

Training Workshop of Waste to Energy for North Africa

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Municipal solid waste incineration and its application in China

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December 05, 2022, Hangzhou

Main Contents

Municipal solid waste generation, characteristics and disposal

Current situation of waste incineration technologies

Waste incineration in China

Experiences of waste incineration application in China

Resume of Prof. Dr. Xiaodong Li

◆ EDUCATION BACKGROUND

- 1983-1994 Ph.D. student in Engineering Thermal Physics, Zhejiang University

◆ WORK EXPERIENCE

- Since 2001, Professor, Institute for Thermal Power Engineering, Zhejiang University
- 2006.09 – 2007.03, as a consultant expert on waste management in Ministry of Civil Construction, China
- 2003.10 – 2003.12, as a senior visiting scholar in US EPA, National Risk Management Research Laboratory (NRMRL)
- 1990-1991, Institute for Electrical Research, Jiangsu Province

◆ MAJOR RESEARCH FIELDS

- Technologies for waste incineration and waste recycling;
- Environmental protection in the energy conversion process;
- Persistent organic pollutants (POPs, especially for dioxins) formation and control from incineration process
- Pollutants environmental impact and risk assessment

◆ SCIENTIFIC AFFILIATIONS AND SERVES

- Funder and Chair of International Consultant Committee of Waste to Energy (ICCWtE);
- Chair of the Education/training Committee, WTERT-Asia;
- Expert of the National Coordination Working Group of China's implementation of the Stockholm Convention (since 2010);
- Member of Persistent organic pollutants committee of Chinese Society for Environmental Sciences.

◆ PUBLICATIONS AND PROJECTS

- 6 books and about 150 papers published in international journals
- In charge of over 50 R&D projects focusing on waste incineration, emission control and so on.

Zhejiang University

Rooted in China, Growing into the Future



- **7** Campuses
- **5** University Libraries
- **37** Colleges & Schools
- **2** International Joint Institutes
- **7** Affiliated Hospitals
- **133** Undergraduate Programs
- **200+** Global Study Programs

- Founded in 1897
- **Top Three** University in China
- **Rank 42 in world** in the QS 2022 ranking
- Selected for **Double First-class Initiative**
 - **63000+** Students
 - 46% undergraduates
 - 30% master's candidates
 - 24% doctoral candidates
- **3,800+** Academic Faculty
- Total area: **689** hectares

Institute for Thermal Power Engineering (ITPE)

- Top Talent Training and Scientific Research Base in the Field of Energy and Environment
- the National R&D Bases
- **Rank 1st in the Top Ten Engineering Research Institutes of Zhejiang University**



Waste Disposal – A Global Problem



Land occupation



Environmental pollution



Danger to public health



Waste amount **increasing!**



Shortage of landfill



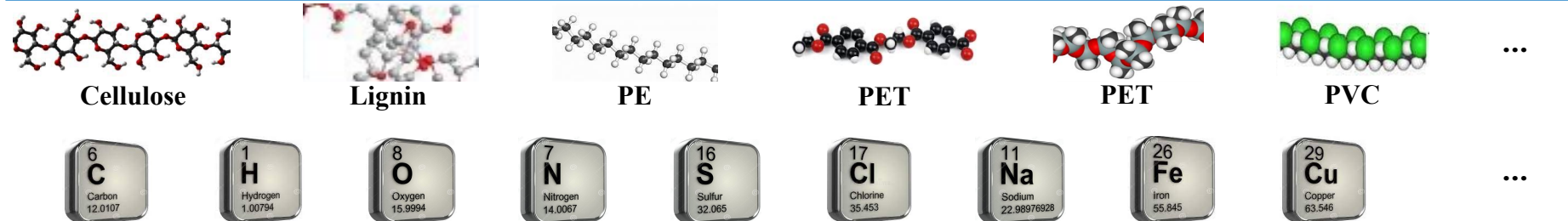
Economic growth

Urbanization

Increase of population

- **How to deal with?**
- Especially for **developing countries**

Classification of Waste



Definitions of Municipal Solid Waste

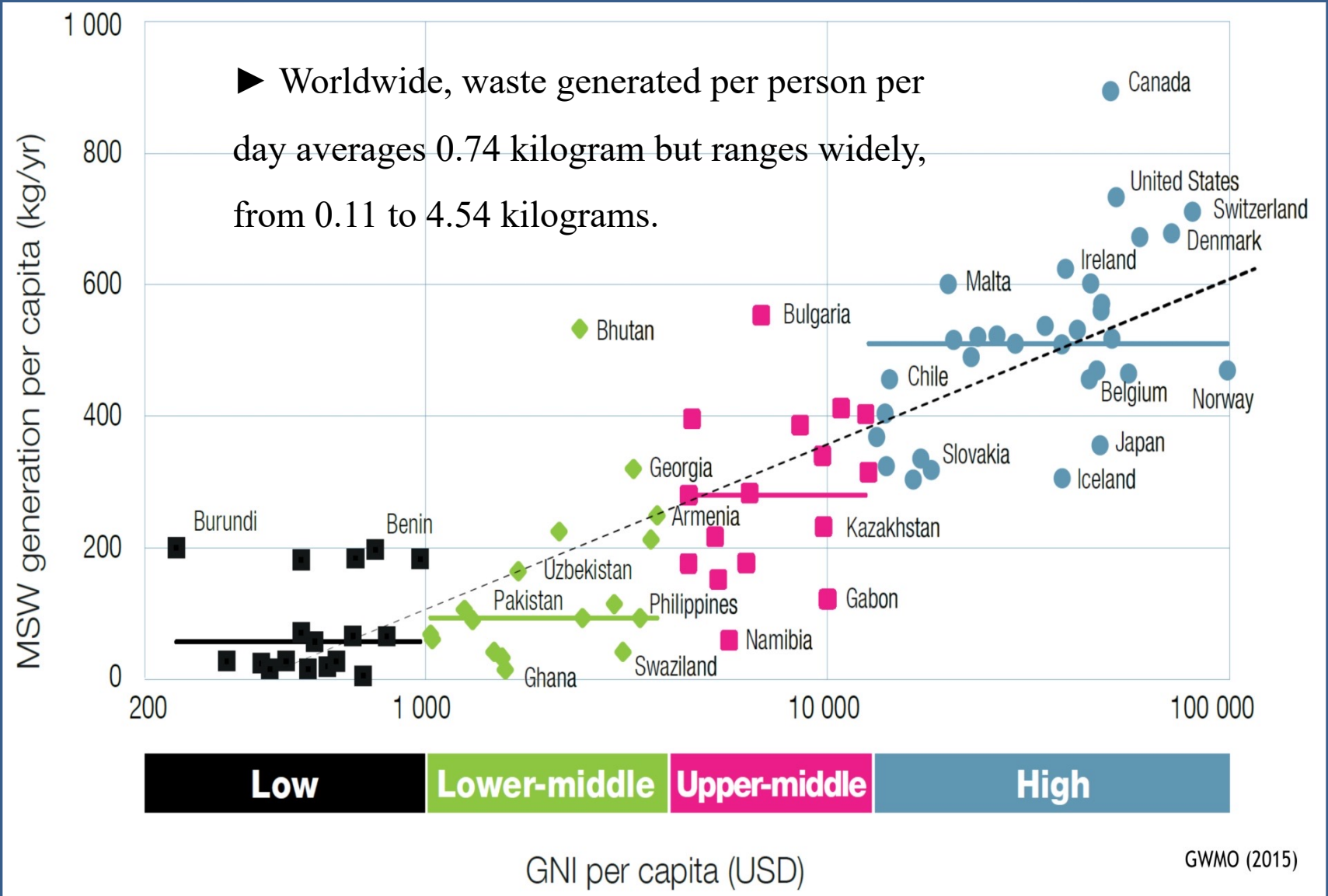
Organization	Definition of municipal solid waste
OECD, Organization for Economic Co-operation and Development	Municipal waste is collected and treated by, or <u>for municipalities</u> . It covers waste from <u>households</u> , including bulky waste, similar waste from <u>commerce and trade</u> , office buildings, institutions and small businesses, yard and garden, street sweepings, contents of litter containers, and market cleansing. Waste from municipal sewage networks and treatment, as well as municipal construction and demolition is excluded.
PAHO, Pan-American Health Organization	Solid or semi-solid waste generated in population centers including domestic and, commercial wastes, as well as those originated by the small-scale industries and <u>institutions (including hospital and clinics)</u> ; market street sweeping, and from public cleansing.
IPCC, Intergovernmental Panel on Climate Change	The IPCC includes the following in MSW: food waste; garden (yard) and park waste; paper and cardboard; wood; textiles; nappies (disposable diapers); rubber and leather; plastics; metal; glass (and pottery and china); and other (e.g., ash, dirt, dust, soil, electronic waste).
China	‘Waste produced in the daily life or the activities to provide services for the daily life of the city, as well as waste ruled by laws and administrative regulations’

MSW Generation in the World

- The current annual Municipal Solid Waste (MSW) generation is estimated to **1.9 billion** tonnes, and almost **30%** of it to remain uncollected.
- landfills and dumpsites: **70%**; recycled or recovered: **19%**; energy recovery facilities: **11%**



MSW Generation Per Capita



Harm Impact from MSW

Improper MSW management will

➤ **Encroach the ground.**

The industrial and agricultural production and life is seriously affected , and the ecological balance of nature is damaged .

➤ **Disseminate disease.**

Human's health is seriously threatened.

➤ **Pollutant soil and aquatic.**

Surface water and groundwater is seriously contaminated

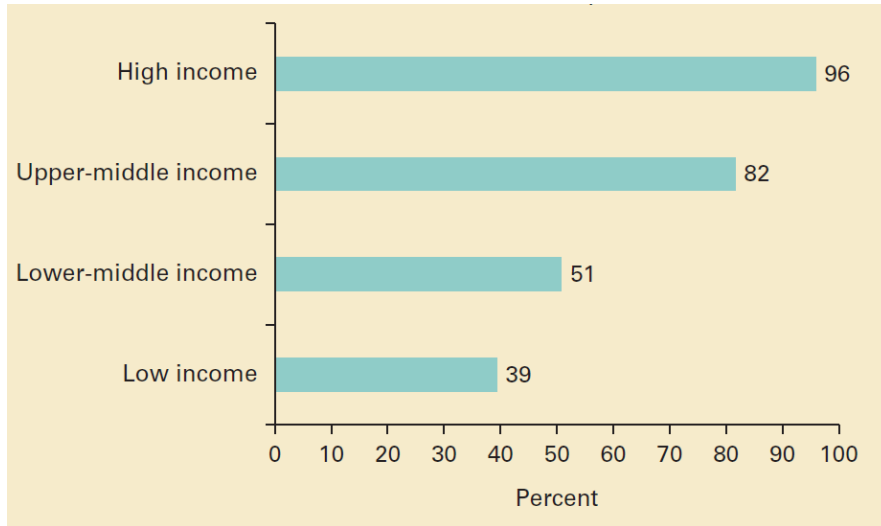
➤ **Emit many air pollutants:**

The MSW open dumping sites always generate foul odors and provide habitat for vectors and rodents. In addition, large amount of harmful gases from open dumping sites are releasing into atmosphere, amongst, **more than 100 types of VOCs are included, which contain many carcinogenic substances.**

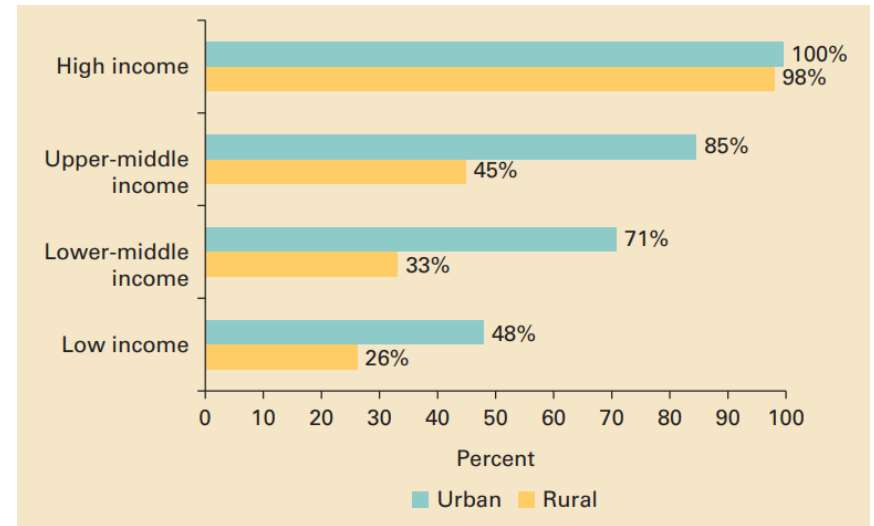


Waste Collection Rates , globally

Waste collection is a critical step in managing waste



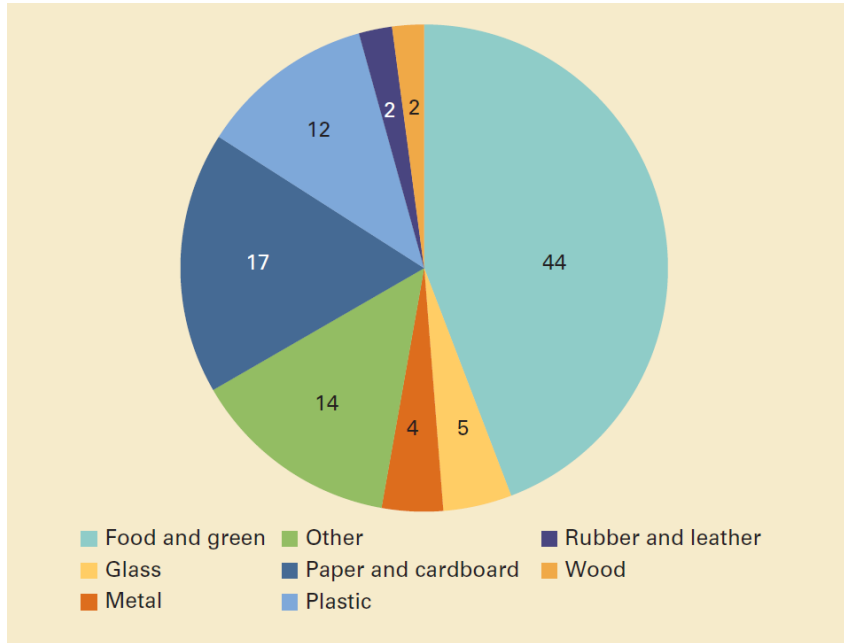
Waste collection rates, by income level (percent)
(from The World Bank website)



Urban and rural collection rates by income level (percent)
(from The World Bank website)

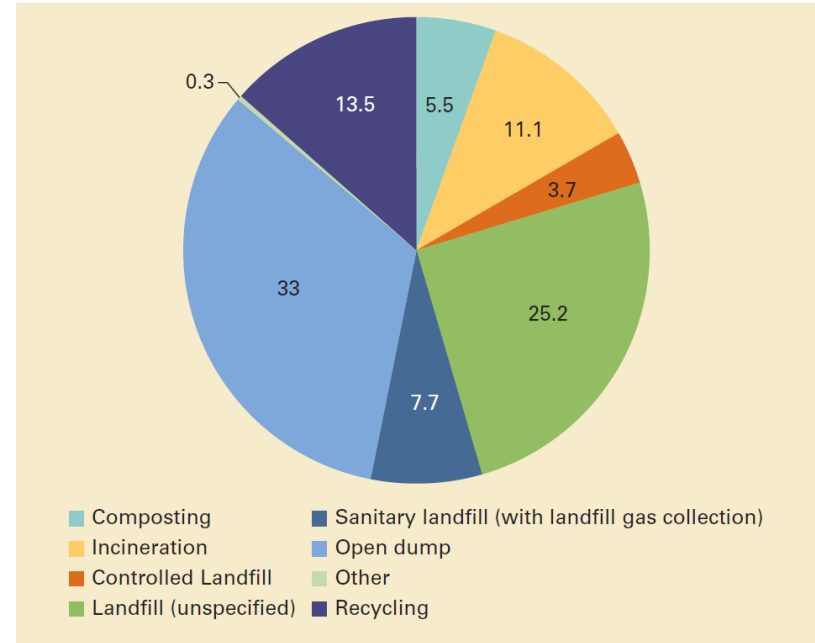
- Waste collection **rates vary largely by income levels**
- Upper-middle- and high-income countries providing nearly universal waste collection
- Low-income countries collect about **48 percent of waste in cities**, but this proportion drops drastically to **26 percent outside of urban areas**.

Waste Management



Global waste composition (percent)
(from The World Bank website)

- Waste composition **differs across income levels**.
- Across regions, there is **not much variety within waste streams** beyond those aligned with income.
- All regions generate **about 50 percent or more organic waste**, on average.



Global treatment and disposal of waste (percent)
(from The World Bank website)

- As for the collected MSW in the world, **70% is dumped or disposed of in some form of a landfill**, 19% is recovered through recycling and composting and 11% is incinerated for final disposal.

Fundamental Characteristics of MSW

- Average weight of various types of solid waste

Average Weight of Solid Waste

Type	kg/m ³
Trash	128.14 - 160.18
Rubbish	128.14 - 160.18
Refuse	240.28 - 320.37
Garbage	480.55 - 560.65
Animal solids and organic wastes	720.83 - 881.02
Garbage (70% H ₂ O)	640.74 - 720.83
Loose paper	80.09 - 112.13
Scrap wood and sawdust	192.22 - 240.28
Wood shavings	96.11 - 128.15
Wood sawdust	160.18 - 192.22

**Average Solid Waste Collected
(kg per person per day)**

Solid Wastes	Urban	Rural	National
Household	0.57	0.33	0.52
Commercial	0.21	0.05	0.17
Combined	1.19	1.18	1.19
Industrial	0.29	0.17	0.27
Demolition, construction	0.1	0.01	0.08
Street and alley	0.05	0.01	0.04
Miscellaneous	0.17	0.04	0.14
Totals	2.59	1.78	2.41

Fundamental Characteristics of MSW

➤ Typical Moisture Content and Heating Value of MSW Components

Moisture Content

NO.	Component	Moisture, %	
		Range	Typical
1	Food wastes	50-80	70
2	Paper	4-10	6
3	Cardboard	4-8	5
4	Plastics	1-4	2
5	Textiles	6-15	10
6	Rubber	1-4	2
7	Leather	8-12	10
8	Garden trimmings	30-80	60
9	Wood	15-40	20
10	Glass	1-4	2
11	Tin cans	2-4	3
12	Nonferrous metals	2-4	2
13	Ferrous metals	2-6	3
14	Dirt, ashes, brick, etc.	6-12	8
Total	Municipal solid waste	15-40	20

Heating Value

NO.	Component	Energy, kJ/kg	
		Range	Typical
1	Food wastes	3489-6978	4652
2	Paper	11630-18608	16747.2
3	Cardboard	13956-17445	16282
4	Plastics	27912-37216	32564
5	Textiles	15119-18608	17445
6	Rubber	20934-27912	23260
7	Leather	15119-19771	17445
8	Garden trimmings	2326-18608	6512.8
9	Wood	17445-19771	18608
10	Glass	116.3-232.6	139.56
11	Tin cans	232.6-1163	697.8
12	Nonferrous metals	—	—
13	Ferrous metals	232.6-1163	697.8
14	Dirt, ashes, brick, etc.	2326-11630	6978
Total	Municipal solid waste	9304-15119	10467

Waste Management

➤ Terminology

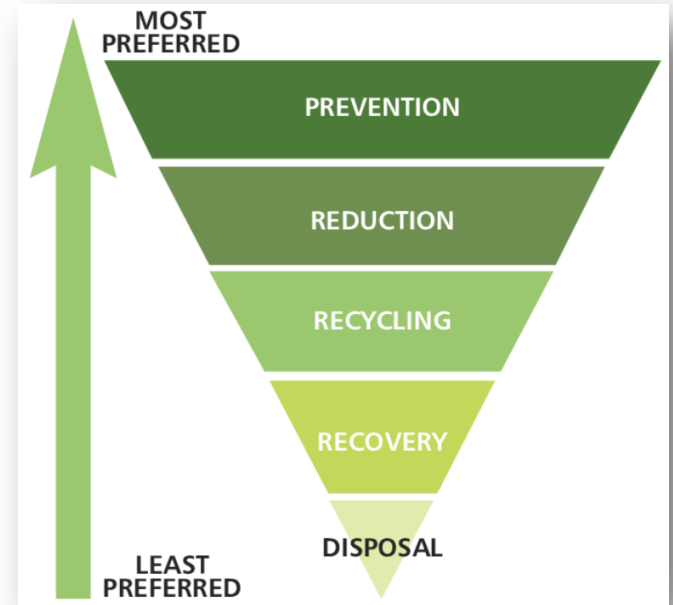
- **Disposal** means final disposal without utilization purpose
 - Usually *landfilling* (or dumping if unofficial) – there can be some utilization still (landfill gas)
 - Can include also incineration *without energy recovery*
- **Recovery** means all kinds of *utilization of waste*
 - **Recycling** – meaning *material recovery*
 - **Energy recovery** – meaning utilization of the energy content
- **Reuse** means the **using of a product** (or its part), which has been *removed* from service, again *in the original purpose* (no breaking up, melting etc.)

Waste Hierarchy

The following waste hierarchy **shall apply as a priority order in waste prevention and management** legislation and policy:

- a) Prevention
- b) Reduction and reuse
- c) Recycling;
- d) Recovery, e.g. energy recovery; and
- e) Disposal

Options that deliver the best overall environmental outcome should be selected.



The EU Waste Hierarchy

@EU Waste Framework Directive

Problems of Waste Management

- The costs of recovery or recycling are often higher than using of virgin raw materials.
- **Reasons**
 - Raw materials are produced with centralized industry in very large volumes
 - The technologies for raw material exploitation have been developed for a long time
 - Supported by many governments
 - Waste streams are distributed
 - Waste streams are heterogeneous → Separating small volumes of recoverables
 - Small industry has less resources for research and development
 - Lots of transportation, small production volumes and developing technology
 - High unit costs of recovery

MSW Disposal Technologies

Landfilling	Incineration	Compost	Other technologies
<ul style="list-style-type: none">• Traditional yarding;• Sea reclamation;• Sanitation landfill;	<ul style="list-style-type: none">• Simple incineration technology;• Waste to energy power generation technology;	<ul style="list-style-type: none">• Anaerobic compost;• Aerobiotic compost;• Mechanical compost;	<ul style="list-style-type: none">• Pyrolysis;• Gasification• Refuse derived fuel technology;• Carbide hydrolysis technology;

Landfill Example - Tianziling, Hangzhou, China



Landfilling - Final Disposal

- Should be the last option for waste treatment
- Correctly designed and built landfill minimizes the environmental and health impacts of final disposal
 - Landfill waters (leachate water, polluted storm water) are not directed to nature without treatment
 - Landfill gas collection reduces
 - Greenhouse gas emissions (methane)
 - Odor problems
 - Health problems for workers and people living near
 - Risk of landfill fires and explosions
 - Other benefits of good engineering
 - Reducing harm from insect pests, rats and birds
 - Reducing dust and aerosol emissions
 - Enhancing plantation at landfills and nearby
 - Preventing dirt distribution from landfill to environment
 - Not too much noise and traffic

Advantage of Landfilling

Advantages of landfilling

Low cost

Readily available sites

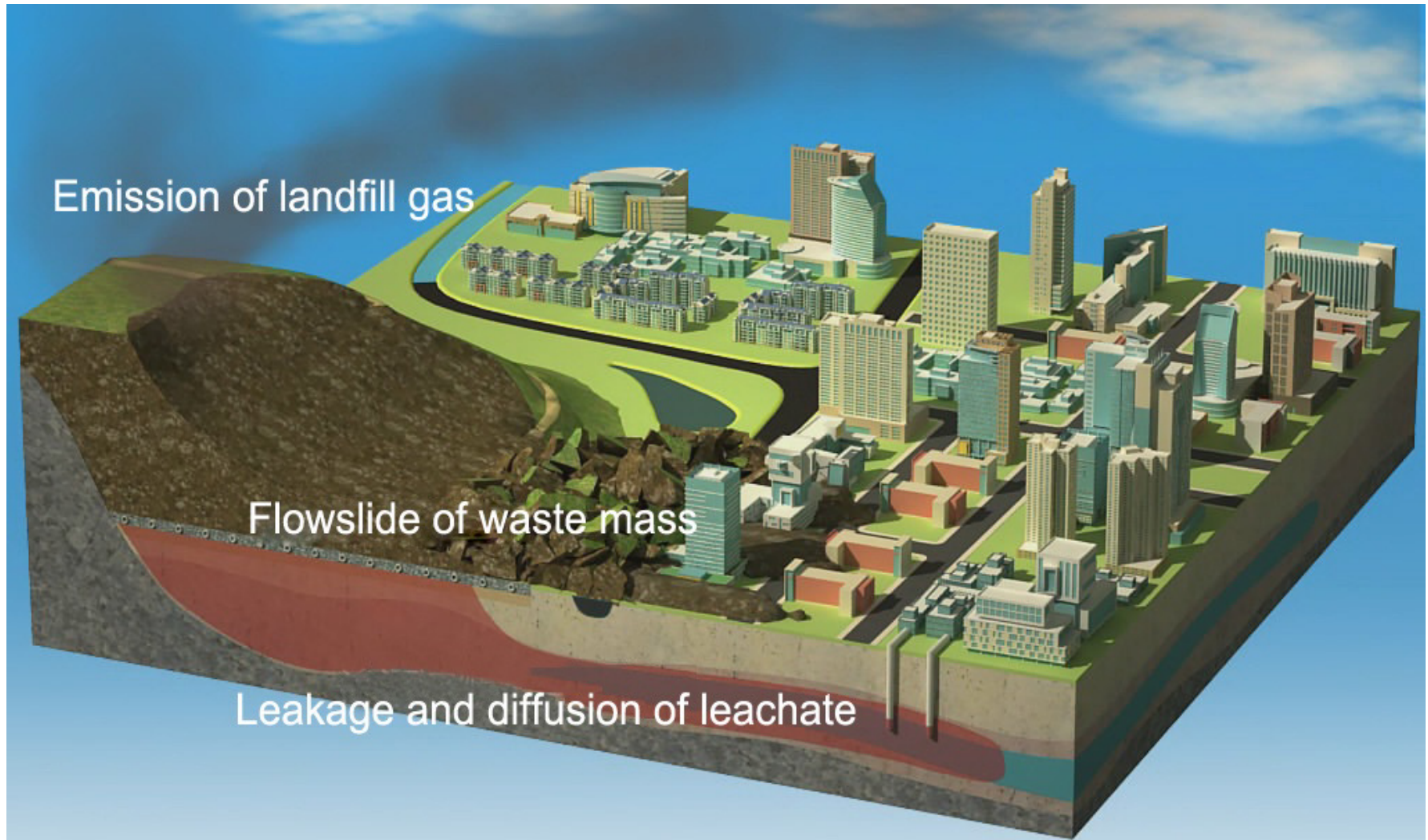
Landfill sites are now fully engineered to protect the environment

Landfills create a use for disused mines and quarries



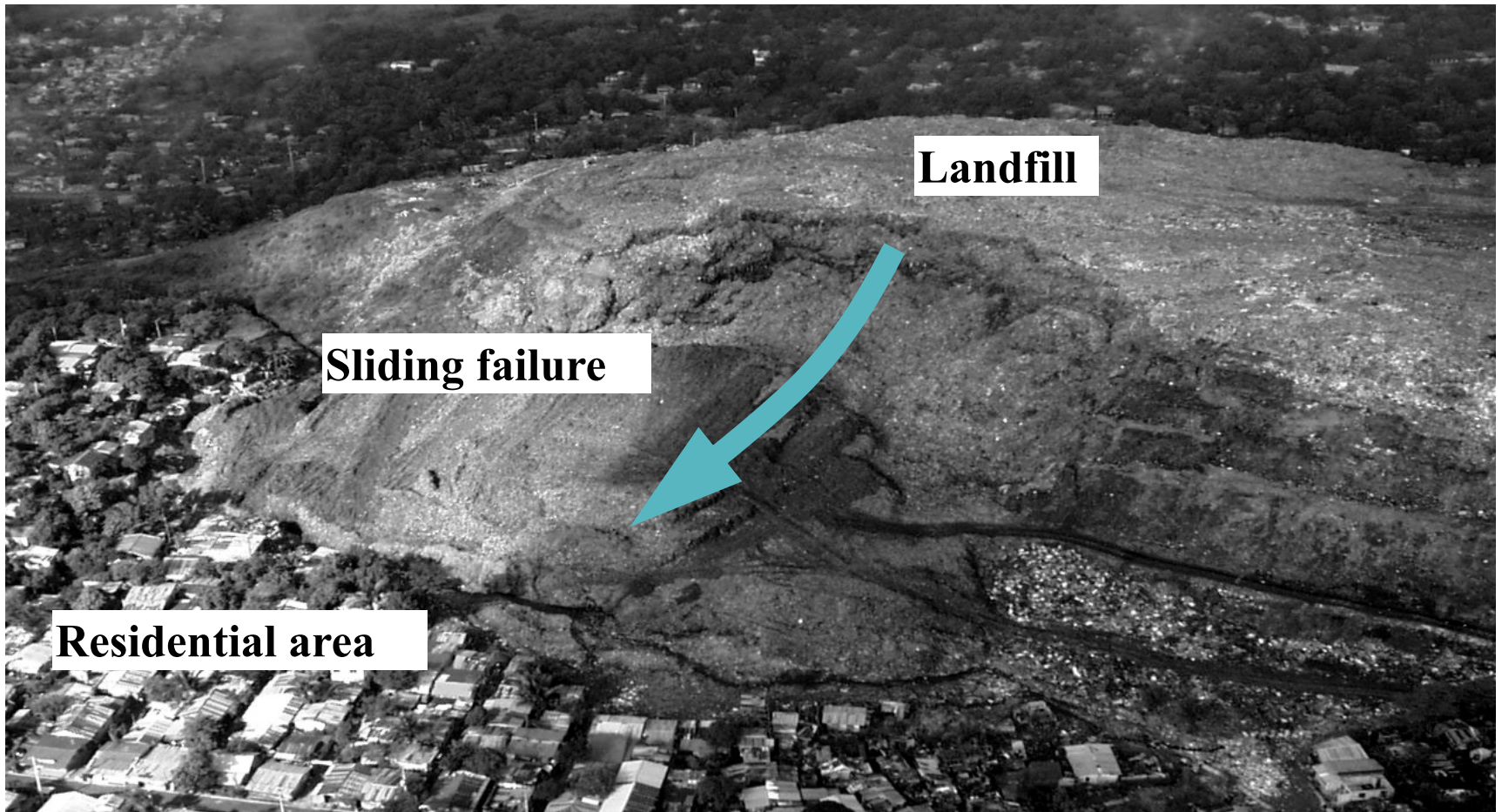
Disadvantage of Landfilling

- Environmental and Geo-environmental hazards



Disadvantage of Landfilling

- Landfill failure causes human death and property loss



A lethal failure in Philippines causing over 600 human deaths

Disadvantage of Landfilling

- Emission of greenhouse gas and fire/explosion hazard
 - Landfill gas: 13 billion m³, 5.8% of the total emission of greenhouse gas in China



Dumping sites of wastes in developing countries



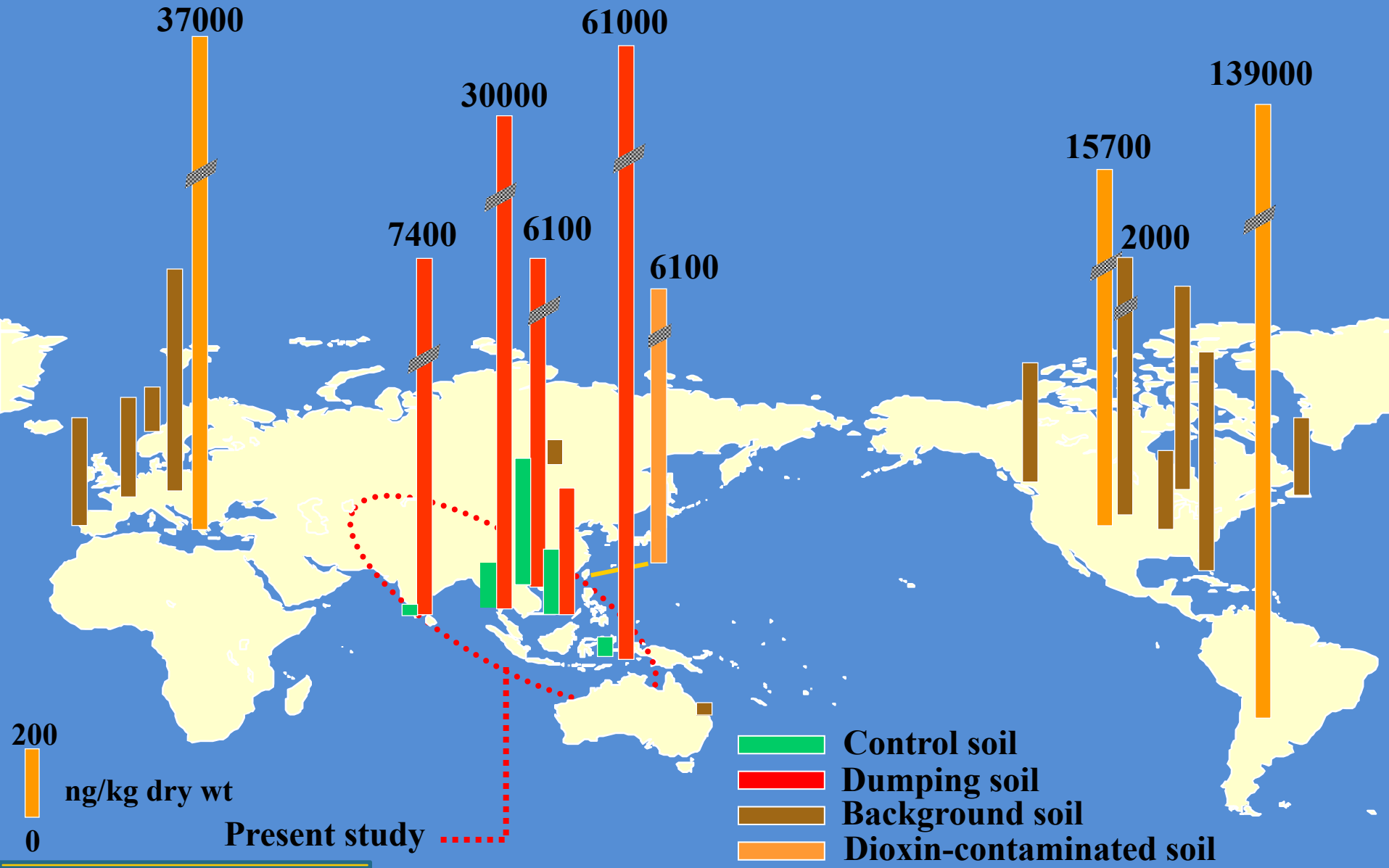
Cambodia (Meanchey, Phnom Penh)

- Ubiquitous in developing countries
- Possible emission source of PCDDs and related compounds
- Usage of organochlorine insecticides for public health purposes

Human exposure & risk ?

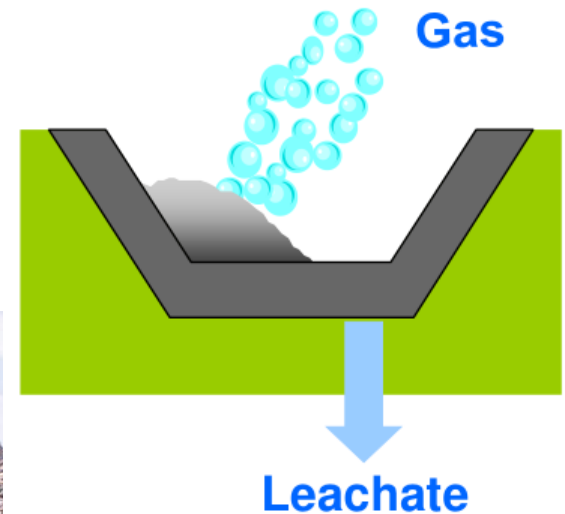
Global Comparison of PCDD/DFs Levels in Various Soil Types

From Shinsuke Tanabe of Japan



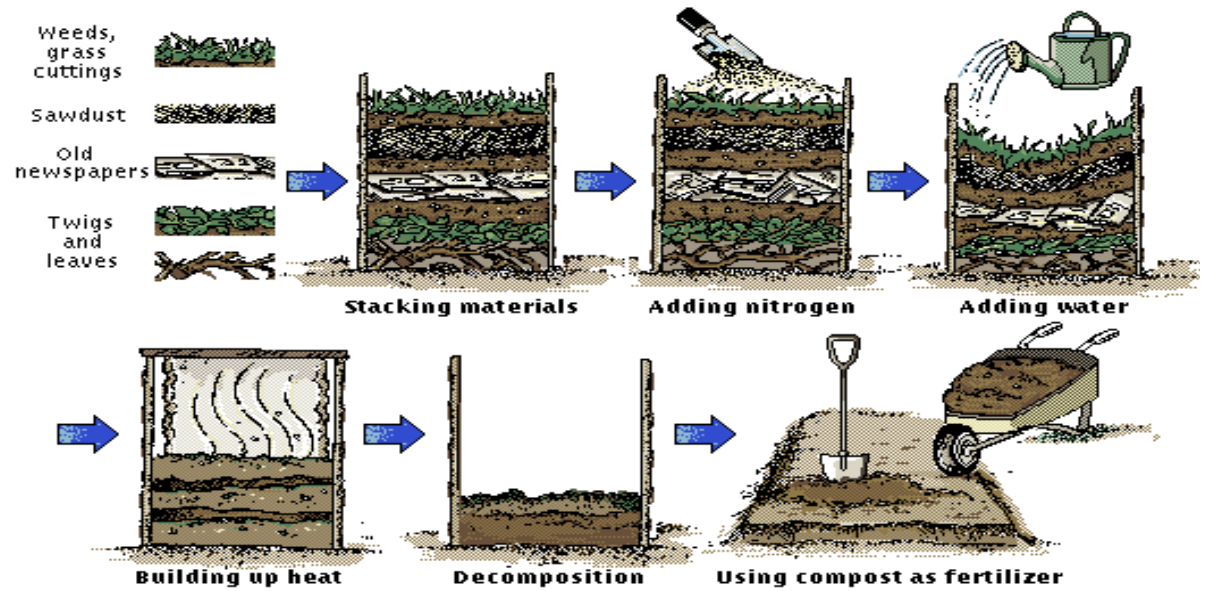
Challenges of Landfilling

- Landfill costs will rise in the future due to:
 - planning constraints;
 - increasing transport distances;
 - rising infrastructure and start-up costs;
 - rising maintenance costs;
 - Government policy



Compost

Compost at home



Large-scale compost



Advantage of Compost

- Volume and mass of the waste reduced
- Pathogens and other harmful organisms eliminated
- Retaining nutrients as well as possible
- Suitable product for fertilizing purposes
- Effective treatment
 - Material treated
 - Uniform product
 - Cost effective treatment



Disadvantage of Compost

- The product has low nutrient content and it is easy to cause soil compaction for a long time
- The leachate can cause the underground water to get bad
- Odour from vented or flared gas
- A variety of pathogenic microorganisms, heavy metals, and other hazardous substances into the soil



Waste to Energy

Three methods of Waste to Energy

Pyrolysis



No air

Gasification



Partial air

Incineration



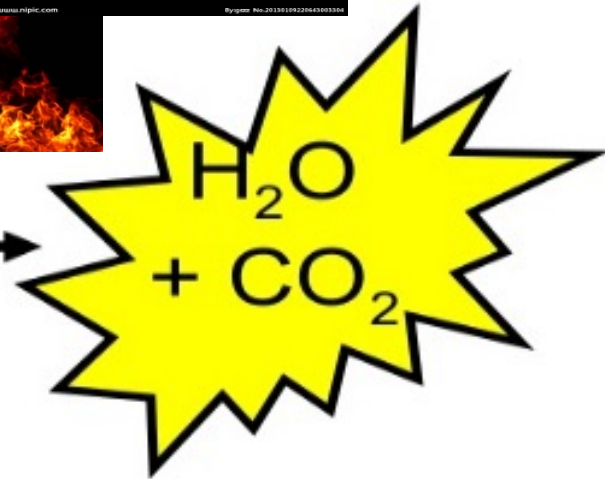
Excess air

Increasing air supply

Definition of incineration

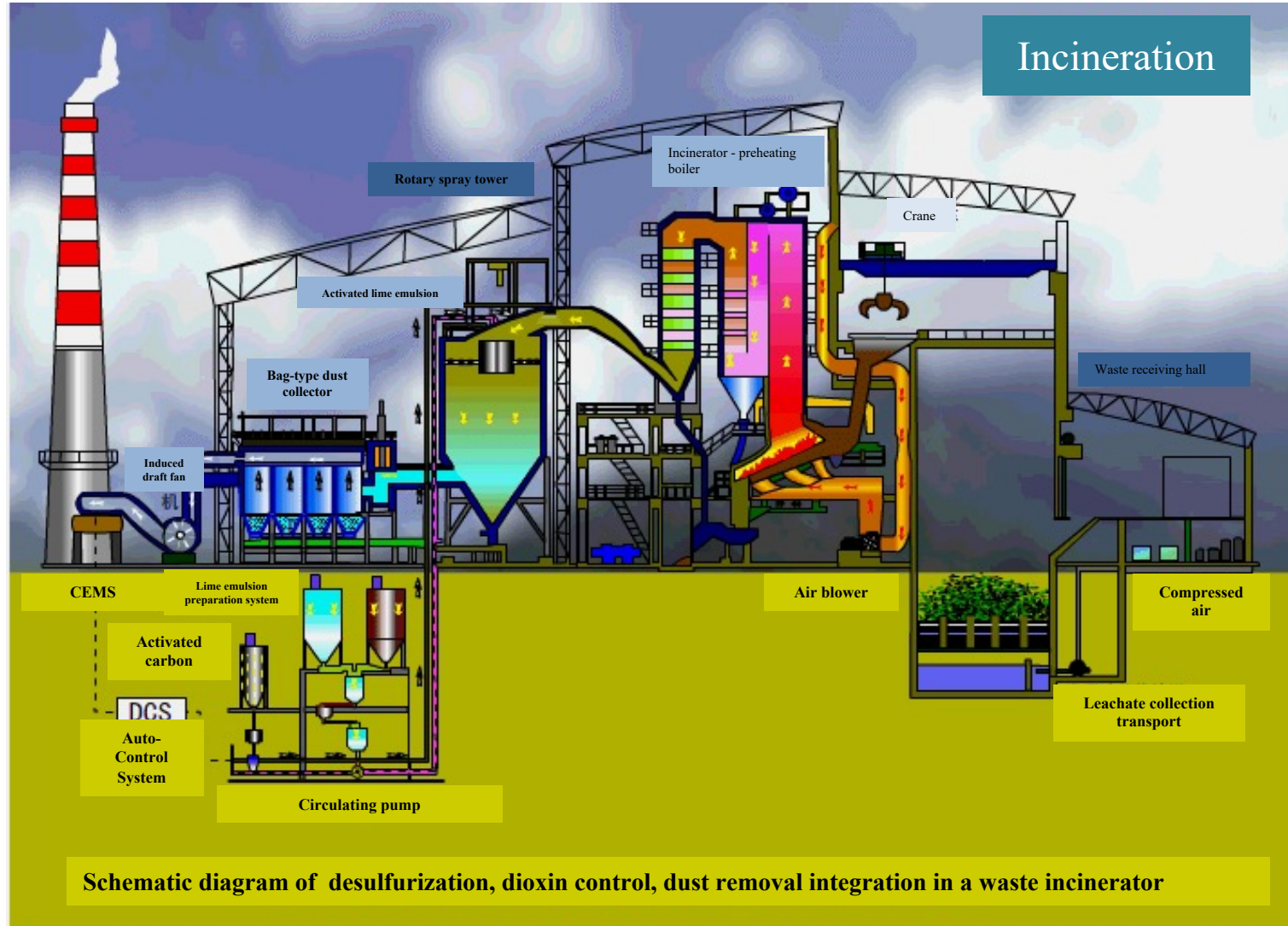


fuel + O₂

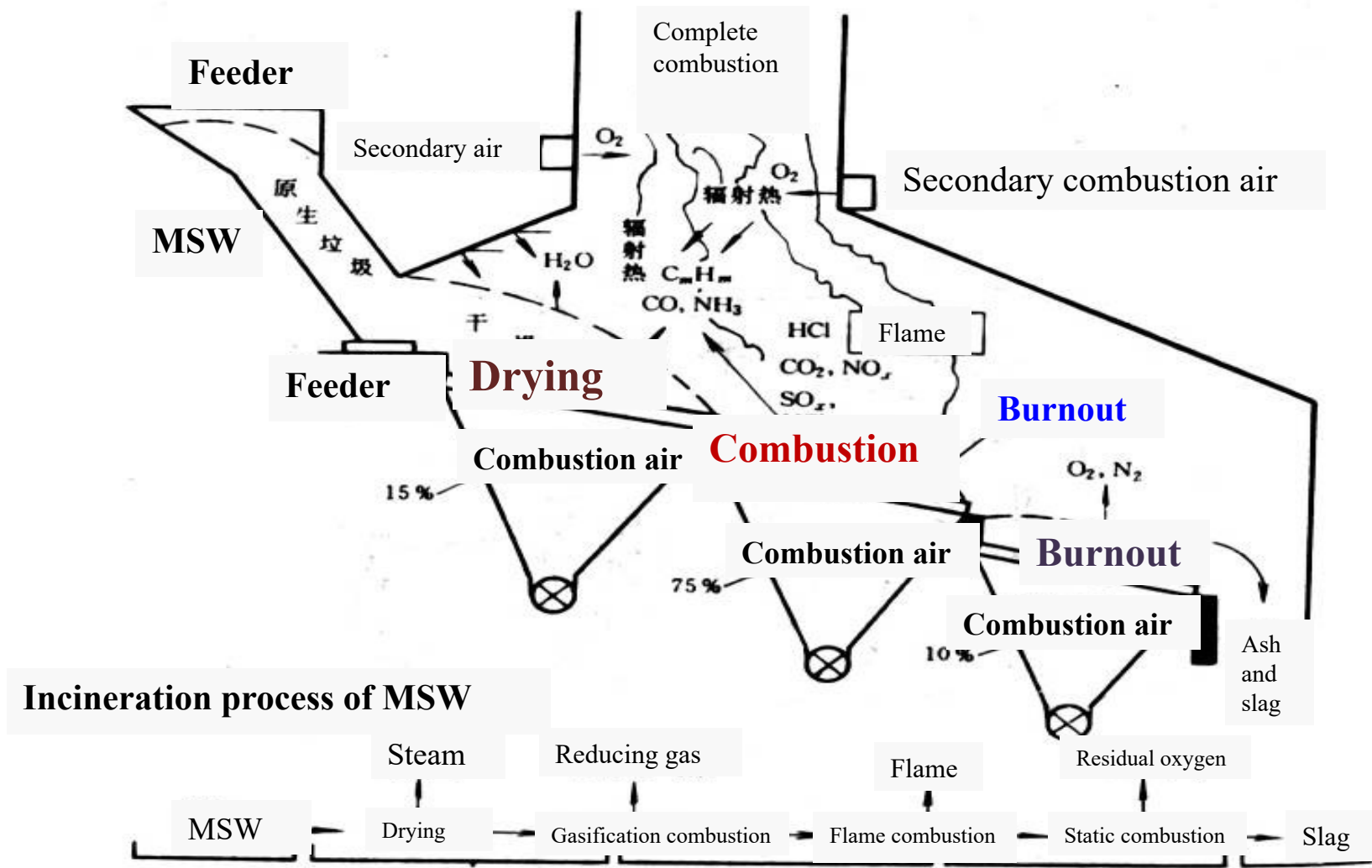


A reaction of a fuel with oxygen, producing energy in the form of heat and/or light.

Incineration



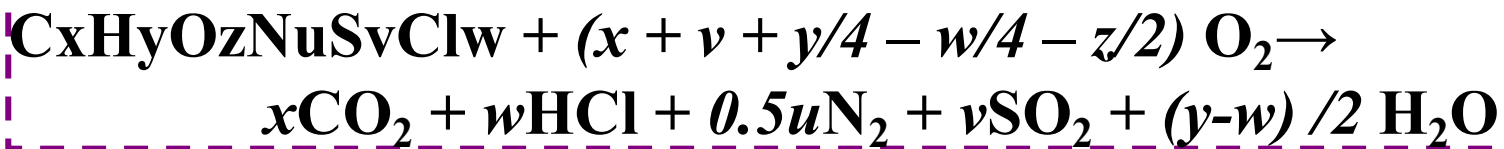
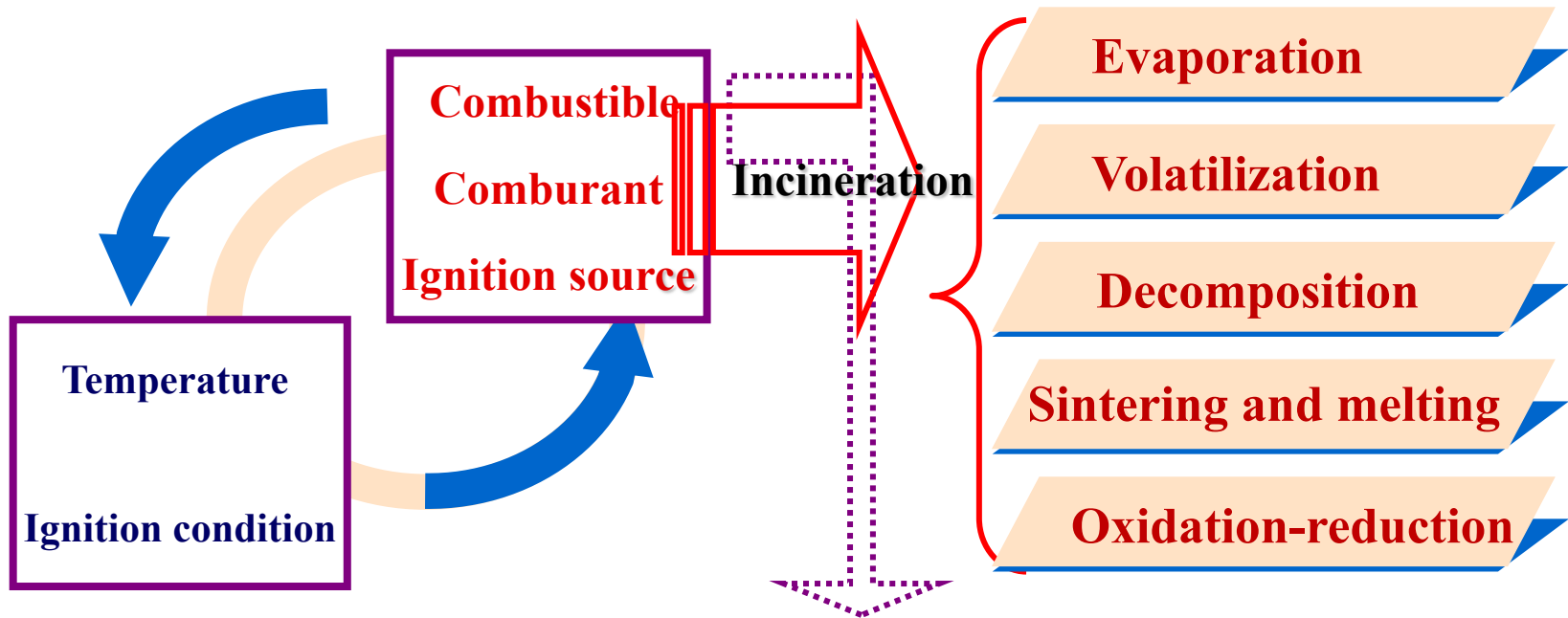
Incineration Process



The concept map of the stocker grate furnace

Incineration Mechanism

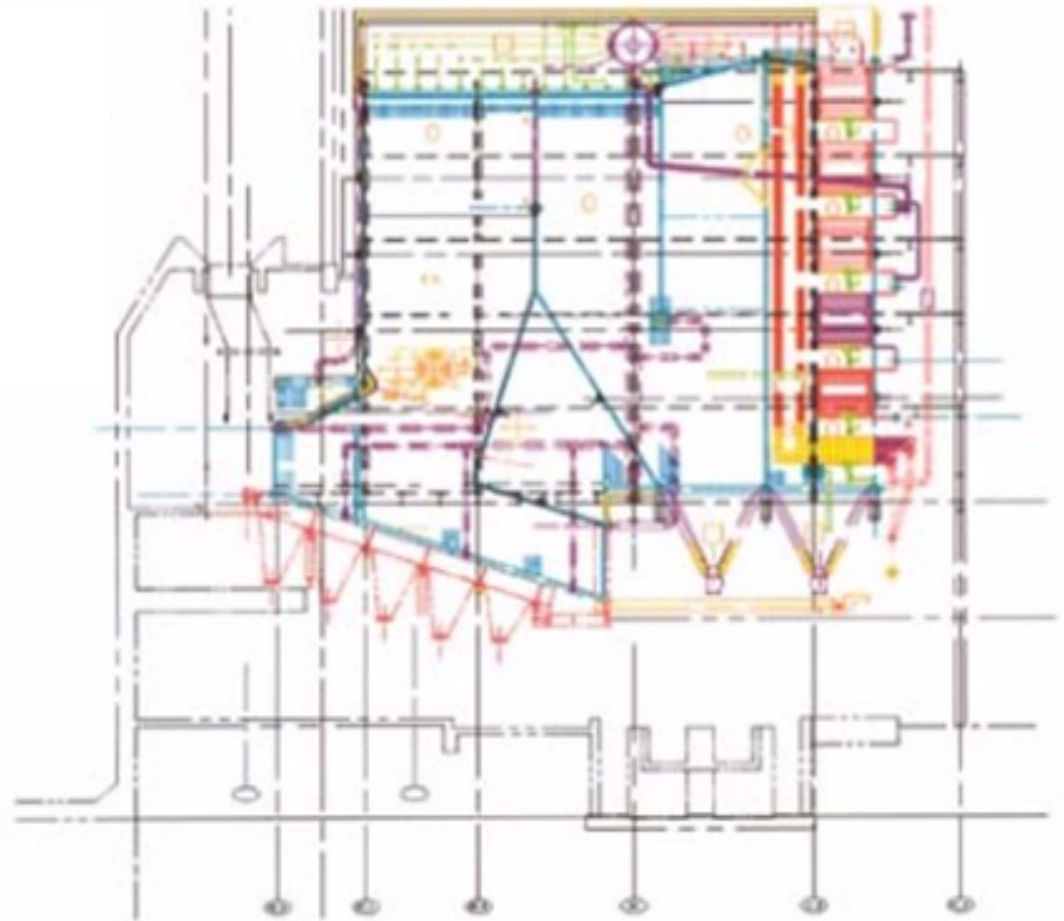
From the viewpoint of engineering technology, the incineration process can be concluded that the combustible material feeds into the incineration furnace and then produces the flue gas and solid residue.



“3 T+O” Incineration Principal

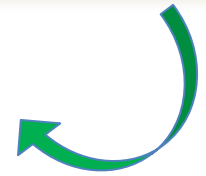
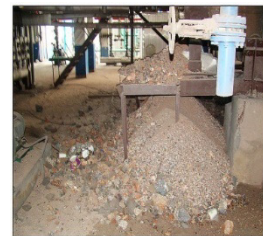
Basic Concepts

- **T**ime
- **T**emperature
- **T**urbulence
- **O**xygen



Advantage of Incineration

- Hygienization of waste - destruction of pathogens
- Reduction of space needed for final disposal of waste
 - **Landfilled mass and volume reduced by 80-90%**
- Reduction of landfilling of biodegradable waste
 - Reduces methane emissions from landfills
 - Reduces landfill fires
- Recovering the chemical energy content of waste
 - Heat
 - Electricity
 - CHP
 - Fuel
- Recovering the end products if possible
 - Bottom ash for earth construction
 - Metals for recycling



Contribution of MSW incineration

- A waste incineration plant with 1000 tons/day capacity can dispose 300kt MSW annually, eliminating the environmental problems of soil, water, and air contamination.
- Can most of cities provide a special land of 300,000 m³ (450 m × 667 m²) for MSW landfill every year?

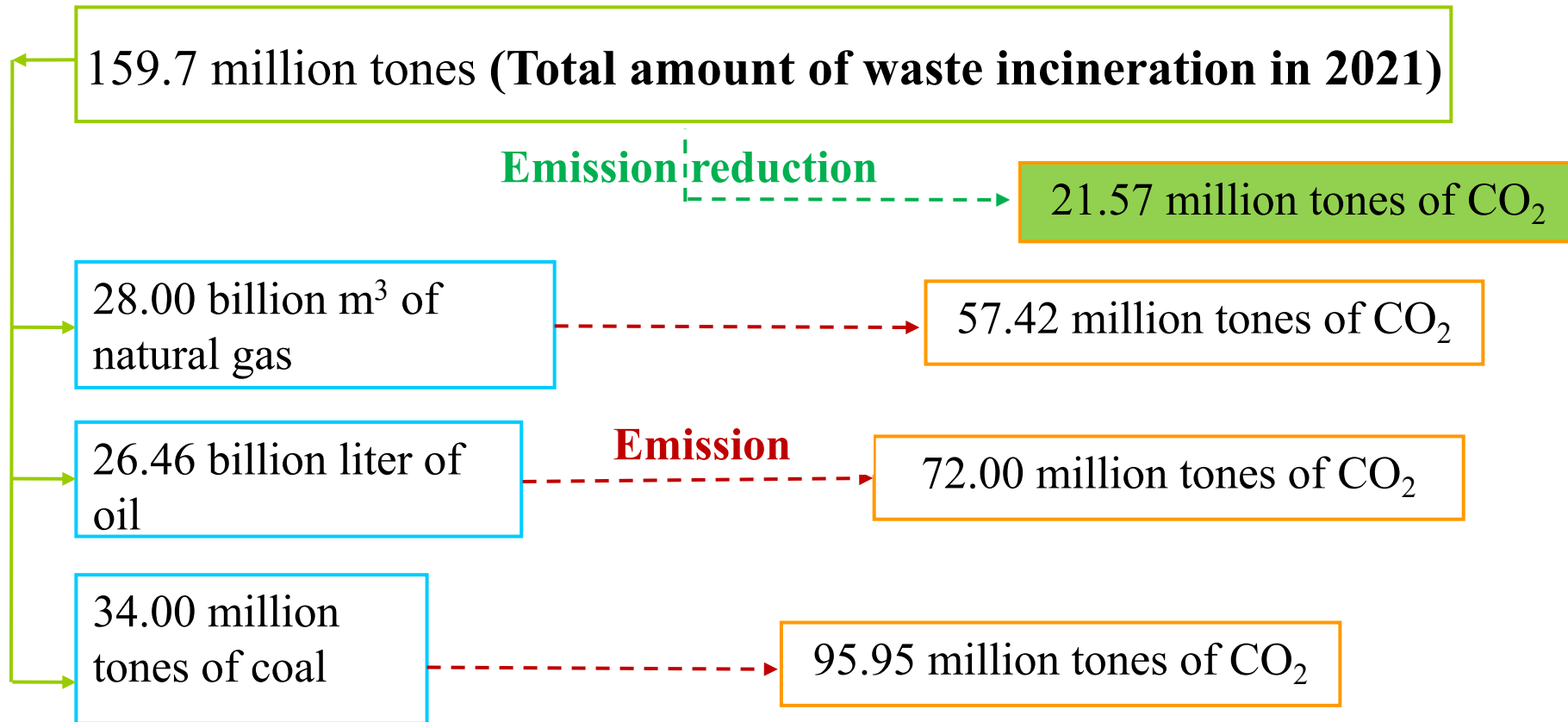
Simple Equations for GHG of MSW Disposal

- Incineration power generation
- $C_6H_{10}O_4 + 6.5O_2 = 6CO_2 + 5H_2O$
+ 2,700 kWh of heat/ton
- Landfill (or anaerobic process)
- $C_6H_{10}O_4 + 1.5H_2O = 3.25 CH_4 + 2.75CO_2$
100 standard m³ methane/ton



Greenhouse effect $CH_4 > 25CO_2$

WtE of Incineration- China Case



***The low calorific value of waste is assumed to be 1500 kcal/kg**

When solving the environmental problems caused by waste, the waste should be reused as energy simultaneously!

Disadvantage of Incineration

- **Expensive process** (USD30/tonne). The cost for composting and landfilling are about USD5/tonne and USD15/tonne.
- It produces dangerous wastes in the form of gases and ash, often creating entirely new hazards:
 - Heavy metals in residue (ash).
 - dioxin emissions to atmosphere.
- Incinerators destroy materials that must then be replaced and prevent us from adopting sensible modern ways of doing business, namely "zero waste" and "clean production".



Cost of an incineration plant-developed countries

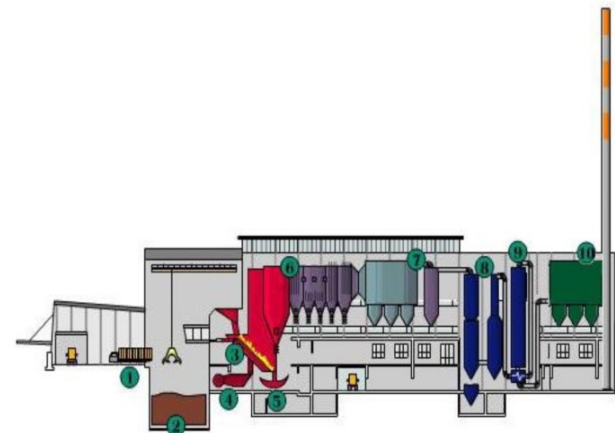
Typical cost of an incineration plant (per ton)

– Financial cost	84.- US\$/to
– Operation costs (personal and material)	115.- US\$/to
– Residues transport and landfilling	<u>33.- US\$/to</u>
– Total cost	232.- US\$/to
– Revenue of the Energy production	<u>-35.- US\$/to - 15 %</u>
– Total cost considering energy production	197.- US\$/to

Source: Costs study of the incineration plants in Switzerland, OFEV

⇒ Revenues from energy production only cover a reduced part of the costs

⇒ Incineration cost = 100 to 200 \$ per ton



Cost of an incineration plant- China

For a plant with 1000 ton/day capacity (per ton of waste disposed)

Cost :

- Financial cost: 15~50 CNY/ton (2.25~7.5 US\$/ton)
- Operating cost: 130~200 CNY/ton (20~30 US\$/ton)

Subsidy :

- **Subsidy: 50-200 CNY/ton (7.5~30 US\$/ton)**
- **Benefit from power generation: 180~200 CNY/ton**
(20~30 US\$/ton)

The cost of fly ash disposal is a key component.

Waste Treatment Technology

Waste to Energy is more costly but efficient.



	Sanitary Landfill	Composting	Anaerobic Digestion	Waste to Energy
Basic Process	Disposal	Biological treatment	Biological treatment	Thermal treatment
Ideal Types of Waste	<ul style="list-style-type: none"> Municipal solid waste, construction and demolition waste, wastewater sludge, non-hazardous industrial wastes 	<ul style="list-style-type: none"> Food waste (including wastes from households, restaurants and markets), fats/ oils/ grease, paper and cardboard, landscaping and garden waste 	<ul style="list-style-type: none"> Food waste (including wastes from households, restaurants and markets), fats/oils/grease, slaughterhouse waste and garden waste 	<ul style="list-style-type: none"> Mixed municipal solid waste, medical waste, demolition wood, auto shredder residue, dried sewage sludge, and some industrial solid wastes
Waste to Avoid	Medical	Non-biodegradable wastes (plastic, glass, metal, inerts)	Non-biodegradable wastes (plastic, glass, metal, inerts), tree clippings	Yard leaves or source-separated food waste
Mass Reduction of Waste (%)		0.5	0.5	80-85%
(kWh/tonne of MSW)	65 (landfill gas)		165 - 245	500-600
Capital costs (US\$/annual tonne)	5 - 52 (US\$/tonne over lifetime)	30-400	220 - 660	190-1000
Operating costs (US\$/tonne)	7 - 30 (up to120)	12-100	22-57	12-55

One of Best MSW Disposal Technologies

Biggest problem:

Most cities in the developing countries are surrounded by MSW



Incineration

Solve!



Landfill

~~Solve~~

Main Contents

Municipal solid waste generation, characteristics and disposal

Current situation of waste incineration technologies

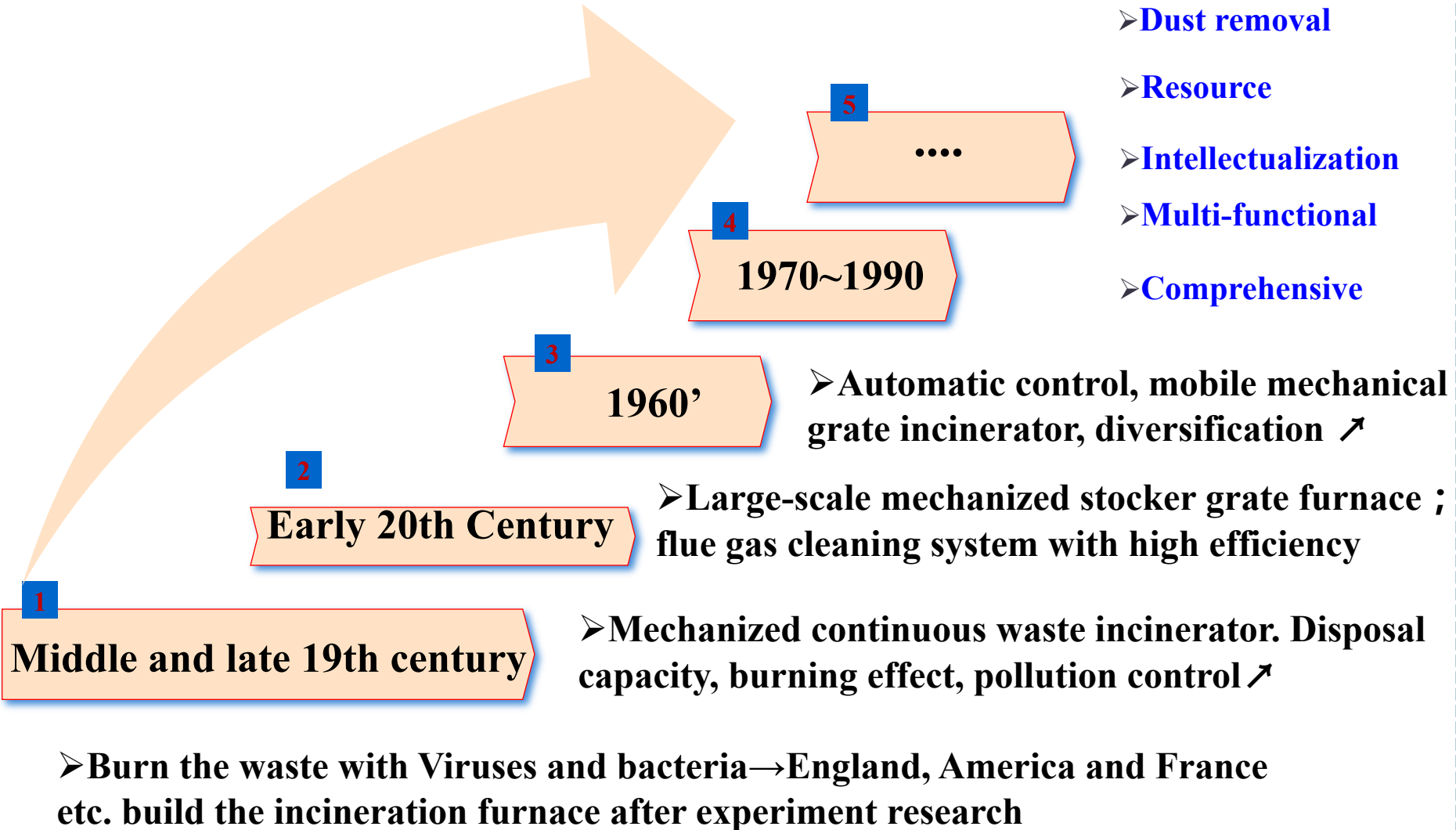
Waste incineration in China

Experiences of waste incineration application in China

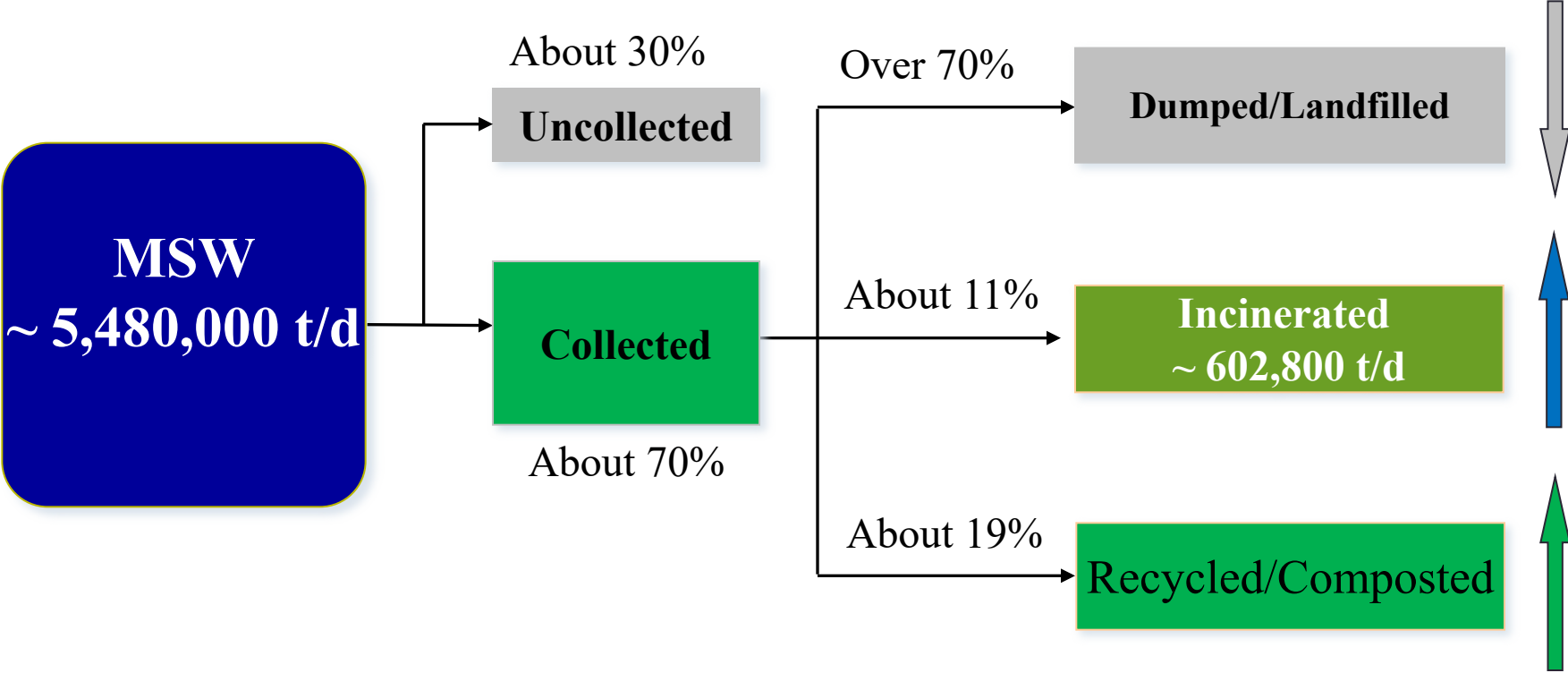
Historical Waste Incineration “Generations”

- **0** **Open-air burning**
- **1st** **1900** *oven*
- **2nd** **1960** *dust removal* **from flue gas**
- **3rd** **1985** *chemical cleaning* **of flue gas**
- **4th** **2000** *recovery of energy and materials*

Development of waste incineration technology



Current Situation of MSW Disposal Technology in the World

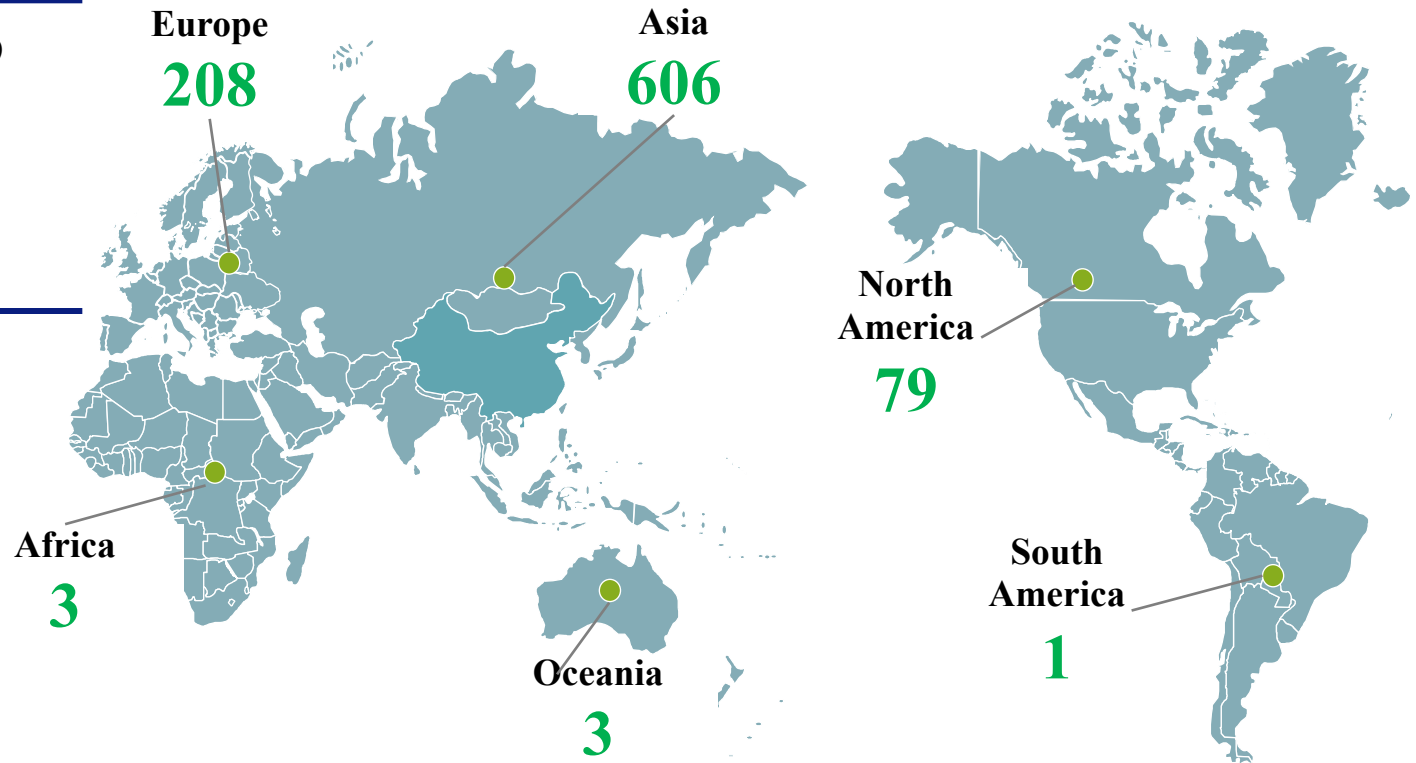


Source: *Waste Atlas*

Global Application of WtE

As of April 2019

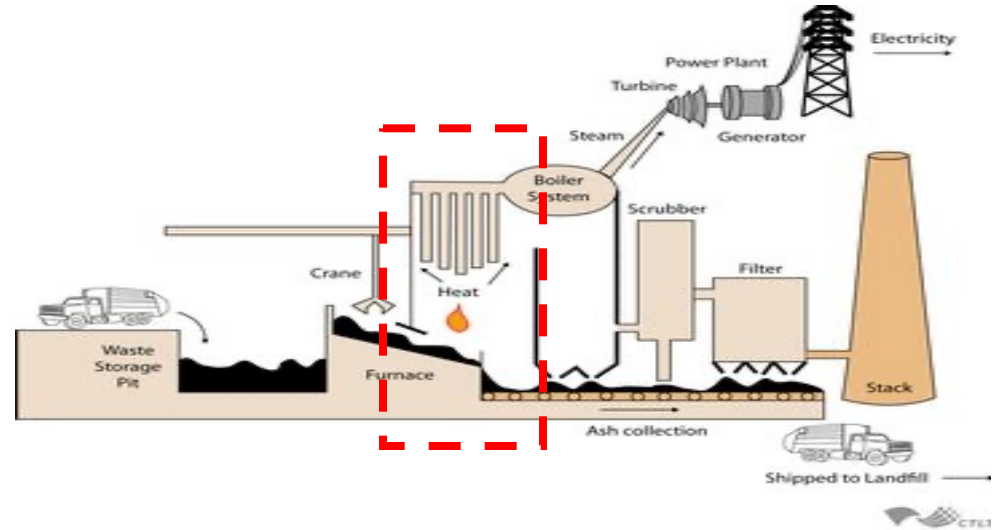
900+



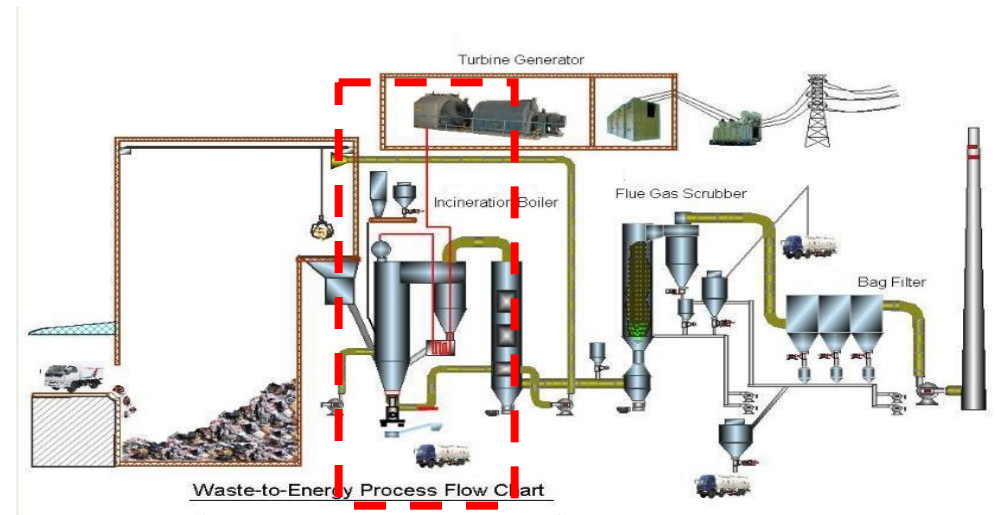
Over 180 million tonnes of waste were converted into energy in over **900 WtE facilities** in the world.

Incineration Technology of MSW

Stoke Grate Incineration System



Fluidized Bed Incineration System

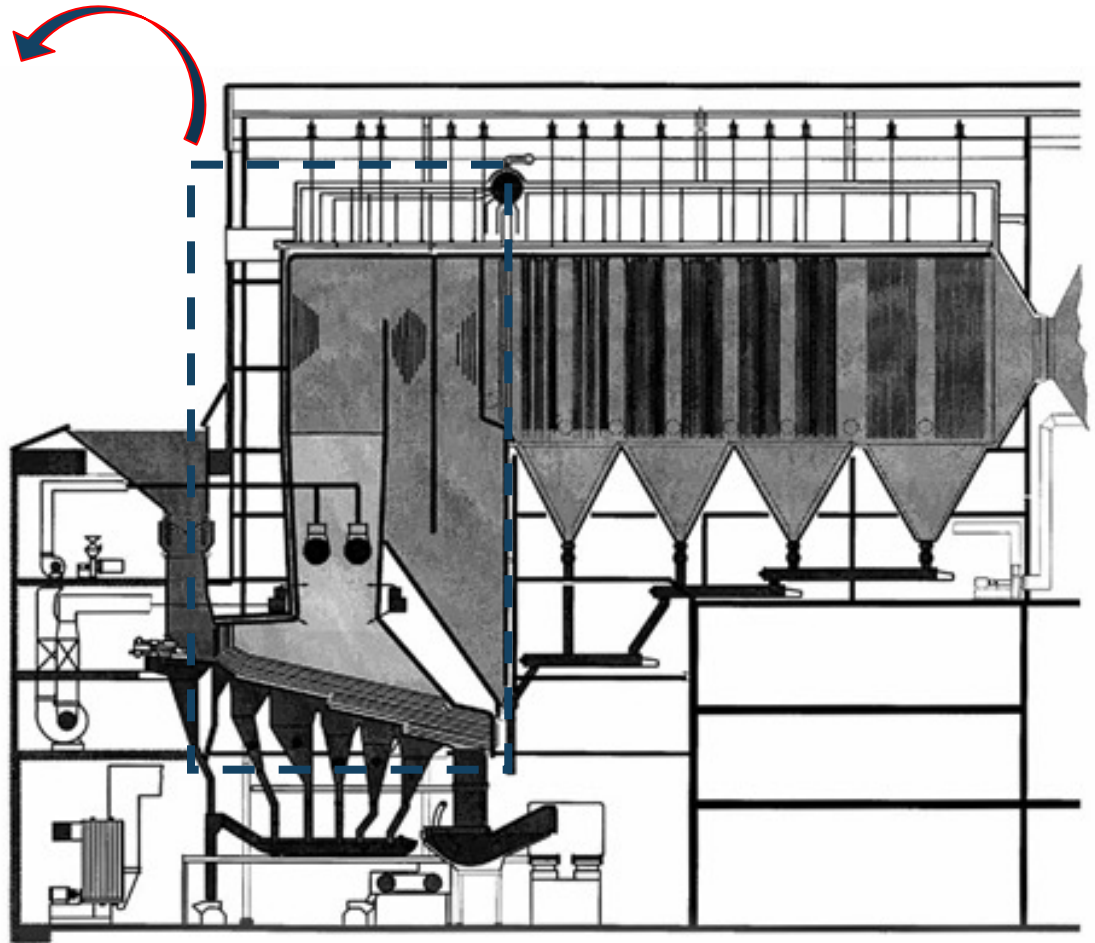
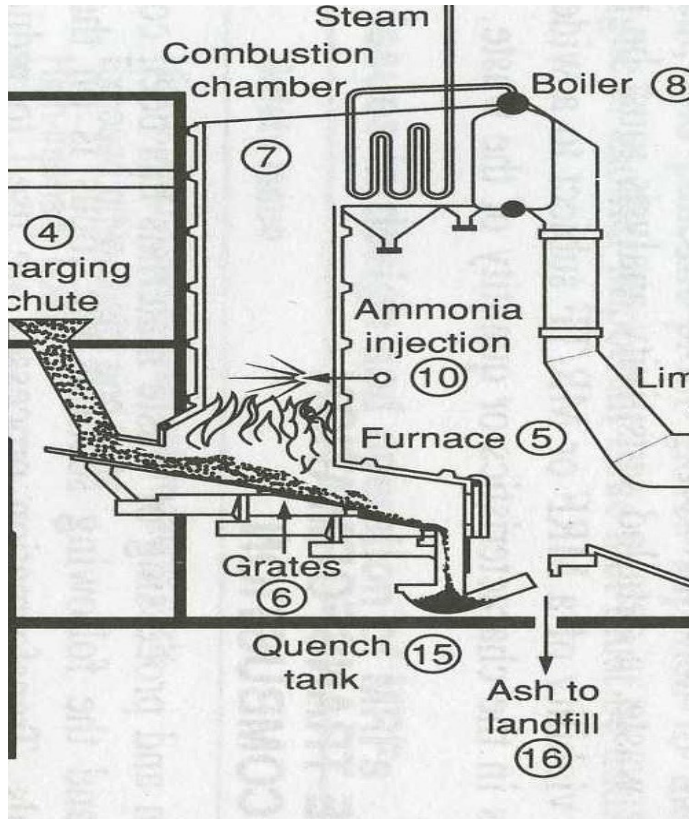


Basic Differences of Incineration Technologies

Grate Furnace Incineration System

- Combustion in a moving bed (layer),
(Moving Grate or Stoke Grate)
- Bed on the grate
- Supply easy also for large particles
- Mechanical transport of the waste during combustion
- Large pieces of waste allowed

Section Distribution of Grate Furnace Incinerator

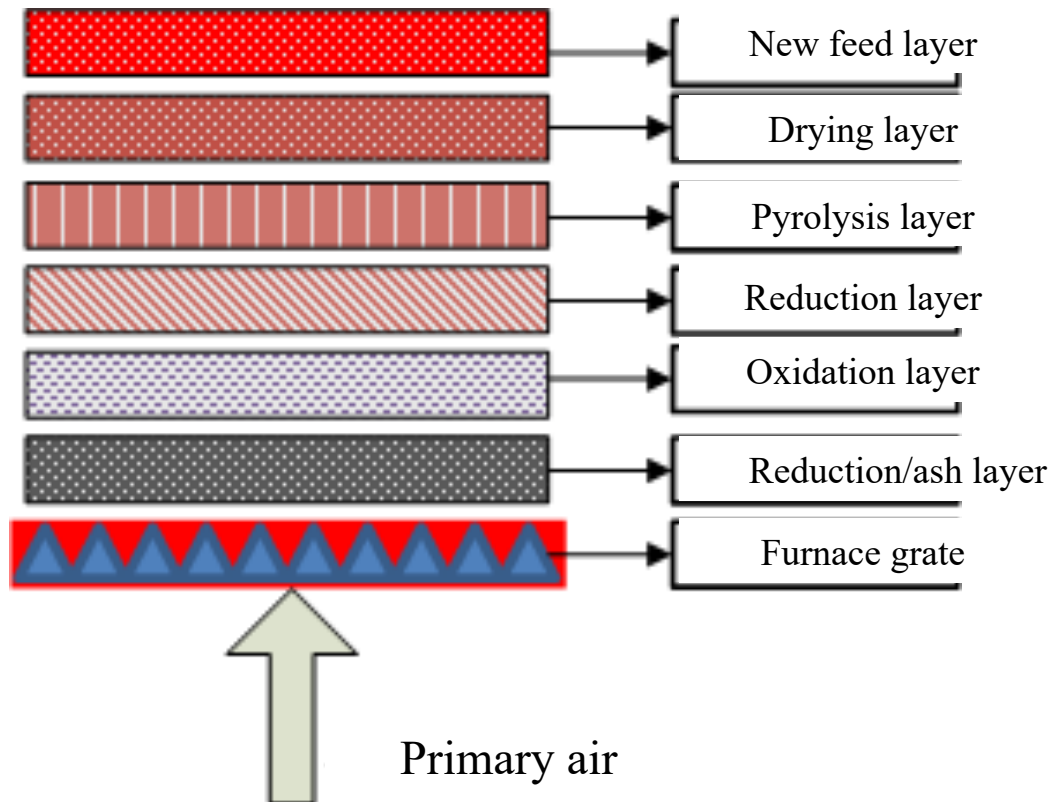


Conventional Membrane Wall Boiler

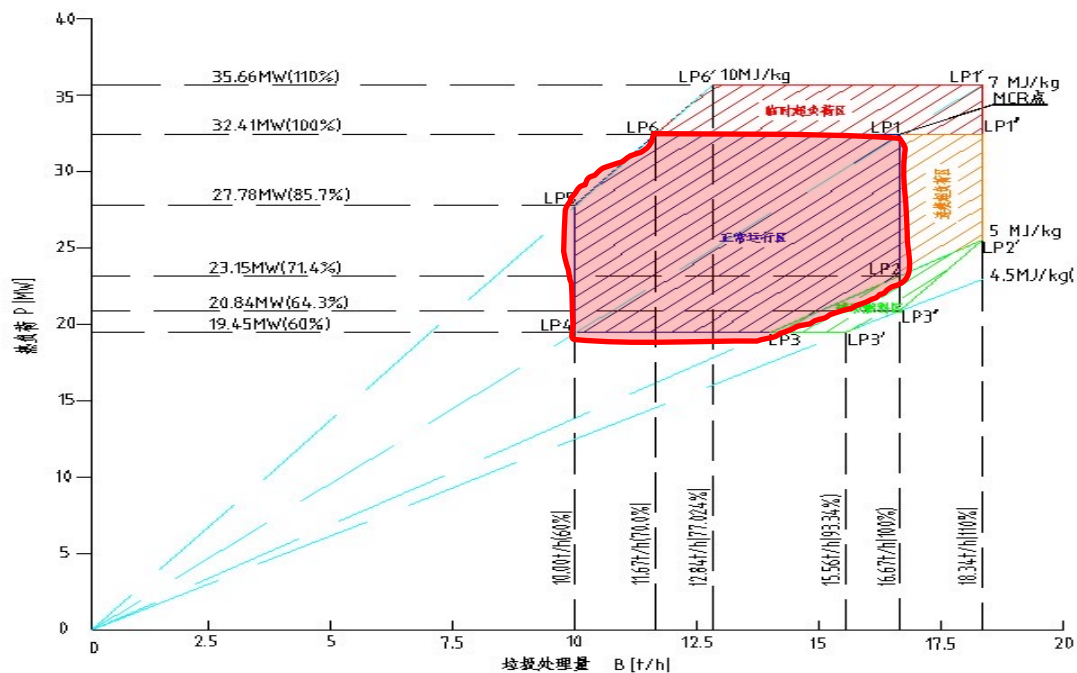
Combustion on Moving Grate (Vertical direction of grate)



The feed is placed on a grate to form a fuel layer of a certain thickness, and the air needed for the combustion is furnished through the lower part of the grate

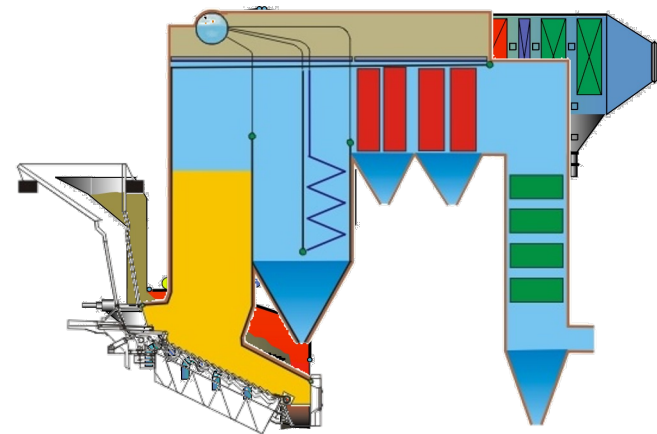
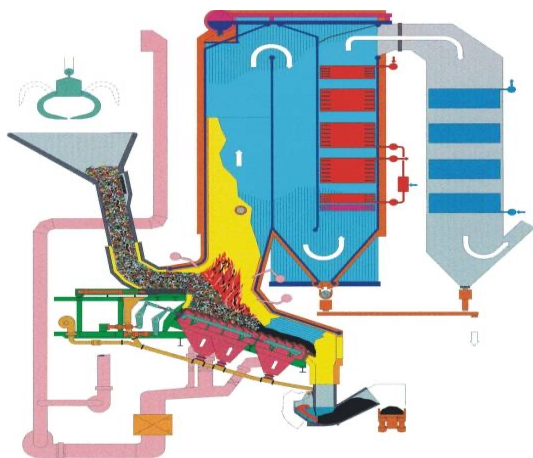


Available Combustion Diagram



X-axis: mass capacity

Y-axis: heat capacity





DEUTSCHE BABCOCK
KUWAIT

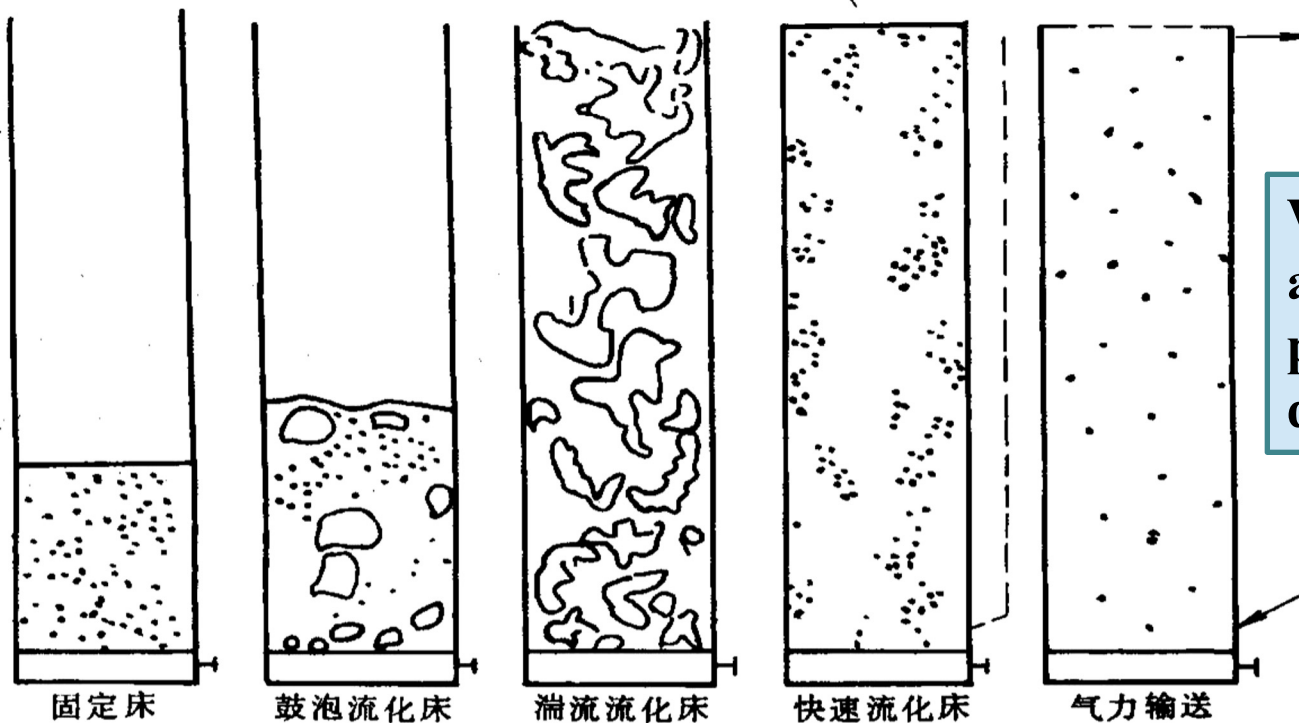


steinmüller
engineering



What is Fluidized Bed

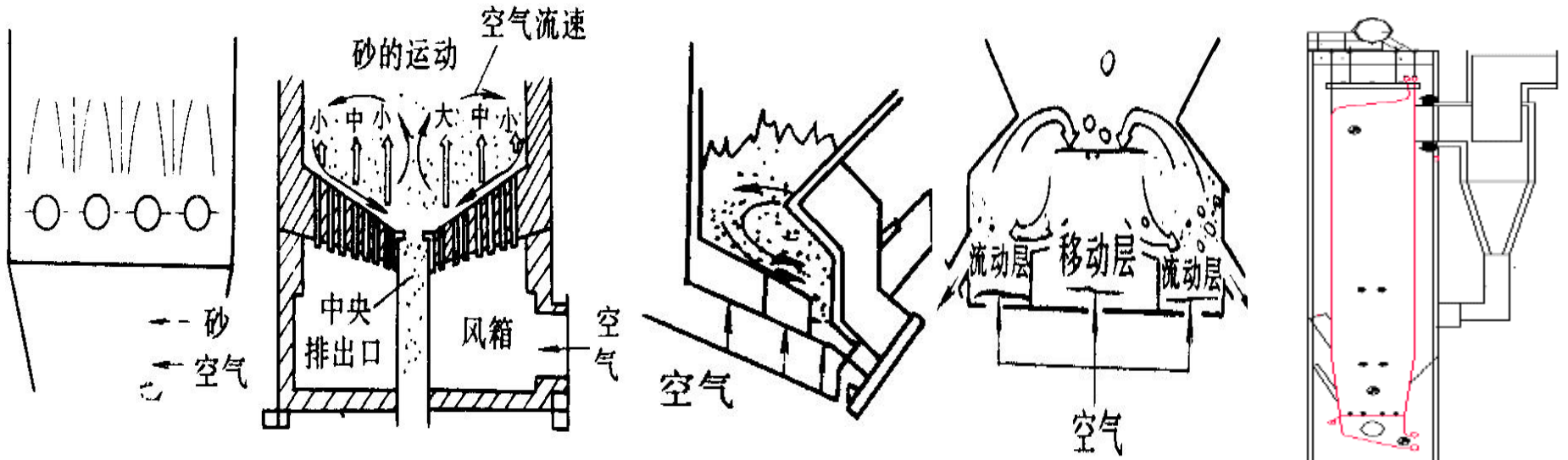
- It is an operation blowing solid particle swarms with gas, making solid particles turn into **fluid-like state**.
- The gravity on the particles is offset by drag imposed on fluid, so particles are at the state of **semi-suspended**.



With the addition of airflow speed, solid particles show different flow state.

流化速度，空隙率增加 →

Types of MSW Fluidized Bed Inineration

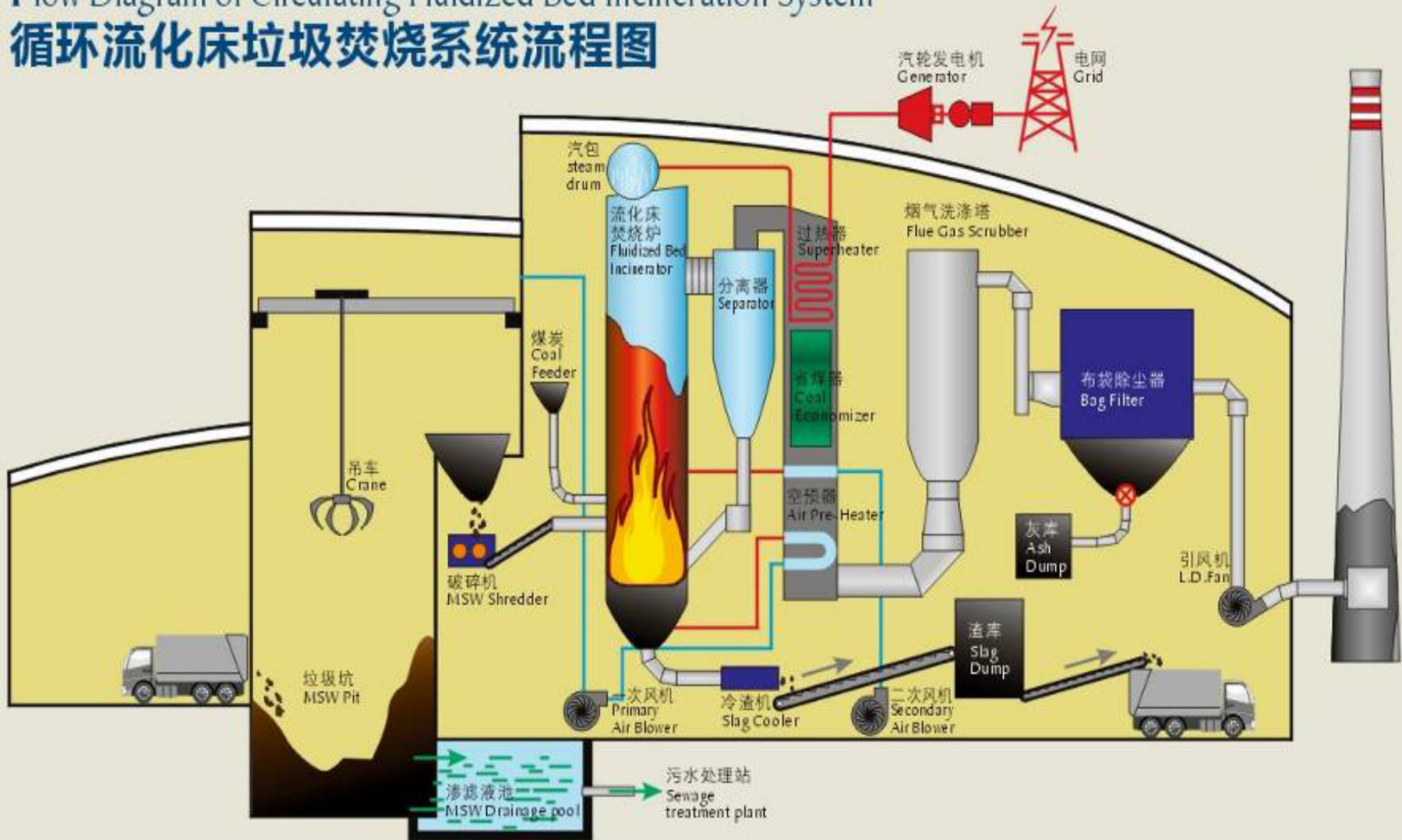


Vertical flow	Spiral-shaped	Downward spiral-shaped	Upward spiral-shaped	Circulating fluidized bed (CFB)
---------------	---------------	------------------------	----------------------	--

Circulating fluidized bed is more available for low heating value waste.

Section Distribution of Fluidized Bed Incinerator

Flow Diagram of Circulating Fluidized Bed Incineration System
循环流化床垃圾焚烧系统流程图



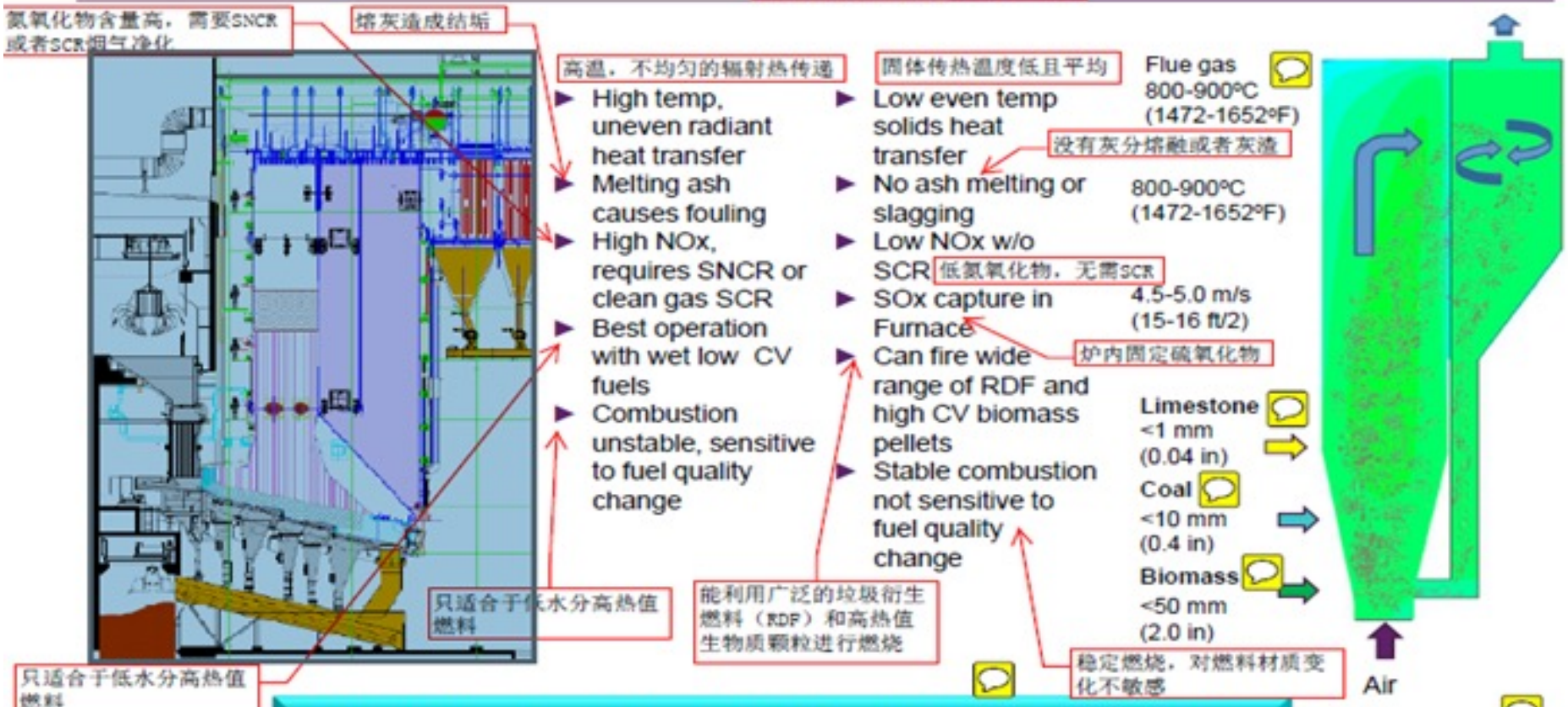
Grate vs. CFB Incineration Technology

From Foster wheeler



Grate vs. CFB Steam Generator Technology

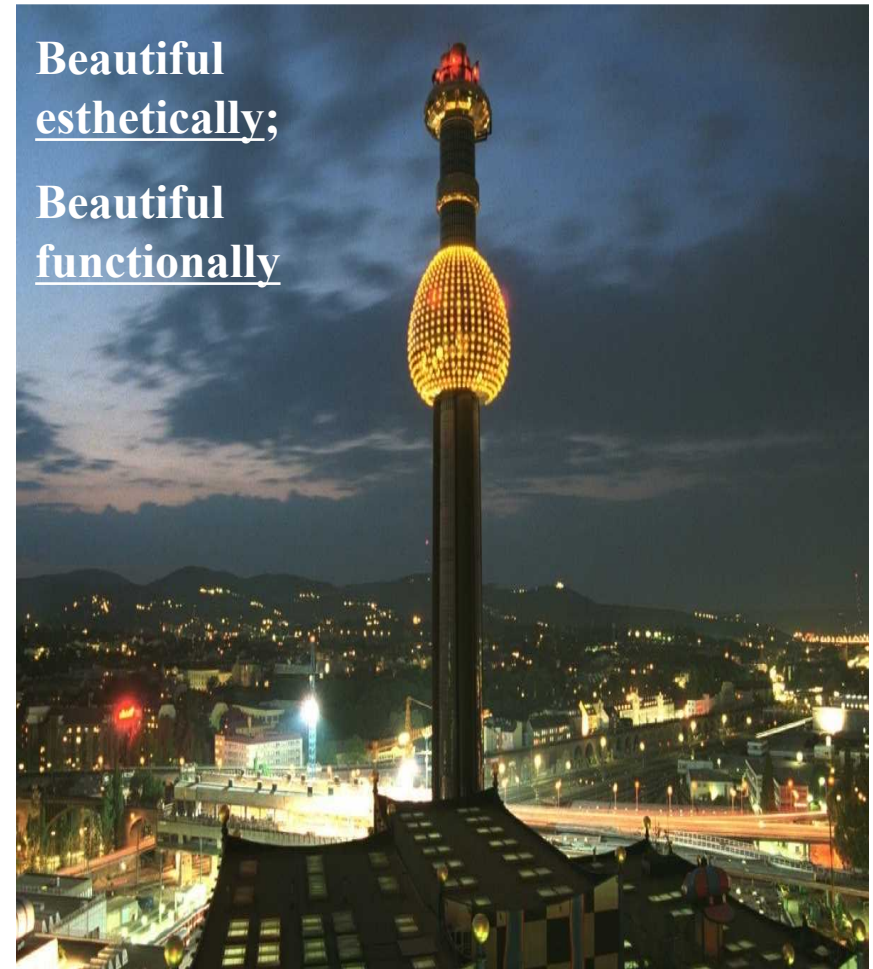
炉排和流化床蒸汽发生技术对比



CFB Technology Offers Fuel Flexibility, High Reliability and Low Emissions with minimum backend equipment

循环流化床技术 (CFB) 用最小化的后端设备的同时，具有燃料的灵活性，高可靠性和低污染排放等特点

Greenpeace, Vienna, Austria about the WtE facility Spittelau, Vienna, 1999: "...The Austrian incineration plants have a high environmental standard as far as air and water emissions are concerned..."



Main Contents

Municipal solid waste generation, characteristics and disposal

Current situation of waste incineration technologies

Waste incineration in China

Experiences of waste incineration application in China

Waste incineration in China

Introduction

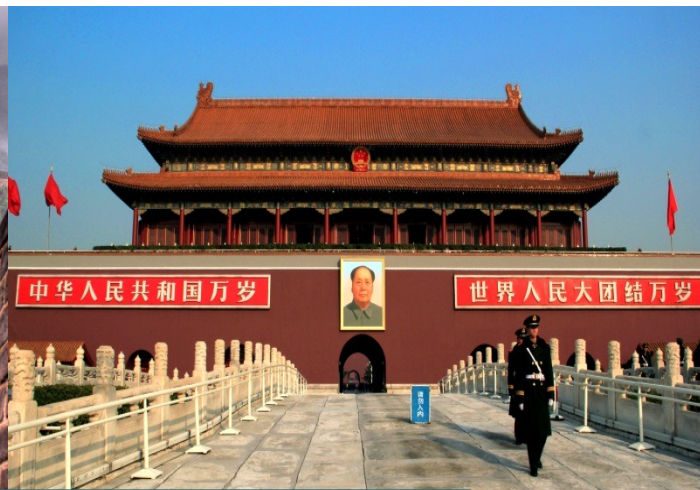
- [The People's Republic of China](#)
- **Overview of MSW in China**

Waste to Energy in China

- **History and technology of WtE**
- **Regulations and policies**

The People's Republic of China (PRC)

- **The most populous** in the world with over 1.4 billion people, approximately one-fifth of the world's population
- **9.6 millions** sq. km (3rd largest)
- **23 provinces**, 4 Municipalities, 5 autonomous regions
- **56 ethnic groups**



Geographical Division of China

Geographical Division Map
of China

中国行政区划及地理区域划分图



- China Mainland is divided into **7 regions**, according to **different geographical locations and climate**.
- The regions differ from each other also in income level, consumption habits, fuel structure, and other aspects.
- Thus, the properties of MSW in different regions varies greatly, and so does the calorific value.

Waste incineration in China

Introduction

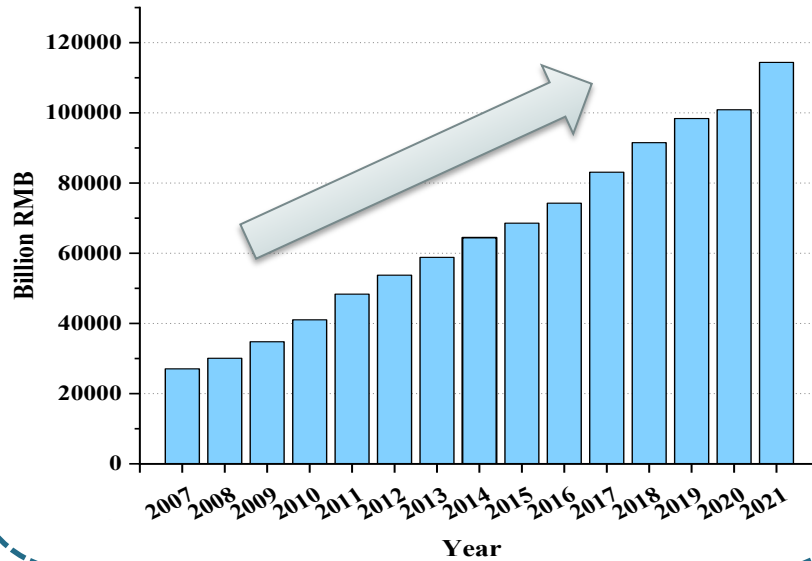
- **The People's Republic of China**
- **Overview of MSW in China**

Waste to Energy in China

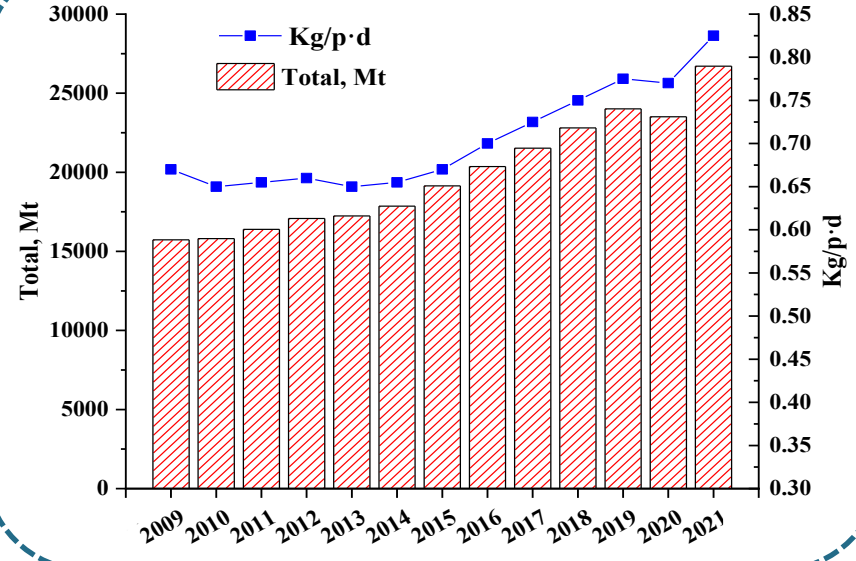
- **History and technology of WtE**
- **Regulations and Policies**

Growth of China's GDP and MSW Generation

GDP



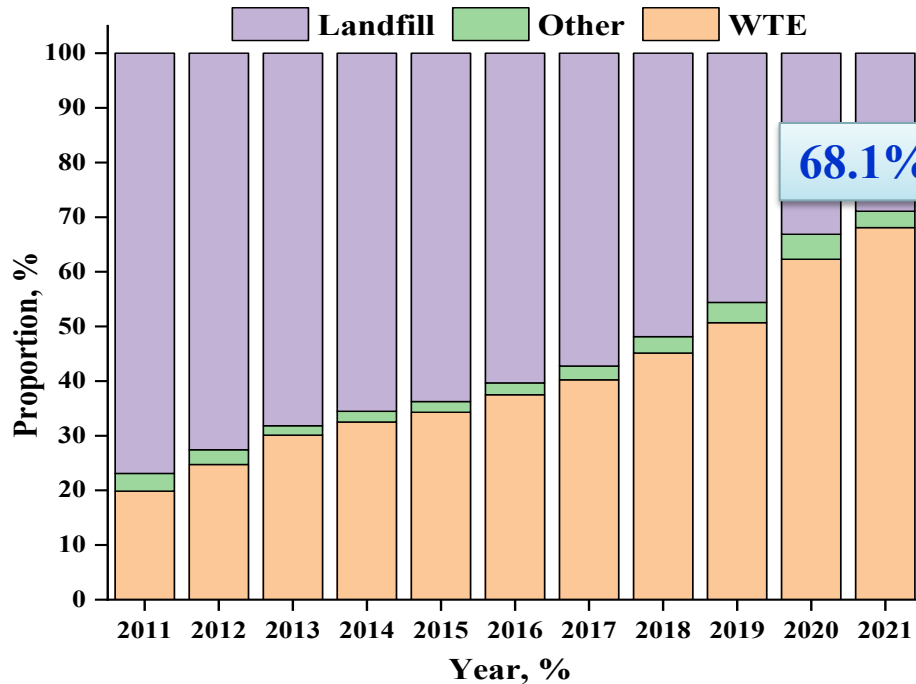
MSW generation



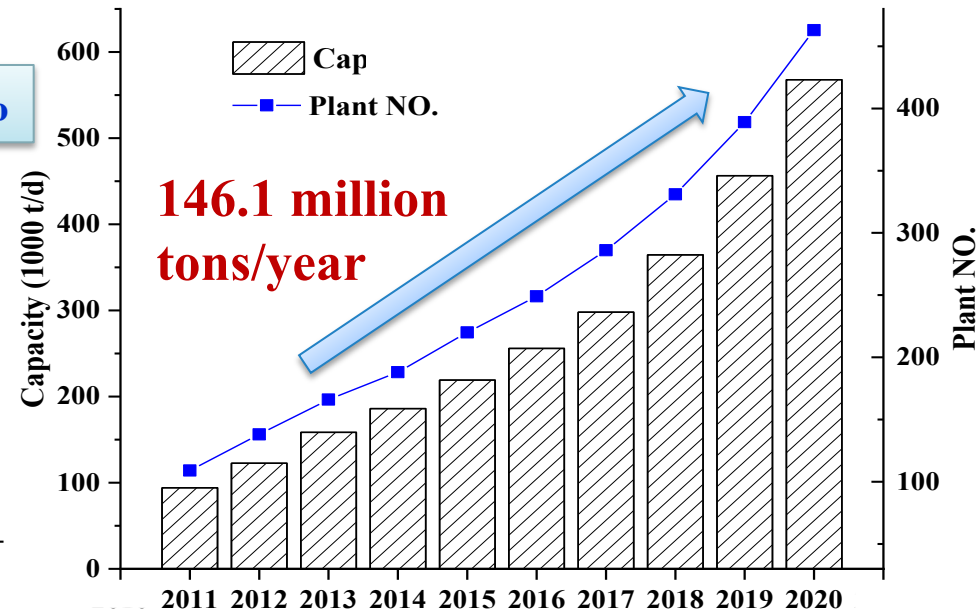
- A strong **link between economic growth and waste generation.**
- Amount of MSW in **2021 reached up to 267.1 million tonnes (0.83 kg/capitay·day)**, with average **increasing ratio of 4.0%.**

MSW Treatment

*Data source: statistical yearbook of China



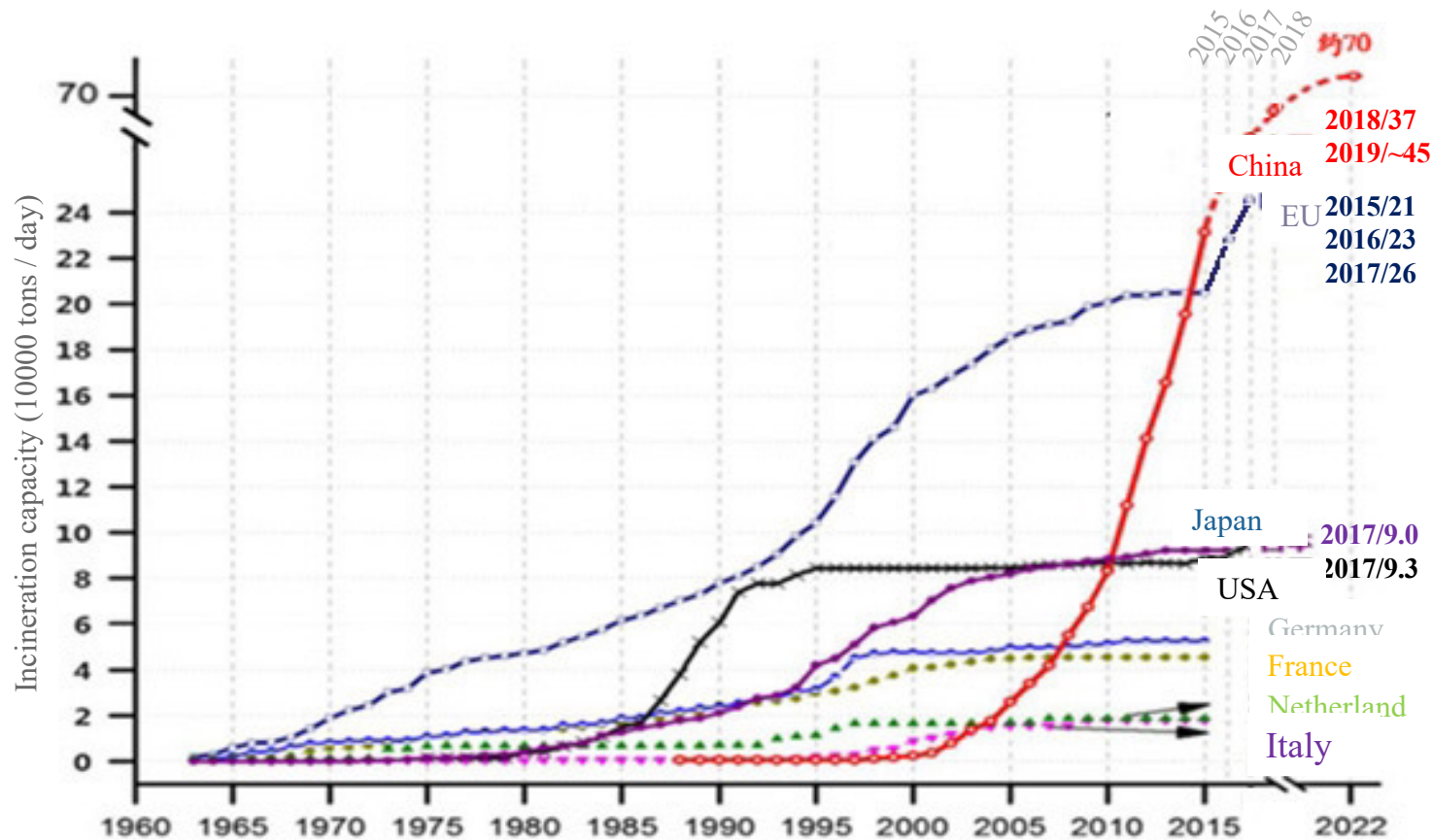
Proportion of different harmless treatment methods along years



WtE Plant No. & Capacity

- **99.88% of MSW generated in 2021 was harmlessly treated.**
- **WtE became the dominant method since 2020 and accounted for 68.1% in 2021.**

Rapid Growth of MSW Incineration



- WtE in China **developed faster since 2005.**
- Even more rapidly in recent years (**40-50 plants/year**)
- Became the **TOP one** in terms of waste incineration capacity in 2015, overtaking the US, Japan, and the EU.

Waste incineration in China

Introduction

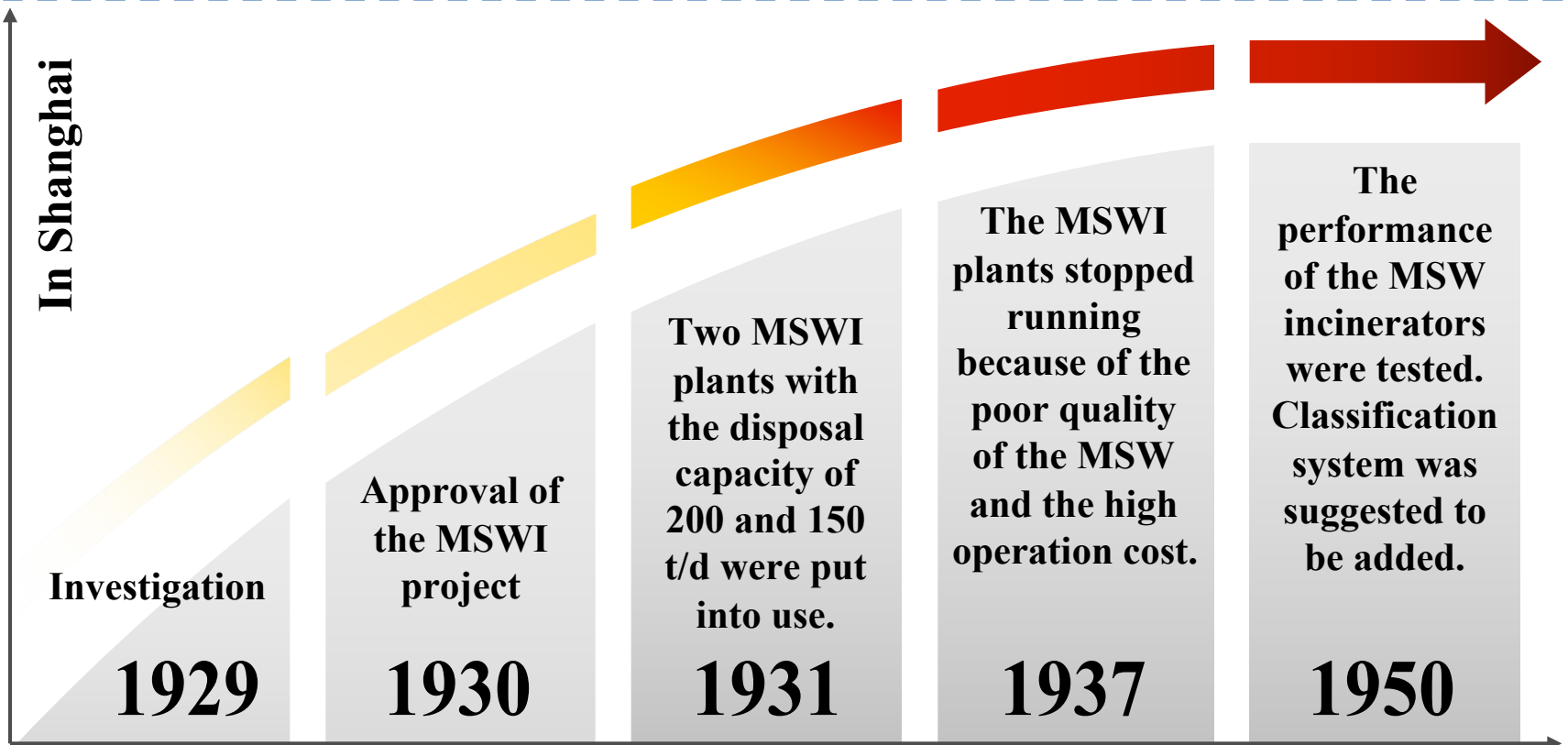
- **The People's Republic of China**
- **Overview of MSW in China**

Waste to Energy in China

- **History and technology of WtE**
- **Regulations and policies**

History of MSWI in China

- In the early 1930s, two MSW incineration (MSWI) plants have been built and put into use in Shanghai. The disposal amount of them was up to 0.1 million t/year.
- Although the early MSWI technology was aborted, lots of inspiration (e.g. the classification of waste) has been got.

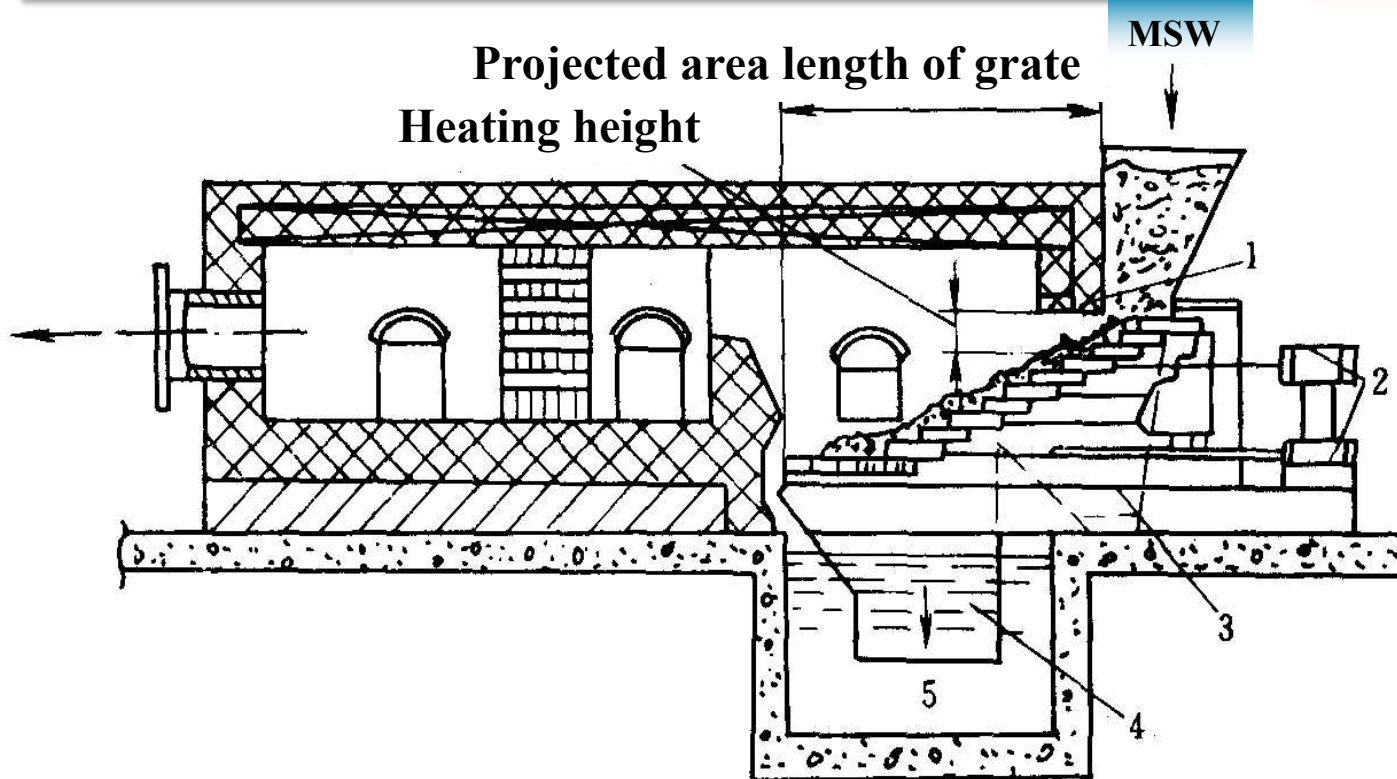


Small-scale Stoker-type MSW Incinerator

10 ~ 100 t/d Incinerator

- Easy to be received in the early 1990s
- Based on coal-fired technology
- Lack of attentions for MSW property
- Serious emission

Stopped

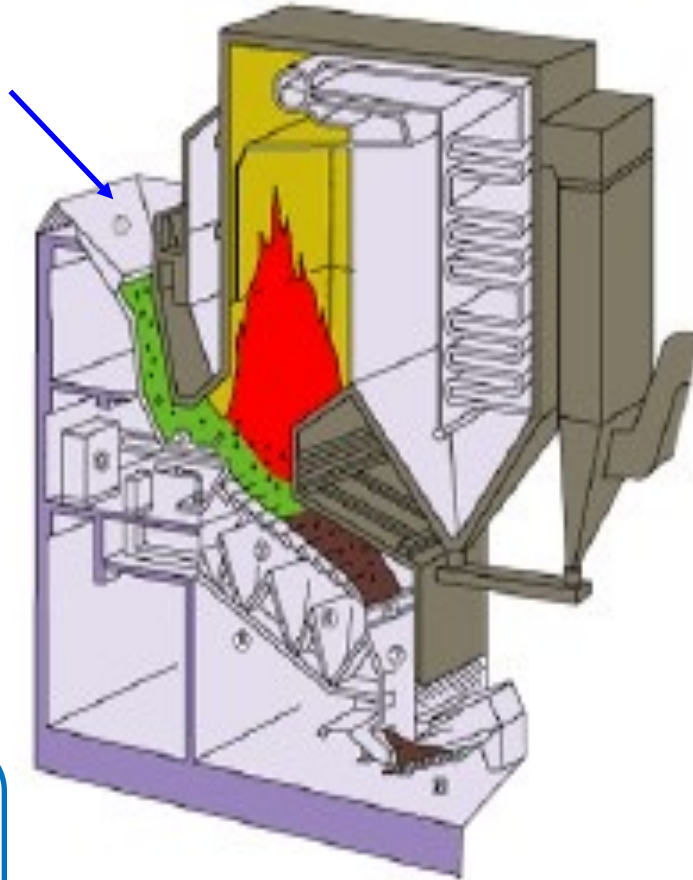


Development of MSWI Technology in China



Properties of MSW :

- Complex
- Variable
- High moisture
- Low heat value



Martin grate furnace

History of development :

- In 1985, Shenzhen began to build the first modern MSWI plant in China. But **the imported Martin grate incinerator was not suitable for the Chinese MSW.**
- Then Shenzhen put much effort into the renovations of technology and process.
- Finally, **a MSWI plant with disposal capacity of 300 t/d was put into operation in 1988.**

Incineration Technology of MSW

At the beginning of a new technology application, there are always more words or concepts related to this technology, the same as in China in the last decade of the last century.

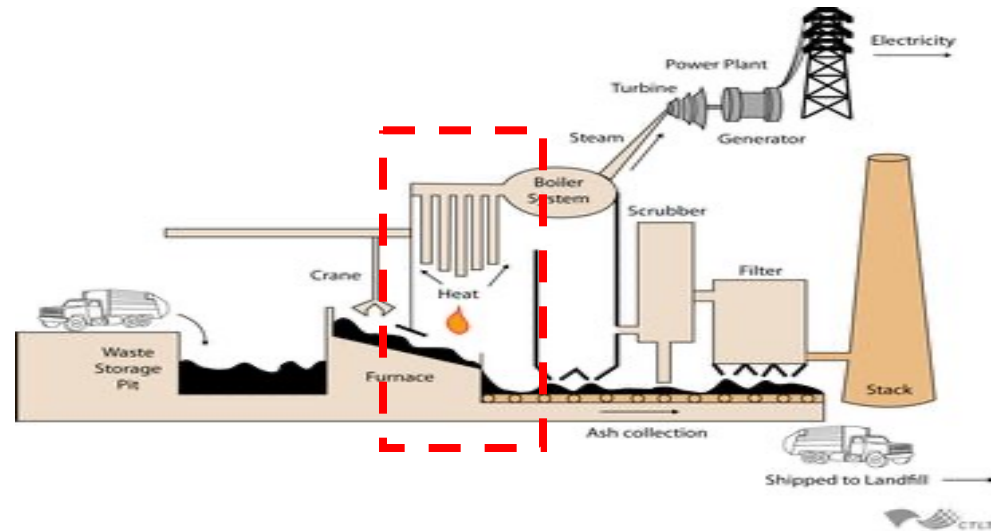
- Incineration
- Segmented incineration
- Oxygen-controlled pyrolysis incineration
- Pyrolysis gasification incineration
- ...



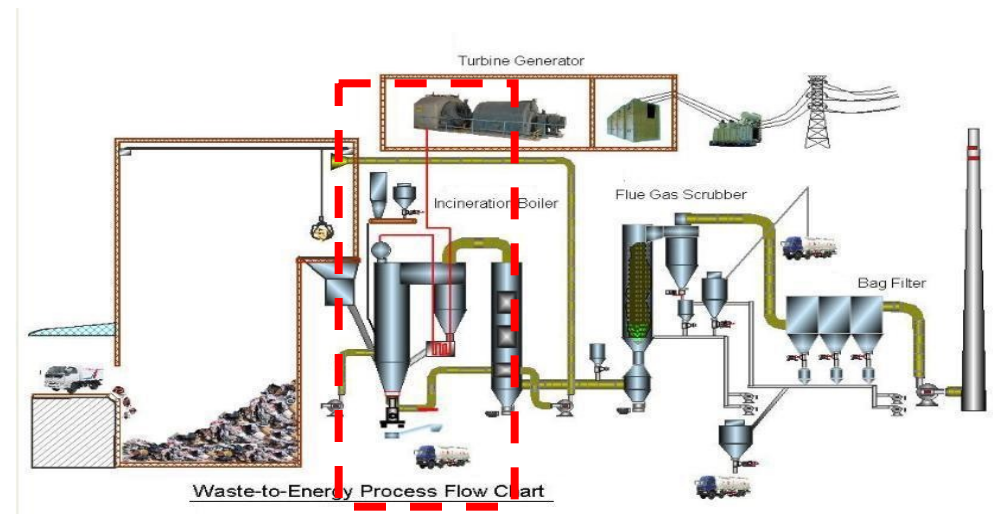
Incineration

Incineration Technology of MSW

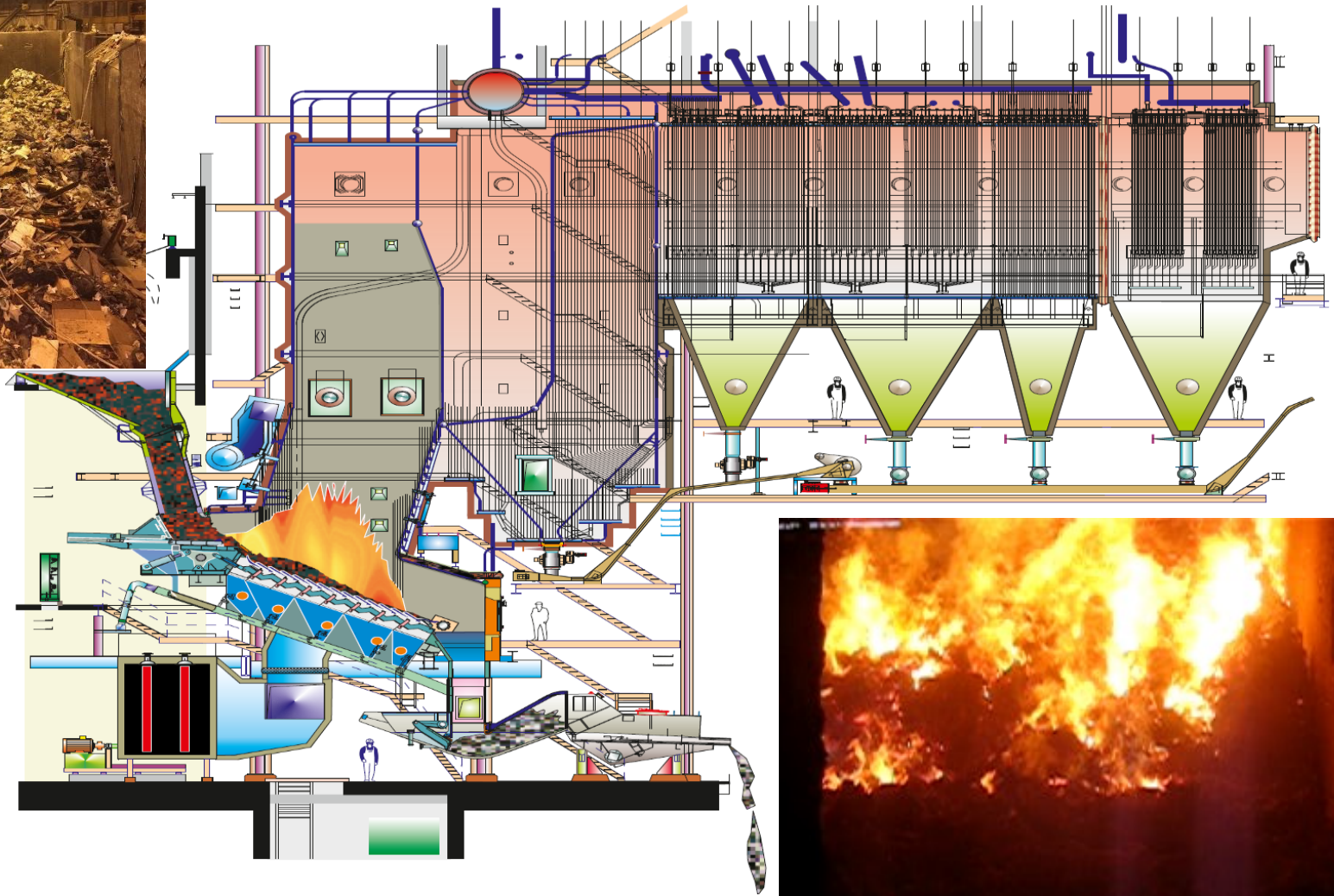
Stoker Grate Incineration System



Circulated Fluidized Bed (CFB) Incineration System



Stoker Grate



Major Manufacturers and Furnace Types in China

Foreign ones

- **Japan Mitsubishi Ltd** (Mitsubishi –Martin reverse acting grate)
 - 1988, Shenzhen, 150t/day
 - 2004, Hangzhou, 450t/day
 - 2015, Dalian, 1000t/day
- **Germany Martin** (horizontal reciprocating, inclined back stepping reciprocating)
 - 2005, Chongqing Tongxing, 1200t/day
 - 2012, Kunming Konggang, 1000t/day
 - 2013, Dongying, 600d/day
- **Japan Takuma Co. Ltd** (Sn type grate)
 - 2005, Tianjin, 1200t/day
 - 2008, Beijing, 1600t/day
- **Belgium Sigs Co.** (SHA multi-stage grate)
 - 2006, Suzhou, 1000t/day
 - 2008, Changzhou, 800t/day
 - 2012, Shenzhen, 3000t/day

From technology **import to absorption**

Major Manufacturers and Furnace Types in China

Foreign ones

- **US Detroit Co. (Ladder mechanical grate)**
 - 2000, Zhuhai, 600t/day
- **Germany Noell-Kerz (Forward stepped grate)**
 - 2002, Ningbo, 1050t/day
- **Germany stanmilar Co. (To-and-fro mechanical grate)**
 - 2005, Shanghai Jiangqiao, 1500t/day
- **France Alstorm Company (CITY2000 Inclined to-and-fro ladder mechanical grate)**
 - 2002, Shanghai Yuqiao, 1000t/day
- **Switzerland VonRoll Co. (R-10540 type grate)**
 - 2007, Xiamen, 400t/day
- **Japan Hitachi Shipbuilding Co. (reciprocating grate with vertical dial fire)**
 - 2011, Haikou, 1200t/day
 - 2012, Ningde, 600t/day

Major **Domestic** Manufacturers and Furnace Types

Import => absorption => **independent** technology
=> **advanced** technology

- **China Tianying** (Forward reciprocating grate)
 - 2011, Liaoyuan, 800t/day
- **Sanfeng Environment** (Localized Martin grate, SITY 2000)
 - 2013, Dali, 600t/day
- **Everbright Environment** (Forward reciprocating grate)
 - 2016, Suzhou Wujiang, 1500t/day
- **SUS Environment** (Three-stage forward reciprocating grate)
 - 2017, Ningbo, 2250t/day
- **More than 15 in total**

Development of Grate Incinerator Plant in China

Yuqiao WtE Plant
Shanghai
1000 t/d
4.0MPa/400°C

Huangshi WtE Plant
Hubei
1200 t/d
6.4MPa/485°C

Jiangyin WtE Plant
Jiangsu, 2200 t/d
6.4MPa/450°C/430°C



Qingshui River WtE Plant
Shenzhen, 300 t/d
1.8MPa/350°C

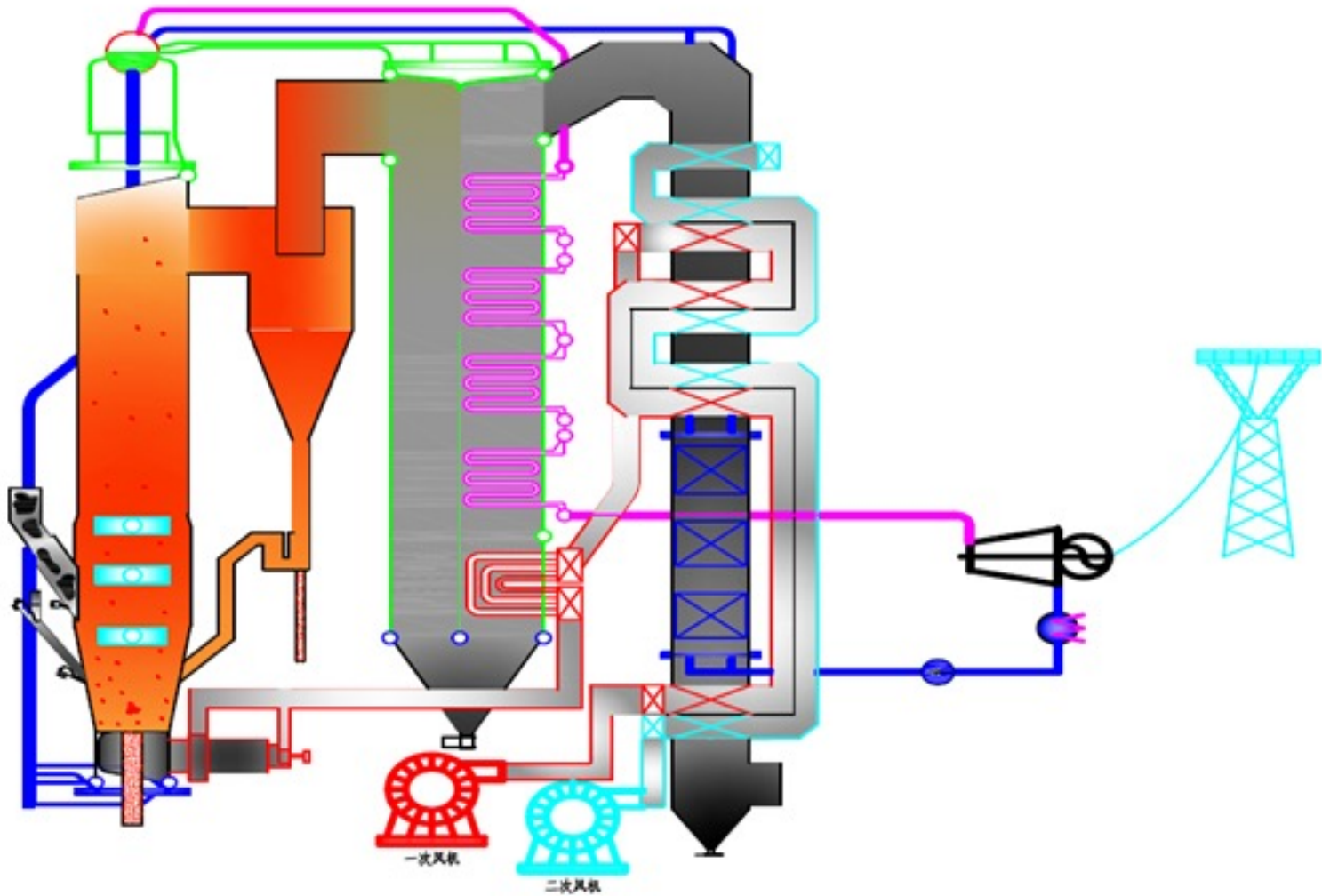
Likeng WtE Plant
Guangzhou
1040 t/d
6.4MPa/450°C

Langfang WtE Plant
Hebei
1800 t/d
6.4MPa/485°C

Sanhe WtE Plant
Hebei
2000t/d
13.5MPa/450°C

- **Higher steam parameters**
- **Bigger capacity (max. 1000t/d/unit; 6000 t/d/ plant)**
- **Incineration => good incineration => clean emission**

Circulating Fluidized Bed (CFB) Incinerator



Zhejiang Uni. CFB

Challenges for MSWI in China

Complex sources and various compositions

(significantly different from fossil fuels)

- *Different density* - *Multi-composition*
- *Different size* - *Multi-pollution source*
- *High moisture* - *Different ignition temperature*
- *Low heat value* - *High Temperature corrosion*



Development of CFB Incineration Technology



Successful application and industrial demonstration of laboratory technology with independent IPR

Industrial demonstration
1998 ~ 2000



Manufacture of equipment and commercial demonstration

Commercial demonstration
2001 ~ 2003



Improvement and perfection of the incineration technology and operations management

Improvement and perfection
2004 ~ 2008

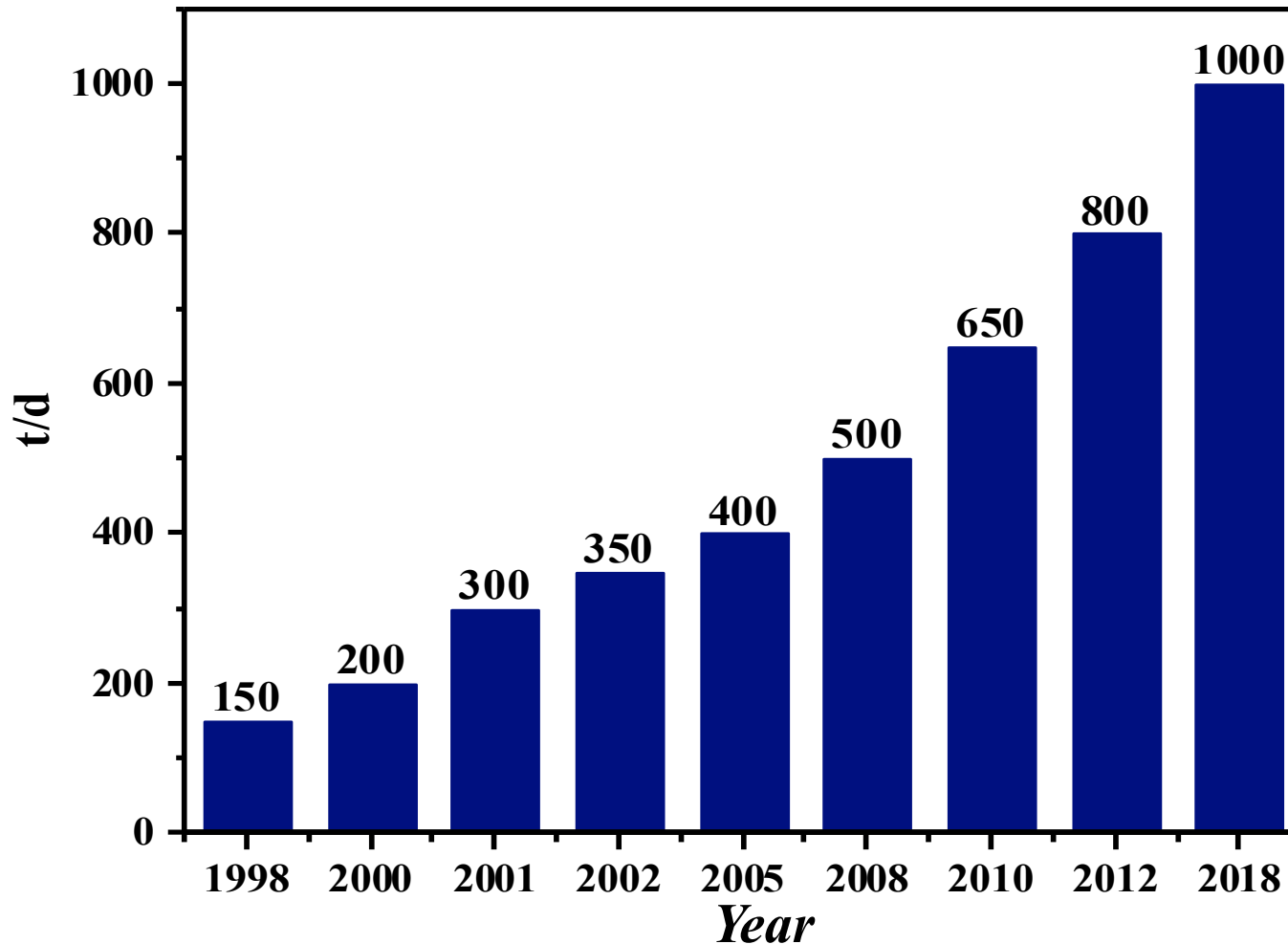


Promotion of the mature integrated technology and successful experience of operations management

Maturity and promotion
2009 ~ to date

Development of CFB Incineration

Capacity of a CFB unit



Key Parts of CFB Incinerator (System)



Waste Crusher

- unique auxiliary equipment of CFB incinerator
- the waste is crushed to adapt to the conditions for the furnace.

Cyclone Separator

- Separating the flue gas and unburned-out particles
- the unburned-out particles is sent to the furnace for further combustion

Distributor

- waste and bed material pass through and distribute evenly across the furnace.

Development to CFBI – Waste Pretreatment



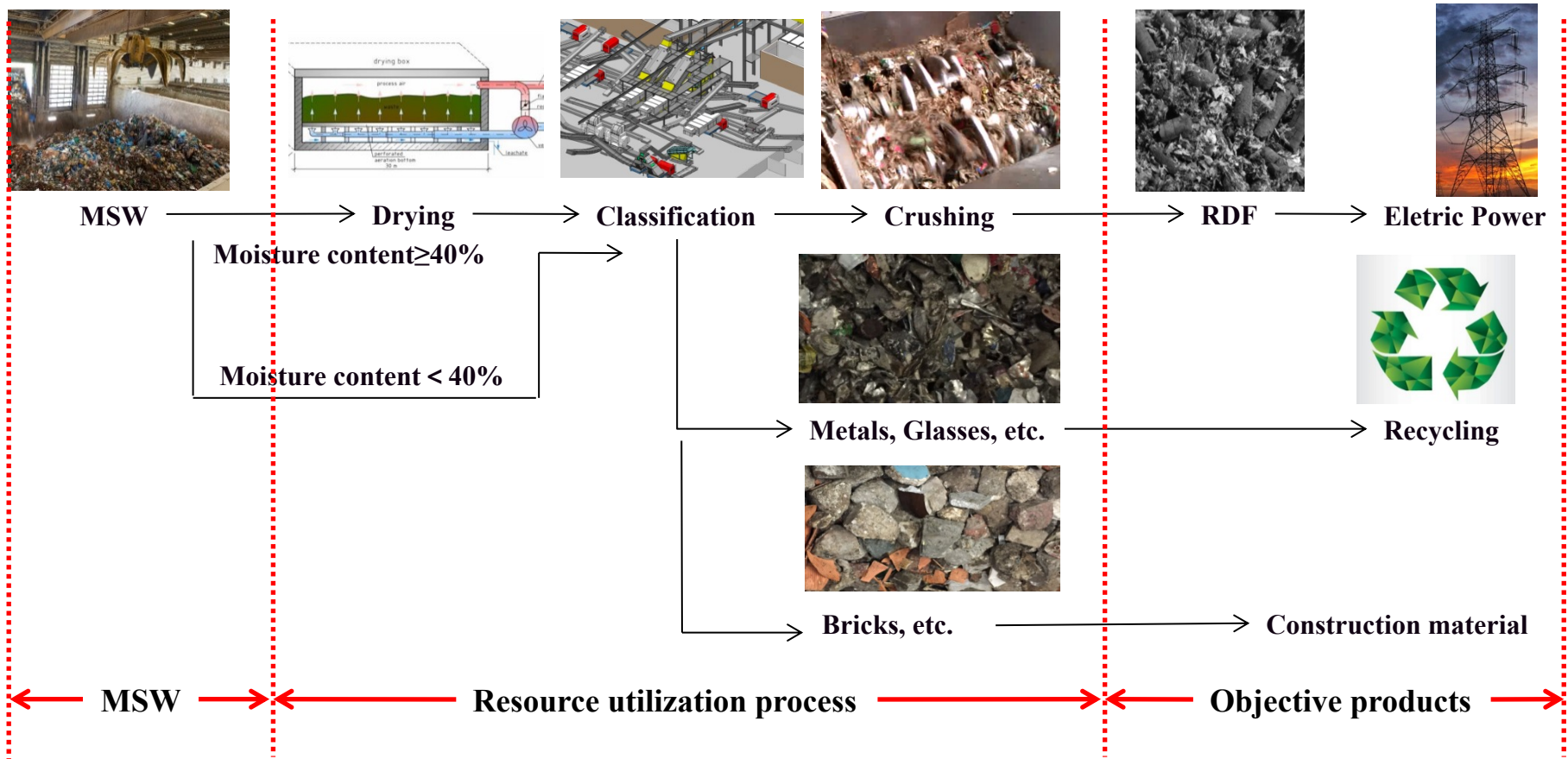
After waste treatment:

- The **combustion and temperature stability is greatly enhanced, heat value of waste is greatly enhanced.**
- Waste feeding stable, by this way the chamber pressure fluctuation range is reduced.
- After waste pretreatment, daily waste incineration increased by 15%, slag decrease of 18%, fly ash decrease of 11%.



Case Study: Linzi CFB Incineration Plant

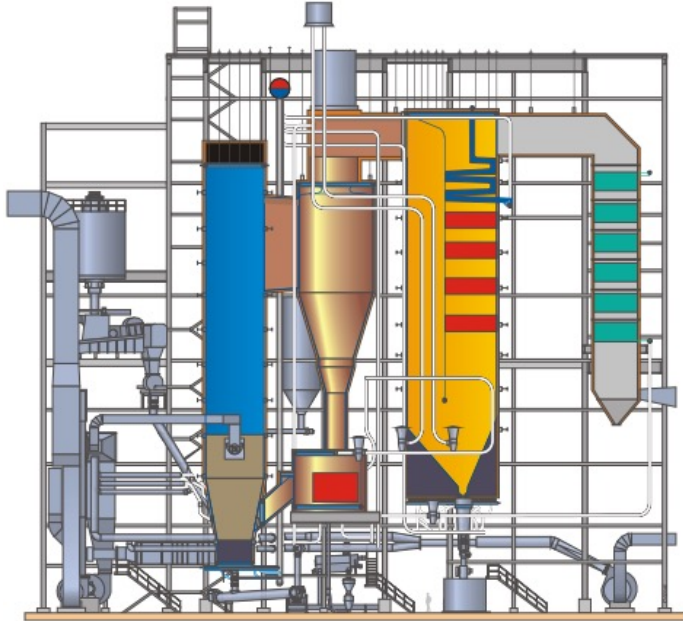
Mechanical-Biological-Treatment (MBT) technology of MSW



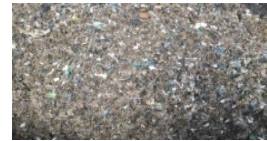
Introducing MBT technology to improve the combustion problems caused by complex components, different sizes and high moisture content of domestic waste.

Linzi Incineration Plant, China

CFB incineration technology with large capacity and high parameter



Co-combusting:



MSW: 0.73 Mt/year
Ratio: 78%



Agricultural & Wood Wastes:
~ 0.10 Mt/year
Ratio: 11%

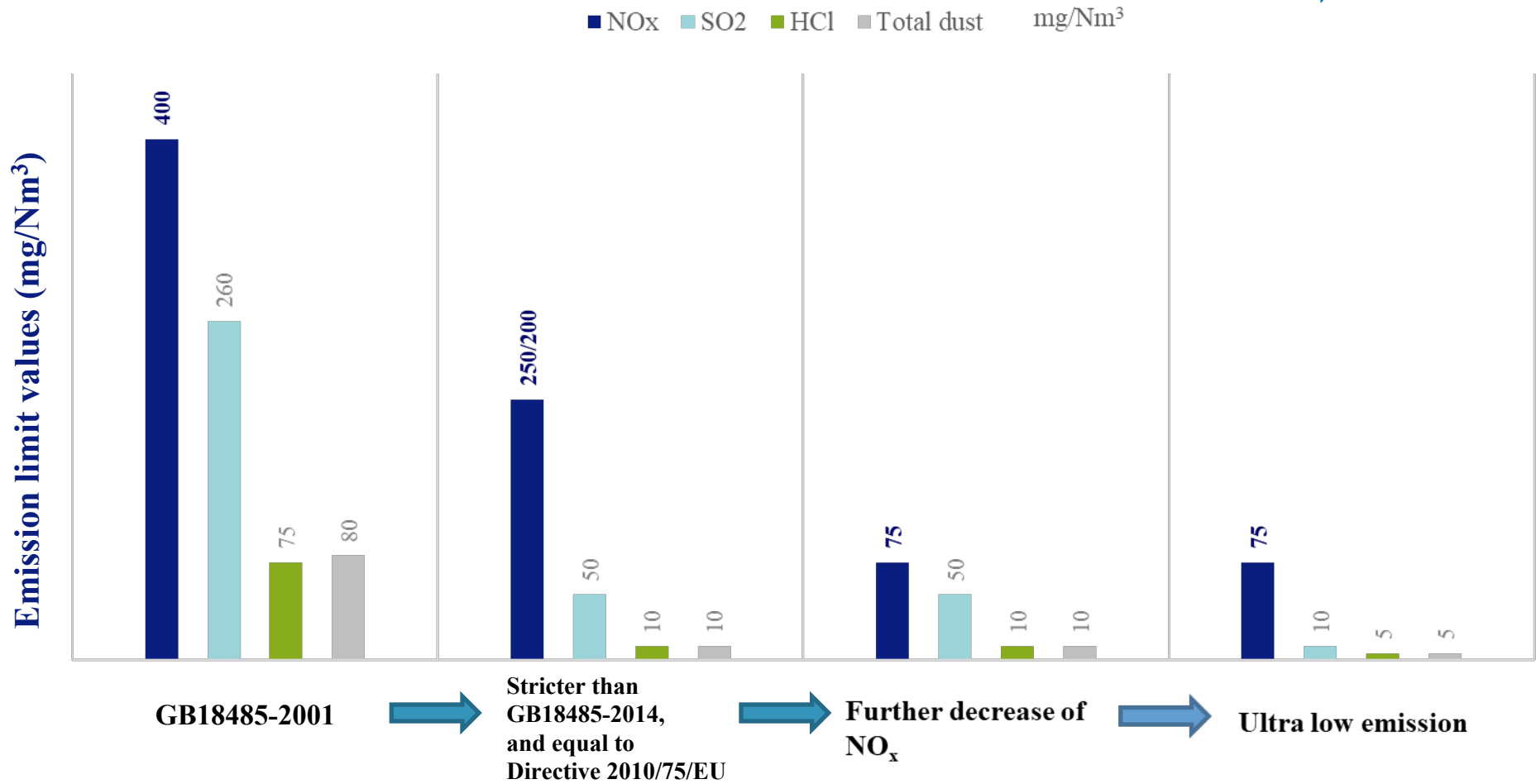


Industry waste: 0.10 Mt/year
Ratio: 11%

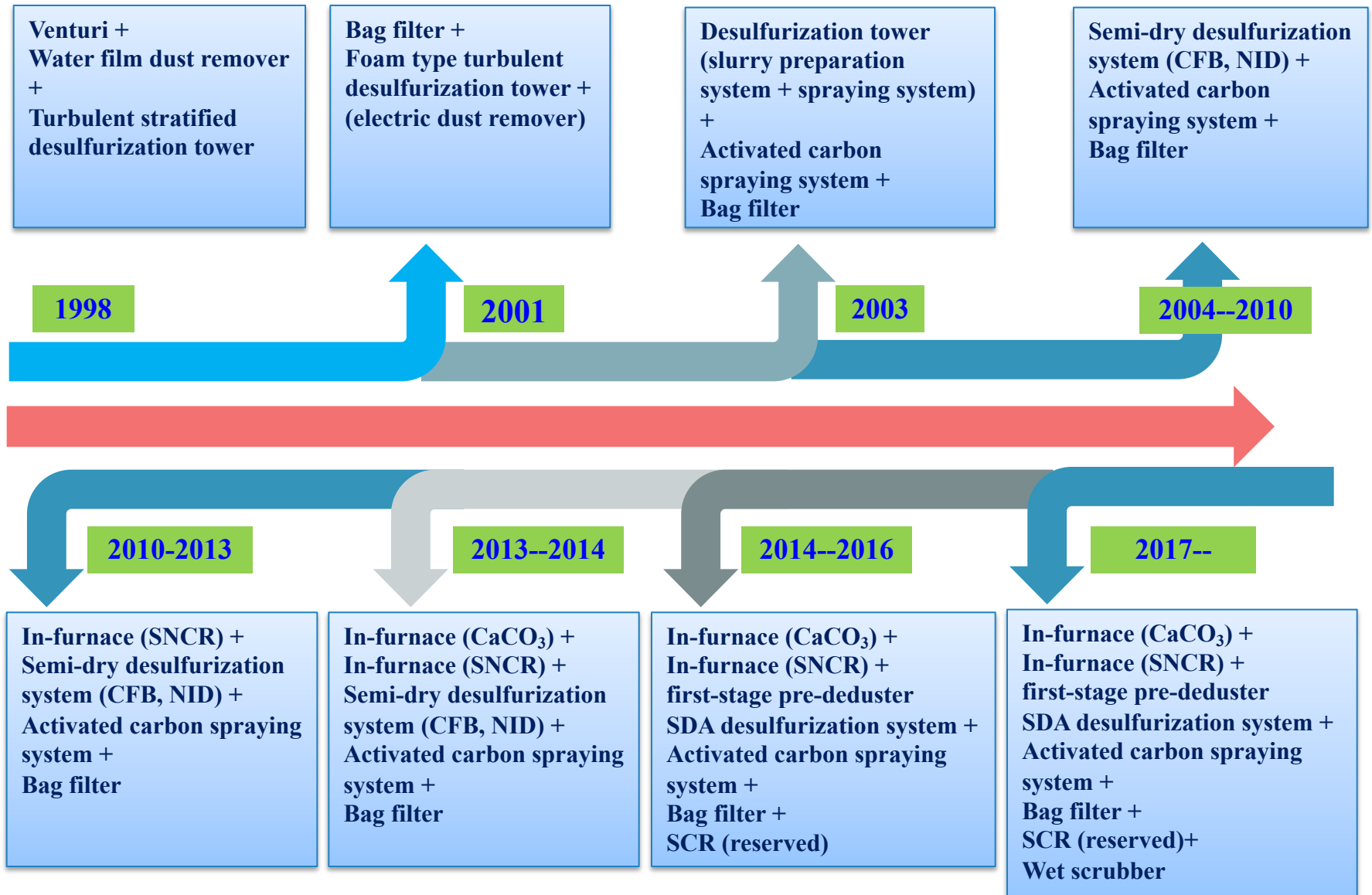
- **Largest incineration capacity of single unit in China: 1000 t/d.**
- **Highest main steam temperature in China: 520 °C/79 bar (the highest).**
- **Improving parameters and efficiency and reducing corrosion effects through optimizing layout.**

More Stringent Emission Standards

More Stringent Standards on Air Pollutants Emission



Development of Air Pollution Control Devices System



Waste Incineration Technology Situation in China



- There are **848 waste incineration plants** in operation, involving **~1850 incinerators**.
- The number of **grate furnaces** accounts for **more than 91%**, and less than 9% of the furnace types are circulating fluidized bed(CFB).
- The total treatment capacity of **grate furnace** exceeds **830,000 t/d**, while the capacity of CFB is only about **90,000t/d**.

Modern WtE Plants in China: Other Representative Projects



Ningbo, 2250 t/d



Linyi, 2000 t/d

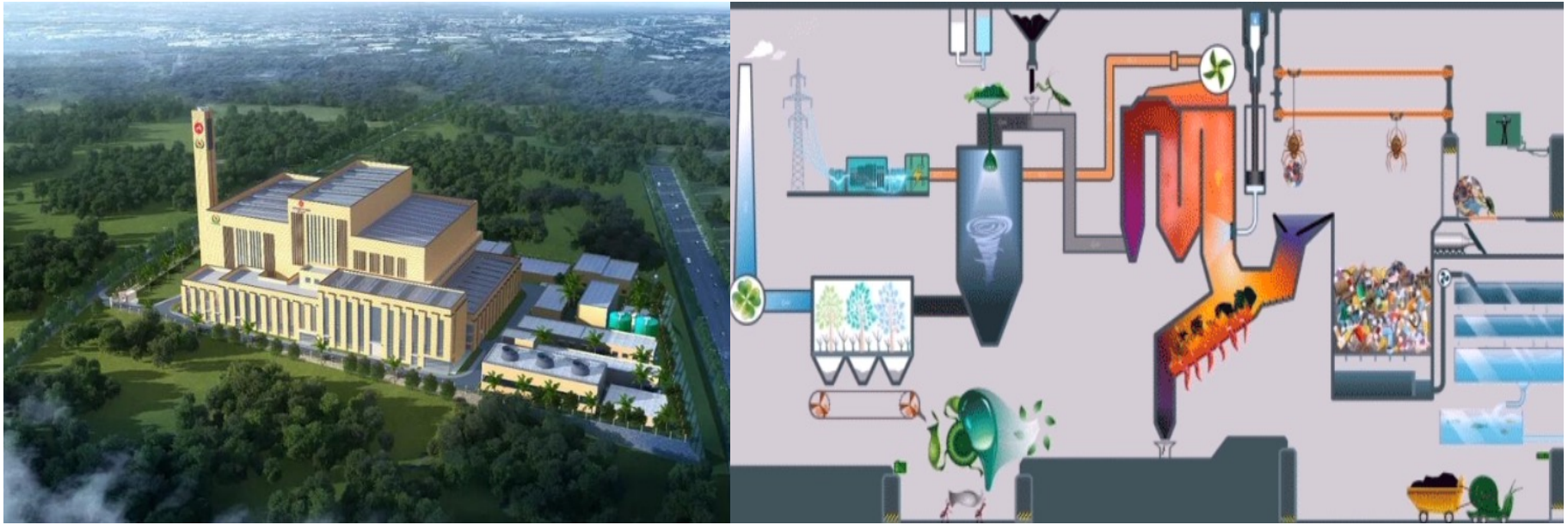


Chongqing, 4500 t/d



Lantian, 2250 t/d

Modern WtE Plants in China: Located in Hanoi, Vietnam



- The project is the product of cooperation between Chongqing Sanfeng Covanta Environmental Co., Ltd.(China) and Serafin Green Environmental Technology Co., Ltd., Hanoi, Vietnam, which is **a new highlight of the eco-environmental industrial cooperation between China and Vietnam.**
- The project is equipped with **three 615-ton/day three-peak reverse mechanical grate furnaces, and the total installed capacity of two turbo-generator sets is 37.5MW.**
- The flue gas purification system adopts the combined process of "in-furnace SNCR + semi-dry spray tower + activated carbon adsorption + bag dust collector", and **the flue gas emission index meets the current EU directives.**
- The project is planned to be completed and put into operation **in February 2024**, when it will effectively improve the urban environment of Hanoi and **help the local ecological civilization construction.**

Waste incineration in China

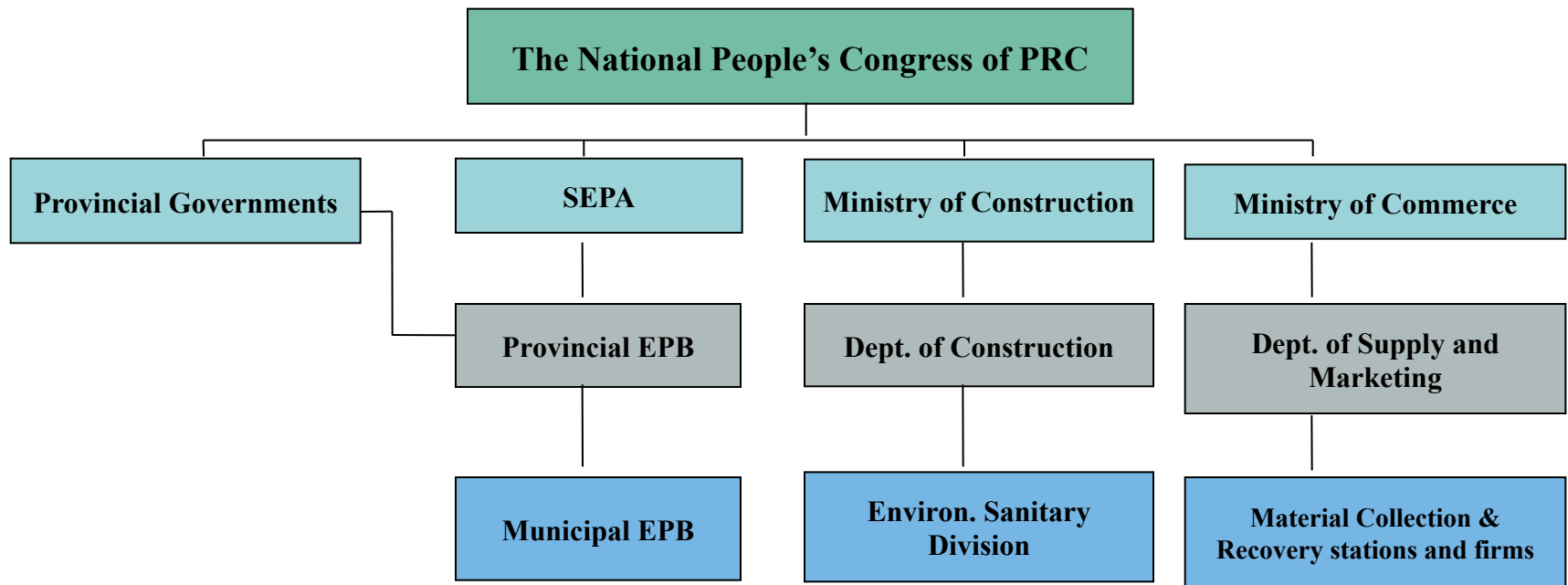
Introduction

- **The People's Republic of China**
- **Overview of MSW in China**

Waste to Energy in China

- **History and technology of WtE**
- **Regulations and Policies**

Management System for MSW Management



Function and Responsibility

-Legislation and issuing standards for technologies and pollution control
-Supervision
-Pollution control
-Executing compulsory measures
-SW import/export

-Legislation
-Administration
-Planning & construction
-Technical Standards, R&D
-Training & Supervision
-Information collection

-Regulation on material collection & recovery
-Material collection & recovery

Law System for MSW Management

The National People's Congress Law

The Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Wastes was emended and awarded at the 13th session of the Standing Committee of the Tenth National People's Congress of the People's Republic of China on December 29, 2004

The State Council Code

The Twelfth Five-Year Construction Plan for Urban domestic waste harmless treatment facilities was awarded by the State Council in 2012 (Decree No. 23 by the State Council)

SEPA/ Ministry of Construction Standard and decree

Notice on Opinions of Further Strengthening the Treatment of Municipal Solid Waste (Decree No. 9 by the Ministry of Construction(MOC))
Municipal Solid Waste management approach (Decree No. 27 by the MOC)
City vehicles cleansing management approach (Decree No. 47 by the MOC)
Municipal utility franchising management approach (Decree No. 126 by the MOC)
Provisions for the condition about the 15 administrative licensing belonging to the decision of the State Council (Decree No. 135 by the MOC)
Standard for Municipal Solid Waste Incineration Construction Project (Decree No. 213 by the MOC)
Management regulation for the ship garbage and solid waste pollution in the coastal waters of the Yangtze River (Decree No. 17 by the Ministry of communication ,MOC and the State Environmental Protection Agency)

Policy or criterion file

Technical policy for the MSW disposal and pollution prevention and treatment(No.120.2000)
Notice of the implementation of MSW disposal fee system for promoting the industrialization (No 872 by the State Development Planning Commission)
Opinion for the promotion of urban sewage and MSW disposal industrialization development by the State Development Planning Commission , MOC and SEPA (No.38, 2007)
Notice for the issuance of China urban and rural sanitation system (No.13, 2006)

Regulation System for MSW Management

Standard System

Standard for Emission :

Standard for Pollution Control on the Municipal Solid Waste Incineration (GB18485-2014)、
(GB18485-2014/XG1-2019)

Standard for Construction:

Construction standard for MSW sanitary landfill project
(Standard of 101 [2001])
Construction standard for MSW composting project
(Standard of 213 [2001])
Construction standard for MSW incineration project
(Standard of 213 [2001])
Ground guideline for pretreatment project of MSW disposal and water supply and sewage treatment
(Standard of [2005] 157)
Notice of the State Council on the Reform of the investment system
(Standard of [2002] 1591)

Standard for Products :

Standard for the classification and the pollution emission of MSW
(CJ/T3033-1996)
Standard for the city appearance
(CJ/T12-1999)
Environmental requirements for MSW landfill
(GB/T18772-2002)
MSW incineration boilers
(GB/T18750-2002)
Classification symbol for MSW
(GB/T19095-2003)
Administrative provisions on renewable energy power Generation (Standard of [2006] 13)

Standard for Technology :

Technical regulations for operating maintenance and security of MSW composting plant (CJJ/T86-2000)
Technical code for MSW incineration plant (CJJ90-2002)
Layout code for city sanitation facilities (GB50337-2003)
Technical code for sanitary landfill of MSW(CJJ17-2004)
Standard for MSW classification and evaluation(CJJ/T102-2004)
Technical guideline on Municipal Solid Waste Incineration (RISN-TG009-2010)
Technical guideline on Municipal Solid Waste fluidized bed incineration (RISN-TG016-2014)

Higher Standards and Cleaner Incineration

Pollutants (daily average values)	China GB 18485-2001	China GB 18485-2014	EU 2010/76/EC	Germany 17 th BImSchV
PM (mg/m ³)	80	20	10	10
HCl (mg/m ³)	75	50	10	10
HF (mg/m ³)	-	-	1	1
SO _X (mg/m ³)	260	80	50	50
NO _X (mg/m ³)	400	250	200	200
CO (mg/m ³)	150	80	50	50
TOC (mg/m ³)	-	-	10	10
Hg (mg/m ³)	0.2	0.05	0.05	0.03
Cd + Tl (mg/m ³)	0.1	0.1	0.05	0.05
Pb (mg/m ³)	1.6	< 1.0	≤ 0.5	≤ 0.5
Other metals (mg/m ³)	-	< 1.0	≤ 0.5	≤ 0.5
Dioxins (ng TEQ/m ³)	1.0	0.1	0.1	0.1
Blackness (Ringelman level)	1	1	-	-

Regulations & Policies

The development stages of policies

In the past 30 years, the national and local governments have issued **more than 100 policies** related to MSW incineration for power generation.

➤ **Preliminary exploration stage (before 2000):**

- China began to encourage the use of waste incineration treatment with policy support. There are only 4 important policies and almost no technical standards.

NO	Name	Time
1	Notice of Suggestions on Solving the Problem of Urban Solid Waste in China	[1992] NO.39
2	Measures for the Recognition and Administration of Power Plants (Units) for Resources Utilization	[2001] NO.198
3	National Catalogue of Equipment (Products) of Environmental Protection Industry Encouraged at Present (First Batch)	[2000] NO.159
4	Policies on the technologies of municipal solid waste disposal and pollution prevention and control	[2000] NO.120

Regulations & Policies

➤ **Further improvement stage (2001-2010):**

- The government supported much on electricity price subsidies, and 5 finance and taxation policies and 2 pollution control and supervision policies were enacted.
- The "environmental assessment approval" was delegated to the local governments, which has greatly promoted the development of the industry.

NO	Name	Time
1	Notice on VAT Policies Concerning the Comprehensive Utilization of Some Resources and other Products	[2001] NO.198
2	Trial Measures for the Management of Price and Cost Allocation of Renewable Energy Power Generation	[2006] NO.7
3	Notice on Strengthening the Management of Environmental Impact Assessment for Biomass Power Generation Projects	[2006] NO.82
4	Notice of Ministry of Finance and State Administration of Taxation on Value-added Tax Policy of Comprehensive Utilization of Resources and Other Products	[2008] NO.156
5	Preferential Directory of Enterprise Income Tax for Environmental Protection, Energy Conservation and Water-saving Projects (Trial)	[2009] NO.166

Regulations & Policies

➤ **Rapid development stage (since 2011):**

- The government **explicitly promoted MSW incineration** and increased support for the research and development of **MSW treatment technologies**.
- The government **support more on electricity price subsidies**, and PPP (Public-Private Partnership) was also encourage to establish and promote.
- The government promoted the integration of waste treatment technology and equipment, **focusing on the development of large waste incineration facilities**, etc.
- The government enacted detailed regulations on furnace temperature control and flue gas pollutant emission supervision in the operation of MSW incineration project.

National Plan & Policies

The 14th Five-Year Plan (2021-2025) at the development of municipal solid waste classification and treatment facilities

The specific goals:

➤ **WtE rate of MSW:**

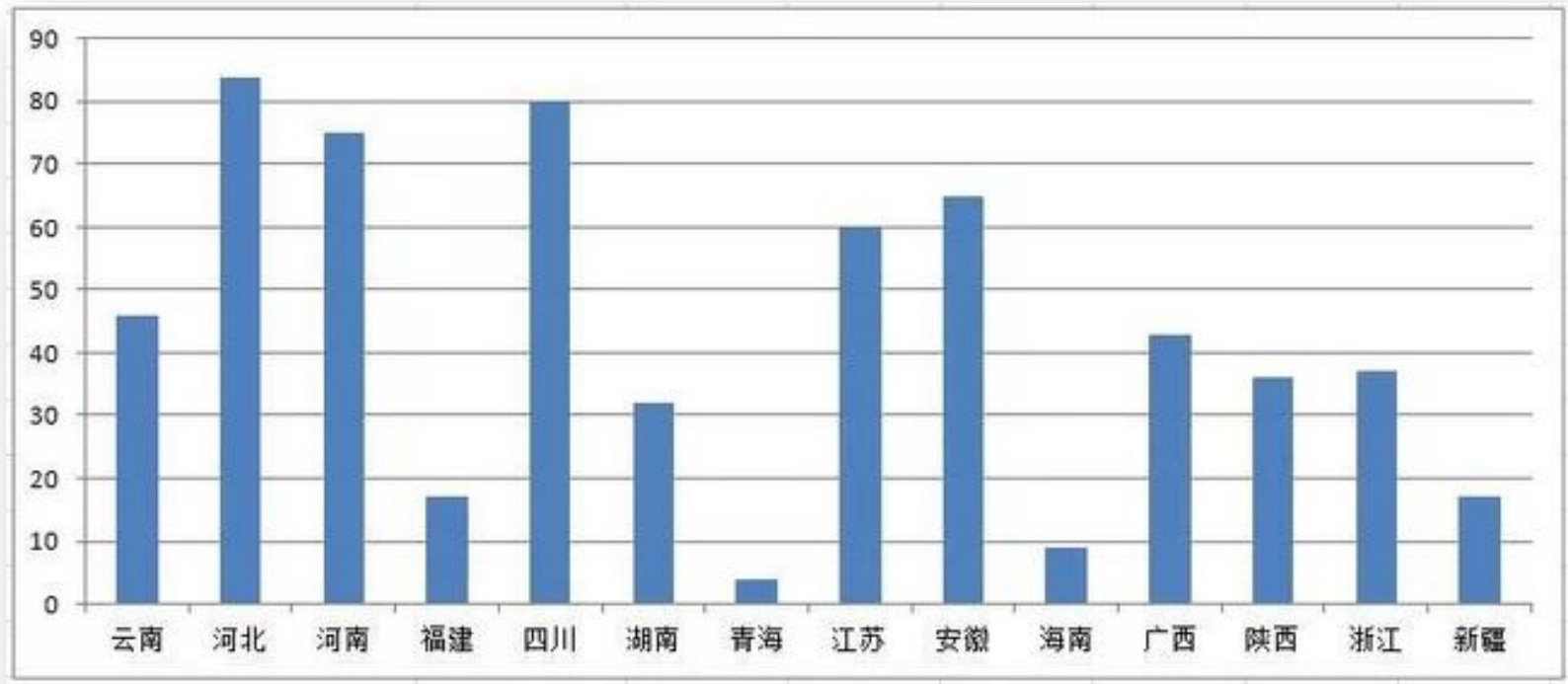
By the end of 2025, the WtE rate will reach about **60%**, **the incineration capacity will reach 0.80 Mt/day.**

➤ **The classification, collection and transportation capacity of MSW:**

By the end of 2025, **the capacity will reach about 0.70 Mt/day**, basically meeting the demand of cities at the prefectural level and above for MSW classification, transportation and disposal.

Planned New Plants by 2030

Planned numbers (about 500) of new WtE plants in selected provinces of China by 2030



An increase of incineration rate in China can still be foreseen in the near future.

Main Contents

Municipal solid waste generation, characteristics and disposal

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Experiences of waste incineration application in China

1. Step by Step Development of WTE

➤ **Development of MSW incineration industry**

From nonexistence to existence, from small to large, from a headlong participation to an orderly development.

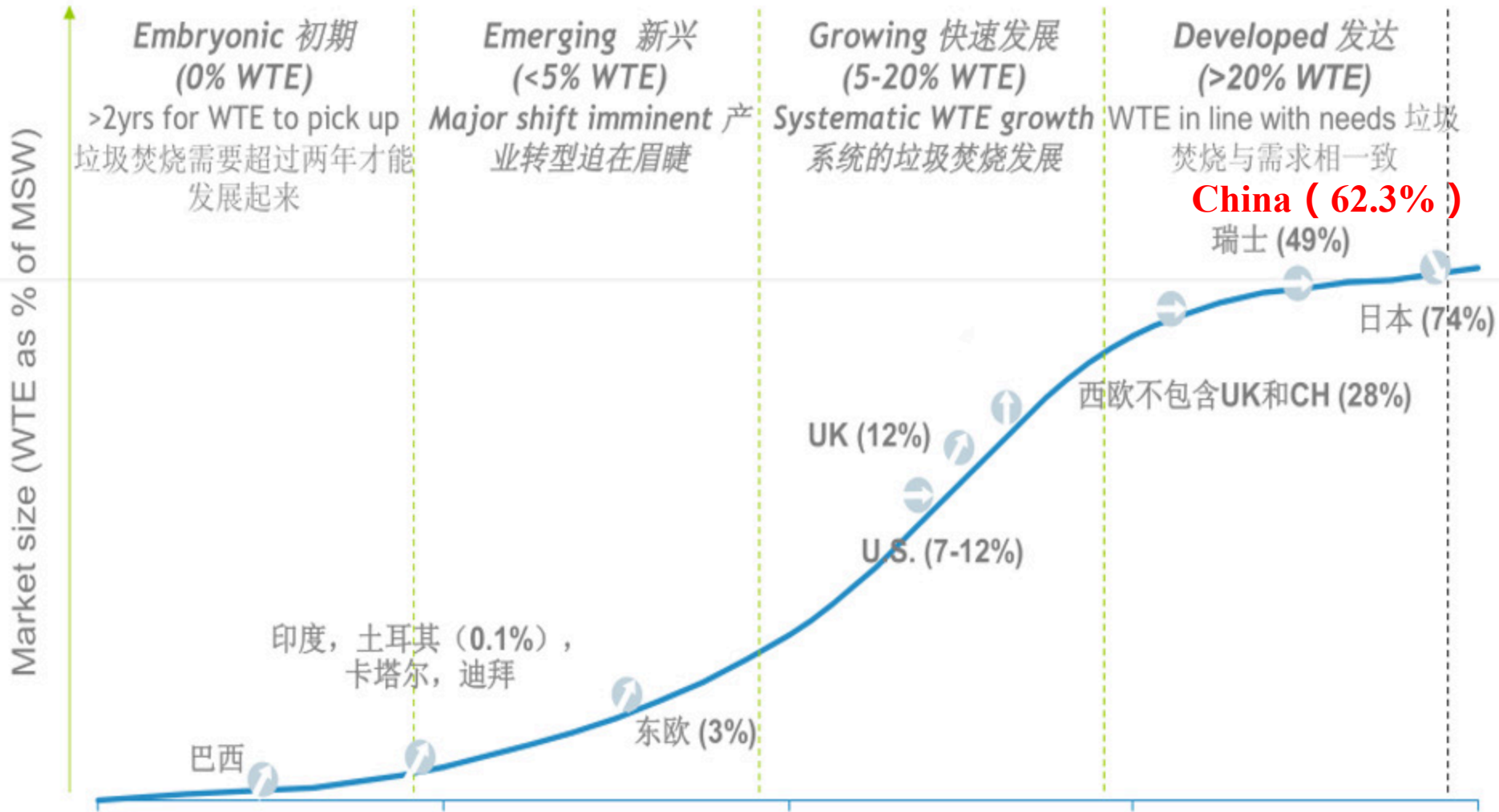
➤ **Development of MSW incineration technology**

From exploration to gradual maturity, and then to a world-class level (even advanced world level).

➤ **Pollution control**

From a simple control to a standardized management, and then to a strict adherence to standards.

International experience



Source: EUROSTAT, Waste Statistics 2010, 4/2012; Ecoprog, Waste to Energy, 4/2010; SEG 8/2011, EPA MSW Generation, Recycling & Disposal 2010, Biocycle/Columbia Univ. EEC State of Garbage in America 2010

Continuous Emission Monitoring Requirements



寻控检查
炉温及烟气排放在线检测

项目	1#线	2#线	国标值
炉温℃	1225.2	1253.0	1100
氯化氢HCL	2.1	63.4	70
二氧化硫SO ₂	4.3	257.5	300
一氧化碳CO	1.8	67.8	80
氮氧化物NO _x	7.4	202.6	500
烟尘DUST	3.4	41.8	80
运行状态	正常	正常	

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The notice, which was published by the Ministry of Environmental Protection, requires :

- The automatic monitoring equipment in MSWI plants must be connected with the environmental protection department;
- Six monitoring indexes and the parameters of flue gas must be included in the networking system;
- One monitor screen must be installed;
- All the work must be finished **before 30th September, 2017.**

Pollutants



Pollutants					Parameters of flue gas				
CO	Particulate	SO ₂	NO _x	HCl	T	P	V	H ₂ O%	O ₂ %

Incinerator

If the monitoring data is faked, the person in charge of the MSWI plant should be prosecuted for **criminal responsibility.**

2. Collaboration of Industry-University-Research

Collaborating with the Industry-University-Research-Application institutes, **establish an innovative R&D and service platform.**

To **be an important source for independent innovation,** and improve the core competitiveness of the industry.



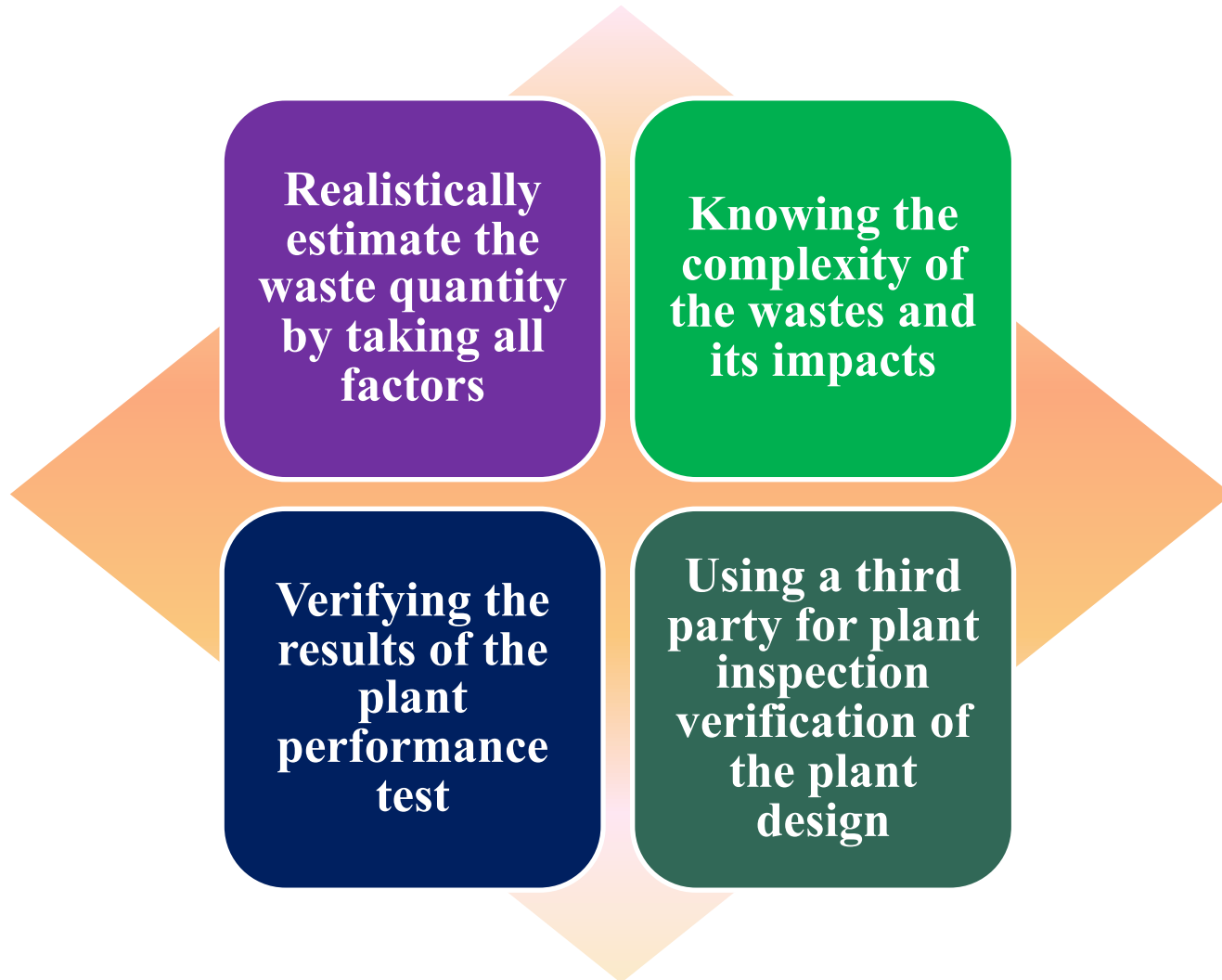
Research **on the common key technology, foresighted technology, and major equipment** that the industry needs urgently.

Develop innovative talents, technically leading the development of the waste to energy industry..

National Engineering Laboratory for Waste Incineration Technology and Equipment

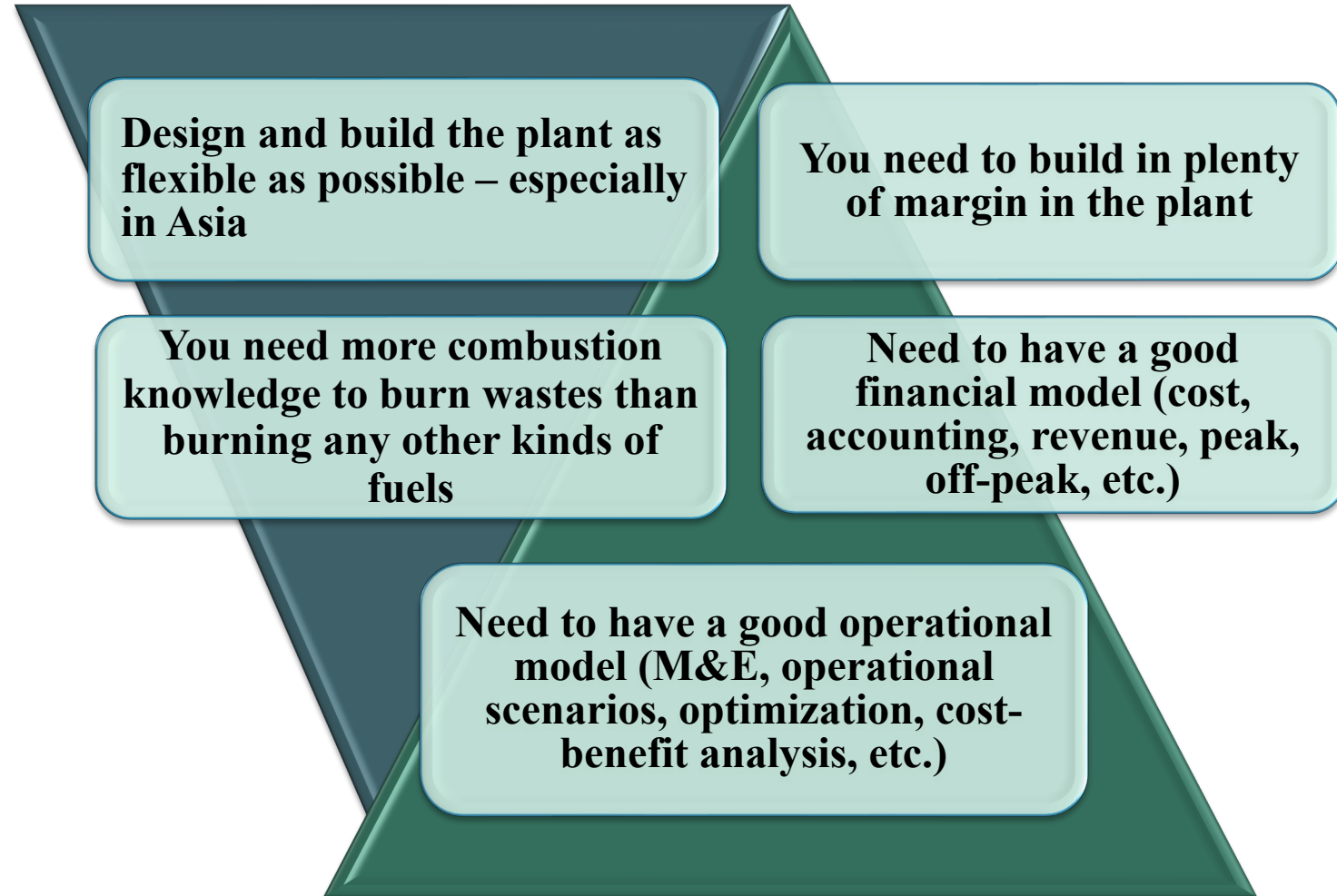
➤ **Know more about the property of waste.**

- Multiple tests are needed (not only the physical properties, but also the chemical properties).



➤ **Pay more efforts during design and construction stage**

- More technical knowledge, practical experience, operational model and financial model are needed



3. The development of MSWI towards clean incineration needs the support of Policy

- Waste classification would lead to the waste leachate reduction and operation stability improvement. The storage of waste in the waste bunker for 5 ~ 7 days, leads to the leaching out of waste leachate and to improve the calorific value of waste.
- The support of electricity price subsidy and waste disposal fee; other support from tax, policies, eg. exemption from income tax, education tax and so on
- The support of technology development from government science and technology projects.

3. The development of MSWI towards clean incineration needs the support of Policy

- Policy of environment protection
(Meeting emission standard)
- Policy of energy utilization
(Improving energy efficient)
- Policy of resource
(Material recycling)
- Policy of climate
(Low-carbon emission reduction)

Policies

Other
Related
Aspects

- Technology improving
- Standardized management
- Safety production
- Reasonable supervision

Municipal solid waste CLEAN incineration

4. The Responsibility for MSW Disposal Should Be Shared

- Multiple efforts and coordination are needed (not only the incineration enterprises).
- Effective measures (e.g., waste to energy subsidies) should be taken to meet the emission standards of pollutants (especially Dioxin).



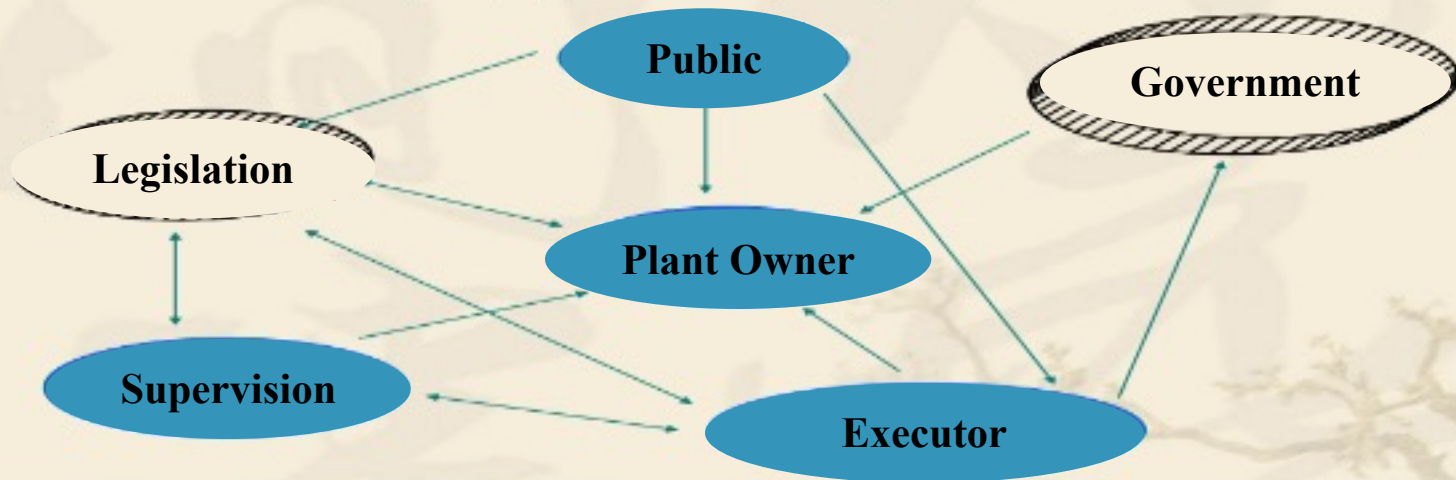
Separation of construction and operation?

5. Balance the Interests of Stakeholders

➤ Understand the public awareness and demands, and balance the interests of all sides

- MSW incineration plant is not simply a project of construction. Various aspects should be taken into consideration and special attention should be paid on public crisis management.

Relationship of Stakeholders



Outlook for the future

- We have achieved research cooperation with many foreign scientific research institutions and scholars from various countries, and **the achievements in cooperation are remarkable and satisfying.**
- With the help of ICCWtE platform and International Training Workshop of Waste to Energy, **we'd like to have more opportunities to help more countries especially along the Belt and Road to deal with increasingly severe waste disposal problems.** www.iccwte.org



[International Consultant Committee of Waste to Energy](http://www.iccwte.org)
(www.iccwte.org)



2016
Group photo of the opening ceremony,
the 1st WtE workshop



2017
Group photo of the opening ceremony,
the 2nd WtE workshop



2018
Group photo of the opening ceremony,
the 3rd WtE workshop



2019
Group photo of the opening ceremony,
the 4th WtE workshop



2021
Group photo of the opening ceremony,
the 5th WtE workshop



Photos of previous sessions of Internal Training
Workshop of WtE



THANK YOU !

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