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Approach to Bioenergy Recovery

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1. Bioenergy and green effect gas (GHG) control potential
2. Bioenergy utilization system
    1. Anaerobic digestion with energy recovery
    2. Waste incineration energy recovery
3. Biofuel production system
    1. Bioethanol
    2. Biodiesel fuel
4. Bioutilization system integration and some considerations

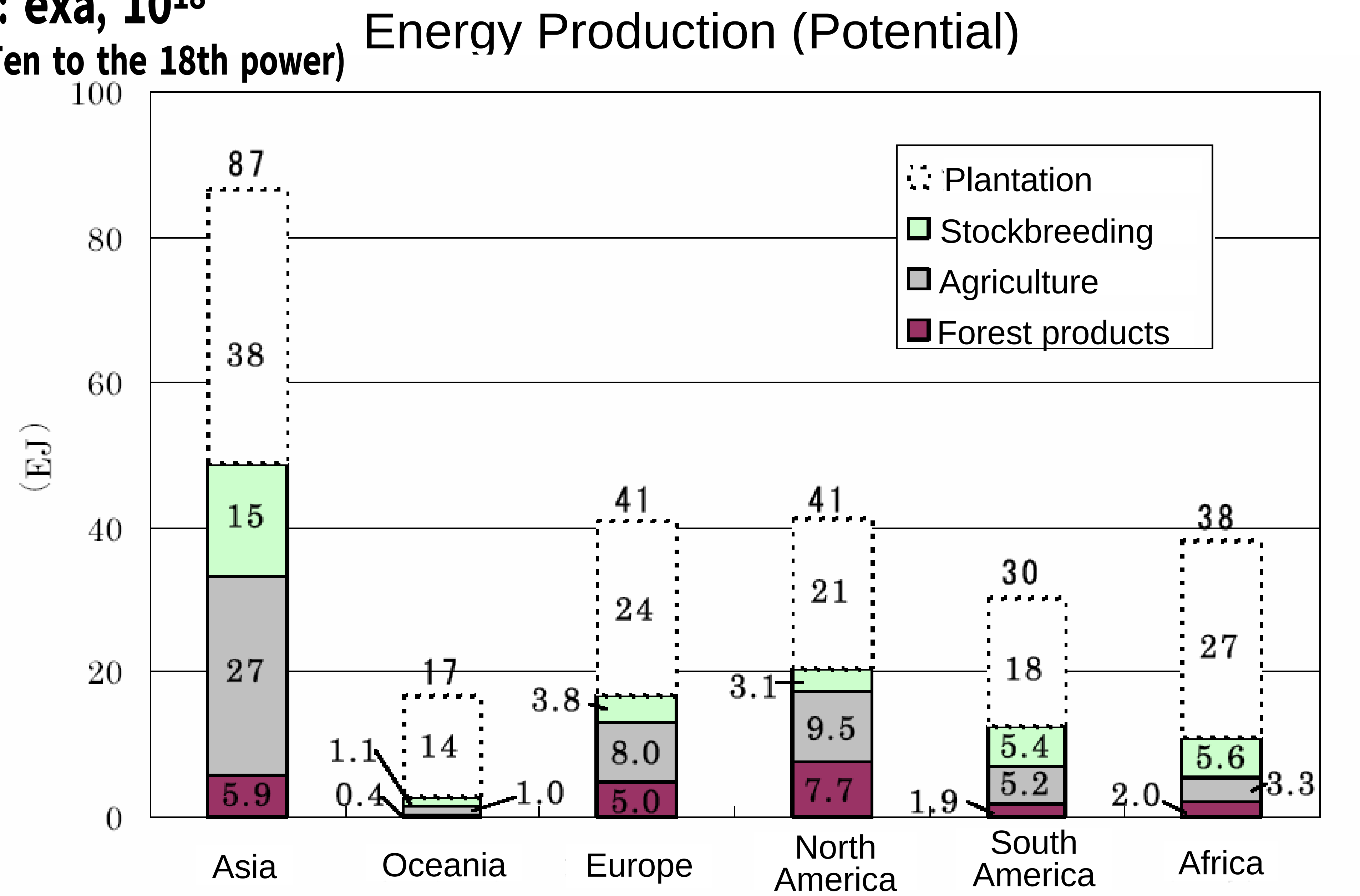
1. Bioenergy and green effect gas (GHG) control potential

3R Measures for Biogenic Waste

- **Feeding**: Use food residues for livestock feed. It is required that ingredients are homogeneous, essential nutrients are contained, and foreign bodies and hazardous substances should not be mixed.
- **Composting:** A biotreatment under an aerobic condition with oxygen, which brings increased temperature. Managing conditions such as a specific temperature (55 ~ 60°C), moisture, the C/N ratio and bacterial sterilization are crucial.
- **Eco-fuel:** A renewable fuel which is produced by processing biological resources. If it is substituted for fossil fuel, it contributes to reduction of the greenhouse effect gases emitted by fossil fuel, which means that it doesn't lead to increase of CO_2.
- **Methane fermentation:** A method to recover fermentation gases including methane generated from biological decomposition of organics under an anaerobic condition. The amount of biogas recovered is about 100 ~ 200 m^3 per ton of municipal solid organic waste. The methane concentration is roughly between 55% and 70%. The energy content is about 20 ~ 25 MJ/m^3.
- **Thermal recovery from incineration:** A method to recover steam and electricity from waste heat in the thermogenic process of degrading carbonaceous matters with the presence of oxygen.

International Biomass Energy Potential

E: exa, 10^{18}
(Ten to the 18th power)



Source) NEDO: Biomass Energy Introduction Guidebook (2nd edition) (September 2005)

Domestic Bioresource Potential

Estimate the domestic potential based on various statistics

⇒ The usable amount is equivalent to 31.51MkL crude oil.

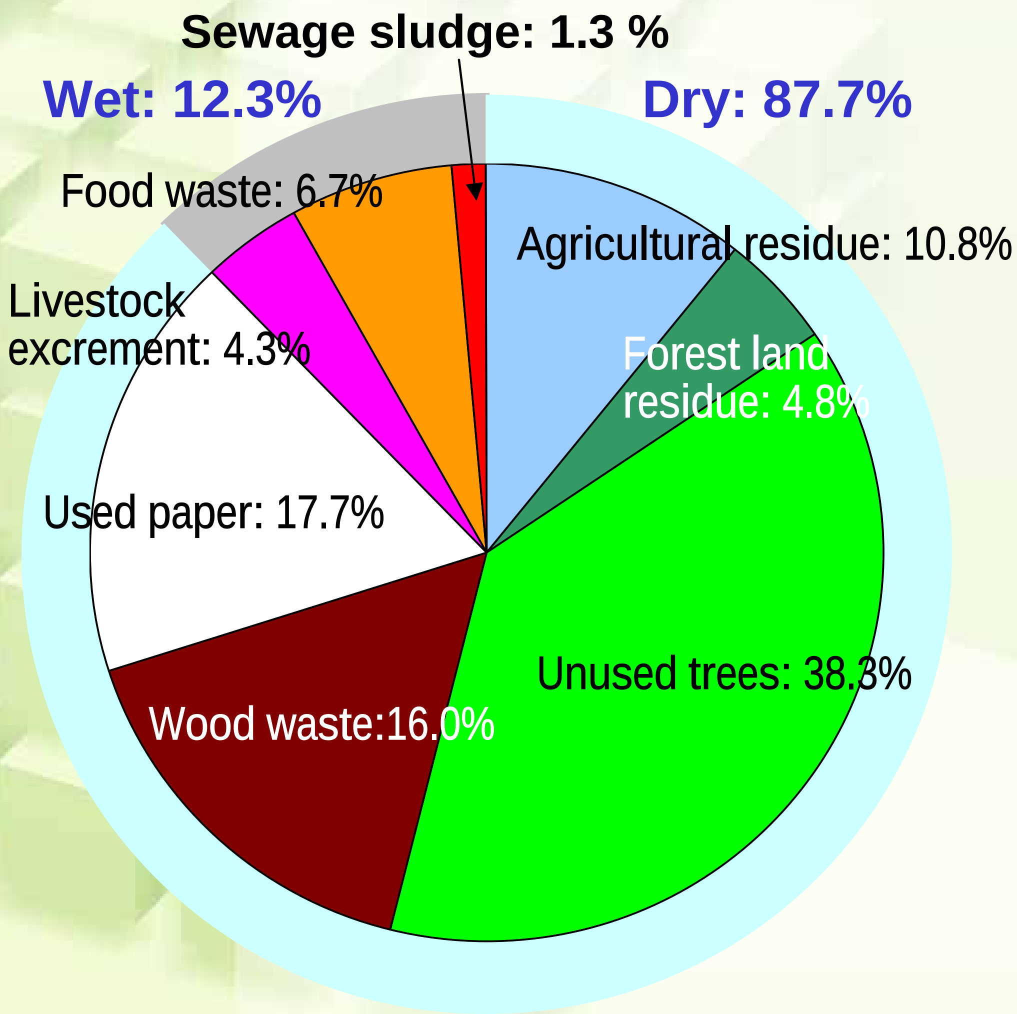
Item		Production (M tons/yr)	Usable (M tons/yr)	In crude oil volume (M kL/yr)
Agriculture	Rice straw, rice chaff and barley straw	13.93	10.92	3.41
Livestock	Livestock excrement	78.93	78.93	1.36
Forest	Forest land residues and thinned wood	9.80	7.47	1.50
	Unused trees	57.00	57.00	12.08
Waste	Food waste	29.43	27.41	1.91
	Cooking oil	0.18	0.18	0.19
	Paper waste	13.47	13.47	5.58
	Waste timbers	16.79	10.60	4.61
	Thinned branches	2.20	2.20	0.44
	Sewage sludge	115.08	72.08	0.41
Total		336.80	280.26	31.51

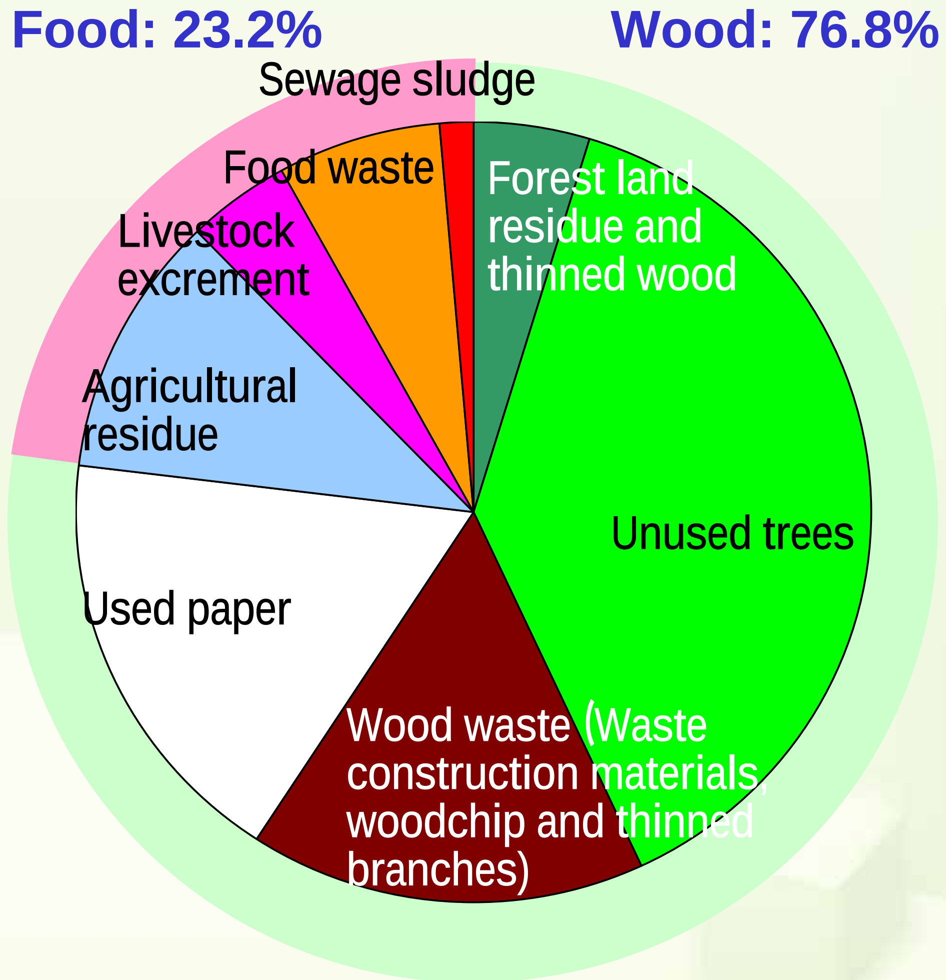
Note) The "Usable" includes the compost usage, the energy usage as well as the current unused amount. It doesn't include only the materials recycled (feed and construction materials) other than compost.

Source) National Institute for Environmental Studies: Development of technology for producing hydrogen from bio resources and waste (March 2006)

Domestic Biomass Amount in Japan (Energy equivalent)

Usable amount: 1,120 PJ/yr (P: 10^{15})





Note) Usable amount = Production – Materials recycled
Calorie calculation method: Dry: Lower calorific value (wet basis); Wet: Bio gas lower calorific value
Source) National Institute for Environmental Studies: Development of technology to produce hydrogen from bio resources and waste (March 2006)

2. Bioenergy Application Systems

2.1 Anaerobic Digestion with Energy Recovery

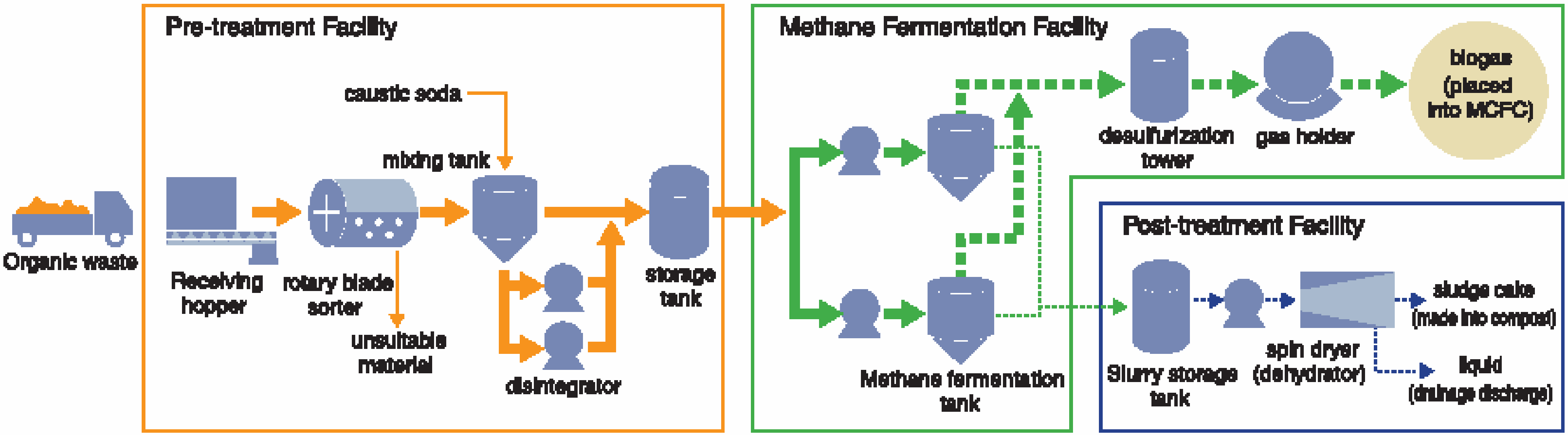
Classification of Anaerobic Digestion Systems

Solid concentration	Fermentation temperature	Shape of digestion tank	# of digestion tanks	Application of biogas
Wet (~10%) / Dry (~ 40%)	Mesophillic: 35°C / Thermophillic: 55 °C	Vertical / Horizontal	1 / 2 (Solubilization + Digestion)	Power generation / heat utilization / fuel for CNG vehicles

Type	Target biomass	Characteristics	System
Wet	Food waste / Human waste / Sewage sludge / Livestock excrement	Advantages: Easy to manage in slurry state; and great achievements Disadvantages: Long-time fermentation and high production of digestive fluids	Bigadan, BIMA, Linde, UASB, Uhde/Renaissa, Mebius, Metakles
Dry	In addition to the above, paper / thinned branches / highly concentrated organics	Advantages: Short-time fermentation; high gas yield rate brought by higher decomposition rate of organics; and low production of digestive fluids, which leads to good sanitation Disadvantages: Necessity of a large heat quantity to heat a fermenter.	Dranco, Kompogas

Source) NEDO: Biomass Energy Introduction Guidebook (2nd edition) (September 2005)

Wet Methane Fermentation System

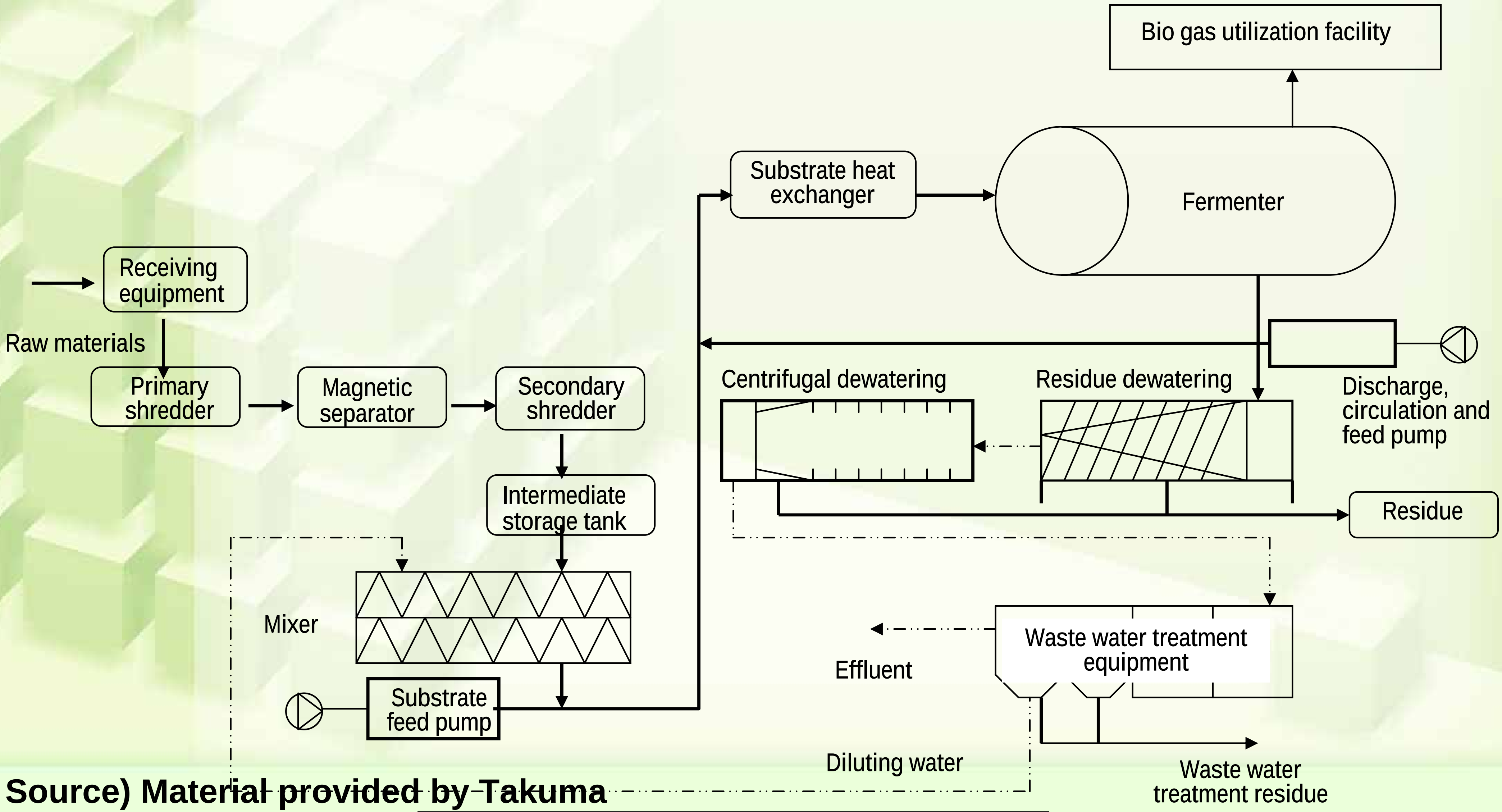


Aich Expo new energy plant
(Food waste: 4.8 tons/day)

Source) NEDO: A Tour of Energy Sources of the Future （http://www.nedo.go.jp/expo2005/energy/publication.html）

Dry Methane Fermentation System

Kampo Recycle Plaza (Sonobe-cho, Kyoto; Food waste and woods & grasses: 50 tons/day)



Source) Material provided by Takuma

S.Sakai, Kyoto University, Asia 3R

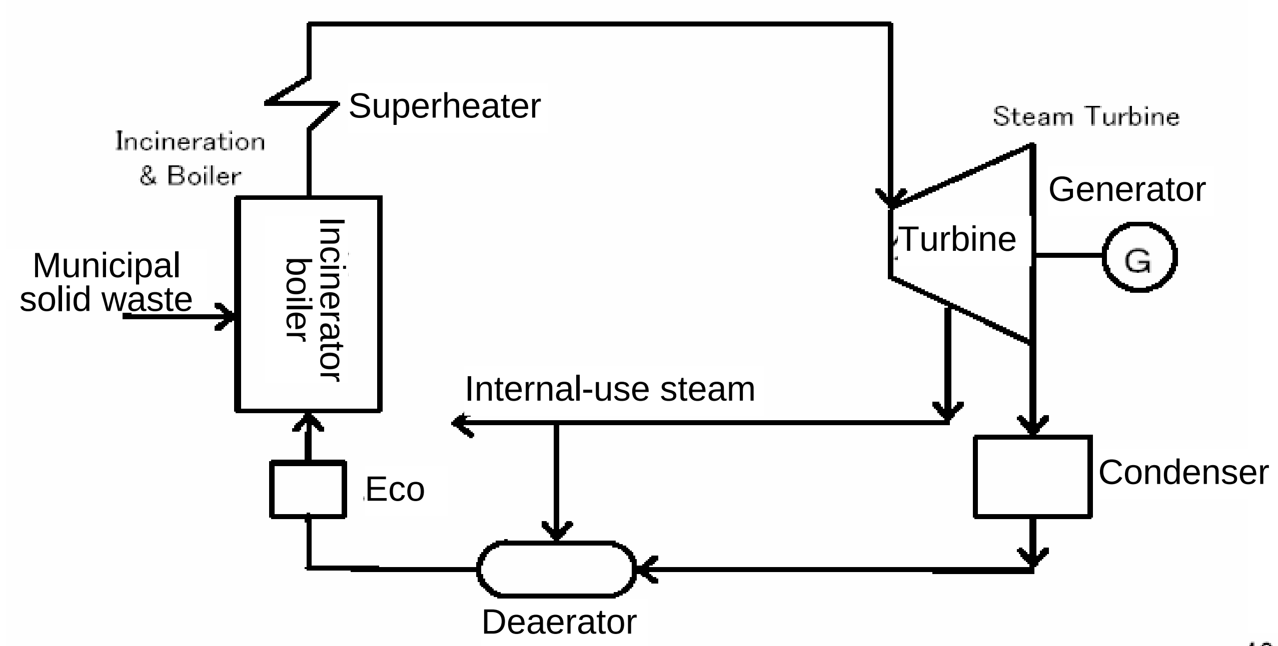
Facilities to Introduce Methane Fermentation and Power Generation

Target biomass	Power Generation	No Power generation	# of Total	Treatment capacity (rough figure)	Note
Livestock excrement	42	28	70	1800 ton/day ~	
Food waste (Solid)	28	19	47	2000 ton/day ~	Including human waste and sewage sludge mix treatment facilities
Food waste (Wastewater)	8	39	47	110000 m^3/day ~	The actual food and plant effluents treated
Sewage sludge	20	1	21		
Total	98	87	185		

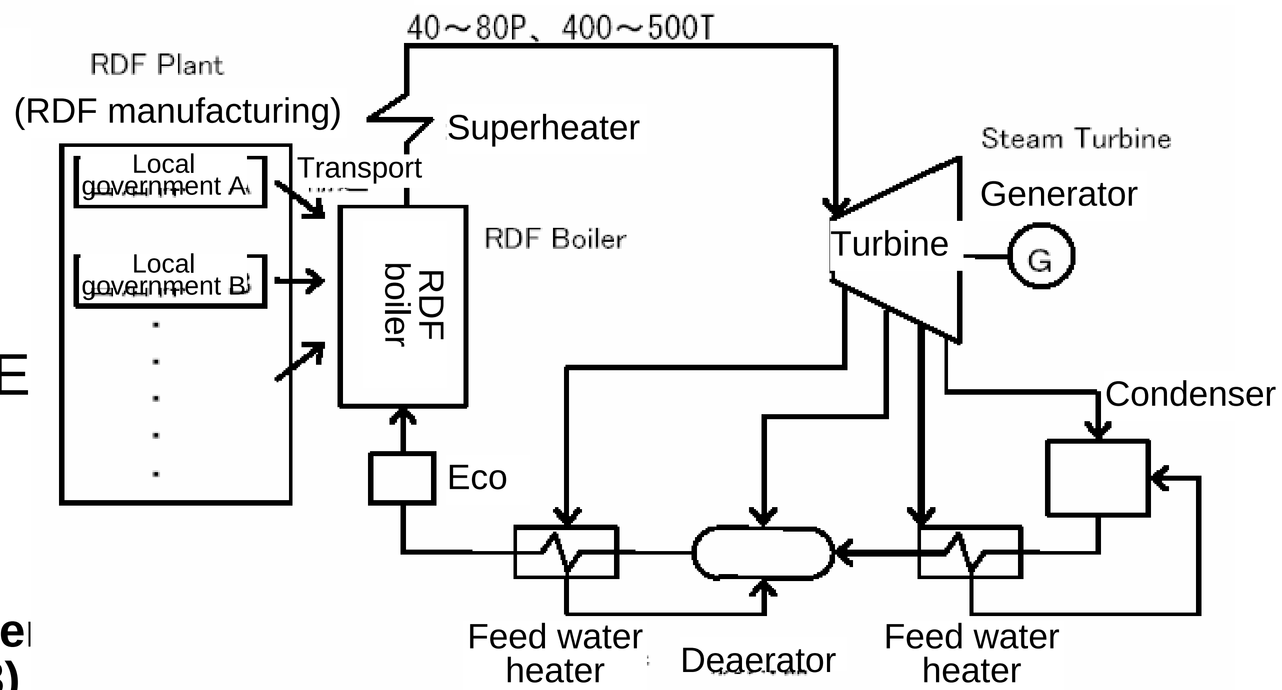
Source) NEDO: Biomass Energy Introduction Guidebook (2nd edition) (Sept 2005)

2.2 Current Status of Waste Incineration Energy Recovery Technologies

Waste Incineration Energy Recovery Technologies



Conventional waste power generation, Flow of Conventional Type WTE (Waste to Energy)



RDF power generation
Flow of RDF Firing Type WTE

Source) Kiichiro Ogawa: Waste power technology trend in Japan (Oct 2003)

Status of Waste Power Generation Technology

- To avoid metal corrosion caused by HCl gas produced from incineration, steam conditions cannot be raised. Therefore, the power generation efficiency is low at about 10-15%.
- In waste incineration facilities, since steam is consumed in the process, some quantity of steam can be input in generator.

Use of residual heat in waste incineration facilities (2003)

Usage	User					Non-user
	Total	Use of hot water	Use of steam	Power generation	Others	
# of facilities	995	923	244	271	79	401

# of waste power generation facilities and its capacity (2003)

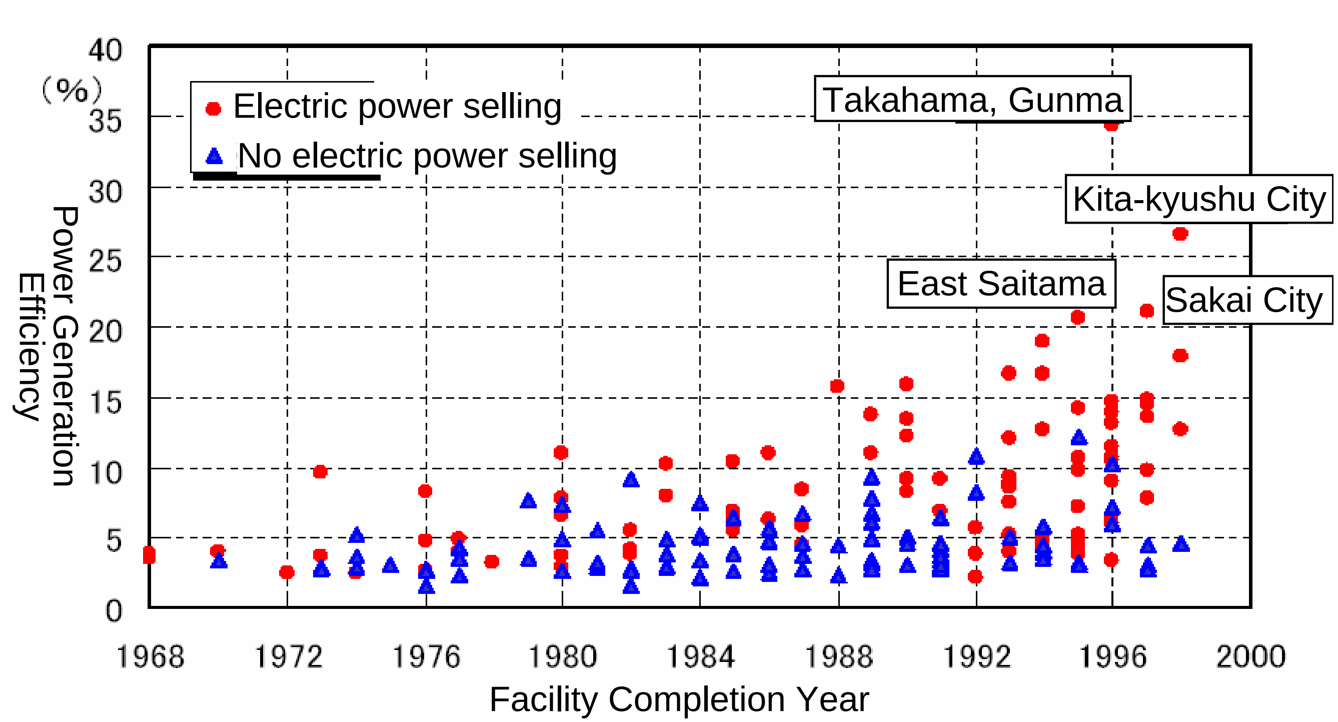
# of facilities	271
Total power generation capacity (MW)	1,441
Average power generation efficiency (%)	10.23
Total power generation (GWh)	7,100

Source) Ministry of the Environment: White paper on recycling-based society 2005

Measures for Power Generation Efficiency Improvement

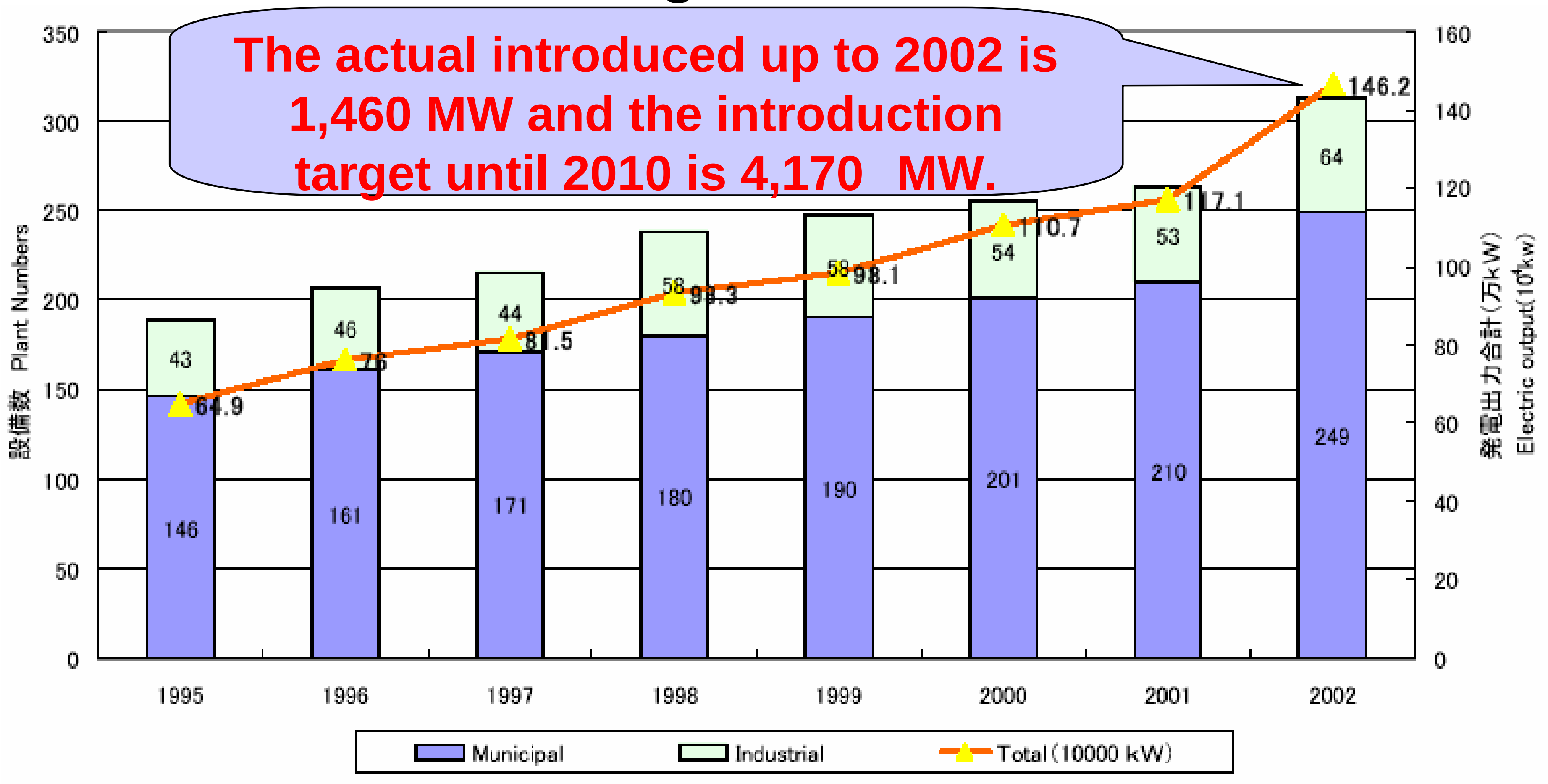
- Improve the boiler steam conditions (Adopt the 4MPa x 400°C class)
- Reheat cycle (Reheat the steam after using for power generation and run the reheat turbine)
- Complex power generation (Super waste power generation and Re-powering)
- Regeneration cycle (Use of extraction steam)
- Recover the turbine exhaust heat (Introduce the water-cooled condenser and district heat and cooling)

Relations between the facility completion year and its power generation efficiency



Source) Kiichiro Ogawa: Waste power generation technology trend in Japan (Oct 2003)

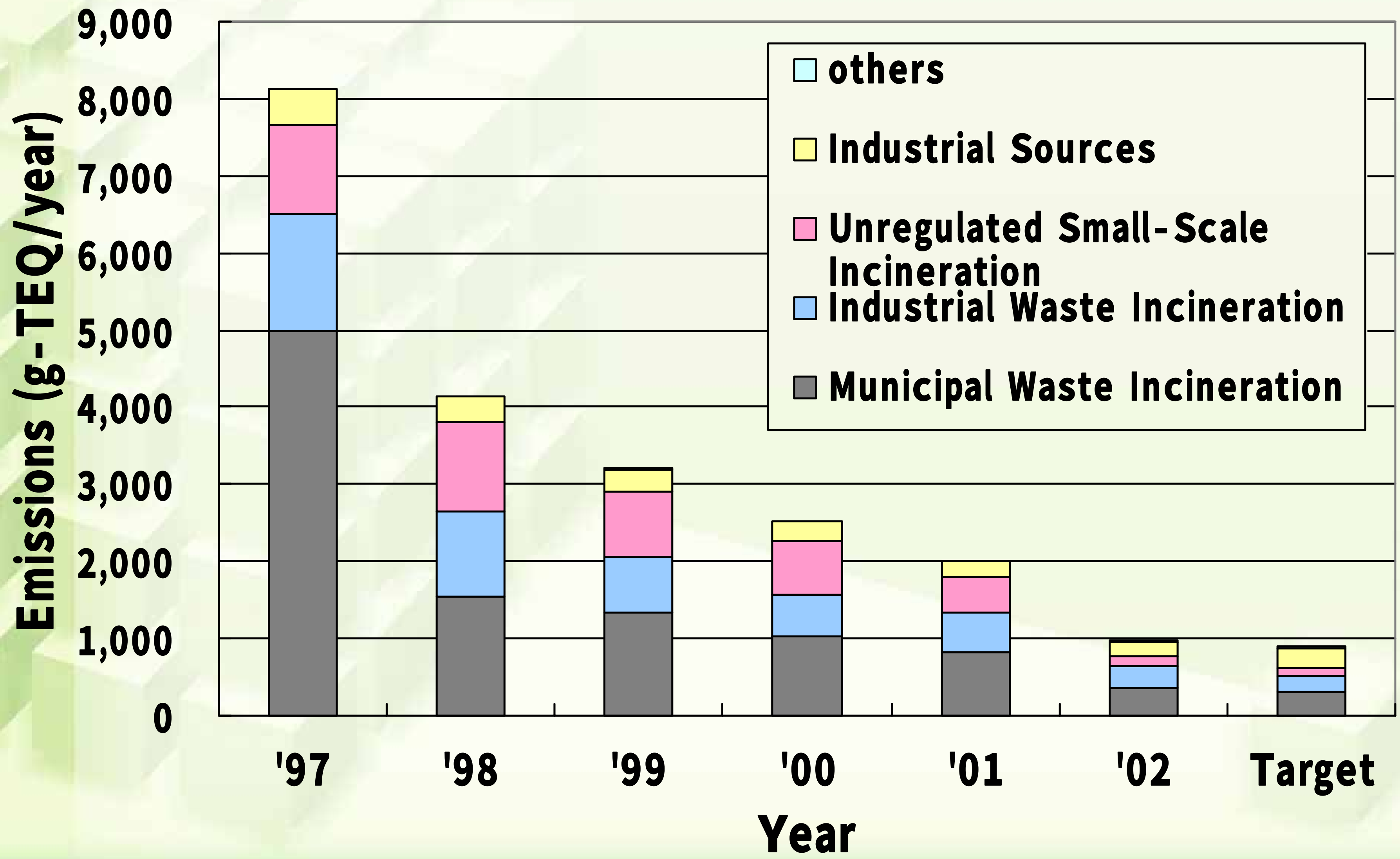
Introduction of Waste Incineration and Power Generation Technologies



Trend of WTE installed in Japan

Note)
The electricity generated in 2003 is 8370 GWh in total, specifically, 6890 GWh from municipal solid waste and 1480 GWh from industrial waste (provided by Agency of Natural Resources and Energy). Assuming the average of electricity generated from all sources is 0.378kg-CO_2/kWh, the CO_2 reduction is equal to 3.16M tons-CO_2.
Source) Kiichiro Ogawa: Waste power generation technology trend in Japan (Oct 2003)

Dioxin Emissions in Japan



BEP of Waste Incineration

Waste management practices

3 R initiative – Reduce, Reuse & Recycle

Waste inspection and characterization

Incinerator operating and management practices

Ensuring good combustion

Avoiding Cold starts, upsets and shutdowns

Monitoring combustion gases

BAT of Waste Incineration

◆BAT of Combustion Techniques

- **Maintain temperatures in the gas phase combustion zones for completing oxidation of the waste (for example, 850°–950° C in grated municipal solid waste incinerators, 1,000°–1,200 ° C when chlorine content of waste is high)**
- **Provide for sufficient residence time (for example, 2 seconds) and turbulent mixing in the combustion chamber to complete incineration**
- **Preheat primary and secondary air to assist combustion**
- **Use continuous rather than batch processing wherever possible to minimize start-up and shutdown releases**

◆BAT for Flue Gas Treatment

- **Improvement of dust abatement and recirculation**
- **Acid gas removal techniques**
- **Activated carbon filter**
- **Selective catalytic reduction**

Achievable performance levels

0.01 - 0.1 ngTEQ/Nm^3

Target for Energy Recovery from Biomass and Waste

- In the plan to achieve the goals of the Kyoto Protocol (April 2005), the target for introducing new energy is 19.1M kL (crude oil equivalent) and the potential reduction in CO_2 emissions is equivalent to approximately 46.9M tons - CO_2 in 2010.

Category	The amount introduced [crude oil equivalent: M kL]	CO_2 reduction [M tons-CO_2]
Solar power generation	1.18	2.90
Wind power generation	1.34	3.29
Waste + Biomass power generation	5.85	14.36
Use of solar heat	0.90	2.21
Use of waste heat	1.86	4.57
Use of biomass heat	3.08	7.56
(for transportation fuel)	(0.50)	(1.23)
Unused energy	0.05	0.12
Black liquor and waste materials	4.83	11.86
Total	19.10	46.90

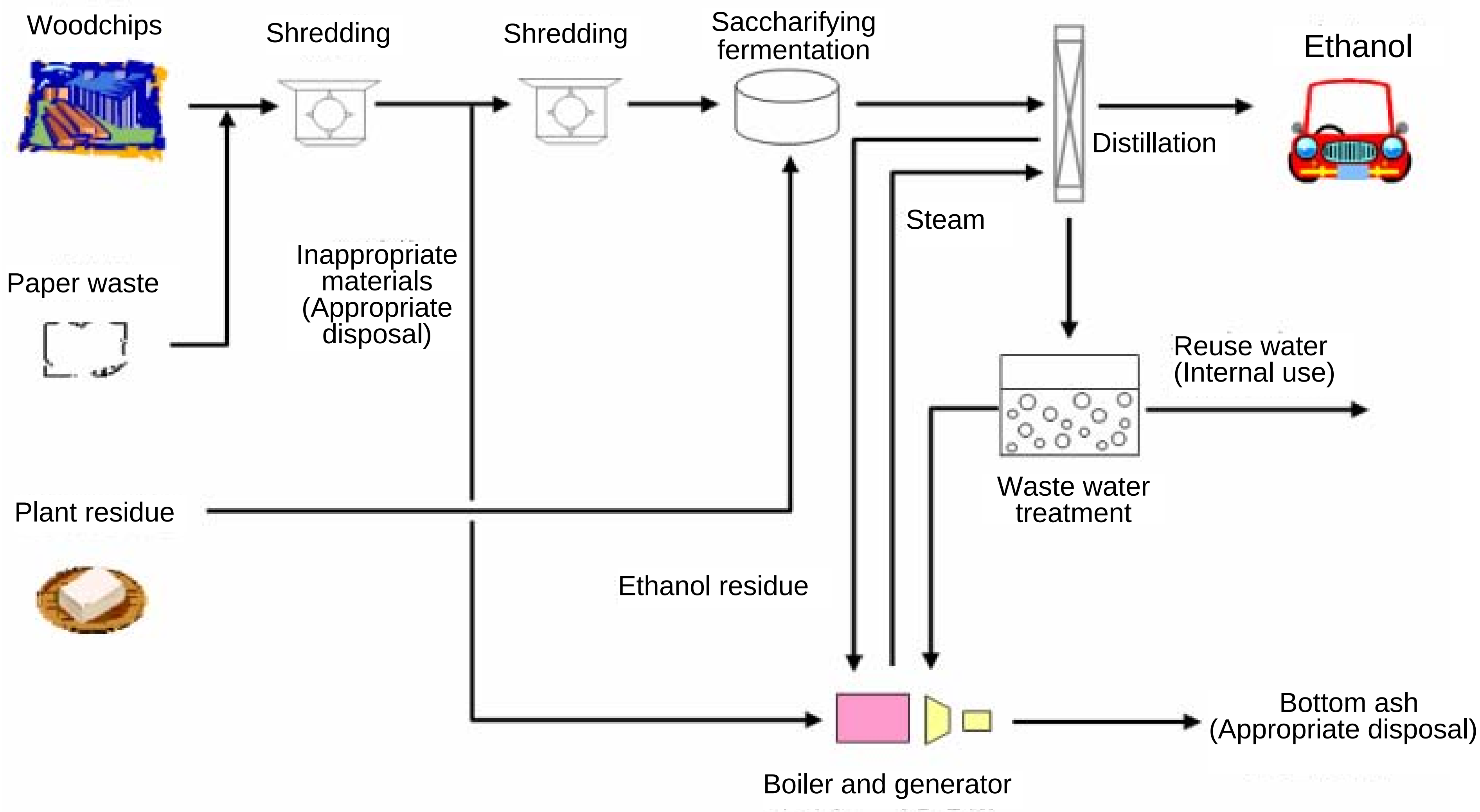
Source) Conference for Eco-fuel Utilization Promotion: Spread and Expansion of Eco-fuel for Transportation (May 2006)

3. Bio Fuel Development System

3.1 Bioethanol

Technology for Producing Ethanol from Waste Wood

Bioethanol Japan Kansai (Osaka): Produce ethanol through saccharification with dilute sulfuric acid, using two kinds of yeasts: one is a genetically modified bacterium (KO11) and the other is yeast. The plant will be completed in 2006.



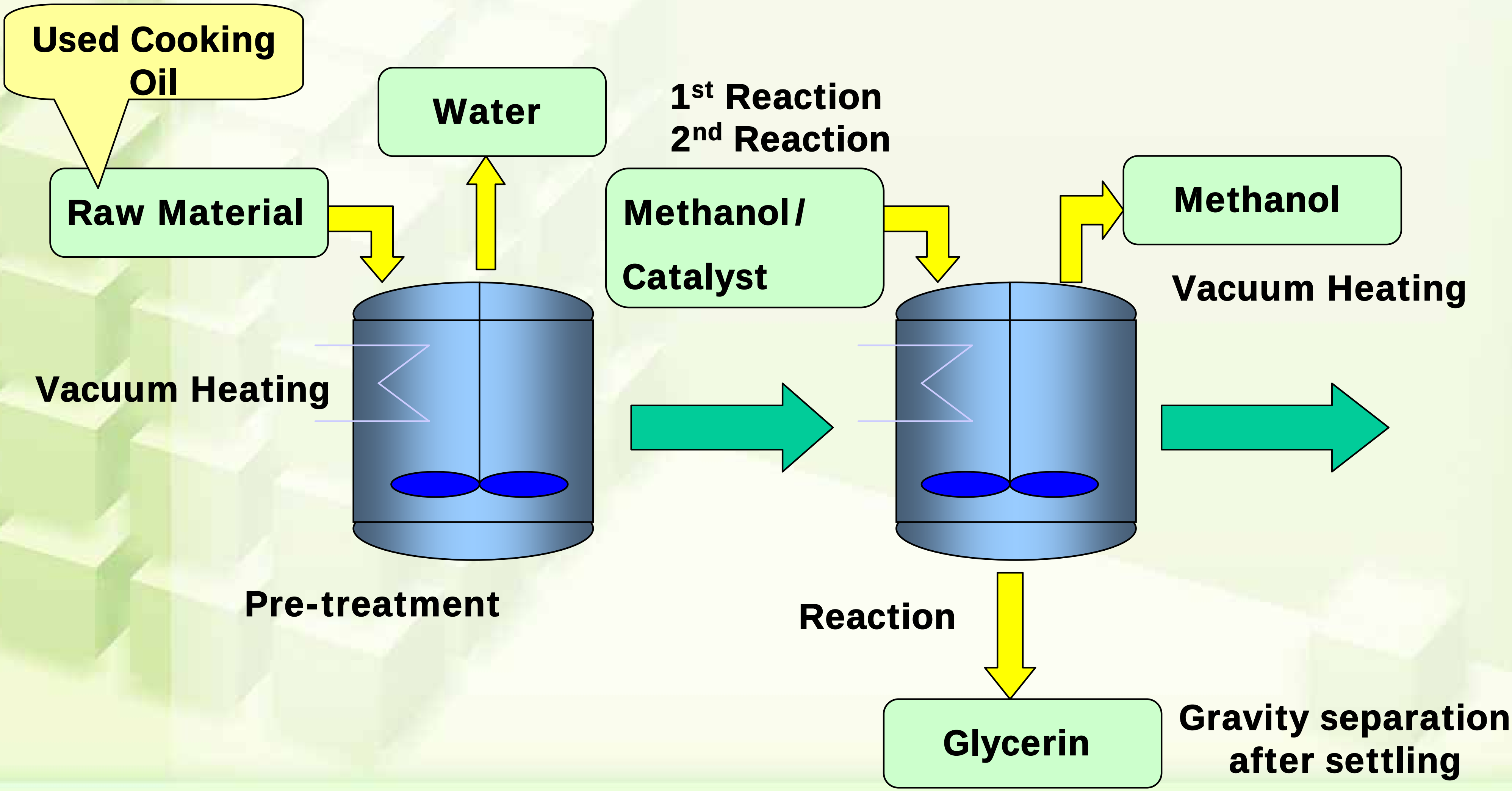
Source) Osaka Eco Town Plan (http://www.epcc.pref.osaka.jp/junkan/ecotown/index.html)

3.2 BDF

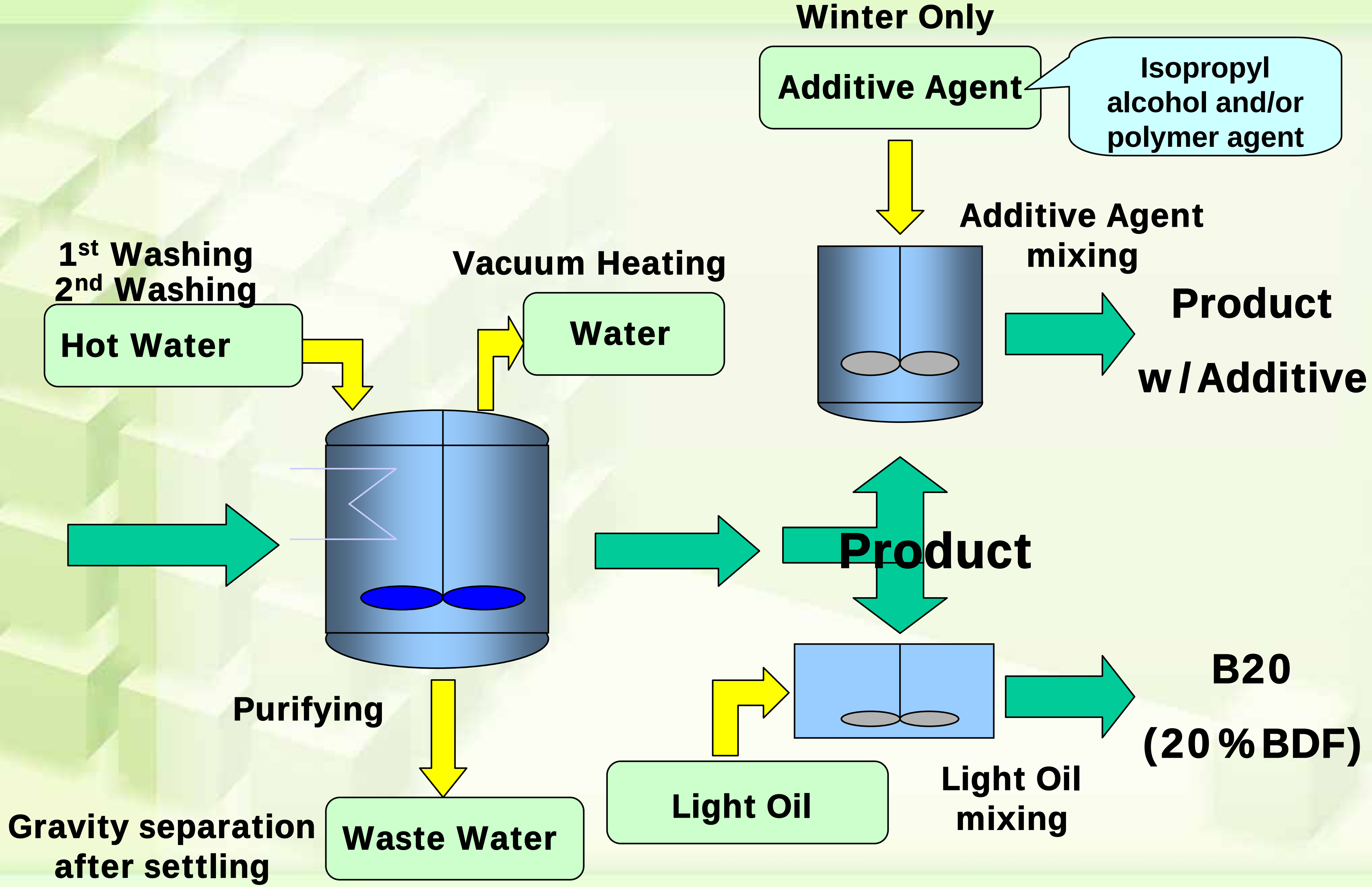
Biodiesel Plant in Kyoto

- Largest capacity in Japan (5000L/day)
- High Product Quality
- KOH (potassium hydroxide) catalyst
- Three(3) major steps
  - Pre-treatment
  - Transesterification Reaction
  - Purification
- Excess MeOH can be recovered and reused
- Blending can be done between B10 and B50

Process Flow of BDF in Kyoto (1)



Process Flow of BDF in Kyoto (2)



Biodiesel Fuel Utilization in Kyoto City

- All Garbage trucks (220 trucks) were supplied B100 from Nov. 1997.
- A part of city buses (95 buses) were supplied B20 from Apr. 2000.
- 1500kL of Bio Diesel Fuel were used annually.

Collecting of the Used Cooking Oil in Kyoto City

Since 1997, there started to place collecting stations of cooking oil. 960 stations (as of end of Mar. 2005) were placed, of which 143 school districts of total 219 school districts. Total amount of collected oil was 130kL in 2005.

Collection by local garbage reduction promoting committees (64 groups), health conference and local womankind groups. (once a month, 1~2 hours)

Eco-fuel Targets in Japan

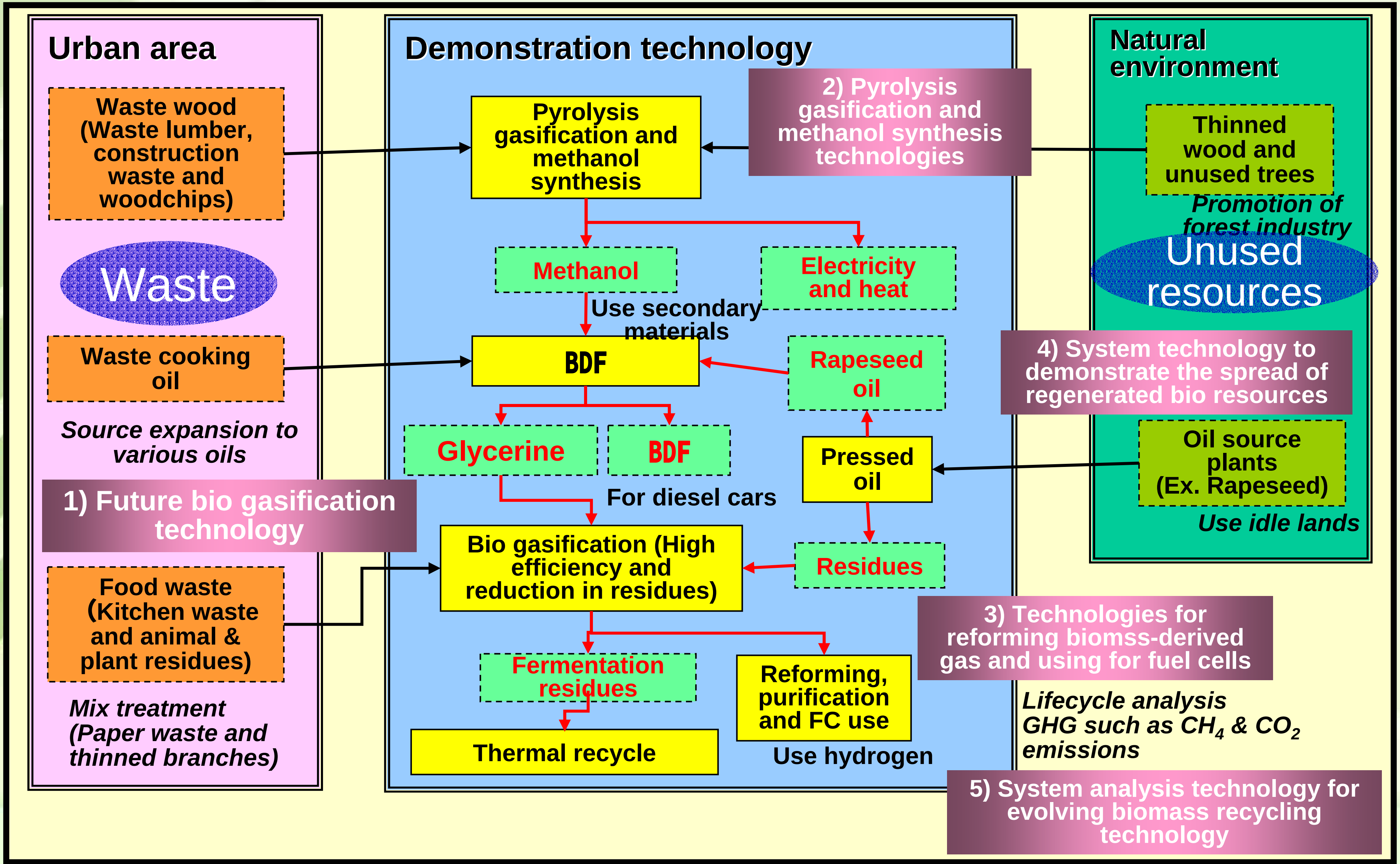
Target year		2010	2020	2030
Transportation ecofuel input		500,000 kL	About 2M kL	About 4M kL
Gasoline substitution (Bioethanol)	Input rate	A half of the total requirement is covered by E3 and ETBE(Ethyl Tert-Butyl Ether)	2/3 of the total requirement is covered by E3 and ETBE	The total requirement is covered by E10
	Input amount	Approx. 480,000 ~ 490,000 kL Of them, domestic production: Approx. 30,000 kL	Approx. 1.1M kL Of them, domestic production: Approx: 600,000 kL	Approx. 2.2M kL
Light oil substitution (BDF, eco-light oil and BTL)	Input rate	Input 2 ~3 times higher amount of domestic BDF	1/3 if the total requirement is covered	The total requirement is covered.
	Input amount	Domestic + import: Of them, approx. 10,000 ~ 15,000 kL is produced in Japan.	Approx. 900,000 kL	約Approx. 1.8M kL
CO_2 reduction potential		Approx. 1.2M tons-CO_2	Approx. 4.9M tons-CO_2	Approx. 9.8M tons-CO_2

Note) All inputs are crude oil equivalent.
Source) Report of Eco-fuel Utilization Promotion: Spread and Expansion of Eco-fuel for Transportation, Ministry of Environment (May 2006)

4. System Integration of Bioresources Utilization

4.1 Project of "Technology Development for Producing Hydrogen from Bioresources and Wastes" (2003 ~) and Kyoto Biocyle Project

Demonstration Image of Kyoto Biocyle Project



S.Sakai, Kyoto University, Asia 3R

Core Technologies for Demonstration of Kyoto Biocycle Project

1) Future bio-gasification technology for wet biomass
   High efficiency non-slurry methane fermentation process through high temperature solubilization of residues

2) Pyrolysis gasification and methanol synthesis for dry biomass
   Synthetic gas production via high-temperature gasification and purification (dust removal and tar decomposition)
   Single-pass methanol synthesis and offgas use for co-generation system

3) Biomass-derived gas reforming and application technology for fuel cells
   Hydrogen production through biogas reforming and use for fuel cells

4) System technology for expansion of renewable bioresources
   Expansion of BDF materials and bio gasification of paper waste and waste glycerine

5) System analysis for technological evolution of biomass cyclic use
   Life cycle system analysis for biomass cycle

Domestic GHG Reduction Potential

Estimate CO_2 reduction potential based on the domestic usable amount ⇒ In case of SOFC-CGS, about 47M tons-CO_2/year can be reduced. (Equivalent to 3.5% of the CO_2 emission in 2004, 1.33B tons)

Scenario / Category	1) GE-CGS usage		2) SOFC-CGS usage		3) FT synthesis		4) Methanol synthesis	
	Surplus electricity	CO_2 reduction	Surplus electricity	CO_2 reduction	Recovered	CO_2 reduction	Recovered	CO_2 reduction
	GWh/yr	M tons/yr	GWh/yr	M tons/yr	10,000 kL/yr	M tons/yr	10,000 kL/yr	M tons/yr
Agriculture	3656	4.692	8778	6.132	121	2.105	379	4.190
Livestock	-1695	1.140	1059	1.914	63	0.319	196	0.761
Forest	10669	14.011	26108	18.350	366	6.237	1144	12.538
Unused tree	9488	12.460	23218	16.319	325	5.547	1018	11.150
Waste	10900	15.879	28346	20.782	409	6.972	1279	14.016
Food waste	3448	3.798	7308	4.883	88	1.754	275	3.267
Paper waste	4897	6.432	11984	8.423	168	2.863	525	5.755
Waste timber	3564	4.680	8720	6.129	122	2.083	382	4.188
Total	23530	35.722	64291	47.178	959	14.994	2998	31.504

Note) The CO_2 reduction potential includes the kerosene substitution effect by heat recovery. The recent diesel oil sales is about 40M kL/yr. The FT oil recovery is equivalent to one forth of the sales. The domestic methanol consumption amounts to 1.83M tons/yr (in 2001; All amount is imported.)

4.2 Bio Energy Recovery Principles in Asia

Bioenergy Recovery Principles in Asia (tentative)

1. To produce bioethanol and biodiesel fuel from organic waste and waste oil as much as possible and constrain the development of new agricultural lands in developing countries.
2. To use existing agricultural lands effectively to newly cultivate sugarcanes and palms for ethanol and BDF production as much as possible.
3. To conduct the sufficient environmental assessment, when developing new agricultural lands from sheer necessity.