“Waste Plastics-to-Resources”
Technologies and its selection

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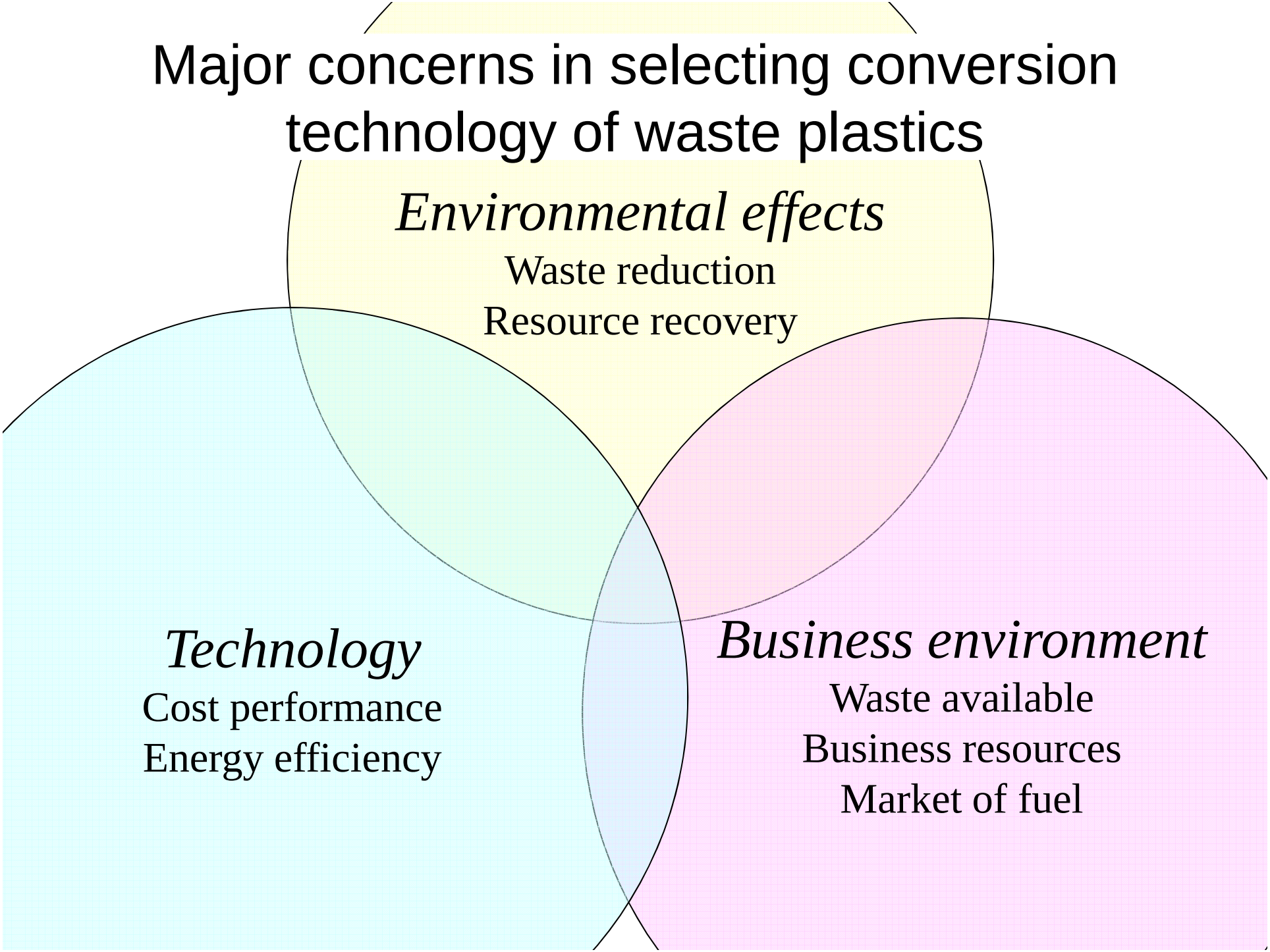
Major concerns in selecting conversion technology of waste plastics



Typical end-user application of waste plastics

Recycled resin

Fuel

Incineration with Heat Recovery

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Linkage among waste plastics, technology and products

Relatively clean waste plastics

Melting and pelletizing

ca 200 ˚C

Recycled resin

Thermoplastics with mixed combustibles without potential hazardous elements.

Briquette preparation

ca 200 ˚C

Solid fuel substituting to coal

Thermoplastics without Cl, etc.

Pyrolysis

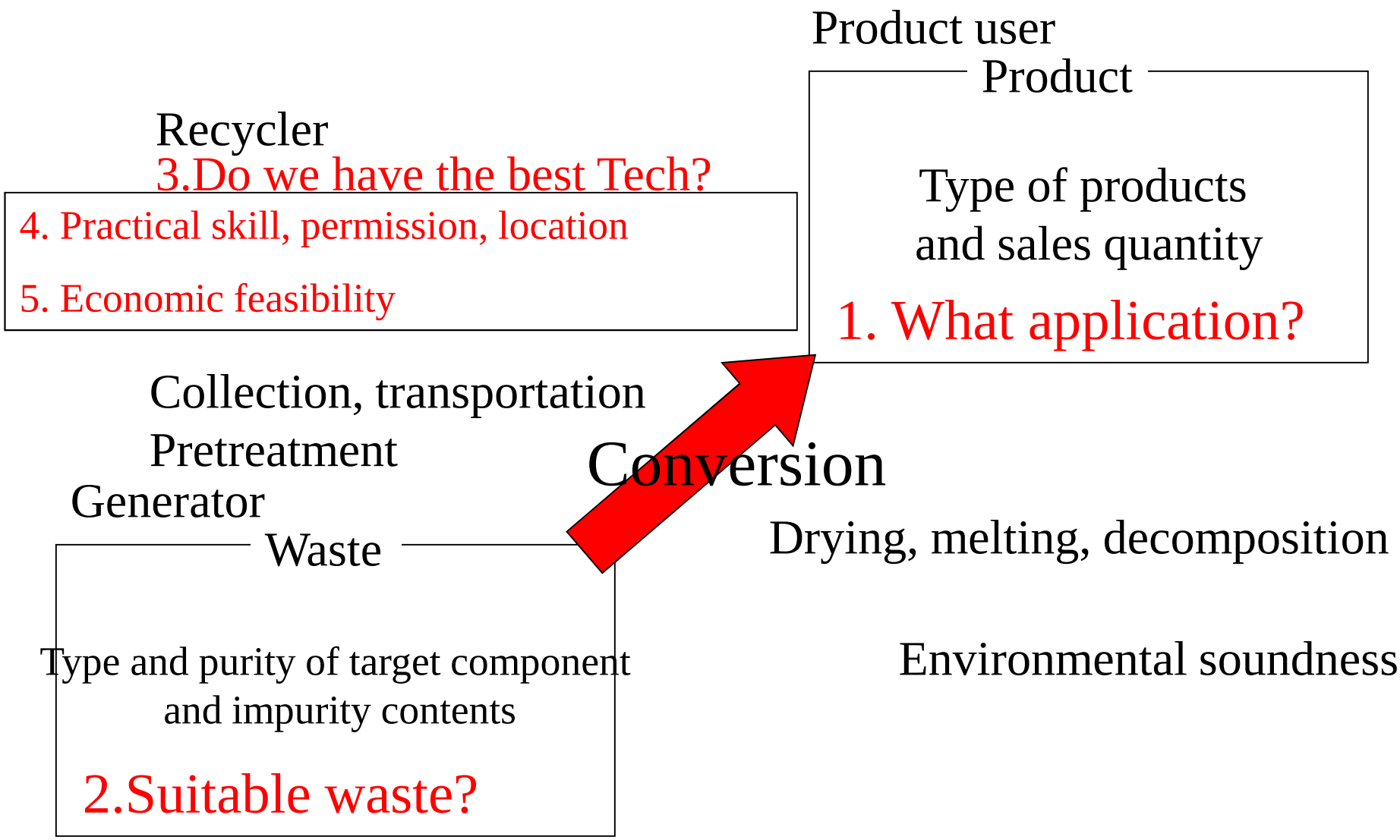
ca 500˚C

Liquid fuel substituting to petro. fuel

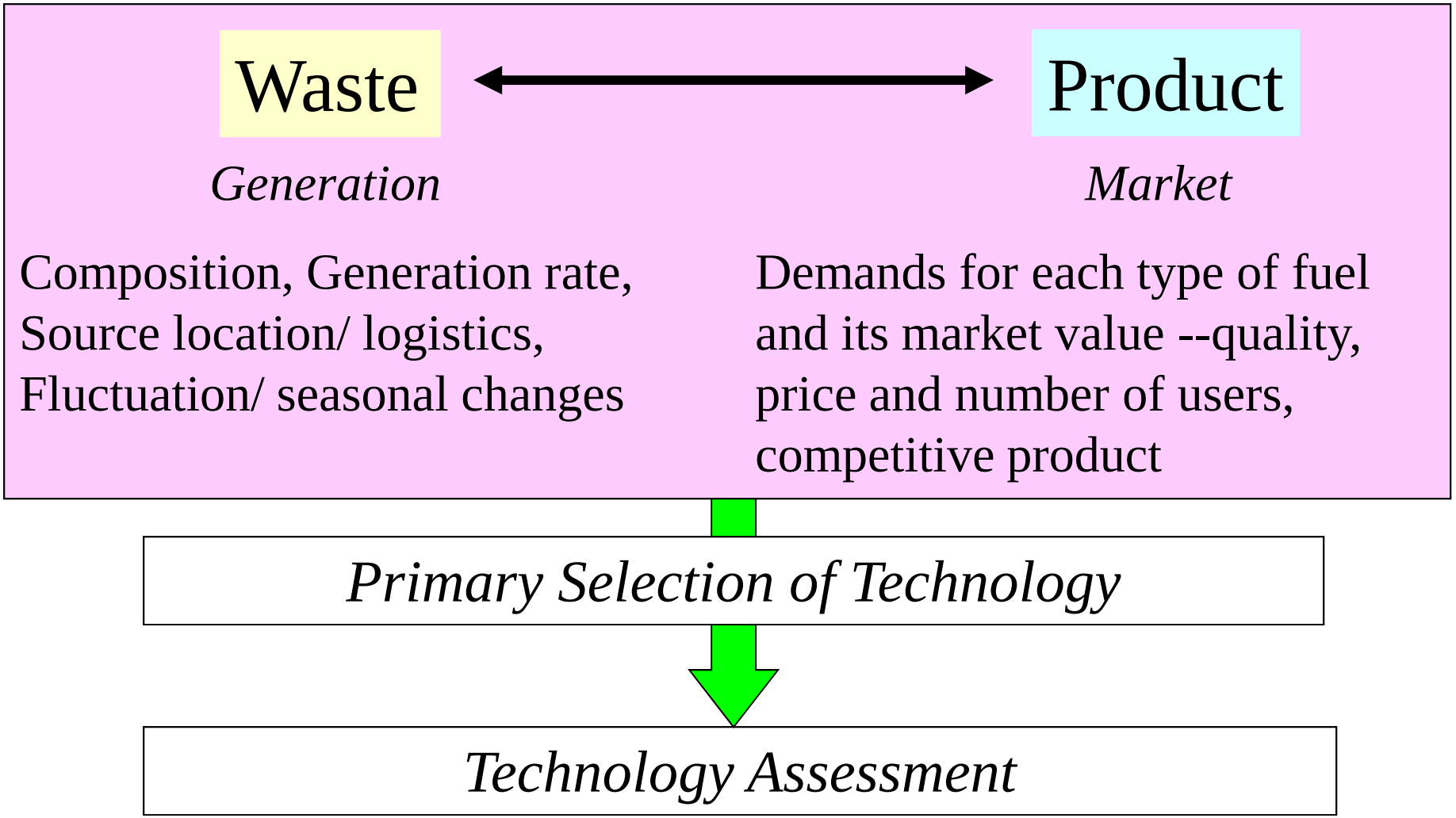
Properties of wastes ⟷ Technology ⟷ Products

Recycling business

Based on social conditions, business environment and technology



Required Date for Technology Selection



Typical example of waste recycling business

No. 1 A target waste is fixed.

Fixed composition of wastes: Thermoplastics, paper,

or kitchen wastes

→Products quality depends on waste composition.

End-user application depends on fuel quality.

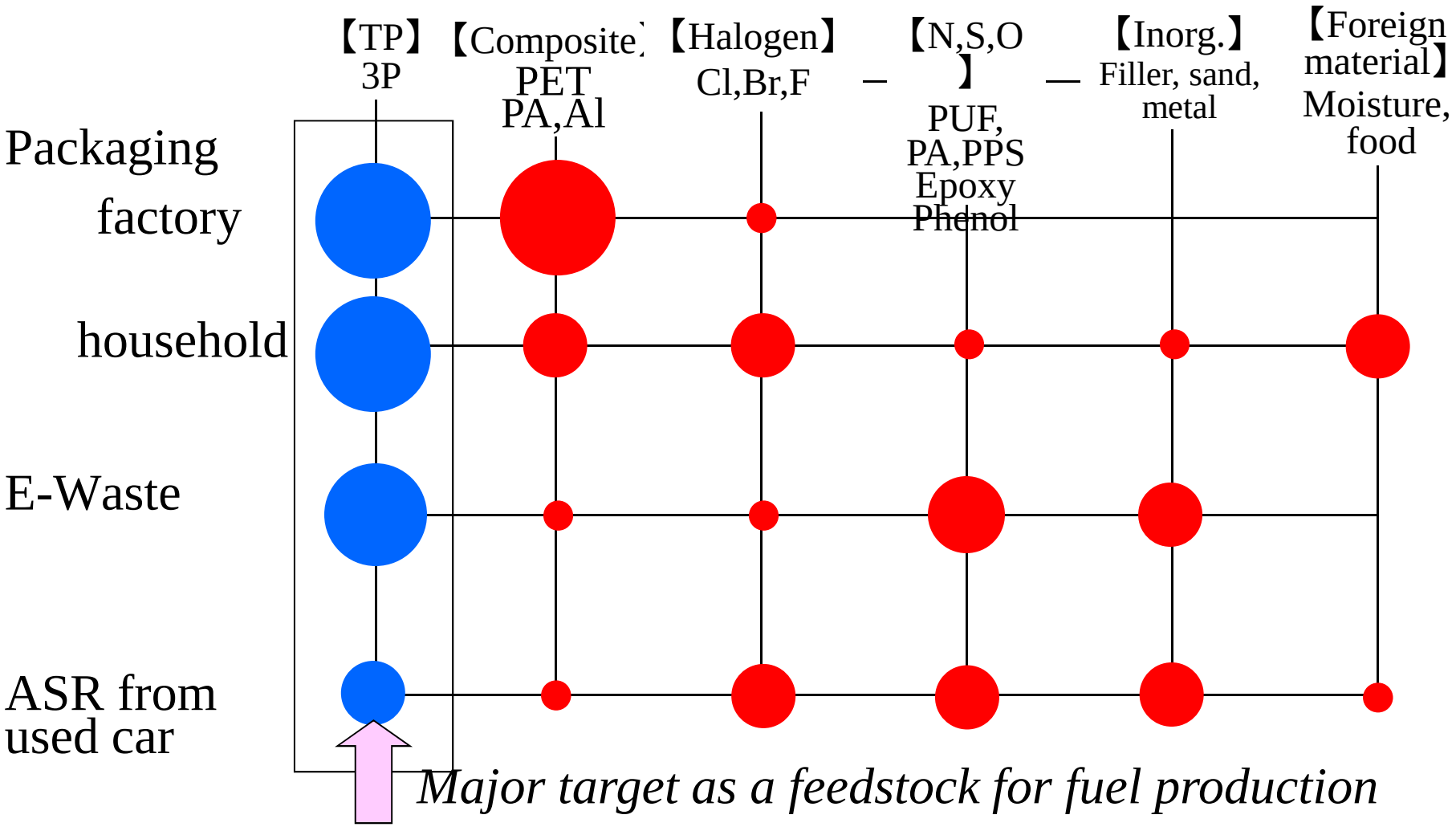
No. 2 A target product is fixed.

Fixed products: Recycled resin, solid fuel or liquid fuel

→Suitable types of wastes should be separately collected

to sorting process.

Different Composition Depending on Waste Sources



Plastics as fuel source 1

Thermoplastics
melting at heating

Thermosetting plastics
not melt at heating

PE Bag, food package
PP Food package, bottle
} Mostly soft plastics
PS Package, casing, TV cabinet

ABS Casing and parts of E device

PET Bottle, packaging material, film
PMMA Signboard, cup, glass substitute

Some are soft film, and some are rigid products.

PVC Bottle, construction material, e-material
PVDC Signboard, cup, glass substitute

PA Rope, cloth, coating
PUR Heat insulation, cushion
Phenol resin
Epoxy resin Electric parts, circuit board

Brominated Epoxy
Circuit board

Elemental composition					
C,H	+N	+O	+Cl	+N,O	+N,Br

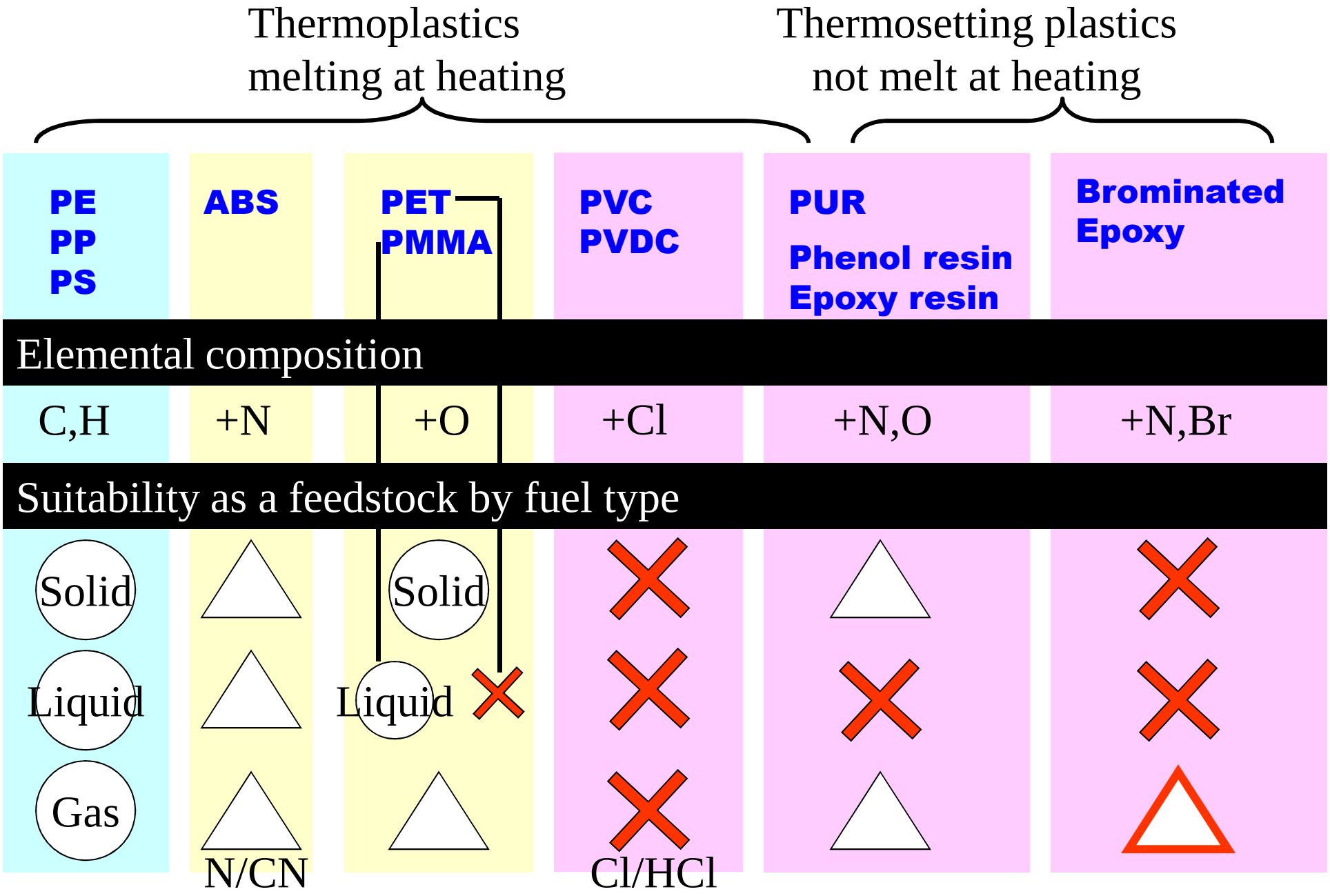
Plastics as fuel source 2

Thermoplastics melting at heating

Thermosetting plastics not melt at heating

PE PP PS	**ABS**	**PET PMMA**	**PVC PVDC**	**PUR Phenol resin Epoxy resin**	**Brominated Epoxy**
Elemental composition					
C,H	+N	+O	+Cl	+N,O	+N,Br
Calorific heat					
High 43-46	Medium 39	Low 22-26	Low 19	Low 24-26	Medium (MJ/kg)
Flue gas quality					
High	Low CN NO_x	High	Low HCl	Low NO_x	Low HBr, NO_x

Plastics as fuel source 3



Influences from the properties of waste plastics

Process	Properties	Influences
Transportation	Bulk density	Transportation cost
Pretreatment-separation, crush	Impurity contents-PVC, metal, glass, etc	Cost, mechanical trouble, treatment capacity, maintenance cost
Conversion	Target plastics content Moisture content	Product yield and quality Energy consumption
	Halogen content	Apparatus corrosion Product quality
Used by Fuel consumers	hydrocarbon, halogen, nitrogen, sulfur contents	Heat of combustion. NOx and SOx emission upon combustion. Boiler corrosion. Sale price of fuel
Business scale	Collectable amount and qualities of waste plastics	Break-even line

Guideline for technology selection

Criteria	Index	Influence
Material	Waste composition	Fitting to the type of product*
Energy	Energy consumption per operation hour	Performance of equipment and the environmental impact
Cost	Costs of facility construction and operation**	Business balance with gate fee and sales price of fuel

*When one wants a specific type of product, pretreatment cost will change. **Products of the higher value require precise separation of feedstock.

Guideline for technology selection

Method	Feedstock	Production	Substitutes
Solid fuel	Combustibles	Pelletization <200 ° C	Coal or wood
Liquid fuel	Thermo-plastics	Pyrolysis ca. 500 ° C	Petroleum
Gaseous fuel	Combustibles	Gasification >800 ° C	LPG, LNG
Incineration	Combustibles	Combustion >1000 ° C	(Non-storable)

*Flue gas quality and ash should be well examined.

Technologies for Energy Recovery

Direct combustion
without processing

Liquid fuel production

Fuel or heat users of
- factories
- public service
- shopping complex
- agriculture sector

in a local community
- blast furnace
- cokes oven
- cement kiln
- power generator
- lime furnace
- city gas supplier

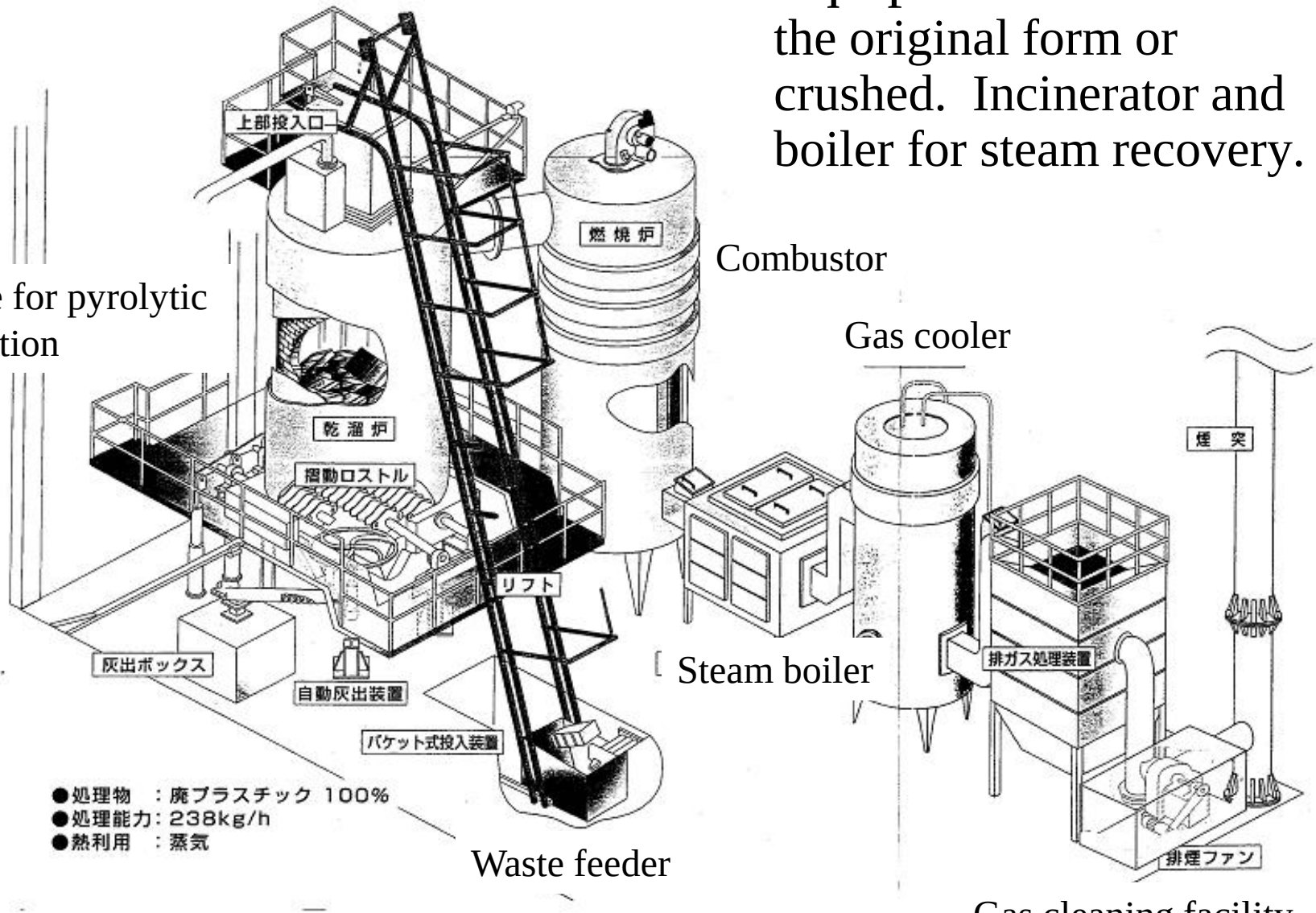
in large industries

Solid fuel production

Gaseous fuel production

Incineration with heat recovery

- Equipment: Wastes of the original form or crushed. Incinerator and boiler for steam recovery.



Furnace for pyrolytic gasification

Combustor

Gas cooler

Steam boiler

Waste feeder

Gas cleaning facility

Difference between incineration with heat recovery and fuel production

—Fuel user can decide where, when and how much heat to use—

	Incineration with heat recovery	Fuel production and heat recovery
Target waste	Most combustibles	Selected feedstock
Shape	Various, allowed to most shape	Pellet, briquette, liquid
Storage & transport	Inconvenient	Convenient
Continuous operation	Depends on waste	Easy
Heat recovery efficiency	Low, typically 10 – 20 %	High, heat recovery of boiler 80 – 90%
Time to use heat	Synchronized with incinerator operation	Anytime upon necessity

*Fuel is produced by considering heat of combustion, impurity removal and type of a boiler.

Solid fuel

- Two typical types:
  - RDF including putrefactive matters like kitchen wastes.
  - RPF consisting of paper, wood and thermoplastics
- Feedstock:
  - non-hazardous combustibles without emission of hazardous flu gas and ash upon combustion.
- Properties and application of fuel:
  - Calorific value 2000 – 4000 (RDF), 5000 – 7000 (RPF) kcal/kg and bulk density is about 0.4 ton/m^3
  - Special attention required for self-ignition and methane evolution in RDF storage
  - Due to flu gas quality, coal-combustion boiler is a typical application in Japan.

Solid fuel

- Production: Crushing and pelletization.
  Drying process is required for wet wastes.
  Pelletization is carried out at ca.200° C.

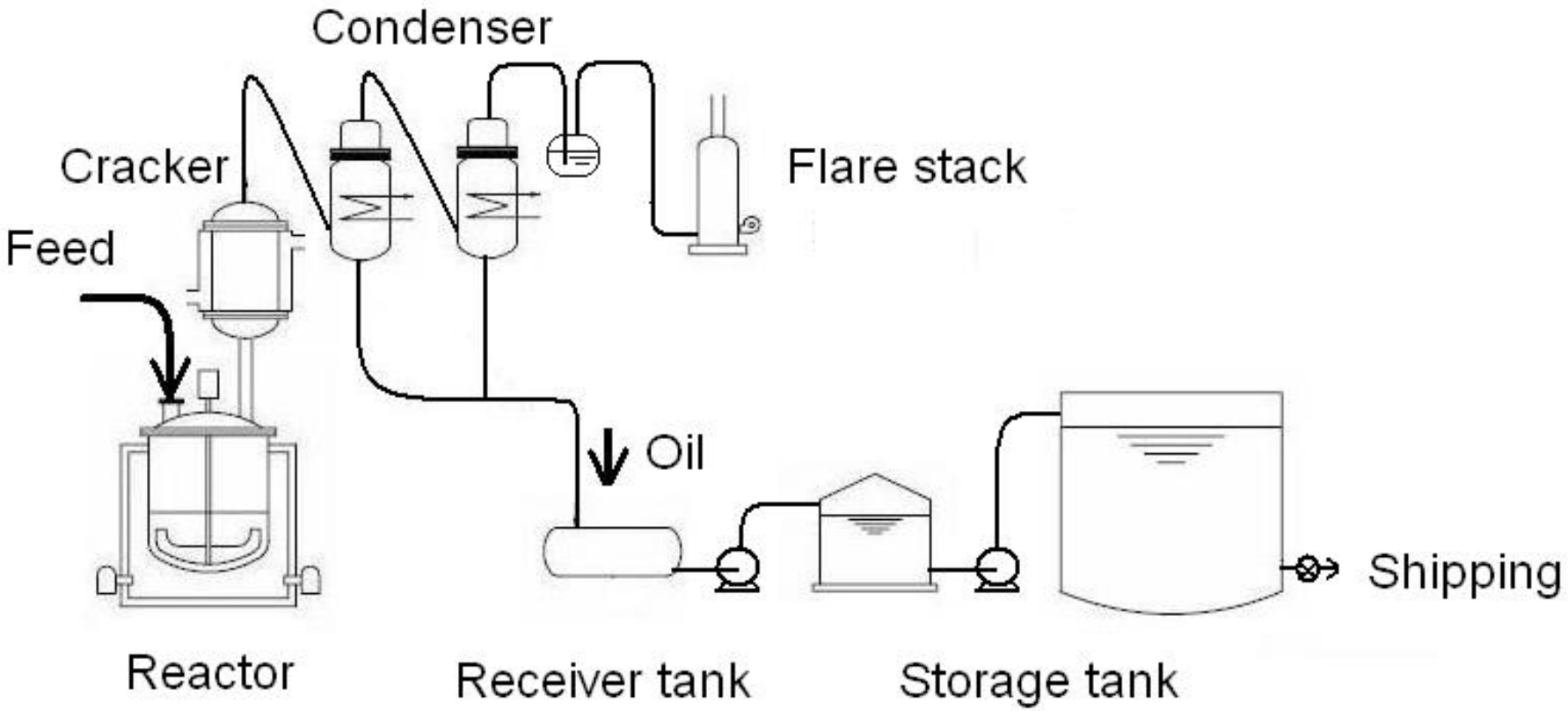
Liquid fuel

- Production of petroleum substitutes:
  - Substituted fuel to heavy oil, diesel oil and gasoline depending on distillation ranges
- Feedstock:
  - Thermoplastics, especially PE, PP and PS without contamination of PVC and PVDC.
- Properties and application of fuel:
  - Calorific value about 10000 kcal/kg, density is about 0.8-0.9 ton/m^3, similar to petroleum products.
  - Contamination of Cl-containing plastics is prohibited, and other materials yielding carbonous matter lowers product yields.
  - Expensive facility cost for the safety to highly flammable products.
  - Skillful operators are required.

Liquid fuel

- Production: Pyrolysis followed by distillation.
  Crushing and separation required for some wastes.

Typical flow diagram of small-scale tank reactor of 3ton/day capacity

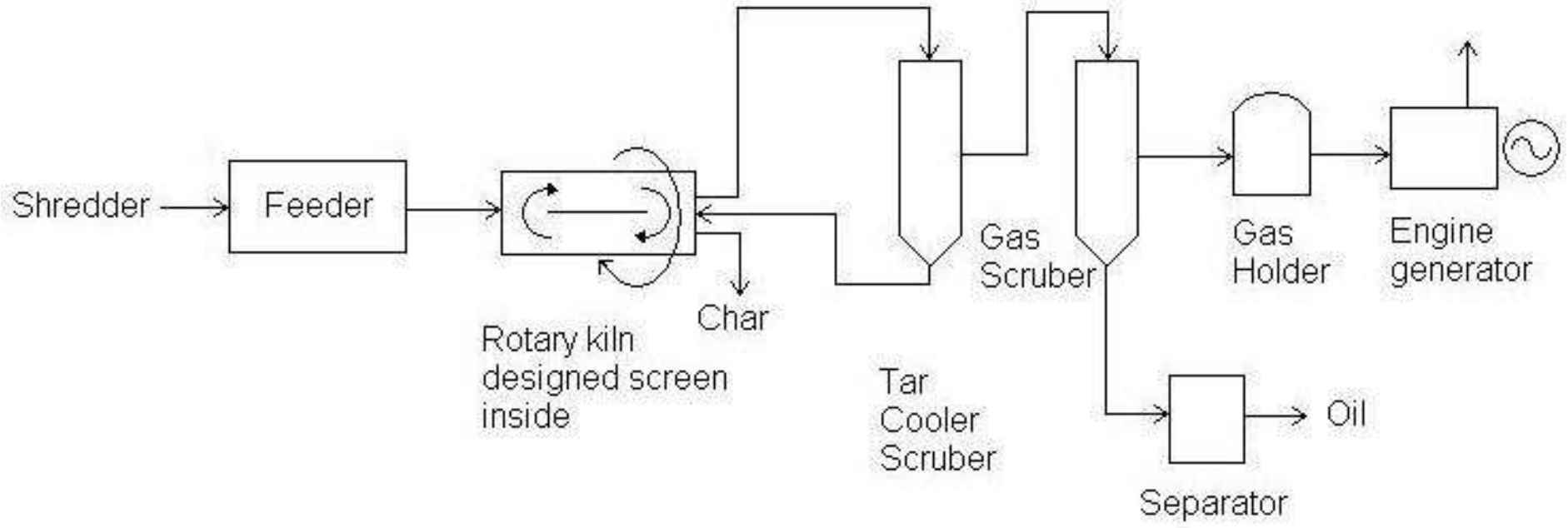


Gaseous fuel

- Two typical types of gas depending on feedstock and reaction conditions:
  - Syngas consisting of hydrogen and carbon monoxide from municipal wastes, mixed plastics and wooden biomass (800°C, 10 min or over 1000°C within seconds).
  - Gaseous hydrocarbons from PE&PP under development (600°C, 10 to 20 min).
- Properties and application of fuel:
  - Calorific value varied with the compositions: hydrogen, carbon monooxide and hydrocarbons of C1 to C5 or 6.
  - A large gas holder is required if it is stored. Hydrocarbons of C3 and C4 can be liquefied under a moderate pressure.
  - Careful operation and skillful operators are required.

Gaseous fuel

- Production: crushing and pyrolysis.
- Steam gen. – power gen., or gas turbine combustion– power gen.
- Major trouble: pluging of tar-ash mixture at a tubing between a kiln and gas-tar separator.



Technology selection for typical plastics and other wastes

Plastics	Fuel product candidate
C&H	Solid/liquid/gaseous fuel
+ O:PET, paper or wood + N: kitchen wastes	Solid/gaseous. No liquid from PET.
+ serious N	None. Incineration with NOx treatment equipment
+ serious Cl	None. Landfill is recommended.

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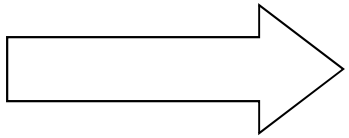
As a summary

Plastics of C&H
- PE, PP, PS and some other types



Solid fuel
Liquid fuel
Gaseous fuel

O contaminants
- Lower calorific value
- Some do not give liquid.

N and S contaminants
- NO_x and SO_x formation

Cleaner fuel: G>L>S
Higher cost: G>L>S
User demands: local issue
Flue gas control: local issue

Cl contaminants *Landfill preferred*
- HCl formation results in equipment corrosion.
- Organic chloride formation leads to HCl corrosion in a boiler and dioxins formation.