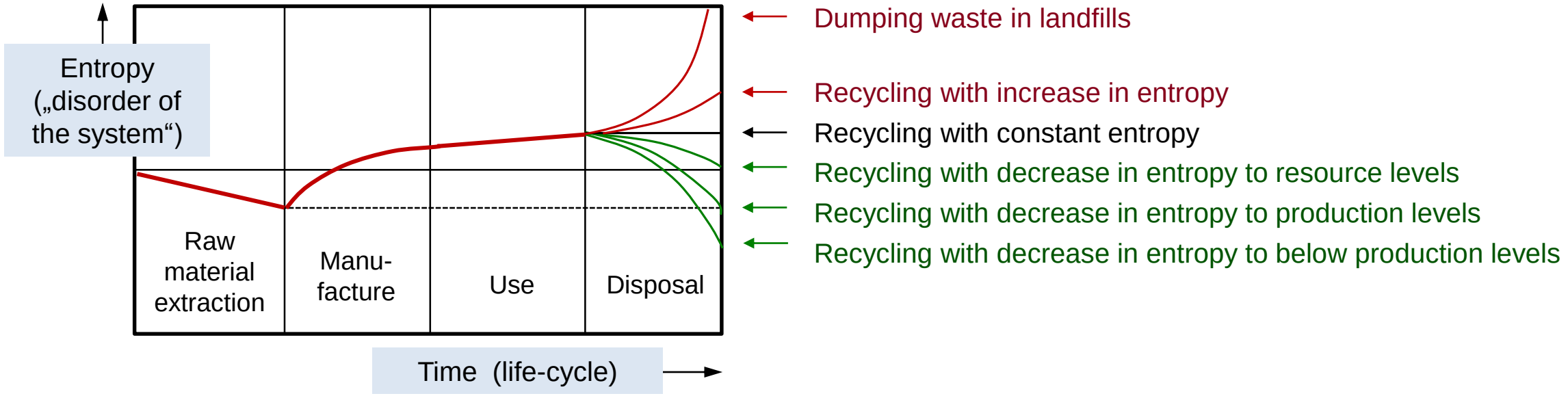
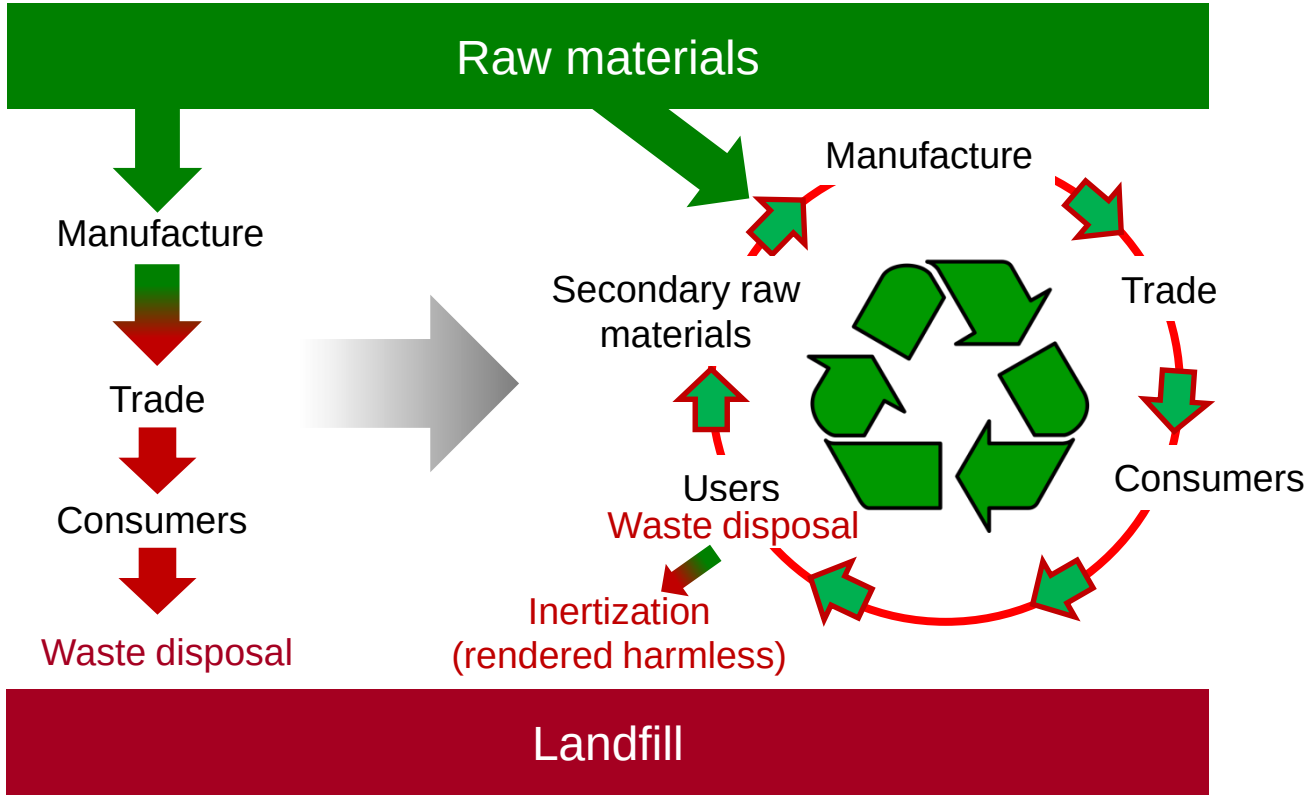
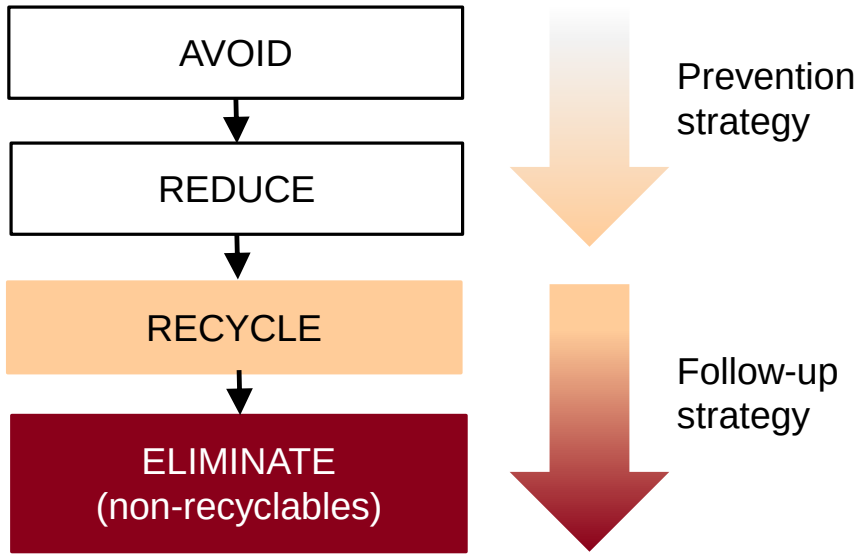
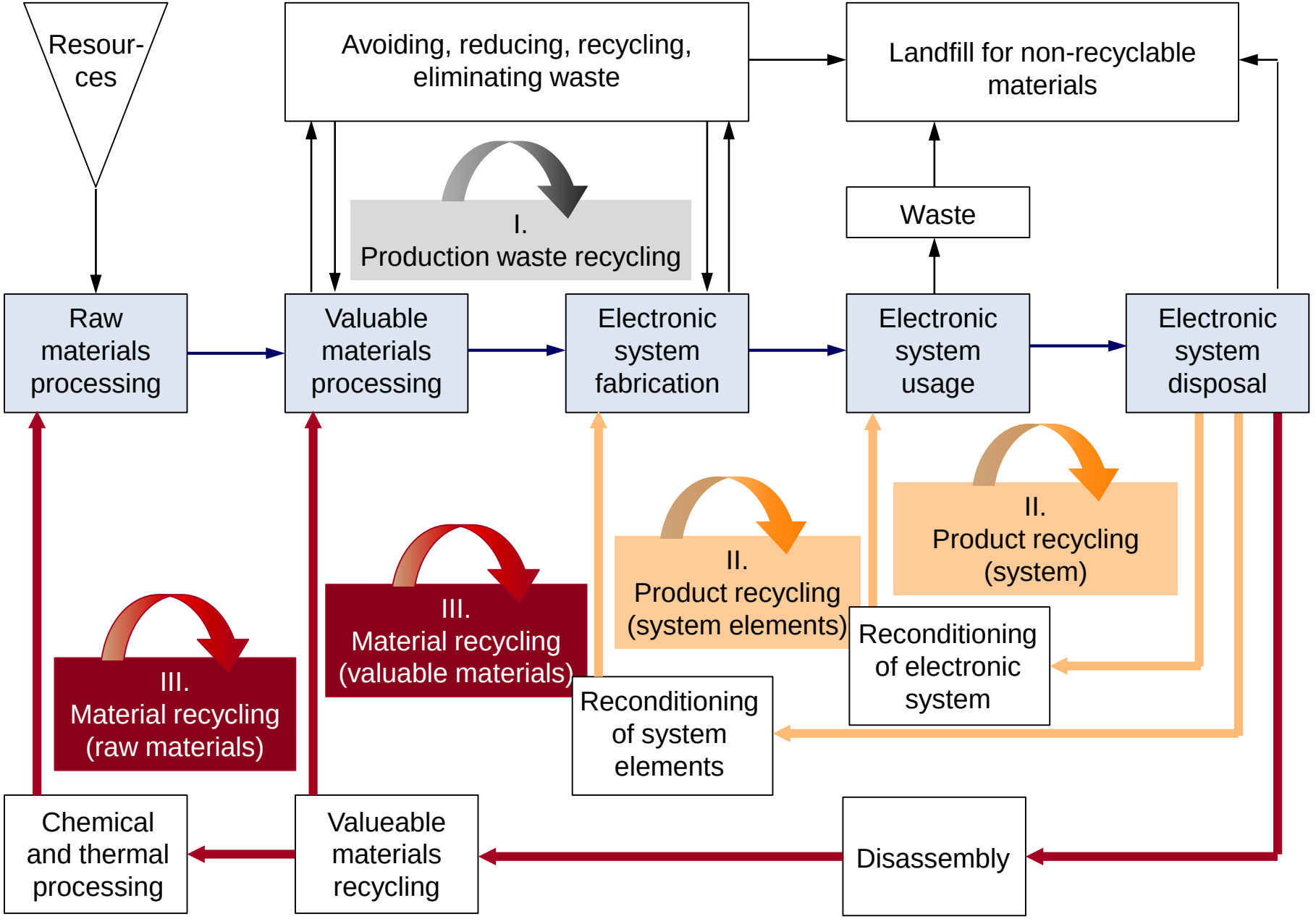
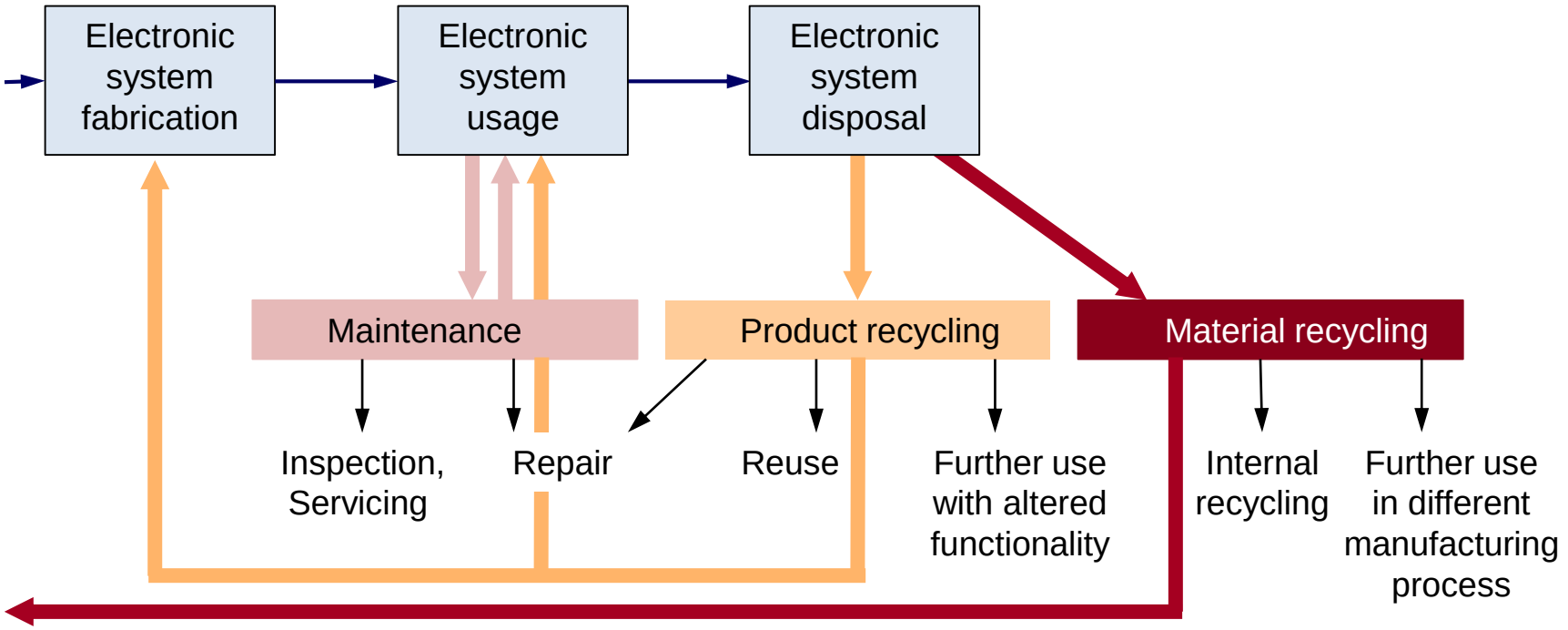


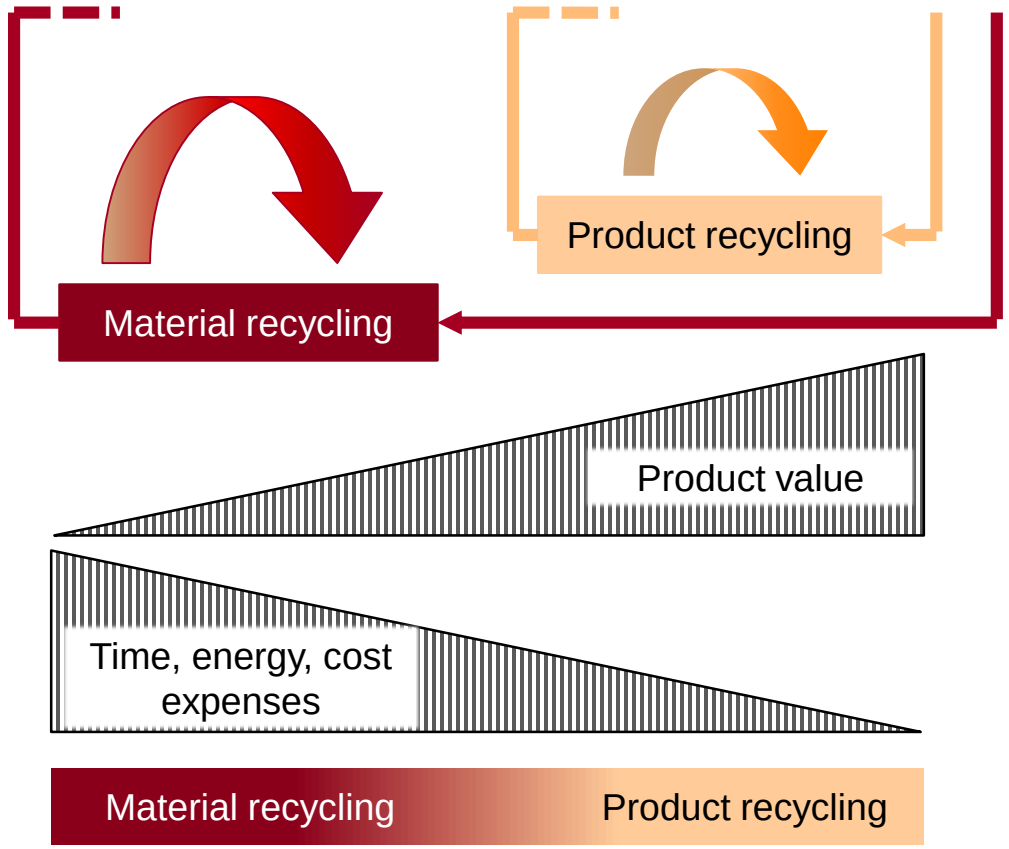
© J. Lienig, H. Bruemmer, *Fundamentals of Electronic Systems Design*. Springer, ISBN 978-3-319-55839-4, 2017.

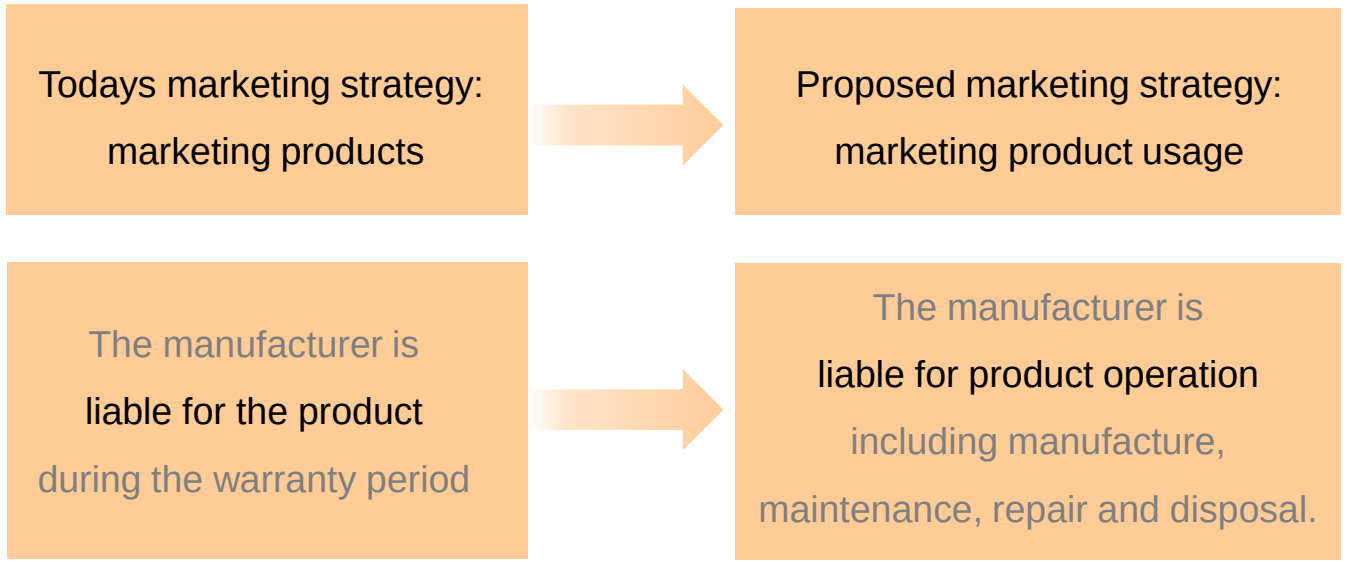

Raw materials
Manufacture
Trade
Consumers
Waste disposal
Manufacture
Secondary raw materials
Trade
Users
Consumers
Waste disposal
Inertization (rendered harmless)
Landfill


AVOID
REDUCE
RECYCLE
ELIMINATE
(non-recyclables)
Prevention
strategy
Follow-up
strategy


Resour-
ces
Avoiding, reducing, recycling, eliminating waste
Landfill for non-recyclable materials
I.
Production waste recycling
Waste
Raw materials processing
Valuable materials processing
Electronic system fabrication
Electronic system usage
Electronic system disposal
II.
Product recycling
(system)
II.
Product recycling
(system elements)
III.
Material recycling
(valuable materials)
III.
Material recycling
(raw materials)
Reconditioning of electronic system
Reconditioning of system elements
Chemical and thermal processing
Valueable materials recycling
Disassembly


Electronic system fabrication
Electronic system usage
Electronic system disposal
Maintenance
Product recycling
Material recycling
Inspection, Servicing
Repair
Reuse
Further use with altered functionality
Internal recycling
Further use in different manufacturing process

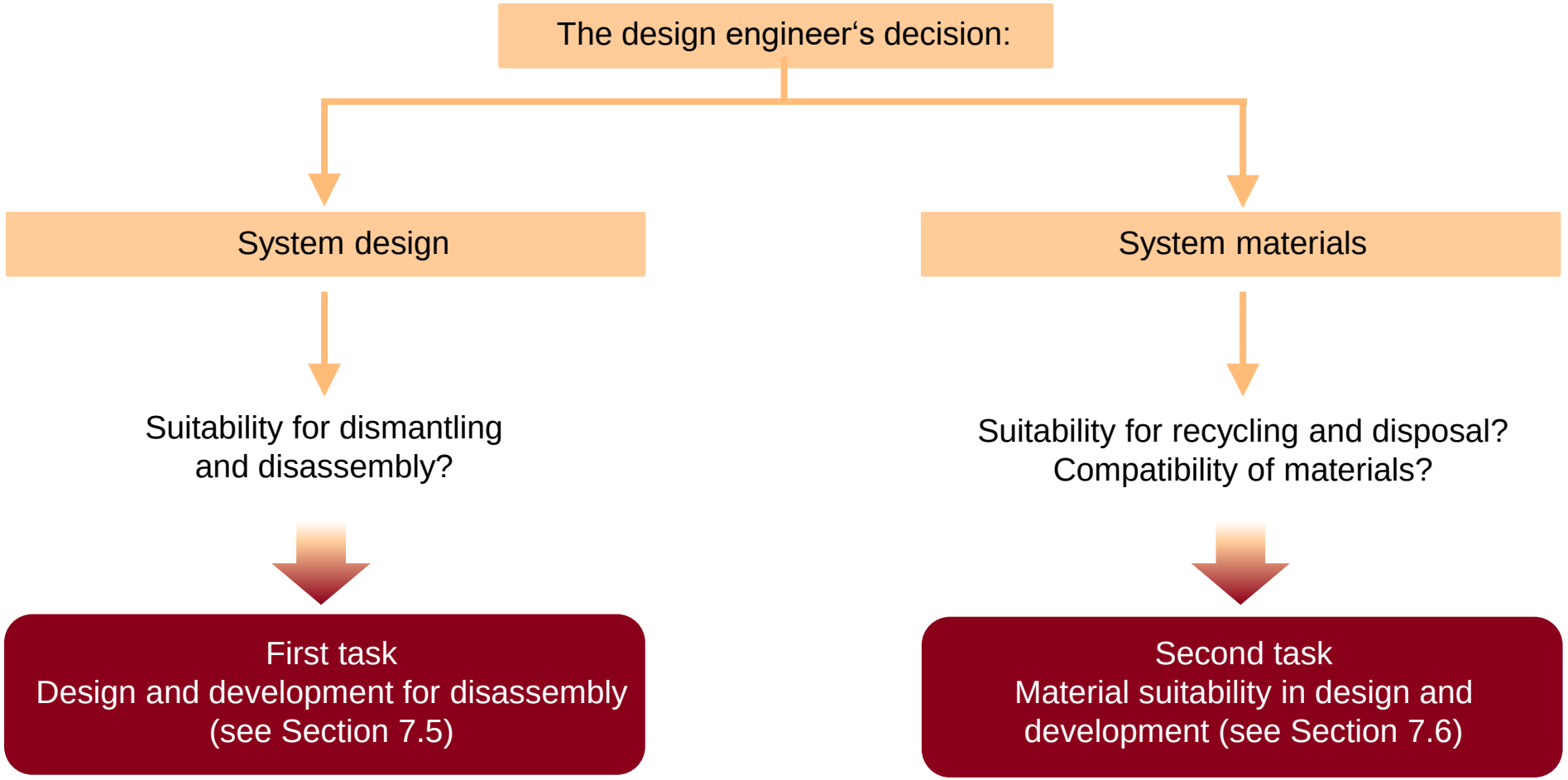

Product recycling
Material recycling
Product value
Time, energy, cost expenses
Material recycling
Product recycling

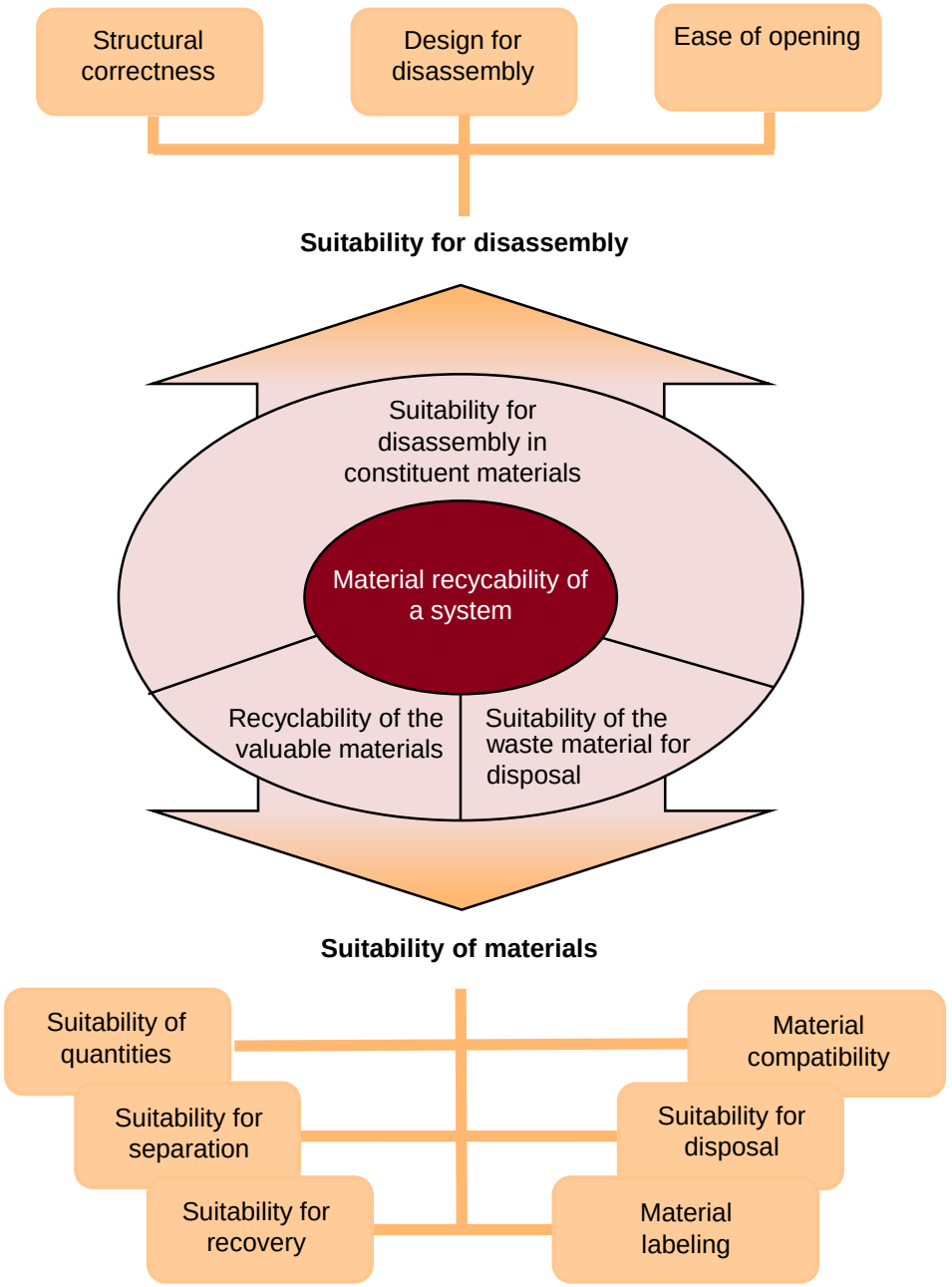

Todays marketing strategy:
marketing products
Proposed marketing strategy:
marketing product usage
The manufacturer is
liable for the product
during the warranty period
The manufacturer is
liable for product operation
including manufacture,
maintenance, repair and disposal.

Design for durability	
Strategy	Dimensioning and designing systems for service over long periods with little or no maintenance.
Principles and guidelines	– Avoiding wear and tear by electronic and optical means – Reducing wear and tear by compensating measures, adjustments and replacement of consumables – Preventing corrosion – Increasing reliability by functional and structural measures (functional elements with lower failure rates, introducing redundancy) – Deploying diagnostics with automatic error correction and scheduled maintenance (preventive maintenance).

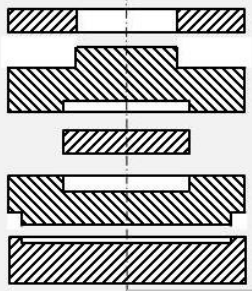
Design for regeneration	
Strategy	Dimensioning and designing systems so that simple and quick repairs can be carried out after a malfunction, and simple refurbishment or regeneration work can be carried out after loss or degradation of functionality, with the objective of a complete recovery to fully operational status.
Principles and guidelines	Enabling ease of disassembly and re-assembly of defective parts or parts for refurbishment (Design for disassembly, see Section 7.5).

Design for adaptability	
Strategy	Dimensioning and designing systems so that they are easy to upgrade to technical, technological and design changes with the objective of improving quality.
Principles and guidelines	– Application of modular design principle (modular design approach or industry-wide standard module development, see Section 3.2.1) – Application of modular design principles by splitting the system into subsystems with long expected service lives and those that are expected to change or be extended, along with a clear separation of functional and design elements. – Assuring the adaptability of modules by pre-emptive standardization. – Long-term acceptance of the design solution by applying the design-for-usability principles of functionality, simplicity and authenticity.

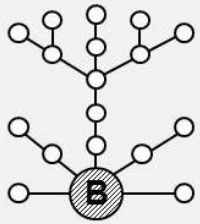
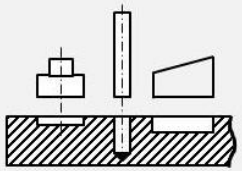

The design engineer‘s decision:
System design
System materials
Suitability for dismantling and disassembly?
Suitability for recycling and disposal? Compatibility of materials?
First task
Design and development for disassembly (see Section 7.5)
Second task
Material suitability in design and development (see Section 7.6)


Structural correctness
Design for disassembly
Ease of opening
Suitability for disassembly
Suitability for disassembly in constituent materials
Material recycability of a system
Recyclability of the valuable materials
Suitability of the waste material for disposal
Suitability of materials
Suitability of quantities
Material compatibility
Suitability for separation
Suitability for disposal
Suitability for recovery
Material labeling

Linear system assembly

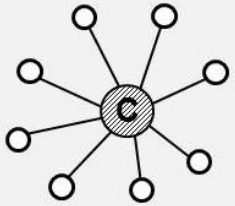
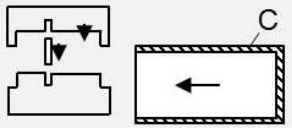
System structure	Assembly principle	Assembly techniques
		Layered assembly Stack assembly Sandwich assembly

Hierarchical system assembly

System structure	Assembly principle	Assembly technique
		Nested assembly - Chassis system

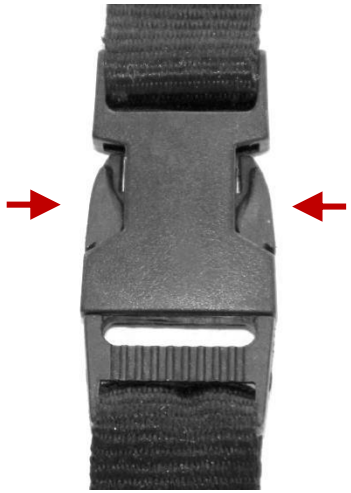
B = base element

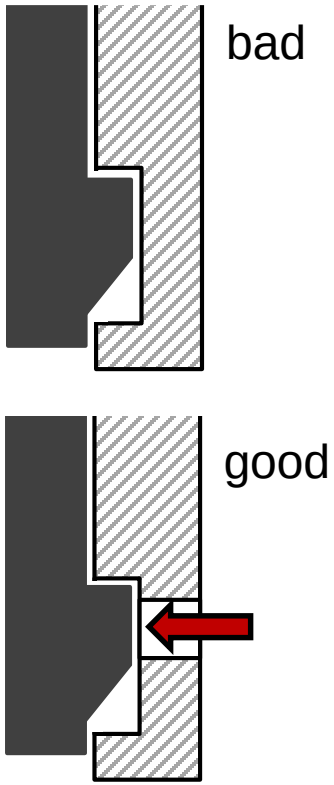
Radial system assembly

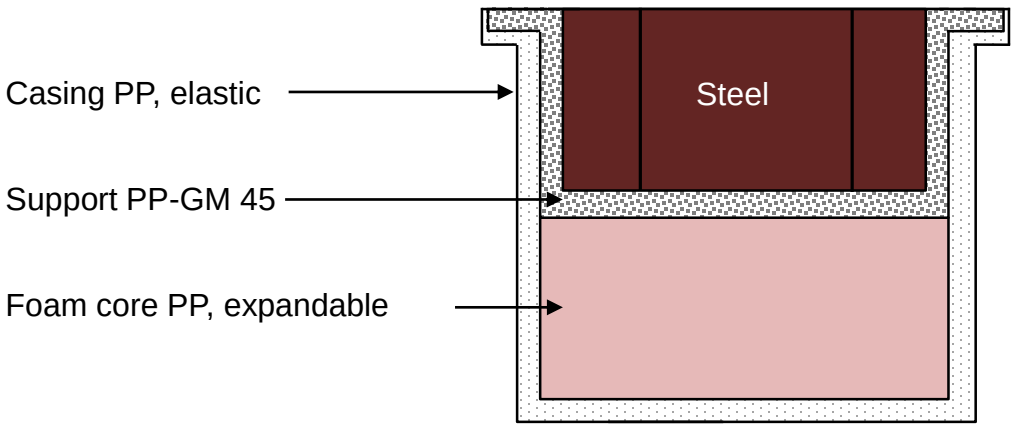
System structure	Assembly principle	Assembly technique
		Box assembly - "Ripcord" technique - "Cutlery tray" technique

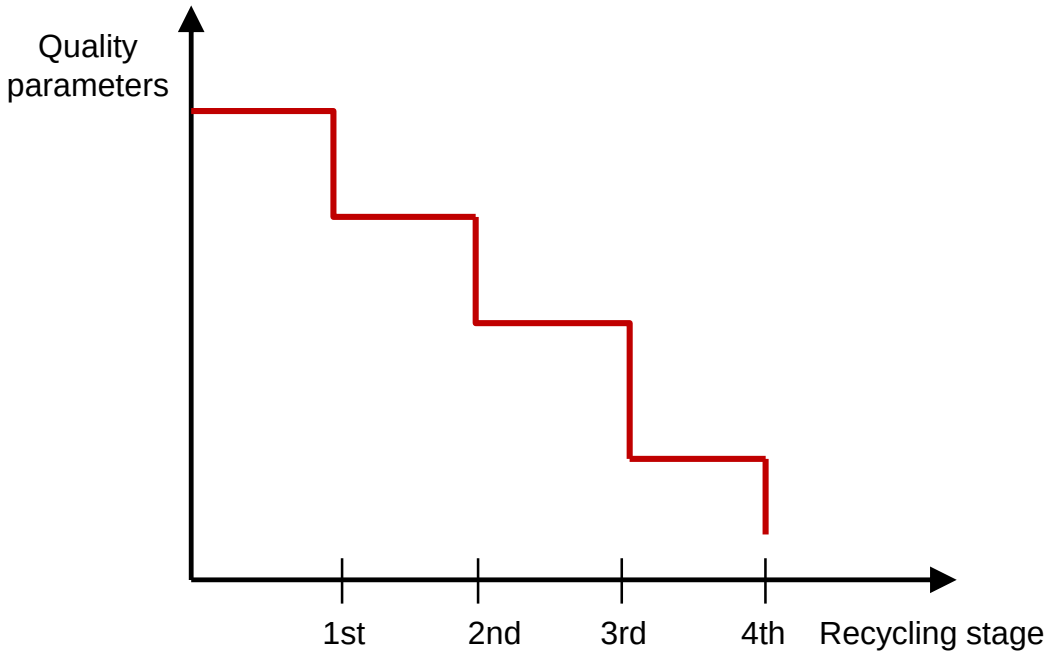
C = connecting element

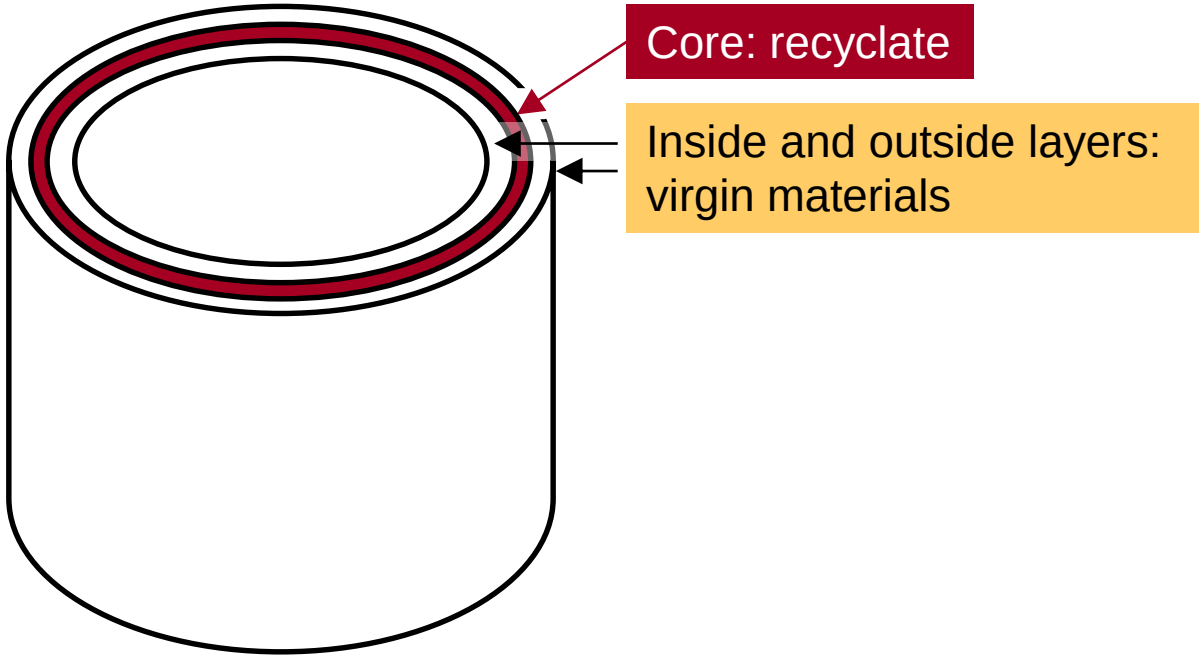
Improving the ease of disassembly
(suitability for dismantling)




bad
good


Casing PP, elastic
Support PP-GM 45
Foam core PP, expandable
Steel


Quality
parameters
1st
2nd
3rd
4th
Recycling stage


Core: recyclate
Inside and outside layers:
virgin materials

		Additive									
Matrix material	Enginee-ring plastics	PE	PVC	PS	PP	POM	SAN	ABS	PBTP	PETP	PMMA
	PE	●	○	○	●	○	○	○	○	○	○
	PVC	○	●	○	○	○	●	◉	○	○	●
	PS	○	○	●	○	○	○	○	○	○	○
	PP	⊙	○	○	●	○	○	○	○	○	○
	POM	○	○	○	○	●	○	○	⊙	○	○
	SAN	○	●	○	○	○	●	●	○	○	●
	ABS	○	◉	○	○	⊙	○	●	⊙	⊙	●
	PBTP	○	○	○	○	○	○	⊙	●	○	○
	PETP	○	○	⊙	○	○	○	⊙	○	●	○
	PMMA	○	●	⊙	○	⊙	●	●	○	○	●

● compatible

◉ partially compatible

⊙ compatible in small amounts

○ incompatible

Polyethylen terephthalat

High-density polyethylene

Polyvinyl chloride

Low-density polyethylene

Polypropylene

Polystyrene

All other plastics

Cardboard

Other paper

Wax Paper (single sided)

Steel

Aluminum