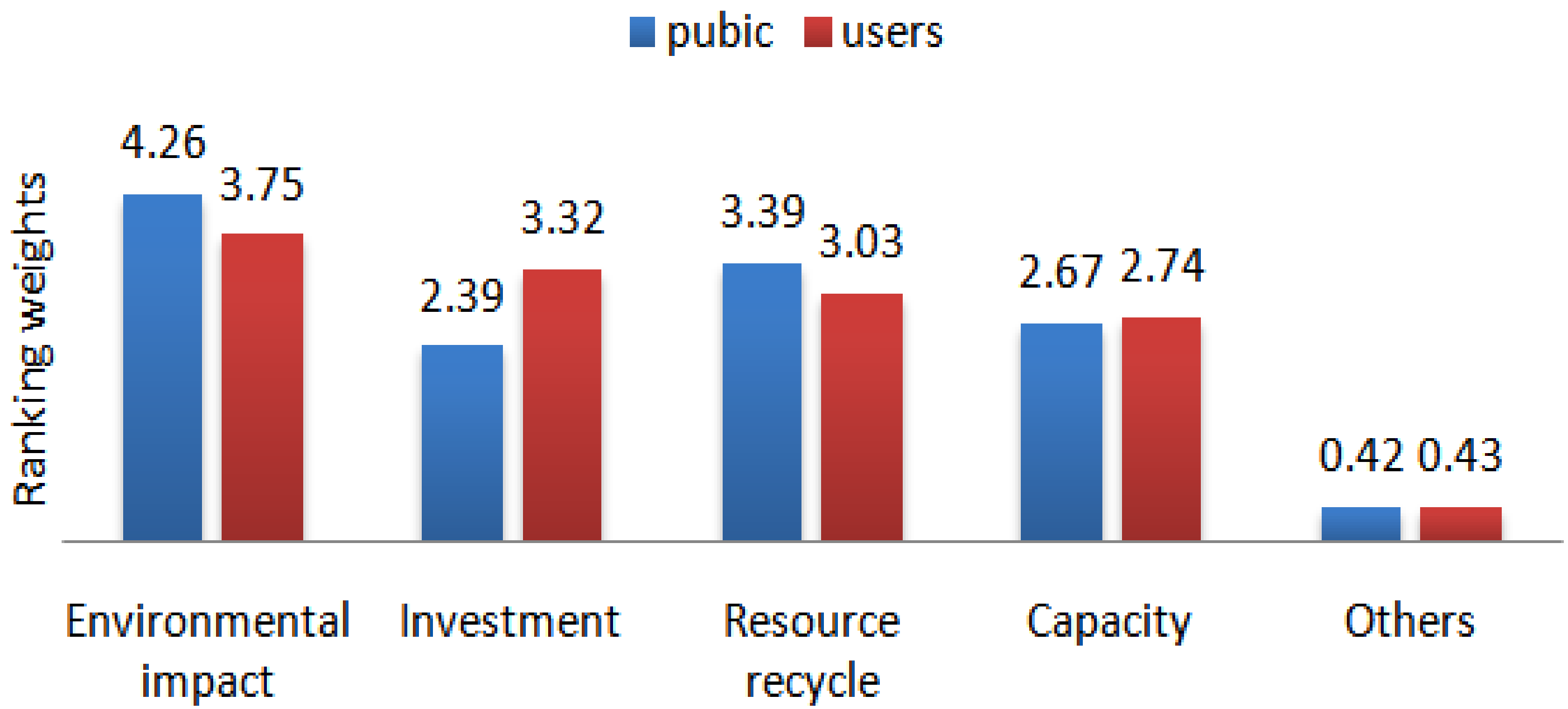
The answer to "Do you hear about those technologies?"



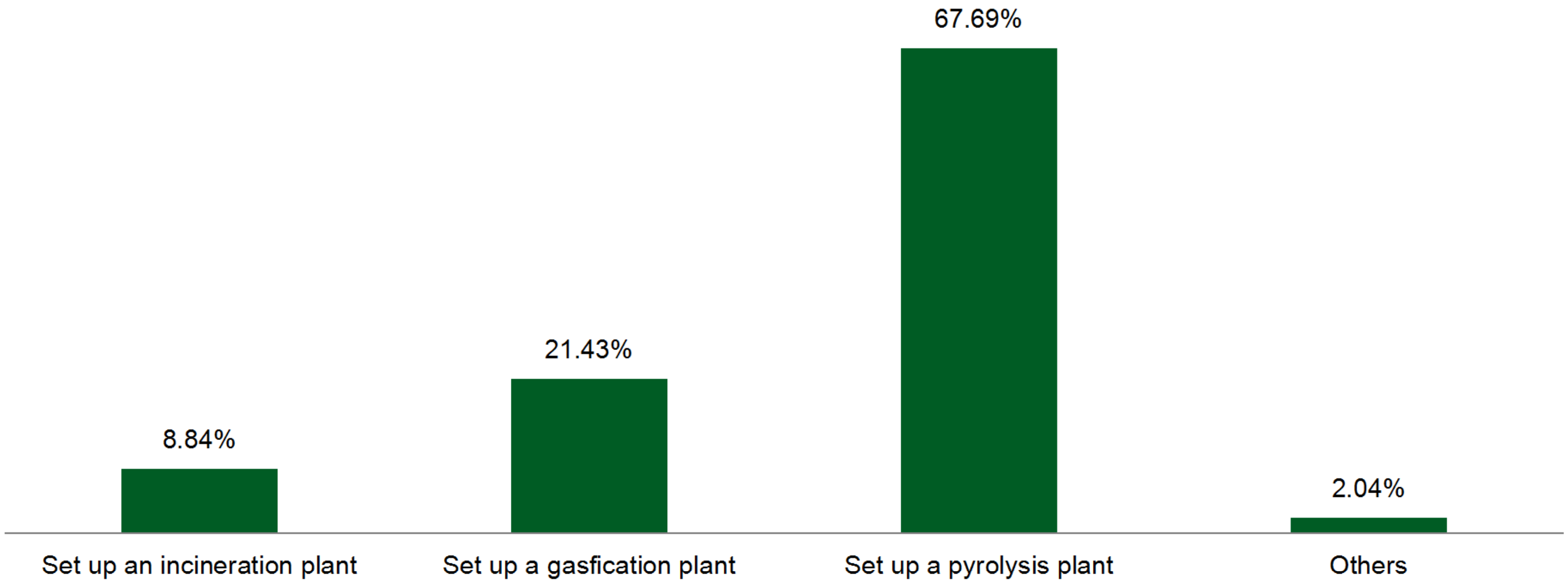
The answer to “most important points when choosing the SS disposal technologies”



The ranking of concerned factors for SS disposal from public side and user side



The answer to "which thermal chemical technology do you support if they are necessary?"



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Conclusion

- There is no SS gasification plant experiences and only very few SS pyrolysis plants in China. The existing operation experiences of SS thermal chemical treatment show that thermal chemical technologies are comparable in investment and operation when SS is treated alone.
- Based on the averaged calorific value of SS in China the LCA has been performed for choice of the thermal chemical technology and LCA results proved that pyrolysis with its volatile reformed is the most suitable technology.
- Questionnaire survey supports that enviromental impact is the most concerned factor for both public and users; and that pyrolysis with its volatile reformed is warmly welcome by public and users if the technology is reliable.

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