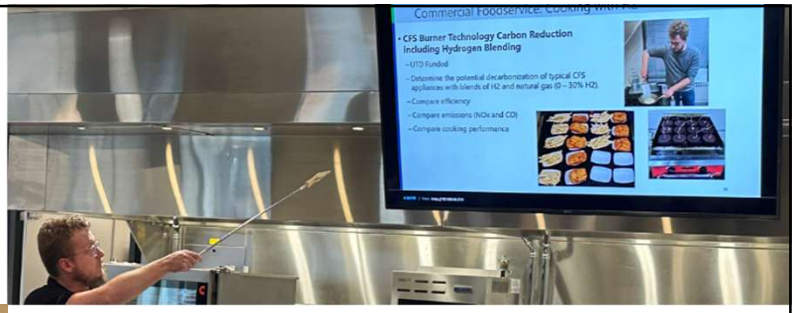
GTI ENERGY
solutions that transform





Advanced Efficient Burners for CFS Equipment



Frank Johnson, PhD

1

80-Year History of Turning Technology into Practical Energy Solutions

GTI ENERGY





World-class piloting facilities headquartered in Chicago area

400+ EMPLOYEES

Collaborative Organizations and Programs

Working with utilities to address critical challenges

OTD Operations Technology Development

UTD Utilization Technology Development

ETP Emerging Technology Program

LCRI LOW-CARBON RESOURCES INITIATIVE

GTI Office

FRONTIER energy

2

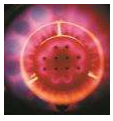
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solutions that transform

: Expertise

GTI ENERGY



Subsurface Technologies
- Sustainable production
- Water management
- Methane emissions mitigation
- CO2 Sequestration



Combustion Systems
- Advanced design and modeling
- Industrial burner development
- Oxy combustion
- Low NO_x equipment



Infrastructure Asset Management
- Data analytics and AI
- Pipeline GIS location, inspection, and maintenance
- Methane emissions mitigation



Gasification & Partial Oxidation
- Raw hydrocarbons to syngas
- Entrained flow and fluidized bed processes
- Biomass & waste conversion



Clean Fuels and Chemicals
- Biomass-to-clean fuels
- Gas to Liquids
- Direct conversion/utilization of methane in low-carbon applications



Pipeline Integrity
- Advanced risk models
- Testing/analysis
- Materials research
- Impacts of RNG and hydrogen



Carbon Capture & Utilization
- Advanced separations
- Carbon capture
- Gas reforming and synthesis



Power Generation
- Combined heat and power
- sCO_2 power cycles (STEP)
- Oxy-PFBC process



Biological and Chemical Analyses
- Methanotrophic microbes
- qPCR genotyping
- Microbial influenced corrosion



Hydrogen (H_2)
- Clean hydrogen production
- Electrochemical conversion
- Storage & delivery infrastructure
- Blending and use in buildings, transportations, and industry



Alternative Transportation
- Engine development and testing
- Modular reactor platform
- LNG and hydrogen use – vehicle, marine and rail

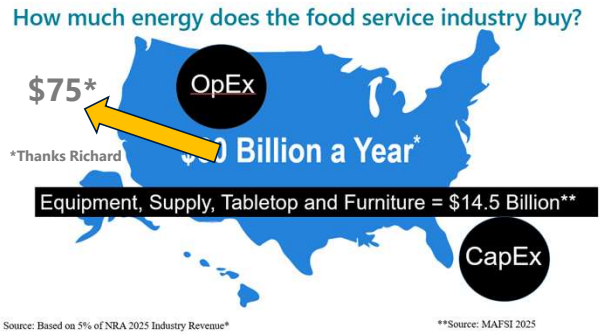


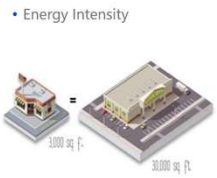
Energy Efficiency (EE)
- Design and oversee EE programs
- Industrial equipment
- Commercial/residential appliances
- Building envelopes

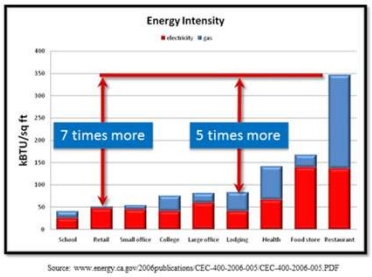
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Foodservice Industry Energy Facts







The Use of Natural Gas in the US Hospitality Sector
- 300 billion cubic feet of natural gas consumed per year
- 76% of restaurants use gas for cooking
  - ~ 538,000 out of 695,000 locations (77%)

4

Foodservice Industry Information

- **NRA Restaurant Performance Index**

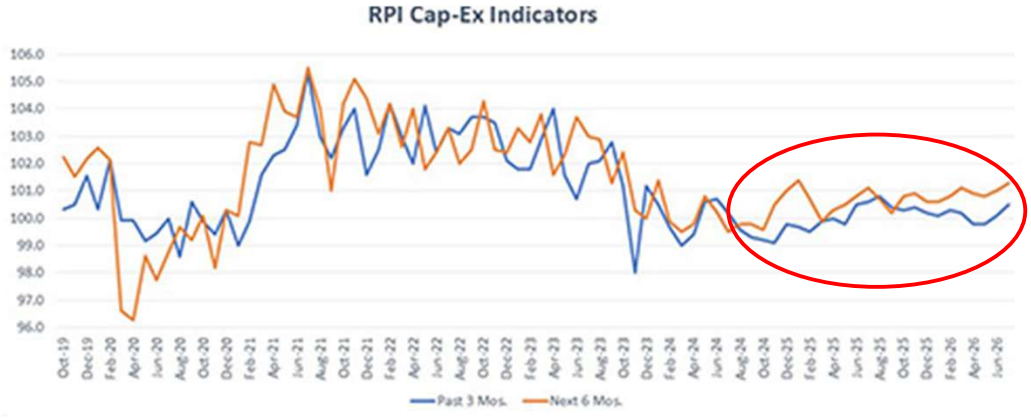


Sources: THE ASHTON REPORT NATIONAL RESTAURANT ASSOCIATION

5

Foodservice Industry Information

- **NRA Capital Spending Indicators Oct 2019-July 2026**

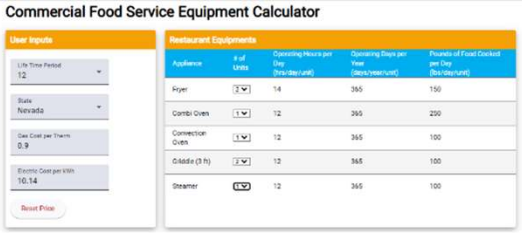


Sources: THE ASHTON REPORT NATIONAL RESTAURANT ASSOCIATION

6

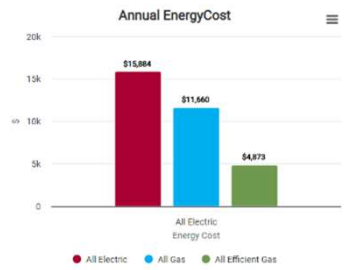
GTI Energy Commercial Foodservice R&D Program

- Focus: Commercialization of advanced, gas-fired foodservice equipment
  - Identifying and developing new technology
  - Educating CFS industry
  - Demonstrating advantages of new technology
  - Addressing technology concerns/issues









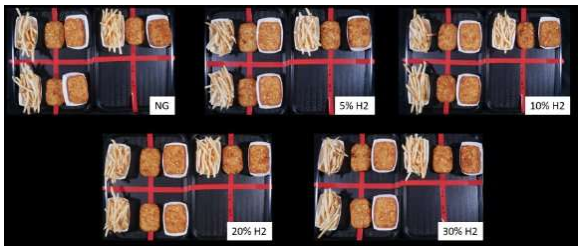
Appliances Commercialized



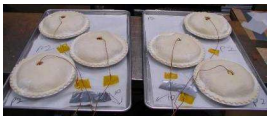
7

Foodservice Laboratories (CDL/BDL)

- **Cooking Demonstration lab (CDL)**
  - Prototype and pre-certification cooking tests
  - Live demonstration space
  - High-resolution gas meters, IAQ instrumentation, flue gas analysis (O2, CO, CO2, NOx, and ULNOx)







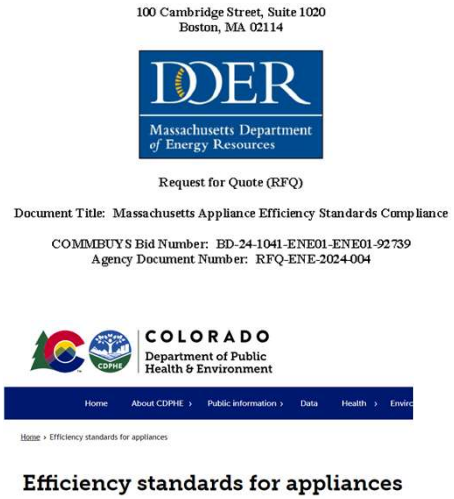


Dough-Sauce Interface, thanks again Richard

8

Commercial Foodservice Industry Issues

- State based energy efficiency requirements
  - –Massachusetts, Colorado
  - –Commercial Foodservice
    - Not ever type of appliance has an Energy Star option
- Federal energy efficiency standards
  - –DOE 2023 NOPR on Standards for Cooking Products (residential)


100 Cambridge Street, Suite 1020
Boston, MA 02114

DOER
Massachusetts Department of Energy Resources

Request for Quote (RFQ)

Document Title: Massachusetts Appliance Efficiency Standards Compliance

COMMBUYS Bid Number: BD-24-1041-ENE01-ENE01-92739
Agency Document Number: RFQ-ENE-2024-004

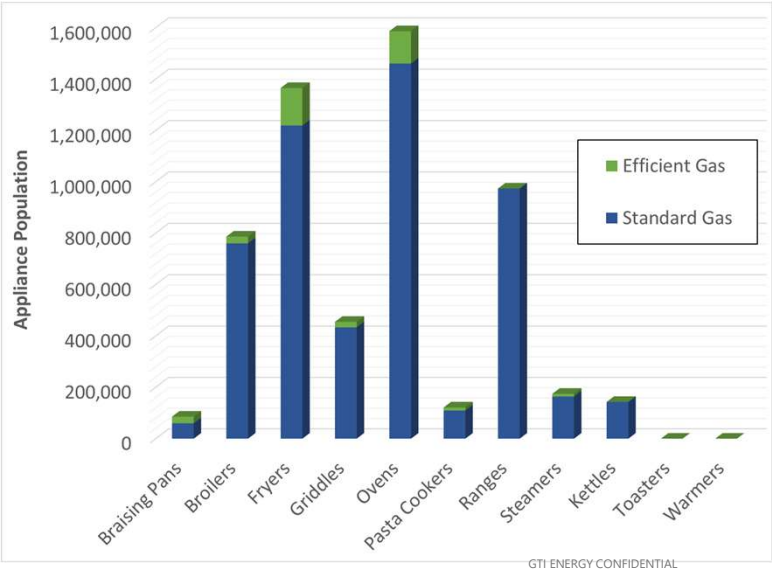
COLORADO
Department of Public Health & Environment

Home › Efficiency standards for appliances

Efficiency standards for appliances

Commercial Foodservice Equipment

- North American Appliance Populations



Efficiency in a Restaurant

- Major Hurdles
  - Higher cost of equipment
  - Limited availability
  - Fluctuating cost of energy
  - Energy intensity
  - Uncertainty about cooking performance
- Cooking for Profit Article, 2014
  - Why Efficiency Still Matters



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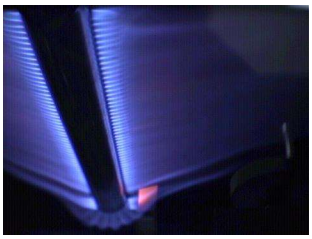
Energy and Commercial Foodservice

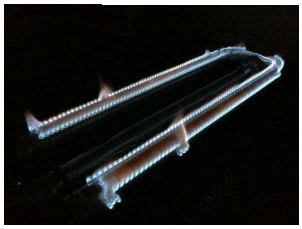
- Natural Gas and Electric









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CFS Research: Burner Technology

- CFS lags behind other industries in terms of burner technology
  - –Cost
  - –Cooking characteristics
    - "Not broke, don't fix it"
  - –Burner expertise



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CFS Research: Efficiency

- Furnaces: 80-93%
- Water Heaters: 80-92%
- CFS: 11-74% (most 30-50%)
  - –Atmospheric vs. Power Burners

Atmospheric Burners



Power Burners



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Atmospheric Burners

- Most common burner, found in all equipment types



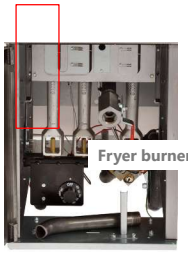
Inshot burner for convection oven



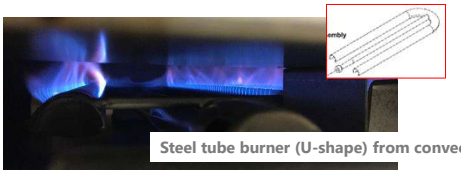
Inshot burner in furnace

Cast iron burner for fryer

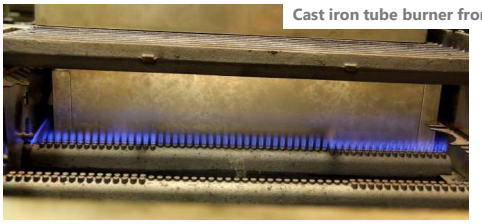




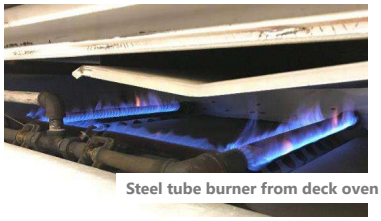
Fryer burners



Steel tube burner (U-shape) from convection oven



Cast iron tube burner from broiler



Steel tube burner from deck oven

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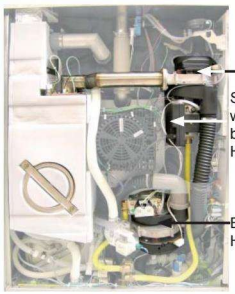
15

Power Burners

- Uses blower to bring in air at a pressure higher than atmospheric; can achieve higher input rates
- Comes with electronic controls and can modulate
- Less excess air used → More efficient, lower NOx
- Found in combi ovens, rack ovens, fryers



Power burner from rack oven



Power burners (1 hot air, 1 boiler) from combi oven



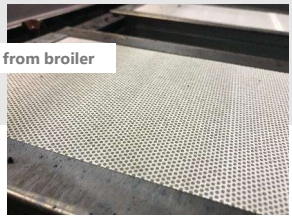
Power burner from boilerless combi oven

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Infrared Burners

- Heat transfer through radiation, as opposed to convection
- Combustion occurs right on the surface, and heat is quickly distributed to the ceramic or steel material. This cools the combustion reaction, lowering NOx.
- Seen in broilers, fryers, griddles, convection ovens:
  - Steel tube IR burner
  - Perforated ceramic IR burner



Ceramic IR burner, from broiler

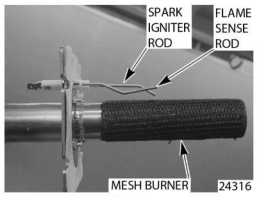


Fig. 61

Tube IR burner from convection oven



Ceramic IR burner, glowing orange



Tube IR burner from fryer

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CFS Research: Technology

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- Show value of bringing cutting edge burner designs to commercial foodservice
- Improve
  - Cooking Performance
  - Efficiency
  - Emissions



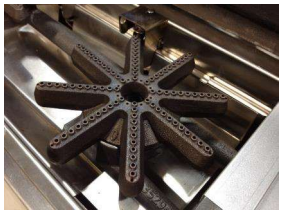


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CFS Research: New Burner Materials

- Typical Burner – Metal with holes



2017
Technology



1917
Technology



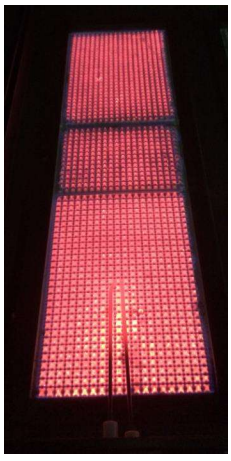
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19

CFS Research: New Burner Materials

- Ceramic





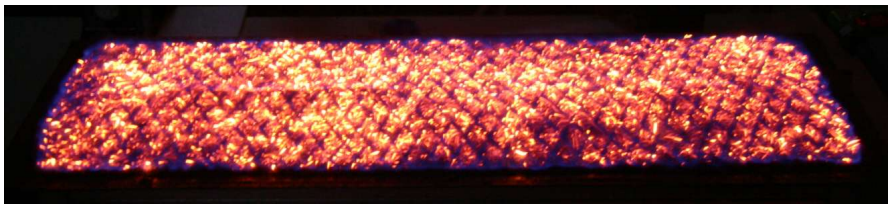
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20

CFS Research: New Burner Materials

- Metal Mesh



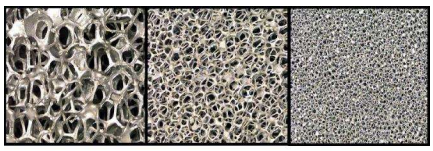


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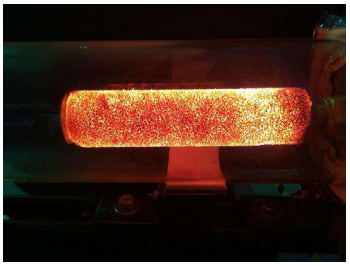
21

CFS Research: New Burner Materials

- Metal Foam







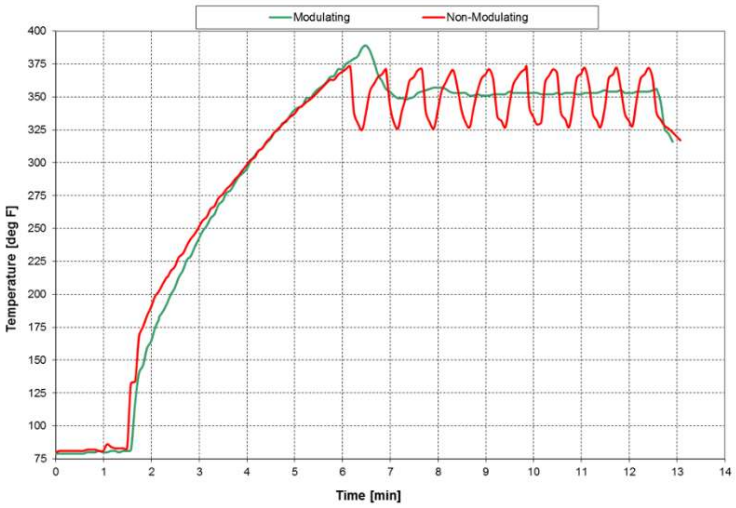
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22

CFS Research: Power Burners with Modulation

- Control air to fuel ratio
- Change energy input based on appliance use





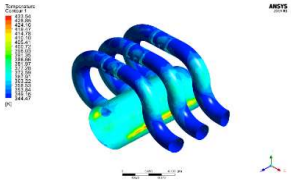
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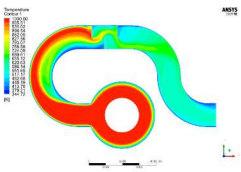
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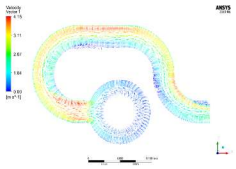
CFS Research: Computation Fluid Dynamics Modeling

- CFD Modeling
  - –Model appliance parts and burners before building



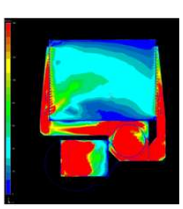












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Why Efficiency Matters

- The operator cares
  - Savings go right to bottom line and can boost profits by 10-30% in a tight margin business



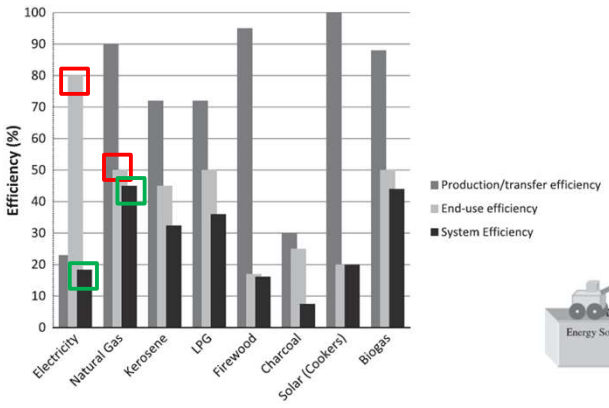




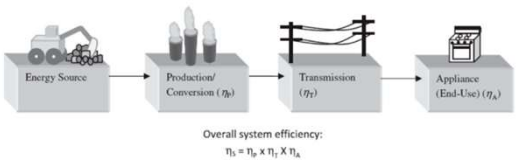
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25

Efficiency: Source vs Site



- Key Results
  - End Use Efficiency
  - System Efficiency
    - Electric is ~18%
    - Natural Gas is ~45%

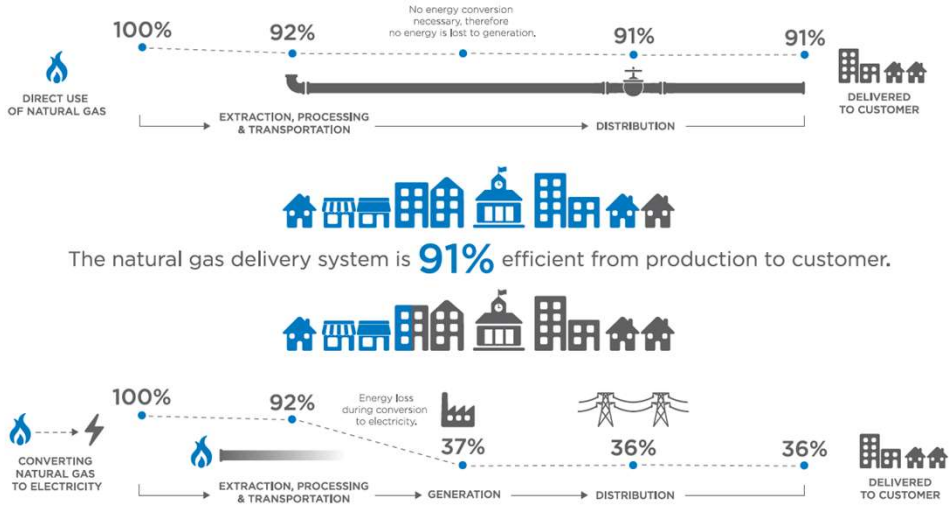


Source: Ramanthan, R., Ganesh, L.S., 1994. A multiobjective analysis of cooking-energy alternatives. Energy 19, 469-478.

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Efficiency: Source vs Site



Source: Duke Energy, Piedmont Natural Gas.

CFS Research: Innovation in CFS

- Appliance Innovations
  - –Ahead of other industries
    - How the appliance works with the user
    - Smart controls, cooking methods, materials
- Combustion Innovations
  - –Way behind other industries
    - Efficiency and emissions
  - –Decarbonization and Resiliency
    - Issues with changing fuel composition



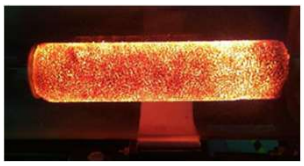
Questions, Feedback or Requests on CFS Technology

- Need More Information*: Contact me at fjohnson@gti.energy

– **Project Team:**
  - Frank Johnson, PhD
  - Shawn Scott
  - Yan Zhao
  - Jacob Pixler
  - William Asher
  - Navroop Singh
  - Mason Bushell

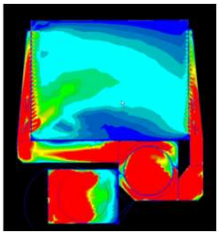












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