

# Food Waste Collection and Recycling for Renewable Biogas Fuel Production in Hong Kong


**Irene M.C. Lo**

*PhD, M.EASA, F.ASCE, F.HKIE, F.HKGSA, M.AEE, CAP*

*Professor of Civil and Environmental Engineering*

*Elected Foreign Member, European Academy of Sciences and Arts*

*The Hong Kong University of Science and Technology*

# Outline

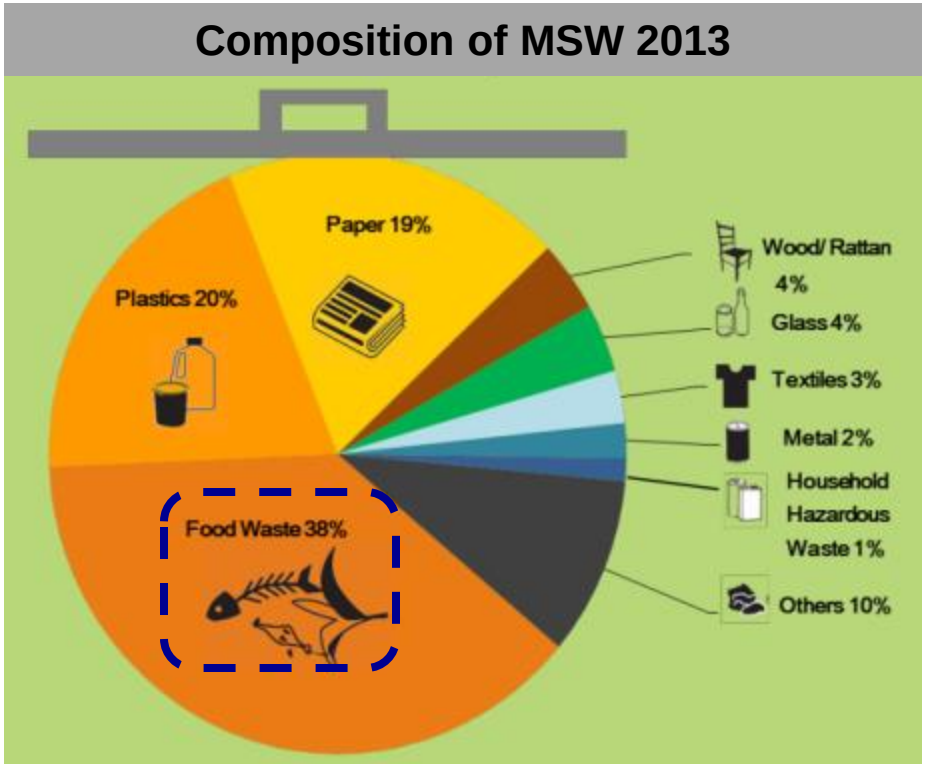
- Food waste management in Hong Kong
- Food waste separation and collection system
  - ✓ Optic bag system
- Valorization of food waste to renewable biogas
  - ✓ renewable biogas: electricity, city gas, and biogas fuel for vehicle use
- Conclusions

# Food waste management in Hong Kong




Source: Environment Bureau, 2014

**~ 9,500 tonnes of municipal solid waste discarded in landfills daily**

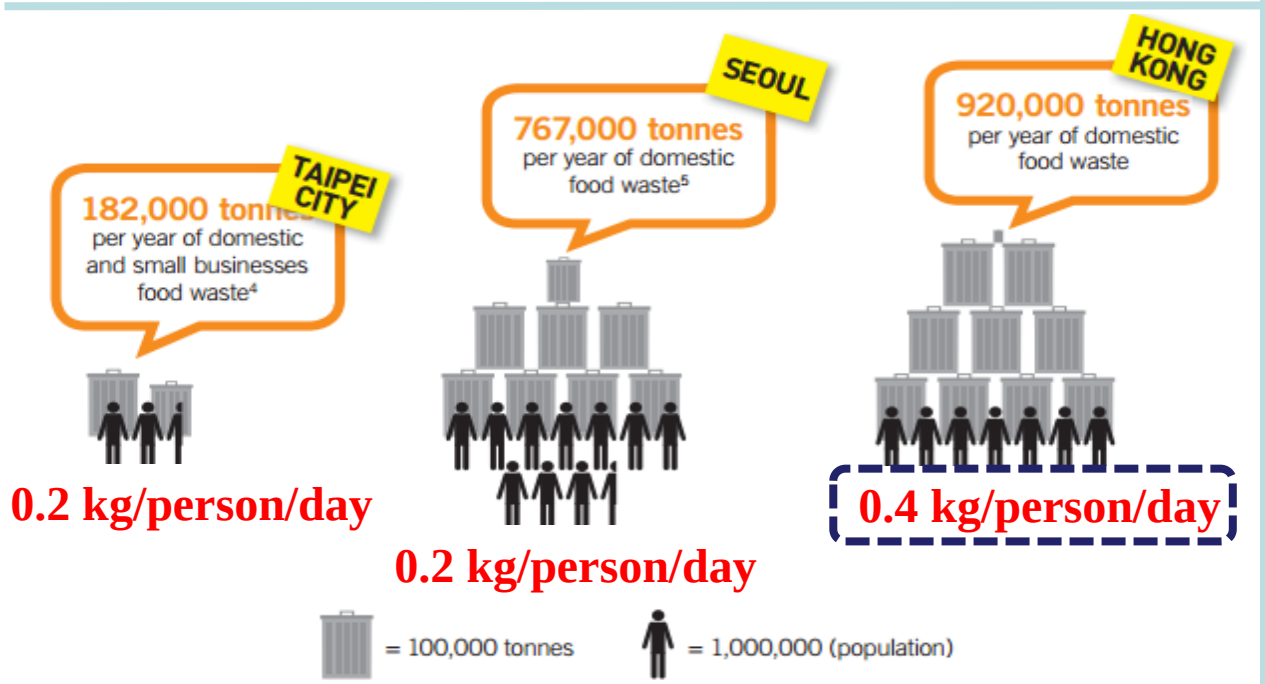



Note: Others include bulky items and other putrescible/ miscellaneous materials

# Facts and figures about food waste in Hong Kong



**~38% of MSW in Hong Kong is food waste** = **~3,600 tpd**




Source: Environment Bureau, 2014



**0.8% of food waste recycling rate (2013)**

# Current food waste management practice in Hong Kong



WENT SENT NENT

**Not sustainable and environmentally undesirable!**

**Unavoidable food waste should be collected systematically and valorized to value-added products!**

Note: WENT: West New Territories; SENT: South East New Territories; NENT: North East New Territories

# Food waste separation and collection

**How to collect food waste efficiently and effectively?**



Photo courtesy of Environment Bureau

**simple sorting with less behavioral change!**

optibag

# Proposed optic bag system in Hong Kong



Food waste



Optic bag (green bag)





Refuse chute/ Garbage bin



Refuse collection vehicle



Other MSW

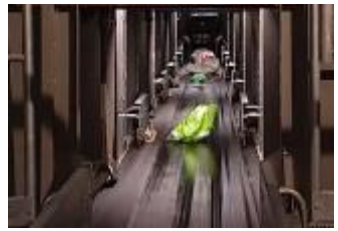


Common plastic bag or designated bag if MSW charging scheme by bag is launched

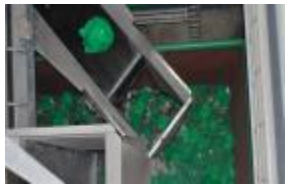


Refuse transfer station

optibag



Optical sorting system



Packed food waste

FOOD WASTE RECYCLING

Assorted food waste recycling facilities



Other packed MSW



Advanced incineration facility

# Optical sorting plant in Oslo, Norway

- **Haraldrud Plant**
  - ✓ In operation since **2009**
- The **world's largest** optical sorting plant
  - ✓ Handles wastes approximately **150,000 tonnes/year**




Video courtesy of Envac Company

# Advantages of optic bag system







- Enable **separation at source** with **less behavioral change**
- No extra **storage space** for the waste fractions
- Perform recycling in existing households and C&I sectors **without having to rebuild properties**

# Proposed Organic Waste Treatment Facilities (OWTF)



Hong Kong Map

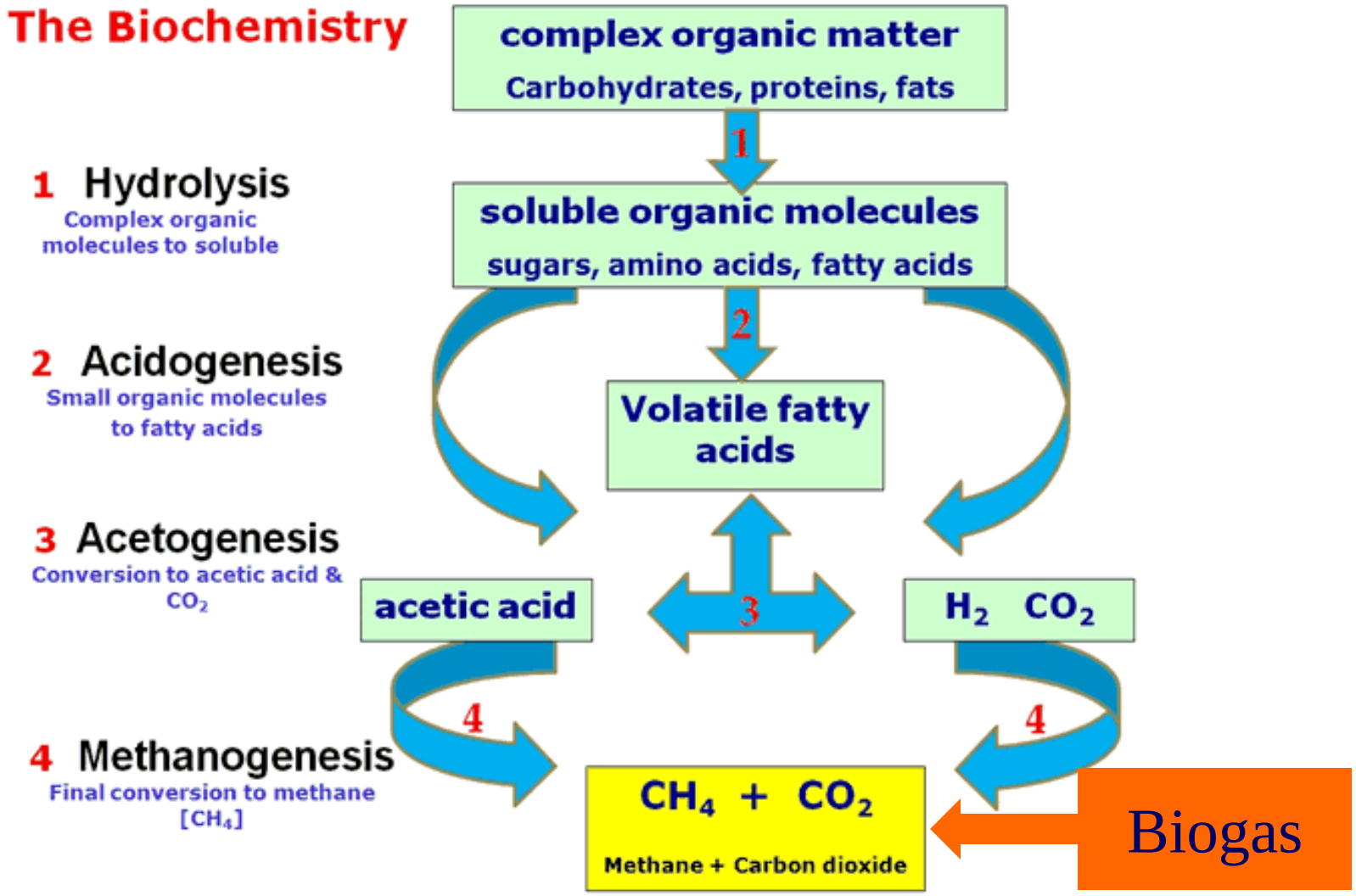



- Will adopt
  - ✓ **anaerobic digestion - biogas for energy generation**
- **Phase 1: 200 tpd** of food waste (expected to commission by 2016)
- **Phase 2: 300 tpd** of food waste (expected to commission by 2017)

- 1,200 tpd – 500 tpd = **700 tpd**
  - ✓ need **3 to 4** more OWTFs…

Source: HKEPD, 2013

# What is anaerobic digestion?



# Major conditions influencing anaerobic digestion

| Condition | Description |
|---|---|
| **Temperature** | Mesophilic (25$^{o}$C – 40$^{o}$C) or<br>Thermophilic (50$^{o}$C – 65$^{o}$C) |
| **pH** | 6.4 – 7.2 |
| **Retention time** | 15 – 30 days for mesophilic or<br>12 – 14 days for thermophilic |
| **Organic loading rate (OLR)** | High OLR causes accumulation of volatile fatty acid. |
| **Carbon to nitrogen ratio (C:N ratio)** | Optimum range: 20:1 – 30:1<br>Source: Monnet, 2003 |

# Co-digestion of food waste with sewage sludge for biogas generation






Food waste separated from other MSW in RTS → Food waste → To food/organic waste treatment facilities (generating biogas for electricity/city gas/biofuel for vehicle use)

**A portion of food waste can be sent to sewage treatment works and mixed with sewage sludge**

Wastewater treatment → Sewage sludge → Anaerobic co-digestion → Biogas production






# Advantages of co-digestion

- Accelerate the growth of anaerobic microorganisms - **improve digestion performance** (Iacovidou et al., 2012)
- **Increase biogas and power production by 2.5-3 times** when food waste is co-digested with sewage sludge (Schafer and Lekven, 2008 )
- Applied in many countries such as **Sweden, Germany, Switzerland, and South Korea** (Braun and Wellinger, 2009)
- Treatment cost in Grindsted, Denmark: HK$90/tonne







Co-digestion of sewage sludge with organic waste

# Case study of co-digestion: Yongyeon wastewater treatment plant, Korea

| Plant | Yongyeon, Ulsan, Korea (2012) |
|---|---|
| Substrates | - Primary sludge<br>- Food waste |
| HRT (d) | 22 |
| Weight of food waste treated (tpd) | 180 |
| Weight of sewage sludge waste treated (tpd) | 600 |
| Mesophilic or thermophilic | Mesophilic |
| Food waste to sludge ratio | 3:10 (weight) |
| Annual biogas production ($Mm^3$) | 11 |
| Annual energy production (GWh) | 40 |

# Production of Biogas from Anaerobic Digestion of Sludge at 4 Secondary STWs in 2013 in HK

渠務署
Drainage Services Department

| Parameters | Shatin STW | Tai Po STW | Shek Wu Hui STW | Yuen Long STW |
|---|---|---|---|---|
| Treated Sewage (million $m^3$) | 85 | 36 | 31 | 10 |
| Biogas produced (million $m^3$) | 5.6 | 2.0 | 1.2 | 0.6 |

Source: "*From Sewage to Energy*" presented at HKIE Environmental Division Annual Seminar 2014

*Using the spare capacity of the 4 STW for anaerobic co-digestion, it is estimated that* ***500-600 tpd food waste*** *can be handled (based on HRT of 22 days and food waste to sludge ratio of 3 : 10 by mass).*

# Renewable biogas for electricity and city gas generation in Hong Kong

**Renewable biogas**



**Electricity**



**City gas**

Other better alternative is to use biogas as **biogas fuel** for vehicle use because zero carbon emission and low air pollutants emitted.

# Less exhaust emissions for passenger car fleet using biogas fuels

The table is adapted from Rydberg et al. (2010). The passenger car fleet is applied in urban area of Sweden.

| Type of fuel | $CO_2$ (kg/km) | $CO_2$, well-to-wheel[a] (kg/km) | $NO_x$ (g/km) | $SO_2$ (g/km) | CO (g/km) |
|---|---|---|---|---|---|
| **Petrol** | 0.23 | 0.27 | 0.45 | 0.0014 | 4.4 |
| **Compressed natural gas** | 0.09 | 0.13 | 0.04 | 0.0004 | 0.99 |
| **Biogas fuel** | 0 | 0.05 | 0.04[b] | 0.0004[b] | 0.99[b] |

[a]Well-to-wheel incorporates the feedstock or fuel production and processing, fuel delivery, and vehicle operation itself.

[b]Since there is no data specifically for biogas fuel, the emissions of biogas fuel are assumed to be the data for compressed natural gas due to similar composition.

# How can it be implemented in Hong Kong?

**Biogas-fueled cars (i.e., hybrid gas cars)**

VOLVO Ford Mercedes-Benz

**1,200 tpd food waste**

- ✓Fuel **~13,000 private cars/day** (3% of total private cars in HK)
- ✓Reduce **~ 150,000 tonne $CO_2$/year** (2% of the total amount by the transport sector in HK)

**Government service cars**



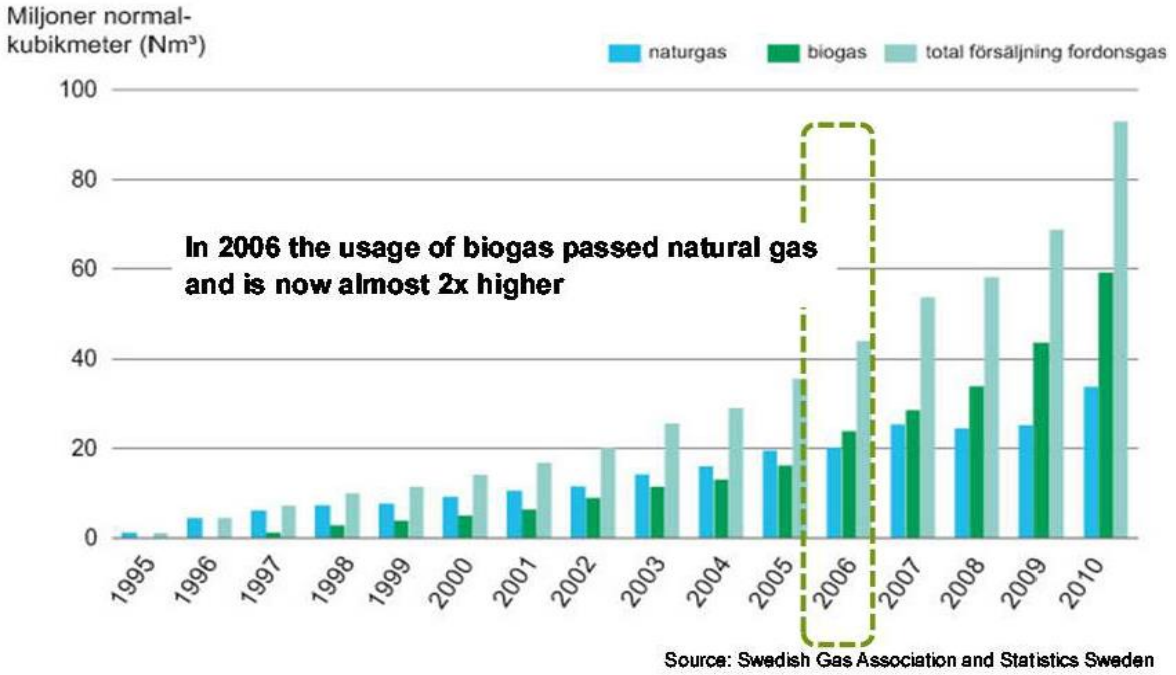
**Private cars**




**Public transport**



# Sweden is the world leader of turning food waste into biogas fuel for vehicle use












**Public filling stations for biogas and/or natural gas in Sweden (~400 stations for 140,000 vehicles)**

Source: Scandinavian Biogas Company

# Linköping in Sweden







**Biogas-fueled car (i.e., bi-fuel car)**



**Biogas-fueled bus**



**Biogas car filling station**



**Biogas bus filling station**

**Food waste produces biogas fuel to ~6% of the vehicle use**

# Lille in France








**Biogas-fueled car**




**Biogas-fueled bus**



**Biogas waste truck fleet**

Photos courtesy of Lille Métropole

# More examples of cities turning food waste into biogas fuel for vehicle use!

**Bern, Switzerland**



**Stockholm, Sweden**



**Haarlem, the Netherlands**



**Oslo, Norway**



# Conclusions

- ✓ Simple yet effective food waste separation and collection system
  - ➢ **optic bag system**
- ✓ Valorization of food waste to value-added products
  - ➢ **Renewable biogas: electricity, city gas, and biogas fuel for vehicle use**

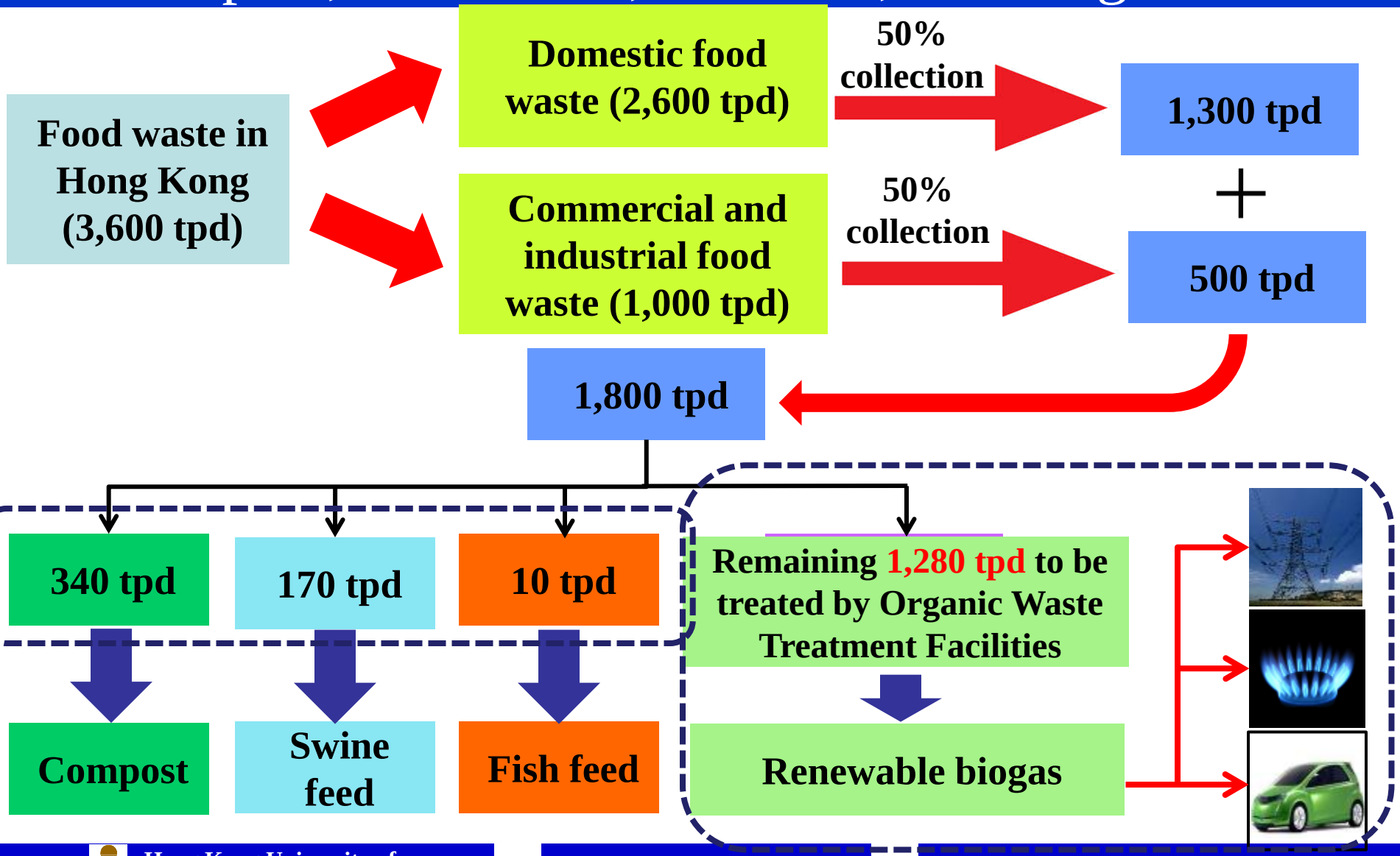
**Integrating food waste recycling, renewable energy with low carbon footprint and circular economy into our waste management roadmap**



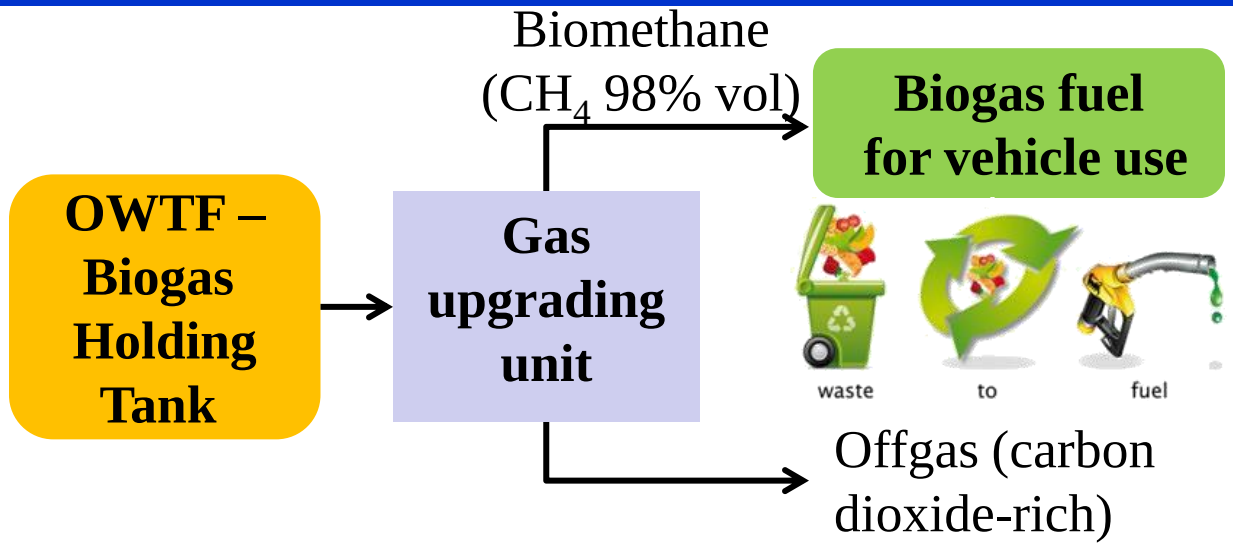


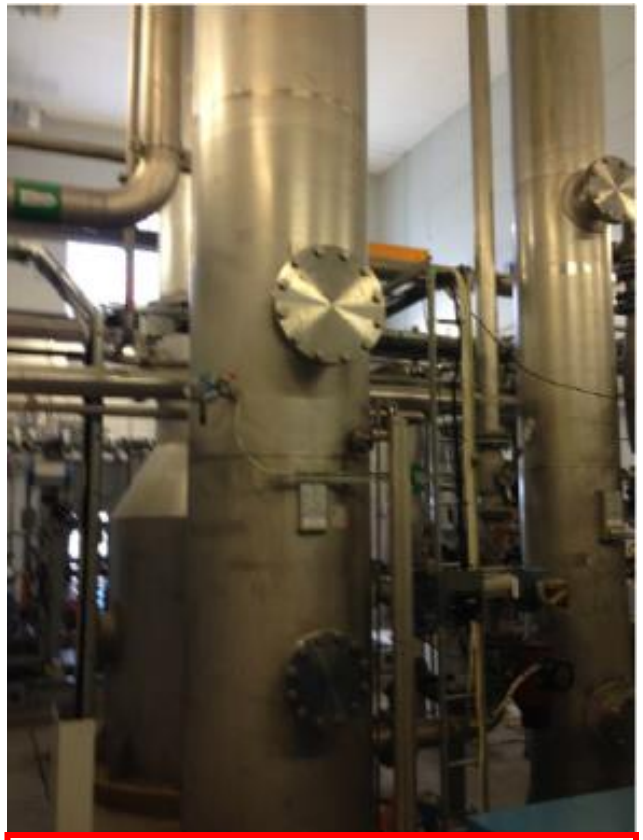

Thank you

# Local consumption of food waste to be converted to compost, swine feed, fish feed, and biogas



# Upgrading to biogas fuel for vehicle use



Biogas upgrading plant

- Biogas: mixture of **$CH_4$ (50-70% vol) and $CO_2$ (25-45% vol)**
- Gas upgrading units: **pressure swing adsorption, water scrubbing, chemical scrubbing**
- Advantages of biogas fuel for vehicle use
  - ✓ **reduce** fossil fuel consumption
  - ✓ **lower emissions** of greenhouse gases and air pollutants (e.g., $NO_X$ and $SO_2$) than fossil fuels (e.g., petrol)