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Waste-to-Energy Perspectives and Energy Conversion Efficiency Analysis in Korea

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Contents

1. Why Waste-to-Energy?

1. Why Waste-to-Energy?

Limited Natural Resources (Petroleum: 40years, Natural gas: 58years, Copper: 28years)

Exhaustion of Natural Resources

1/3 reduction in fresh water supply per capita in 25 years

Shortage of agricultural water

Water Shortage Problem

5-20% decline in global GDP per annum with the existing industrial structure (likely to cause the 2nd Great Depression)

Increasing GHG Emissions

50% increase in global energy consumption by 2030

Increase of Energy Consumption

1. Why Waste to Energy?

Solution???

Energy from Waste

Waste to Energy is a common solution for numerous environmental challenges

- Renewable energy
- Safe and economic waste disposal
- Reduce emission of greenhouse gas

ENVIRONMENT

- CO_2 Emission Reduction
- Emission Control
- Landfill Environmental Impact Reduction

ECONOMY

- Cost Reduction
- Profit Product
- New Industry

ENERGY

- Energy Recovery
- Alternative Energy Potential
- Improved Energy Efficiency

2. Waste Management in Korea

2. Waste Management status in Korea

Waste to Energy : Comprehensive Policy Establishment

- Waste to energy comprehensive policy (2008)
- Measure for waste resource and biomass energy (2008), action plan (2009)

Policies for promoting new & renewable energy (2010)

-New energy (3) : Fuel cell, Coal liquefaction and gasification, Hydrogen

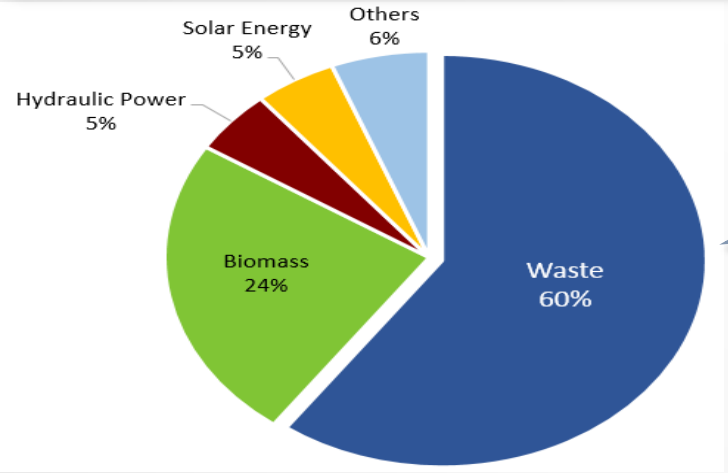
-Renewable (8) : Solar heat, Photovoltaic, Biomass, Wind power, Hydraulic-power, Geothermal heat, Tidal energy, Waste

- Policy for recycle economy society (2018)

-Establishment of resources recycle production

• Basic strategy • Expansion of EPR (51 items at 2018)

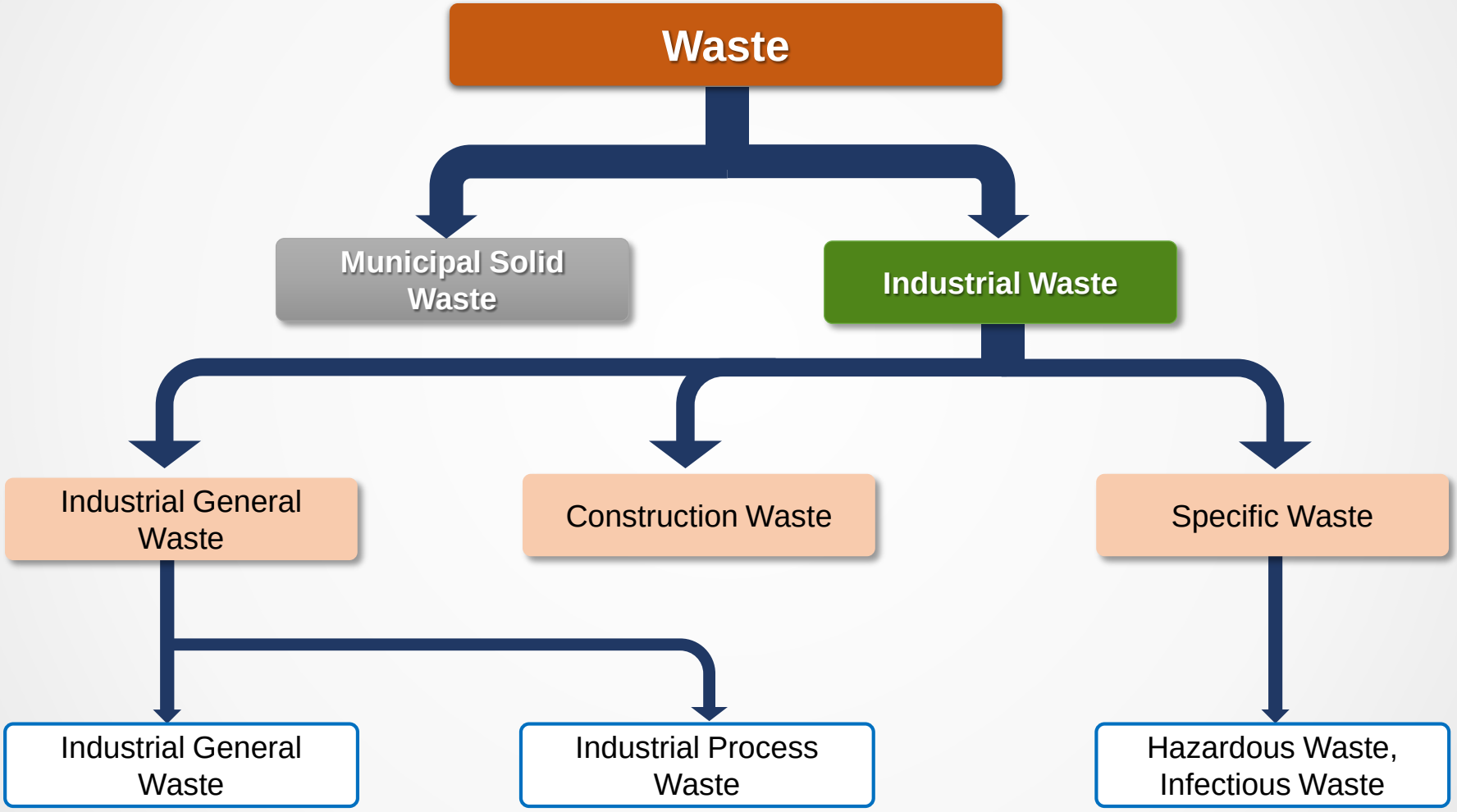
-Eco-friendly consumption



New/Renewable Energy Supply Resource in Korea (2014)

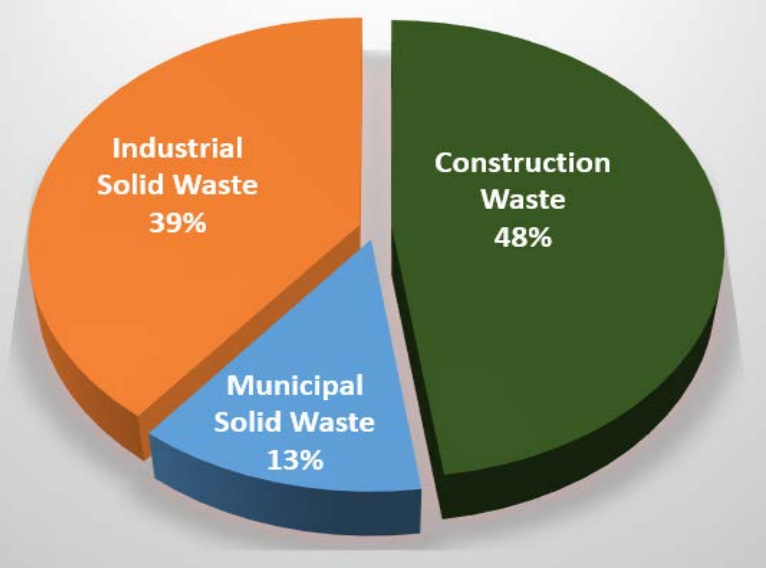
- Type of Energy from Waste
  - Oil Production from Pyrolysis process
  - Syngas Production from Gasification process
  - SRF Manufacture
  - Waste Heat Recovery from Incineration

2. Waste Management in Korea

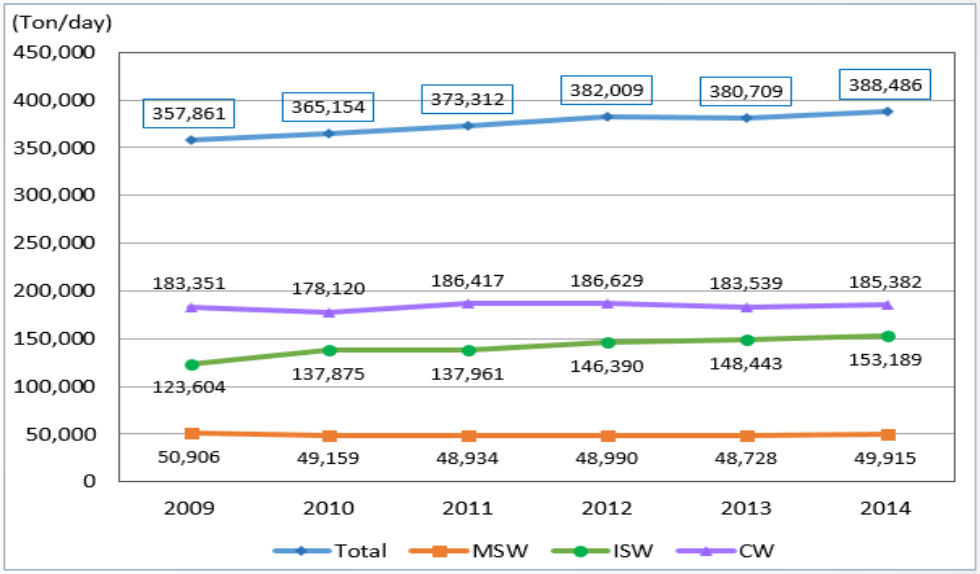


2. Waste Management in Korea

Waste Generation Status in Korea



Rate of Waste Generation by Type (2014)

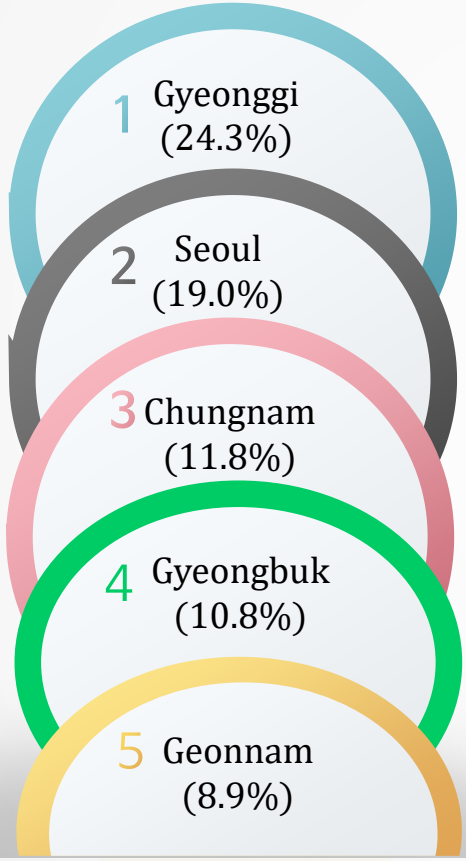


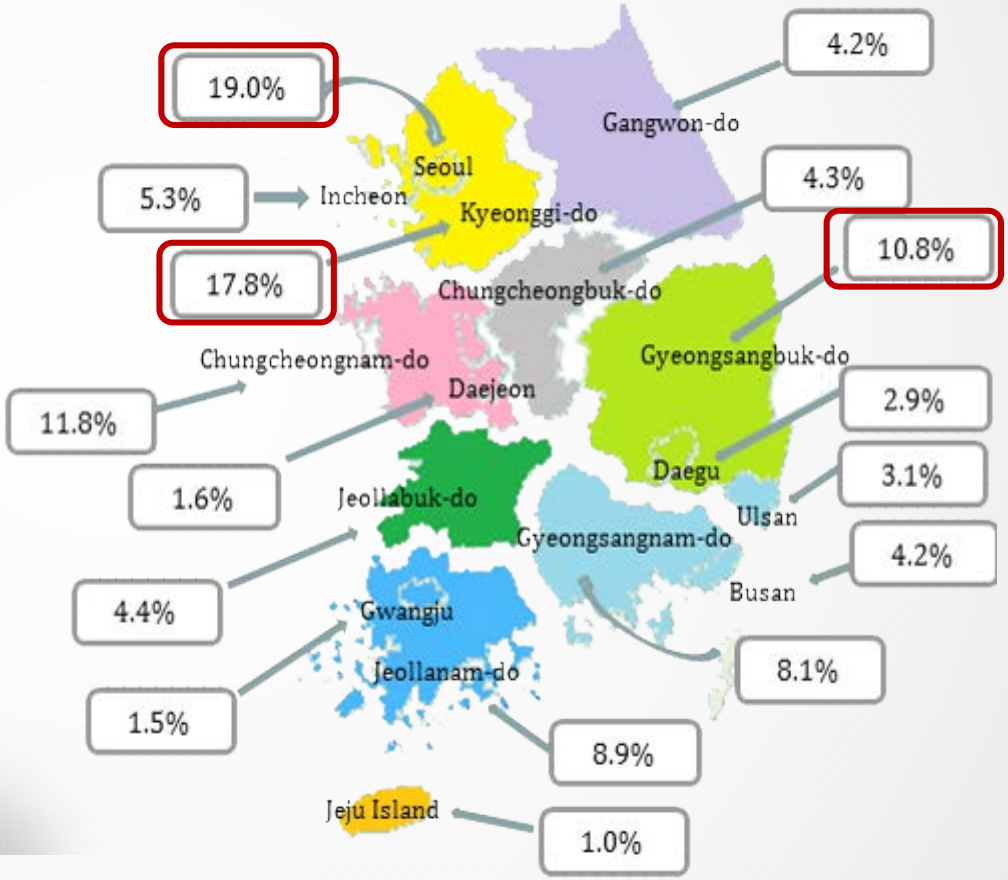
Waste Generation Trend in Korea

- Total Waste Generation in Korea has been sightly increasing for 5 years, and was 388,486 ton/day in 2014
- Municipal Solid Waste Generation tends to reduce while, Industrial Solid Waste Generation tends to increase

2. Waste Management in Korea

Waste Generation Status in Korea



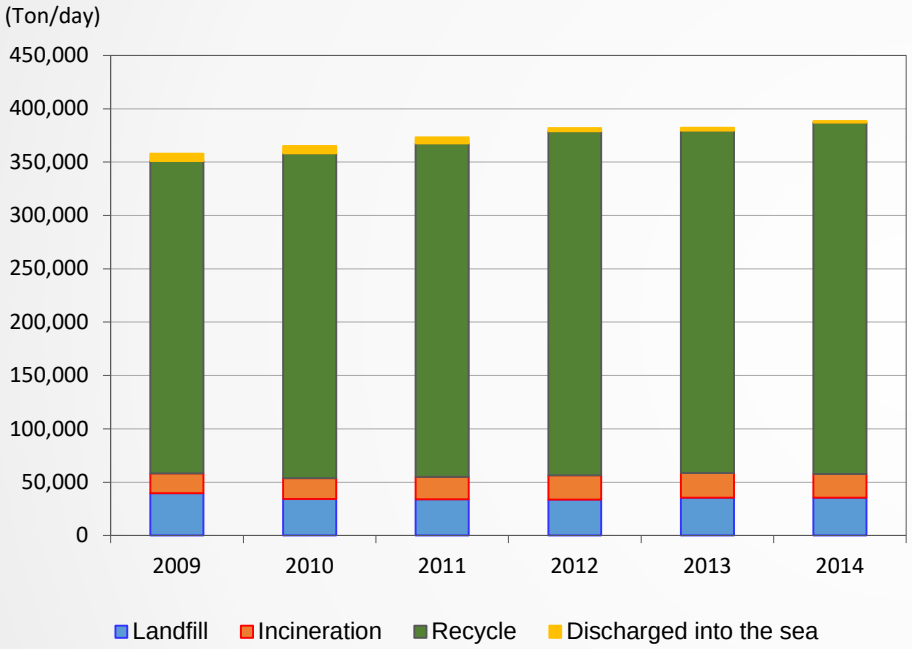


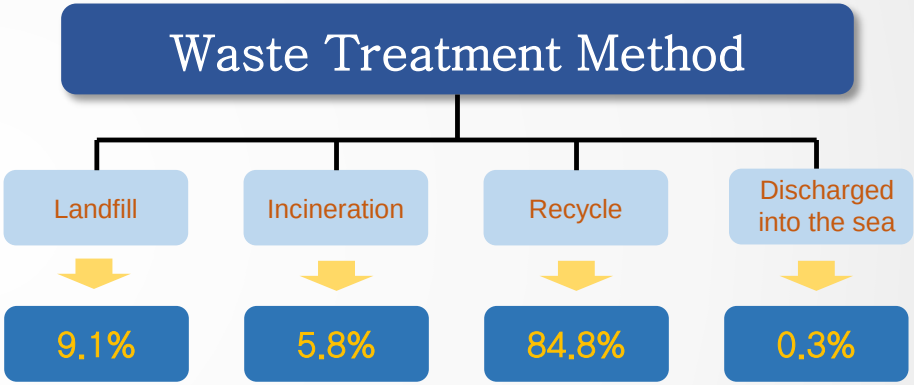
< Regional Waste Generation Rate >

Total of 5 cities & metropolis : 74.8%

2. Waste Management in Korea

Waste Treatment Status in Korea





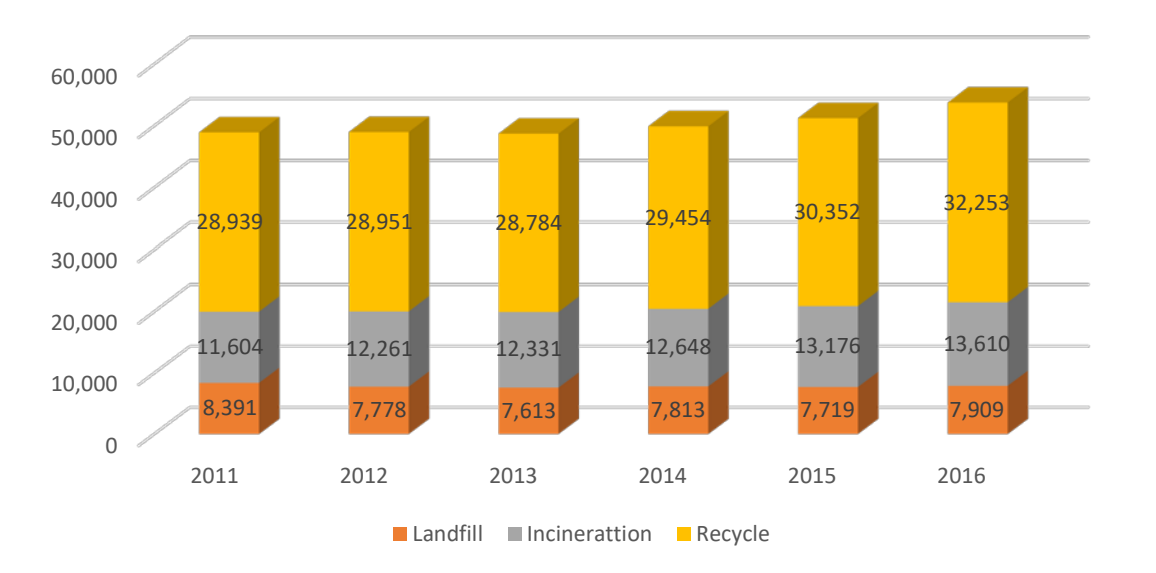
- Incineration and Recycle of Waste treatment have gradually increased for the past five years, until Discharged into the sea has gradually reduced
- Among total Waste generation in 2014, rate of Waste Recycling was 84.8%, Landfill was 9.1%, Incineration was 5.8% and Discharged into the sea was 0.3%

2. Waste Management in Korea

Waste Treatment Status in Korea

01 Municipal Solid Waste Treatment Situation

	2011		2012		2013		2014		2015		2016	
	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%
Total	48,934	100	48,990	100	48,728	100	49,915	100	51,247	100	53,772	100
Landfill	8,391	17.2	7,778	15.9	7,613	15.6	7,813	15.7	7,719	15.1	7,909	14.7
Incinerattion	11,604	23.7	12,261	25	12,331	25.3	12,648	25.3	13,176	25.7	13,610	25.3
Recycle	28,939	59.1	28,951	59.1	28,784	59.1	29,454	59	30,352	59.2	32,253	60

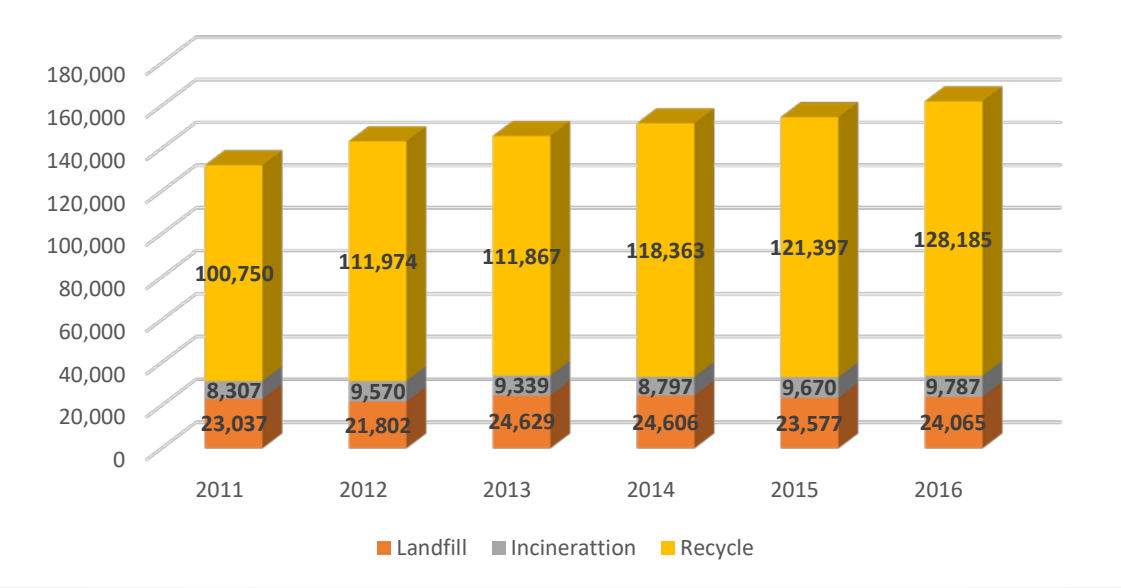


2. Waste Management in Korea

Waste Treatment Status in Korea

02 Industrial Waste Treatment Situation

	2011		2012		2013		2014		2015		2016	
	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%
Total	137,961	100	146,390	100	148,443	100	153,189	100	155,305	100	162,129	100
Landfill	23,037	16.7	21,802	14.9	24,629	16.6	24,606	16.1	23,577	15.2	24,065	14.8
Incinerattion	8,307	6	9,570	6.5	9,339	6.3	8,797	5.7	9,670	6.2	9,787	6
Recycle	100,750	73	111,974	76.5	111,867	75.4	118,363	77.3	121,397	78.2	128,185	79.1

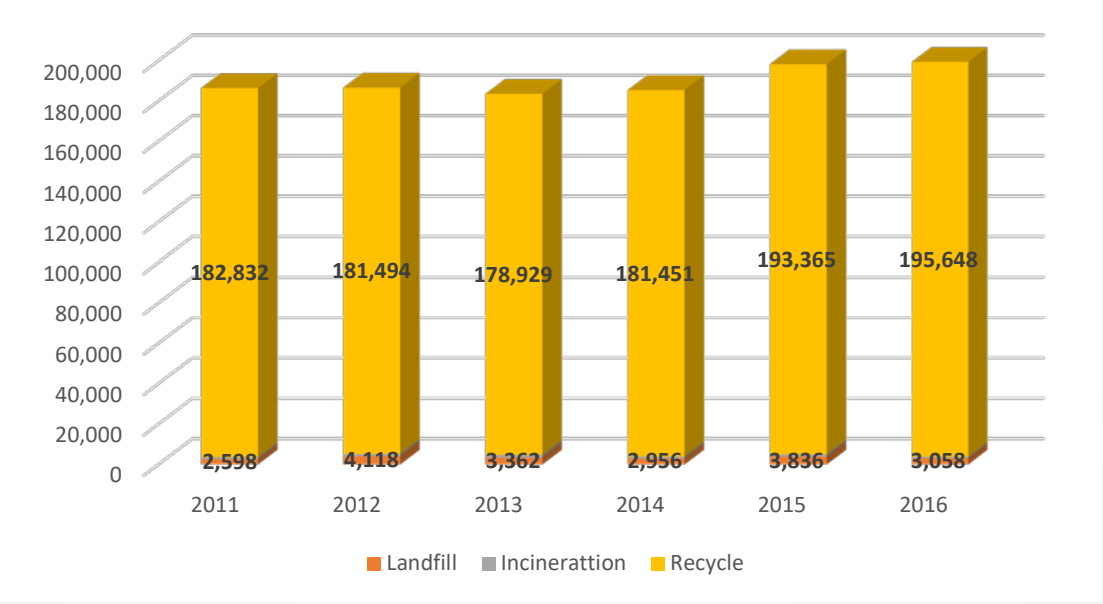


2. Waste Management in Korea

Waste Treatment Status in Korea

03 Construction Waste Treatment Situation

	2011		2012		2013		2014		2015		2016	
	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%	Ton/day	%
Total	186,417	100	186,629	100	183,538	100	185,382	100	198,260	100	199,444	100
Landfill	2,598	1.4	4,118	2.2	3,362	1.8	2,956	1.6	3,836	1.9	3,058	1.5
Incinerattion	987	0.5	1,017	0.5	1,247	0.7	976	0.5	1,059	0.5	738	0.4
Recycle	182,832	98.1	181,494	97.3	178,929	97.5	181,451	97.9	193,365	97.6	195,648	98.1



2. Waste Management in Korea

Waste Incinerator Experiences

Absolute Shortage of Landfill Sites

- Development of Incineration Technologies

Incinerator Facilities Installation

- - 14,791 facilities by the end of 1999 (recently reduced)
  - 14,059 (95%) under 100 kg/hr scale
  - 93 (0.6%) larger than 2 ton/hr scale, ~70% of total Incineration
- Industry : ~70% of total Incinerators

  Schools, Governments, Apartments, Landfill Sites, Public Facilities, etc

Problems of Incinerators

- Introduction of rapid small-scale Incinerators
  - Air Pollution problems
  - Opposition to new Facilities
- Ban on small-scale facilities (<25kg/hr) at 1999
  - Very stringent Emission Regulations
  - Recent reduction of New Incinerators Installation

2. Waste Management in Korea

Technological Aspect of Waste Incineration Management

Types of Incinerators

- Stoker Type - Main types for MSWs in Korea
- Fluidized Beds - Recently introduced for MSWs
  - Widely adopted to wastewater sludge ttreatment
- Rotary Kilns - Applied to industrial wastes
- Pyrolysis/Gasification/Melting - Adopted recently
  - ➢ Depending on waste compositions, Heat Values etc.

Municipal Wastes

- Stoker types - A lot of experiences
- Fluidized bed incinerators - Several cases in recent years
- Ash Melting systems

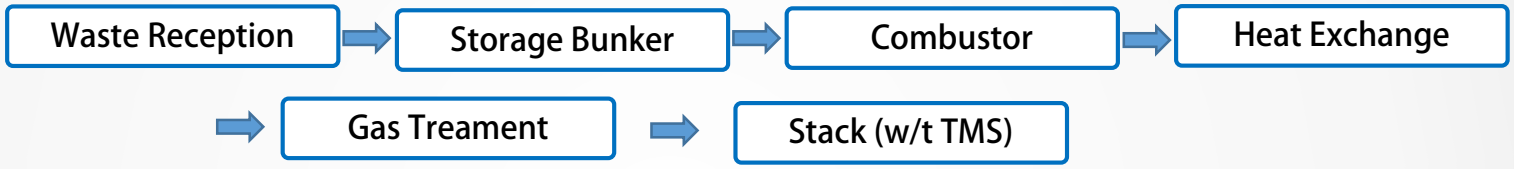
Industrial Wastes

- Stoker Types
- Rotary Kilns
- High Temperature Thermal Treatment

2. Waste Management in Korea

Technological Aspect of Waste Incineration Management

Incinerator System Configurations



New concept of Waste Thermal Treament

- Odor Control: Waste Bunker, Ash Treatment, Air Curtain etc
- Temperature Control : higher than 850 ℃, longer than 2 seconds at Second Combustor Chamber
- Rapid temperature reduction at Heat Exchanger
- BACT Technology for emission control: SDA — A/C Injection — Bag Filter — (SCR) — Stack
  (recently SNCR is widely adopted)
- Ash treatment:
  - Separation of bottom and fly ash, solidification and melting of ash
- TMS(Telemetry system for air pollutants monitoring) installation for major facilities

2. Waste Management in Korea

Technological Aspect of Waste Incineration Management

Technological Management of Small-scale Incinerators

- Regulation of air pollution emission on >100kg/hr (previously)
- Rapid increase of small-scale facitiles
- Introduction of emission standards to small incinerators(1999.10)\

New Inpection System for All Incinerators

- Start of inspection system: 1993. 12
- Start-Up test, Regular Periodic test - every 3 years (1999. 8)

2. Waste Management in Korea

Technological Aspect of Waste Incineration Management

Technological Guidelines for MSW Installation

- Aims to support government officials and technical group to plan, install the facilities
- Applies to >50ton/day facility
- No Legal Obligations, but Technological Guides
- Contains 1) Purpose
  2) Application range
  3) Installation procedure
  4) Detail Guides for units etc.

Technlonogical Guideline for Incinerator Operation and Maintenance

- General Guides for MSW Incinerators

- Waste Reception	- Emission Control	- Noise/Vibration Control
- Odor Control	- Measurement/Control	- Training
- Combustor Management	- Water/Wastewater Management	- Data Management etc
- Heat Exchange	- Ash Management	

2. Waste Management in Korea

Environmental Issues of Waste Incinerator

Air Pollutant Emissions

- Particulate Matters
  - Contains Heavy Metals, Volatile Metals (Hg, As etc)
- Gaseous Pollutants
  - CO, NOx, HCl, VOCs, Odors
- Dioxins/Furans

➡ Depends on Waste Composition, Incineration Method, System Structure, Emission Control System

Waste Ash Generation

- Bottom Ash
  - 15～20% of Treated Waste
  - Another Environmental Load
  - Landfill in the past, Solidification/Melting Recycle
- Fly Ash
  - High Potential of Risk
  - Special Treatment

2. Waste Management in Korea

Environmental Issues of Waste Incinerator

< Dioxin Emission Standard>

Unit: ng-TEQ/Nm³

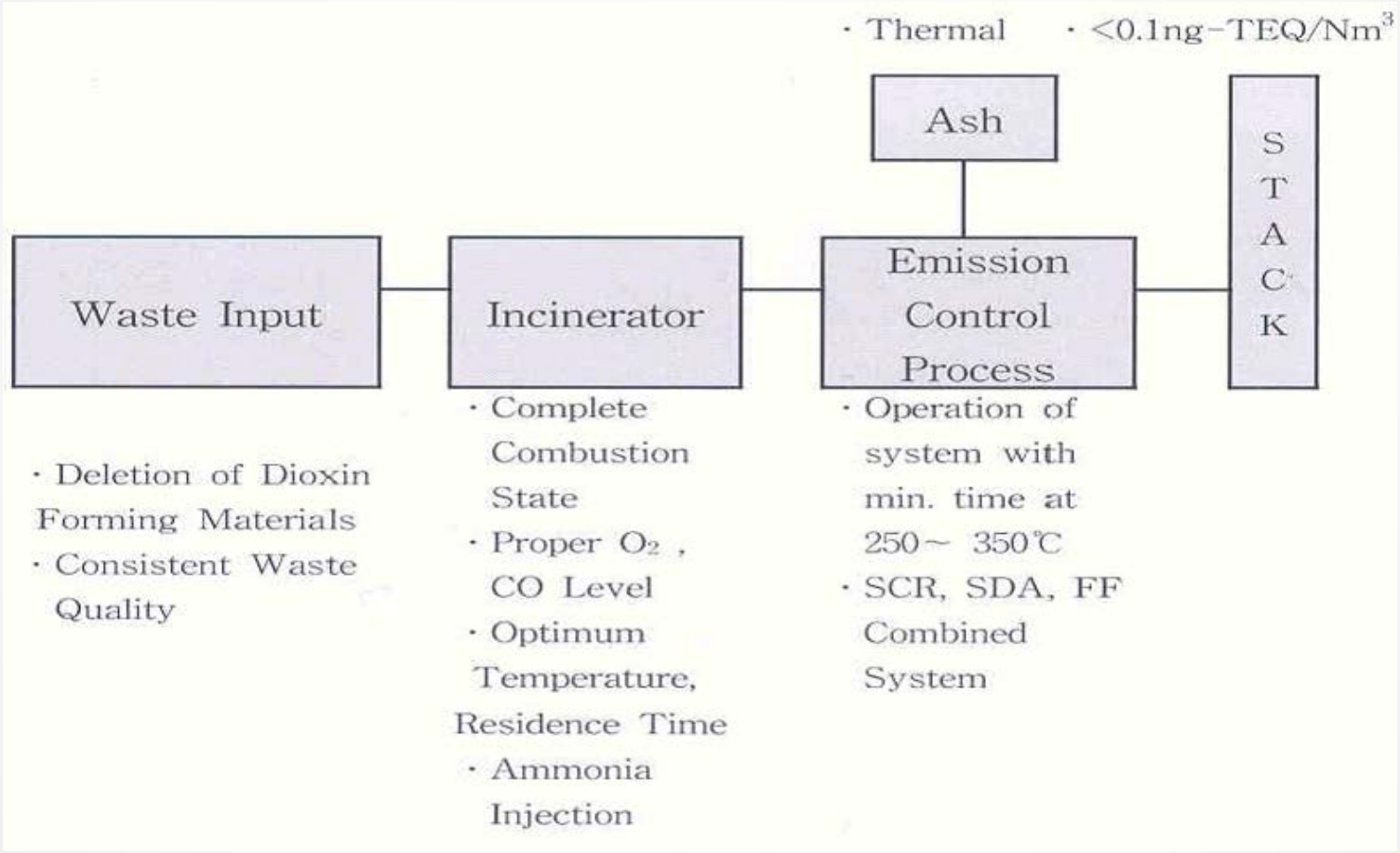
Incinerator Type	Capacity	Emission Guideline	
MSW	> 2.0 ton/hr	0.1	
Industrial Waste		Before 12/31/05	After 1/1/06
	> 4.0 ton/hr	20	1
	> 2.0 ton/hr	40	5
	> 200 ton/hr	40	10
	> 25 ton/hr	-	10
	<After 1/1/07> < 25 ton/hr	prohibited	

< Dioxin Emission Guidelines>

- Dioxin reduction from Incinerator
  - Waste, Combustion, Exhaust Gas Control, Operation Procedure, Ash Treatment etc
- Control for After-Combustion Zone
  - Prevention of Dioxin precursors during Cooling Process, input condition to Filter System <200℃

2. Waste Management in Korea

Environmental Issues of Waste Incinerator



< Dioxin Control Strategies in Incinerators >

2. Waste Management in Korea

Introduction of Innovative Incineration and Pyrolysis/ Melting Technologies

Limit of Landfill and Incineration Technologies

- Landfill: 2nd environmetal problems, site shortage
- Incineration: Generation of incomplete combustion substances
  - Dioxins/Heavy Metal emissions
  - Ash treatment problems
  - Site problems

Introduction of New Concept of Thermal Conversion

- Traditional incineration + Ash Melting(Mapo MSW Incinerator, 2005.6)
- Pyrolysis + Char Combustion/ Melting (Oxygen Application, Electric Arc)
- Gasification + Secondary Combustion + Melting

Experiences for New Technologies

- Pilot plant for Bottom Ash Melting
  - Combined Combustion + Ash Melting (Real MSW Plant, 2001)
  - Pyrolysis/Gasification/Melting System (2003)
- Development of Novel Thermal Technologies for Industrial & Municipal Wastes

3. Management of Resource Recirculation Policy

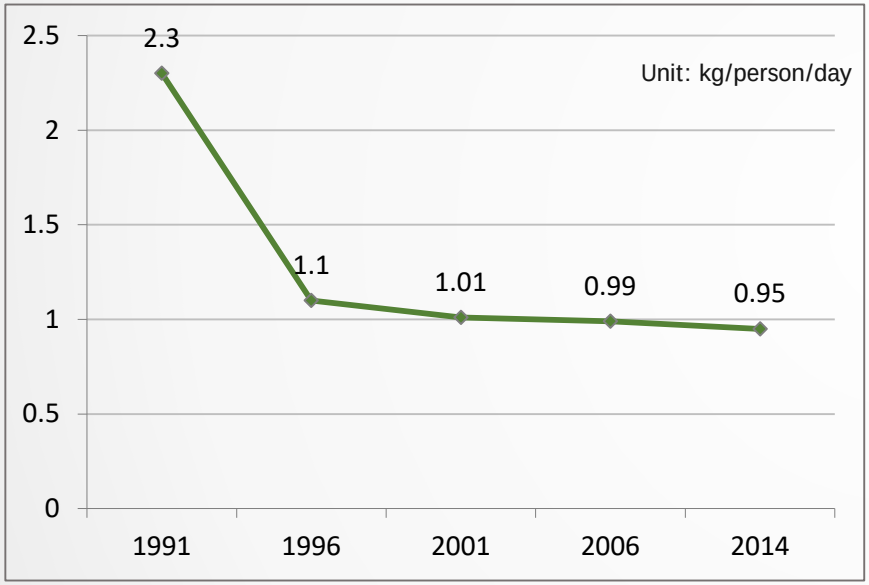
3. Management of Resource Circulation Policy

Flow of Past Resource Circulation Policy

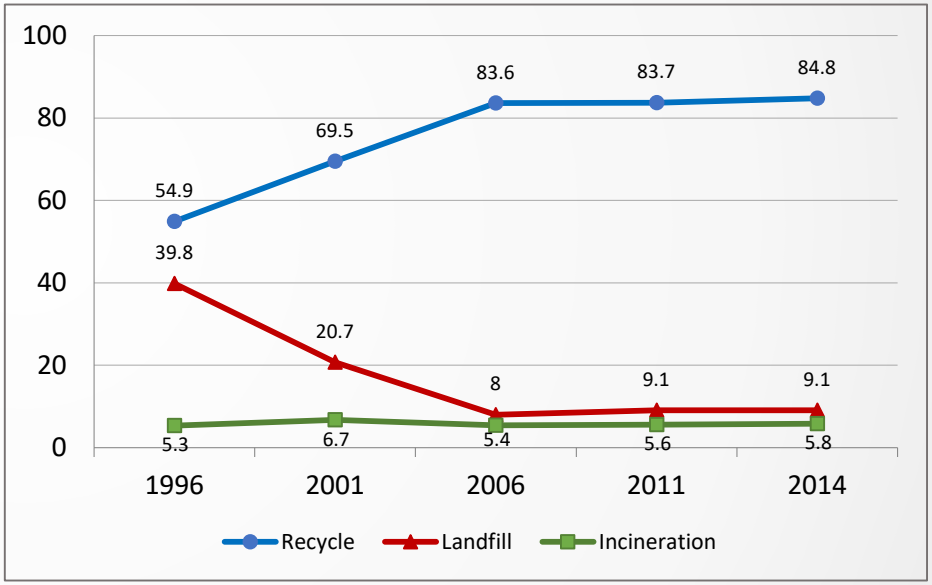
	'80 Years	'90~'00 Years	'00 Year~
Goal	Safety Treatment	Recycle	Resource Circulation
Stratetgies	Waste Control Act(1986)	- Resource Recycle Conservation(92) - Basel (92) - Promotion of Waste Treatment Facility Installation and Support for Nearby Area Act (95) - Construction Waste Recyle (03)	- Electric Product and Vehicle Resource Cicurlation (07)
Institution	- Construction of Infrastructure Facilities	- Deposit Refund·Fee System(92) - Discharge Separation Obligation (92) - Waste Trade Licensing System (94) - Volume-based Garbage Disposal System (95) - Recycle Responsibility System for Manufacture (02) - Legal Waste Disposal System (02) - Recycling Aggregates Obligation (04)	- Ban on Direct Reclamation of Food Trash (05) - Recycling Aggregates Quality Certification Mark (07) - Waste Trade Report System (08) - Electric Product Environmetal Incentive System (08) - Volume-based Food Trash Disposal System (12)

3. Management of Resource Circulation Policy

Flow of Past Resource Circulation Policy



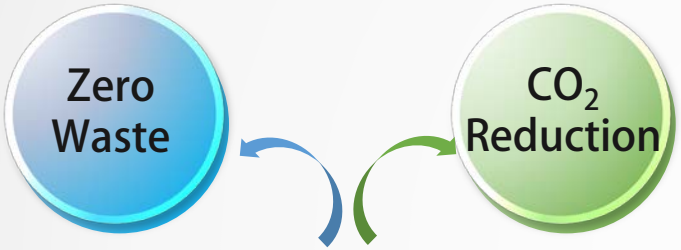
Municipal Solid Waste Generation Trend in Korea



Waste Treatment Trend in Korea

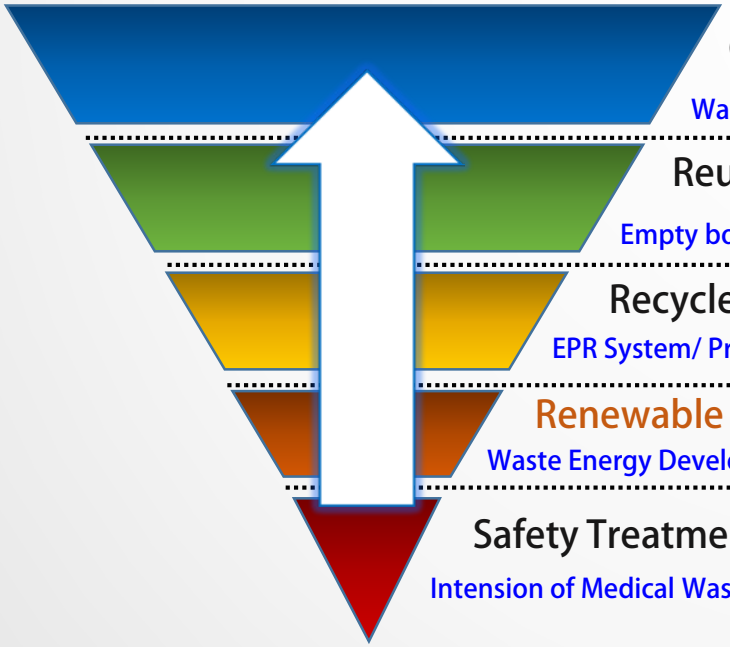
3. Management of Resource Circulation Policy

Trend of Resource Circulation Policy



3R (Reduce, Reuse, Recycle)

4R (Reduce, Reuse, Recycle, Recovery)



Generation Control

Waste Fee System/ Disposable Product Reduction Regulation/Eco Labelling

Reuse

Empty box Deposit System/ Refillable Product Recommendation/ Recycling Center/ Green Shop

Recycle

EPR System/ Promotion & Supportation of Recycling Industry/ Electical product & Vehicle Recycle

Renewable Energy

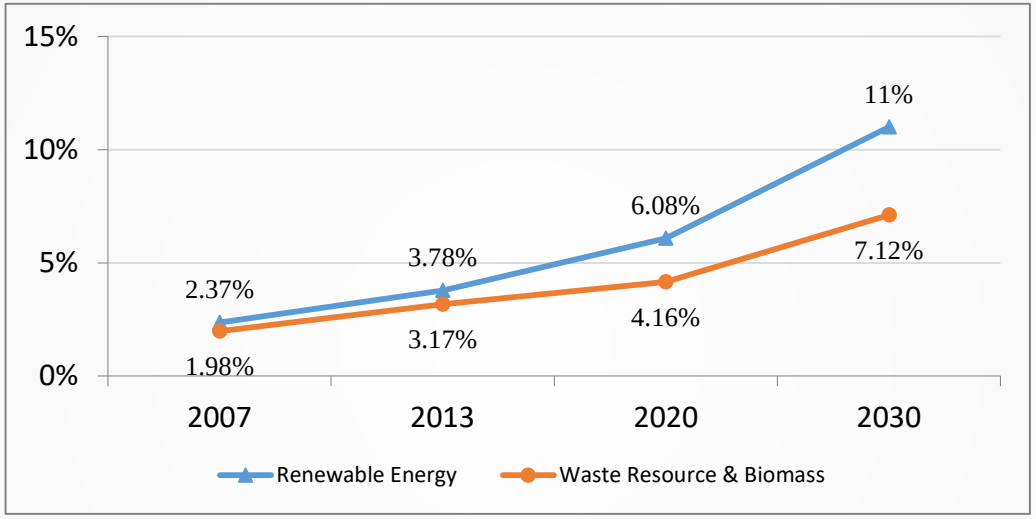
Waste Energy Development/ Landfill and Incinerator Energy Recovery/ Energization Technology Development

Safety Treatment

Intension of Medical Waste Management/ Legal Waste Disposal System

3. Management of Resource Circulation Policy

National Dissemination Goal of Energy from Waste



National Dissemination Goal of Energy from Waste

- Statement of Implementation Plan for "Strategy of Waste Resource & Biomass Energy" (2009)
- Setting Waste Resource & Biomass Energy Dissemination Goal up to 4.16% in order to achieve National Dissemination goal of New/Renewable Energy year 2020

- New policy of "Renewable Energy 3020"
  -Role of renewable energy in total electricity : 7 → 20% by 2030
  · Solar : 5.7 → 30.8GW, Wind : 1.2 → 16.5GW
  -Reduction of nuclear power electricity generation

3. Management of Resource Circulation Policy

Strategy of Waste Resource & Biomass Energy

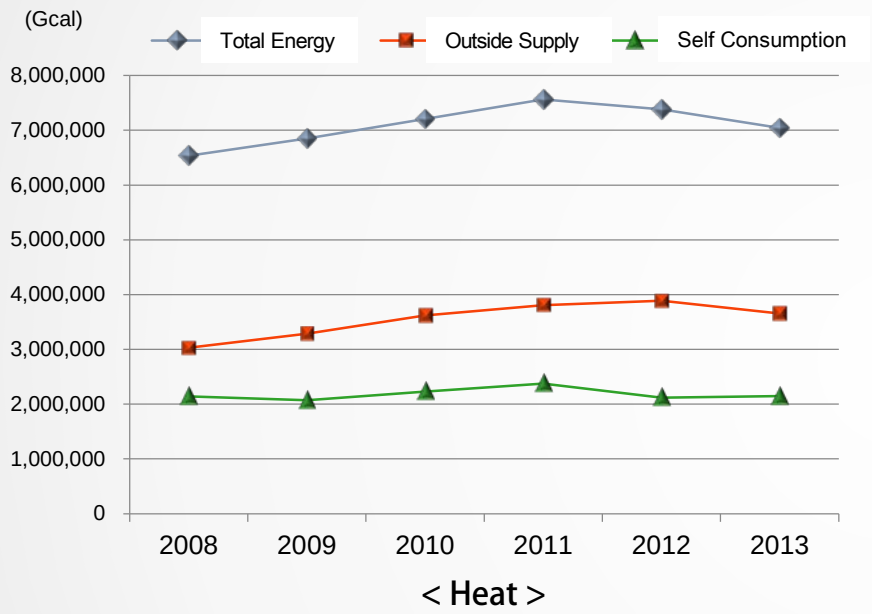
- Plan of Securing Green Energy
- New Power for National Development
- Effective Counterplan for Framework Convention on Climate Change

Conbustible Waste Resource	Organic Waste Resource	Wood Composite	Herbaceous Plant & Maritime
Paper, Plastic	Food Trash, Sewage Sludge, Animal Dung, Animals & Plants Residue	Tree, Waste wood, Woodcutting	Canola, Corn, Straw, Chaff, Seaweed
Solid Refuse Fuel (SRF)	Bio-gas(CH_4)	Solid Fuel (Pellet, Charcoal)	Bio-fuel (Ethanol, Methanol)
Heat Source & Power Generation	Power Generation & Vehicle Fuel	Heat Source Fuel	Vehicle Fuel

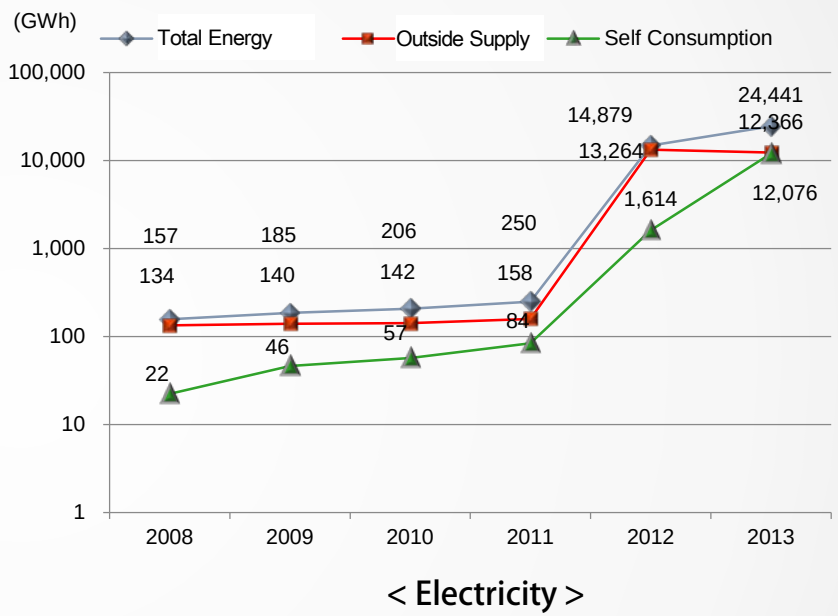
4. Efficient Waste-to-Energy Conversion Practices in Korea

4. Efficient Waste-to-Energy Conversion Practices

Waste Heat Utilization Status



< Heat >



< Electricity >

- Waste Heat Recovery has been utilized for Outside supply such as Steam or Electricity and Onsite Consumption
- Waste heat supply to District Heating system has increased
- Since 2011, electricity production and sales have grown rapidly
  - Self consumption was about 50% of electricity production in 2013

4. Efficient Waste-to-Energy Conversion Practices

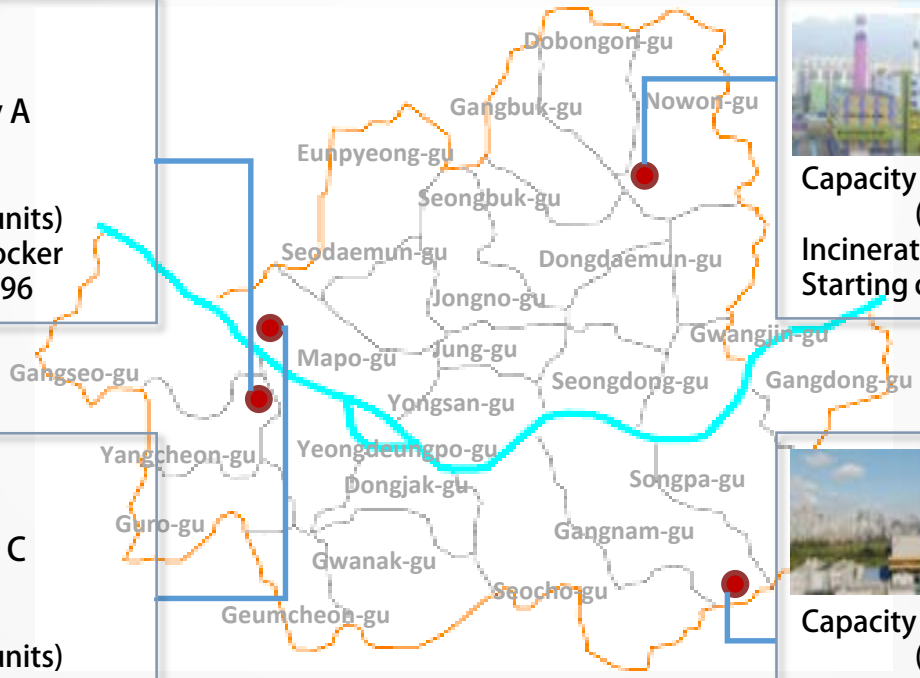
WtE Plants in Seoul Metropolitan Area

Facility A

Capacity : 400 ton/day
(200 ton/day × 2 units)
Incineration type : Grate stocker
Starting operation year : 1996

Facility B

Capacity : 800 ton/day
(400 ton/day × 2 units)
Incineration type : Rotary stoker
Starting operation year : 1997



Facility C

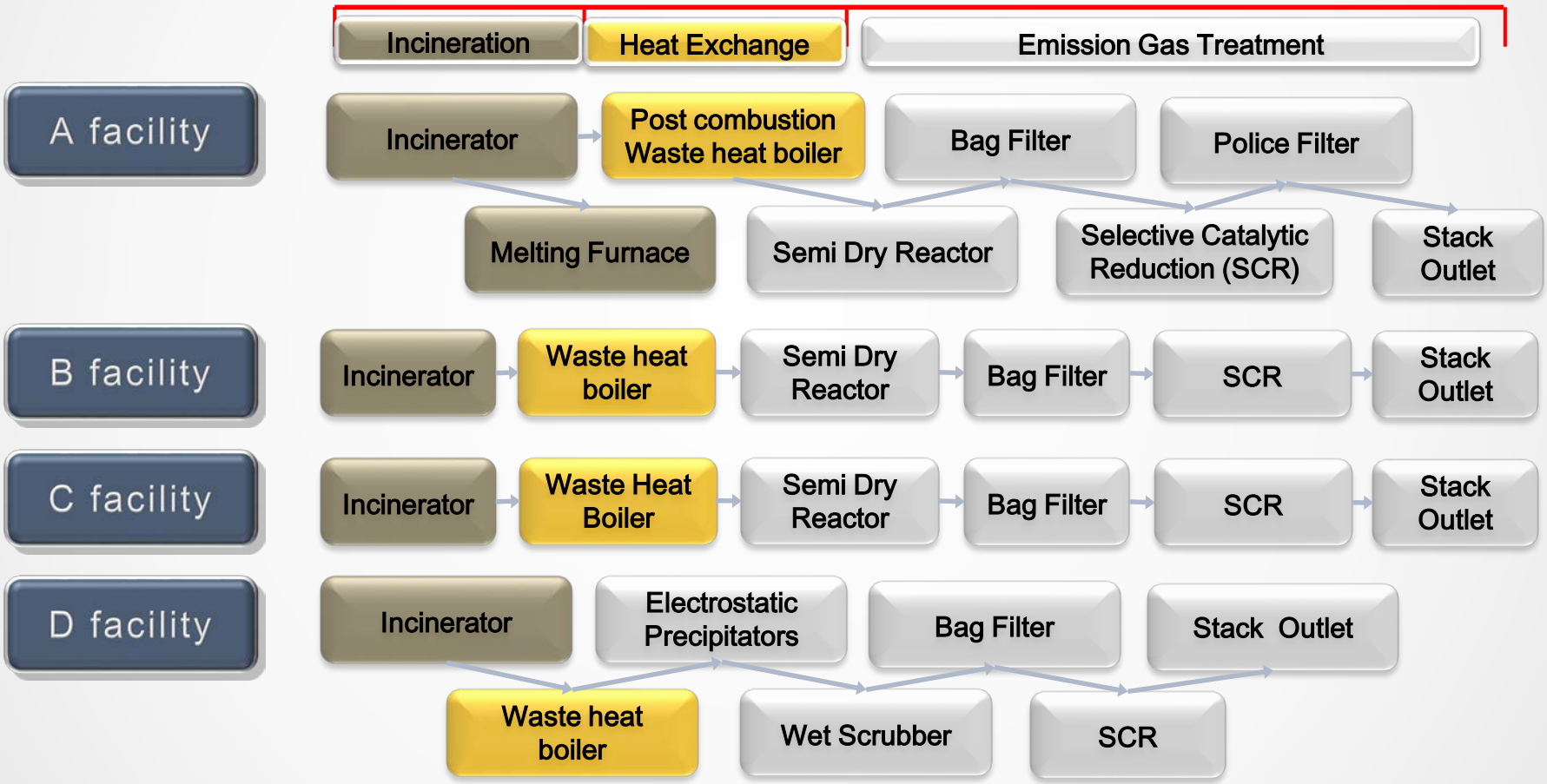
Capacity : 750 ton/day
(250 ton/day × 3 units)
Incineration type : Stoker, Rotary kiln
Starting operation year : 2005

Facitilty D

Capacity : 900 ton/day
(300 ton/day × 3 units)
Incineration type : Horizontal stocker
Starting operation year: 2002

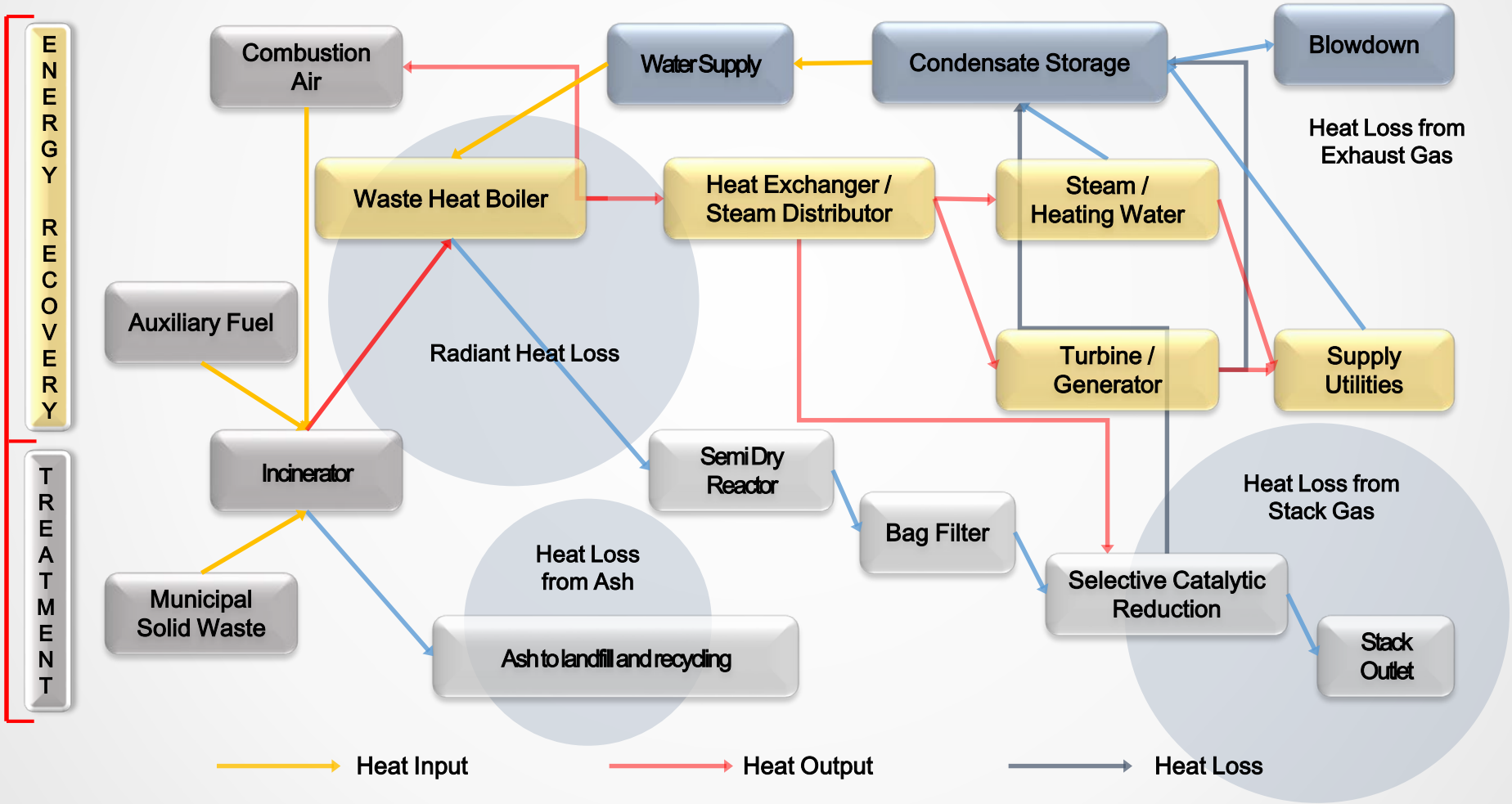
4. Efficient Waste-to-Energy Conversion Practices

Process Configuration of WtE Plants in Seoul



4. Efficient Waste-to-Energy Conversion Practices

Process Configuration of WtE Plants in Seoul



4. Efficient Waste-to-Energy Conversion Practices

Energy Recovery at WtE Plants

WtE Plant		Facility A		Facility B		Facility C		Facility D	
		Usage(Gcal)	(%)	Usage(Gcal)	(%)	Usage(Gcal)	(%)	Usage(Gcal)	(%)
Steam	Onsite	94,085	21.4	53,863	24.2	22,212	4.5	84,853	24.4
	Outside	59,931	13.6	157.875	70.8	467.269	95.5	263,492	75.6
Hot Water	Outside	255,009	58.0	-	-	-	-	-	-
Electri-city	Onsite	19,648	4.5	7,368	3.3	-	-	-	-
	Outside	10,822	2.5	3,280	1.7	-	-	-	-

The utilization status of waste heat in Seoul area (2013)

- In case of facility A and B, waste heat was supplied as energy source for heating purpose and partly converted to electricity by power generator. Whereas facility C and D has produced steam only.

4. Efficient Waste-to-Energy Conversion Practices

Energy Recovery Equation

Korea's Energy Recovery Method

$$\text{Recovery Efficiency} = \frac{\text{Total Recovered energy}}{\text{Total Input energy}} \times 100$$

Heat Loss

$$\text{Heat loss} = 1 - \frac{\text{Total Heat Loss}}{\text{Total Heat Input}} \times 100$$

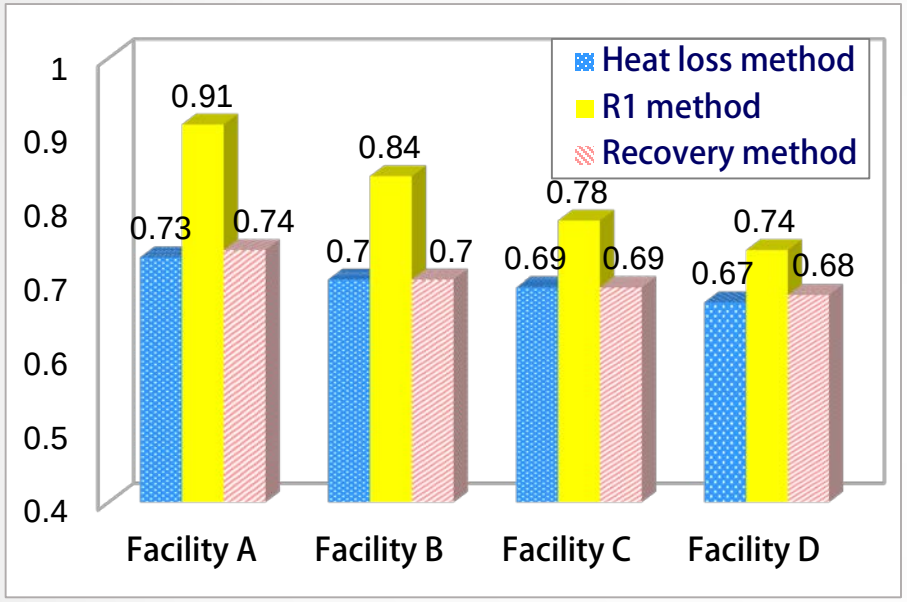
R1

$$R1 = \frac{E_p - (E_f + E_i)}{0.97 \times (E_w + E_f)}$$

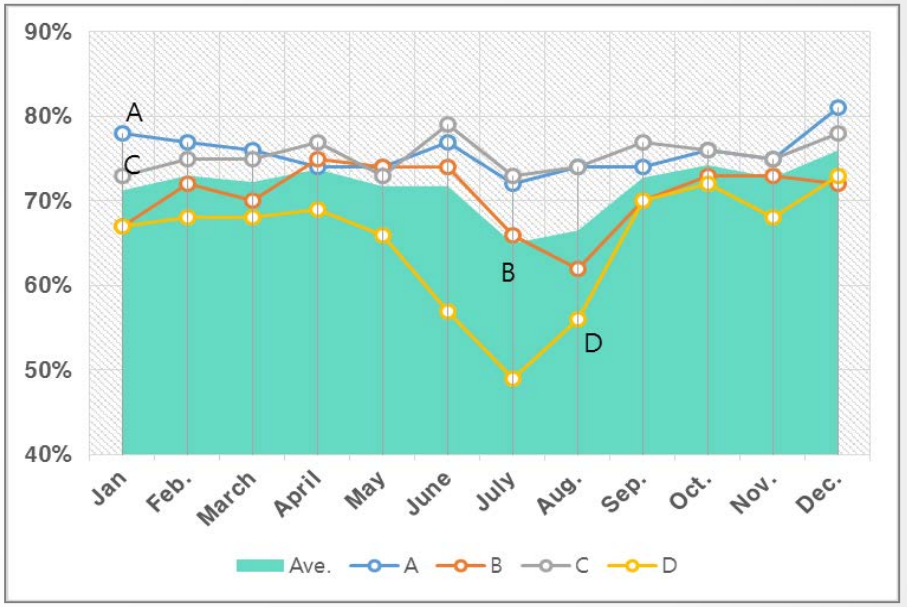
E_p : $1.1 \times E_{th} + 2.6 \times E_{elec}$
Annual energy produced as heat or electricity (GJ/year)
E_f : Annual energy input to the system from fuels contributing to the production of steam (GJ/year)
E_w : Annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)
E_i : Annual energy imported excluding E_w and E_f (GJ/year)
0.97: A factor accounting for energy losses due to bottom ash and radiation

4. Efficient Waste-to-Energy Conversion Practices

Efficient Waste-to-Energy Conversion



Energy recovery efficiency at each WtE plant (2013)



Seasonal variation of energy recovery efficiency at each WtE Plant (2013)

- According to Recovery Efficiency formula, the average of energy recovery efficiency in 2013 was 0.70 and was 0.68 when calculated by Heat Recovery Method, Heat Loss Method but R1 Method showed the highest value of 0.81
- Heat Loss Method and Heat Mecovery Method showed similar values, and R1 is showing the highest value at all WtE plants
- The average energy recovery efficiency except in summer was 71.2 ~ 76.1%, while it was 63.4 ~ 68.9% in summer

4. Efficient Waste-to-Energy Conversion Practices

To Enhance Efficiency of Energy Recovery

Securing WtE facility development budget

- Arrangement of Master Plan for Renewable Energy by Various W-t-E Facilities

Improving Energy Recovery Technology

- Expansion of Waste Heat Utilization Research and Pilot Plants

Securing Environmental Stability

- Assessment of Environmental Performance and System Improvement

Construction of Efficient Incineration Systems

- Optimization of Flue Gas Control facility
- Minimization of Heat Loss due to Flue gas Control Process, Incinerator, Waste Heat Boiler

5. Environmental Energy Town

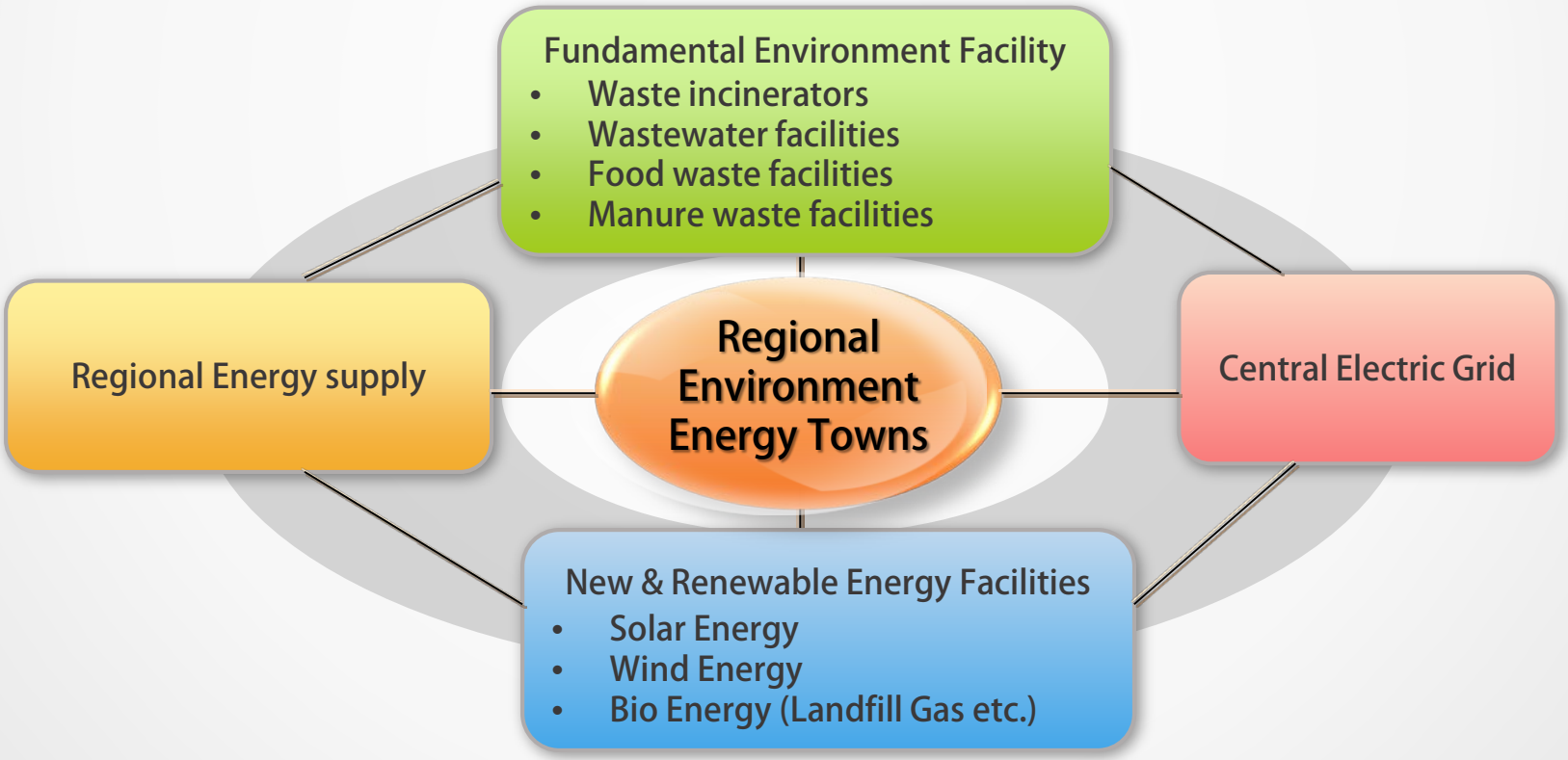
5. Environmental Energy Town

Conceptual Flow

NIMBY facilities
(Not In My Back Yard)

→

PIMFY facilities
(Please In My Front Yard)

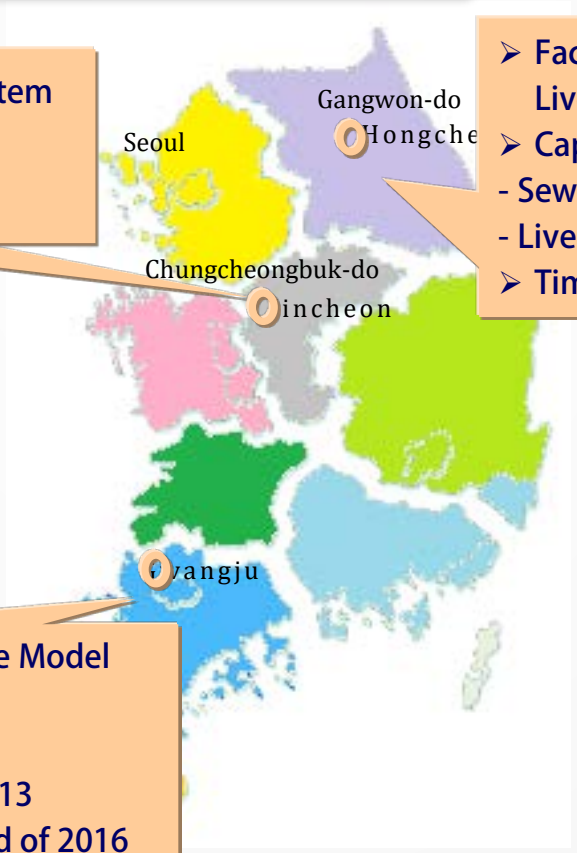


5. Environmental Energy Town

Pilot Projects of Environmental Energy Towns in Korea

No. of Environment Energy Town : 3 Towns (2014. 1)
(Gangwon-do Hongcheon, Gwangju, Chungcheongbuk-do Jincheon)

- Facility : Solar electricity generation system
- Area : 262 km²
- Time of Establishment : 2014. 12



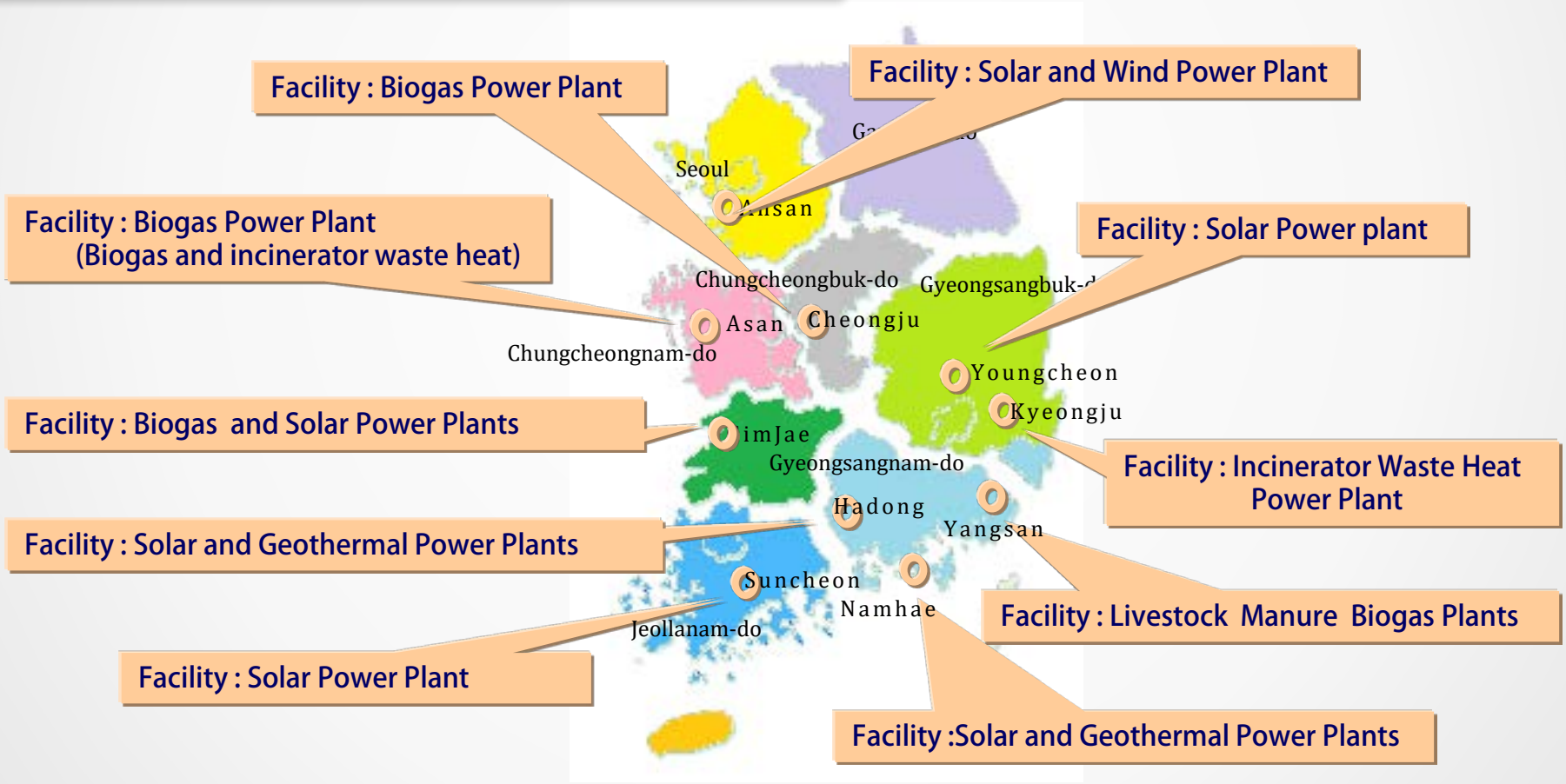
- Facility : Sewage Treatment Plant, Livestock Manure Treatment Facility
- Capacity
  - Sewage treatment : 11 kton/day
  - Livestock manure treatment : 120 ton/day
- Time of Establishment : 2015. 9

- Facility : Renewable Energy Convergence Model
- Area : 29 km²
- Time of Establishment
  - -Sewage Treatment Plant : at the end of 2013
  - -Public Facility : To be completed at the end of 2016

5. Environmental Energy Town

2rd Period Projects of Environmental Energy Towns

No. of Environmental Energy Town : 10 Towns (2015)



5. Environmental Energy Town

2rd Period Projects of Environmental Energy Towns

Case of Cheong-ju city

- Construction of Waste-to-Energy Facility

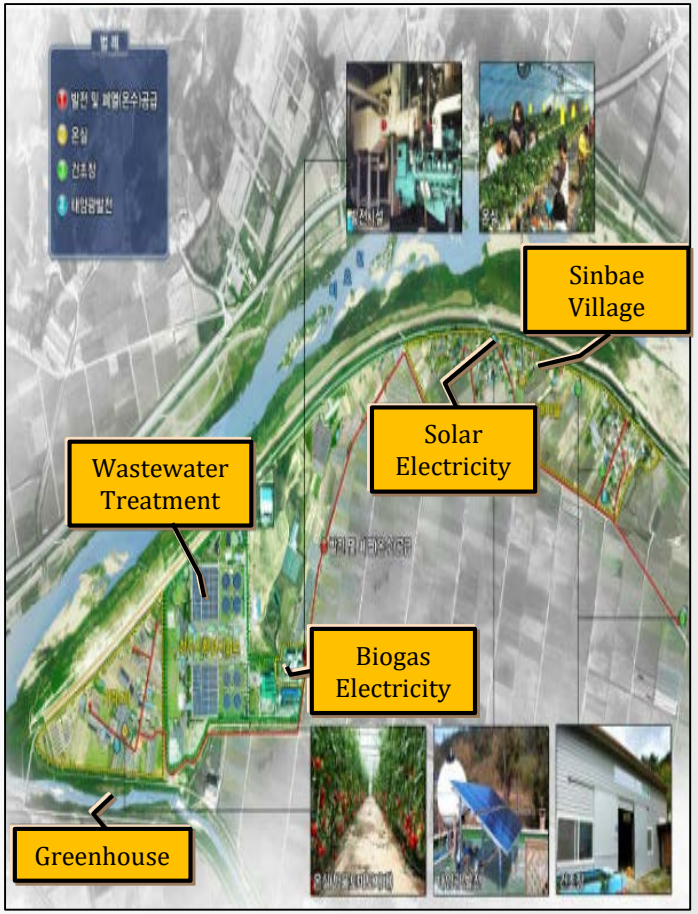
  - Electricity Generation by biogas & Pipeline Construction for hot water utilization by waste heat
  - Biogas production from food-waste wastewater anaerobic digestion : 8,300 m^3/day
  - Electricity generation : 760 kW

- Construction of greenhouse & drying facility

- Construction of solar energy electricity generators

- Investment & profits estimated

  - Investment : 8 billion KWon/yr
  - Profits : 0.87 billion KWon/yr from biogas electricity generation(total 1.27 billion KWon/yr)



<Environmental Energy Town at Cheong-ju city>

5. Environmental Energy Town

2rd Period Projects of Environmental Energy Towns

Case of Asan city

- Construction of Waste Heat utilization Facility from WtE Plant

  - Operate washing facility utilizing for hot water by incineration waste heat
  - Incineration Waste Heat generation : 90 Mcal/h

- Construction of multiple theme park
- Construction of glass greenhouse
  (for insects bio business & paprika cultivation)
- Improvement of environmental science park
- Investment & profits estimated

  - Investment : 5.9 billion KWon/yr
  - Profits : 0.36 billion KWon/yr from washing facility operation(total 1.14 billion Kwon/yr)

<Environmental Energy Town at Asan city>

5. Environmental Energy Town

2rd Period Projects of Environmental Energy Towns

Case of Kyeongju city

- Construction of Waste Heat utilization Facility from WtE Plant

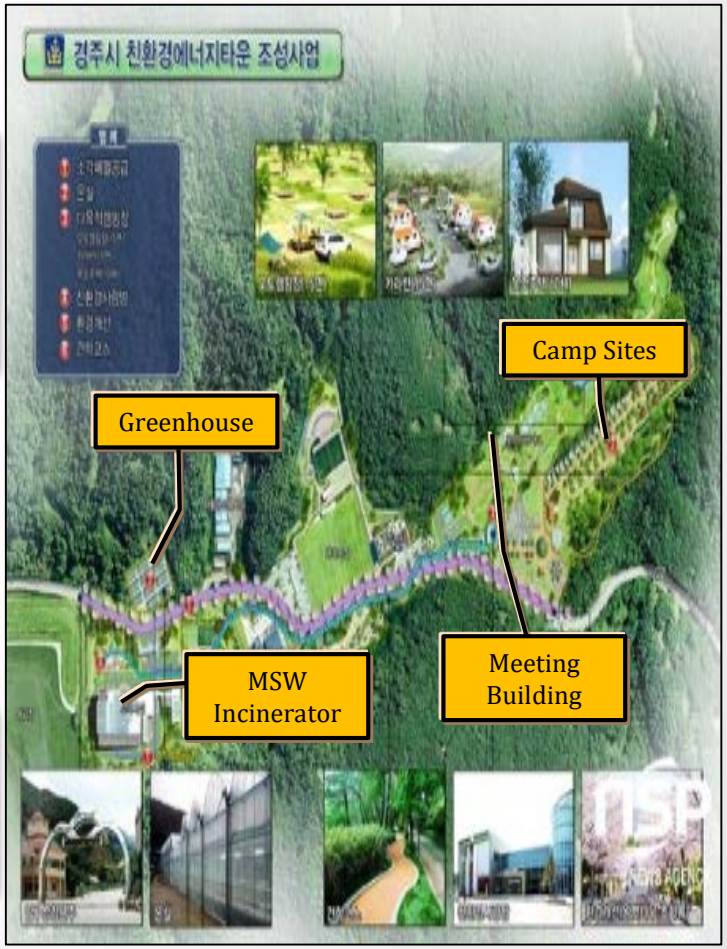
  - Heat supply pipeline construction for hot water utilization by incineration waste heat
  - Heat energy production from incineration waste heat : 700 Mcal/h
  - electricity generation by incineration waste heat : 760 KW

- Construction of camping & eco friendly meeting building

- Construction of ecological park & improvement of the landscape

- Investment & profits estimated

  - Investment : 6.1 billion KWon/yr
  - Profits : 0.25 billion KWon/yr from heat supply
    (total 1.14 billion KWon/yr)



<Environmental Energy Town at Kyeongju city>

5. Environmental Energy Town

Future Perspectives of Environmental Energy Towns

1st stage

- 15~20 Environmental Energy Towns (Government Managed Projects)

2nd stage

- Extended Environmental Energy Towns Projects (Private Sector Managed Projects)

Additional multi-dimensional approaches

- Various project models for more profitable cases
- Standardization of projects for more participation from industries & citizens

Expansion of projects to developing countries

- Cooperation of various institutions
- International network incorporated

6. Summary

6. Summary

Renewable energy

- The importance of renewable energy is becoming greater than before
- Waste/biowaste is expected to become more important primary energy resource in Korea and Asia Region

Energy conversion efficiency

- High energy conversion efficiency technology is important rather than simple treatment technology
- High energy utilization method should be considered

Environmental safety

- Safest environmental protection should be secured
- Social agreement and compensation for nearby society should be pursued

Thank for Your Kind Attention

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