INL/CON-22-68546-Revision-0

Preprocessing of municipal solid waste towards thermal insulating material

August 2022

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Changing the World's Energy Future

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Preprocessing of municipal solid waste towards thermal insulating material

Idaho National Laboratory

Outline

- Municipal solid waste (MSW)
- How the MSW is being currently handling?
- Potential opportunities of MSW
- Case study as thermal insulation material
- Results and discussions
- Conclusions
- Future works

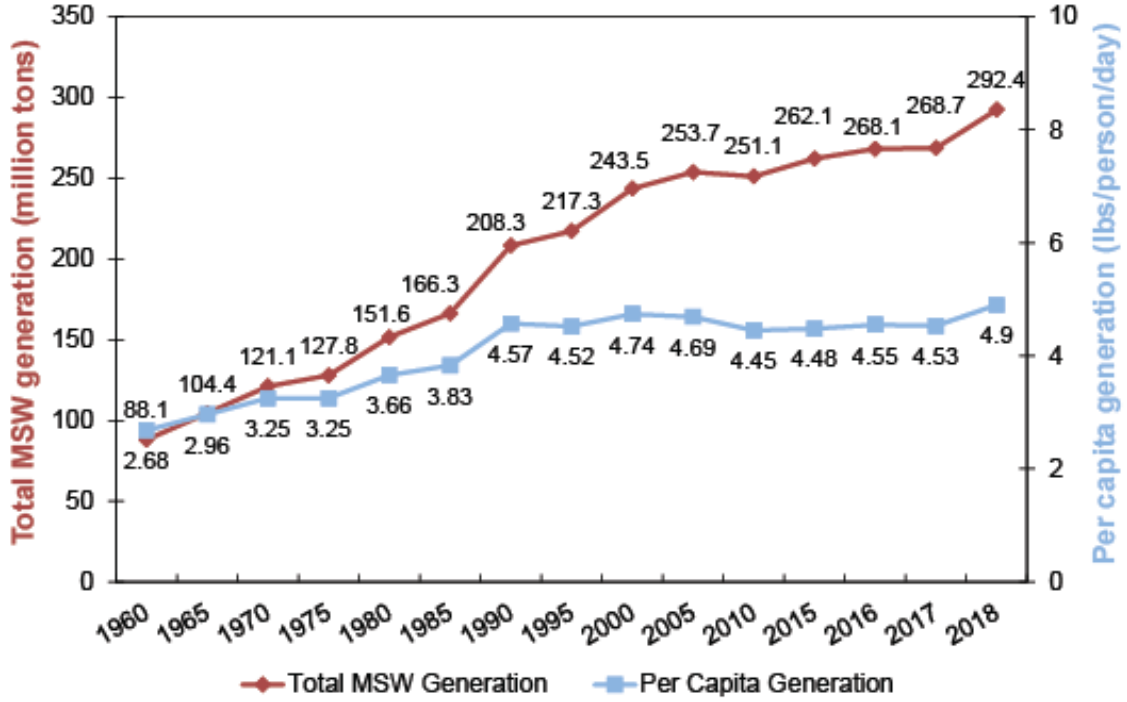
Municipal solid waste (MSW)

- Municipal Solid Waste (MSW), commonly called “trash” or “garbage” consists of everyday items we use and then throw away, such as:
  - Product packaging,
  - Grass clippings,
  - Furniture,
  - Clothing,
  - Bottles,
  - Food scraps,
  - Newspapers,
  - Appliances,
  - Etc.

Accessed at https://www.pngitem.com/middle/hxoJbRw_municipal-solid-waste-png-transparent-png/ on 06.28.2022

Generation of MSW

- Total annual MSW generation in the U.S. has increased by 93% since 1980 to 2018.
- Per capita MSW generation increased by 34% over the same time period (3.7 to 4.9 lbs per person per day). As comparison, MSW generation rates (lbs/person/day) are 2.8 in Sweden, 3.7 in Germany, and 2.7 in the United Kingdom.



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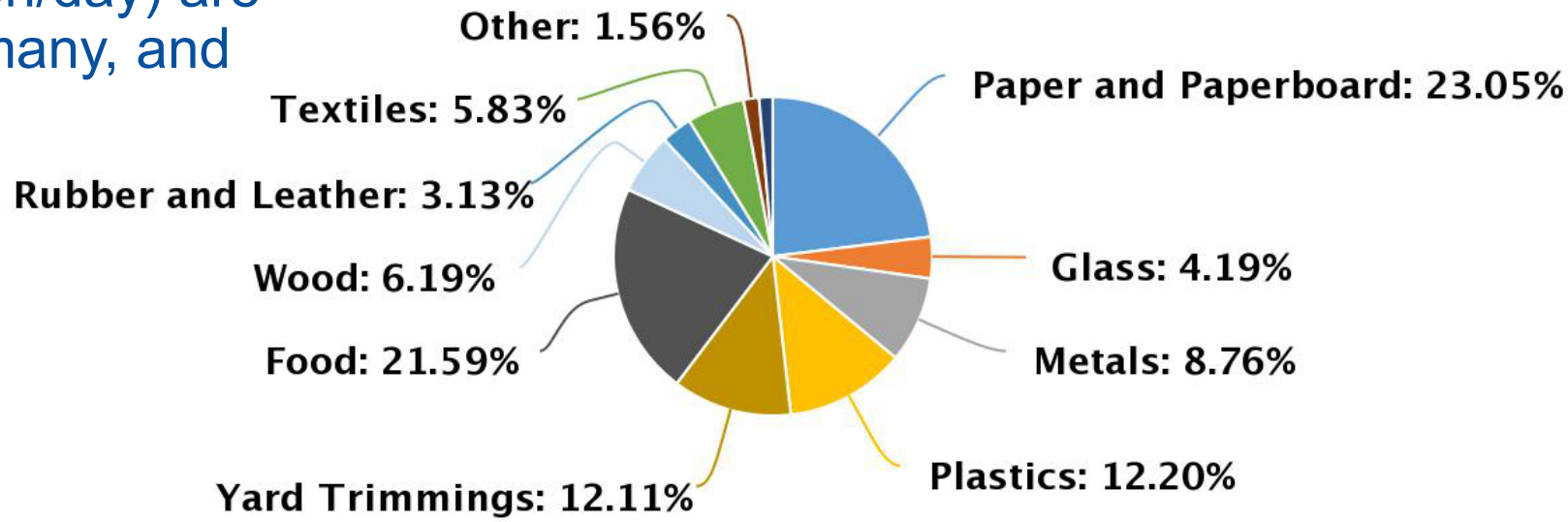
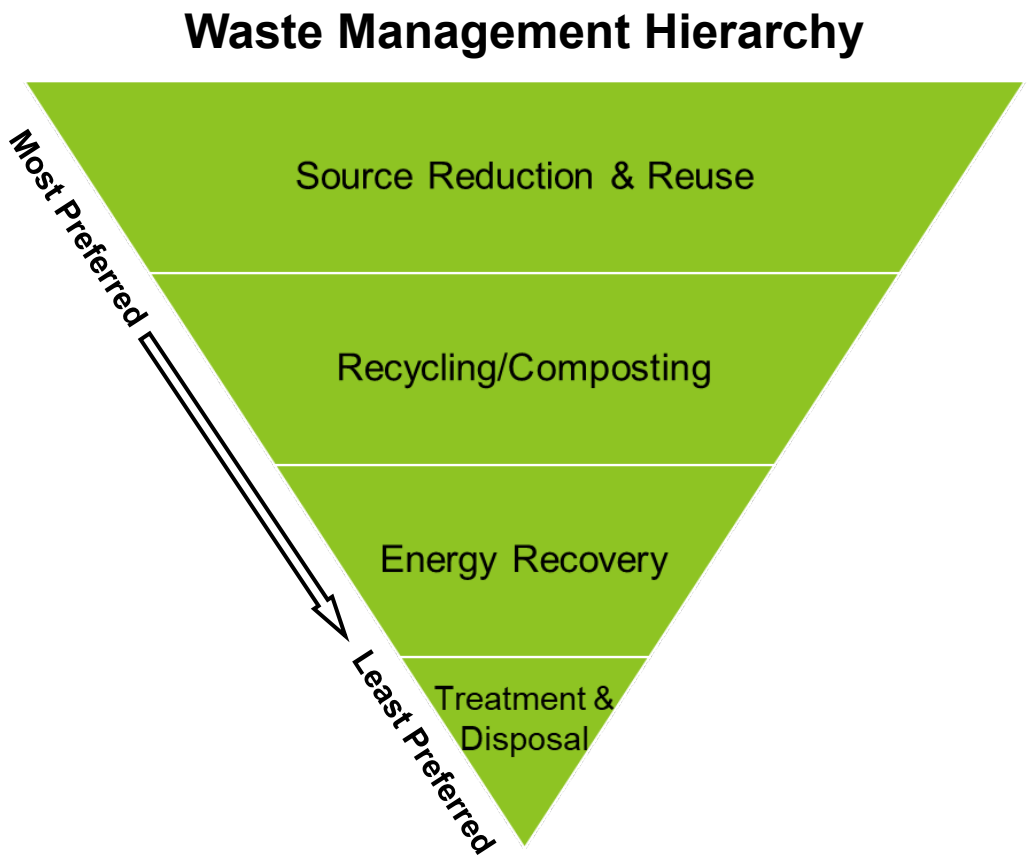
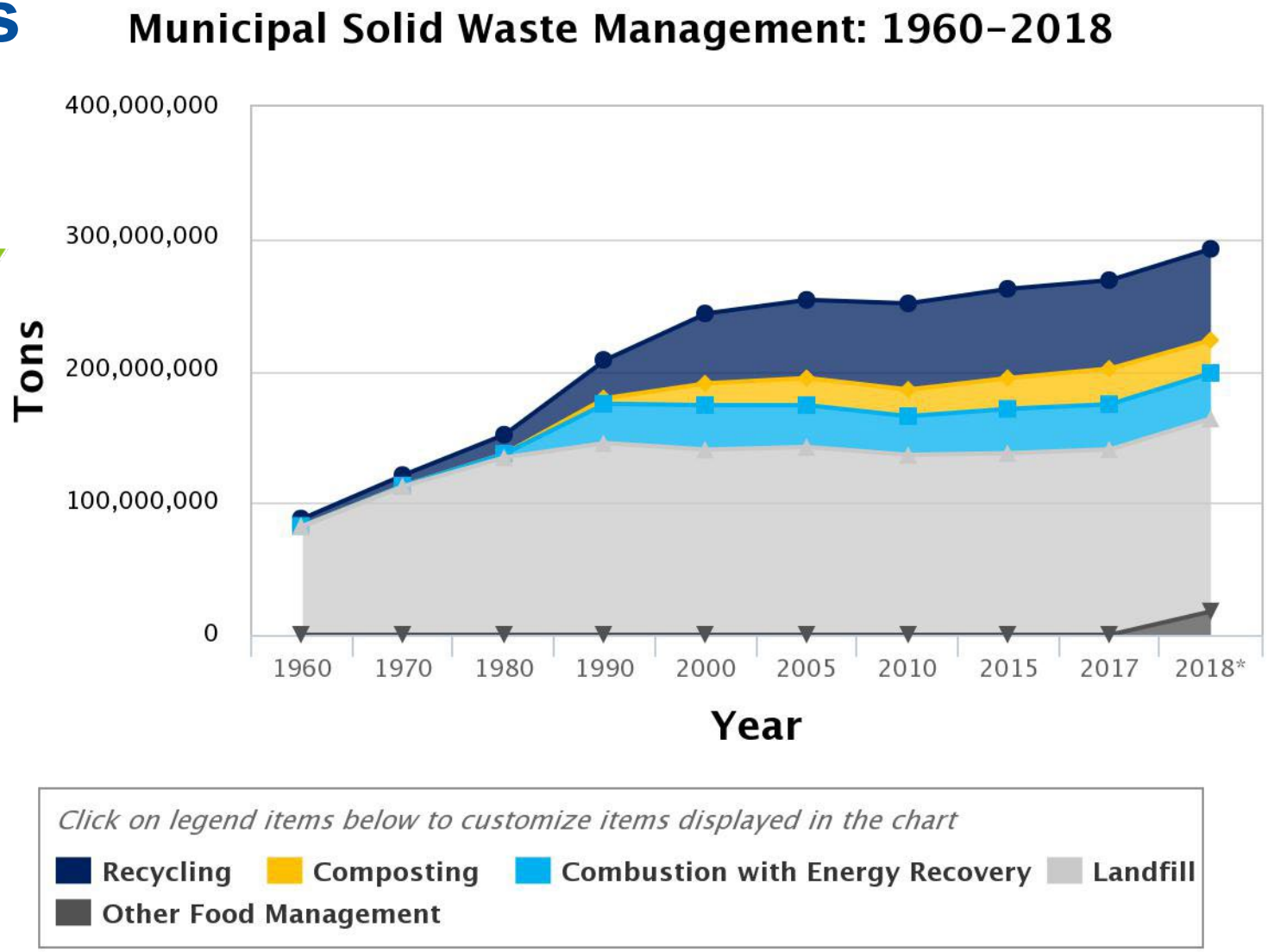


Management methods



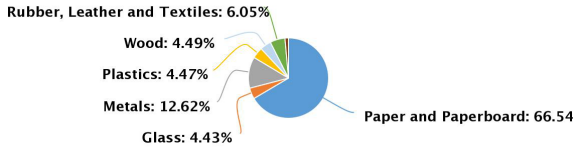


Accessed at https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials on 06.28.2022

Summary of management methods

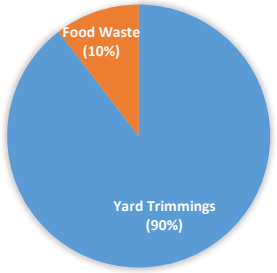
Recycled:

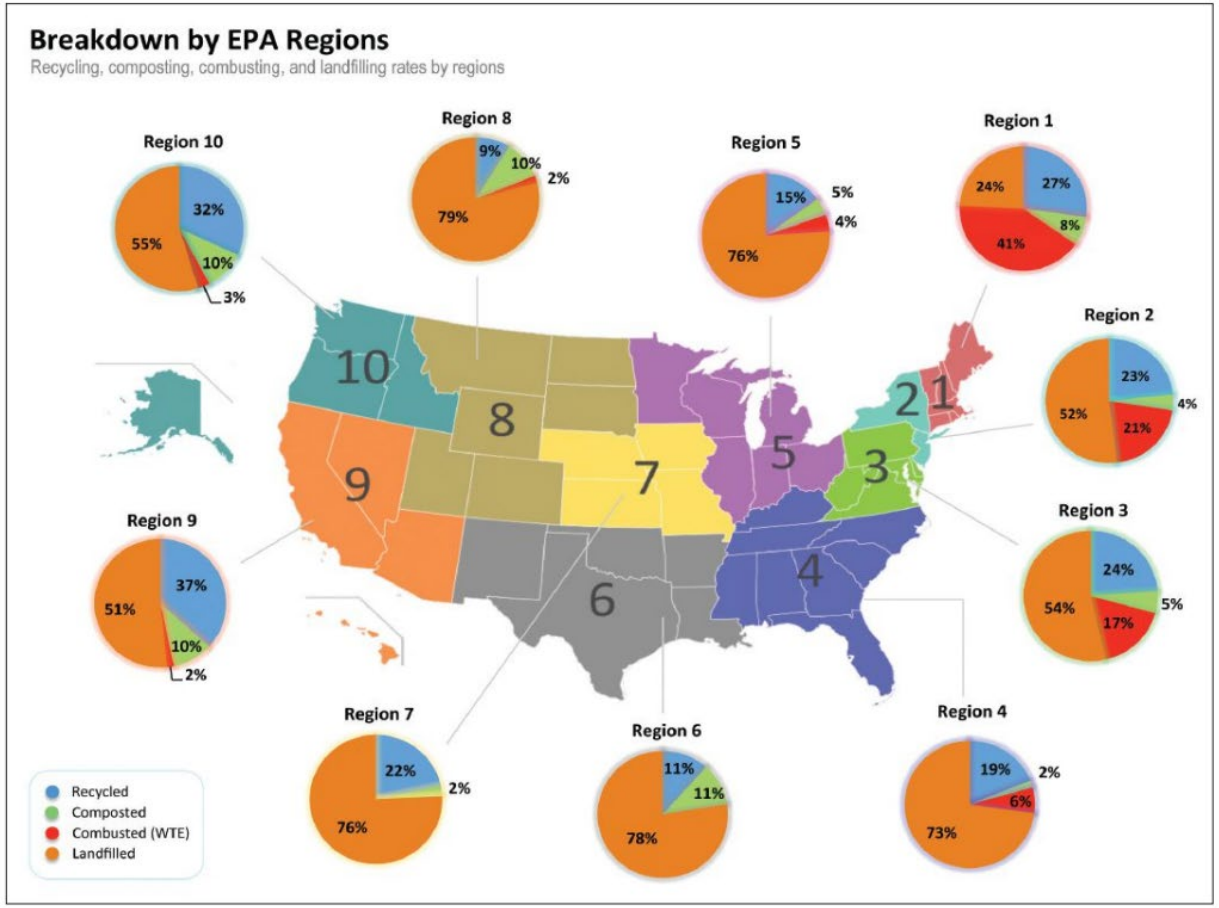
In 2018, 69 million tons MSW was recycled.



Composted:

In 2018, 25 million tons MSW was composted.

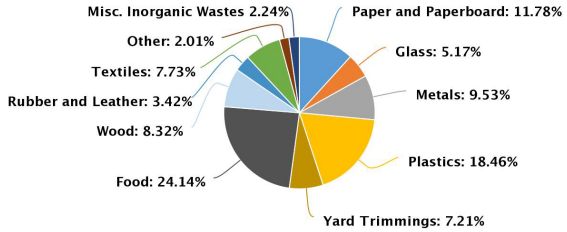




Accessed at https://www.mswmanagement.com/ on 06.28.2022

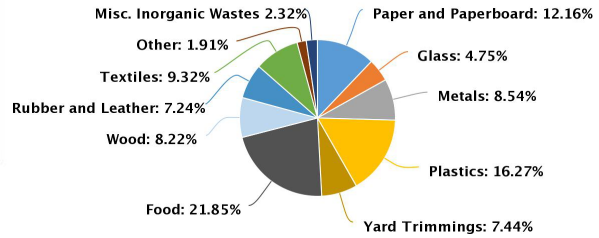
Landfilled:

In 2018, 146 million tons MSW was landfilled.



Combusted:

In 2018, 35 million tons MSW was combusted.



Greenhouse gas benefits

In 2018,

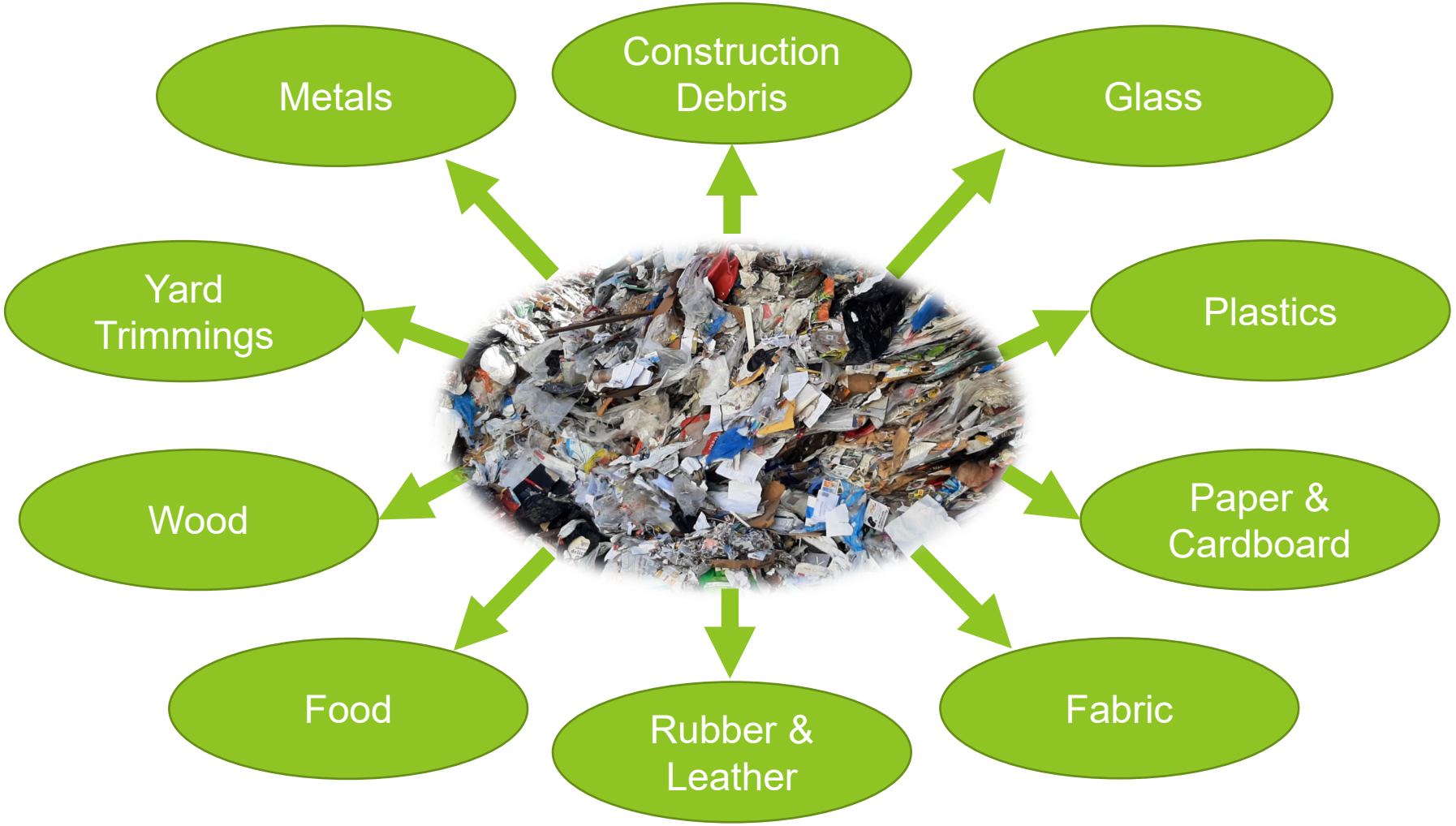
Recycled (MT)	Composted (MT)	Combustion with Energy Recovery (MT)	Landfilled (MT)
69	25	35	146

Note: numbers in parentheses indicate a reduction in either greenhouse gases or vehicles, and therefore represent environmental benefits.

MSW's environmental impact

- >15% of methane emissions in the USA.
- These methane amounts
  - Are equal to emissions released by over 20 million passenger vehicles driven over the year.
  - Can trap 20 times more solar radiation than CO_2.

What are we sending to landfill?



Potential opportunities of MSW utilization

Syngas → Hydrogen, Carbon monoxide

Liquid Fuels → Sustainable aviation fuel (SAF), Sustainable green diesel, Sustainable home heating oil

Solid Products → Activated carbon, Insulation materials, Durable goods, And so on…..

Feedstocks

Glossy Paper

Waxed Paper

Mixed Paper

MSW

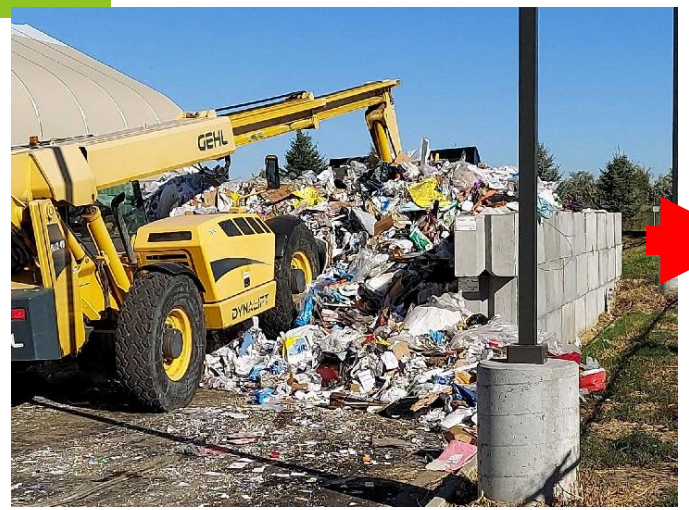
Commercial Cellulose

Reese

Strawberry

Mixed Plastic

MSW to thermal insulation: Processing



Thermal insulation and/or energy material

Sample nomenclature

- Mixed Plastic_13mm
- Mixed Plastic_6mm
- Mixed Plastic_2mm
- Strawberry Plastic_13mm
- Reese Plastic_13mm

- Mixed Papre_13mm
- Mixed Paper_6mm
- Mixed Paper_2mm
- Wax Paper_13mm
- Glossy Paper_13mm

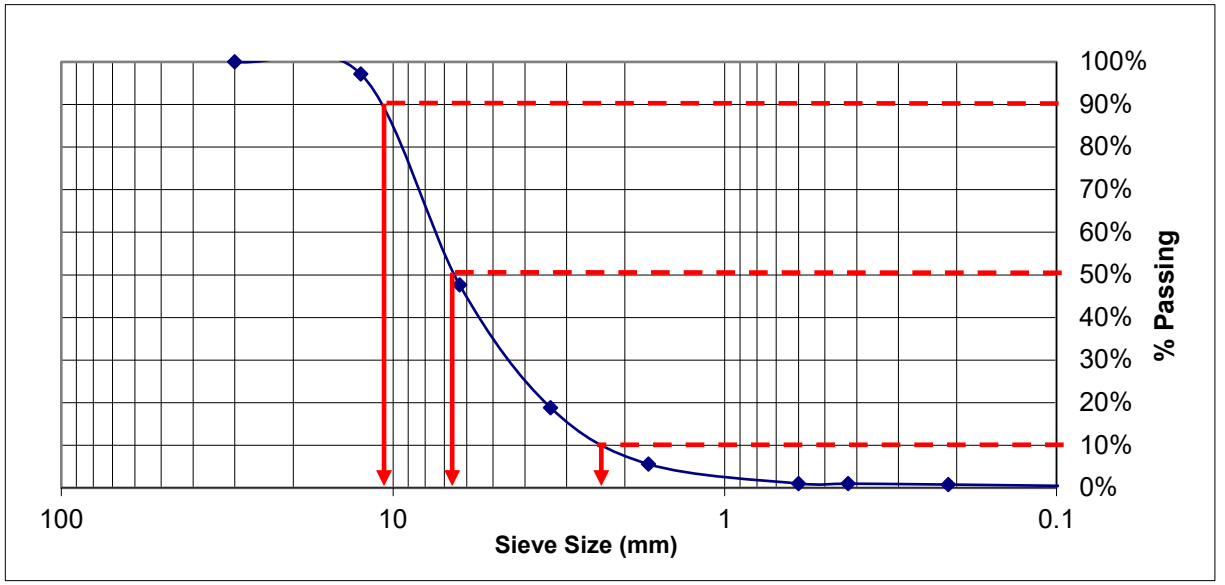
- Pap:Pla_1:1_13mm
- Pap:Pla_2:1_13mm
- Pap:Pla_1:2_13mm

Commercial Cellulose

Physical properties

Particle size density (PSD)

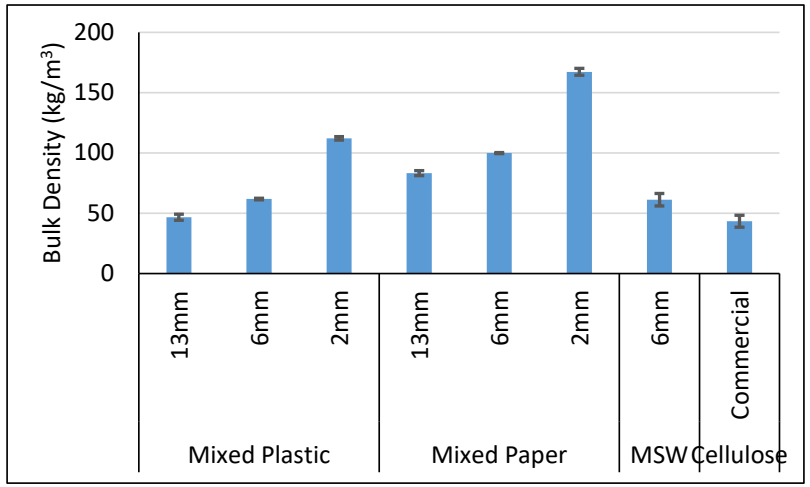
Ro-tap

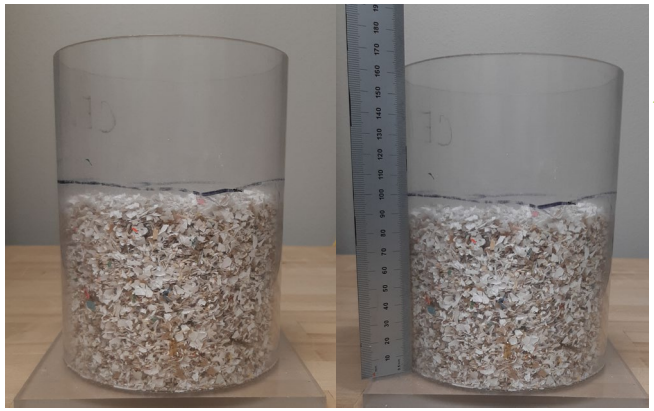


Sample	d_{10} (mm)	d_{50} (mm)	d_{90} (mm)
Mixed Plastic_13mm	3.51	8.52	16.99
Mixed Plastic_6mm	0.79	1.94	3.13
Mixed Plastic_2mm	0.27	0.71	1.51
Mixed Paper_13mm	2.25	6.59	11.61
Mixed Paper_6mm	0.65	1.66	3.06
Mixed Paper_2mm	0.12	0.49	1.40
MSW_6mm	2.66	5.45	8.64
Commercial Cellulose	0.09	1.09	3.21

Physical properties

Bulk density, Skeletal density, & Envelope density





Cylinder

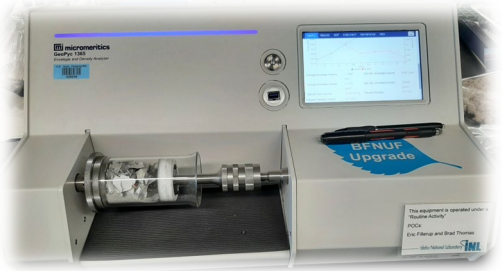
Density = Mass / Volume

Bulk

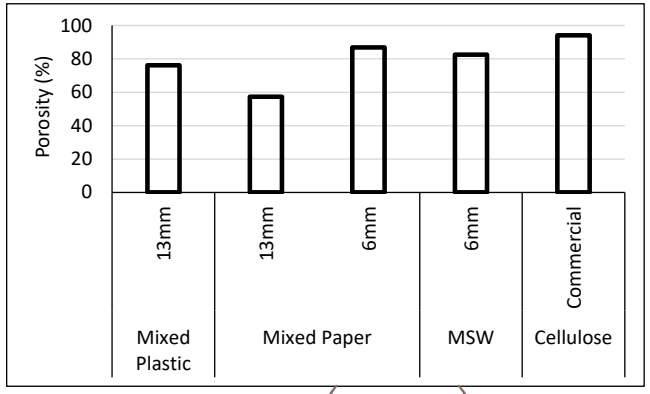
Envelope

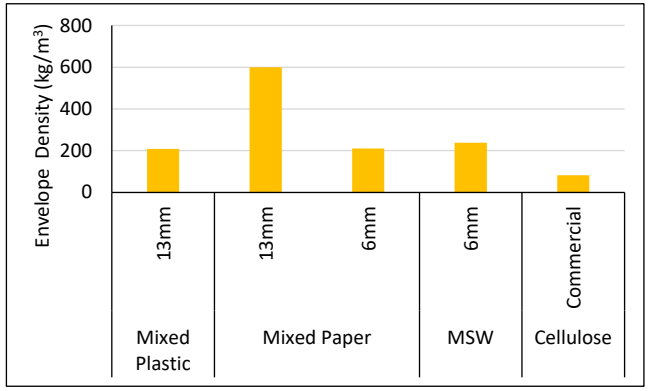
Skeletal

Gas pycnometer

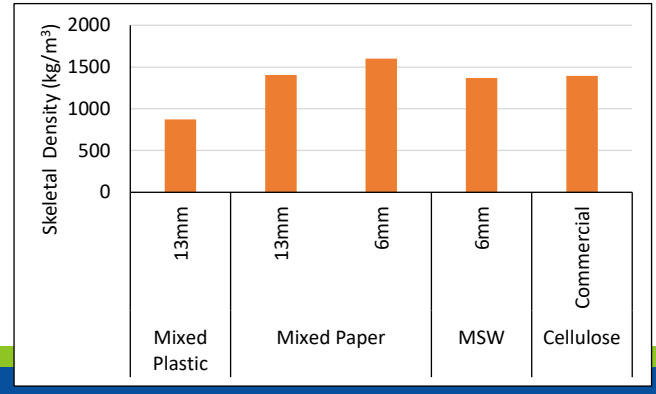


GeoPyc 1365



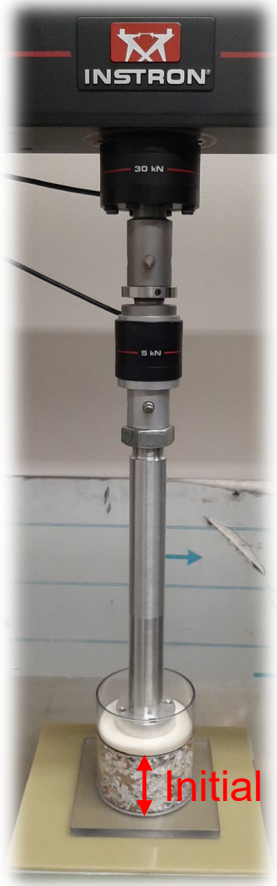


$$Porosity = \left(1 - \frac{\rho_e}{\rho_s}\right)$$



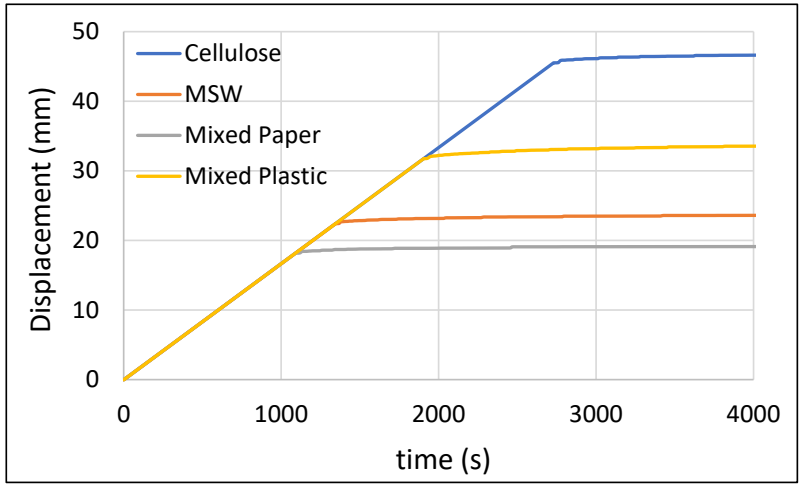
Physical properties

Compressibility

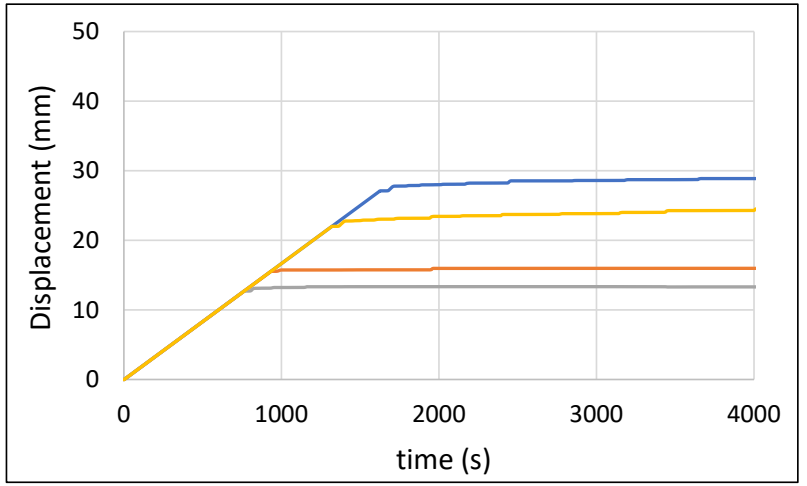


Instron load frame (model 5982)

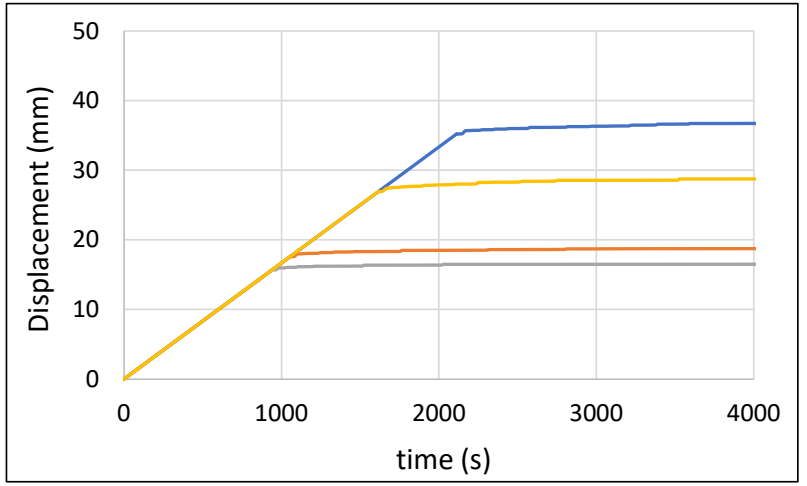
Compression force: 3N



Compression force: 1N



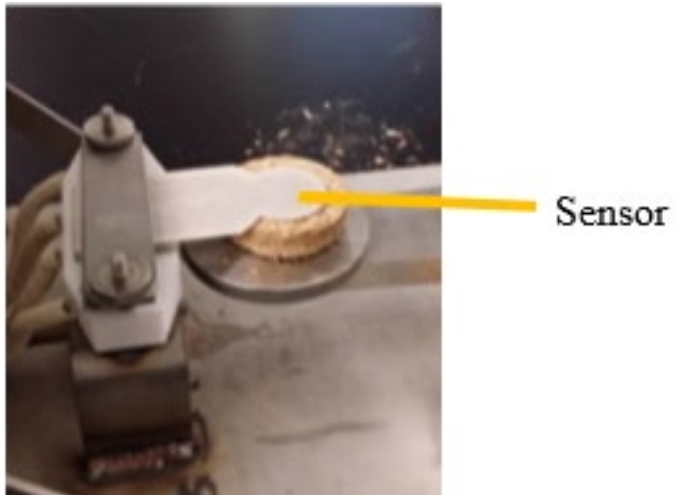
Compression force: 2N



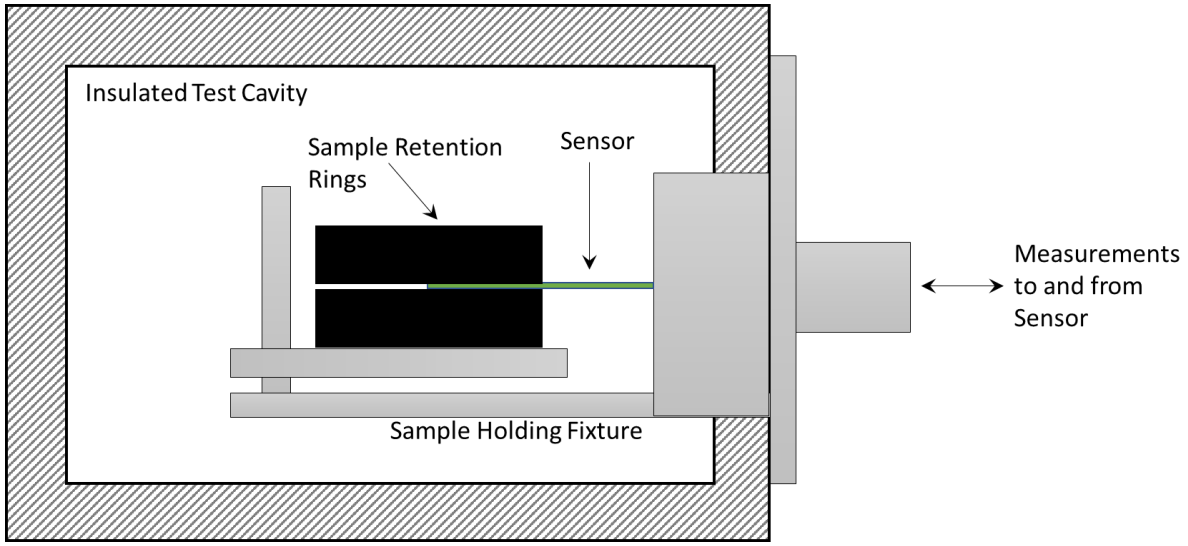
Insulating properties measurement

A

B



C



A) The sample retention ring packed with paper and fiber wastes recovered from MSW.

B) Thermal sensor surrounded by sample.

C) A side-view cartoon of the test setup, as placed inside an insulated chamber to maintain a quiescent atmosphere.

Calculation of insulation properties

- Thermal conductivity (k):

$$\Delta T(\tau) = P\left(\pi^{3/2} r k\right)^{-1} D(\tau)$$

$$k = \sqrt{\mathrm{k_a k_r}}$$

- Thermal diffusivity (α):

$$\alpha = \frac{k}{\rho C_p}$$

- R-value:

$$R = \frac{\Delta x}{k}$$

$\Delta T(\tau)$ = time dependent avg temp. increase of the TPS sensor

P= electric power to the sensor,

r= radius for a hot disk style sensor,

k= geometric mean of the axial (k_a) and radial (k_r) thermal conductivities

$D(\tau)$ = characteristic function (D-function)

τ= dimensionless form of time

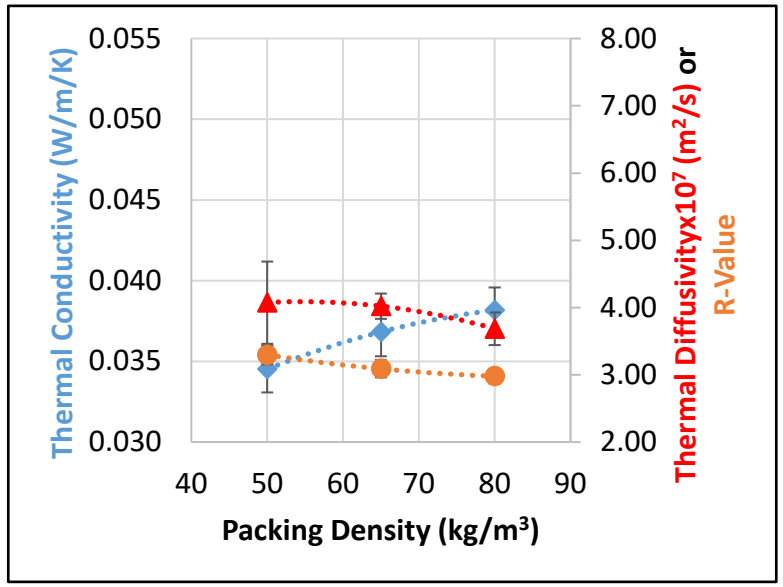
ρ = density

C_p = specific heat

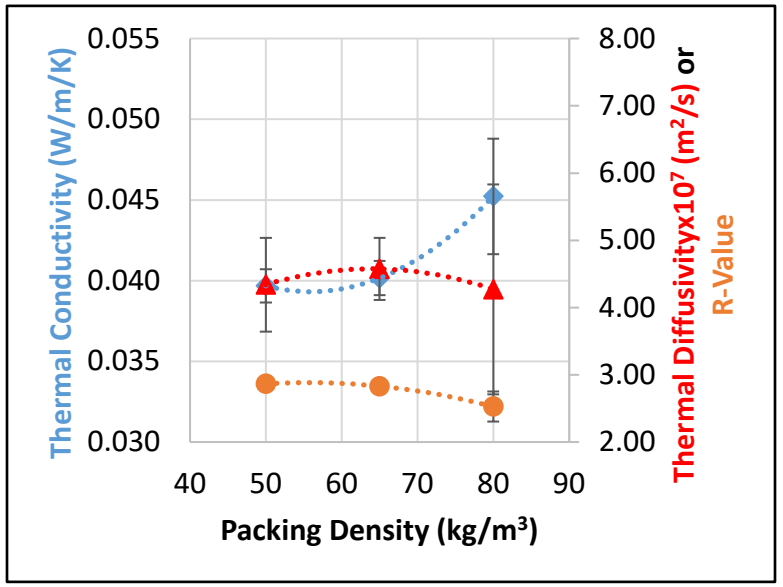
Δx= thickness of the sample

Thermal properties
Effect of packing density

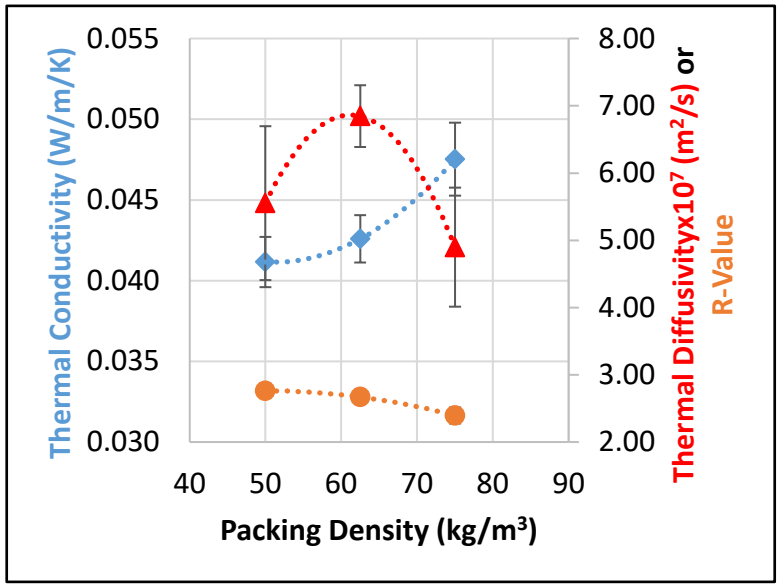
Commercial Cellulose



Mixed Plastic



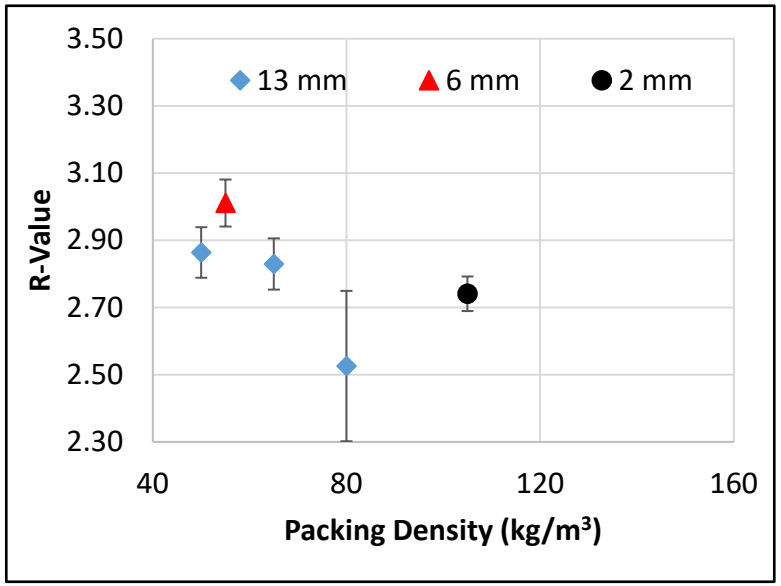
Mixed Paper



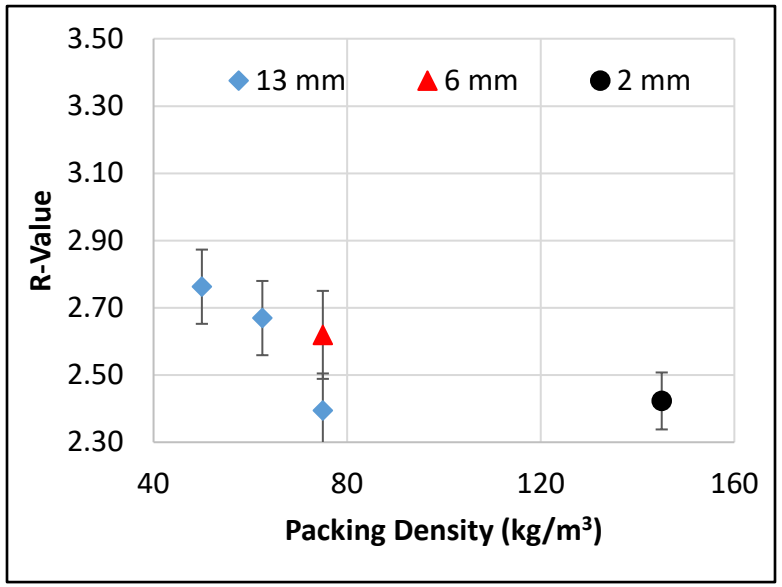
- As the density increased, the conductivity increased, and the diffusivity decreased which resulting in decrease of R-value.

Thermal properties
Effect of particle size

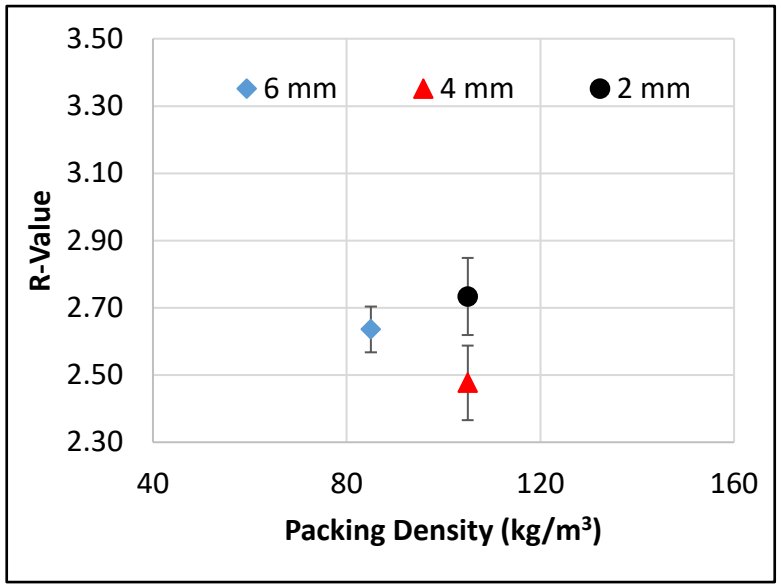
Mixed Plastic



Mixed Paper



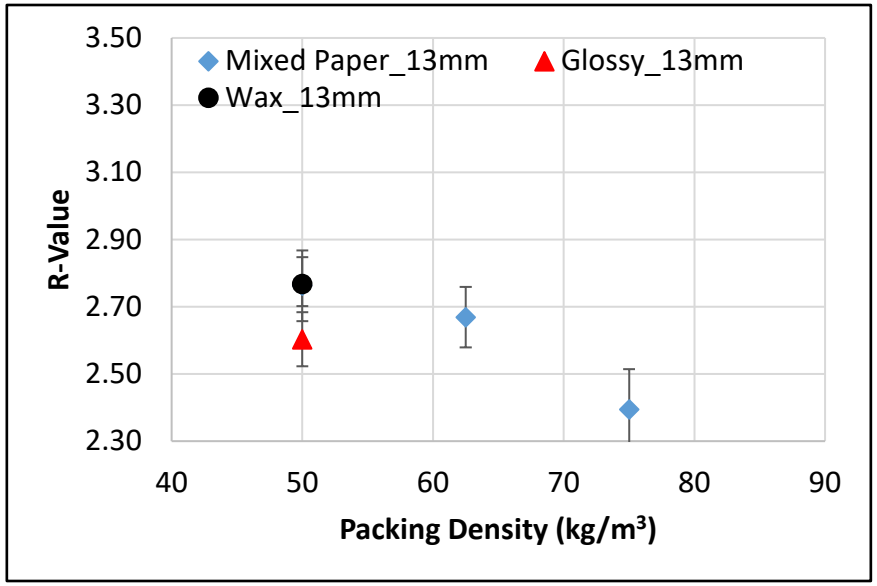
MSW



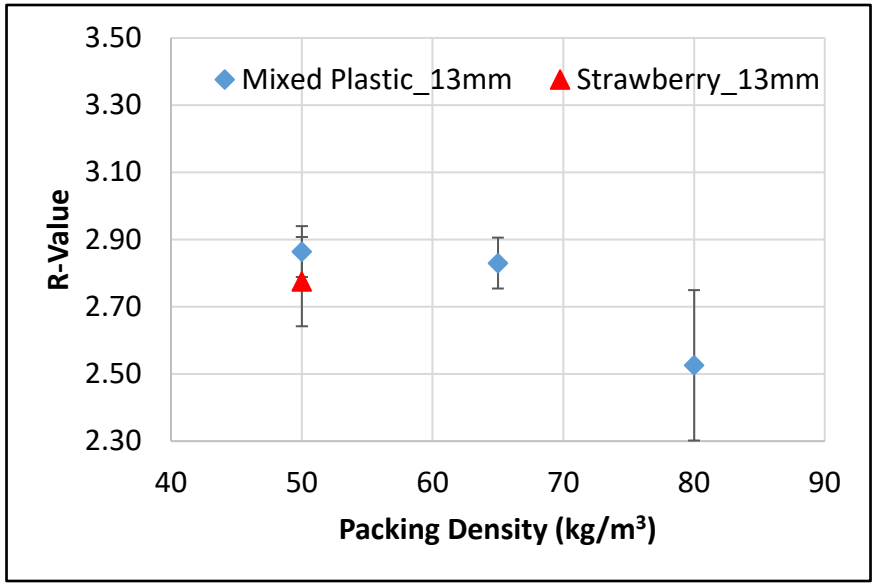
- Smaller the particle, higher the R-value at a specific density.
- Lower the particle size, higher the porosity resulting in the higher R-value.

Thermal properties
Effect of feedstock type

Paper



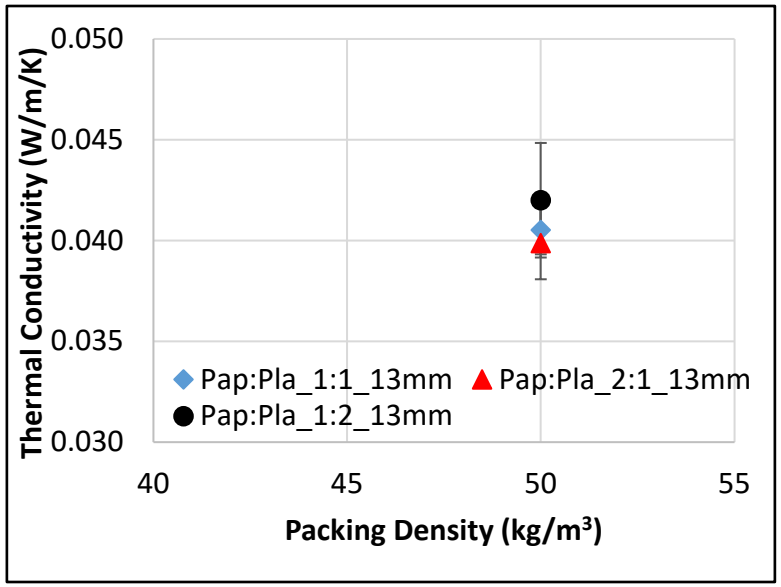
Plastic



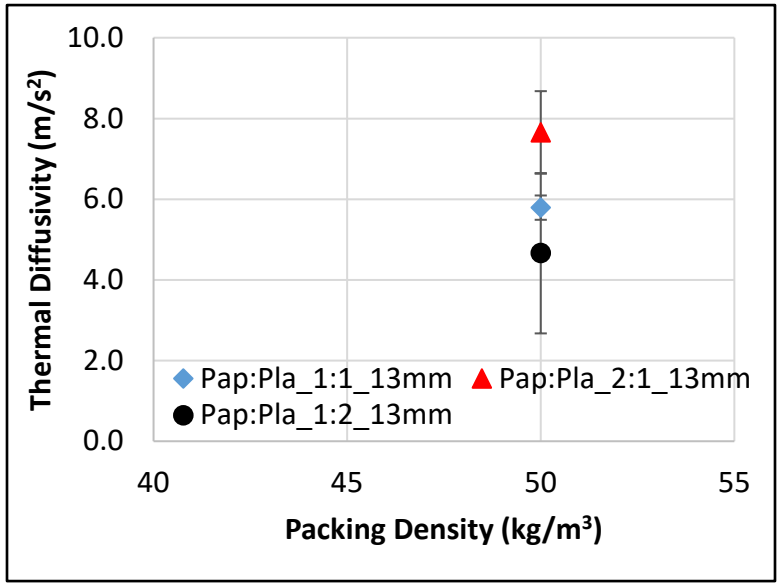
- Waxed paper showed similar R-value as the mixed paper; however, the glossy paper showed lower R-value.
- Specific type plastic (strawberry raping) showed a little lower R-value value compared to the mixed plastic.

Thermal properties
Mixing effect

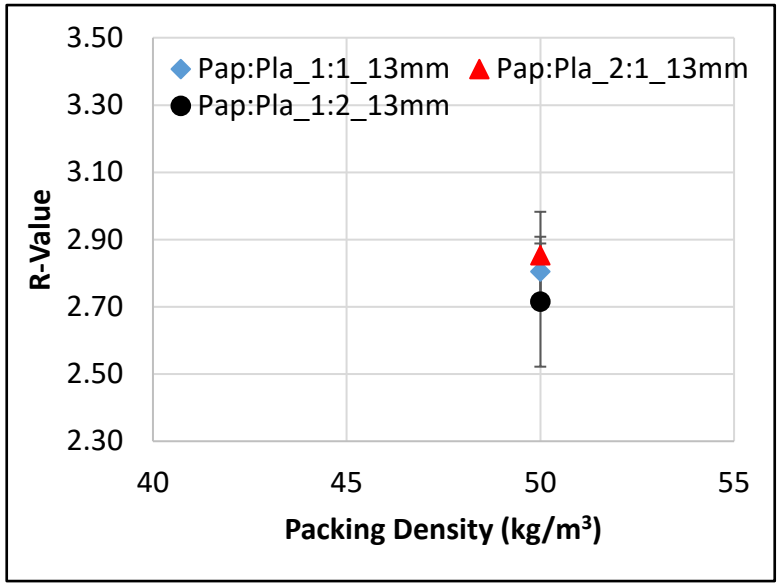
Thermal Conductivity



Thermal Diffusivity



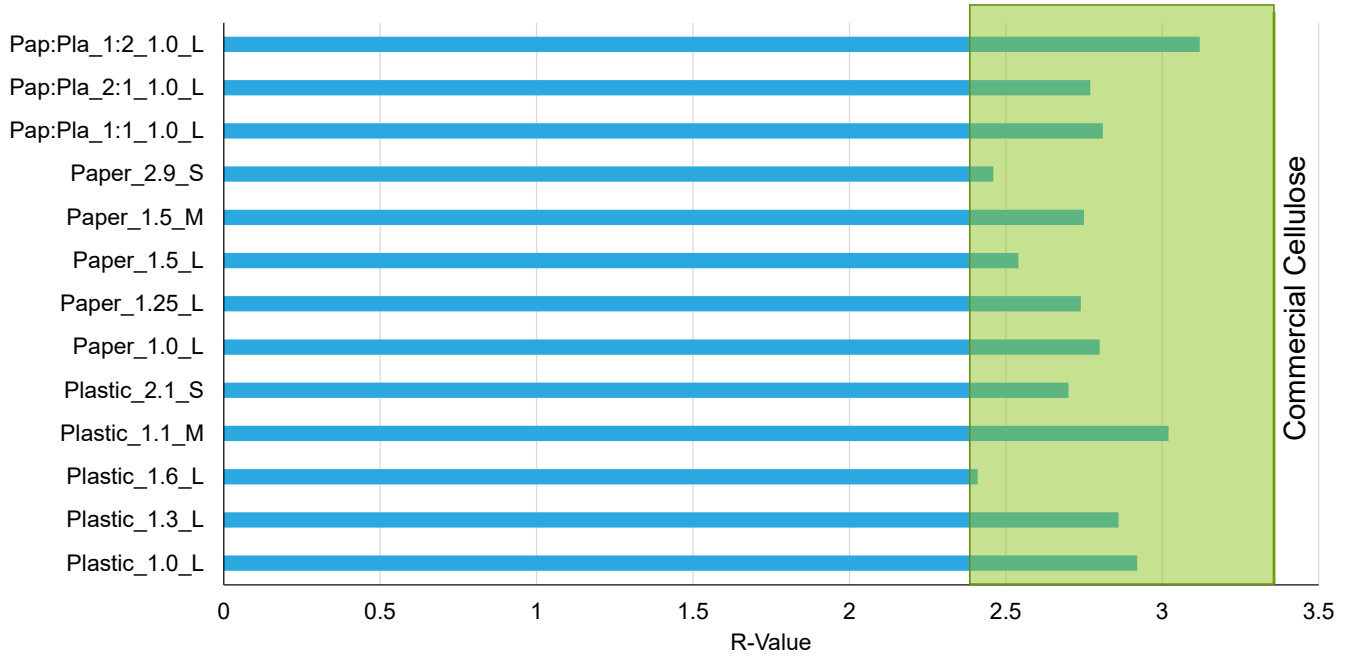
R-Value



- Mixing of plastic and paper in 1:1, 1:2, and 2:1 did not show significant change in the R-value.

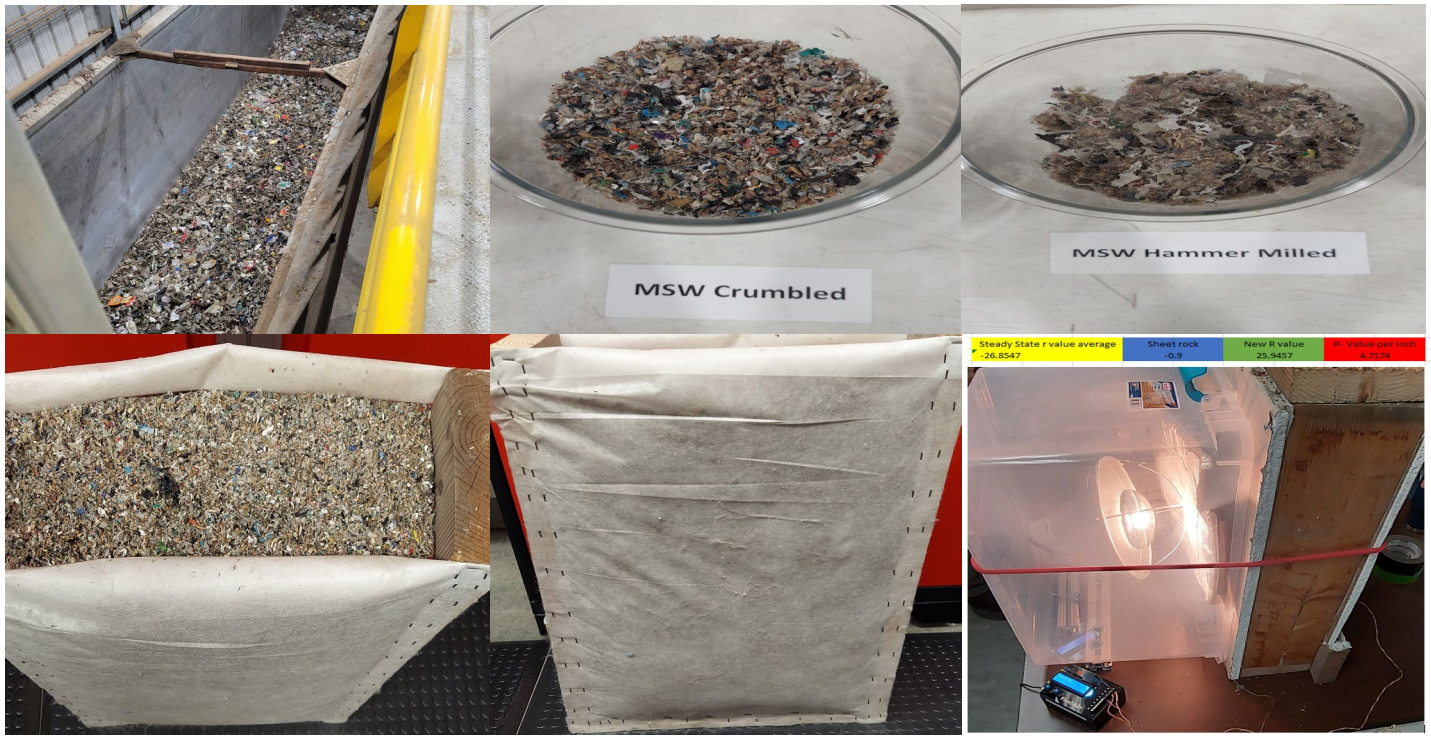
Conclusions

- The R-values of all tested materials are within the 70% of the commercial cellulose insulation.
- R-values are independent on type of the plastic or paper while depended on the size. In addition, the porosity and the packing density of the material greatly affect the R-value.



Future works

- Investigate other properties (e.g., surface emissivity, fire resistance) of the MSW before using it as home insulation material.
- Examine the insulation properties of MSW after addition of an antifungal chemical (e.g., boric acid) to avoid formation of molding or growing insects inside the insulation.
- Finally, conduct inline test using MSW.



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Thank You!

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