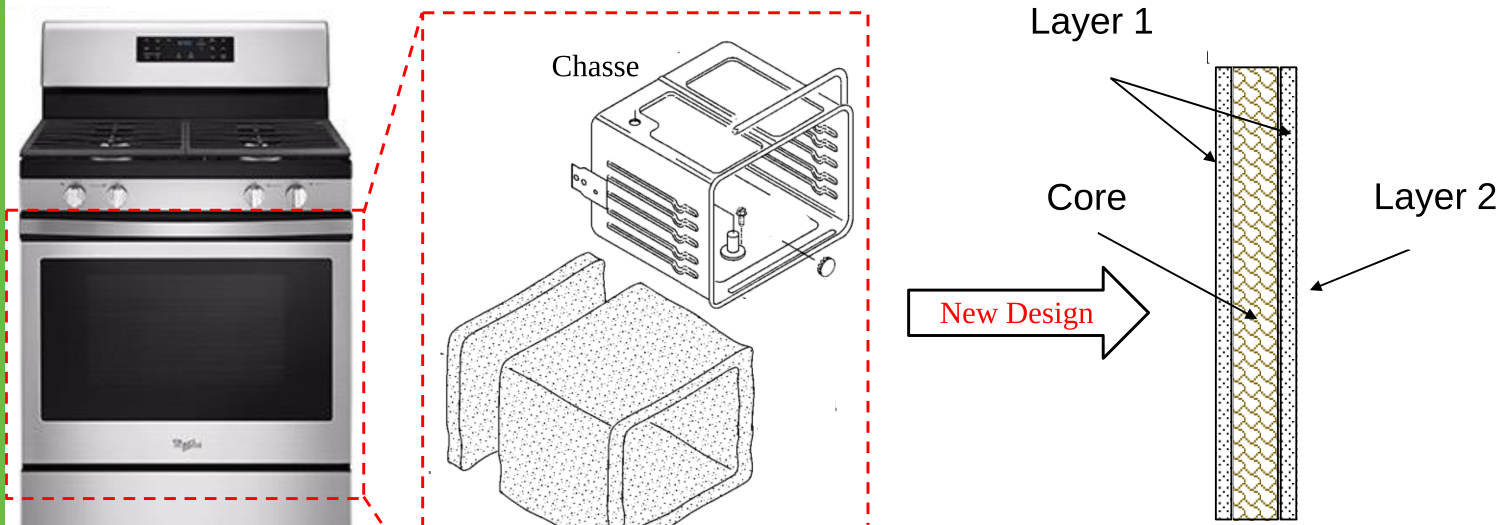
Domestic Electric Oven Reimagined: Eco-Friendly Cooking Oven at Scale Using Recycled Reinforced Composites



Monolithic Chasse Wall with Integrated Insulation and Reflective Layer

Conventional Design

New Innovative Design

Oak Ridge National Laboratory (ORNL)

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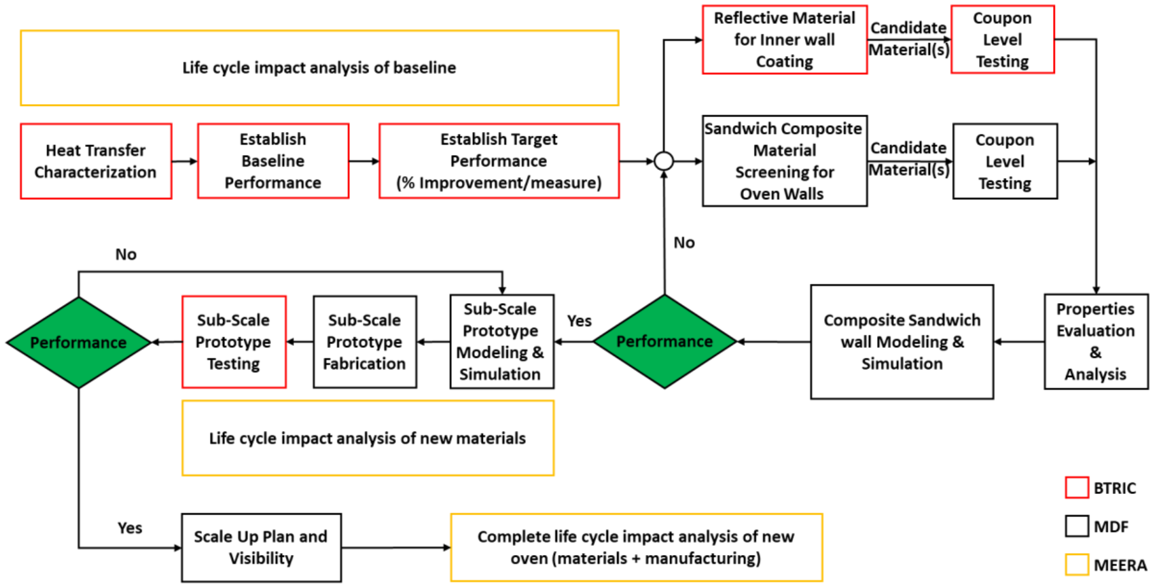
Buildings and Transportation Division

Project Summary

Objective and Outcome

Develop and demonstrate a new and innovative new design for domestic electric ovens that has an improved thermal efficiency and lower environmental impact by replacing the steel oven cavity with insulating reinforced composites made from sustainable materials.



Team and Partners

Oak Ridge National Laboratory

The American University in Cairo

Whirlpool Corporation

Carbon Rivers

The University of Tennessee Knoxville

Stats (Project Started in *March 2023*)

Performance Period: **2023-2026**

DOE budget: **$1.2M**, Cost Share: **($250K tentative** - CRADA in Process)

Milestone 1: Development of heat transfer and safety specifications is completed

Milestone 2: Complete the exploration for sandwich materials and formulations that satisfy requirement

Problem

- Electric ovens are currently only 10–12% energy efficient and consume ~100 TBtu of primary energy nationwide annually
- Most of that energy does not go into cooking the food, rather it is largely lost through the exterior: radiated away or by convection
- Retaining the heat in the air mass and cavity walls for extended periods of time is challenging with the current design
- Oven cavity interior surfaces are coated with enamel (high temperature resistance and high emissivity ~0.96. high emissivity is beneficial for good radiative heat transfer from the walls of the cavity to the load. However, it also increases the heat transfer from the outer walls of the cavity to the insulation
- The insulation is constrained by the available space between the cavity enclosure and the out walls of the cabinet and by the maximum operating temperature of the outer wall of the cavity enclosure
- Energy is supplied in square wave form (heater ON/OFF) at high power level to ensure storing enough energy to over the come the heat transfer to the load and the heat loss to the ambient

Alignment and Impact

- Using advanced composite material with ***sustainable materials*** as oven construction material to replace steel
  - ➢ Composites are highly utilized in different applications such as wind turbine blades, boating industry, transportation, and sporting goods, and at their end of life they can be reclaimed, upcycled or downcycled, to be used in other applications
  - ➢ Waste composites is expected to increase due to the renovation of the wind turbine fleet (20 years service life of the blades)

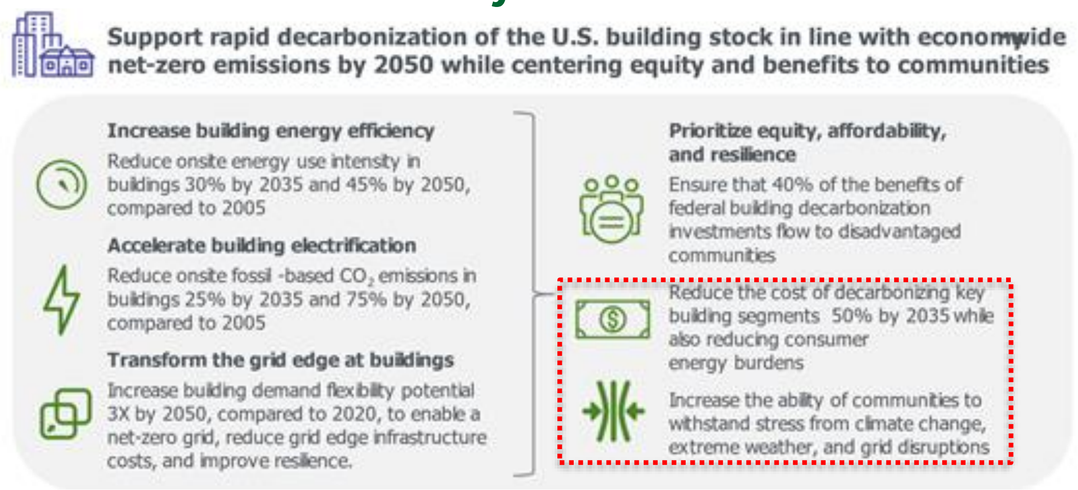
- Consolidation of parts to ***reduce manufacturing steps*** and parts count
  - ➢ Currently cavity are made using progressive stamping techniques – for each cavity wall 3 to 4 tools are needed (total of 10-12 molds)
  - ➢ High capital process to start a new line with very limited chance for product modifications

- Manufacturing the oven chassis using ***advanced techniques***
  - ➢ Using molding processes will reduce the tooling requirements
  - ➢ Reducing the footprint of the manufacturing setup
  - ➢ More flexibility in the assembly process

Impacts of a Proposed vs. Target Conventional Oven

	Conventional	Proposed
Thermal efficiency	12%	30%
Electric demand, kW	X	0.6X
Weight, kg	50	30
Price point at maturity	$	<= 1.1$
Technical potential savings, TBtu	0	100
Embodied energy, MJ	1,427	450

EERE/BTO's vision for a net-zero U.S. building sector by 2050



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Whirlpool CORPORATION

Alignment and Impact – DEI

- Lowering the life cycle environmental impact of domestic cooking and reducing its energy consumption as proposed will directly impact <u>***low-income consumers by reducing their utility bills***</u>, which are a larger percentage of income compared to the national average

- The project team will include a full-time staff and a postdoctoral research associate or a gradate student from an underrepresented minority in STEM such as MSIPP

- The team members will attend trainings, workshops (such as events by the Women in Science and Engineering (WiSE) committee at ORNL), or other events to better understand the challenges the project minority members face in the workplace that other members may not be aware of or not fully understand

- Whirlpools believes that all people matter, regardless of their nationality or ethnicity. Whirlpools values, work environment and company culture all seek to reward uniqueness

- The project team includes a local sustainable, green circular economy small-business, Carbon Rivers, who are in the process of scaling up their production. This project will provide them with the opportunity to establish demand

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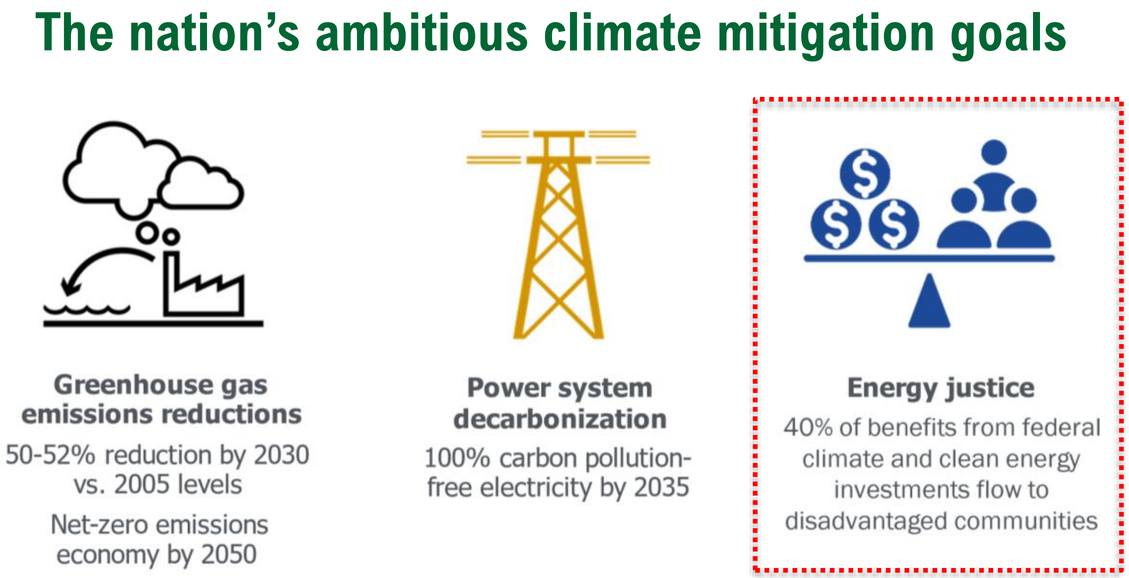

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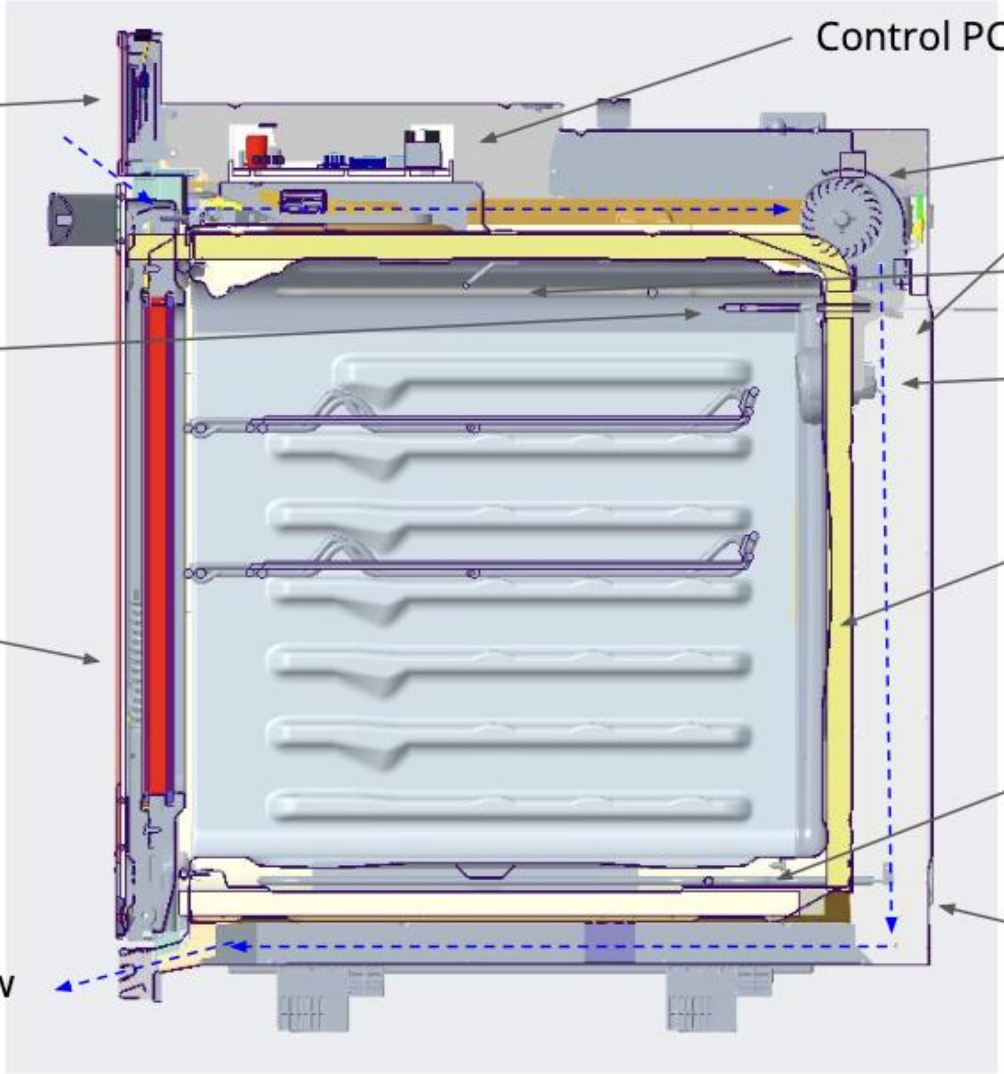
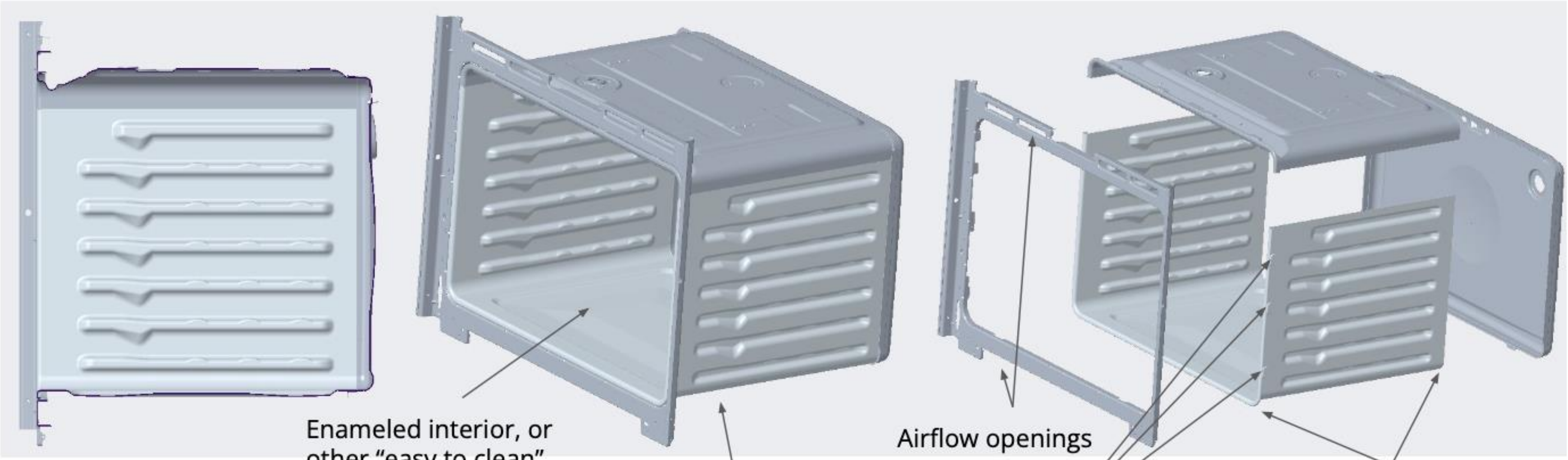
Approach



Whirlpool CORPORATION

Approach



Cleaning Cycle

User max temp setting: 550 F (288 C)
Pyrolytic cycle (not all units): 932 F (500 C) - consumer non-preferred, but best cleaning perf
Aqualift cycle (not all units): 550 F (288 C) - consumer preferred

Whirlpool CORPORATION

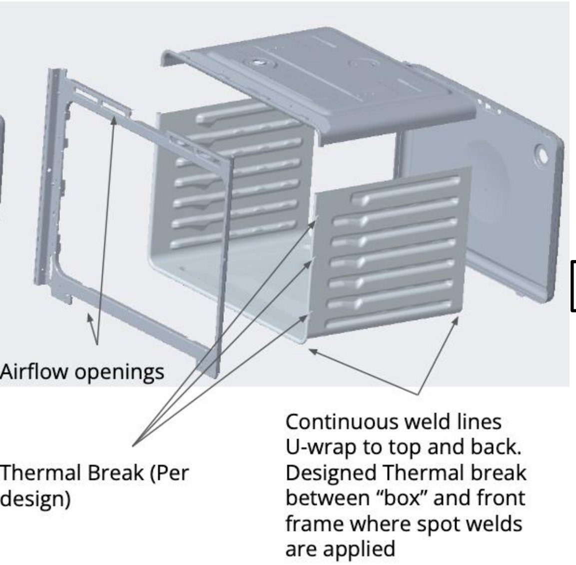
Approach

What makes a good cavity design?

- Heat retention and reflection for improved cooking performance (no need for additional insulation)
- Energy efficiency
- Sustainability (start and end of life)
- Modularity (high flexibility, simple tooling)
- Manufacturability
- Low Cost

Approach

Food Safe High Temperature Materials Development – Materials Selection



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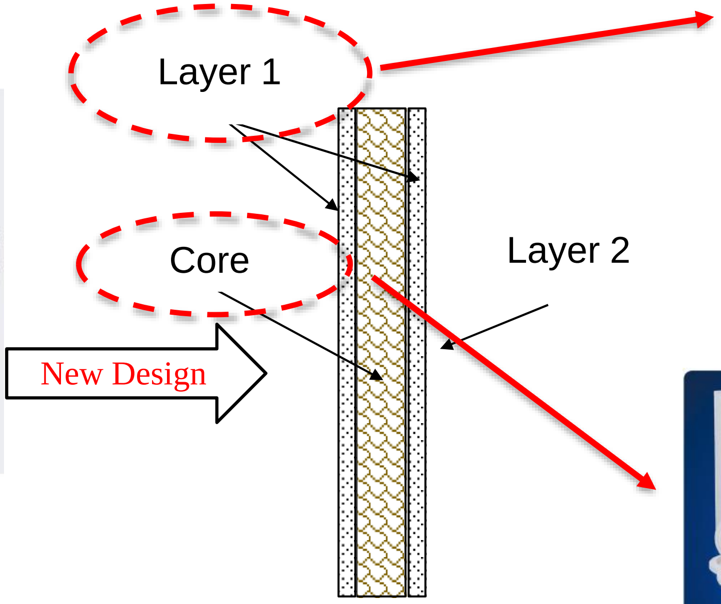
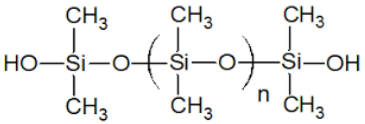


Monolithic Chasse Wall with Integrated Insulation and Reflective Layer

New Innovative Design

Fiber Reinforcement

Open Cell Ceramic Foams Thermal Conductivities of ceramic foam are ~ 0.05 to 0.08 W/mK up to 400 ºC



Impregnation with Thermoset Materials

Preceramic Polymers

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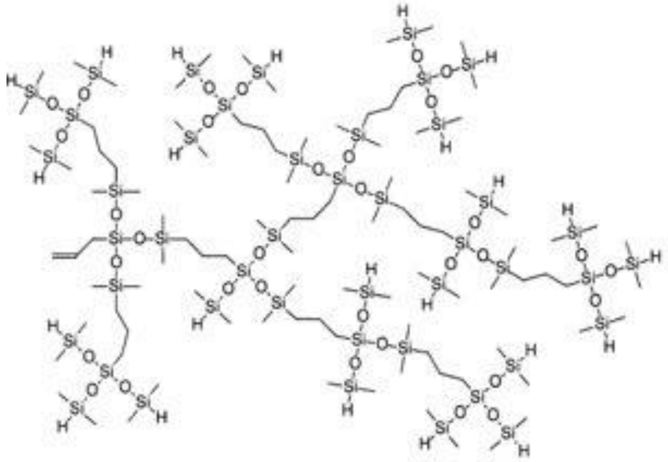
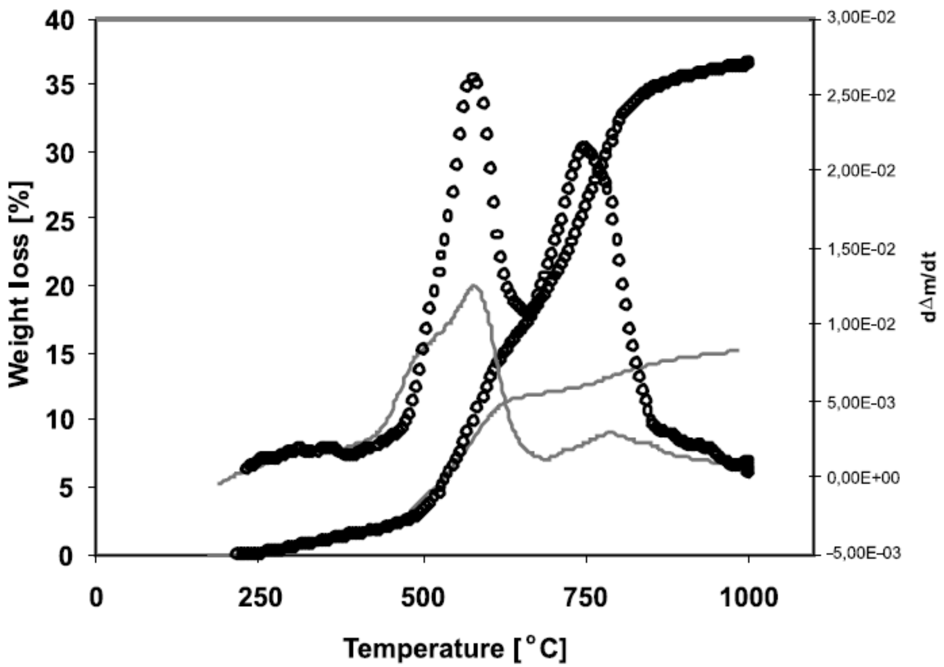
Progress and Future Work

Food Safe High Temperature Materials Development – Materials Selection



Thermoset are routinely used in ovens - silicone baking sheets



TGA and DTG curves for an example thermoset material

Brus, J. et. al. Journal of Non-Crystalline Solids 289 (2001) 62-74

Thin layer of amorphous ceramic over the composite insultation provides a high emissivity surface in lieu of enamel coated steel

Thermosets are thermally stable to 350ºC, <10% weight loss.

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Progress and Future Work

Manufacturing and Characterization

Thermoset Polymer

Fiber Reinforcement

SMC Line Located at the MDF/ORNL

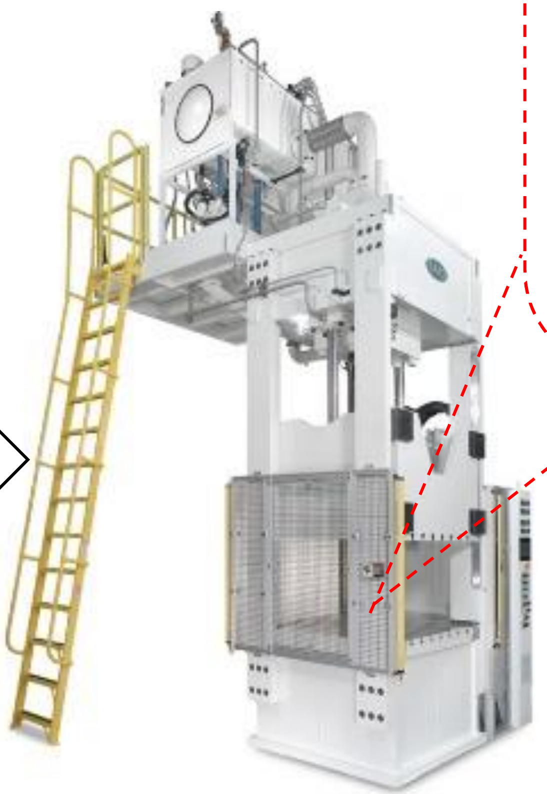
Product

Ceramic Insulation Foam

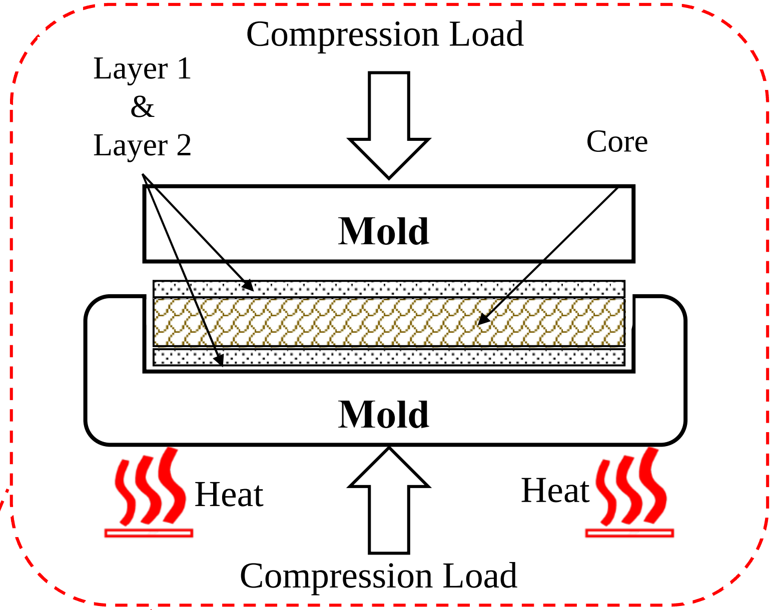
+

SMC Composite Sheet

Transfer



500T Press Located at the MDF/ORNL



Lay up of Sandwich Chasse

Progress and Future Work

Metrics (marketing/technical) a composite oven could improve?

- Performance
  - ➢ Heat retention
  - ➢ Preheat times
  - ➢ Application to specific components for a more efficient cavity/structure
  - ➢ Health: outgassing, does a standard exist (FDA), etc.
  - ➢ Even temperature distribution in oven

- Energy efficiency

- Manufacturing
  - ➢ End of life and Sustainability

Progress and Future Work

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- Manufacturing
  - End of life and Sustainability

M.S.1.2 Complete experimental validation of the heat transfer model is complete to within 10% prediction accuracy of temperatures and heat flows

M.S.1.4 Processing of composite sheets, at least 3 different formulations are done

M.S.1.5 At least 5 samples of skin composites tested (Tensile, Flexural, Creep) and (Cp, thermal conductivity).

M.S.1.6 Manufacturing of the sandwich composite walls. 5 plaques with dimensions up to 14” x14”

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Thank you

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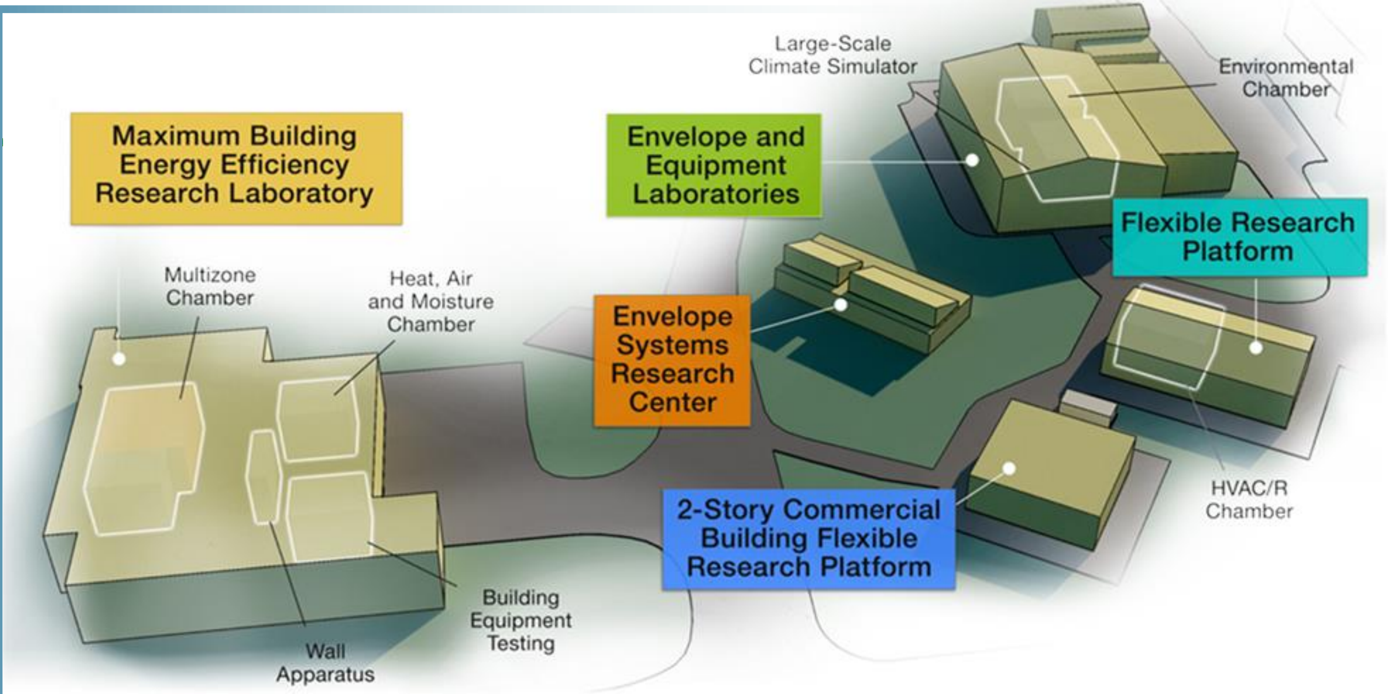

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54 university partners
13 R&D 100 awards
52 active CRADAs

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