REDEFINING PACKAGING: ADVANCING MYCELIUM-BASED MATERIALS FOR A SUSTAINABLE FUTURE

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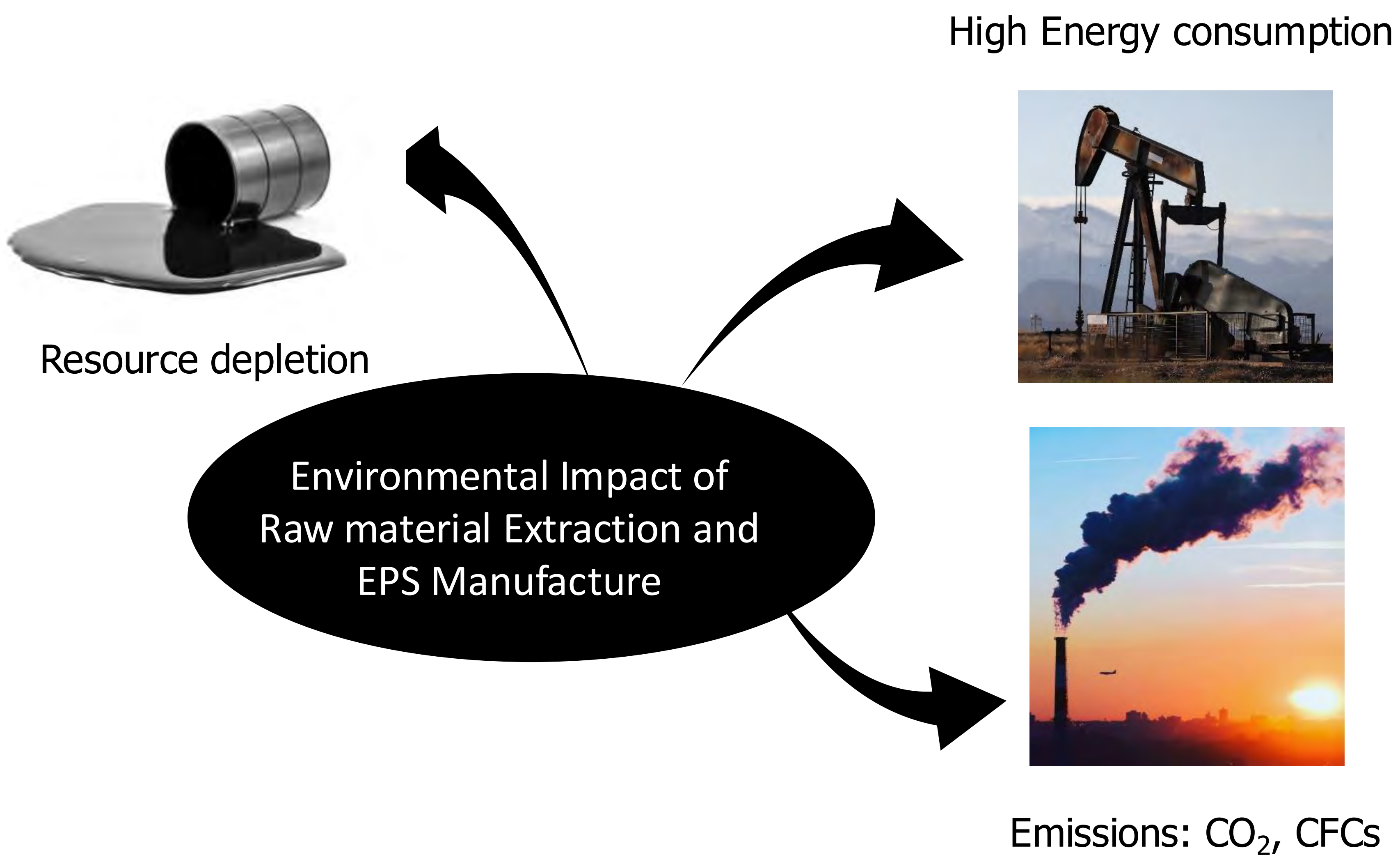
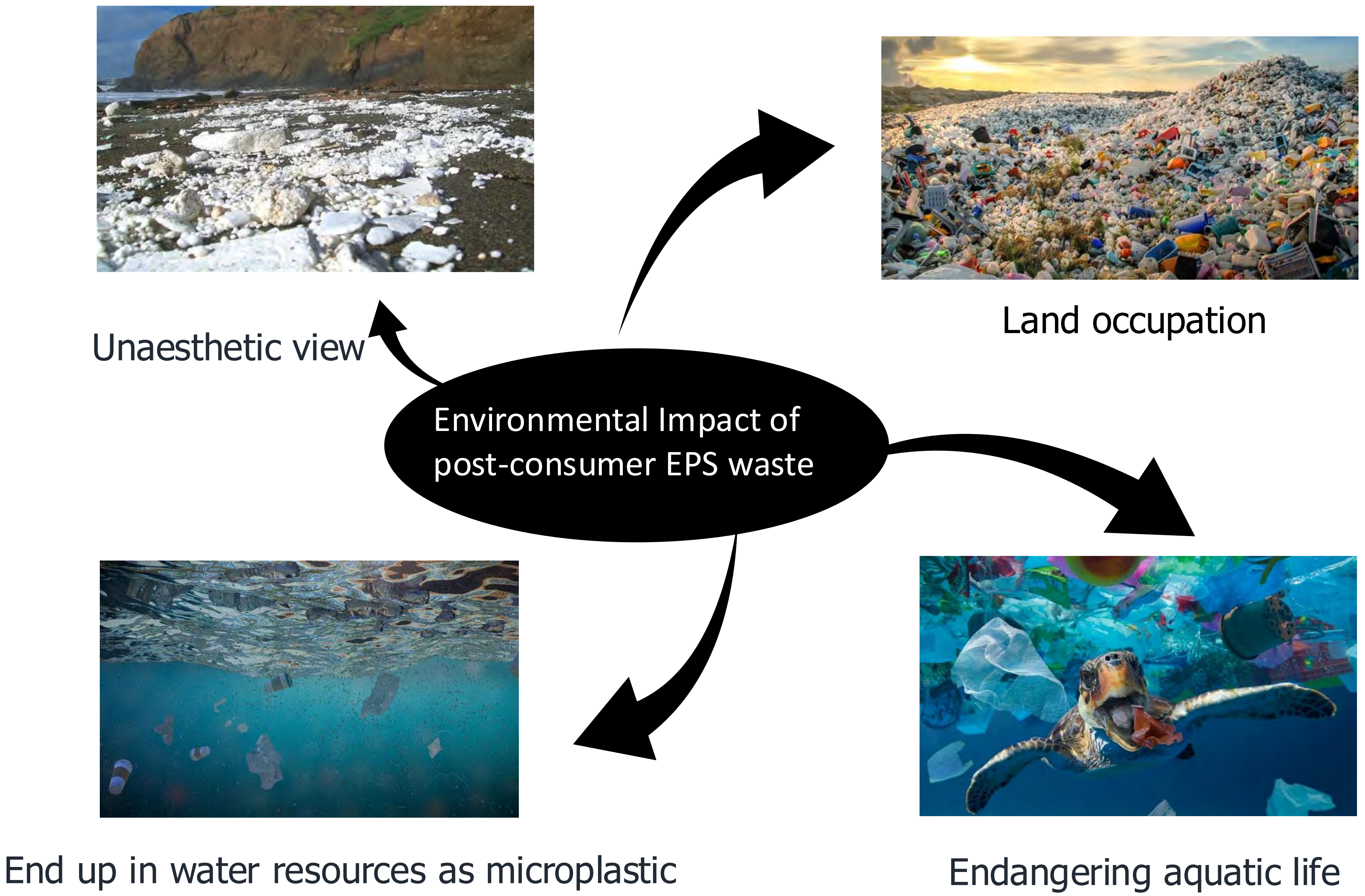
Background Information

The Problem with Conventional Packaging

- **Expanded Polystyrene (EPS)** → cheap, light, non-biodegradable
- **PFAS** coatings → water and grease resistance, highly persistent
- Break down into **microplastics** → accumulate in ecosystems
- **Hard to recycle, slow to degrade, harmful when incinerated**

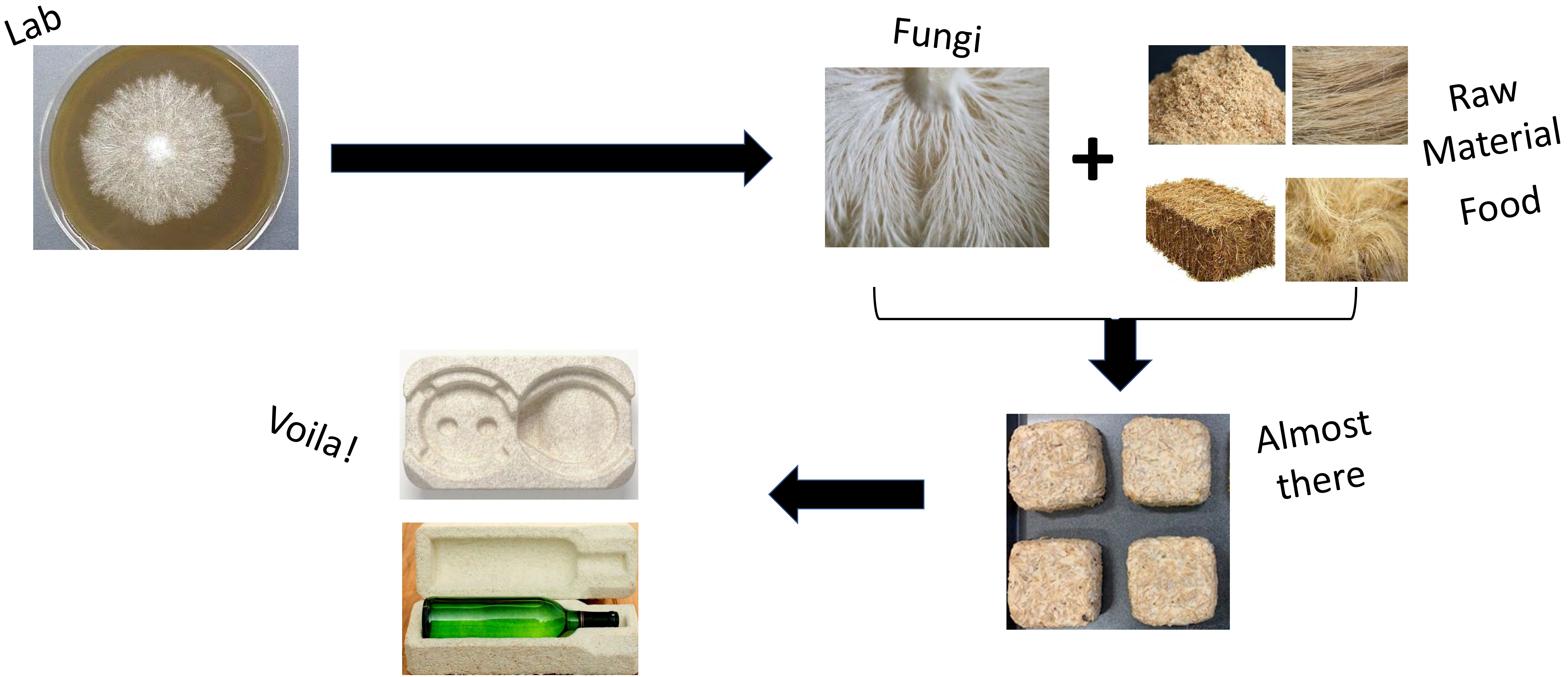




Environmental and Health Impacts - Why Alternatives Matter

- **Packaging**: Largest source of plastic waste globally around 40% in 2019 (OECD, 2022)
- **Microplastics** found in oceans, lakes, soil
- **Lake Winnipeg:** ~193,000 particles/km^2 (Warrack et al., 2017)
- **PFAS:** Detected in >97% of human blood samples (CDC, 2024)
- **Brain tissue:** Microplastics found in neural samples (Nature Medicine, 2025)
- **Associate with**: cancer, neurotoxicity, endocrine disruption
- **No Biodegradable**, prompting calls for safe, scalable, and circular alternatives
- **Our research**: mycelium-based packaging

Mycelium Bio-foam Problem-Solution Fit



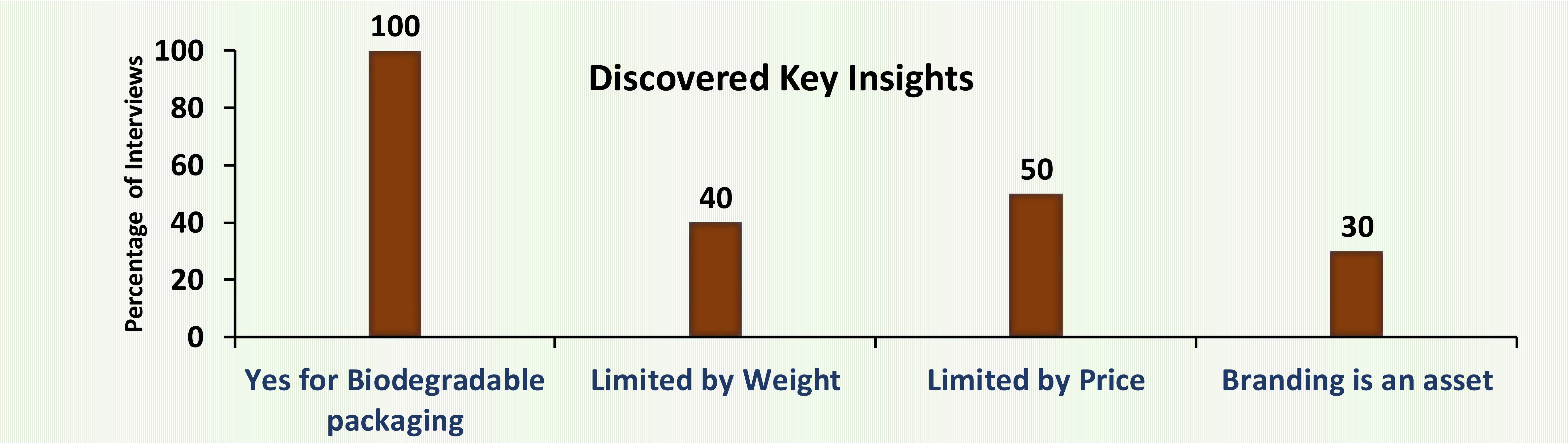
Benefits of the Solution

- Grown from fungi
- Binds to agricultural and upcycling (carboard) wastes → molded into packaging
- **Fully biodegradable**, no toxic residues
- Fire-resistant, compostable, insulative properties
- Potential EPS replacement

What are the consumers perceptions of Bio-foams?
What are the limiting factors to market adoption and how to overcome them?

Market Potential & Consumers perception

- End Consumers
- Foam packaging-consuming Companies
- Packaging Waste Management Stakeholders

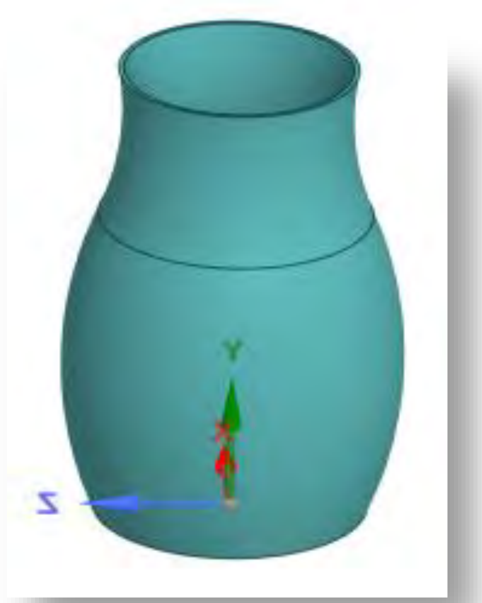


- ❑ Current packaging foam market is over USD 17.3 billion
- ❑ Consumers are aware of the environmental impacts of EPS foam and willing to adopt Bio-foams
- ❑ Bio-foam weight and price are considered limiting factors for adoption

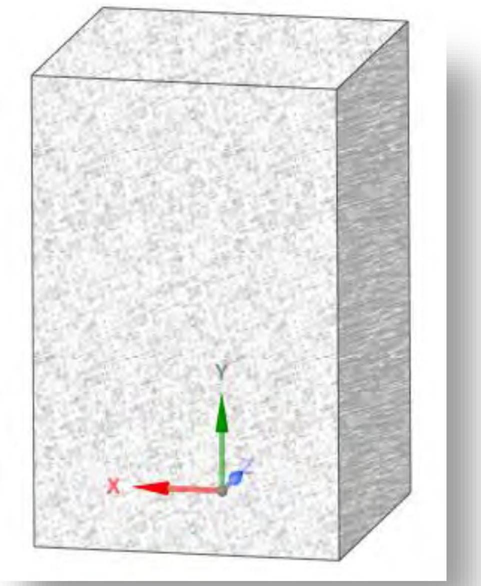
Next step: Optimize the MBF packaging design through simulations to achieve lighter, more cost-effective, and environmentally friendly packaging solutions.

SHOCK ABSORPTION MODELING FOR SUSTAINABLE MBF PACKAGING

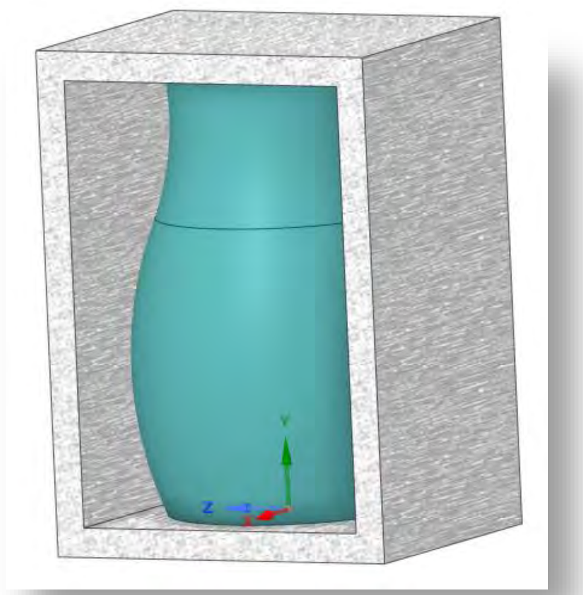
- Using **Ansys Explicit Dynamics** to simulate the drop impact of a 32-inch flat-screen TV and a porcelain vase secured with various MBF packaging configurations and density



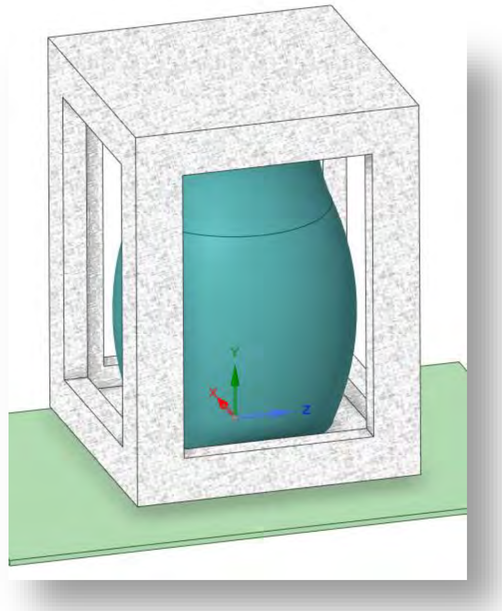
Porcelain Vase



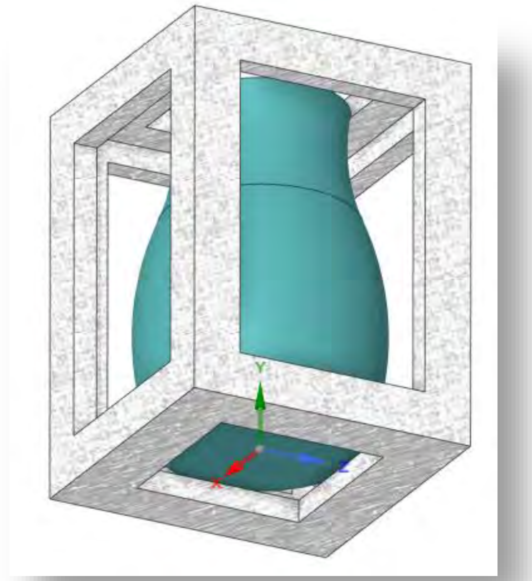
MBF1



MBF2

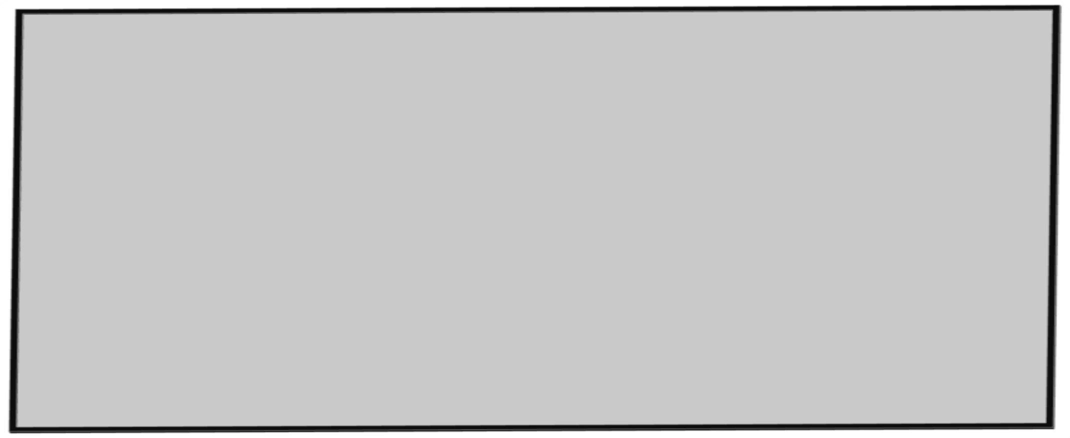


MBF3

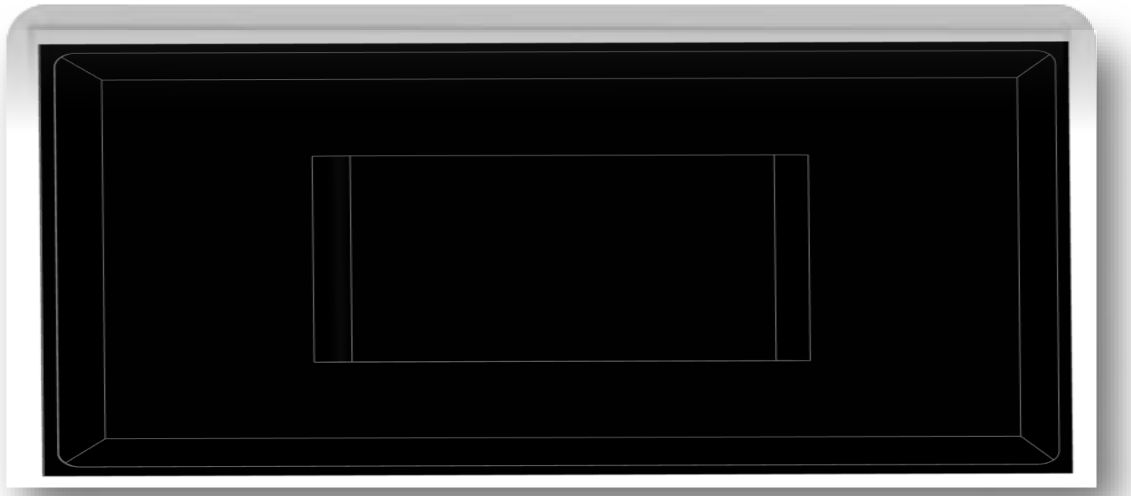


MBF4

Flat TV Screen

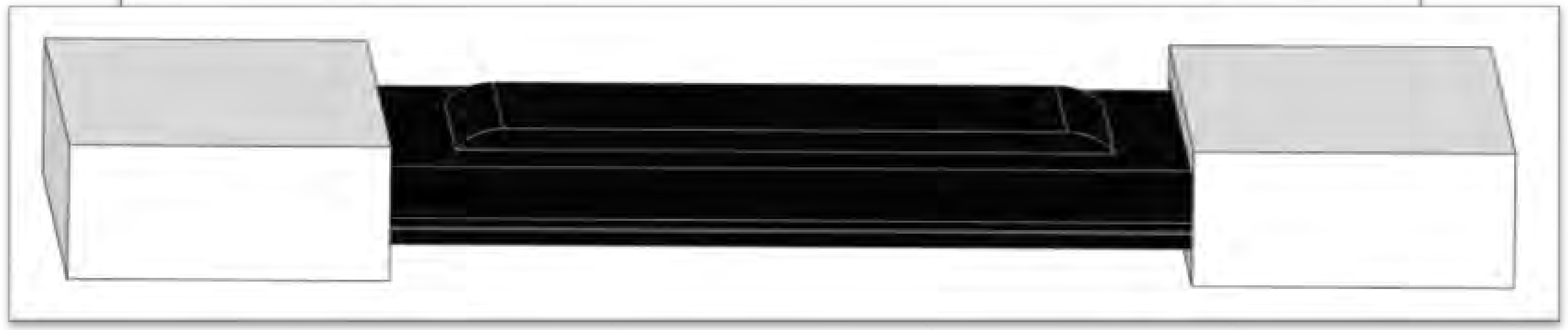


Flat TV Back



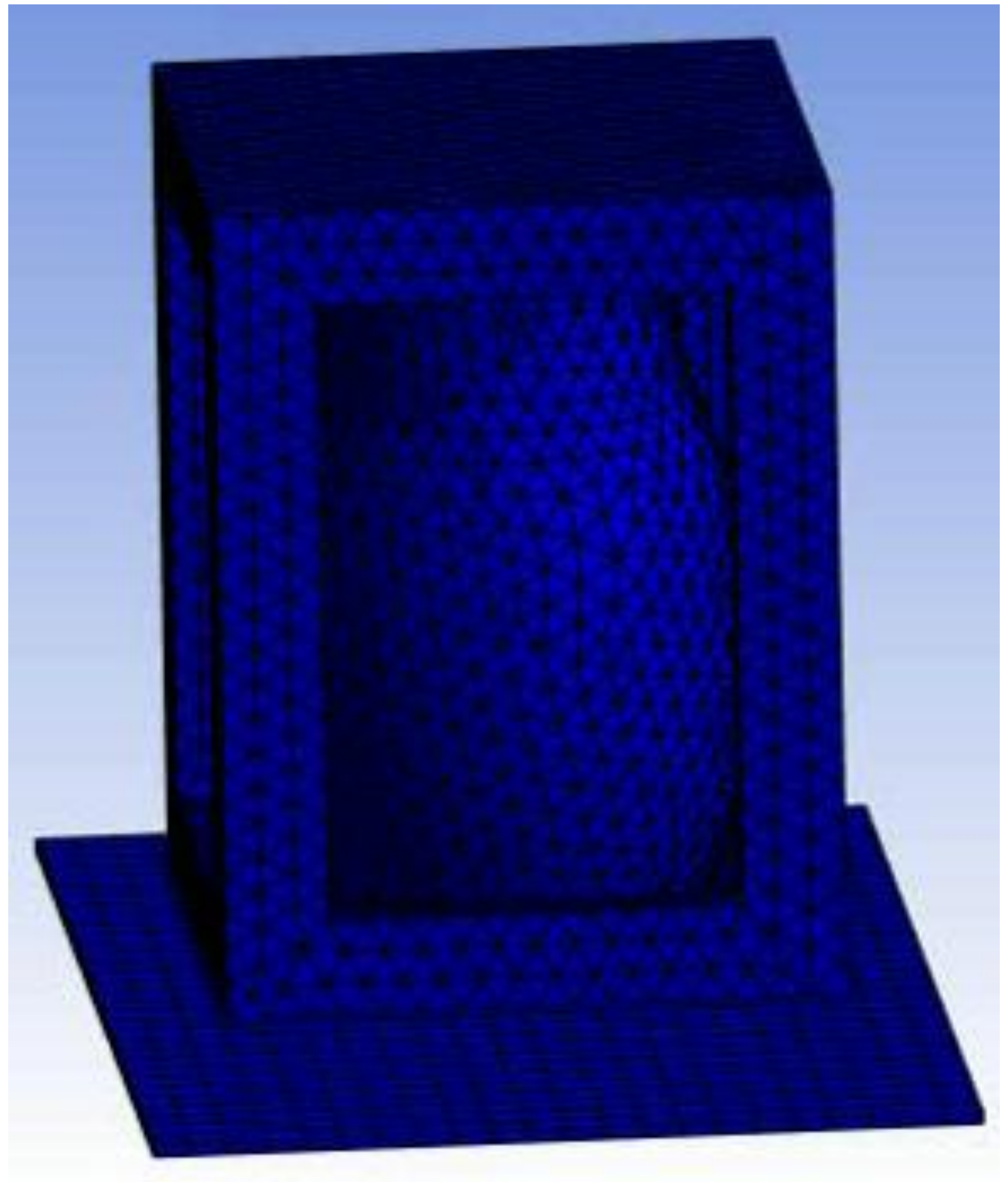
50 mm foam coverage

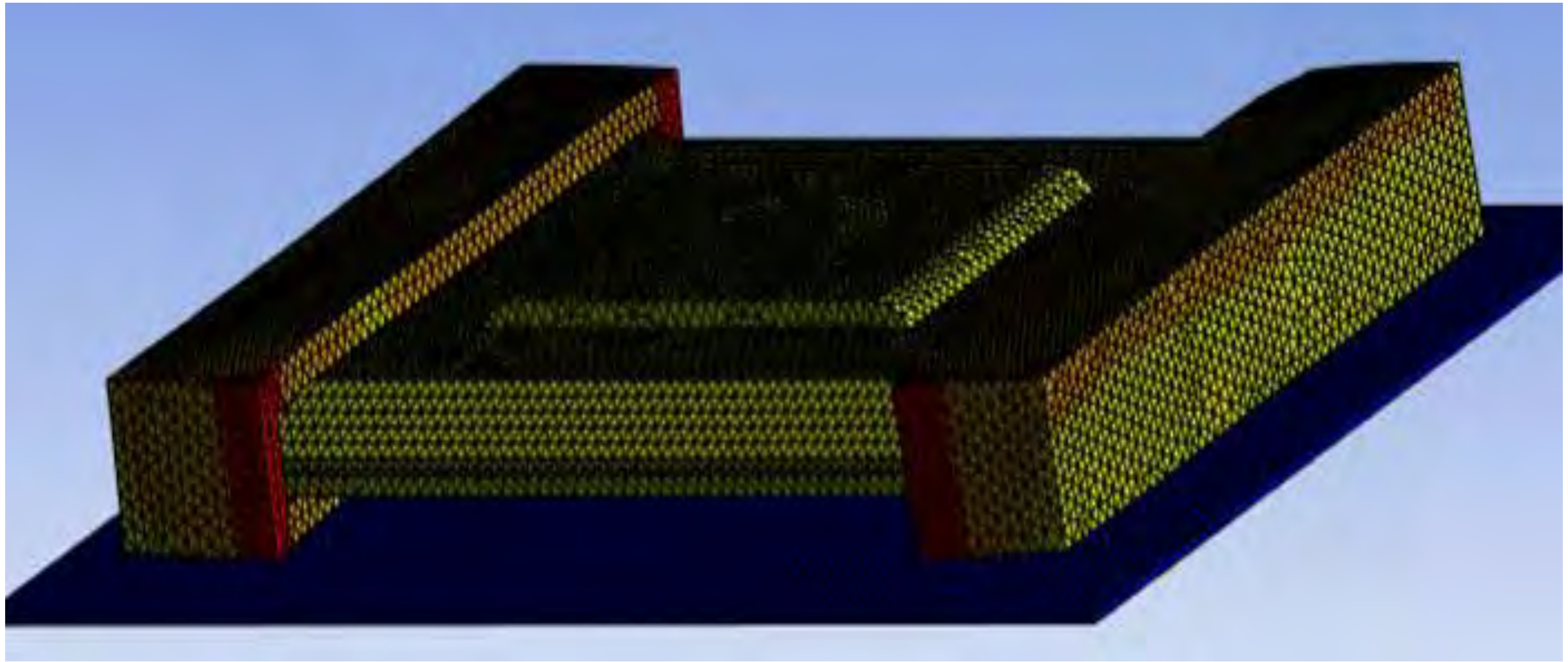
100 mm foam coverage

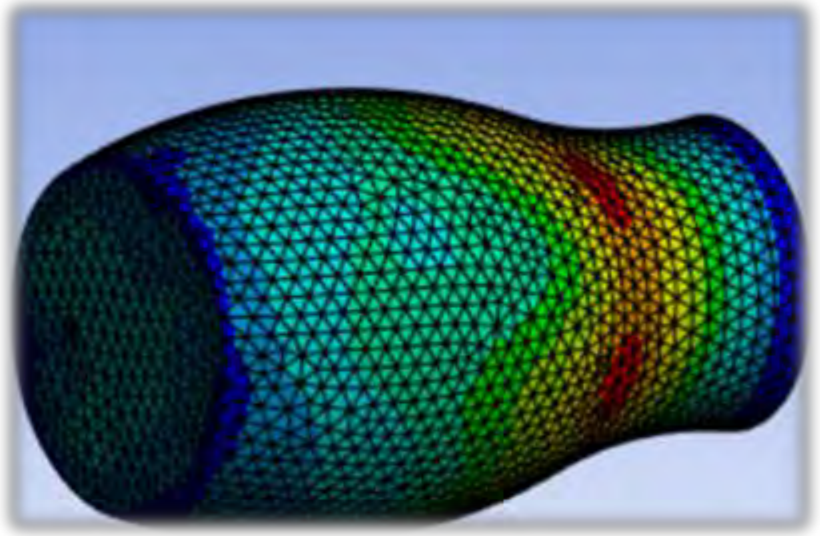


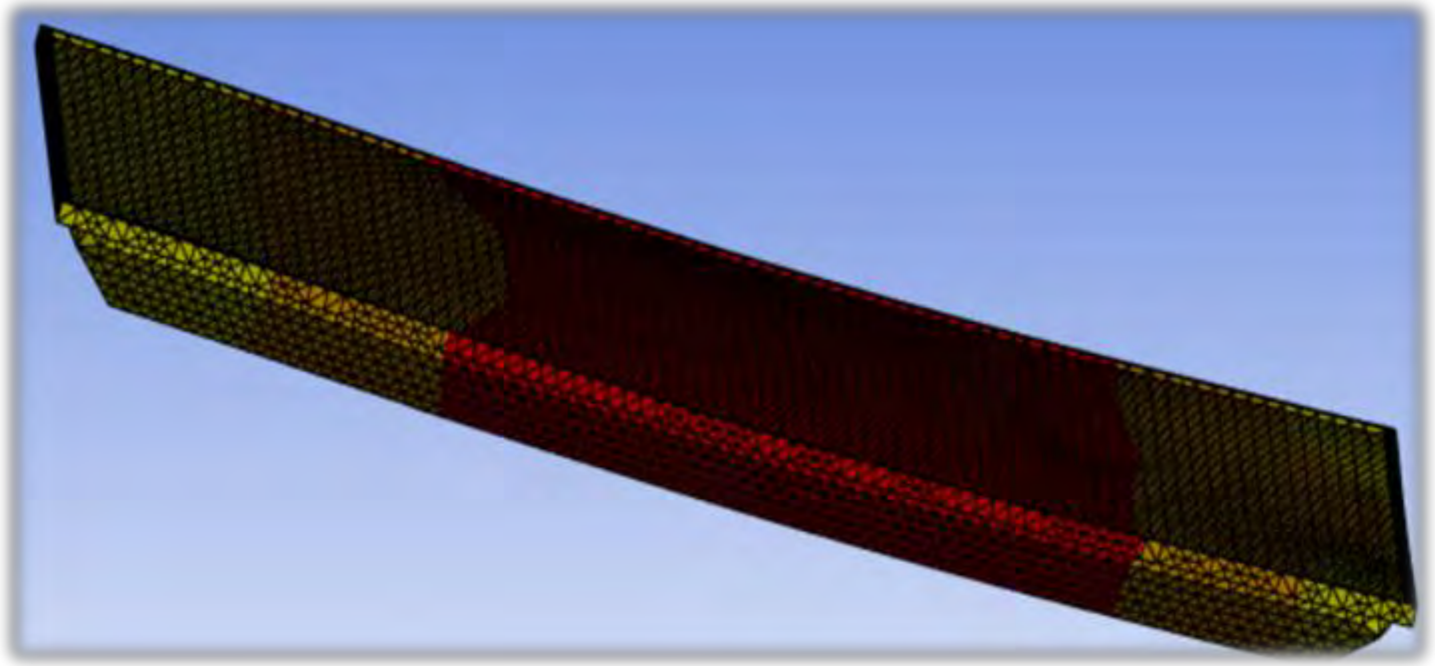
150 mm foam coverage

❖ Results of the Shock Absorption Performance of MBF



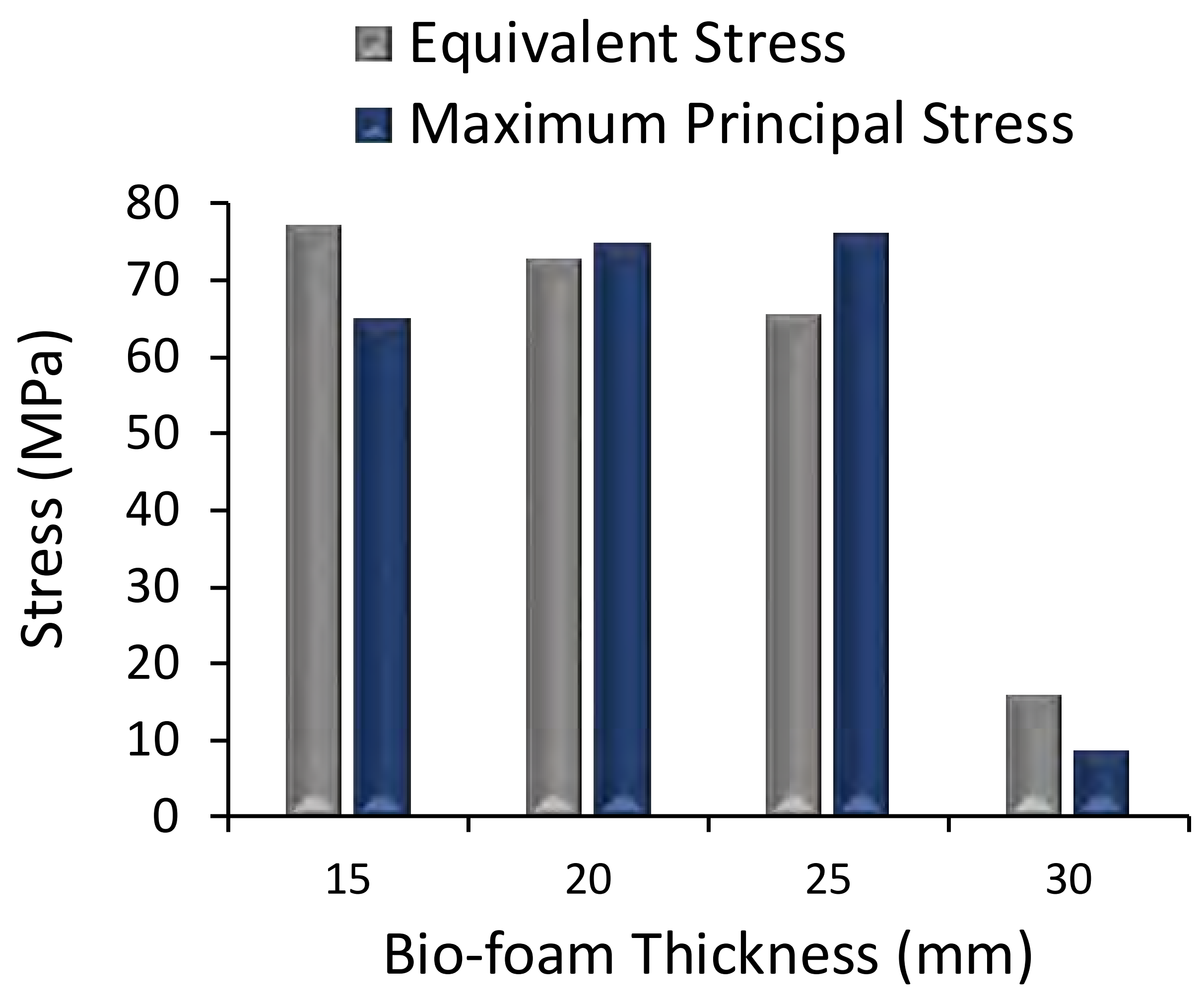




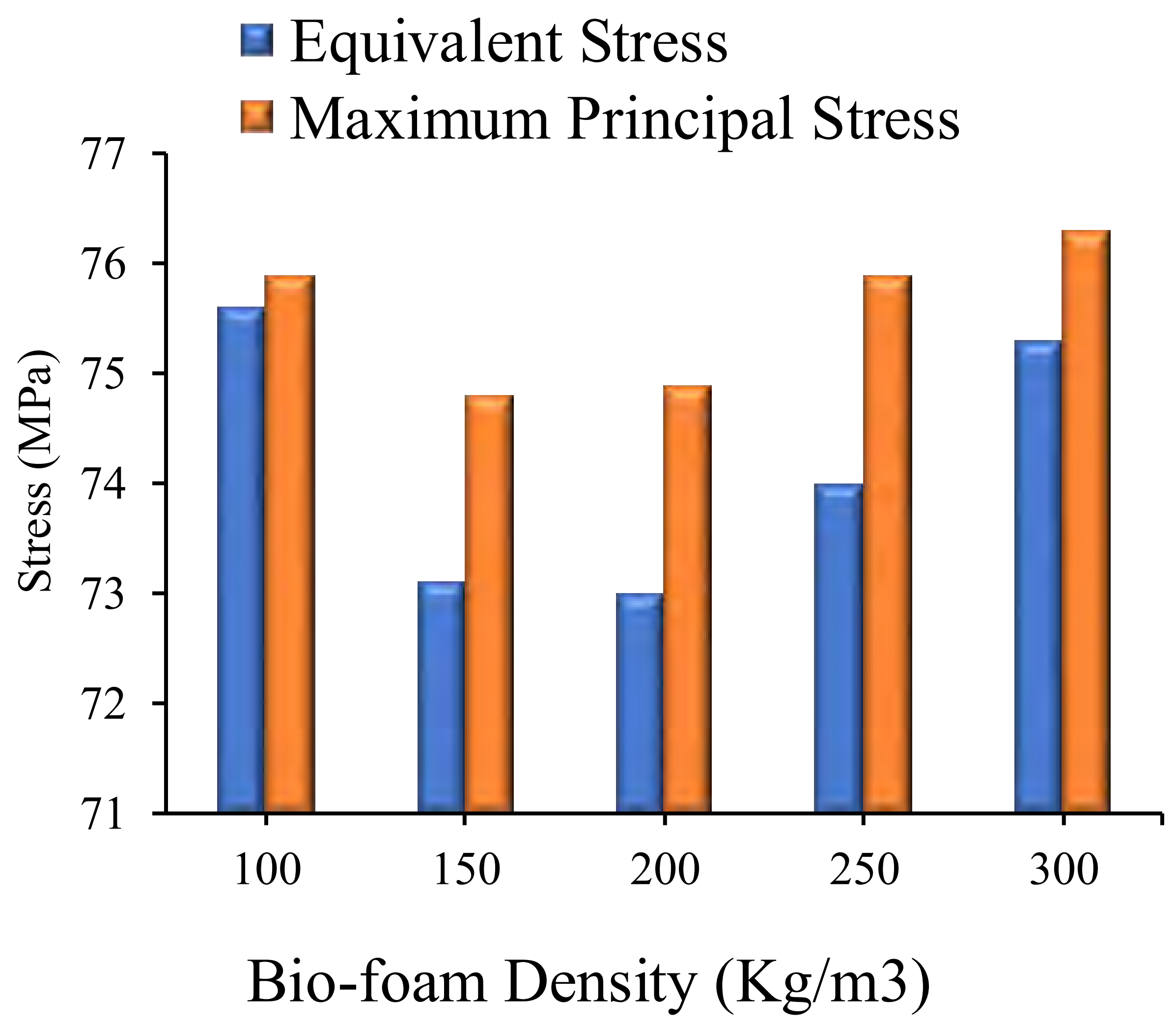


❖ Impact of MBF Design and properties on Flat-screen TV Shock Absorption

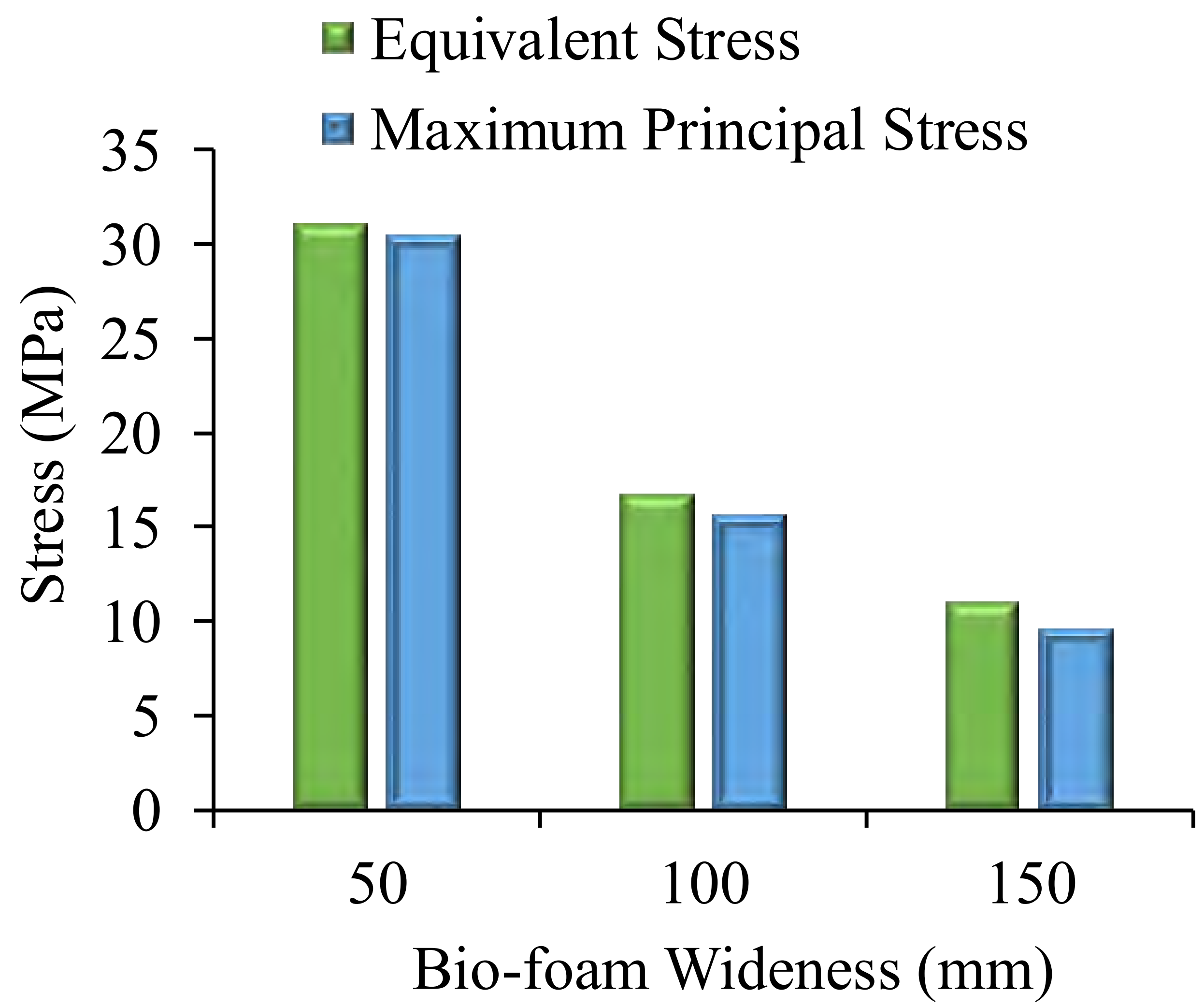
- ○ **Foam thickness**



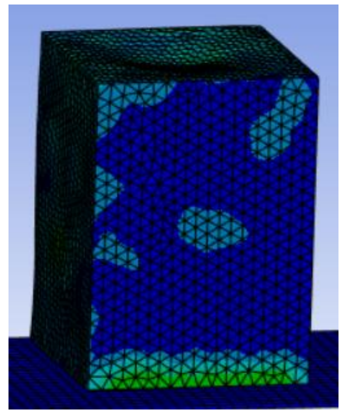
- ○ **Foam Density**



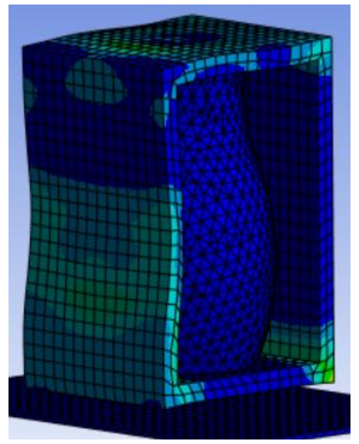
- ○ **Foam Wideness**



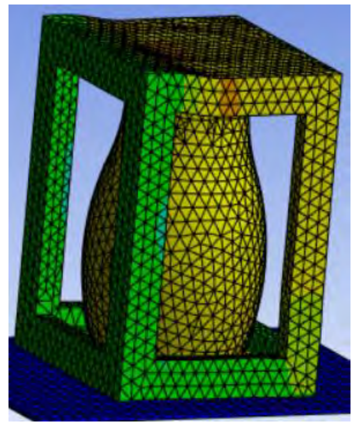
❖ Impact of MBF Design on Porcelain vase Shock Absorption



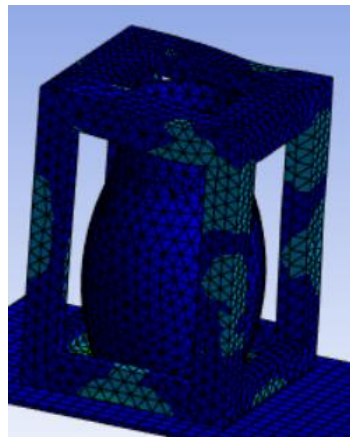
MBF1



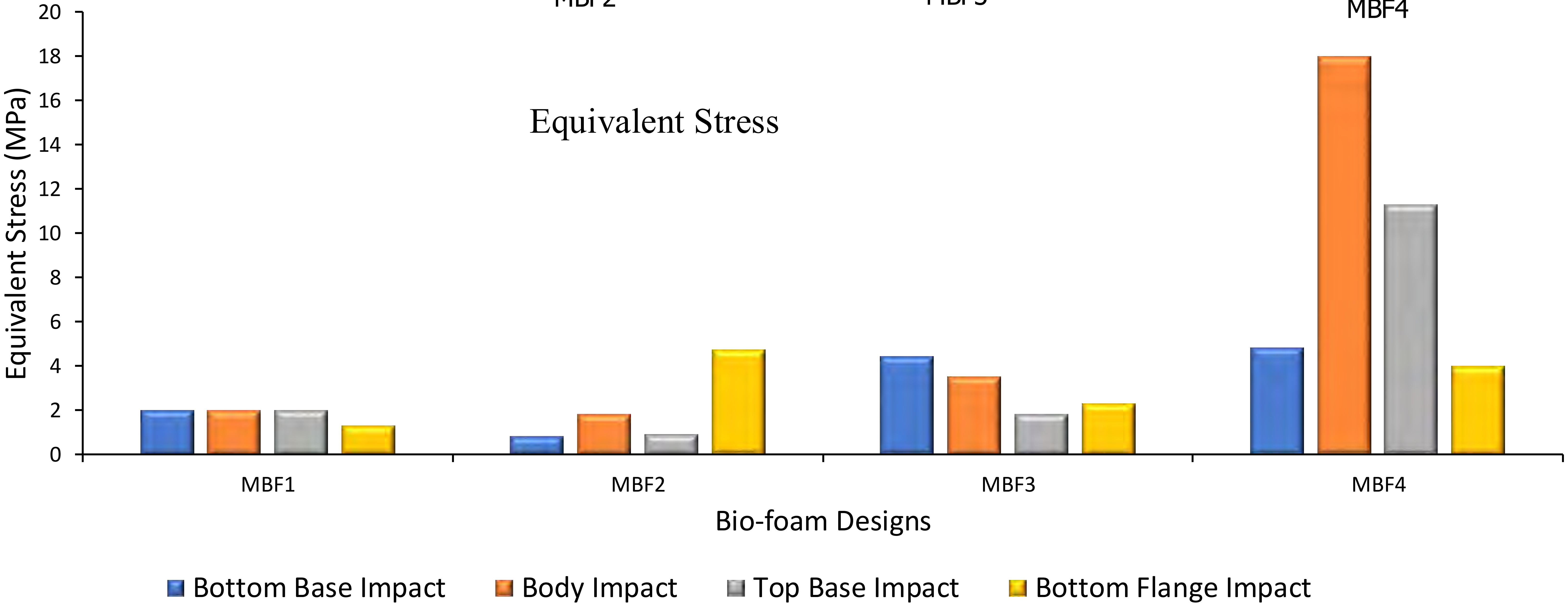
MBF2



MBF3



MBF4



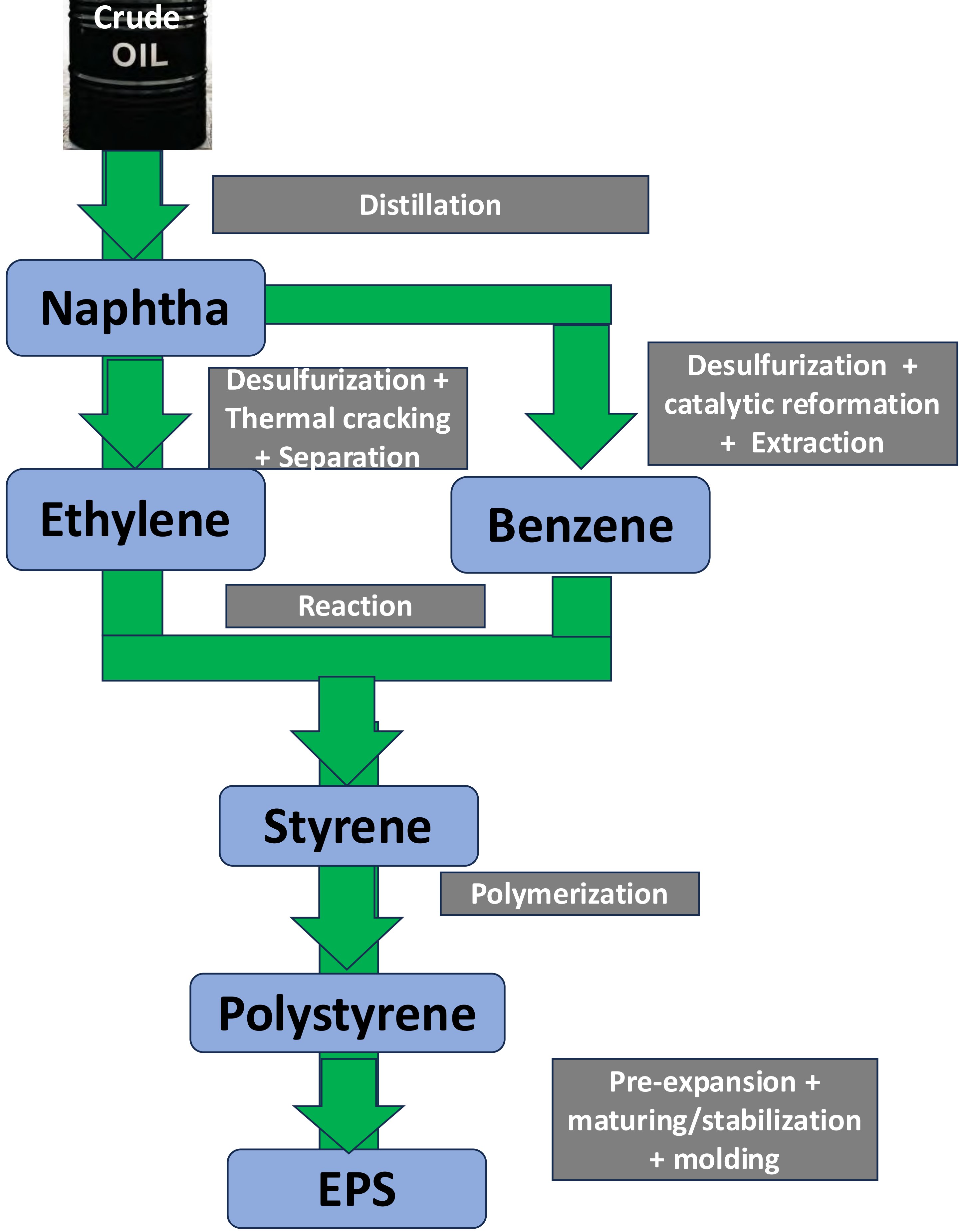
Key findings

- Increasing MBF density beyond 150 kg/m³ does not improve the shock absorption performance,
- MBF **design, thickness** and **density** impact the cushioning performance but also **MBF weight, cost, and overall sustainability,**
- Tailored MBF design for each product, considering vulnerable spots, can optimize packaging performance while minimizing weight.

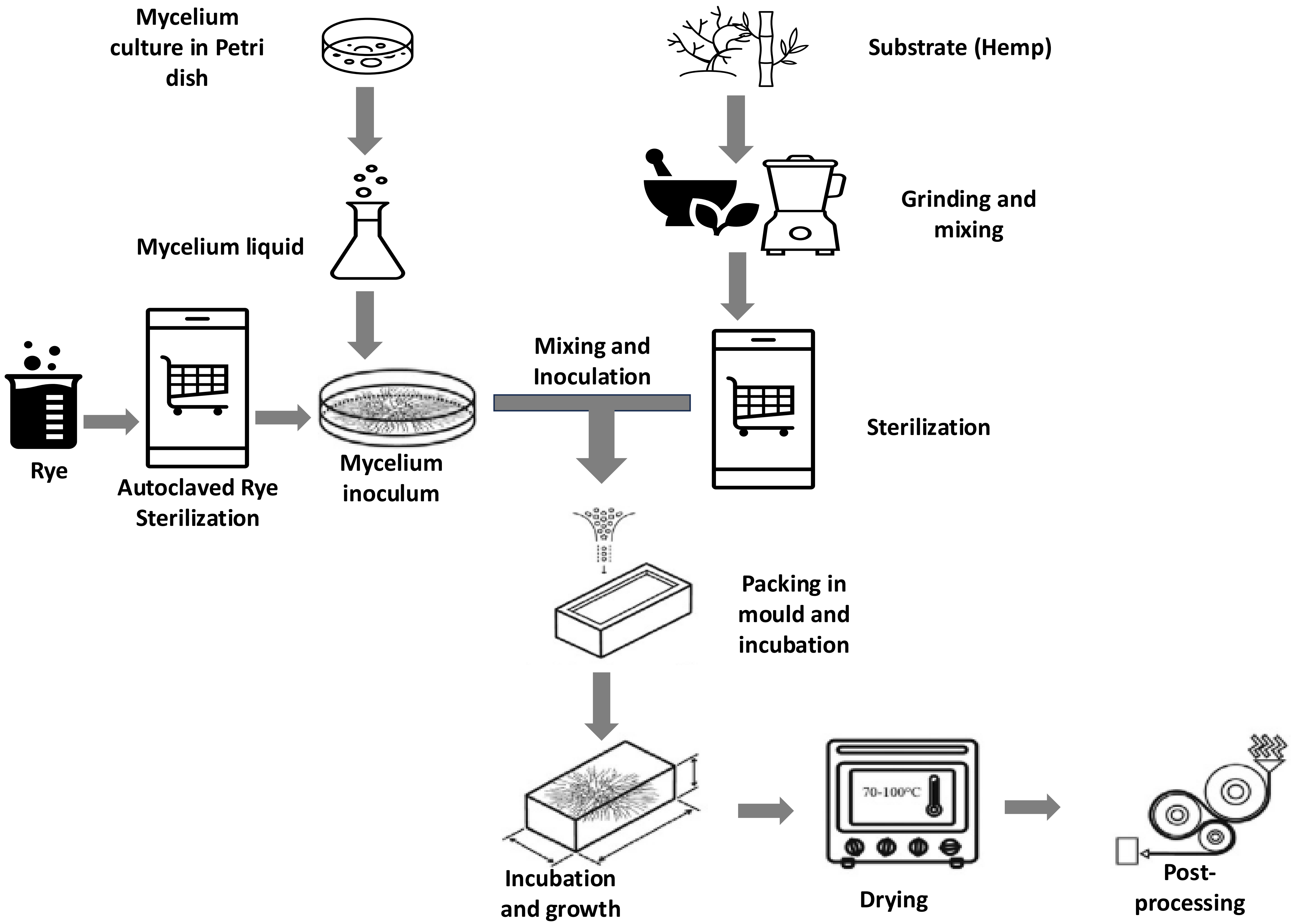
COMPARATIVE LCA OF MBF AND EPS

- **Software**: OpenLCA
- **Goal and scope**: Comparative environmental impacts assessment of MBF and EPS packaging to secure a 32-inch flat-screen TV
- **Function**: Secure a 32-inch flat-screen TV and prevent damage during shock events
- **Functional Unit**: The quantity of foam required to secure a 32-inch flat-screen TV: 63 g, 315 g and 472.5 g for EPS, MBF_100 and MBF_150, respectively.

EPS Production Process

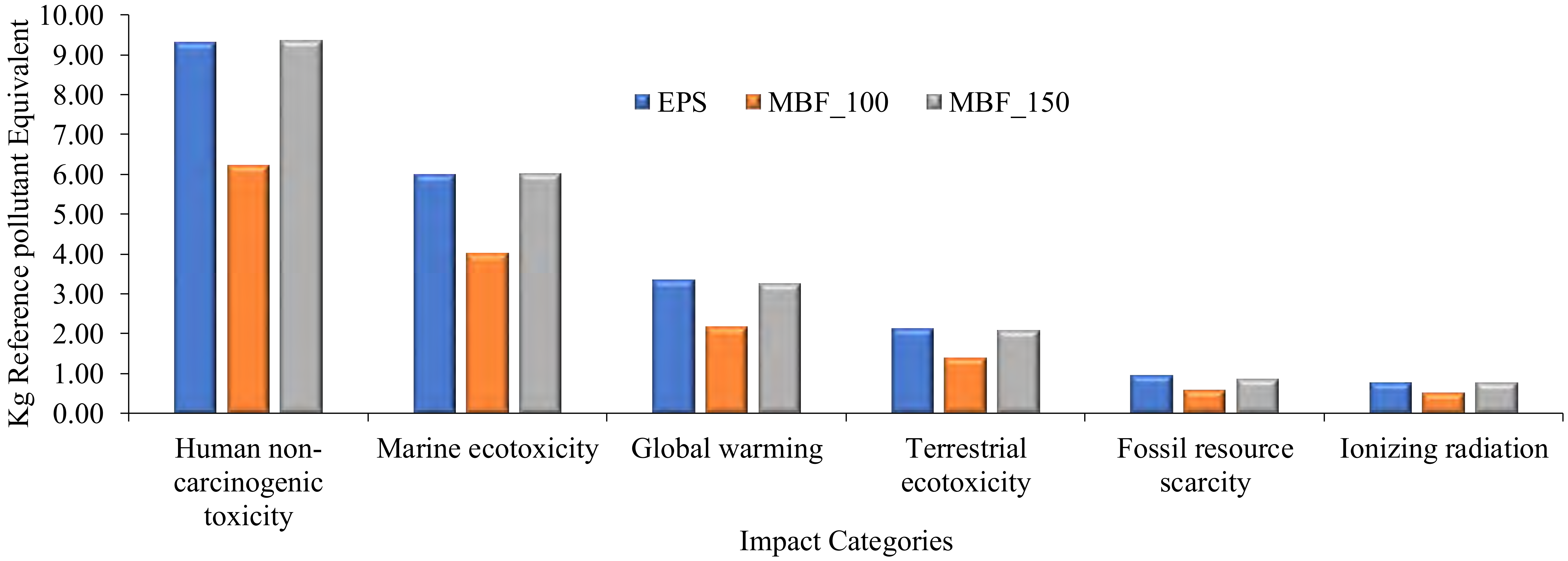


MBF Production Process



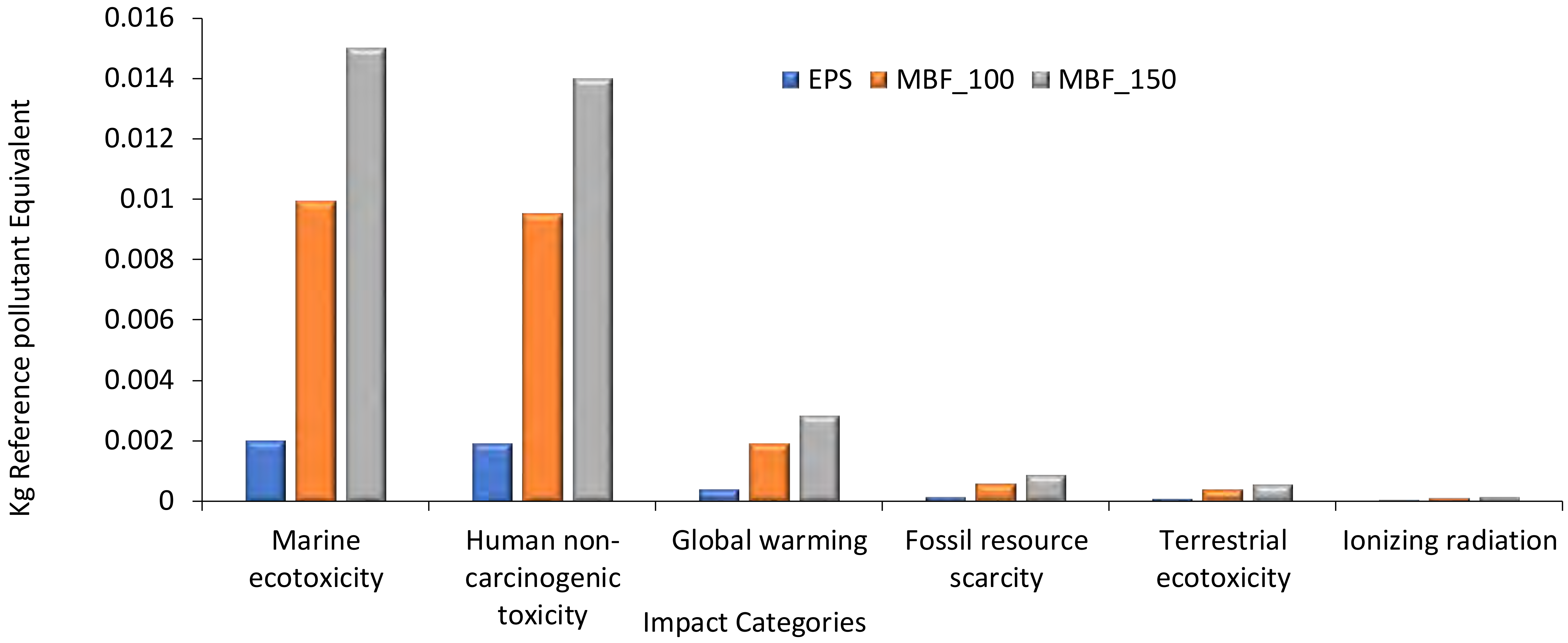
❖ Environmental Impact assessment

○ Raw Material Acquisition and Manufacture Phase



❖ Environmental Impact assessment

○ Consumption Phase



❖ Environmental Impact assessment

- **End of Life Management Process**

Comparison	EPS	MBF
Biodegradability	No biodegradable	Biodegradable
Management	Landfilling, incineration, recycling	Recycling, Composting, landfilling
Landfilling Concern	bulky nature, occupying high space	Biodegradation emissions
Alignment Principle	Linear economy	Circular economy

❖ Importance of Sustainable Packaging Design

○ MBF material extraction and manufacture stages

Impact categories	Human non-carcinogenic toxicity (kg 1,4-DCB)	Marine ecotoxicity (kg 1,4-DCB)	Global warming (kg CO_2 eq)	Terrestrial ecotoxicity (kg 1,4-DCB)	Fossil resource scarcity (kg oil eq)
MBF150	9.36	6.02	3.24	2.07	0.86
MBF100	6.23	4.01	2.16	1.38	0.57
Impact Reduction	33.4 %	33.4%	33.3%	33.3%	33.7%

○ MBF material consumption stage

Impact categories	Marine ecotoxicity (kg 1,4-DCB)	Human non-carcinogenic toxicity (kg 1,4-DCB)	Global warming (kg CO_2 eq)	Fossil resource scarcity (kg oil eq)	Terrestrial ecotoxicity (kg 1,4-DCB)
MBF150	0.015	0.014	0.00282	0.00084	0.00054
MBF100	0.00995	0.00952	0.00189	0.00056	0.00036
Impact Reduction	33.7 %	32%	33%	33.3%	33.3%

Conclusion

- ❖ **MBF Market Potential and Adoption:**
  - There is an enormous MBF market potential, but price, weight and proven environmental benefits are challenges to be addressed to facilitate adoption.
- ❖ **MBF Performance and Sustainability**
  - Optimizing MBF properties such as density, thickness, and design configurations improves the cushioning performance while reducing price, weight and environmental impact
- ❖ **Environmental Impact (EI)**
  - MBF has lower EIs during material acquisition, manufacturing, and end-of-life management stages compared to EPS but its heavier weight increased transportation emissions.
- ❖ **Recommendations**
  - MBF shock absorption performance is best when tailored for each product


THANK YOU