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Status of Waste Management and Waste to Energy Technologies in Korea

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Content

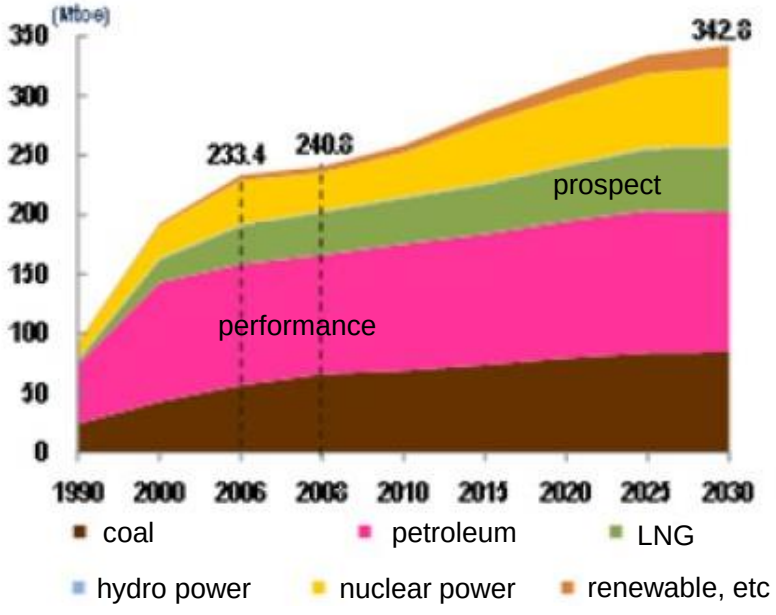
1. Introduction

❖ Demand prediction of domestic primary energy

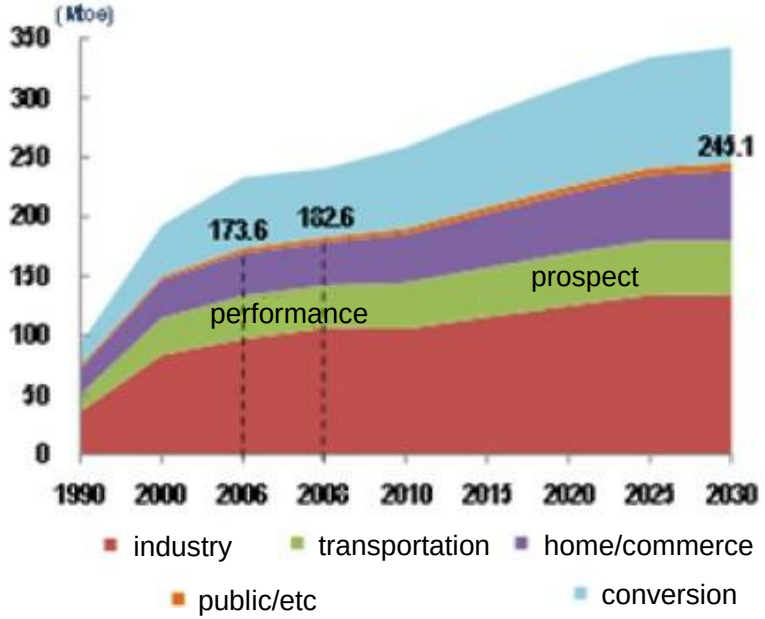
◆ **Domestic primary energy demand is predicted 343 million TOE in 2030 according to avg.1.6 % increasing rate from 2006 to 2030**

◆ **97.5 % of Energy is imported from other countries**

<Demand prediction of primary energy source>



<Demand prediction of final energy>



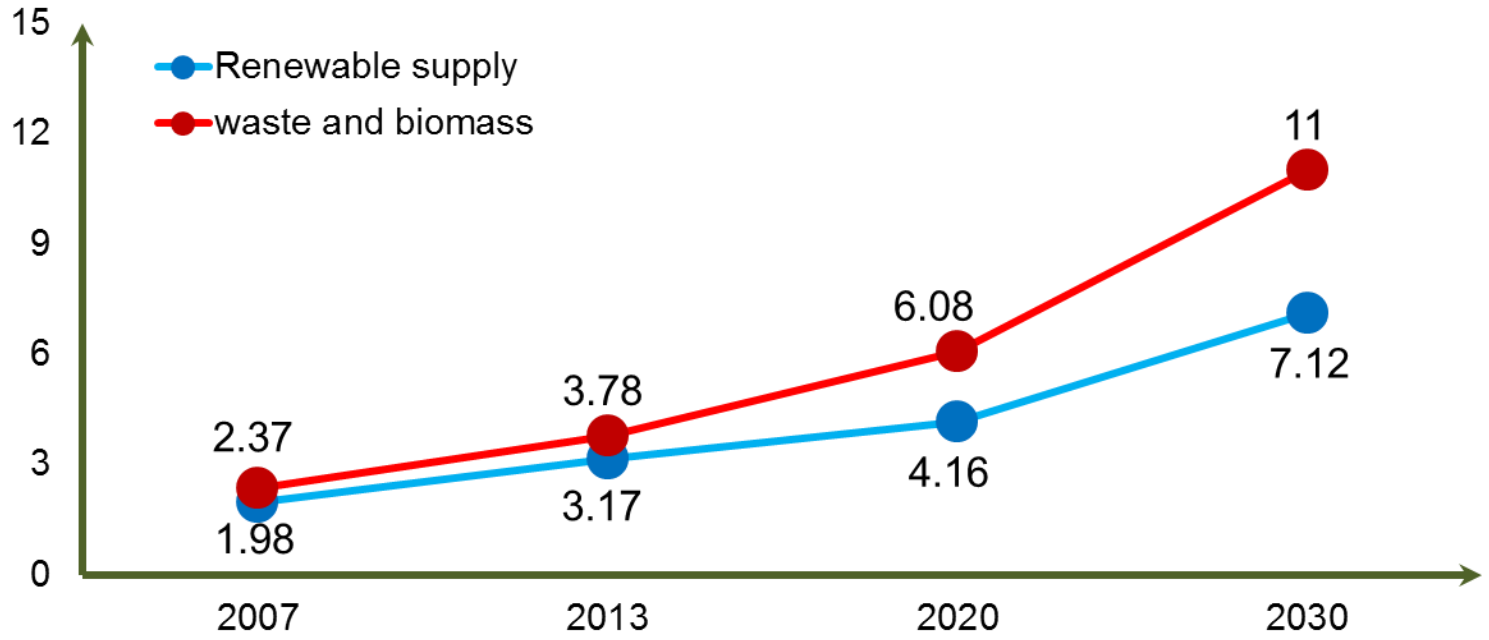
Source: KEMCO, Reduction policy of green-house gas for green growth, 2010

1. Introduction

❖ Goal of Korean ministry of environment

◆ **3.17 % realization as using waste and biomass to achieve the supply rate of renewable energy until 2013**

➡ **Achievement of 4.16 % in 2020, 7.12 % in 2030**



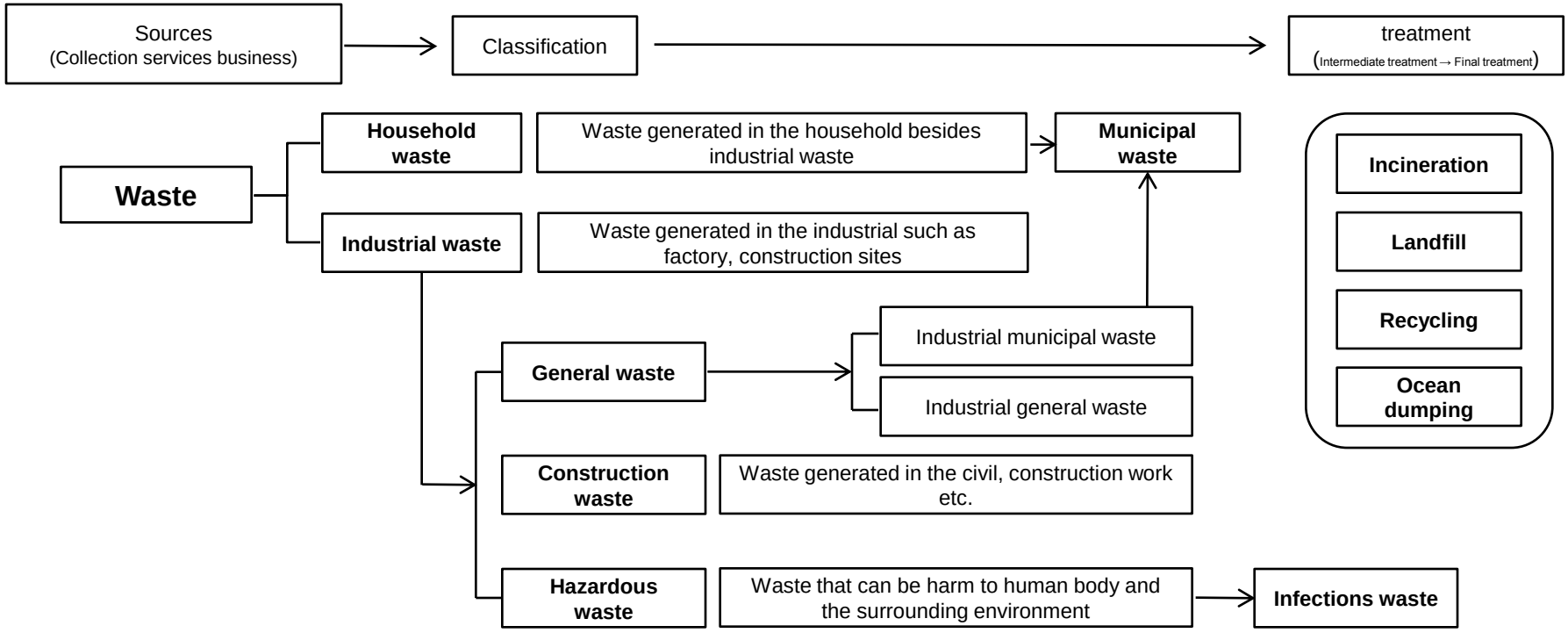
※ Contribution ratio of waste and biomass of renewable supply amount until 2013 could be more 80 %, but increasing of medium and long-term production is limited according to restriction of waste generation and biomass available amount

2. Historical review and status on waste management

❖ Classification of waste

▪ Based on the hazards of waste, waste has been classified as general waste and certain waste, but waste has been classified municipal waste and industrial waste in 'Waste Management Law' ('95)

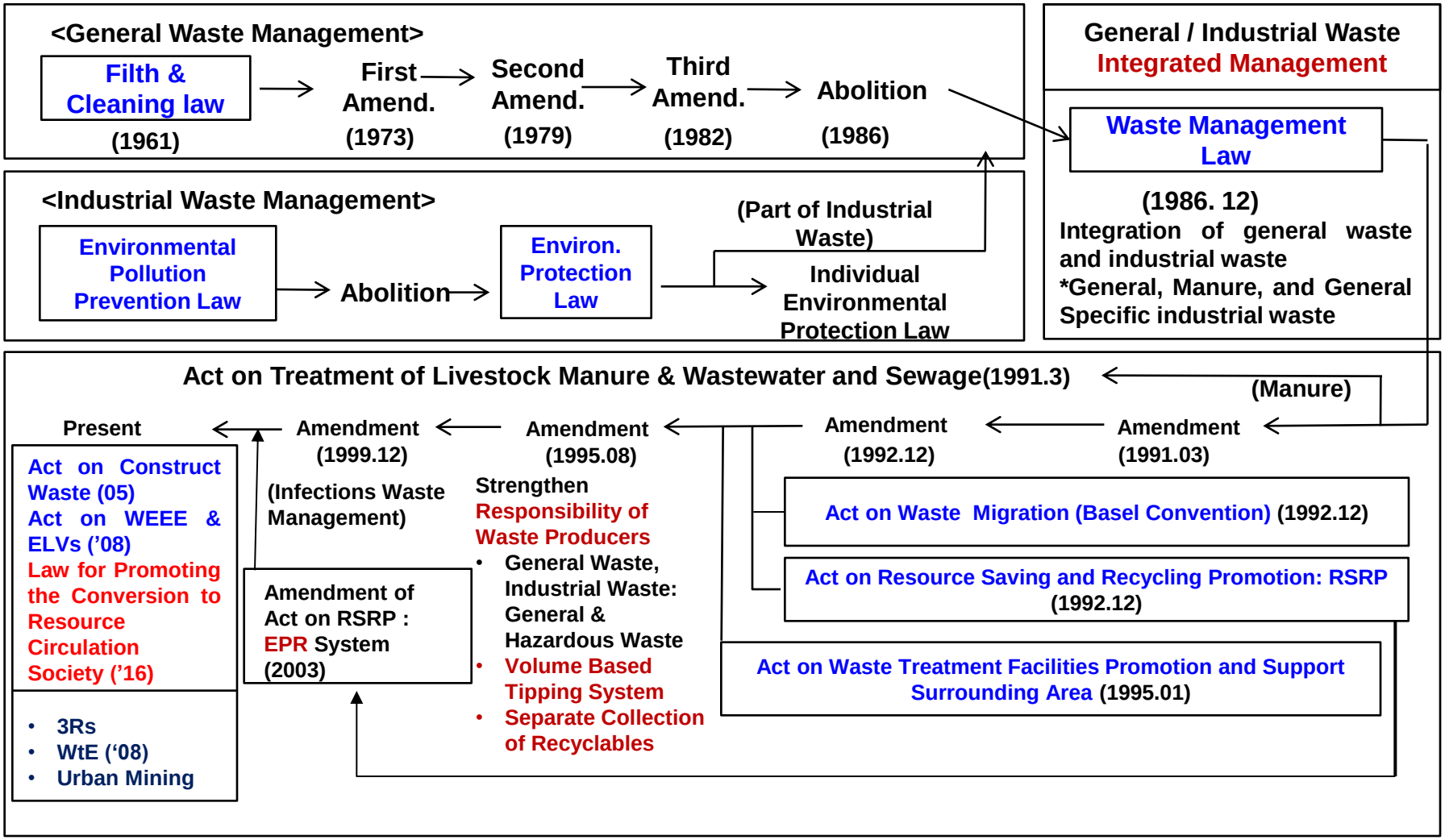
- Increase the efficiency of waste management



Source: Municipal Solid Waste Management in Asia and the Pacific Islands, Environmental Science

2. Historical review and status on waste management

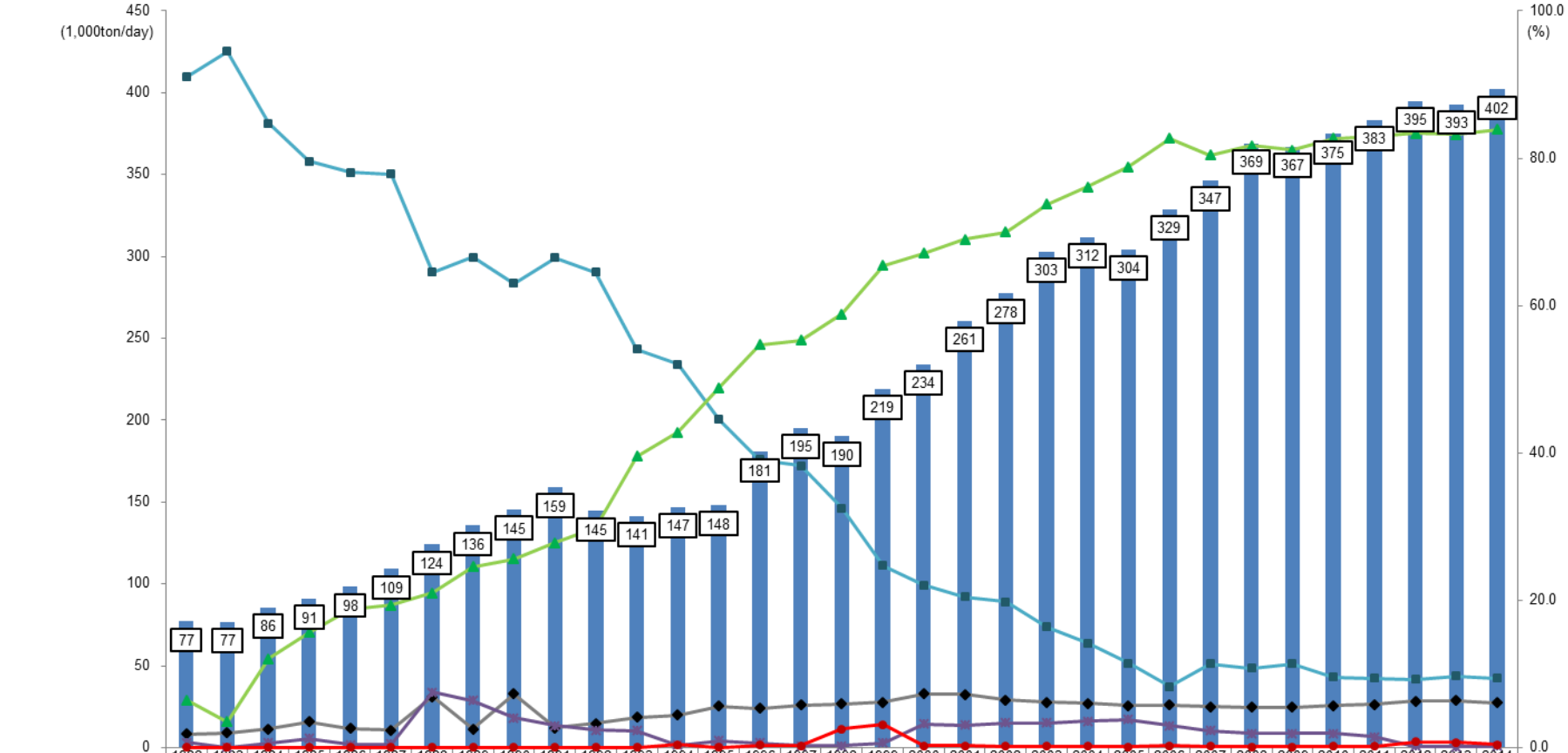
❖ History of legislation for waste management in Korea



Reference: Yang & Seo et al (2015) J Mater Cycles Waste Manag 17:207-217.

2. Historical review and status on waste management

❖ Waste generation and treatment in Overall(‘82 ~ ‘14)

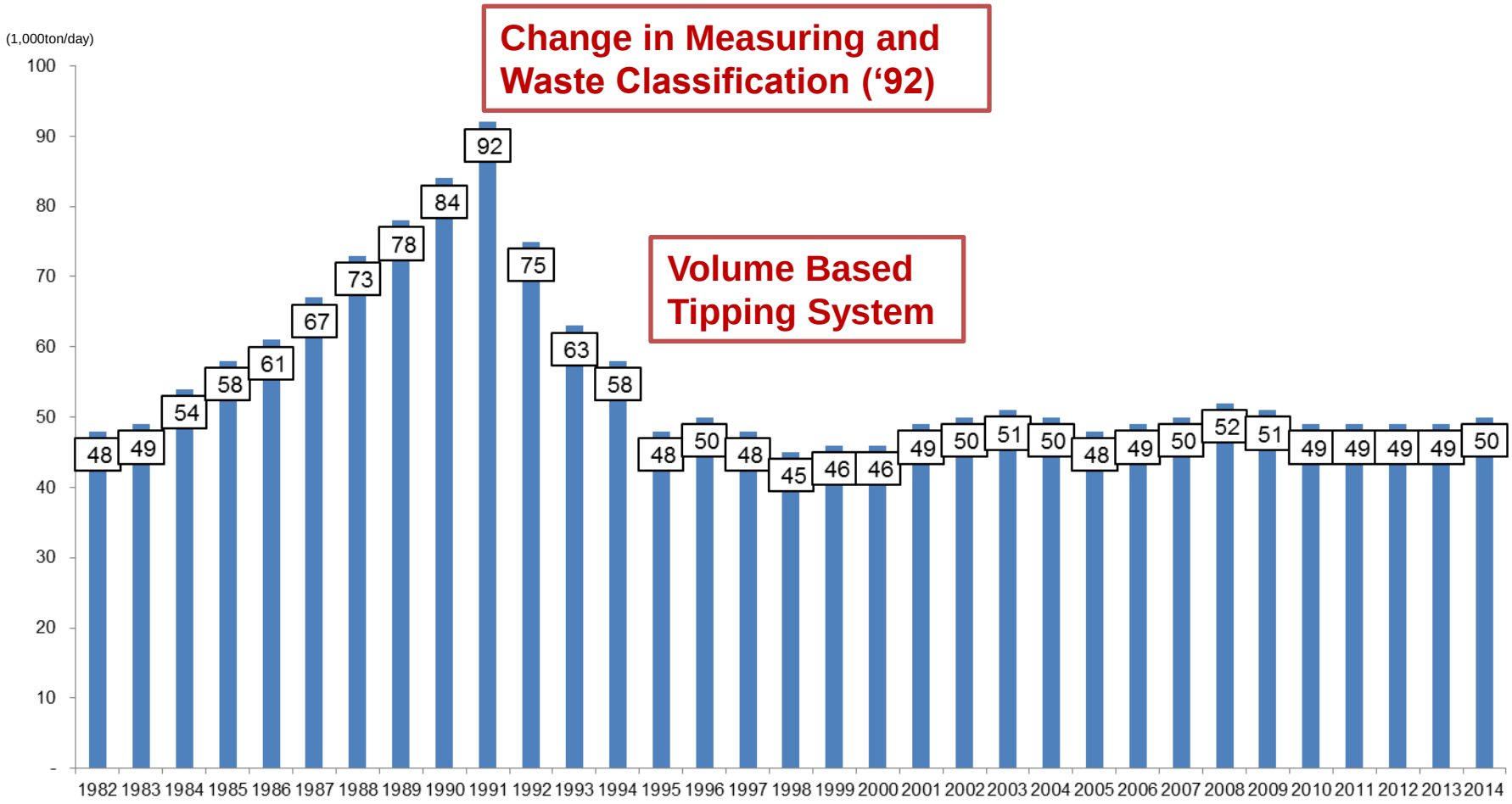


	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Generation	77	77	86	91	98	109	124	136	145	159	145	141	147	148	181	195	190	219	234	261	278	303	312	304	329	347	369	367	375	383	395	393	402
Landfill	91.0	94.5	84.7	79.6	78.1	77.8	64.6	66.5	63.0	66.5	64.5	54.1	52.1	44.6	39.1	38.2	32.5	24.7	22.1	20.5	19.8	16.4	14.2	11.5	8.3	11.4	10.8	11.4	9.6	9.4	9.3	9.7	9.4
Incineration	1.8	2.0	2.6	3.5	2.6	2.4	6.9	2.5	7.3	2.7	3.3	4.1	4.4	5.6	5.3	5.8	5.9	6.2	7.3	7.2	6.5	6.2	6	5.7	5.8	5.6	5.5	5.5	5.7	5.9	6.3	6.4	6.1
Recycling	6.4	3.5	12.1	15.6	18.8	19.3	21.0	24.6	25.6	27.8	29.8	39.5	42.8	48.9	54.7	55.3	58.8	65.4	67.1	69	70	73.8	76.1	78.8	82.7	80.4	81.7	81.1	82.7	83	83.4	83.2	83.9
Other	0.7	0.0	0.6	1.3	0.4	0.5	7.5	6.4	4.0	3.0	2.4	2.3	0.3	0.9	0.6	0.3	0.2	0.6	3.2	3.1	3.4	3.4	3.6	3.8	3	2.3	1.9	1.9	1.9	1.5	0.2	0.1	0.2
Ocean dumping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.3	0.3	2.5	3.1	0.3	0.3	0.2	0.2	0.2	0.1	0.3	0.2	0.1	0.1	0.2	0.2	0.8	0.7	0.4

Source: Environment statistics yearbook, Korean Ministry of Environment

2. Historical review and status on waste management

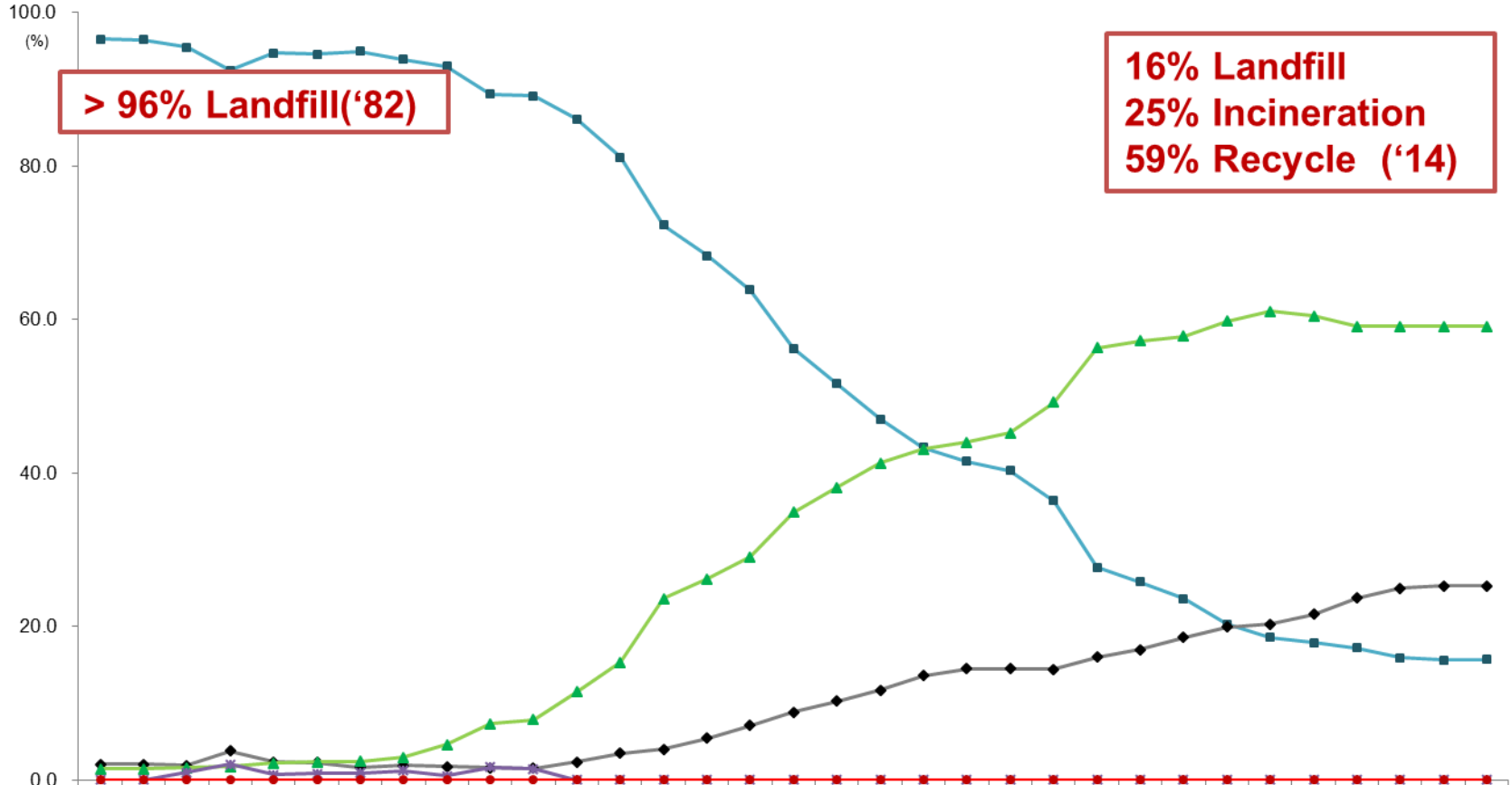
❖ **Household waste generation in 2014 is 49,915 ton/day**



Source: Environment statistics yearbook, Korean Ministry of Environment

2. Historical review and status on waste management

❖ Treatment of Household waste (‘82 ~ ‘14)

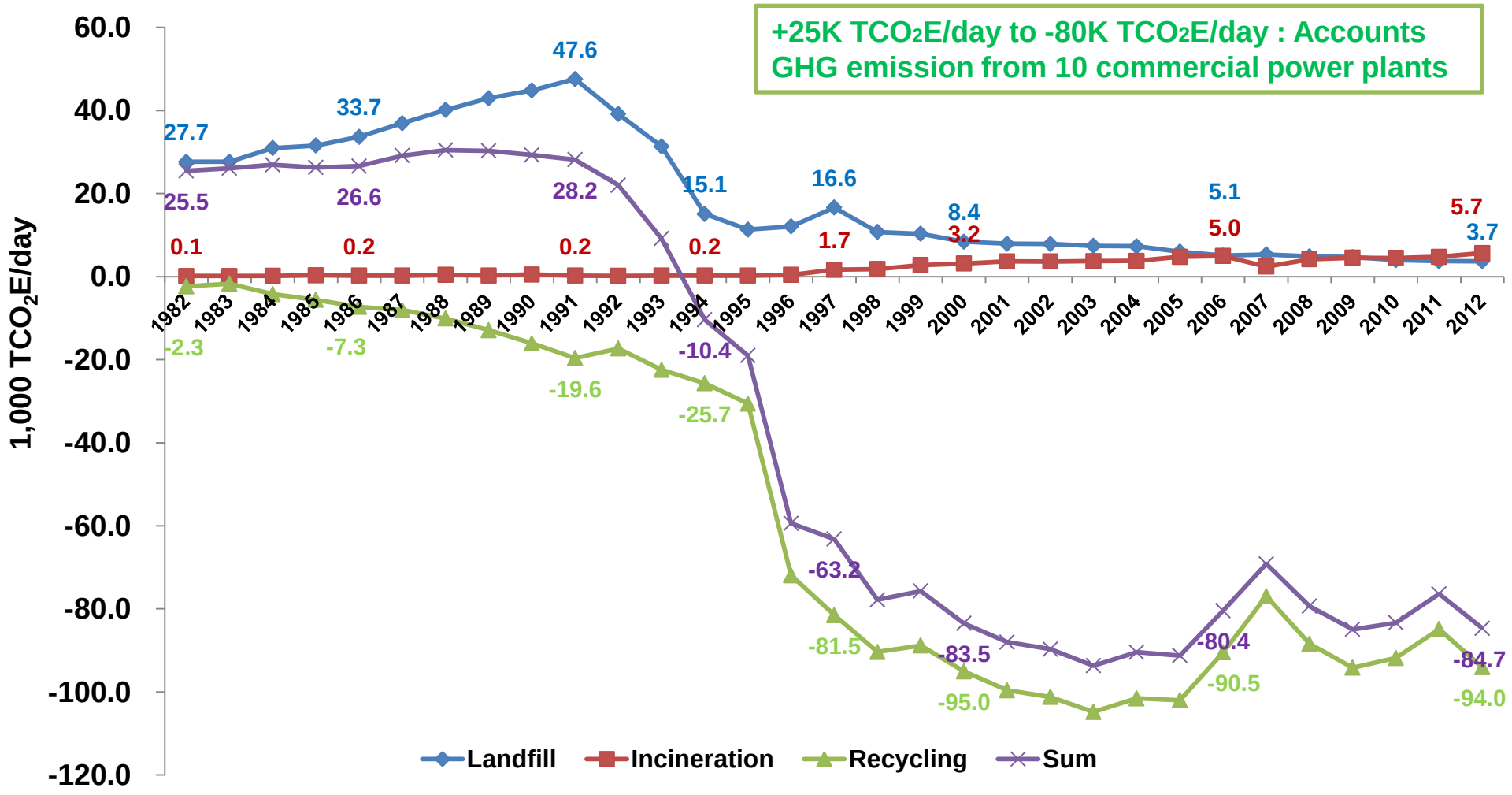


	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Landfill	96.5	96.5	95.5	92.5	94.7	94.6	95.0	93.9	93.0	89.3	89.2	86.2	81.2	72.3	68.3	63.8	56.2	51.6	47.0	43.3	41.5	40.3	36.4	27.7	25.8	23.6	20.3	18.6	17.9	17.2	15.9	15.6	15.7
Incineration	2.0	2.1	1.9	3.8	2.3	2.2	1.7	1.9	1.8	1.6	1.5	2.4	3.5	4.0	5.5	7.1	8.8	10.2	11.7	13.6	14.5	14.5	14.4	16.0	17.0	18.6	19.9	20.3	21.6	23.7	25	25.3	25.3
Recycling	1.4	1.5	1.6	1.8	2.2	2.3	2.4	2.9	4.6	7.4	7.9	11.5	15.4	23.7	26.2	29.0	34.9	38.1	41.3	43.1	44.0	45.2	49.2	56.3	57.2	57.8	59.8	61.1	60.5	59.1	59.1	59.1	59.1
Other	0.0	0.0	1.0	2.0	0.7	0.8	0.9	1.2	0.6	1.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0
Ocean dumping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0

Source: Environment statistics yearbook, Korean Ministry of Environment

Waste Management Practices : Status in Korea

GHG Emission Reduction by Effective Waste Management



3. Major waste management policies and systems

❖ Effective waste management policies

- **Comprehensive plans of waste management since 1993**

Establishment of 1st Comprehensive Plan of Waste Management, 1993

- Enacted new legislation
- Volume-rate garbage treatment system
- Acceleration of local self-governing system
- Change in waste characteristics/classification

Revision of Plan, 1996
(Revised 1st Comprehensive Plan, 1996 – 2001)

- Improvement of 1st plan
- **Reduction** of waste generation
- Maximum of waste **recycling**
- Settling resource circulation waste management

Establishment of 2nd Comprehensive Plan of Waste Management, 2002

- Increase waste values and advance in facilities
- Resource circulation society with Zero waste, EPR

Additional Comprehensive Plan on Waste to Energy
with Settling Resource Circulation Society , 2008

- Waste to Energy as main portion of renewable Energy
- Waste = Resource, 4R Policy, Urban mining
- Act on Recycling WEEE and ELVs (2008)

3. Major waste management policies and systems

❖ Effective waste management policies

▪ Volume Based Tipping System(1995.1~)

1994

1.33 kg/day/person

Reduction of Generation

2014

0.95 kg/day/person

❖Volume Based Tipping System(1995.1)

Saving cost of transportation and landfill
: about 6 billions $

Households buy bags (priced) from supermarkets. Price of a bag by volume will be determined by local governments depending on the cost of waste handling. (fractionally supported by govt.)

Source: Korean Ministry of Environment

3. Major waste management policies and systems

❖ Effective waste management policies

- EPR(Extended Producer Responsibility) System (2003.1~)

Setting of Obligatory Total Recycling Amount (Ministry of Environment)

Reports of total operation

Target amount

Enforcement Agency (Korea Resource Recovery and Reutilization Corporation >>> KEC)

Performance management

Reports of obligatory recycling

Performance management

Producer

Share of expenses

Acting obligatory recycling

Selected Items

Fund support

Contract on consigned

Recycling Operator

Product

Distribution Dealer

Demand of Taking over

Contract on consigned

Fund support

Waste recycling

Purchase

Product

Consumer

Collection, Selection

Transfer

Selected Items

Secondary Market

Waste

Waste

Source: Korean Ministry of Environment

3. Major waste management policies and systems

❖ Effective waste management policies

- **Comprehensive plan on waste to energy (2008-2020)**

Year	'07	'13	'20
WtE rate for Recyclables	1.9%(220 thousands ton)	33%(3.8 millions ton)	100%(12 millions ton)

Combustible>> RDF

'13	'20
1.8 millions ton	3.8 millions ton

Organic >> Biogas

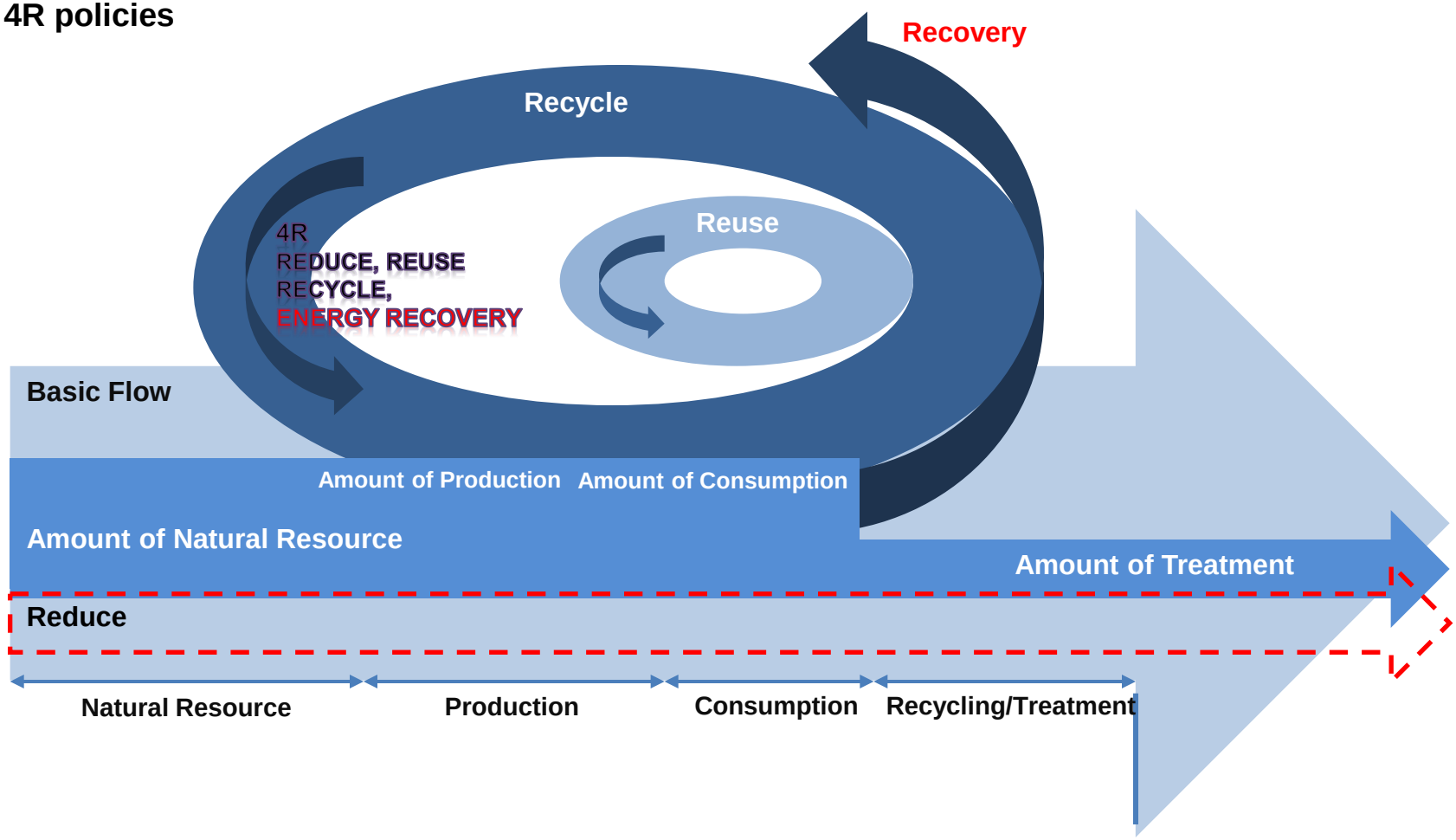
'13	'20
2.0 millions ton	7.9 millions ton

Source: Korean Ministry of Environment

3. Major waste management policies and systems

❖ Effective waste management policies

- 4R policies



Source: Korean Environmental Industry & Technology Institute

3. Major waste management policies and systems

❖ New waste management policy

▪ Goals

▪ Landfill Rate of Waste in Overall

2011
9.4%
(13,104 thousand ton/yr)

2017
6.6%
(9,674 thousand ton/yr)

2020
3.0%
(4,416thousand ton/yr)

※ Landfill rate of household waste of developed country is 0.42% in Germany, 0.97% in Sweden, 3.8% in Japan based on 2010
So, those countries actually achieved the landfill zero of recycling available resource

▪ Landfill Rate for Recyclable Waste

2011
56.0%
(7,338 thousand ton/yr)

2017
18.8%
(2,463 thousand ton/yr)

2020
0.0%

Source: Korean Ministry of Environment

3. Major waste management policies and systems

❖ New waste management policy

▪ Strategy and Actions for Establishing Resource Circulation Society

Establishment of Resource Circulation Society

Landfill Zero of Recycling Waste (Waste = Resource)

Enactment of "**Law for Promoting the Conversion to Resource Circulation Society**"
& Amendment of "Act on Resource Saving and Recycling Promotion"

Maximum Securement of Recycled Resources	Support of Recycling Business & Market Creation	Expansion of Recycling Infrastructure
• **EPR Items Expansion** • ***Free Collection to Door by Call for WEEE*** • **Fund Establishment for RCS (*Landfill Tax* etc.)**	• **Moderating Regulations and Market Support** • **Trade Center for Recycled Products** • **Demand Expansion of Recycled Resources**	• **Establishment of Resource Circulation Complexes** • **Expansion of WtE Facilities and R&Ds Support for WtE Technologies**

Source: Korean Ministry of Environment

4. Waste to energy technologies

❖ Waste to energy

- ◆ Most of WtE plants as incinerators were constructed in 1990s till 2005
- ◆ New Waste to Energy policy was established to use all the potential renewable energy sources in the country in 2008.

Category of waste and energy conversion

Combustible waste (paper, vinyl, plastic, wood, etc)	➡	Solid fuel production
Organic waste (Food waste, sewage sludge, etc)	➡	Biogas Solid fuel production
Remaining heat of incineration (paper, vinyl, plastic, wood etc)	➡	Heat, electricity production
Landfill gas	➡	Heat, electricity production Vehicle fuel(oil refinery)
Industrial Waste gas	➡	Heat, electricity production

Characteristic of waste

◆ High calorific value

✓ Combustible waste
2,500 ~ 3,500 Kcal/kg

✓ Solid fuel
4,500 ~ 5,000 Kcal/kg
(Anthracite 4,600 Kcal/kg)

4. Waste to energy technologies

❖ Thermal conversion – combustion (incineration)

- **Combustion or Incineration is a conversion or disposal process to burn organic portion in biomass or waste by introducing sufficient air (oxygen) to obtain energy.**
- **The existing incineration plants place mostly for stable disposal of waste. However, their energy efficiencies are very low, sometimes just to get heat only not electricity. Due to emission of air pollutants it has received bad images by publics, so gasification and melting technology has been introduced**

▪ Commercial incineration plant of Changwon-si

(MSW)

Changwon-si incineration facility capacity
: 400ton (200ton×dual unit)

(Financial profits : 2.53 millions $)

(Supply 430 tons/day steam by the incineration waste heat)

(LG Electronics in changwon)

Additional revenue(0.18 millions $) is created by reducing CO_2(18,241t)

(Savings according to the use of alternative energy : 6.21 millions $)

Source: Waste to energy technology status and market prospect, KECO

4. Waste to energy technologies

❖ Status of Incinerators in operation (Constructed in 1990-2005)

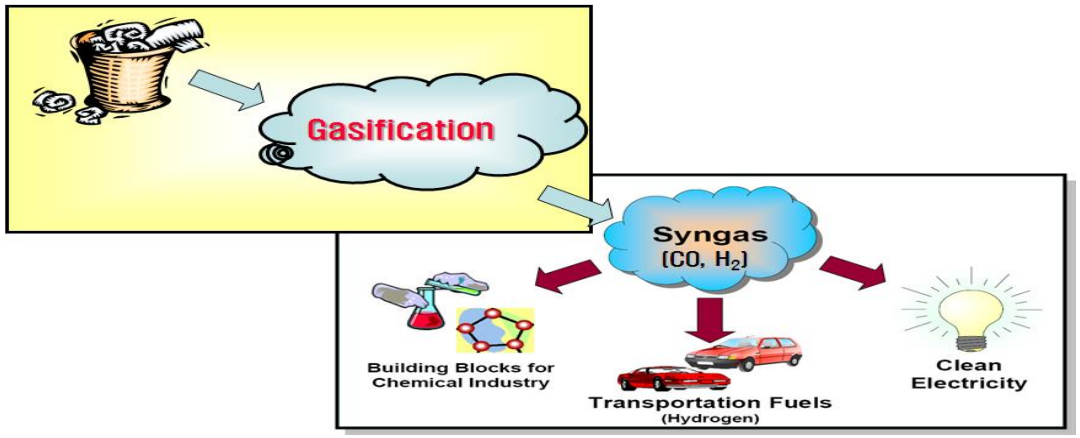
Region	Local government			Private sectors (domestic waste)			Private sectors (Industrial waste)		
	Plant	Capacity (ton/day)	Disposal (2014, ton)	Plant	Capacity (ton/day)	Disposal (2014, ton)	Plant	Capacity (ton/day)	Disposal (2014, ton)
Total	185	16,769	4,342,480	19	52	9,840	202	7,847	1,811,662
Seoul-si	4	1,998	514,466	-	-	-	1	240	45,000
Busan-si	2	510	153,269	3	1	8	10	9	1,489
Daegu-si	1	480	135,534	-	-	-	5	307	66,280
Incheon-si	11	1,797	528,056	5	13	801	16	267	41,307
Gwangju-si	1	320	88,122	-	-	-	1	10	2,844
Daejeon-si	1	400	101,300	-	-	-	2	679	163,563
Ulsan-si	2	650	189,552	-	-	-	1	400	65,564
Sejong-si	1	45	13,217	-	-	-	1	330	53,467
Gyeonggi-do	26	5,114	1,174,015	8	9	1,689	67	912	224,073
Gangwon-do	16	582	159,762	-	-	-	-	-	-
Chungcheongbuk-do	10	499	149,270	1	2	40	17	1,396	295,485
Chungcheongnam-do	9	660	206,572	2	27	7,302	9	36	3,322
Jeollabuk-do	2	600	148,723	-	-		16	1,926	547,694
Jeollanam-do	53	496	107,953	-	-		9	481	91,217
Gyeonsangbuk-do	20	739	207,659	-	-		14	315	60,018
Gyeonsangnam-do	19	1,601	396,691	-	-		31	493	137,550
Jeju-do	7	278	68,319	-	-		2	47	12,790

Source: Environment statistics yearbook, Korean Ministry of Environment

4. Waste to energy technologies

❖ Thermal conversion – gasification

1. • Waste gasification technology is to produce synthesis gas (syngas) by reacting waste with partially supplying oxidizing agents (air, oxygen, steam)
2. • Main compositions of syngas are the same as fuel gas such as methane(CH_4), hydrogen(H_2) and carbon monoxide(CO)
3. • After purification steps, syngas can be used as a clean fuel.
4. • Syngas is possible to utilize as a gaseous fuel at combustion boilers, power generation (gas engine, gas turbine, steam turbine) and to convert into chemical raw materials (hydrogen, methanol, ammonia, DME, SNG etc.)



Source: Technology of using syngas from waste, IAE

4. Waste to energy technologies and their status

❖ Thermal conversion – gasification/melting

▪ Status of waste gasification-melting plants in Korea

Location	Capacity	Supplier	Technology	Type	Year	Waste
Yangsan-si	100ton/day. Dualunit	POSCO Corporation	NSC	Shaft furnace	2003	MSW
Yangju-si	100ton/day. Dual unit	Dongbu Corporation	R21	Rotary kiln	2005	MSW
Goyang-si	150ton/day. single unit	POSCO Corporation	NCS	Shaft furnace	2006	MSW
Eunpyeong New Town	48ton/day. Dual unit	GS Corporation +Hyosung Ebara	EBARA	Fluidized bed	2006	MSW
Pangyo-si	45ton/day. Dual unit	Halla Development	KOBELCO	Fluidized bed	2006	MSW
Hwaseong-si	150ton/day. Singe unit	GS Corporation +Hyosung Ebara	EBARA	Fluidized bed	2007	MSW
Daegu-si Dalseong-gun	70ton/day. Single unit	Hyosung Ebara	EBARA	Fluidized bed		MSW
Chenan-si	24ton/day. Single unit	Etin System	Etin System	Kiln+ reforming furnace	2007	Infection waste
Yangyang-si	30ton/day. Single unit	Halla Development	Halla Development	Fixed bed		MSW
Cheongsong-gun	10ton/day. Single unit	GS Platech	GS Platech	Plasma	2008	MSW

Source: Technology of using syngas from waste, IAE

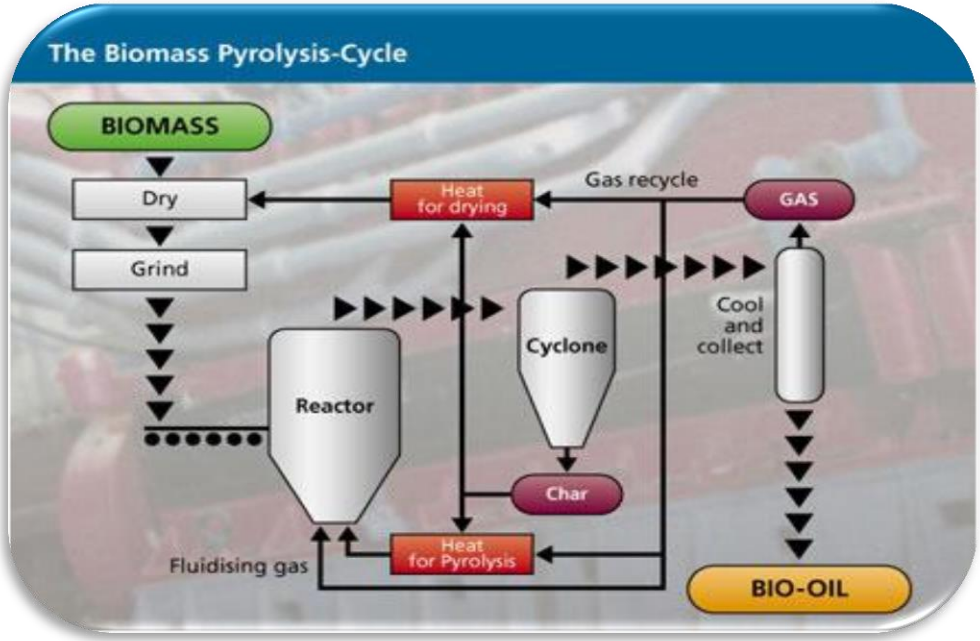
4. Waste to energy technologies

❖ Thermal conversion – pyrolysis

• The process of decomposing organic compound into Gas, Oil, Tar or Char to apply heat in anaerobic condition, no air supply. It is sometimes called Devolatilization or Carbonization.

• Some R&Ds and small scale plants are under development and in operations.

Feedstock + Heat → Gas + Liquid + Solid



Source: Aston University/PyNe

4. Waste to energy technologies

❖ Mechanical conversion – SRF (solid refuse fuel)

• Waste and biomass with containing organic portion can be separated and pelletized as solid fuel forms. Due to high heating value of them, it is combusted or converted to energy at boilers, cogeneration plants.

• Metropolitan Landfill Pretreatment facility

• Facility size : 200 tons/day
• SRF production : about 70 tons/day

• SRF (Pellet)

• SRF sales expense (53,000 wons/ton)

• SRF is used as fuel in Joenju Paper

• Busan fuel manufacturing and power plant (Fluff – Not Pelletizing)

• Fuel manufacturing facility
• Facility size : 900 ton/day

Supply to power plant facility after to be fuel

• Power plant facility
• Facility size : 500 tons/day
• Power amount : 25MW

Source: Waste to energy technology status and market prospect, KECO

4. Waste to energy technologies

❖ Mechanical conversion – SRF (solid refuse fuel)

▪ Status of SRF plants

Local government	Project period	Capacity	SRF type		Note
Namhae-gun	2003～	25	Pellet	Biocon	In Operation
Wonju-si(1)	2006～	80	Pellet	Hanwha E&C	In Operation
Metropolitan Landfill(1)	2010～	200	Pellet	Posco E&C	In Operation
Bucheon-si	2012～	90	Pellet	Daewoo E&C	In Operation
Buan-gun	2012～	25	Pellet	Dokeon Eng.	In Operation
Gapyeong-gun	2012～	80	Pellet	Humantec Eng.	In Operation
Sejong-si	2013～	130	Pellet	Taeyoung E&C	In Operation
Muju-gun (Jinan-gun)	2013~	80	Pellet	Hyosungebra Eng.	In Operation
Busan	2013~	900	Fluff	Posco E&C	In Operation
Suncheon-si(Gurye-gun)	2014~	220	Pellet	Daesun E&C	In Operation
Naju-si(Hwasun-gun)	2014~	130	Pellet	Hanlla I&C	In Operation
Mokpo-si(Sinan-gun)	2014~	230	Pellet	Kolong E&C	Pre-testing
Daejeon-si	-	200	-	GS E&C	Under construction
Wonju-si(2)	-	110	Pellet	Hanwha E&C	In Operation
Daegu-si	-	760	Fluff	GS E&C	Under construction
Gwangju-si	-	600	Fluff	Posco E&C	Under construction
Pohang-si	-	500	Fluff	Posco E&C	Under construction
Metropolitan Landfill(2)	-	1,200	-	-	Designing
Suncheon-si(Gurye-gun)	-	90	-	-	Designing

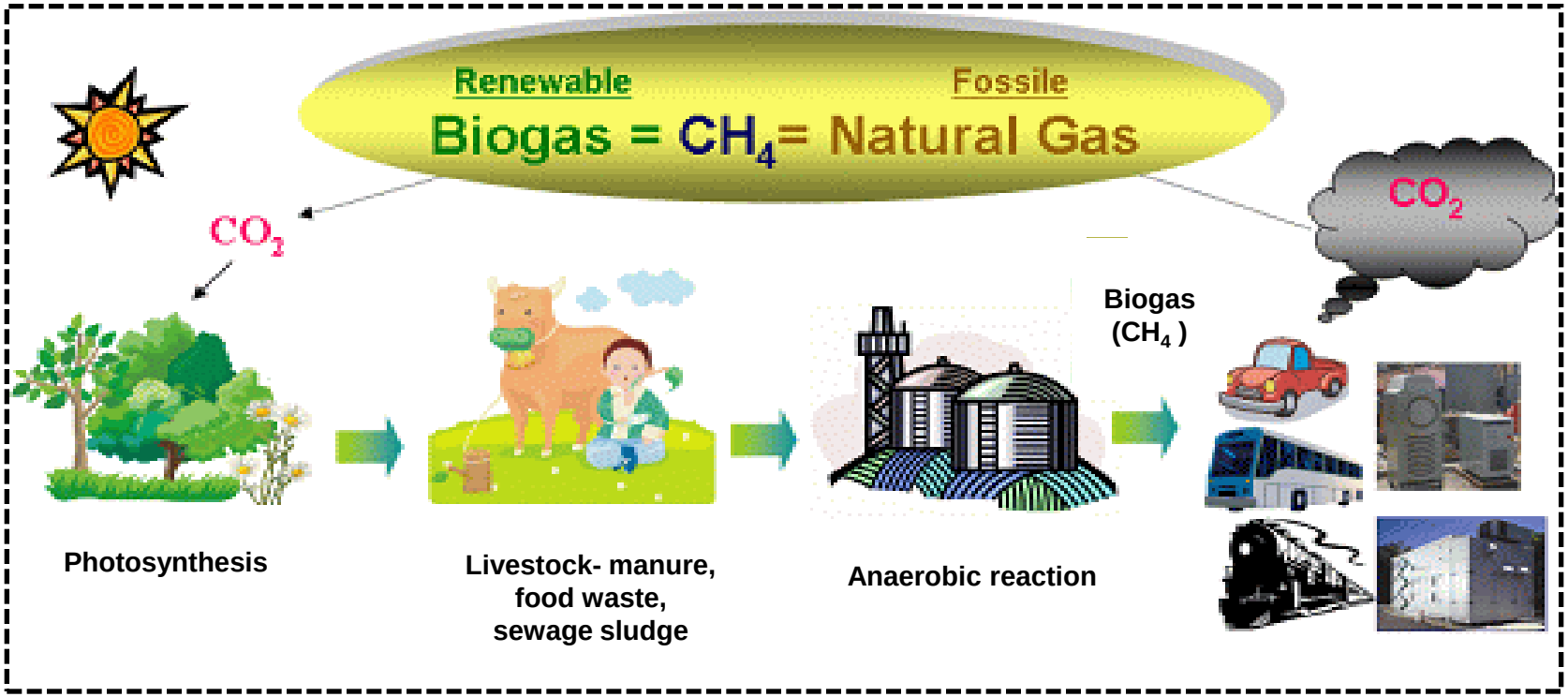
Source: Waste to energy technology status and market prospect, KECO

4. Waste to energy technologies

❖ Organic waste to energy

▪ Bio-gas

• Bio-gas is made by livestock manure, food waste, sewage sludge, organic MSW(Municipal Solid Waste), and organic industrial waste using anaerobic processes



Source: Waste to energy technology status and market prospect, KECO

4. Waste to energy technologies

❖ Organic waste to energy

Generation : 80 million ton

- ◆ Sewage sludge : in the domestic, over 300 sewage treatment plant
- ◆ Liquidated Manure : 50 million tons/year
- ◆ Food waste : 5 million tons/year

Current problem

- ◆ London Convention and 96 revision protocol
  : A ban on the dumping of sewage sludge at sea(~ 2011)
- ◆ Environment : Effective January 1. 2005, it is forbidden to bury sewage
- ◆ Up to date, most sewage sludge has been ocean disposal, incineration, landfill, scattering at land → Alternative ?

Estimation of energy conversion

- ◆Energy conversion estimation of Liquidated Manure, Food waste, Sewage sludge
- ◆ Approximately 11 trillion kcal/year = 1.1 million tons/year
- ◆ Cost of energy import = Approximately 830 billion/year reduction
- ◆ CDM (Clean Development Mechanism) : 3.4 million tons CO_2/year

4. Waste to energy technologies

❖ R&Ds on WtE Technology Development (KEITI)

New R&Ds for WtE (KMOE, 2012)

KEITI 한국환경산업기술원 Korea Environmental Industry & Technology Institute

Objective

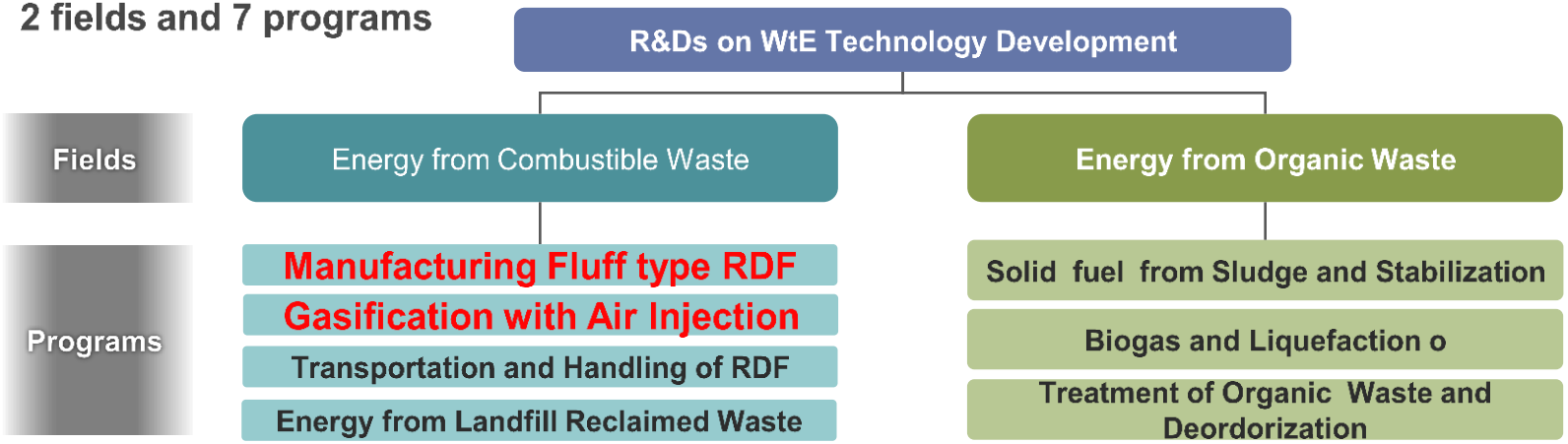
- (Domestic Technology development) – Demonstration system and exportable technology by integrating existing elemental technologies and adjusting to domestic waste streams

Period and budget

- 2013 ~ 2020 (8yrs), 134 M $

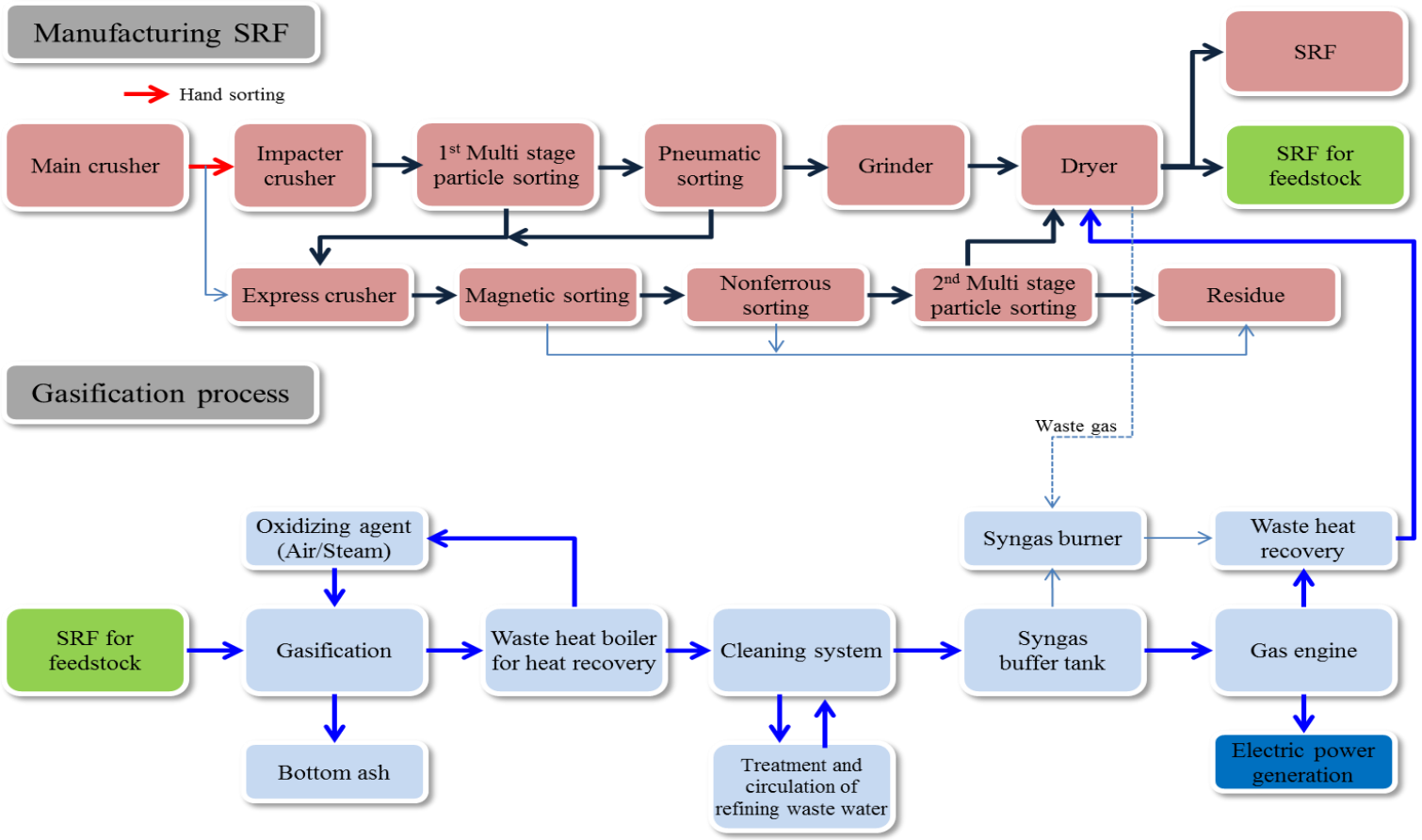
Project contents

- 2 fields and 7 programs



4. Waste to energy technologies

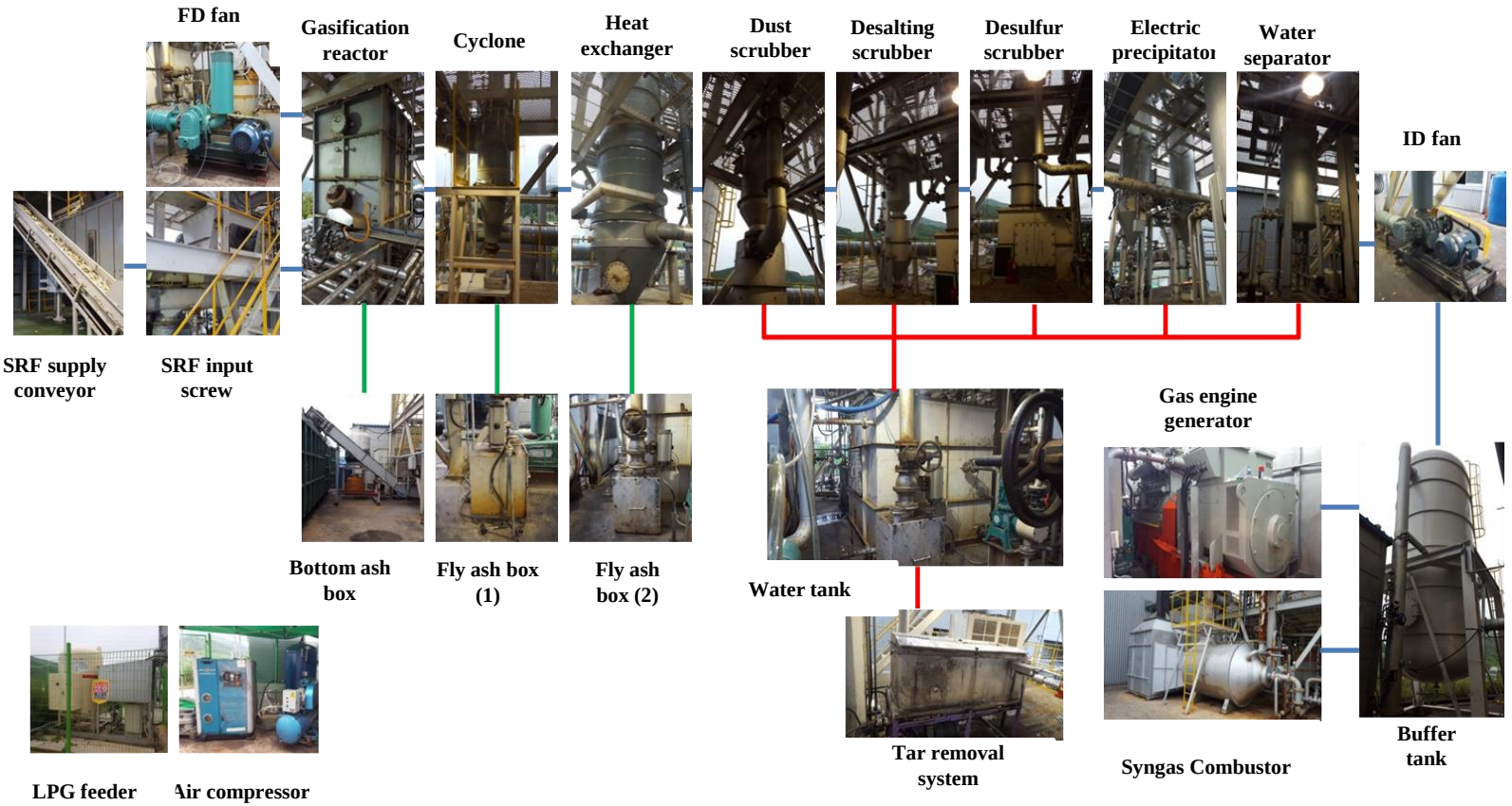
❖**Development of MSW-RDF Manufacturing and Pilot-scale Gasification System (8tons/day Capacity)**



4. Waste to energy technologies

❖ Pilot-scale Gasification Process (in Y city, Developed by Samho, IAE, Yonsei)

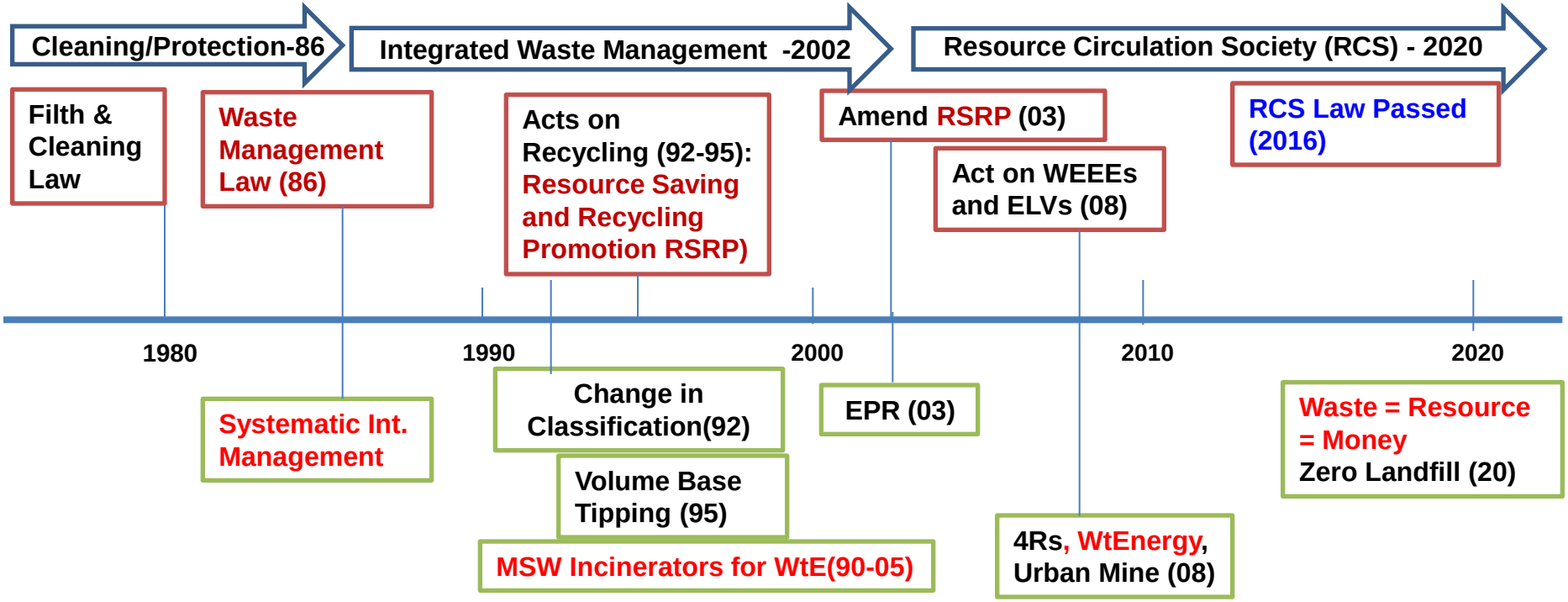
- **8 tons/day scale SRF gasification process & Generation of electricity by gas engine (250 kW)**
- **5 days continuous operation, 20-30 % of H2 and CO in syngas, 0.75kW/kg of waste, 80 tons/day under design**



4. Waste to energy technologies

❖ **Photograph of pilot-scale gasification plant (in Y city)**

5. Conclusion



Landfill	95% (83)	45% (95)	16% (03)	9% (11)	3% (20)
Recycle	3.5% (83)	49% (95)	74% (03)	83% (11)	87% (20)

Major Policies and Strategies with Integrated Waste Management System such as VBT, EPR, WtE and RCS have been effectively applied and Further efforts to RCS establishment are undergoing.

Around 20% of waste is converting to energy with appropriate technologies and still some R&Ds on advanced technologies are being conducted for better efficient conversions in WtE program.

Air & Waste Engineering Laboratory (AWEL)

❖ People in AWEL

	No.
Research Professors	1
Post doctors	2
Ph.D. Students	7
MS Students	6
Undergraduate Students	-
Alumni (Since 1995)	
Ph.D. Graduates	16
MS Graduates	45

❖ Main Research Activities

- ➢ Thermal Treatment Technologies of Waste, Coal and Biomass (Incineration/Pyrolysis/Gasification)
- ➢ Air Pollution Control and Monitoring (Fine PM and HAPs)
- ➢ Emission Characteristics and Management of Mercury and HAPs

Air & Waste Engineering Laboratory (AWEL)

❖ Main projects

- ➢ Technology of thermal energy production and solid refuse fuel using mixing waste of low calorific value (w/Forcebel, Posco E&C, Institute for Advanced Engineering)
- ➢ Gasification of fluff type SRF from household waste (w/Samho Enviro-Tech Inc., Institute for Advanced Engineering)
- ➢ The Development of innovative gasification technology with tar free and purified producer gas for MSW-RDF (Korea-India R&D Program, w/Chogen Powers Ltd., Samho Enviro-Tech Inc., Institute for Advanced Engineering)
- ➢ Development of the integrated treatment technology for high mercury contents (w/J-E tech Co., Ltd.)
- ➢ Estimation on natural emission of long range transported mercury and assessment of contributions by anthropogenic emission between surrounding nations (w/Seoul National Univ., Ajou Univ., Kangwon National Univ.)