BioPack: a technology for waste inhibition and compaction for Life Support Systems

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Kayser Italia in pills

Private System Engineering company with a multidisciplinary staff of 70 highly specialized scientists and engineers, with expertise in electronics, aeronautics, mechanics, thermo-dynamics, physics, computer science, optics, chemistry, cellular and molecular biology/biotechnology.

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Problem description

Re-supply and waste management are critical components of crewed space exploration. A significant part of pressurized cargo uploaded mass is composed of food packaging and padding material, which cannot be recycled/transformed into resources and become ultimate mission waste.

- Even if the storage time of the collected waste is limited, the crew is exposed to (bio)safety risks due to the growth of microbes on the food/drinking packaging and food leftovers. Specific inhibition tecniques should be investigated.
- Considering the high volume of padding materials within mission waste, specific volume reduction technique should be investigated.

Objective of the activity (1/2)

Under the aegis of the European Space Agency, Kayser Italia – along with the Ghent University – is developing a ground technological demonstrator to validate and optimize the compaction and inhibition technology.

Objective of the activity is to develop an innovative system to compact and inhibit selected waste by studying technological solutions to reduce human safety risks by inhibiting microbes, compact and re-process selected wastes, which also make use of the biodegradable packaging.

Objective of the activity (2/2)

This objective is intended through the study of:

- Technologies for microbial inhibition of food/beverage waste generated during the mission, in view of safe, long-term storage, and which allow further processing and recovery of resources by Life Support Systems (i.e. MELiSSA CI compartment) or Materials Processing Systems (e.g. additive manufacturing).
- Technologies for compaction/volume reduction of padding waste generated during the mission, in view of safe, long-term storage, and which allow further handling by Materials Processing Systems.

Waste management approach on the ISS

The current waste management approach on the ISS is simple and low-tech:

- Hand-compacting the waste material (not sorted).
- Wrapping it into small bundles ("trash footballs").
- Loading up a docked resupply vehicle.
- Burn it during atmospheric re-entry.

Credit: NASA

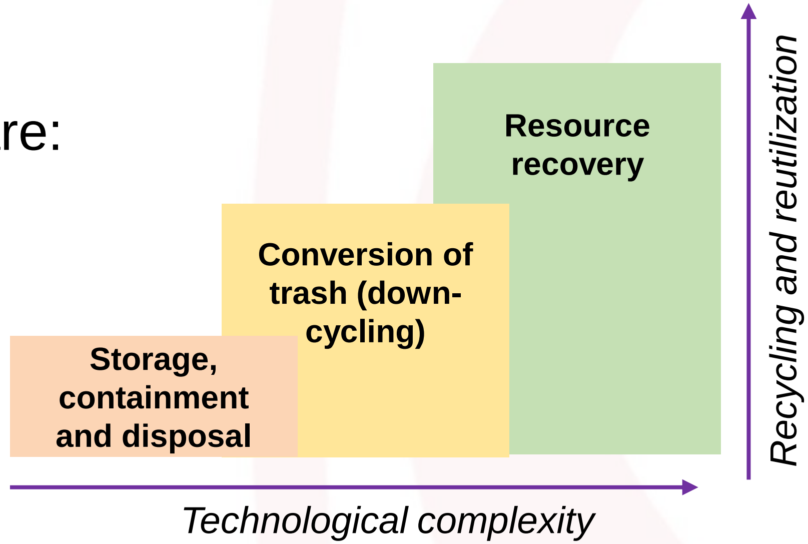

Credit: NASA

Waste management during long-term exploratory human space missions

Long-duration exploratory human spaces missions require an adequate waste management approach.

Possible waste management approaches are:

- Storage, containment and disposal.
- Conversion of trash (down-cycling).
- Resource recovery.



Deep-space mission crews will be largely on their own, which means that space agencies are increasing emphasis on the three R's of trash management: ***reduce, reuse, recycle***.

Waste handling and management key aspects

Key aspects for the waste management system design:

- Crew operations.
- Containment.
- Potential microbial inhibition.
- Storage volume.
- Storage duration.

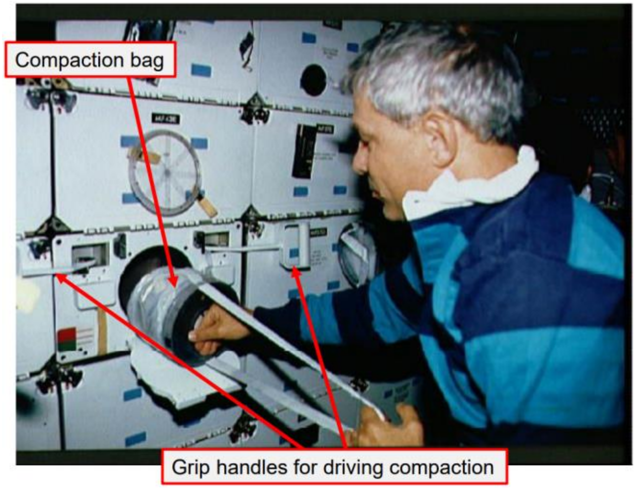
Credit: NASA

Credit: NASA

Waste compaction and inhibition processes investigated by NASA

NASA has been developed solid waste management systems since the mid-1980s.

- In 1990 a manual mechanical compactor was tested in space (STS-35).
- In 2003 investigation of a compaction systems for future long-duration space missions begun. Several demonstrators were design and built (e.g. Compress Melt Unit in 2003, NASA Gen 1 Heat Melt Compactor in 2008).
- The most advanced demonstrator, currently under test, is the NASA Gen 2 Heat Melt Compactor (HMC).



Credit: NASA

Credit: NASA

Mission scenario considered

The mission scenario considered is derived from the Lunar Gateway scenario.

- Number of crew members: 4.
- Mission duration: 1 to 3 years.
  - Man-tended duration (crew members presence): 30 to 90 days.
  - Unmanned duration: up to 3 years.
- Logistics: 1 resupply per mission (prior to crew arrival).

Waste description	Waste amount g/(CM·d)	Detail
Food/beverage packaging	352 (see column "Detail")	Food/beverage packaging (different values are found in literature): – 352 g/(CM·d) (source: AIAA 2014-0497) – 247 g/(CM·d) (source: Summary of AES Logistics project Exploration Waste Model v3.2) – 230-310 g/(CM·d) (source NASA/TP-2015-218570 Rev.1) – 260 g/(CM·d) food packaging + 210 g/(CM·d) food storage (source: AIAA 2013-3362) Food/beverage leftovers: – Waste food adherent to packaging: 100 g/(CM·d) (source: NASA/TP-2015-218570 Rev.1) – Inedible and not opened food waste: 400 g/(CM·d) (indicated in AIAA 2013-3362 as generic "food waste") Note: AIAA 2013-3362 indicates a generic value of food waste of 310 g/(CM·d))
Padding	48	– Foam packaging for launch: 40 g/(CM·d) (source: AIAA 2014-0497) – Polyethylene zip top bags: 8 g/(CM·d) (source: summary of AES Logistics project Exploration Waste Model v3.2)

Food/beverage packaging characterization

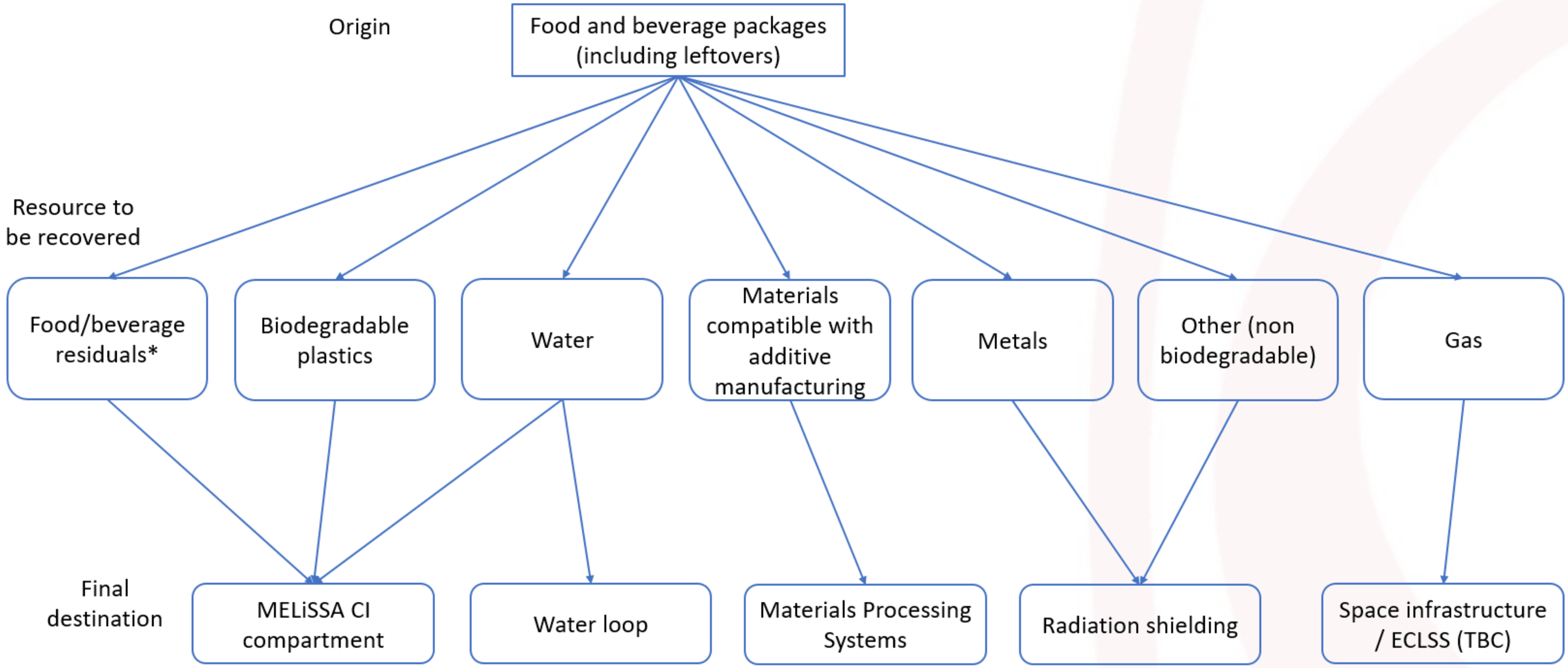
Type of packaging	Composition
Flexible pouch	Polyester, Aluminium and PP (composite)
Retort pouch	PET, Nylon, Aluminium foil, CPP (composite)
Flexible pouch	Polyester, Aluminium, Nylon and CPP (composite)
Bite size pouch	Nylon, EVOH, PE (composite)
Beverage pouch with septum adapter	PET, Aluminium Foil, LLDPE+LDPE (composite)
Rehydratable pouch with septum adapter	Nylon, EVOH, PE (composite)
Septum adapter	LDPE, silicone, PET (composite)
Large overwrap	PET, white-LDPE, Aluminium foil, Surlyn (composite)
Small overwrap	PET, white-LDPE, Aluminium foil, Surlyn (composite)
Commercial food packaging	PE/ Nylon/ EVOH
Bowls/cans	Aluminium alloy with magnesium or manganese

Credit: NASA

Credit: NASA

The food/beverage packagings currently used on the ISS are not biodegradable.

Resource recovery from food/beverage packaging



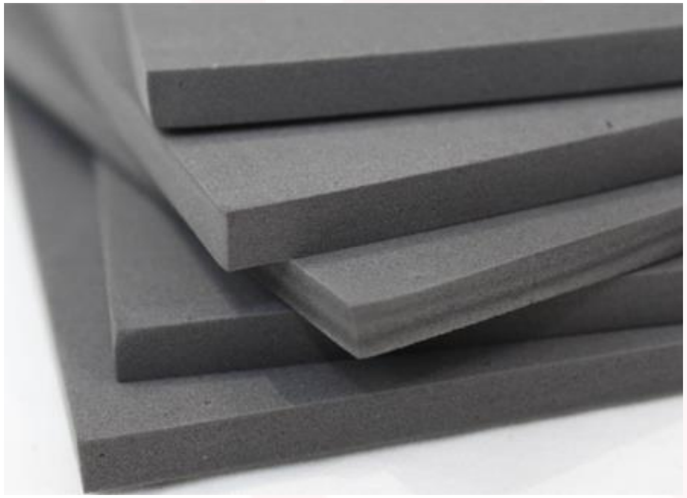
** Only if contained in biodegradable packaging. Including waste food adherent to packaging, inedible and not opened food waste*

The food/beverage packages (including leftovers), if contained inside a biodegradable packaging, could be recycled in the MELiSSA CI compartment.

Padding characterization

Padding material is used to protect the hardware during upload, on-orbit stowage or download. There are typically three types of packaging material used.

Material	Type of packaging
PVDF (polyvinylidene fluoride)	Foam
XPS (extruded polystyrene)	Foam
PE (polyethylene)	Bubble wrap
	Standard bubble wrap
	Ziplock bags

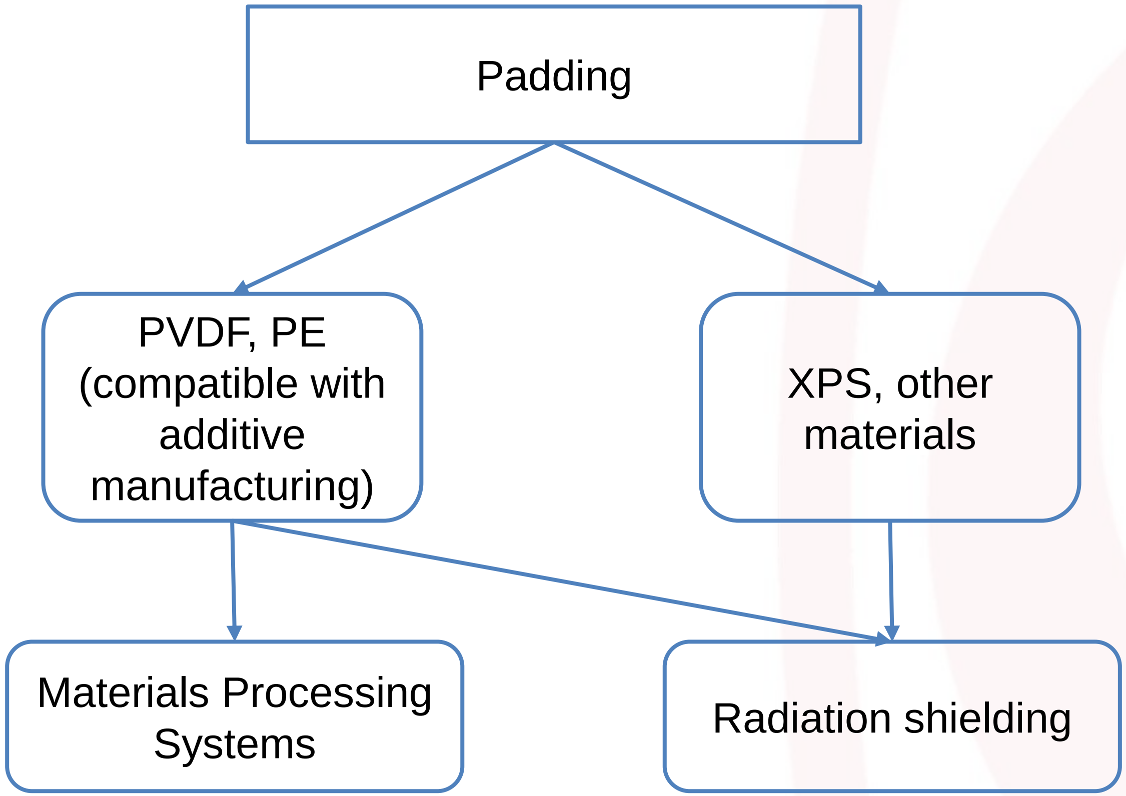


Resource recovery from padding

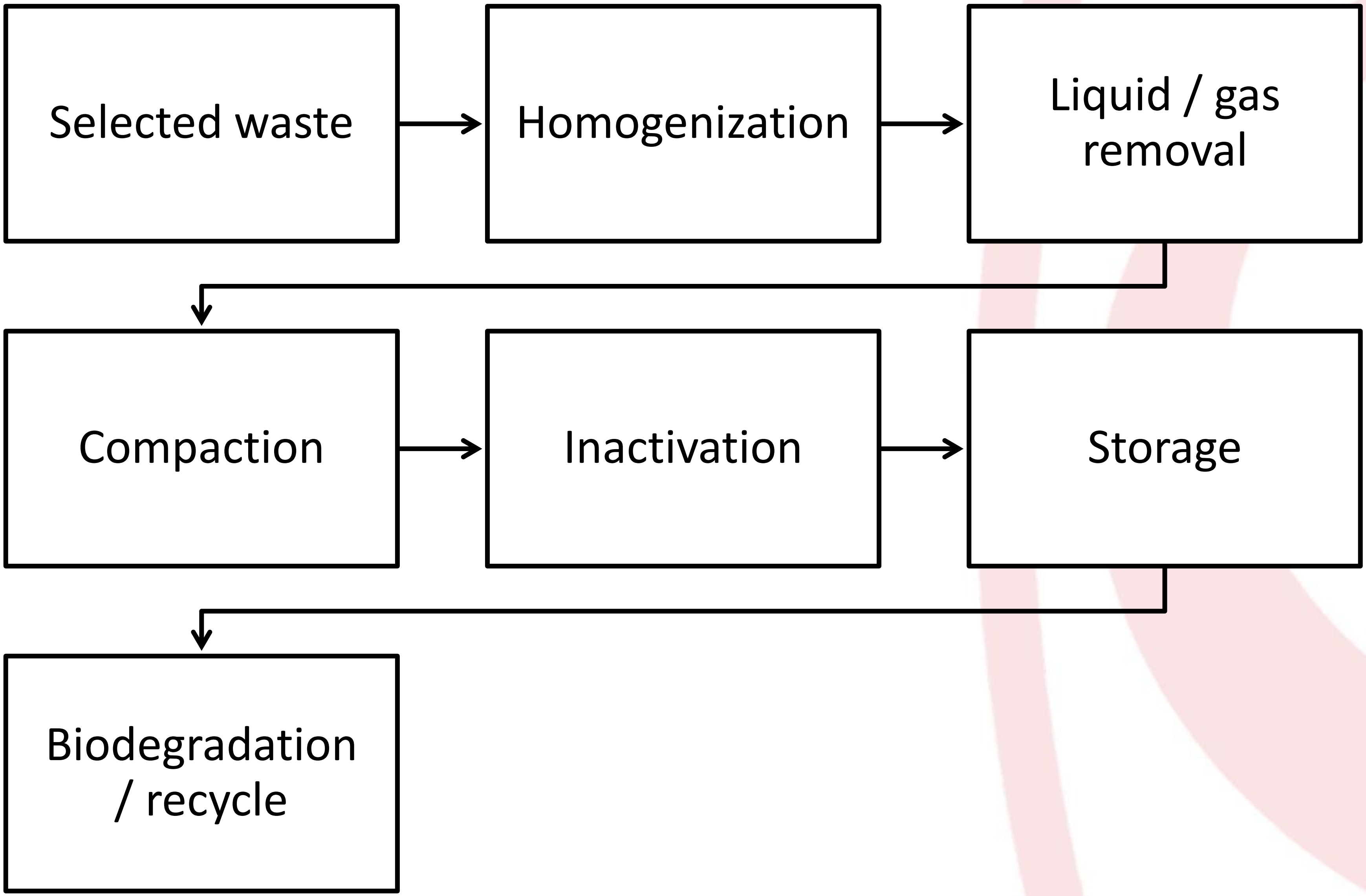
Origin

Resource to be recovered

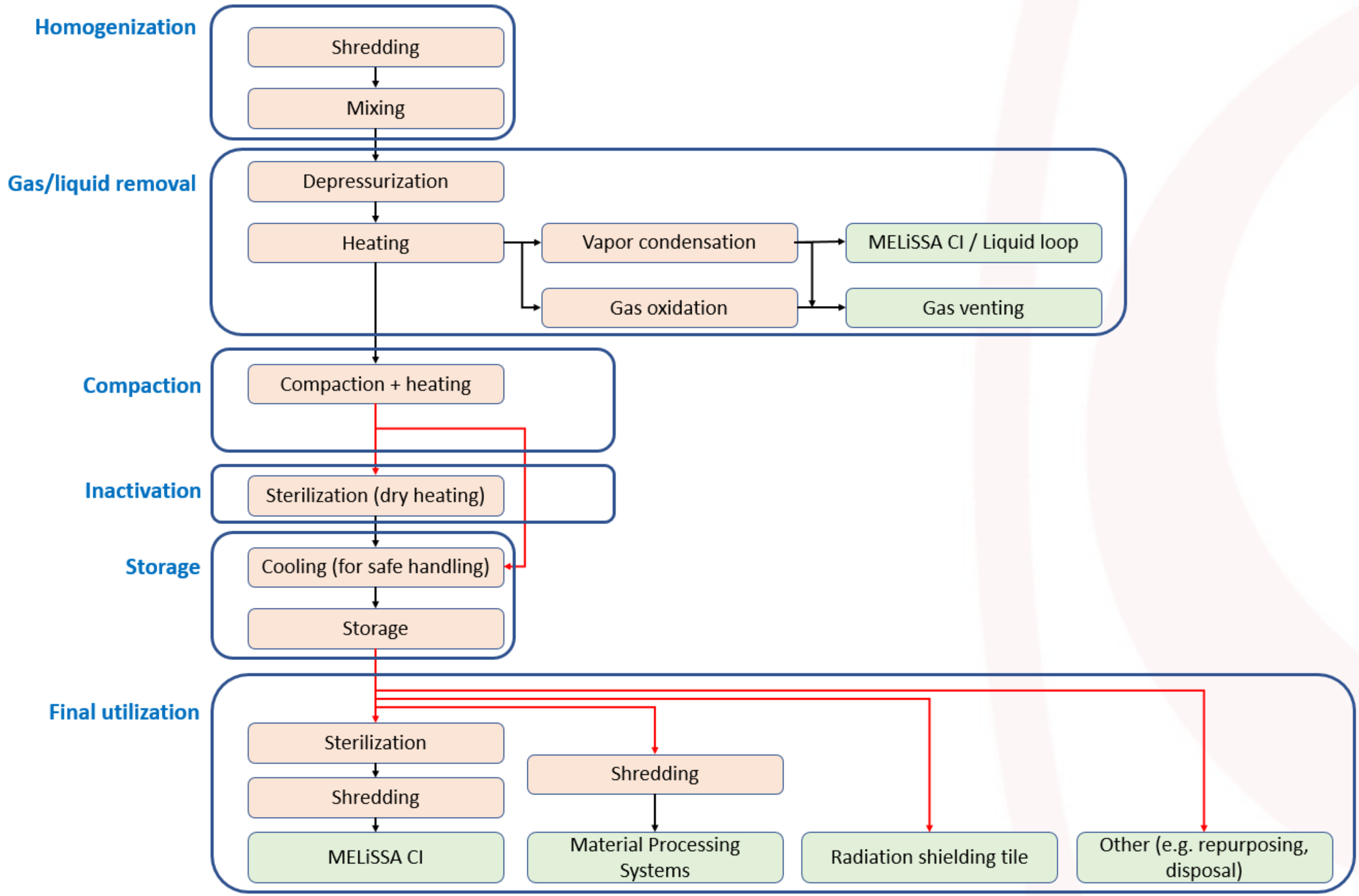
Final destination



Logic scheme for inhibition and compaction of selected waste

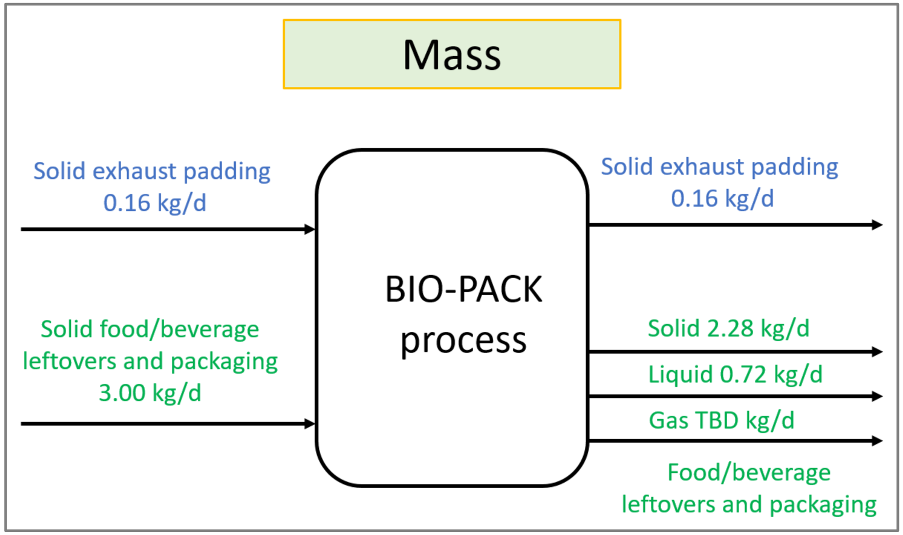


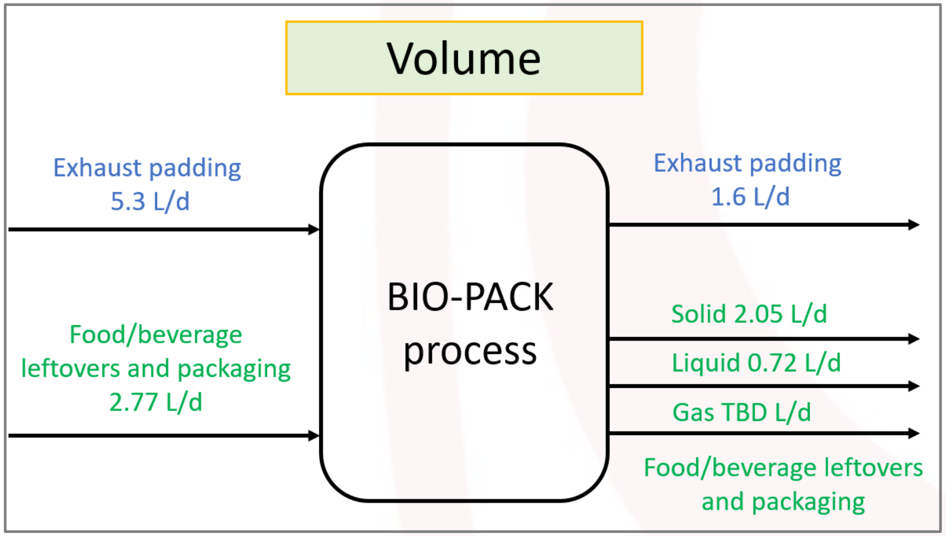
Compaction and inhibition process conceptual design



Mass and volume fluxes

Preliminary mass and volume fluxes in the waste compaction and inhibition process considering both the food/beverage packaging and the padding.





BioPack ground technological demonstrator description

The ground technological demonstrator is designed to:

- Compact the waste inside the waste chamber.
- Enable waste drying by using heat and vacuum.
- Enable the water vapor condensation and liquid water recovery.
- Inactivate the waste using high temperature.
- Cool down the tile obtained after the end of the processing cycle.

The technology is under validation by optimizing the following operative parameters:

- Process steps duration.
- Inactivation temperature.
- Compaction pressure.
- Vacuum level.

After compaction and inhibition, the waste:

- Will be microbially inert.
- Will be dimensionally stable for at least 6 months.

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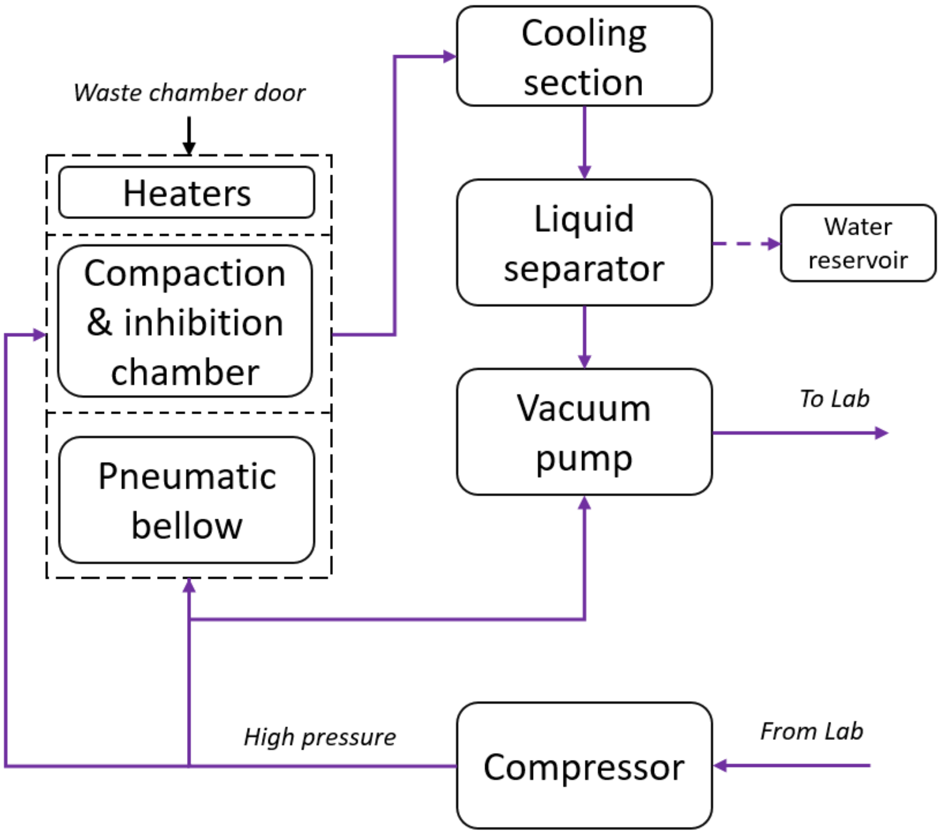

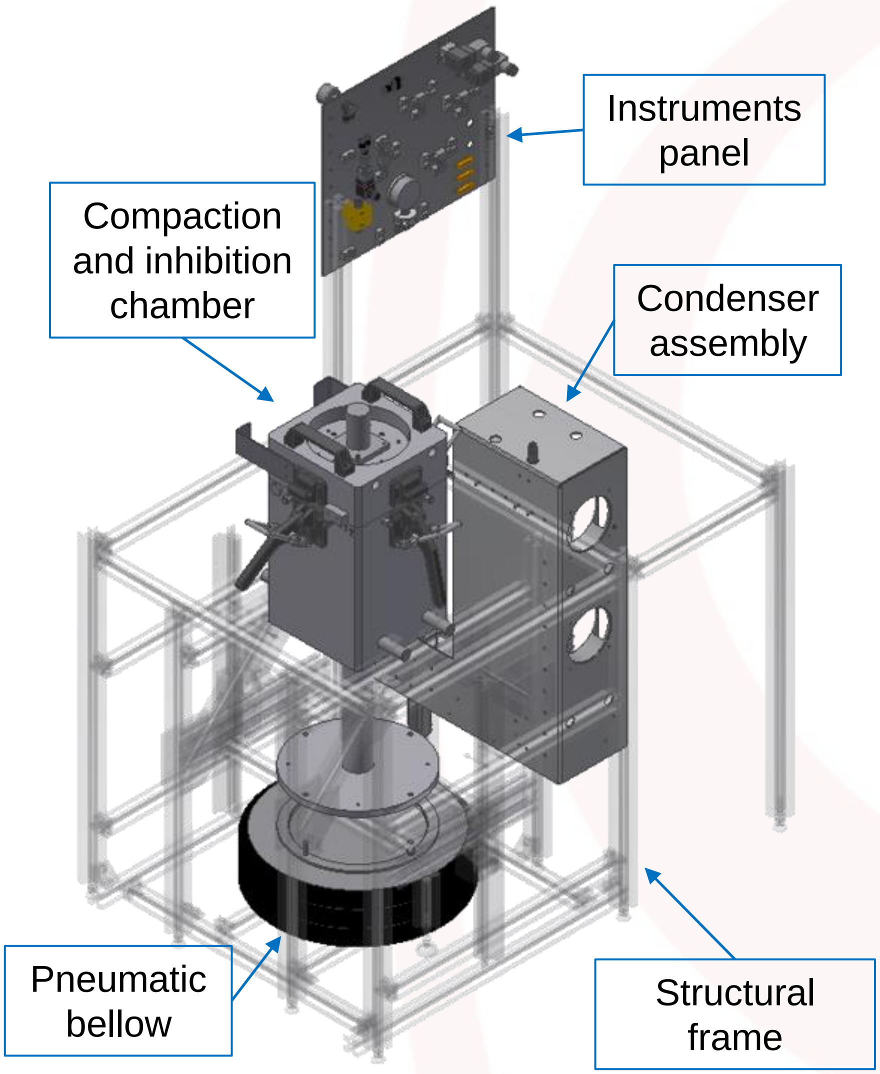

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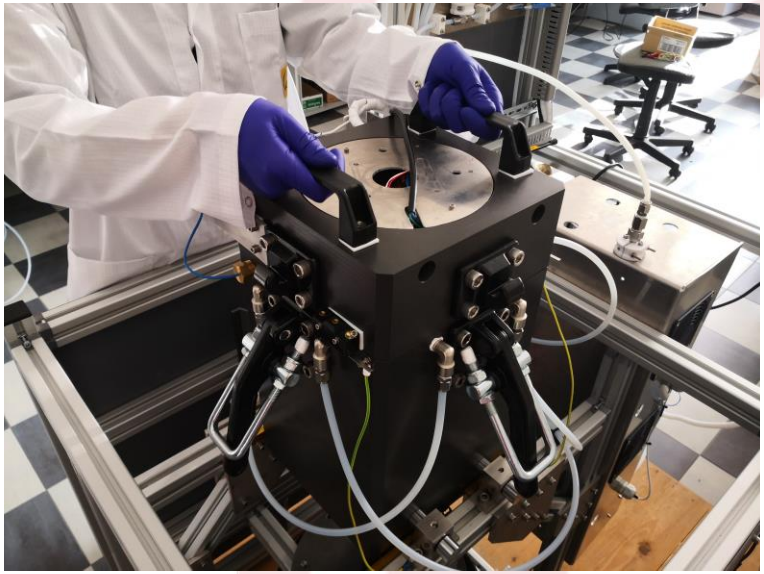

Conclusions / future developments

The ground technological demonstrator is currently under functional tests at Kayser Italia premises.

After this phase it will be delivered at the Ghent University for the scientific test campaign.

- The ground technological demonstrator is used to validate and optimize the compaction and inhibition technology for padding and biodegradable packaging materials.
- The tests will verify, using different materials:
  - The dimensional stability of the treated waste.
  - The biological inactivation over time.
- The optimized process and operative parameters could be used as reference for the requirements definition of a future flight model.
- A possible alternative application for this technology could involve the maritime sector, due to the change in legislation for waste management while on open sea.

Acknowledgements

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… and thank you all for your attention!