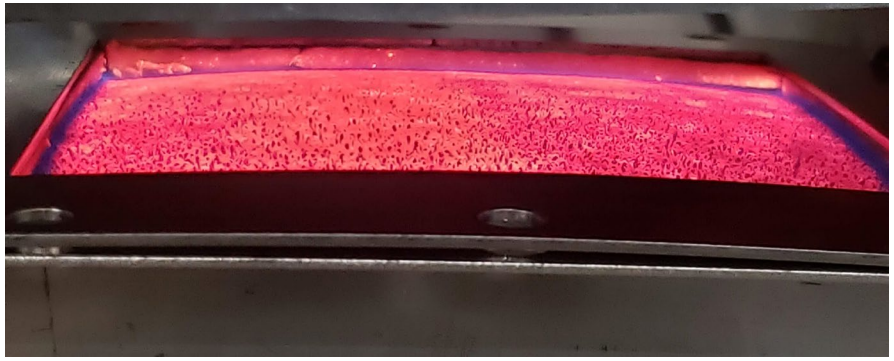
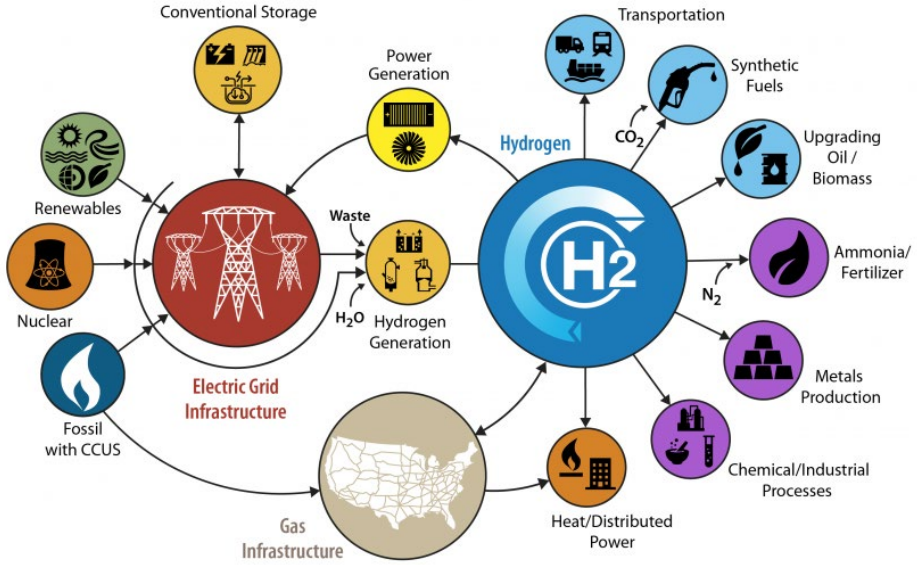
NG blend with hydrogen fuel cooking appliances





ORNL, Southern California Gas, Samsung Electronics America
Praveen Cheekatamarla, Senior R&D staff
865.341.0417, cheekatamapk@ornl.gov

Project Summary

Timeline:

Start date: 03/05/2021 **(New project)**
Planned end date: 12/30/2022

Key Milestones

1. Single burner evaluation: 11/30/2021
2. Fuel-flexible cooking appliance fabricated: 5/30/2022
3. Prototype appliance with hydrogen blends: 08/31/2022

Budget:

Total Project $ to Date:

- DOE: $250k
- Cost Share: $200k

Total Project $1000k

- DOE: $500k
- Cost Share: $470k (CRADA, SCG)
- Cost Share: $30k (in-kind, SEA)

Key Partners:

Southern California Gas – cooperative research and development agreement (CRADA) partner
Samsung Electronics America – in-kind cost share partner
Renewable Hydrogen Alliance*
Northwest Natural*

* General interest in the project progress

Project Outcome:

- **Enabling renewable hydrogen utilization in buildings**
- **Cooking energy carbon footprint reduction by >30%**

A clean, safe, fuel-flexible cooking appliance fueled by renewable hydrogen blended fuel.

Key objectives:

1. Novel heterogeneous oxidation technology
2. Flashback safety
3. Non-precious metal based catalytic oxidation at moderate operating temperatures

Team




- Praveen Cheekatamarla – Product design and development (FY21 - FY23), 16 years of industrial experience in thermo-chemical and thermo-electro-chemical systems, hydrogen and fuel cells
- Zhiming Gao – product design and development, heat transfer, integration, safety (FY22, FY23), 16 years of research experience in building equipment
- Viral Patel – system design and integration, heat transfer (FY22, FY23), 6 years of research experience in building appliances
- Brian Goins – system evaluation, installation (FY22), 30 years of experience in building equipment

OAK RIDGE National Laboratory

SoCalGas
A Sempra Energy utility

Cost share partner –nation's largest gas distribution utility, SoCalGas delivers affordable, reliable, clean and increasingly renewable gas service to 21.8 million customers.

SAMSUNG

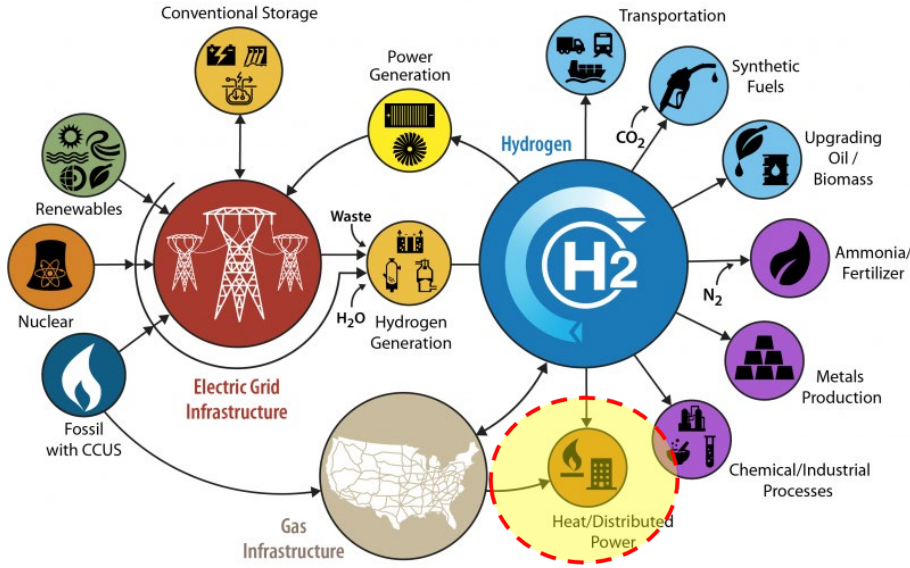
Technical cost share partner – Leading appliance manufacturer with a full line of major appliance products.

Challenge

Green hydrogen for decarbonization:

- Clean, sustainable hydrogen from domestic renewable energy resources
- Long-term energy storage (of excess renewables) in chemically bound form at a utility scale
- Affordable clean energy transition
- Decarbonization of all sectors – buildings, transportation, and industrial

H2@Scale Initiative, HFTO, EERE, DOE



Source: www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office

- ~ 100 million metric tons of CO_2 emissions per year by cooking equipment in residential and commercial buildings
- Renewable hydrogen can significantly decarbonize cooking appliance energy consumption, but faces technical barriers
- **This project aims to enable green hydrogen introduction (>30%) and utilization in cooking appliances in residential and commercial buildings**

Impact

- Fuel consumption by cooking equipment in buildings
  - > 33% of residential buildings use fuel for cooking, ~930TBtu (RCES[1], EIA)
  - Commercial buildings (mostly food service industry): ~805TBtu (CBECS[2], EIA)
  - Combined CO_2 footprint = 97Mt/yr
- Renewable hydrogen for cooking alone can lower this impact by > 30% if blended with gas
- Extension to space & water heating can potentially decrease ~ 379 Mt CO_2/yr
- Commercial food service process
  - highest energy intensive segment in commercial sector (> 275,000 Btu/ft^2)
  - difficult to electrify
  - 23% of commercial building fuel usage is consumed by cooking
- **Cooking carbon footprint reduction via renewable hydrogen**

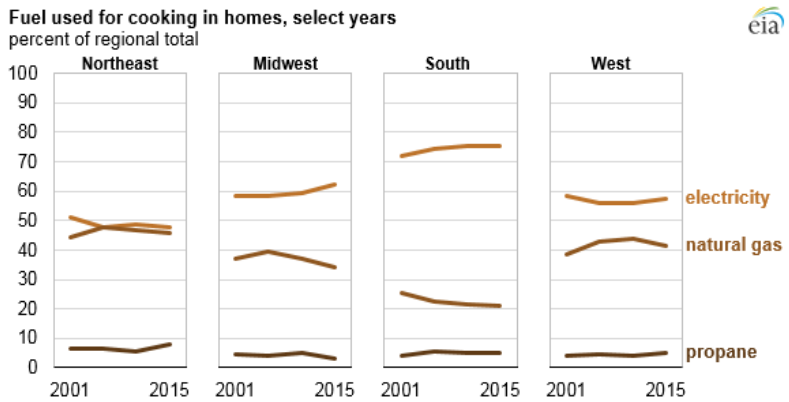
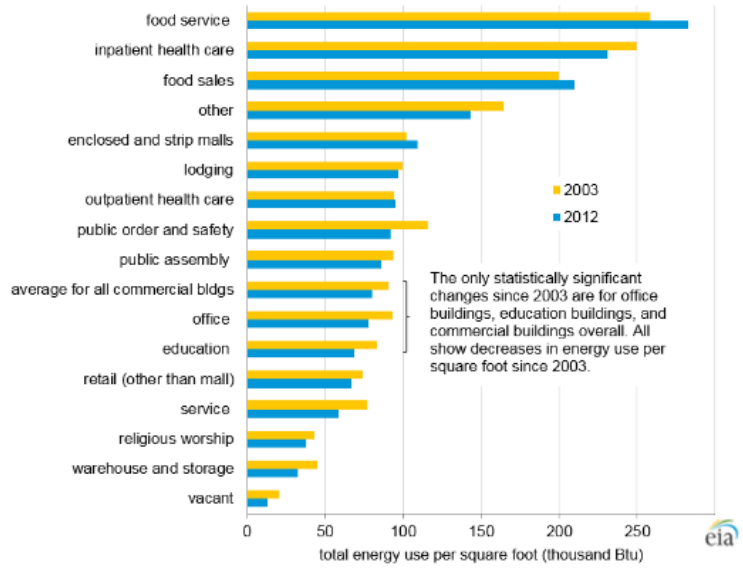


Figure 4. Food service buildings and hospitals are the most intensive users of energy overall



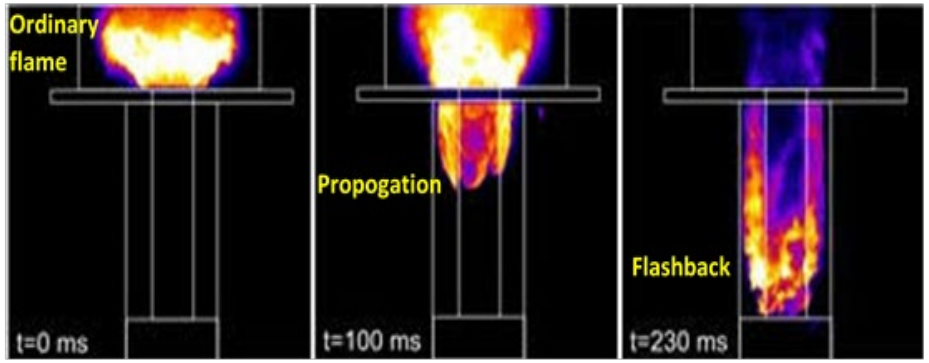
Source: U.S. Energy Information Administration, Commercial Buildings Energy Consumption Survey.

[1]https://www.eia.gov/consumption/residential/; [2]https://www.eia.gov/consumption/commercial/reports/2012/energyusage/

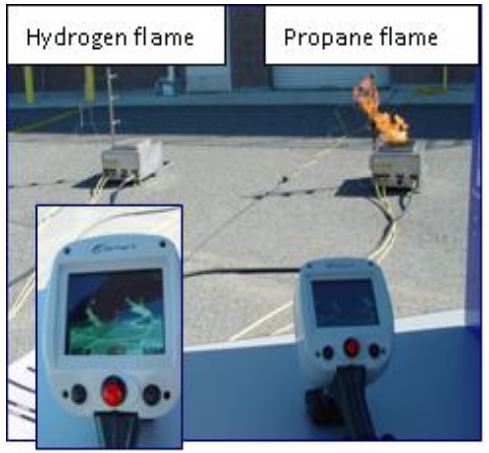
Challenge

Research gaps associated with hydrogen usage in building equipment

- Design and operational challenges
  - High flame velocity – flame propagation from combustion to premix zones, leading to flashback
  - High flame temperature – thermal NOx
- Appliance efficiency
- Combustion visibility and flame stability
- Energy modulation capability (turn-down)



Source: www.netl.doe.gov/node/933



Source: h2tools.org/bestpractices/hydrogen-flames

Approach

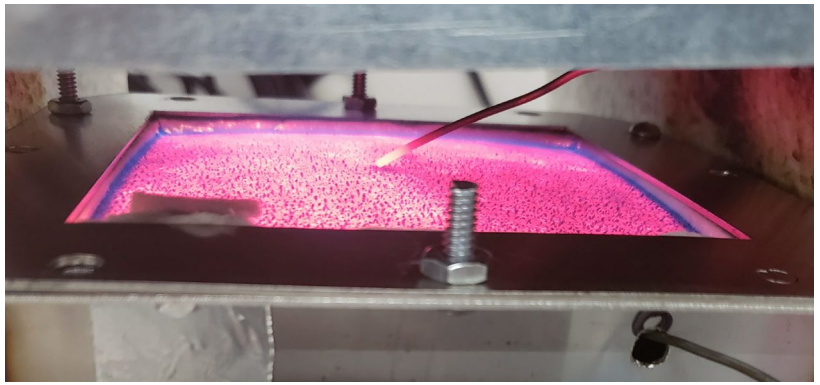
- Heterogeneous (catalytic) oxidation via engineered surface burner
- Fast response, shock resistant design
- Flame propagation pathway smaller than flame-quench diameter – flashback safety
- Provide reaction zone extension for complete oxidation at moderate temperatures – wide turn-down and air-to-fuel ratios
- Non-precious metal catalyst
- Infrared (IR) heat output: efficient direct energy transfer

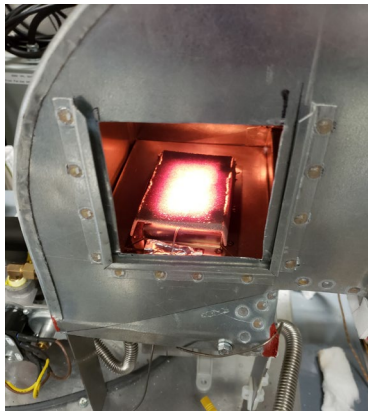
Approach

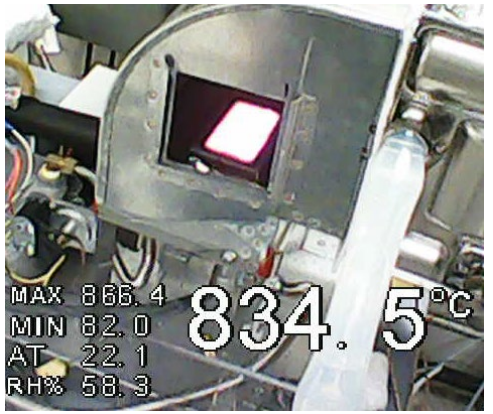
- **Design Considerations**
  - Address adiabatic flame temperature rise and flashback/autoignition of hydrogen fuel blends
  - Moderate temperature requirement for cooking (>1500 deg C source vs < 800 deg C need)
  - Emissions suppression
  - Efficiency
  - Turn-down
  - Reliability and robustness
- **Safety, controllability and high exothermicity at moderate temperatures**

Progress

- Project began in Q3, FY 2021
- **Current status: early stage**
- CRADA executed
- Completed 4 milestones on time
- Identified critical design requirements
- Preliminary design concept evaluation with 35% hydrogen blend







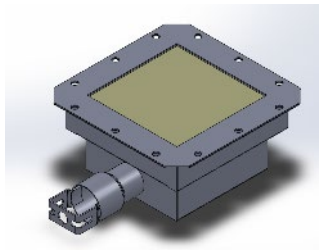
Design Specification

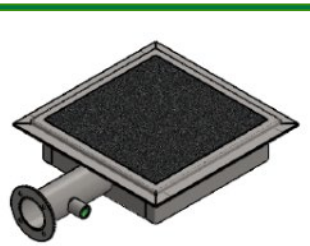
- Based on a comprehensive survey of commercial product line

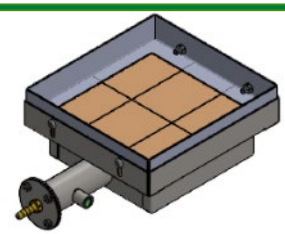
Requirement	Specification
Total Btu rating (cook top)	40,000 Btu/h
Physical dimensions	24” – 30” wide
Number of Burners	4 or 5
Ignition	Electronic
Gas connection	5/8” OD pipe (4’ long)
Gas supply pressure	5” - 14” water column
Electrical connections	120V/15A
Safety	Auto re-ignition, shut-off
Gas supply valve (manual)	5/8-in OD x 3/4-in MIP
Min. Btu/h	5,000
Max. Btu/h	15,000 – 18,000
Burner protection	Sealed
Turn-down	1:3

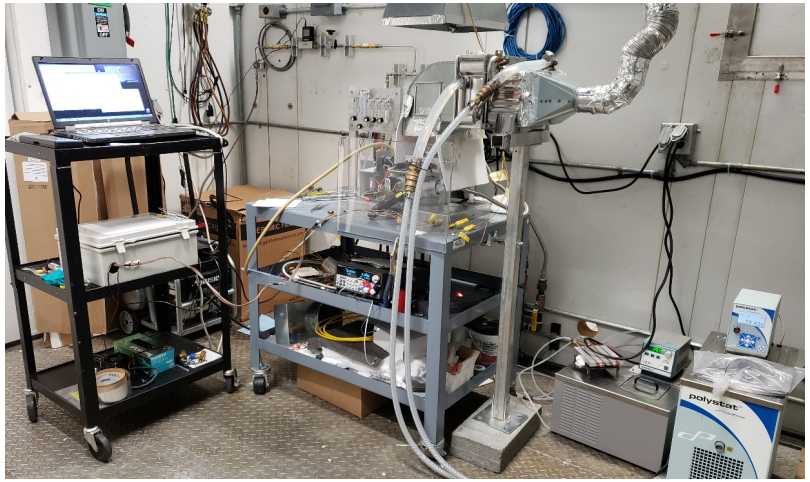
Progress

- Milestones accomplished to date
  - system specification
  - design concept development (invention disclosure filed)
  - prototype fabrication
  - test facility commissioned
- Safety features, feed blending, data acquisition, thermal conditioning and ventilation
- Preliminary design concept evaluation complete
- 4,000 Btu/hr burner evaluated with 35% hydrogen blend









Stakeholder Engagement

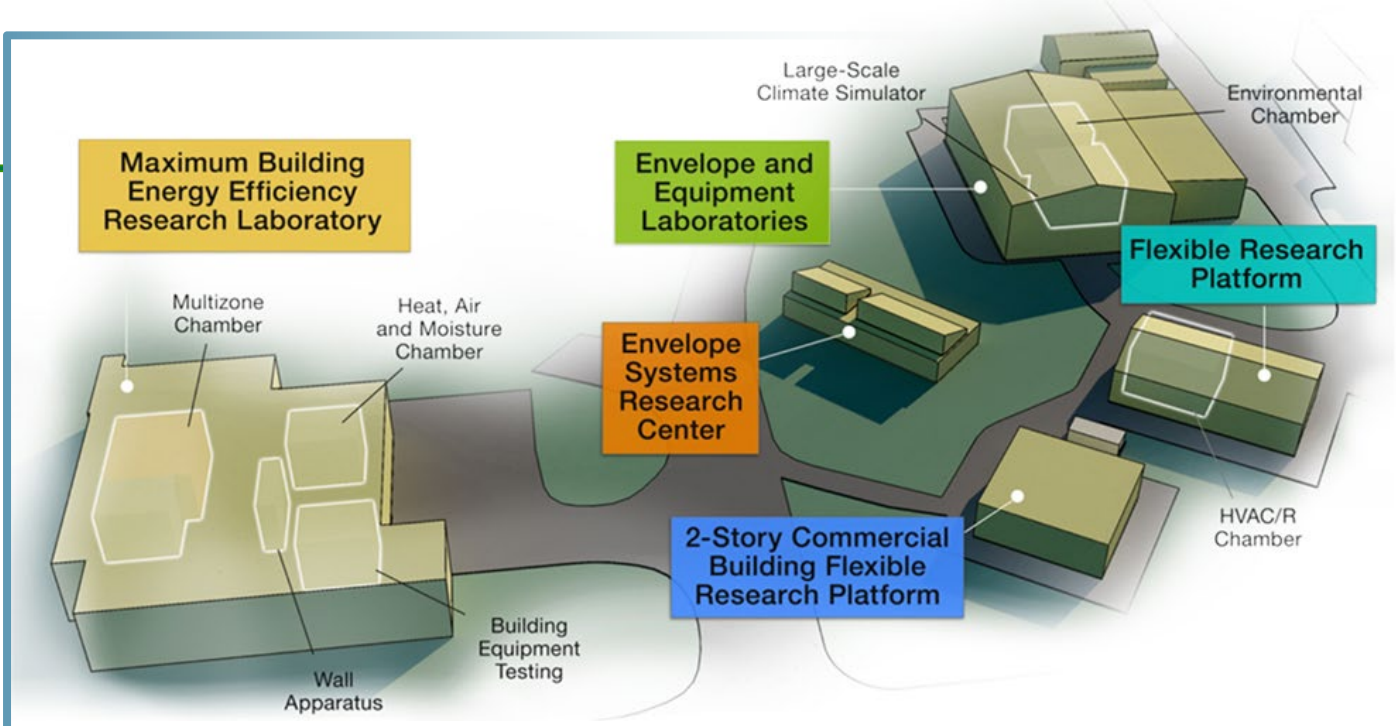
- Project kick-off in March 2021
- Cooperative research agreement (CRADA) between ORNL and SoCalGas is fully executed
- SoCalGas
  - co-sponsorship (funds-in)
  - engagement with engineering personnel during design, integration and implementation stages
- Samsung Electronics America
  - Engineering resources
  - Product design knowledge sharing
  - Product samples
  - Prototype testing
  - Commercialization feasibility evaluation

Remaining Project Work

- **Prototype burner evaluation and optimization**
  - Safety
  - Thermal capacity (Btu/hr-in^2)
  - Composition
  - Emissions
  - Control
  - Turn-down
- **Burner integration with commercial appliance**
- **Packaged prototype design finalization and fabrication**
- **Prototype performance study and optimization to meet/exceed design specifications**
- **Stakeholder engagement for commercialization feasibility study**
- **Successful field evaluation in SoCalGas' "Hydrogen Home" – NetZero Building**
- **Final reporting**

Thank you

Oak Ridge National Laboratory
Praveen Cheekatamarla, Research Staff
(865)-341-0417 | cheekatamapk@ornl.gov



ORNL's Building Technologies Research and Integration Center (BTRIC) has supported DOE BTO since 1993. BTRIC is comprised of 50,000+ ft^2 of lab facilities conducting RD&D to support the DOE mission to equitably transition America to a carbon pollution-free electricity sector by 2035 and carbon free economy by 2050.

Scientific and Economic Results

238 publications in FY20
125 industry partners
27 university partners
10 R&D 100 awards
42 active CRADAs

BTRIC is a DOE-Designated National User Facility

REFERENCE SLIDES

Project Budget

Project Budget: $1000K
Variances: none
Cost to Date: ~ $105k
Additional Funding: $500k (CRADA, in-kind), included in the total above
New FY21 project

Budget History					
03/05/2021 – FY 2020 (past)		FY 2021 (current)		FY 2022 – 12/30/2022 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
-	-	$250k	$200k	$250k	$300k

Project Plan and Schedule