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Sewage Sludge Policy of Korea

July 23, 2014

KWWA
KOREA WATER AND WASTEWATER WORKS ASSOCIATION

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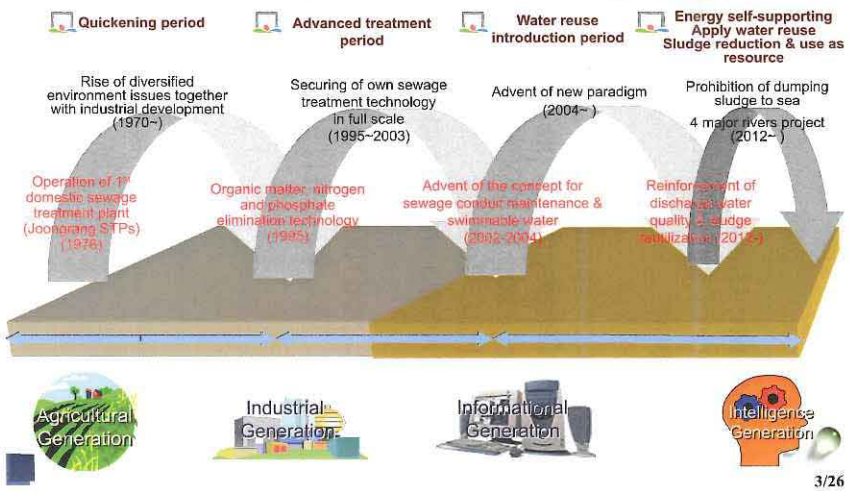
Ⅰ. Progress of Sewage Sludge Policy

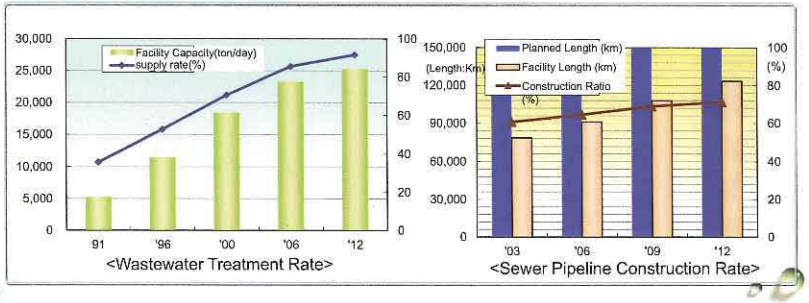
History of Wastewater Works Policy



Ⅰ. Progress of Sewage Sludge Policy

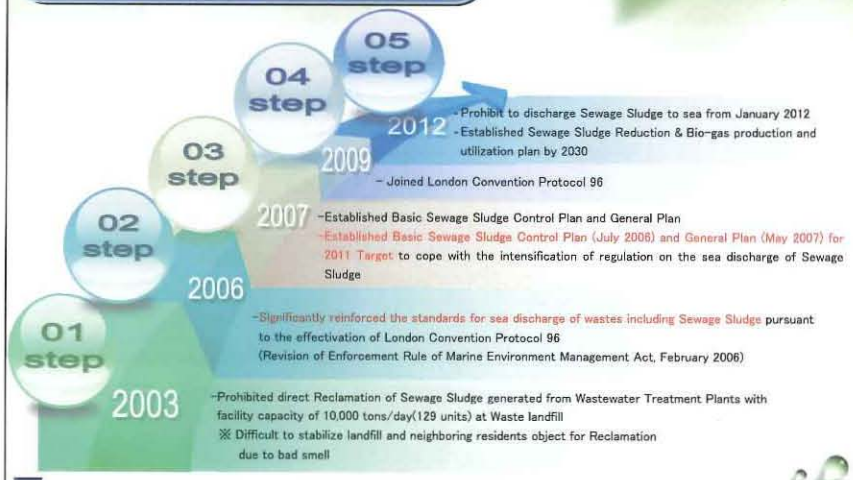
Sewerage supply service rate

Sewerage supply service rate	35.7%('91) ⇒ 52.6%('96) ⇒ 70.5%('00) ⇒ 85.5%('06) ⇒ 91.6%('12)
Pipeline	60.6%('03) ⇒ 64.5%('06) ⇒ 68.9%(' 09) ⇒ 75.8%('12)



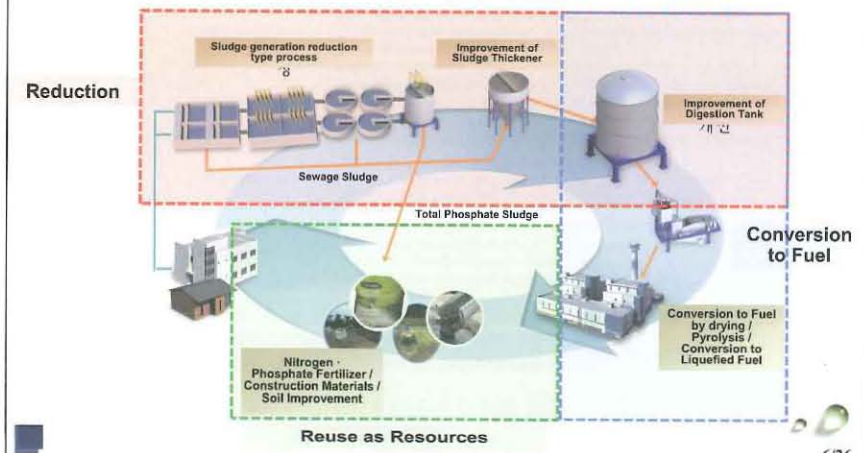
Ⅰ. Progress of Sewage Sludge Policy

Change in Sewage Sludge Policy



Ⅰ. Progress of Sewage Sludge Policy

Sewage Sludge Disposal

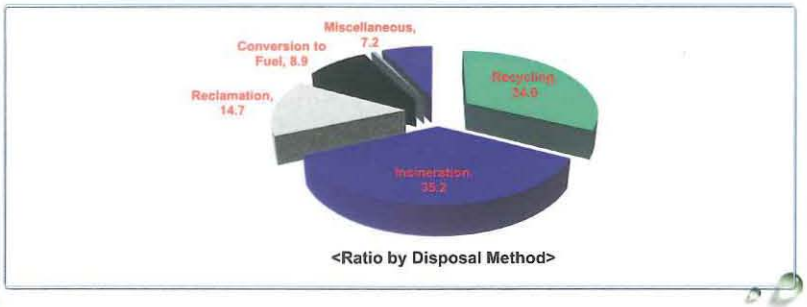


Ⅰ. Progress of Sewage Sludge Policy

Sewage Sludge Generation & Disposal

Generation Quantity: 3,557 ton/day (1996) ⇒ 7,513 ton/day (2006) ⇒ 9,930 ton/day (2012)

Disposal (2012): Recycling 3,380 ton/day, Incineration 3,496 ton/day, Reclamation 1,455 ton/day, Conversion to Fuel 883 ton/day



<Ratio by Disposal Method>

Ⅱ. Status of Sewage Sludge Generation & Disposal

Status of Generation

- Quantity of Sewage Sludge generated continues to increase by 5.9% every year due to expansion of sewer facilities and the installation of total phosphate treatment facilities
- Total Sewage Sludge treatment cost increased from 87.7 billion won(85.7milllion USD) in 2006 to 164.5 billion won(160million USD) in 2011 due to energy cost increase together with sludge generation quantity increase

※ 1USD = 1,023won('2014.5)

< Progress of Sewage Sludge Generation Quantity>

Year		2007	2008	2009	2010	2011	2012	2015 (Estimated)	2020 (Estimated)	2025 (Estimated)
Facility treating more than 500 ㎥/D	No. of STP	357	403	433	470	496	546	639	811	984
	Capacity (thousand ㎥/D)	16,745	17,113	16,681	16,111	18,353	20,392	22,900	27,080	31,260
Quantity of Sewage Sludge Generation (ton/D)		7,518	7,719	8,295	8,438	9,156	9,930	10,763	12,728	14,692

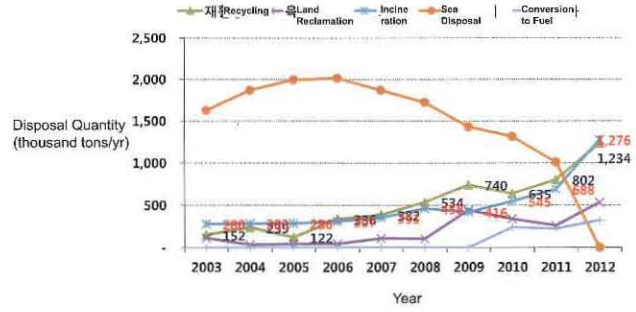
※ Facility capacity means the capacity of the facilities which treat more than 500 tons/D, and figures for 2015, 2020 and 2025 are estimates based on original unit of 0.047% per 1 m^3.

Ⅱ. Status of Sewage Sludge Generation & Disposal

Actual State of Sewage Sludge Treatment

- The result of survey on Sewage Sludge disposal method by year for the period from 2003 to 2012 revealed that recycling and incineration methods showed bigger increases compared to other methods.

< Trend of Change in Disposal Method by Year>



Ⅱ. Status of Sewage Sludge Generation & Disposal

Disposal Costs & Facility Expansion

- Sludge disposal costs increased from 87.7 billion won(85.7million USD) in 2006 to 164.5 billion won(160.8million USD) in 2011 showing annual 13.6% increase on an average
- As of the end of May 2012, 89 facilities (9,157 tons/D) are being operated, and 22 facilities are under construction/design (3,056 tons/D)

< Status of Sewage Sludge Disposal Costs>

Category	2006	2007	2008	2009	2010	2011
Total quantity generated (ton/yr)	2,717,790	2,744,070	2,817,435	3,027,675	3,080,042	3,341,940
Total costs (million USD/ton)	85.7	102.7	115.2	122.5	130.4	160.8
Disposal cost per ton (USD/ton)	31.5	37.4	40.5	40.9	42.4	48.1

< Status of Sewage Sludge Disposal Facilities>

Category	No. of Places	Capacity (ton/D)	Project cost (hundred million USD)	Disposal Method					
				Incineration	Drying	Composting	Carbonization	Solidification	Not decided
Total	111	12,213	14.3	17	48	13	16	13	4
Facilities under operation	89	9,157	8.6	16	32	13	16	12	
Facilities under construction	22	3,056	5.7	1	16	-	-	1	4

Ⅱ. Status of Sewage Sludge Generation & Disposal

Sludge Disposal & Recycling Technology 1

Category		Characteristics
Solidification	Advantages	▪ Disposal cost is insignificant when using earth-sheltering materials ▪ High possibility of recycling of byproducts as construction materials and earth-sheltering materials
	Disadvantages	▪ Quality of earth-sheltering materials deteriorate due to poor curing ▪ Byproducts increase due to use of solidification agent (120~140%) ▪ Solidifying disposal of organic sludge hinders recycling of organic resources ▪ Market demand for bio-soil is very limited (Demand decrease possibility for earth-sheltering materials for reclamation)
Drying (Conversion to Fuel)	Advantages	▪ Levels of foreign and domestic technologies are high ▪ High stability thanks to complete elimination of organic matters when disposing dries matters for fuel ▪ Currently disposal costs are not generated (Free of charge), but in the future sales proceeds are expected to be generated when new renewable energy is introduced through the introduction of RPS (Renewable Portfolio Standard) for new renewable energy.
	Disadvantages	▪ Issue of inefficiency for the use of energy pursuant to incineration after drying is under debate (Partially reusable as fuel) ▪ Limited to sludge with high organic matters in case thermo-electric power plant is the consumer of byproducts. ▪ The consumers of byproducts are mostly located with long distance (Excessive transportation costs)

Ⅱ. Status of Sewage Sludge Generation & Disposal

Sludge Disposal & Recycling Technology 2

Category		Characteristics
Incineration	Advantages	▪ Excellent reduction effect (More or less 8%) ▪ Excellent technical reliability and stability ▪ Good sanitation thanks to thermal disposal based on incineration ▪ High energy efficiency thanks to utilization of waste heat
	Disadvantages	▪ Required long project period due to civil petition possibility ▪ Requires large scale environment pollution prevention facility ▪ Causes civil petitions due to environmental impact
Carbonization	Advantages	▪ High technology level and excellent reduction rate (More or less 10%) ▪ Reutilization of by-products such as the use of steel thermal insulation materials ▪ Efficient use of energy by reuse of carbonized gas as source of heat for drying ▪ Discharge gas after carbonization is comparatively harmless and also discharge volume is low
	Disadvantages	▪ Disposal is limited to organic sludge ▪ Excessive fuel consumption due to heat exchange efficiency deterioration at the time of excessive moisture and organic matter contents decrease
Composting	Advantages	▪ Reutilization in the form of organic matters in by-product ▪ Reduction rate is not high but disposal cost is not required thanks to demand for by-product
	Disadvantages	▪ Very few domestic technology companies ▪ Comparatively high fuel consumption as heat source for drying before decomposition tank ▪ Compost utilization for agricultural products is low due to reinforcement of fertilizer quality standards (Horticultural fertilizer use only)

Average Cost per Ton by Disposal Method

- Average installation cost per ton is 249 million won (24 ten thousand USD)
  - Decomposition is the highest as 340 million won (33 ten thousand USD) while exclusive incineration is the lowest as 140 million won (13 ten thousand USD).
- Survey results showed that installation cost for carbonization technology was somewhat high with high operating costs while in the case of drying/solidification, operation cost versus installation cost is low.

< Average Project Cost per Ton by Disposal Method >

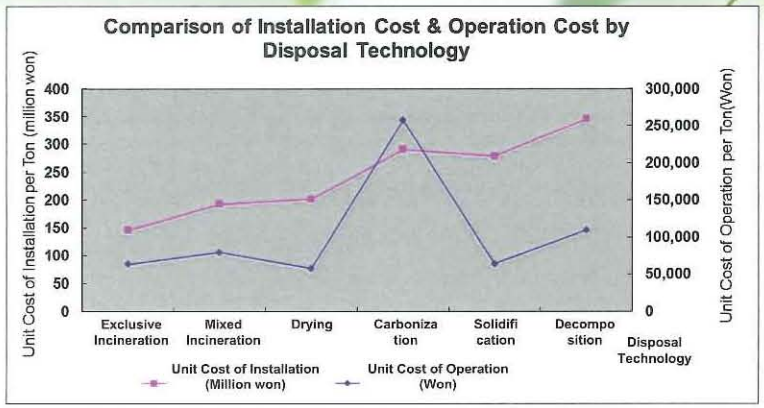
Category	Exclusive Incineration	Mixed Incineration (Drying)	Drying	Carbonization	Solidification	Decomposition
Unit Cost of Installation (ten thousand USD/ton)	13	18.8	19.7	28.3	27.2	33

Unit Cost of Operation per Ton by Disposal Method

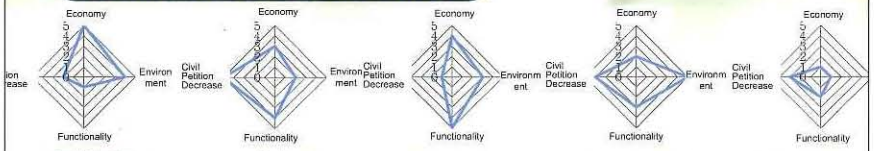
- In the case of incineration, mixed incineration (Stoker method) cost was higher by approximately 16,197 won per ton(16 USD/ton) as compared to exclusive incineration (Fluidized method) cost
  - Due to mixed incineration of living wastes, operation cost for chemicals for the disposal of incineration gas was estimated to have been increased.
- In the case of conversion to fuel/raw material for cement/LFG resources through drying, survey result showed that operation cost was the lowest
- In case the percentage of water in dry sludge is high or disposal volume is less than installed capacity, survey result showed that heat efficiency deteriorates rapidly and thus fuel consumption was higher.
- Even in the case of decomposition facilities, small volume disposal resulted in low heat efficiency and thus fuel consumption was higher.

< Unit Cost of Operation per Ton by Disposal Method >

Category	Exclusive Incineration	Mixed Incineration (Drying)	Drying	Carbonization	Solidification	Decomposition
Unit Cost of Operation (USD/ton)	61.4	77.2	55.6	251.3	62.0	107.1



Comparison of Disposal Method



Category	Solidification	Drying	Incineration	Carbonization	Decomposition
Economy	◎	●	●	▲	▲
Environment	●	▲	●	◎	▲
Functionality	▲	●	◎	●	▲
Civil Petition Decrease	▲	◎	▲	●	●

◎: Extremely excellent, ▲Excellent, ●: Average

- It is expected that Drying method with excellent economy, functionality and civil petition decrease effect will supplement environment effect when utilizing new renewable energy (Digestion gas). When civil petition is solved, incineration is also possible. Carbonization needs to be supplemented.

Ⅲ. Sewage Sludge Reduction & Energy Generation

Sludge Disposal Paradigm Shift

- 30~40% of Sewage Sludge generated were dumped to sea but sea dumping was prohibited from 2012 and thus Sewage Sludge disposal Cost was increased.
  ※ Disposal cost of public ground disposal facility is at 100 thousand won per ton(98 USD/ton), which is 2 times of the sea dumping cost for 50 thousand won (49USD /ton) per ton
- For the reduction of sludge disposal cost, fundamental reduction of sludge generation is required.
- Parallel implementation of sludge disposal facility and sludge reduction and bio-gas production facility will be efficient.
  - In line with the prohibition of sea dumping so far, focus was given to the Expansion of sludge disposal facility and enough attention was not paid to sludge reduction and bio-gas production

Sludge generation should be reduced through sludge reduction and bio-gas should be produced.

Ⅲ. Sewage Sludge Reduction & Energy Generation

Status and Operation State of Digestion Tank

- Among 470 public wastewater treatment facility, the facilities with digestion tank are 65, and 57 of which are under operation except for 8 non-operating facilities (As of the end of 2010)
- Total capacity of the digestion tanks under operation is 1,824 thousand tons, digestion tanks with the capacity of 10,000~50,000 tons are operated in most cases
- Total digestion gas volume generated is used for heating digestion tanks while some are used for heating/cooling of treatment facilities, and reminder is combusted as surplus gas

< Number of Treatment Facilities by Digestion Tank Capacity >

Capacity of Digestion Tank (thousand m³)	Total	Over 50	Below 50 ~ Over 20	Below 20 ~ Over 10	Below 10 ~ Over 5	Below 5
Number of Treatment Facility	57 (100%)	7 (12%)	13 (23%)	12 (21%)	7 (12%)	18 (32%)

< Status of Digestion Gas Utilization >

Use of Digestion Gas	Total volume generated	Heating of Digestion Tank	Others			Incineration
			Cooling/Heating	Power Generation	External Supply	
Volume generated (thousand m³/D)	429,483	249,100	21,474	21,045	30,493	107,371
Ratio (%)	100	58%	5%	4.9%	7.1%	25%

Ⅲ. Sewage Sludge Reduction & Energy Generation

Problems in Digestion Tank Operation & Improvement Plan

- In case total phosphate with high concentration is eluted and recycle water containing High level of total phosphate is flow into treatment plant again during the digestion process, total phosphate treatment efficiency is deteriorated.
- Digestion efficiency of digestion tank is average 35.2% which is below designed efficiency of 50%.
- Domestic technology level for digestion tank operation is low

- For sludge reduction by enhancing digestion efficiency of digestion tank, surplus sludge pretreatment (Solubilization) technology should be introduced.
  - Technology to enhance biodegradability of sludge at the digestion tank by destructing cell wall of surplus sludge

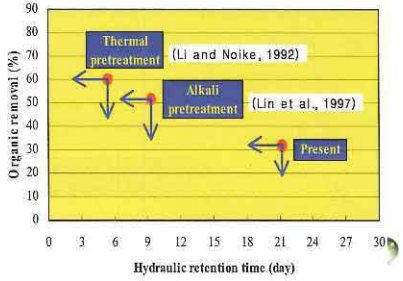
Ⅲ. Sewage Sludge Reduction & Energy Generation

Surplus Sludge Pretreatment Method & Effect

<Surplus Sludge Pretreatment Method>
- ☞ Mechanical treatment: Electron beam irradiation, ultrasonic wave, high pressure injection, cavitation
- ☞ Heat treatment: 60 ℃~175 ℃
- ☞ Chemical treatment: Acid/alkali treatment, ozone treatment
- ☞ Biological treatment: Hydrolysis enzyme injection, use of thermophilic bacteria
- ☞ Mixed treatment: Heat treatment + Chemical treatment, Mechanical treatment + Chemical treatment

<Surplus Sludge Pretreatment Effect>
- ☞ Increase post-bioprocess (Aerobic, anaerobic) efficiency
- ☞ Improve sludge dewatering function
- ☞ Extinction of pathogenic germs
- ☞ Suppress foam generation at digestion tank

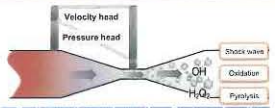
<Impact of Anaerobic Digestion>
- ☞ Increase digestion rate based on surplus sludge cell destruction, sludge reduction effect → Increase digestion gas volume generated
- ☞ Decrease of detention time in digestion tank



Ⅲ. Sewage Sludge Reduction & Energy Generation

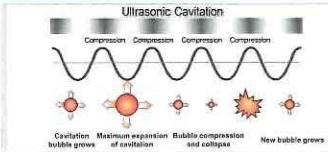
Pretreatment Application Case

Hydrodynamic Cavitation



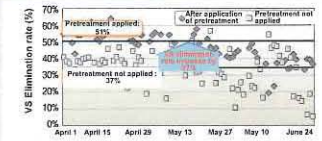
- When fluid flows reduced cross-section area like Venturi, cavitation is created due to pressure drop from flow speed increase
- Decomposition of surplus sludge Biofloc and destruction of cell wall (SCOD increases by more than 100%)

Ultrasonic Cavitation



- Cavitation is created at the ultrasonic wave generating area due to pressure drop from wavelength of acoustic wave
- Bio-degradation of digestion sludge is promoted and activation of micro-organism is also promoted

Nanji STP



- VS elimination rate is 51% (Raw sludge + surplus sludge) → Increase by 37% compared to existing rate

Surplus Sludge Destruction

Before treatment	After treatment

- Decomposition of surplus sludge Biofloc and destruction of cell wall
- Undifferentiation of sludge particles

Ⅲ. Sewage Sludge Reduction & Energy Generation

Records of Reduction Technology Application

- Applied solubilization technology based on thermohydrolysis, hydrodynamic, ultrasonic wave to 8 sewerage treatment plants
- According to reduction technology application, sludge was reduced to 246 tons/D and dewatered sludge reduction cost was 9.02 billion won/year(88 ten thousand USD/year). Urban gas substitution cost was 15.94 billion won(15.6million USD), from which operating cost is saved by 24.96 billion won(24.4million USD) per annum

Name of Treatment Plant	Application Method	Dewatered Sludge Volume generated		Expected Effect (ten thousand USD/Yr)		
		Before installation (ton/D)	After installation (ton/D)	Sub-total	Sludge reduction cost	Urban gas substitution cost
A City (520000 ㎥/D)	Thermohydrolysis + Mesophilic digestion	271	223	321.9	171.2	150.7
B City (150000 ㎥/D)	Mesophilic digestion	65	53	137.0	43.1	93.9
C City (500000 ㎥/D)	Thermohydrolysis + Mesophilic digestion	192	158	272.0	121.3	150.7
D City (900000 ㎥/D)	Hydrodynamic + ultrasonic wave + Mesophilic digestion	460	379	947.2	292.6	654.6
E City (530000 ㎥/D)	Hydrodynamic + ultrasonic wave + Mesophilic digestion	262	215	431.5	164.4	267.1
F City (70000 ㎥/D)	ultrasonic wave + Mesophilic digestion	37	31	68.5	25.4	43.1
G City (30000 ㎥/D)	ultrasonic wave + Mesophilic digestion	20	16	123.3	14.7	108.6
H City (200000 ㎥/D)	Mesophilic digestion	80	66	140.9	49.9	91.0
Total		1,387	1,141	2,442.3	882.6	1,559.7

Ⅳ. Future Policy Direction

Policy Objectives & Strategy

- By 2025, 150 billion won(1.5 hundred million USD) will be invested to 82 Public Sewerage Treatment Facilities (Over 40000 ㎥/D) for new installation and improvement of Digestion tanks to reduce sludge and save energy

- (Short-term strategy) Implement Pilot Projects
  - Completed 8 pilot projects and diffuse/share the results of projects
- (Mid/long-term strategy) Sludge reduction and gas production increase through new installation and improvement of digestion tanks
  - 1st stage (2012~2020) : Improve Treatment Plants with low digestion rate (39 plants) and new installation of digestion tanks (9 places)
  - 2nd stage (2021~2025) : Improve existing digestion tanks (10 places) and new installation of digestion tanks (24 places)

- Maintain total sludge generation volume to 2008 level through sludge reduction
  ※Estimated sludge generation volume by 2025 (14,692ton/D) → Maintain 7,720ton/D level through sludge reduction
- Using Sewage Sludge, produce and utilize 655 thousand ton/D of bio-gas
  ※ Represents 1.5 times of 2011 level (429 thousand ton/D), fuel for 22,000 cars (20L per car)

Ⅳ. Future Policy Direction

Model Project Implementation Results

- Implemented pilot projects for Sewage Sludge reduction and bio-gas production and use (2010~2012)
- 91.9 billion won(89.9 million USD) was invested to 8 places for the production of 98,137 ㎥/D bio-gas and utilized it for digestion tank heating, urban gas substitution, power generation and fuel for vehicles
- Energy self-supporting rate of 8 treatment plants from 11% to 21% on an average

Facility Category		Sewage treatment capacity (㎥/D)	Max. estimated bio-gas production volume (㎥/D)	Bio-gas utilization plan	Amount required (million USD)
Total		2,900,000	98,137	-	89.9
1st stage	Suwon Sewage Treatment Facility	520,000	9,790	Urban gas substitution	9.8
	Chuncheon Sewage Treatment Facility	150,000	6,090	Cogeneration	9.4
	Changwon Sewage Treatment Facility	500,000	9,750	Vehicle fuel	8.4
2nd stage	Bucheon Sewage Treatment Facility	900,000	42,455	Cogeneration	17.8
	Ansan Sewage Treatment Facility	530,000	17,322	Urban gas substitution	21.5
	Asan Sewage Treatment Facility	70,000	2,774	Cogeneration	7.6
	Mungyeong Sewage Treatment Facility	30,000	7,027	Cogeneration	10.4
	Gunsan Sewage Treatment Facility	200,000	5,929	Urban gas substitution	5.0

Ⅳ. Future Policy Direction

Expected Effects

- (Bio-gas Production) Production of total 655,000 ㎥/D of bio-gas and its utilization through installation and improvement of digestion tank for sewage treatment facility with the capacity of over 50,000 ton/D
  - Bio-gas generated for 655,000 ㎥/D through installation and improvement of digestion tanks will generate revenue for 38.3 million USD(in the case of cogeneration) per annum by supplying it for cogeneration(Heating of digestion tanks using surplus heat generated) and urban gas substitution

- (Greenhouse Gas Reduction) Energy generation from sewage sludge will give the effect of greenhouse gas reduction for 740,660 CO^2 ton/year, representing economic effect for 4.2 million USD annually
  - Through energy generation from digestion gas of sewage treatment facilities, internationally acknowledgeable CER(Certified Emission Reductions) for approximately 740,000 tons of CO^2 can be secured by 2025

- (Sludge Reduction) Applicable for the expansion to use as sewage sludge reduction facility
  - When digesting sewage sludge and producing bio-gas, sludge volume generated is expected to reduce by more than approximately 29%