6th EWA / JSWA / WEF Joint Conference
„The Resilience of the Water Sector“
15-18 May 2018, Munich, Germany

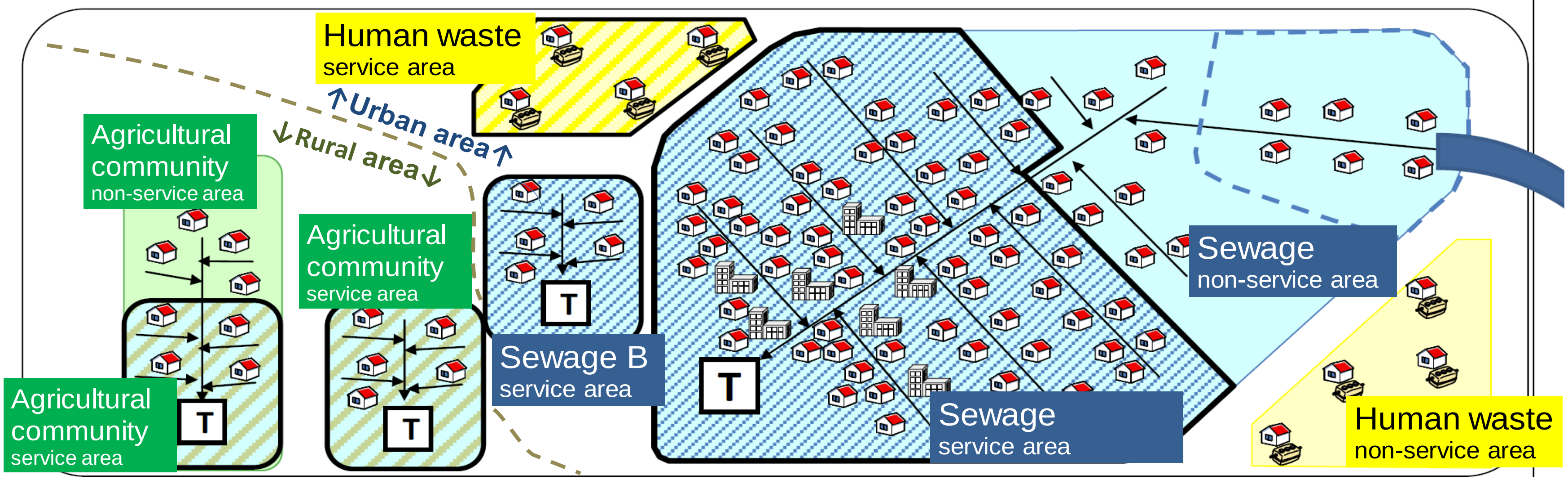
Optimization method for sustainable wastewater treatment systems in the population declining society

Takeshi Ishikawa, Ryo Matsumoto, Tsuyako Fujii, Hiromasa Yamashita

National Institute for Land and Infrastructure Management , Japan

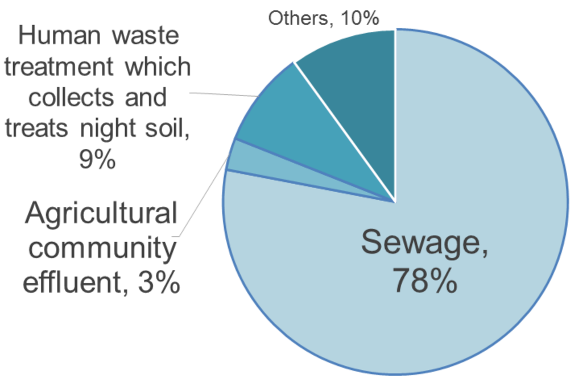
17 May 2018

Introduction (Wastewater treatment of Japan)



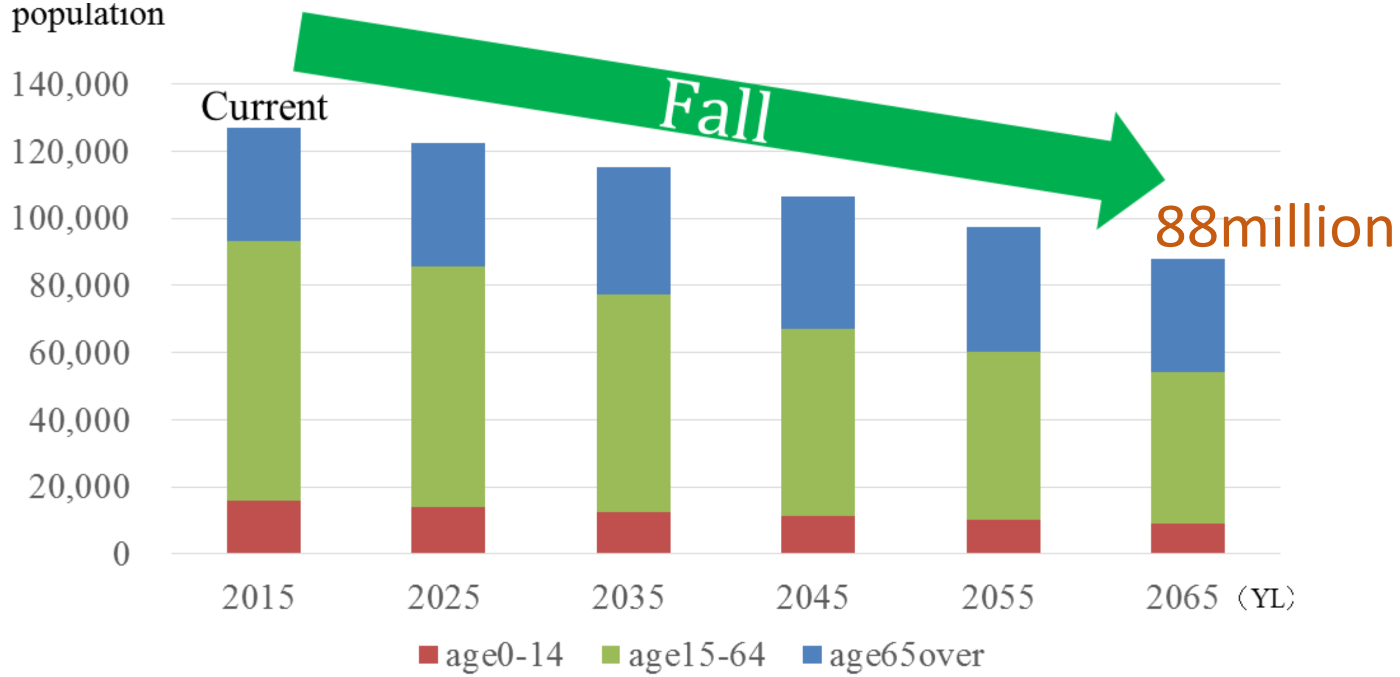
Local governments have adopted the waste water treatment system , which are suitable for their regional condition.

- The wastewater treatment service ratio is 90.4%.
- Service population is about 115 million people (Total population 127million)



Introduction (Population declining of Japan)

The overall population of Japan is expected to fall from the present level of around 130 million to around 88 million in 2065.



The service population of wastewater treatment and then its sewage inflow also will decrease.

The sustainability of the wastewater treatment service is now on crisis.

- The operation efficiency of the facilities could be decreased.
- The revenue from user-fee would also be decreased.
- The shortage of financial resources
- The shortage of technical staff
- Demand for the reconstruction / renewal of aged facilities in the near future…..

It’s necessary to introduce sustainable wastewater treatment system under the population declining society.

Our research

The optimization method of wastewater treatment systems

- Collected and created cost functions
- Clarified the relation between the operating rate and the maintenance cost
- Developed the estimation method of the maintenance cost in population declining society
- Evaluated for technical and environmental points

Target facilities in this research

Target on the small to medium-sized treatment plants which would be sensitively affected due to decrease in inflow.

Facility (Occupy approximately 90% of the total)	**Capacity (Small to medium)**	**Process** (Those of accounted for about 80%)
Sewerage (piping, urban area)	10,000 m^3 / day or less	Oxidation ditch process (OD) , Conventional activated sludge process (CAS)
Agricultural community effluent (piping, rural area)	1,000 m^3 / day or less	JARUS-Ⅰ,Ⅲ,XⅠ,XⅡ,XⅣ (Japanese standard)
Human waste treatment (non-piping)	100kl/day or less	All

The optimization method of wastewater treatment systems(outline)

Basic survey and setting prerequisites

- Basic information (population, inflow, service situation etc.)

Setting representative integration scenarios

- (no integration, full integration, partial integration)

Comparison of economics

- Calculate life cycle cost(consider operating rate)
- Confirm the most economical one

Technical and environmental evaluation

- Facility capacity, Energy consumption etc.

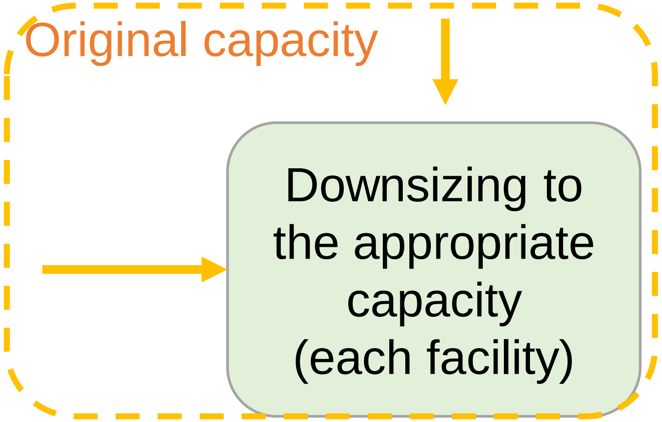
Comprehensive evaluation

- Select the integration scenario
  → Sustainable wastewater treatment system

Representative integration scenario 1

No integration

(Downsizing separately)

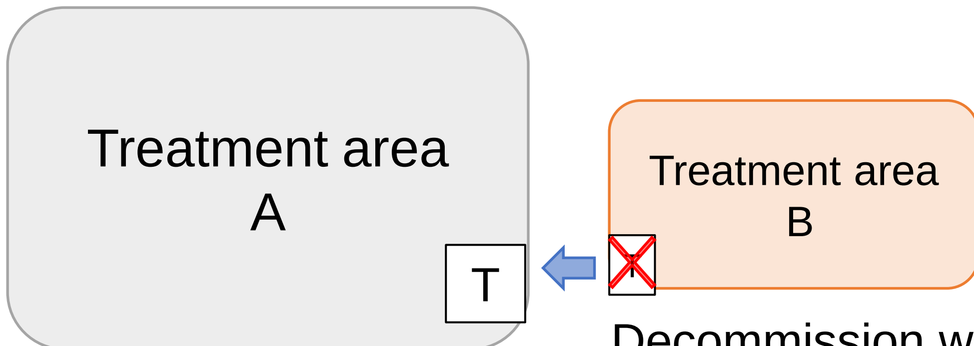


Efficiency could be improved by reducting the facility size (downsizing) to appropriate facility capacity based on the future inflow prediction.

Representative integration scenario 2

Full integration

(Unify treatment areas)



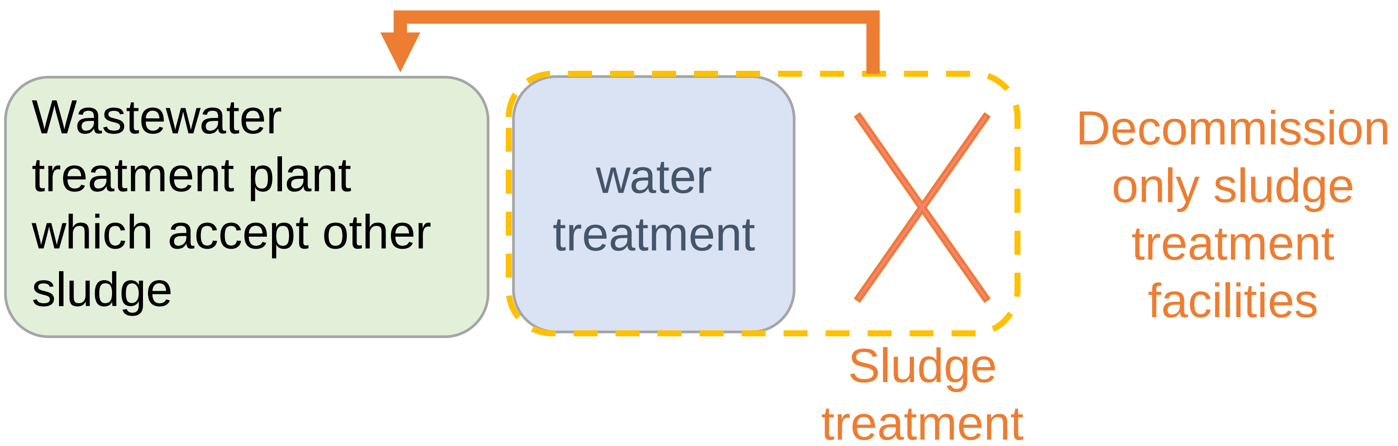
Decommission wastewater treatment plant and connect to another ones

Efficiency could be improved by decommissioning one of treatment facility and unifying treatment areas.

Representative integration scenario 3

Partial integration

(Unify sludge treatment function)



Efficiency could be improved by decommissioning the function of sludge treatment in one of treatment facility and unifying it.

Collection and creation of cost functions (some example)

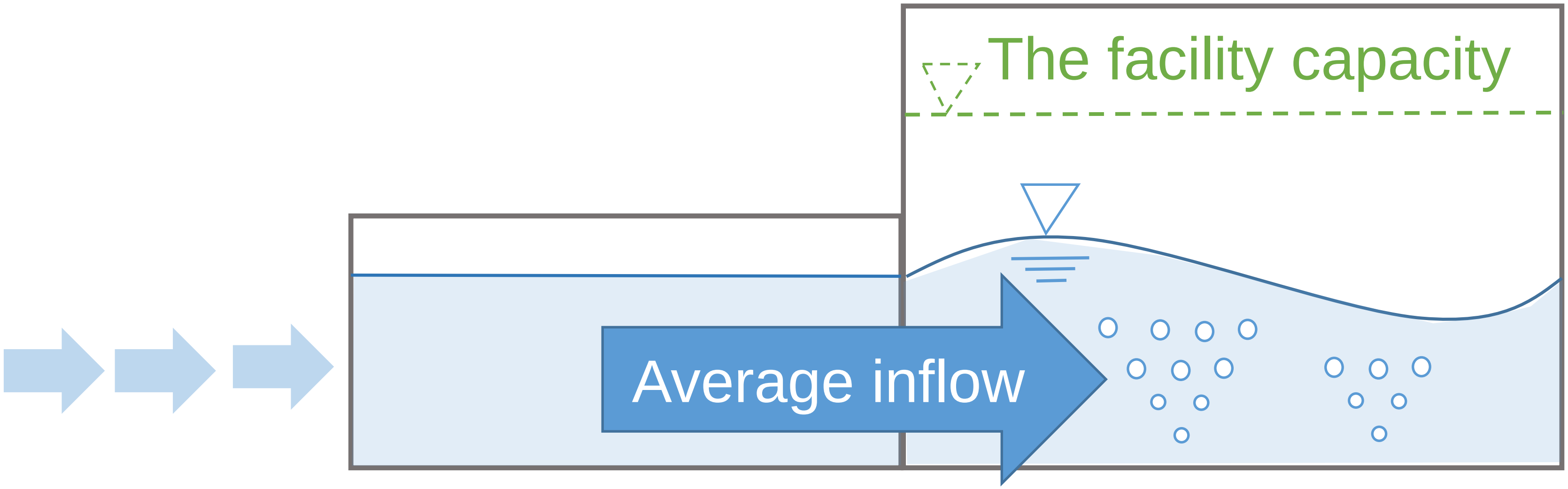
facilities , equipment			variable (x)	usable range	function(y)
1.reconstruction / renewal cost [thousand JPY]					
sewerage	CAS	●overall※	m^3/day	10,000～50,000m^3/day	y = 1,550,000（x/1,000）$^{0.58}$ ×(103.3/101.5)
		mechanical	m^3/day	1,000～10,000m^3/day	y = 72,734x$^{0.26}$
		mechanical(water treatment)	m^3/day	1,000～10,000m^3/day	y = 978x$^{0.59}$
	OD	●overall※	m^3/day	～299m^3/day	y = 14,680x$^{0.49}$
		●overall※	m^3/day	300～1,300m^3/day	y = 505,000（x/1,000）$^{0.64}$
		●overall※	m^3/day	1,400～10,000m^3/day	y = 1,380,000（x/1,000）$^{0.42}$ ×(103.3/101.5)
		mechanical(water treatment)	m^3/day	1,000～10,000m^3/day	y = 1,580x$^{0.66}$
agricultural community effluent		●overall	person	-	y = 2271.2x$^{0.6663}$
human waste treatment	over all	standard process	kl/day	20～100kl/day	y = 237,636x$^{0.4571}$
	pretreatment equipment	standard process	kl/day	20～100kl/day	y = 57,548x$^{0.5274}$
pipe	construction	●manhole type pumping station	point	-	y =9,200x
		●gravity system	m	-	y =63x
		●pressurized sewer	m	-	y =45x
		●small scale	m	-	y =56x
2.maintenance cost［thousand JPY/year］					
sewerage	CAS	overall	m^3/day	1,000～10,000m^3/day	y = 2,468x$^{0.382}$
		●overall		10,000m^3/day～	y = 18,800（x/1000）$^{0.69}$×(103.3/101.5)
	OD	●overall	m^3/day	300～1,300m^3/day	y = 19,000（x/1000）$^{0.78}$
				1,400～10,000m^3/day	y = 28,600（x/1000）$^{0.58}$×(103.3/101.5)
agricultural community effluent		●overall	person	-	y = 37.811x$^{0.6835}$
human waste treatment	over all	overall	kl/day	20～100kl/day	y = 17,845x$^{0.57}$
	pretreatment equipment	overall	kl/day	20～100kl/day	y = 6,716x$^{0.2692}$
pipe		●manhole type pumping station	point	-	y =220x
		●pipe（standard）	m	-	y =0.060x
		●pipe（small scale）	m	-	y =0.031x

●The function described in the past document

※Including structures, machinery and electrical equipment

The relation between the operating rate and the maintenance cost

Operating rate x
= (Average inflow volume) (m^3/day)
/ (The facility capacity) (m^3/day)



The relation between the operating rate and the maintenance cost

- Arranged the maintenance cost as M-coefficient ”*km*”.
- “*km*” indicates the maintenance cost per unit inflow at a certain operating rate.

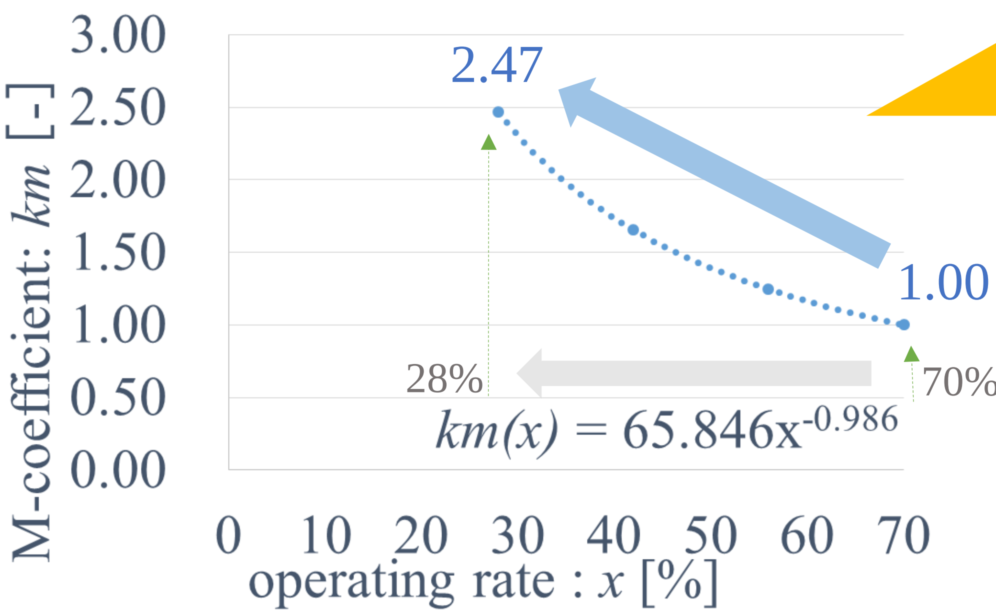
Maintenance cost
per unit inflow
(certain operating rate)

***km* (ratio)**

Referance value(Fixed)
(ones at max operating rate)

The larger “km” indicates the more inefficient operation situation.

“*km*” is increased as the operating rate decline.



The maintenance cost doesn’t decrease, even if the inflow decreases.
(*km* isn’t constant)

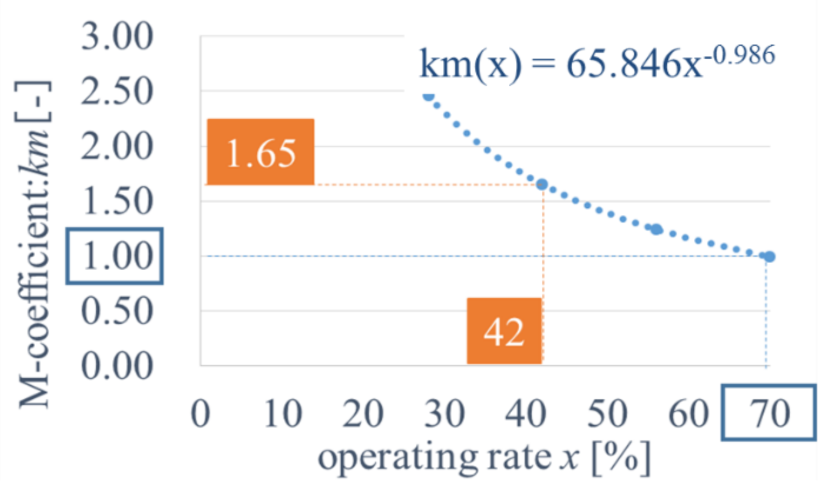
Difficult to control aeration(single channel) etc.

Fig. Relation between the operating rate and M-coefficient (Sewerage:OD)

<u>The lower the operation rate, the worse the operation efficiency of the facility.</u>

The future maintenance cost estimation(an example)

Condition	
Facility type	Sewerage(OD)
Current maintenance cost	65,000,000JPY/year
Current inflow	1,000,000m³/year
Current operating rate	70%
Future inflow (estimate)	600,000m³/year
Future operating rate	42%



- *km*'s ratio (current and future)　1.65 / 1.00 = 1.65
- Future maintenance cost(per unit inflow) 65 × 1.65 = 107.25 JPY / m^3
- Future maintenance cost(total)　107.25 × 600,000 = **64,350,000** JPY / year

Reference: Estimated results without considering operating rate　***Big difference***

65(using current unit of maintenance cost) × 600,000　= **39,000,000** JPY / year

The cost estimation would be more accurate by this method.

Some important points for the examination in case of the integration is listed for technical evaluation.

Sort	problems that must be checked
Pipe	Whether the flow capacity is satisfied or not
	Whether the flow velocity is satisfied or not
	How often the pipe cleaning is required
pumping station	Whether the pumping capacity is satisfied or not
Wastewater treatment plant	Whether the capacity is satisfied or not
	In the case of acceptance of night soil etc., its receiving ratio

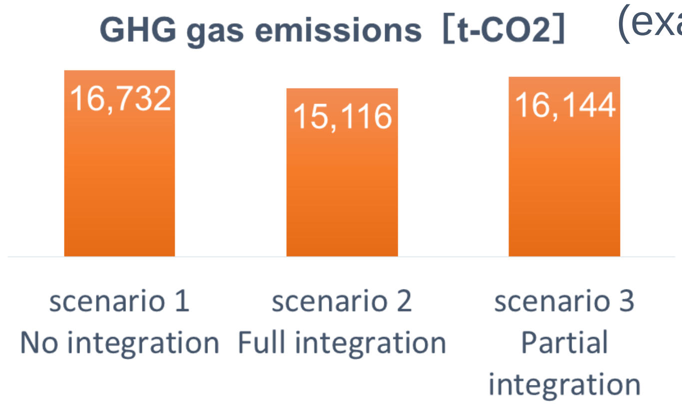
Essential points

In particular, Notice when the ratio exceeds 10%.

Environmental evaluation (some example)

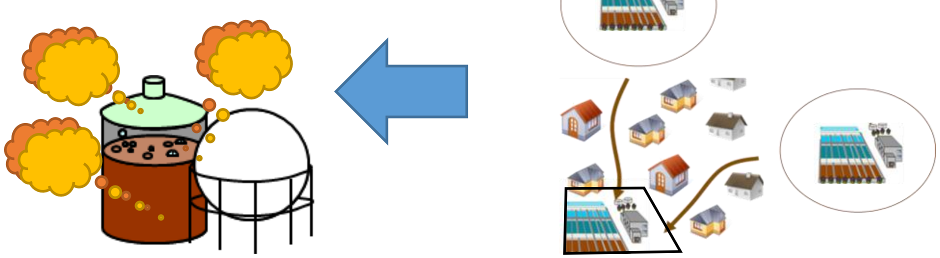
- Calculation the energy consumption and greenhouse gas(GHG) emissions from the power consumption.

(example)



- The merit of sludge concentration by integration
  increase of digested gas generation amount, etc.

Increased digested gas



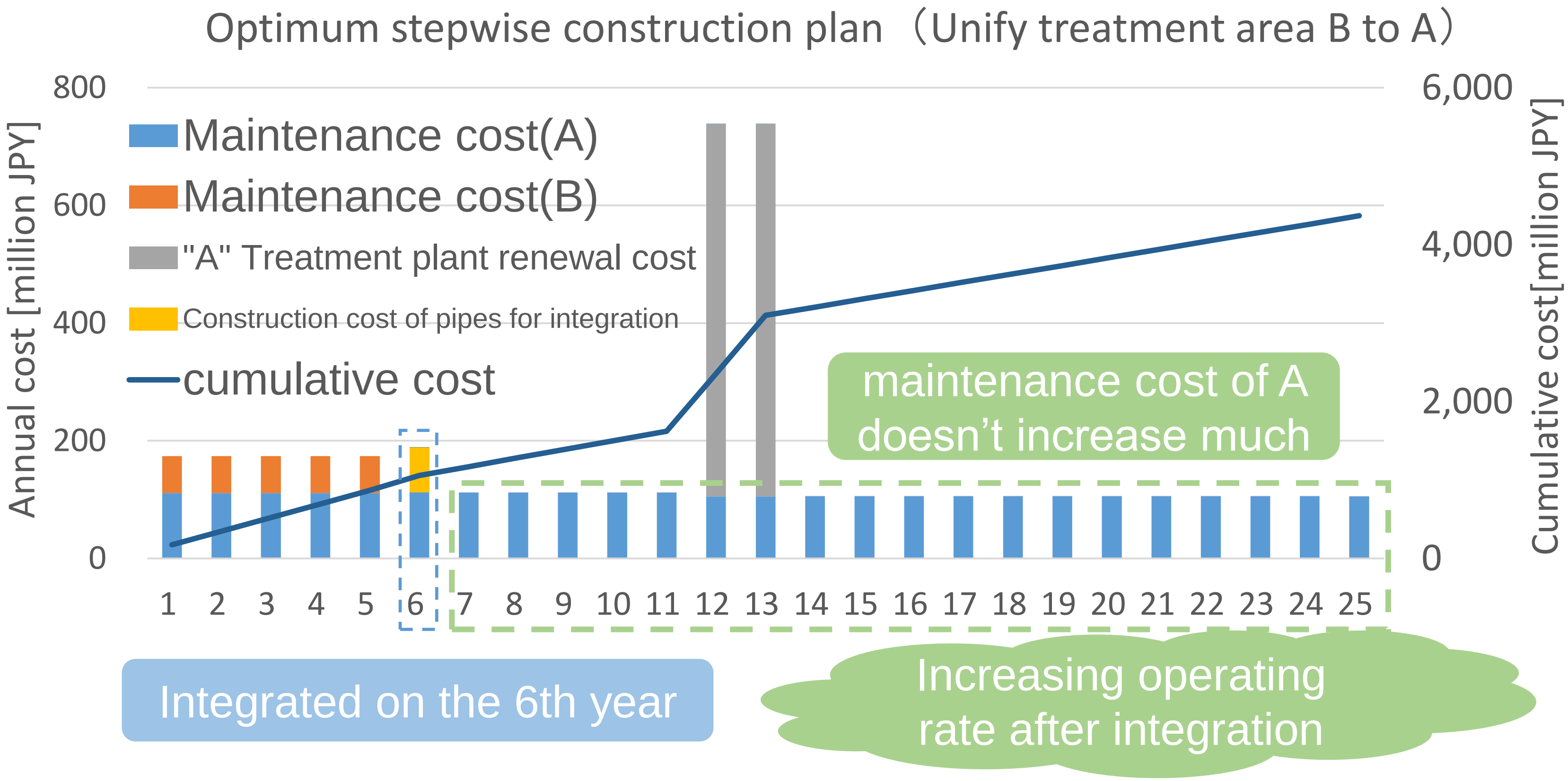
E.g. Collect of sludge by integration.

Comprehensive evaluation by optimization method(example)

Factors	scenario 1	scenario 2	scenario 3
Overview	no integration	full integration	partial integration
Life cycle cost [million JPY]	5,879	4,368	5,016
Technological evaluation	-	the capacity of the pipe etc.	the capacity of the treatment plant etc.
Environmental evaluation			
Energy consumption [Mega joules]	120 million	109 million	116 million
GHG emissions [t-CO_2]	16,732	15,116	16,144
Evaluation results		most efficient	

In this example, Scenario2 (full integration) was found to be the most efficient.

Considering the renewal schedule of each facility(treatment plant, pipes of A,B) for the selected scenario, optimum stepwise construction plan was developed.



Summary

- Developed into **the coefficients** from **the relation** between **the operating rate** and **the maintenance cost**. It enable us to estimate the maintenance cost in the future.
- Confirmed **the tendency** that **the maintenance cost per unit inflow ”*km*”** increase as the operating rate declines each facilities.
- Developed **the optimization method for sustainable wastewater treatment systems** in the population declining society.

Thank you very much

for your attention!