Building Materials: Case Studies of Economics at the FEW Nexus

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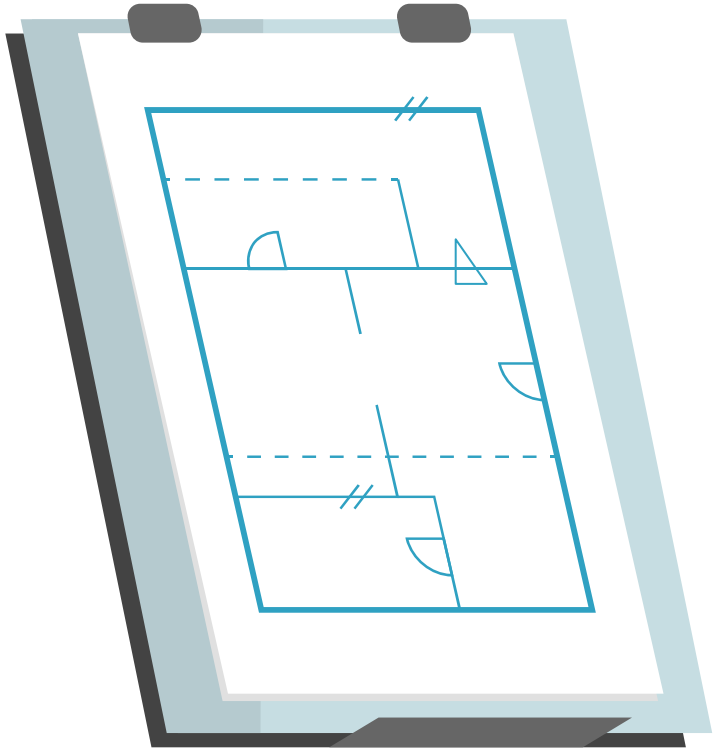
SCHOOL OF PUBLIC HEALTH
University of Maryland Global STEWARDS
Future changemakers at the food-energy-water nexus
A. JAMES CLARK SCHOOL OF ENGINEERING

Presentation Outline



Background & Introduction

Problem explanation & insulation basics

Current Industry Trends

Market size, saved costs

Case Study: Textile Waste

Textile waste for insulation

Case Study: Wood Waste

Wood chips in insulation products

What is the most effective way to save energy?

01

Turn off the lights

02

Shut off appliances

03

Recycle

04

Use public transportation

05

Insulate the home

Energy efficiency methods are more effective than energy curtailment efforts

Heat Loss in Homes: The Most Effective Way to Waste Energy

35%
Walls

Gaps in walls or large cavities can let heat seep out

25%
Roof & Attic

Heat can escape from the top of poorly insulated attics

15%
Floors

Unfinished basements with poor insulation or open seals allow leakage

25%
Windows & Doors

Poor fittings from old caulking and weather strips let heat escape

$2,000

Average US family spends per year on home utility bills

Proper Insulation: The Most Effective Way to Save Energy

20%

Of a home's energy bill can be saved by good roofing materials

40%

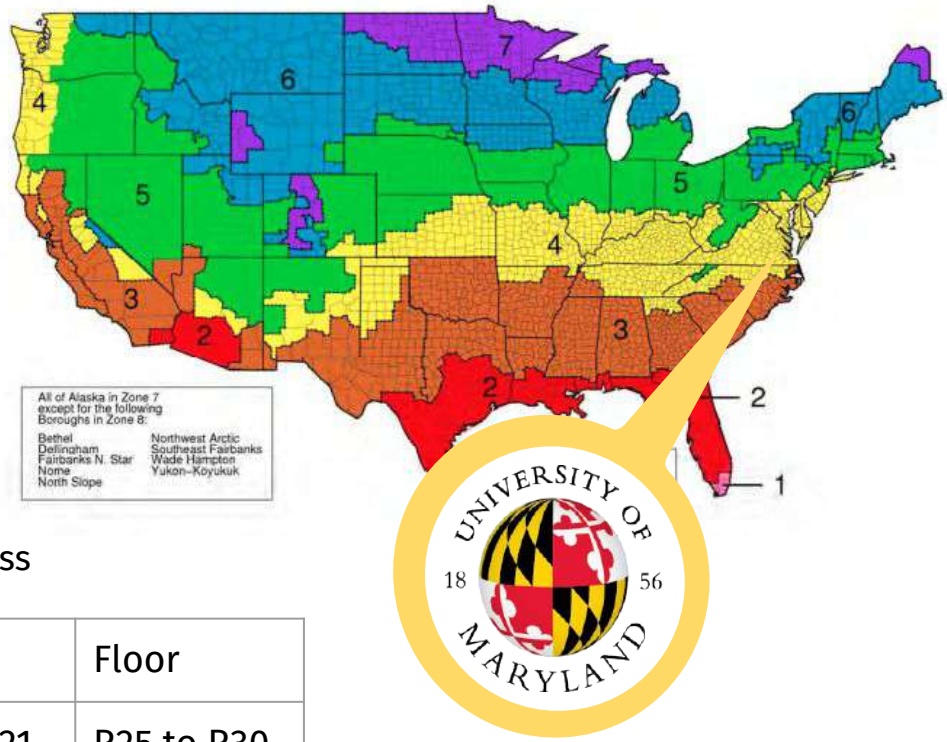
Of a home's heating/cooling cost can be reduced by proper insulation

Insulation Basics

- Goal: Maximize thermal performance
  - Cool during summer
  - Warm during winter

- Type of insulation depends on energy used
  - Local climate
  - Size/shape of house
  - Family living habits
  - Fuel/heating system

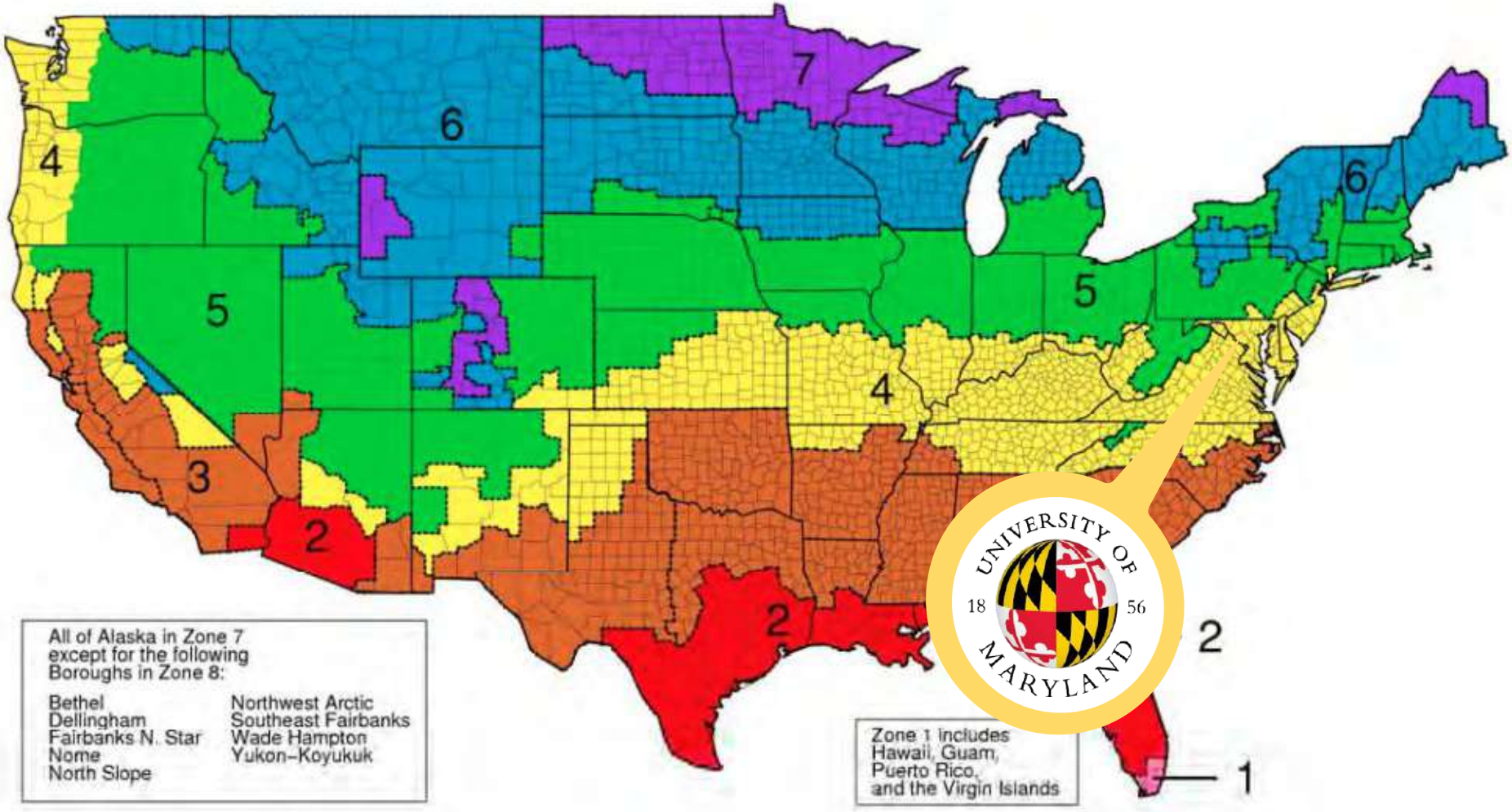
- R-value system
  - Rated for thermal resistance
  - High R value = greater insulating effectiveness



UMD Zone 4

Attic	Wall	Floor
R38 to R60	R13 to R21	R25 to R30

(Energy Star, 2008)


7
6
4
6
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3
2
2
2
1
All of Alaska in Zone 7
except for the following
Boroughs in Zone 8:
Bethel
Dellingham
Fairbanks N. Star
Nome
North Slope
Northwest Arctic
Southeast Fairbanks
Wade Hampton
Yukon-Koyukuk
Zone 1 includes
Hawaii, Guam,
Puerto Rico,
and the Virgin Islands
UNIVERSITY OF
18
56
MARYLAND

Insulation Examples

Fiberglass

Most common type made from skin/lung irritant materials.

Plastic Foams

Polystyrene/poly-urethane foams that can be sprayed in walls.

Mineral Wool

Synthetic rock (minerals) or slag (molten metal) fire-resistant materials.

Loose Fill

Mixed insulation type, that requires special equipment when blown into place.

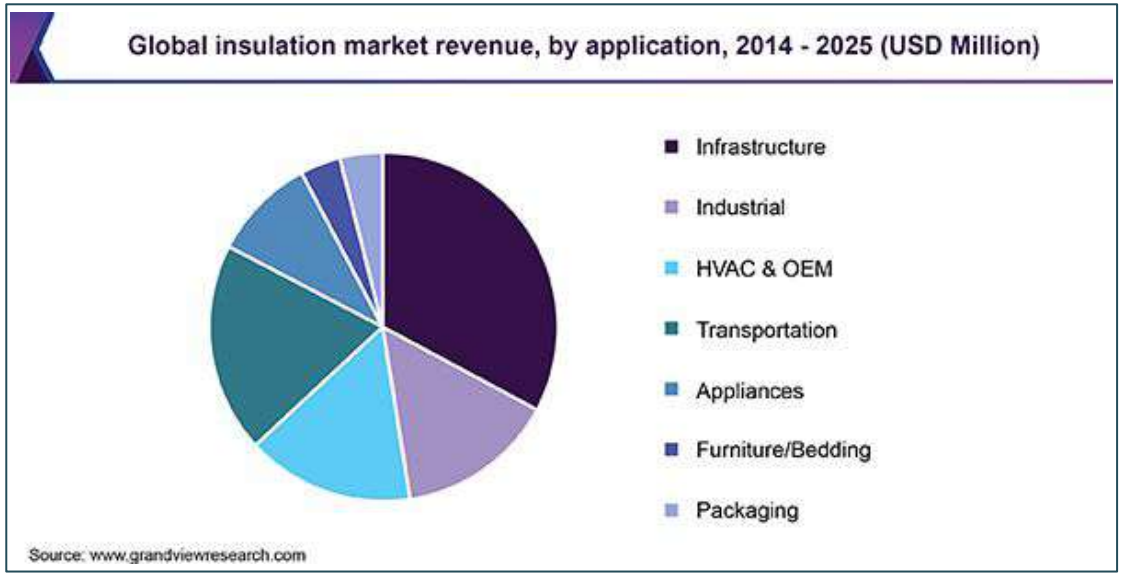
Environmental Impacts

- Reducing energy consumption of buildings is critical in limiting the carbon footprint of buildings
- Expanded polystyrene and polyurethane are produced from petrochemical products
    - Polystyrene can be recycled into expanded polystyrene
    - Materials cannot be recycled
- Fiberglass requires the mining of sand
    - 6-8% boron oxide
    - 20% recycled glass per EPA guidelines
- Pollution from resource extraction
    - Air and water pollution
    - Land erosion from mining

(National Park Service; Image: LA Times)

Current Industry Trends

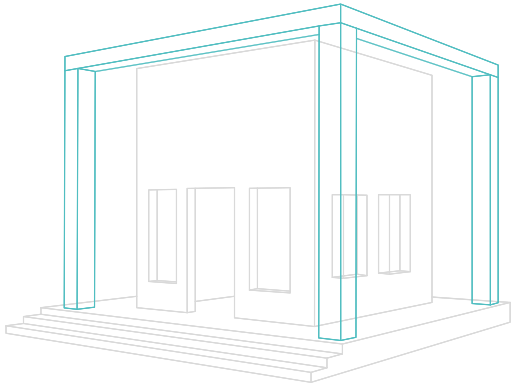
- Worldwide, buildings use **30-40%** of total energy produced
- The most commonly used insulation materials are expanded polystyrene and fiberglass
- Global insulation market valued at approximately $58 billion
    - Forecasted to grow to approximately **$77 billion** in 2025



(Abu-Jdayil et al., 2019; Grand View Research, 2019)

Economic Benefits

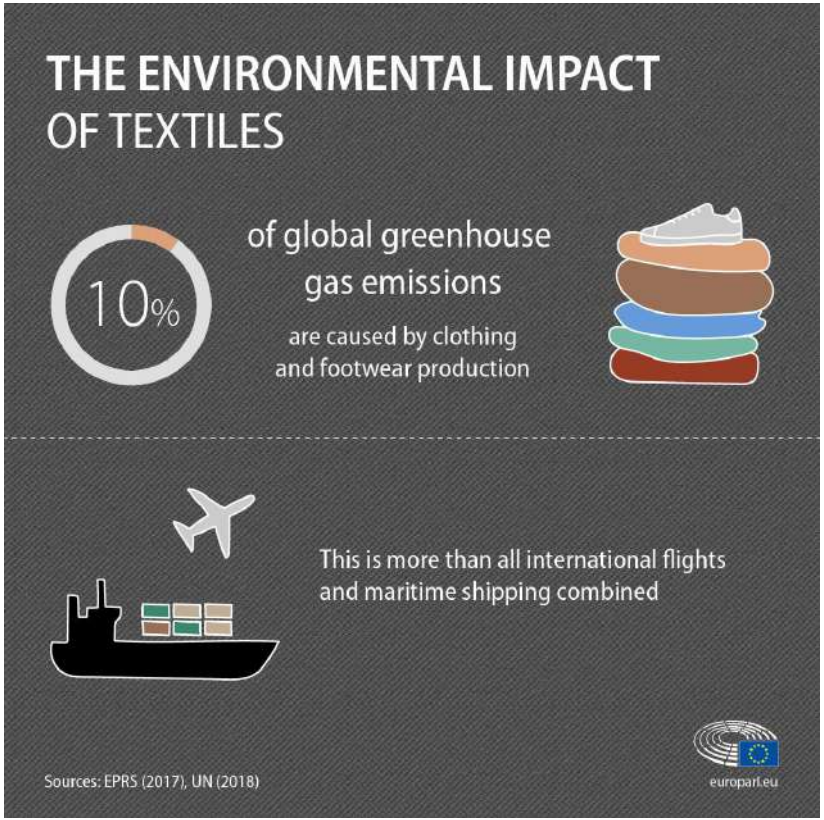
- Estimated that sealing air leaks and improving home insulation would save **15%** on heating and cooling costs in the average US household
    - Low-income households tend to have poor insulation
- Investments in energy efficiency can boost the local economy and create jobs
    - **2.2 million** Americans employed in energy efficiency industry



EPA, 2018

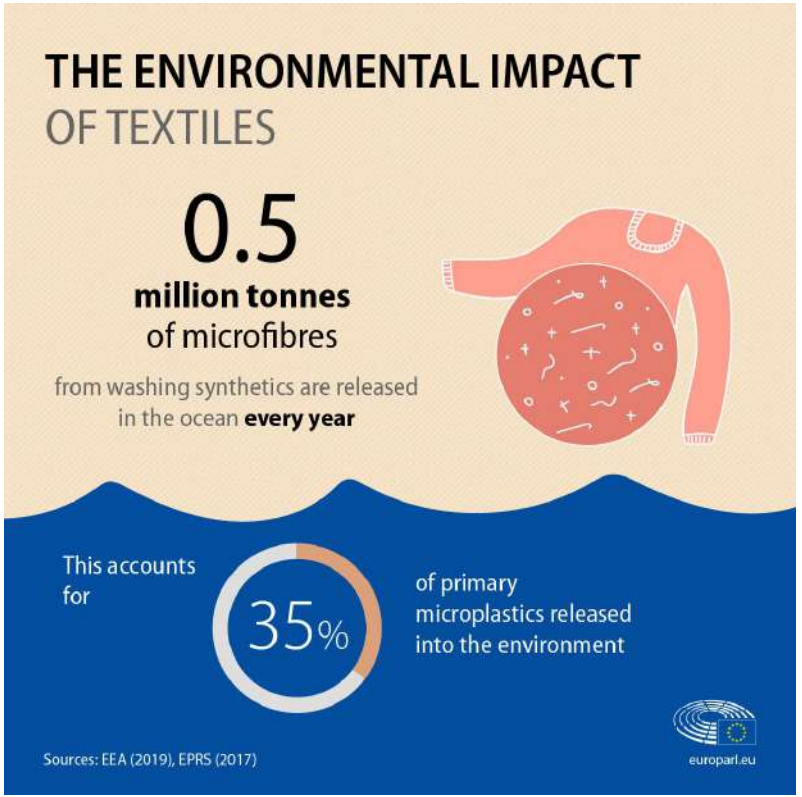
Case Study: Textile Waste

- **$1.3 trillion** market value
- **100 billion** garments produced annually
- Textiles are often used for a short period of time, then typically sent to landfills or incinerators
  - 12.4 million tons in US
  - 26.0 million tons in China
  - 1.0 million tons in UK
- Total greenhouse gas emissions from production: **1.2 billion tons**, annually
- Every year, **$500 billion** is lost
  - Underutilization
  - Lack of recycling



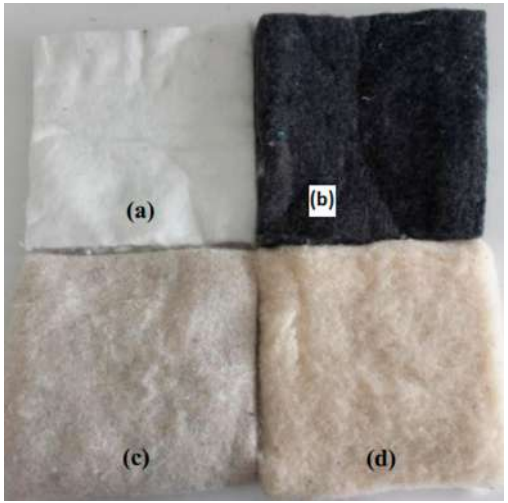
(Gounni et al., 2019; Herrmann, 2017; European Parliament, 2020)

Case Study: Textile Waste



(European Parliament, 2020)

Textile-Based Insulation



a) Acrylic spinning b) acrylic knitting c) wool raw d) wool carpet
Image from Gounni et al. (2019)

- Similar thermal conductivity ratings compared to expanded polystyrene, extruded polystyrene, and mineral wool
- Demonstrated environmental, sustainable and economic advantages
- Other research has found that cotton and textile ash waste can be used to make bricks and wall/ceiling panels that have good insulation properties

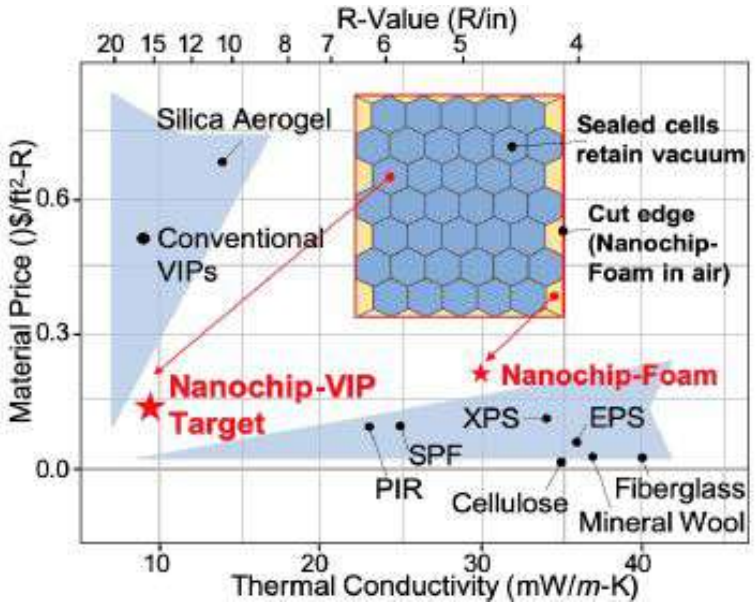
(Abu-Jdayil et al., 2019; Gounni et al., 2019)

Denim Insulation

- Widely available
- Easy for homeowners to install without contractor
- More expensive than other types of insulation for equivalent R-value
- Use can assist with obtaining LEED certification
    - Green building certification system
- Better acoustic insulation compared to fiberglass

Case Study: Wood Waste

- Create high-performance, **sustainable** insulation products
  - Wood is a waste product
  - Delignified wood has lower thermal conductivity
- Vacuum Insulation Panels (VIP) use vacuums for creation
  - Absence of air = no thermal conductivity
  - Excellent thermal efficiency
- VIP global market **$8.8 billion** (USD) value
- Use honeycomb grid structure for creating insulation panels
  - Structural reinforcement from shape
  - **Highly insulative** nature from materials



(Hu, DoE 2021)

Wood Waste Delignification Process

1

Preparation

Add appropriate chemicals & pre-soak wood chips

2

Cooking

Cook wood in pressurized digester for lignin removal

3

Rinse & Dry

Use vacuum pump for effective acid & chemical removal

4

Foaming

Foam with bio-based binders into honeycomb structure

Preliminary Cost Analysis of VIP Insulation (Density ~ 100 kg/m^3)

Materials	Price ($/ton)	Dosage (kg)	Cost ($/ ft^2 in)
Base 1	330	0.95	0.224
Base 2	330	0.95	0.224
Wood Chips	50	0.95	0.111
Binders	3,000	0.95	0.035
Envelope	1,600	0.022/ft^2	0.044
Total Material Cost			**0.538**

Insulation Comparison

01

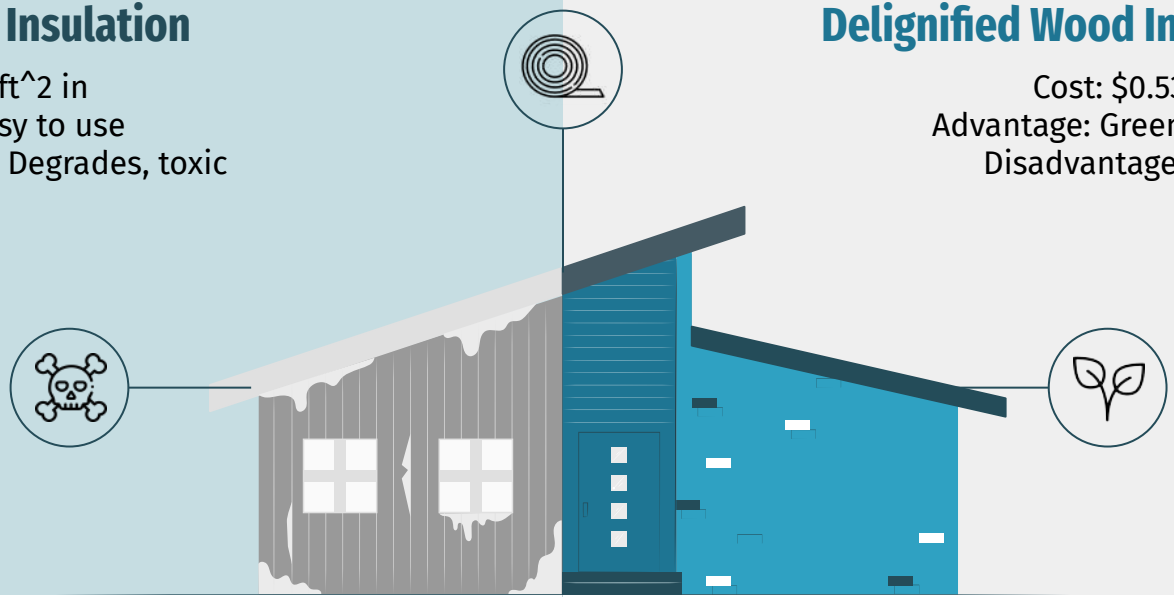
Traditional Insulation

Cost: $10-12 / ft^2 in
Advantage: Easy to use
Disadvantage: Degrades, toxic

02

Delignified Wood Insulation

Cost: $0.538 / ft^2 in
Advantage: Green materials
Disadvantage: Technical



Building Materials: Economics & the FEW Nexus

Sustainable Insulation

Environmentally friendly insulation products avoid harmful irritants & pollutants

1

2

Recycling Materials

Finding alternative solutions for waste (textile, wood chips) through recycling

Saving Energy

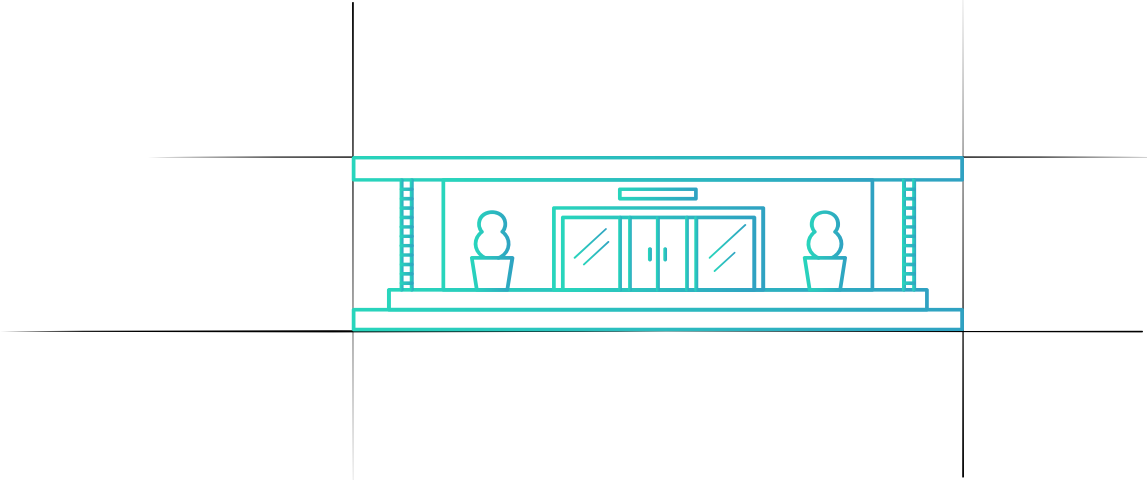
Saving energy required for heating/cooling systems in homes

4

3

Reducing Cost

Lowering cost to typical utilities & promoting new industries



Thank You!

Are there any questions?

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