

# The Span of OSU Energy Research

## Basic Science for the Future and Applied Solutions for the Now

**Dr. Kenneth Sewell**

Vice President for Research

**Dr. Jeffery L. White**

Professor and BP Chair  
School of Chemical Engineering

**Dr. Daniel E. Fisher**

Professor and Van Weathers Chair  
Director, Zink Center for Competitive Innovation  
Interim Director, Center for Integrated Building Systems  
School of Mechanical and Aerospace Engineering

**UAB Seminar, The Energy Council's 2024 Annual Meeting, Tulsa Oklahoma, September 13, 2024**



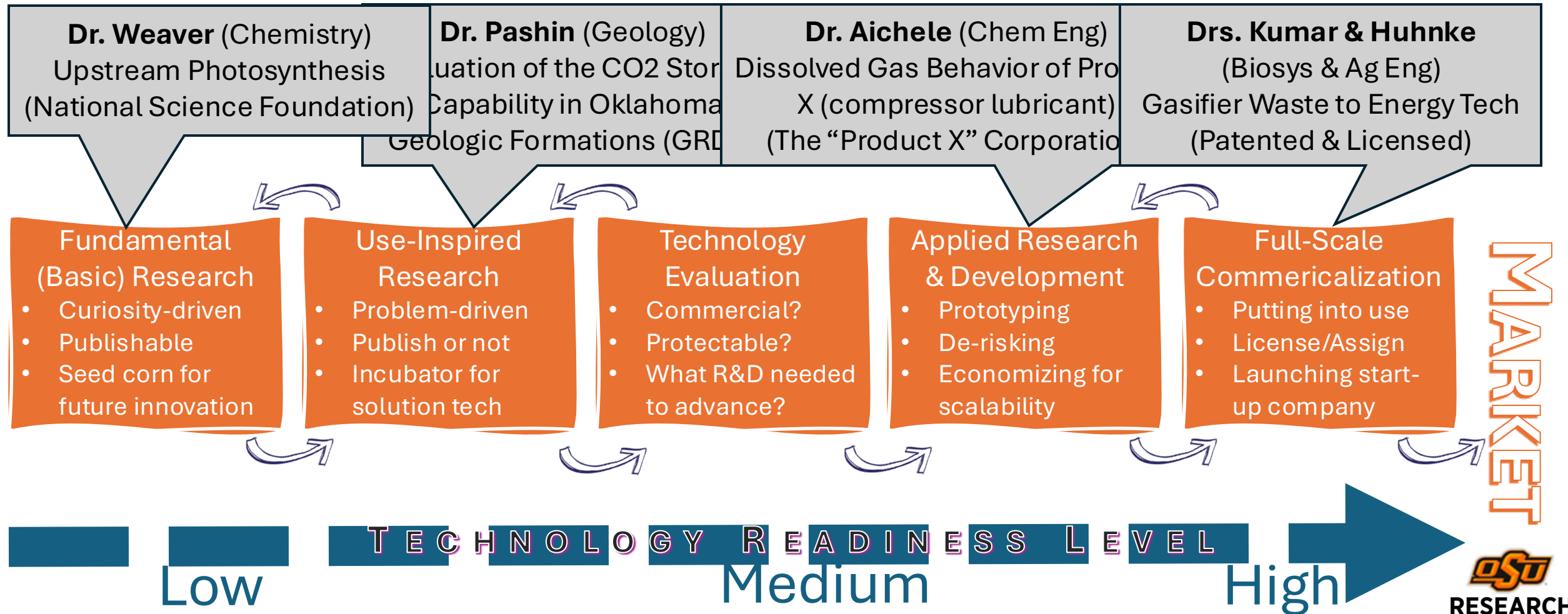
**RESEARCH**



# Research Across the Spectrum

## ...from Basic to Applied...

### at a Comprehensive Research University





**GEO THERMAL**

**CCUS**

SUPPLY DEMAND  
RISK MANAGEMENT

ENERGY POLICY  
ENERGY ACCOUNTING  
BIOFUEL

ENERGY SOCIOLOGY  
ENERGY ECONOMICS  
MANUFACTURING

**HYDROGEN  
BIOFUELS**

ARCHITECTURE  
TRIBAL

**OIL & GAS ELECTRIC GRID**

CONCRETE  
DRONES

**HVAC EFFICIENCY**

**METHANE**

TRANSPORTATION

**CHARACTERIZATION**

**EXPLORATION**

**ENHANCED EXTRACTION**

**ENERGY FINANCE**



**RESEARCH**



Theoretical

Mathematical

**Concepts**—Possibilities—Observations—**Frameworks**—Practical Controls—Engineered **Solutions**

Sensor  
Development

Implementation  
Science

Social  
Uptake

Quandary



Information



Decision

Experimentation

Characterization

Economics

Statistical  
Modeling

High Performance  
Computing



# Oklahoma State University

## Energy Research

**Basic Science for the Future**

**Dr. Jeffery L. White**

Professor and BP Chair

School of Chemical Engineering



**RESEARCH**



# Jeffery L. White

## Catalysis, Materials, and Energy Carriers

**Mervin Kelly, Bell Labs Director (1950):** *“...basic research is the foundation on which all technological advances rest” and “...we must hire individuals of the same high qualities as are required for distinguished pure research in universities”.*

*Bell Labs still most accomplished research institution to date in both fundamental science and technological advances:*

- 10 Nobel Prizes and 4 Turing Awards
- Inventions include:
  - transistor and integrated circuits
  - first communications satellite
  - MASERS → LASERS
  - information theory
  - computer programming languages (Unix, C, etc.)
  - cell phones
  - microwave transmission of data (cosmic background radiation!)
  - quantum Hall effect
  - quantum dots and nanoparticles
  - ...and many more.

*When one masters the fundamentals, good things follow!*

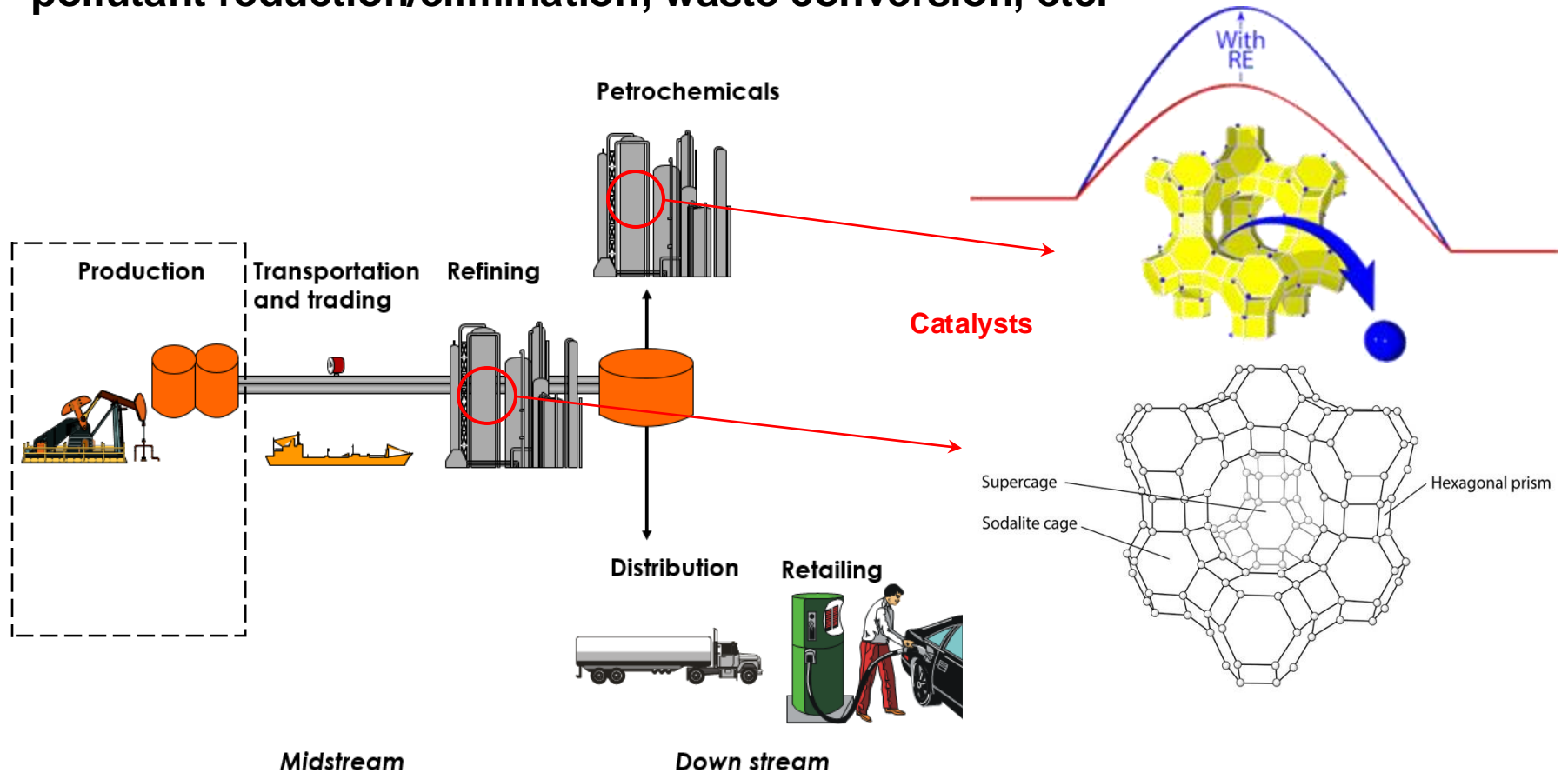


*School of Chemical  
Engineering*



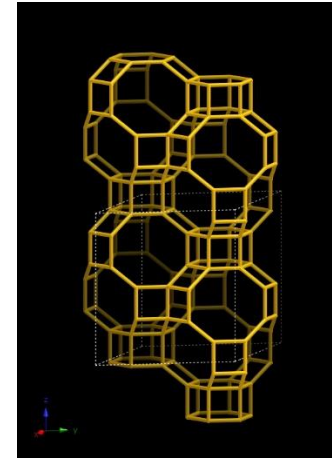
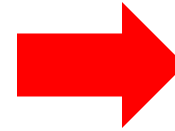
# Catalysis: Controlling Molecules for Our Benefit

**Benefits:** fuels, feedstocks for materials, pharmaceuticals, fertilizers, pollutant reduction/elimination, waste conversion, etc.

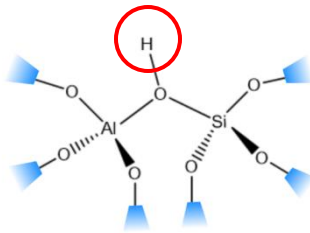




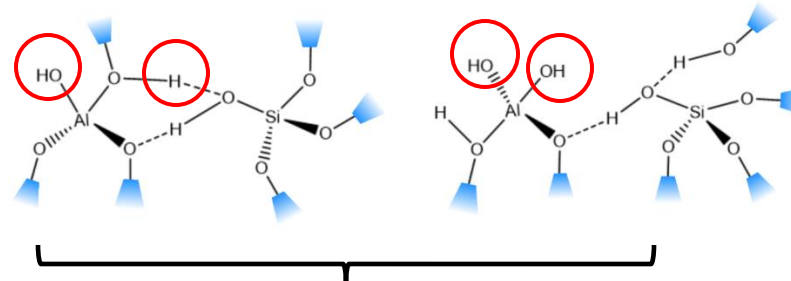
Know the Structure (Measurement)  
Control the Structure (Synthesis)  
Improve the Function (Engineering)



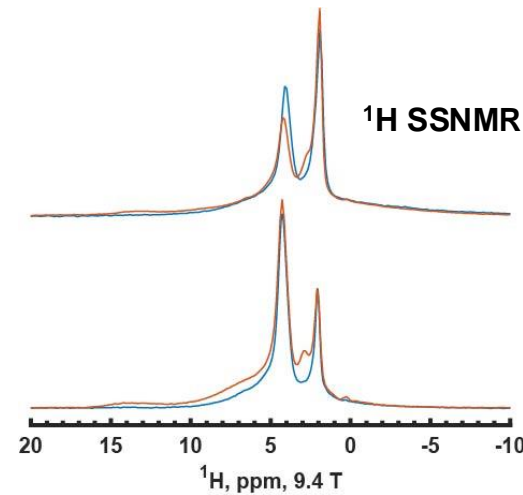
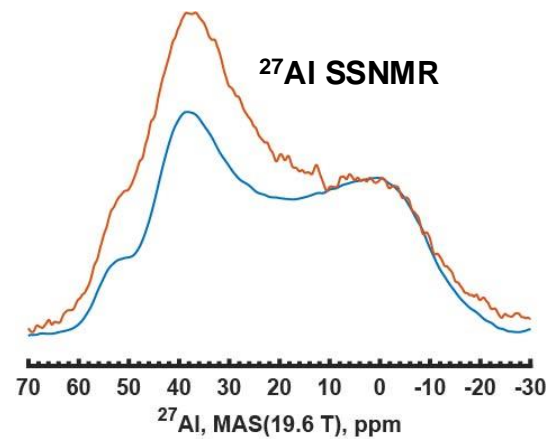
~1 nm →



Al(IV)-1

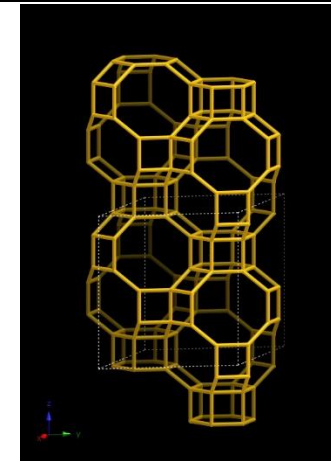
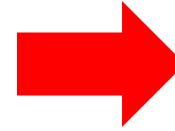


Al(IV)-2

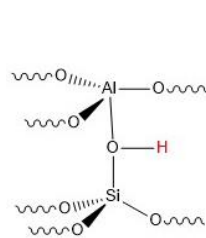




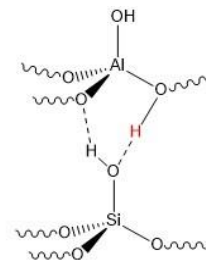
**Know the Structure (Measurement)**  
**Control the Structure (Synthesis)**  
**Improve the Function (Engineering)**



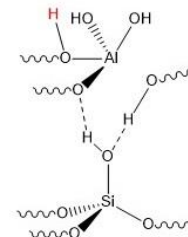
← ~1 nm →



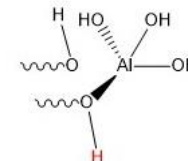
a.



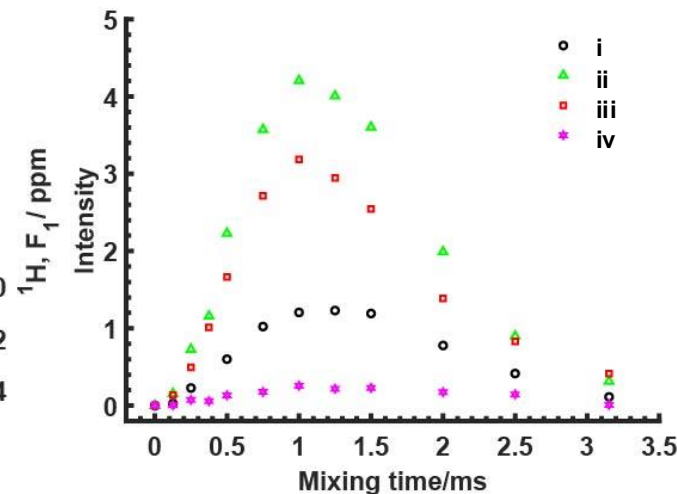
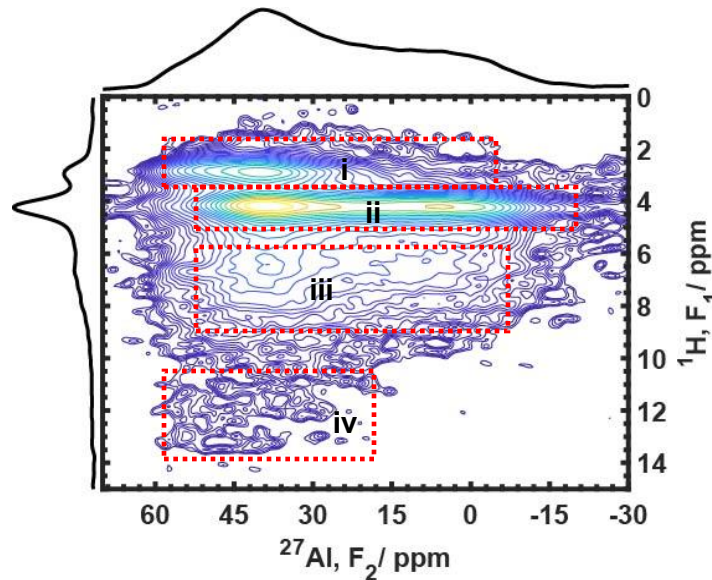
b.



c.

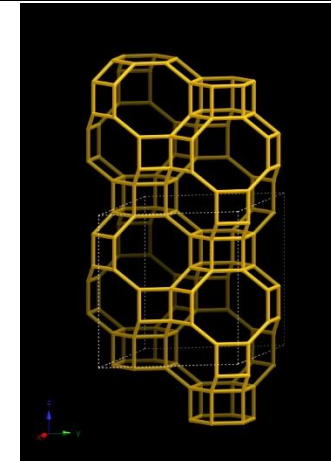
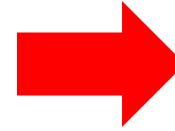


d.

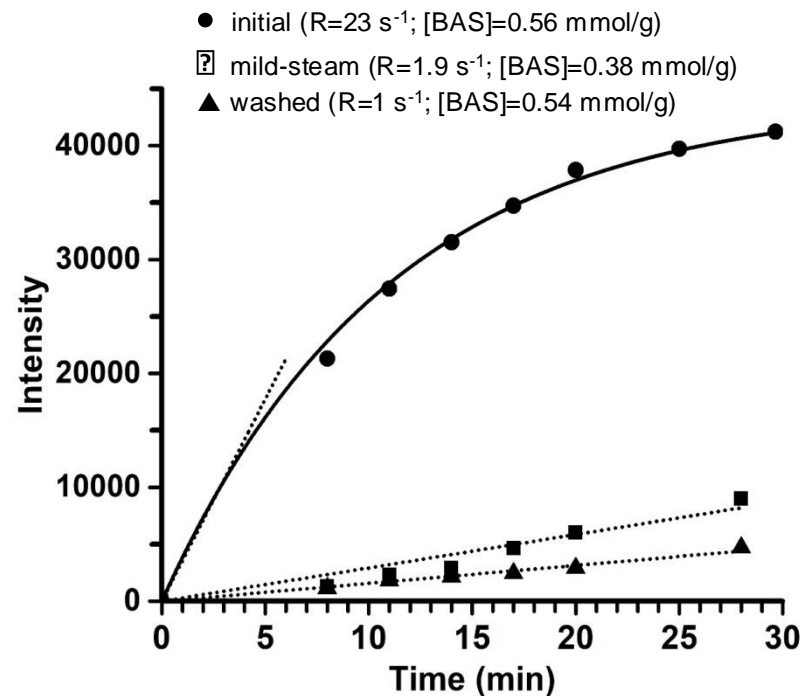




Know the Structure (Measurement)  
Control the Structure (Synthesis)  
Improve the Function (Engineering)



← ~1 nm →

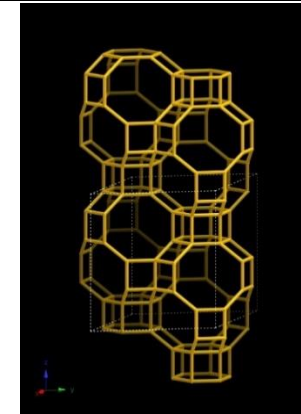
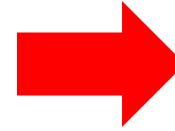


#### Key Findings and Implications

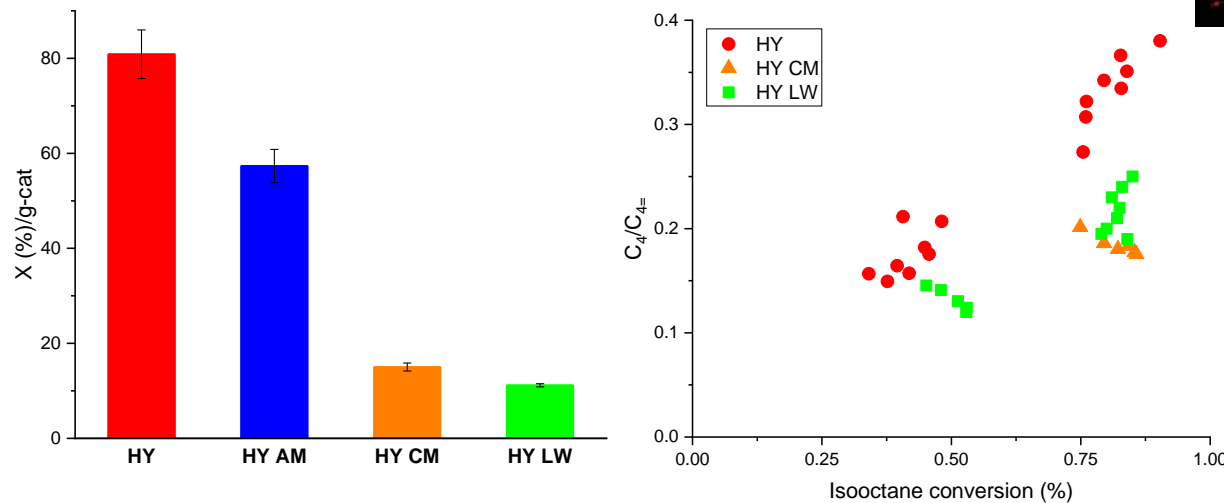
1. Catalysts with unique Al-2 sites and their associated protons more active than conventional catalysts
2. Catalysts with unique Al-2 sites and their associated protons actually become even more active in the presence of some moisture, and more stable in presence of moisture
3. We can control these site distributions
4. Guides preparation and use for industry
5. Enables use in “messier” reactions



Know the Structure (Measurement)  
Control the Structure (Synthesis)  
Improve the Function (Engineering)



← ~1 nm →



a.

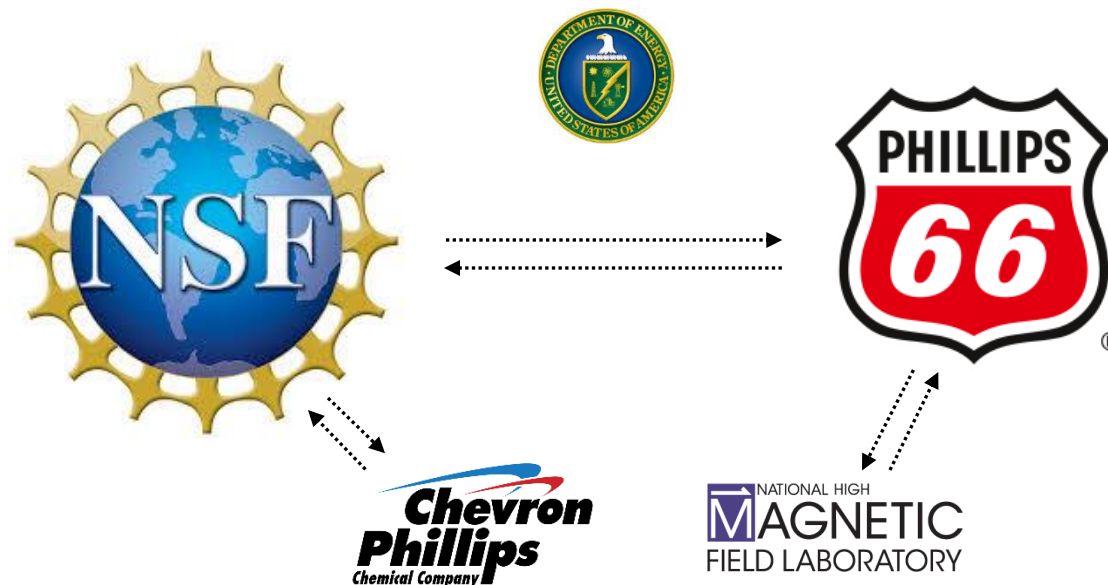
b.

**Figure.** (a) Isooctane (2,2,4-trimethylpentane) conversion per gram catalyst mass in flow reactor using HY prepared from NH<sub>4</sub>Y according to the calcination treatment in the Experimental section, compared to that for HY exposed to different vapor- or liquid-phase water treatments as noted. Error bars reflect the deviation in activity over 225 min time on stream. (b) C<sub>4</sub>/C<sub>4=</sub> (predominately isoalkane to isoalkene) ratio vs. isooctane conversion demonstrating that selectivity is also impacted by water exposure and removal.



## Conclusion: Advances in Fundamentals Have Practical Impacts

1. Zornes, A.; Abdul Rahman, N.; Das, O.; Gomez, L.; Crossley, S.; Resasco, D.; White, \* J. L., **Impact of Low-Temperature Water Exposure and Removal on Zeolite HY**, *J. Am. Chem. Soc.*, **2024**, *145*, 1132-1143.
2. Chen, K.; Zornes, A.; Crossley, S.; Nguyen, V.; Wang, B.; Gan, Z.; White\*, J. L.  **$^{17}\text{O}$  Labeling Reveals Paired Active Sites in Zeolite Catalysts**, *J. Am. Chem. Soc.*, **2022**, *144*, 16916-16929.
3. Chen, K.; Gan, Z.; Horstmeier, S.; White\*, J. L. **Distribution of Aluminum Species in Zeolite Catalysts:  $^{27}\text{Al}$  NMR of Framework, Partially-Coordinated Framework, and Non-Framework Moieties**, *J. Am. Chem. Soc.* **2021**, *143*, 6669-6680.
4. Chen, K.; Horstmeier, S.; Nguyen, V. T.; Wang, B.; Pham, T.; Crossley, S.; Gan, Z.; Hung, I.; White\*, J. L. **Structure and Catalytic Characterization of a Second Framework Al(IV) Site in Zeolite Catalysts Revealed by NMR at 35.2 T** *J. Am. Chem. Soc.* **2020**, *142*, 7514-7523.
5. Chen, K.; Abdolrahmani, M.; Sheets, E.; White\*, J. L. **Direct Detection of Multiple Acidic Proton Sites in Zeolite HZSM-5** *J. Am. Chem. Soc.* **2017**, *139*, 18698-18704.





# Oklahoma State University

# Energy Research

**Applied Solutions for the Now**

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**RESEARCH**





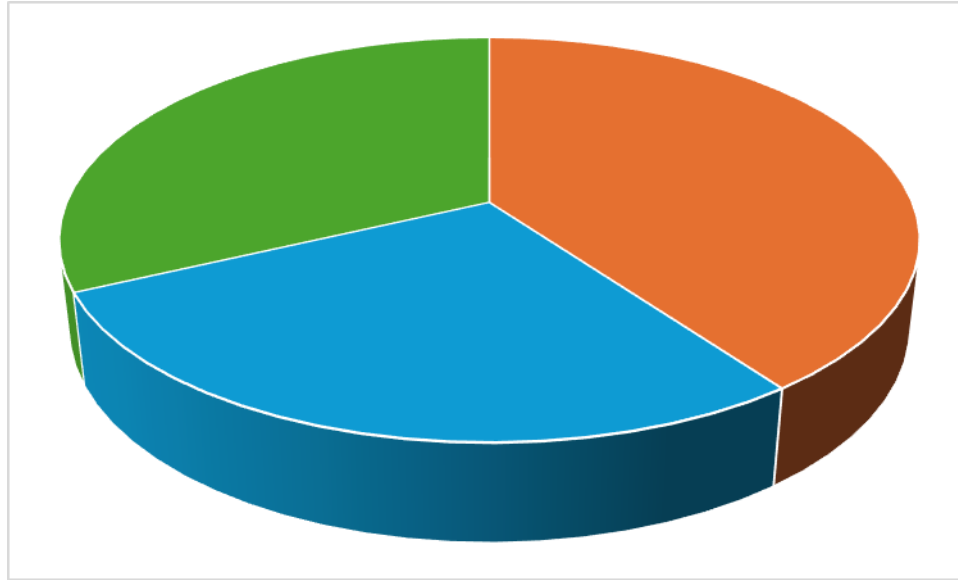
# **Applied Research in the Energy Sector**

*CENTER FOR INTEGRATED BUILDING SYSTEMS (CIBS)*

*GREAT PLAINS CENTER OF EXCELLENCE*

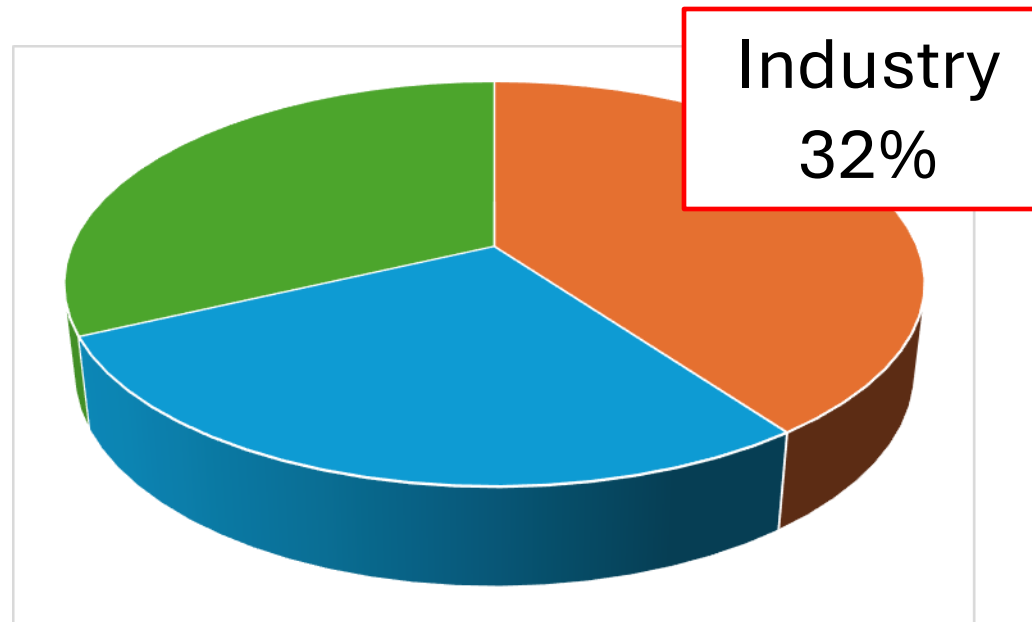


# Energy Use in the US



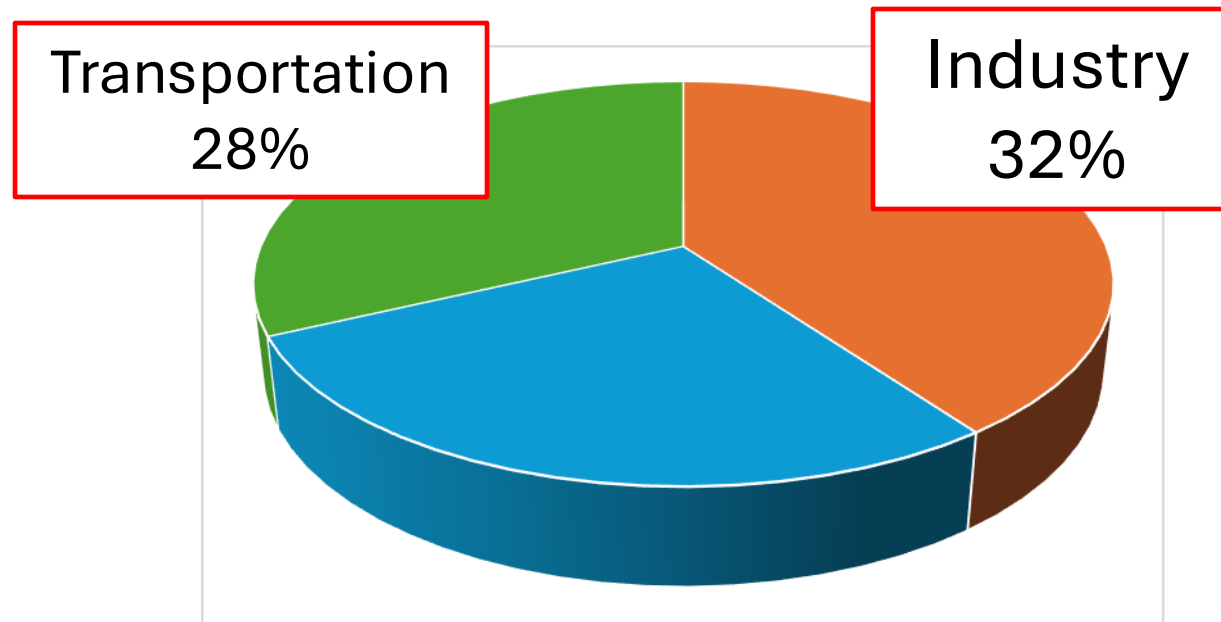


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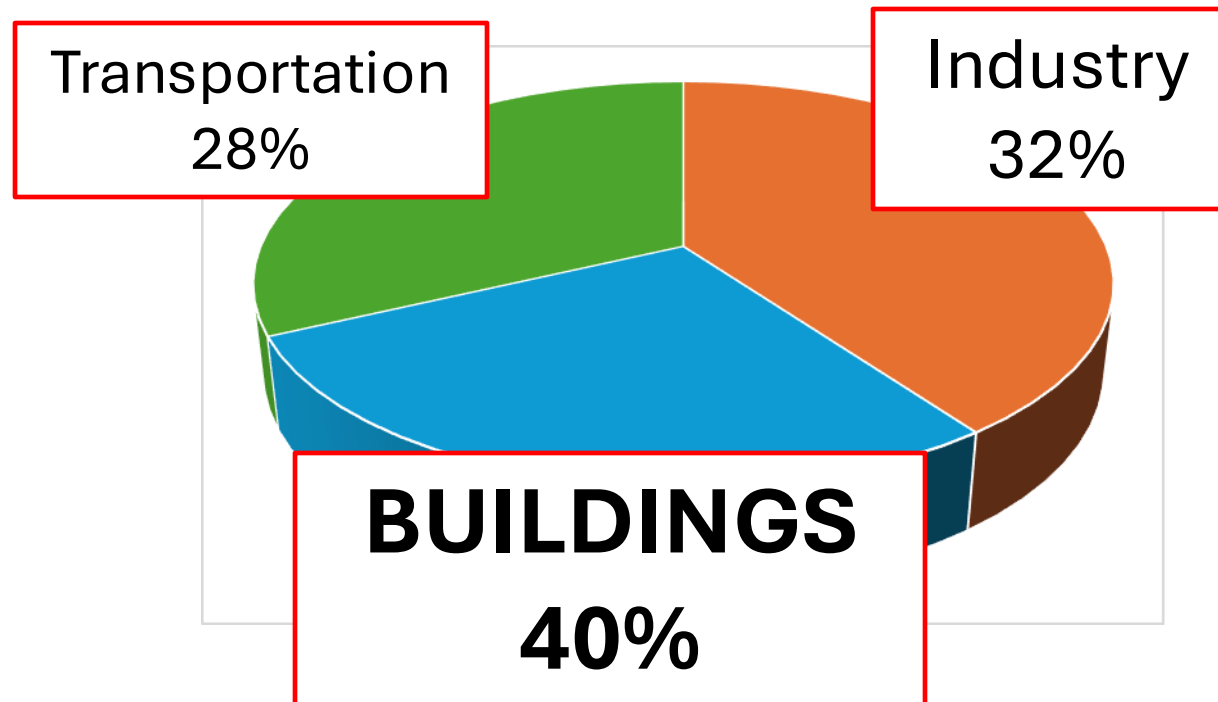


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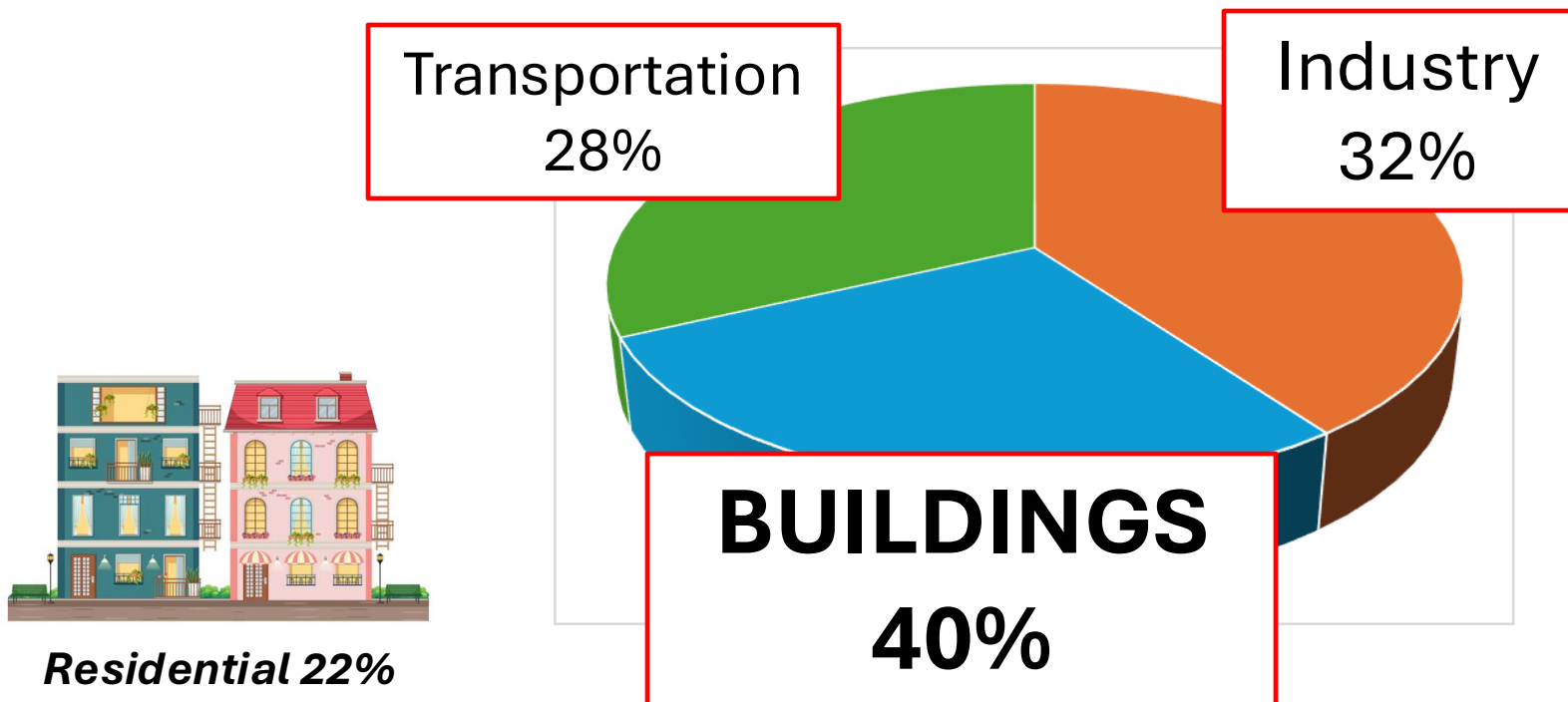


# Energy Use in the US



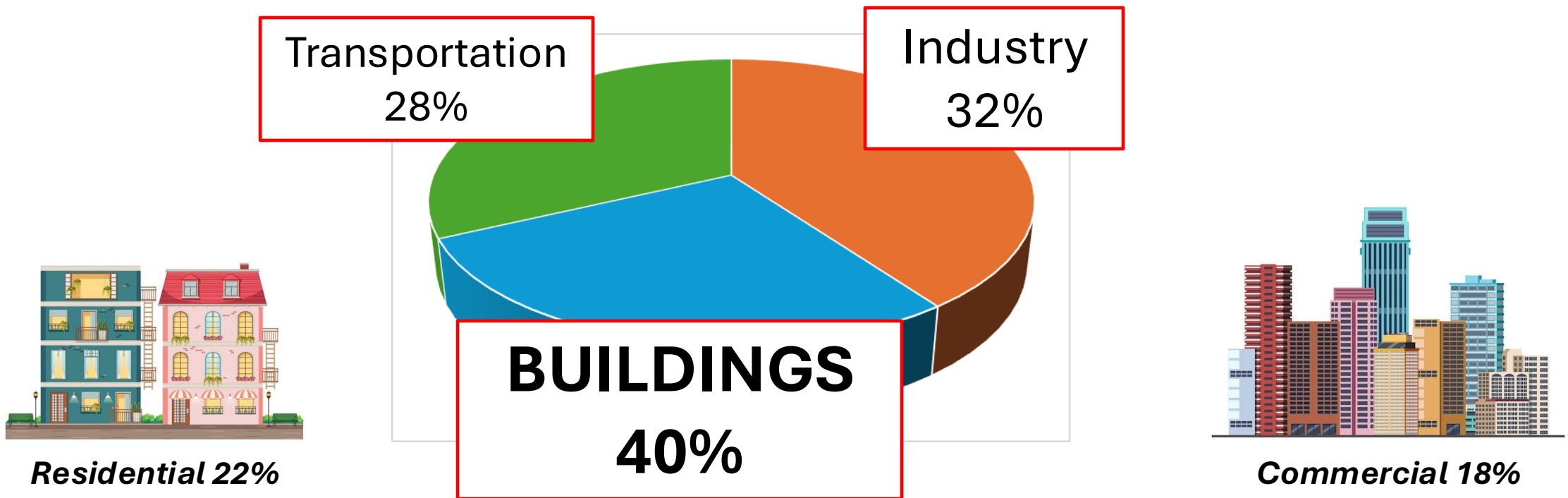


# Energy Use in the US





# Energy Use in the US





# Applied Research on the Demand Side

- *CENTER FOR INTEGRATED BUILDING SYSTEMS (CIBS)*
  - *Industry sponsored*
  - *Delivers software tools, data and codebases for HVAC&R Industry*
    - *Equipment*
    - *Energy Storage*
    - *New Refrigerants*





# Applied Research on the Demand Side

- *CENTER FOR INTEGRATED BUILDING SYSTEMS (CIBS)*
  - *Industry sponsored*
  - *Delivers software tools, data and codebases for HVAC&R Industry*
    - *Equipment*
    - *Energy Storage*
    - *New Refrigerants*
- *GREAT PLAINS CENTER OF EXCELLENCE (GPCE)*
  - *DOE sponsored*
  - *Performs Energy Audits for Industry partners in the great plains region*
    - *Assesses and recommends application specific energy saving technologies*





# CIBS Research Portfolio

*Components/Refrigerants*



*HEAT PUMPS*



# CIBS Research Portfolio

*Components/Refrigerants*



*HEAT PUMPS*

- ☐ High efficiency components



# CIBS Research Portfolio

*Components/Refrigerants*



## *HEAT PUMPS*

- ☐ High efficiency components
- ☐ Low GWP Refrigerants



# CIBS Research Portfolio

*Components/Refrigerants*



*HEAT PUMPS*

☐ High efficiency components

☐ Low GWP Refrigerants

☒ *Propane!*



# CIBS Research Portfolio

*Components/Refrigerants*



*HEAT PUMPS*

- ☐ High efficiency components
- ☐ Low GWP Refrigerants
  - ☒ *Propane!*

*Thermal Energy Storage & Use*



*GROUND-SOURCE  
HEAT PUMPS*



# CIBS Research Portfolio

*Components/Refrigerants*



*HEAT PUMPS*

- ☐ High efficiency components
- ☐ Low GWP Refrigerants
  - ☒ *Propane!*

*Thermal Energy Storage & Use*



*GROUND-SOURCE  
HEAT PUMPS*

- ☐ *Design Tools for ground heat exchangers*



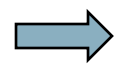
# CIBS Research Portfolio

**Components/Refrigerants**

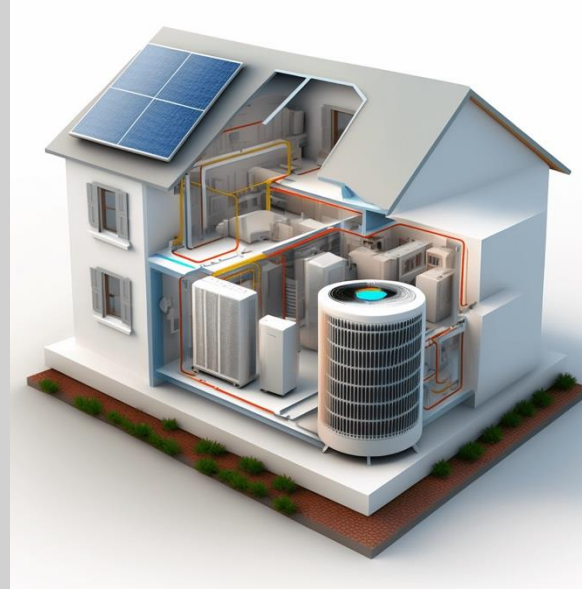


*HEAT PUMPS*

- ☐ High efficiency components
- ☐ Low GWP Refrigerants
  - ☒ *Propane!*



**Integrated Buildings**



**Thermal Energy Storage & Use**



*GROUND-SOURCE  
HEAT PUMPS*

- ☐ *Design Tools for ground heat exchangers*



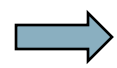
# CIBS Research Portfolio

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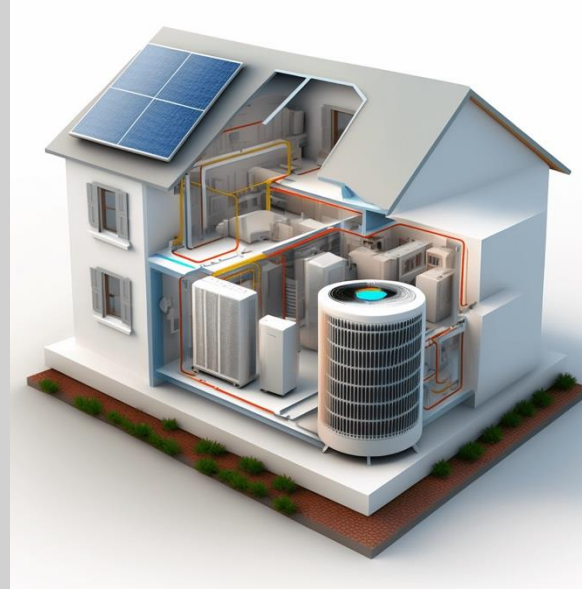


### HEAT PUMPS

- ❑ High efficiency components
- ❑ Low GWP Refrigerants
  - ❑ *Propane!*



## Integrated Buildings



- ❑ Optimal performance



## Thermal Energy Storage & Use



### GROUND-SOURCE HEAT PUMPS

- ❑ *Design Tools for ground heat exchangers*



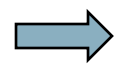
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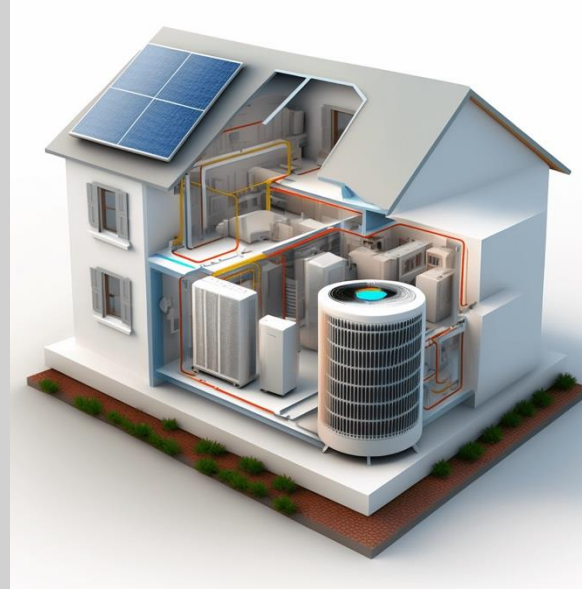


### HEAT PUMPS

- ☐ High efficiency components
- ☐ Low GWP Refrigerants
  - ☒ *Propane!*



## Integrated Buildings



- ☐ Optimal performance
- ☐ High energy efficiency



## Thermal Energy Storage & Use



### GROUND-SOURCE HEAT PUMPS

- ☐ *Design Tools for ground heat exchangers*



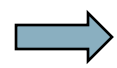
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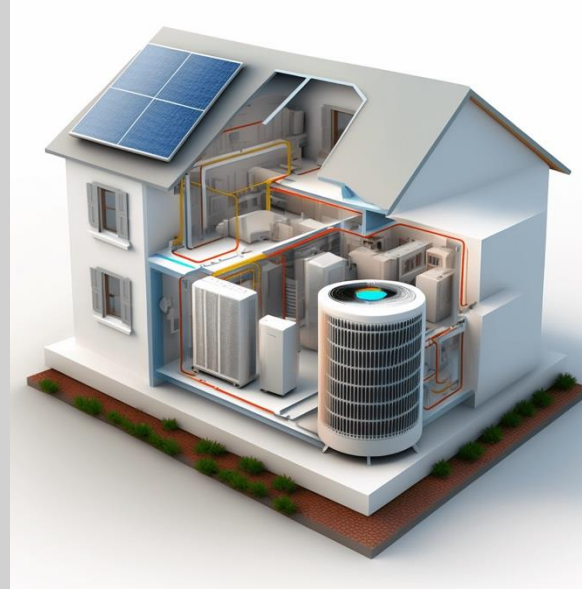


### HEAT PUMPS

- ☐ High efficiency components
- ☐ Low GWP Refrigerants
  - ☒ *Propane!*



## Integrated Buildings



- ☐ Optimal performance
- ☐ High energy efficiency
- ☐ Low carbon footprint



## Thermal Energy Storage & Use



### GROUND-SOURCE HEAT PUMPS

- ☐ *Design Tools for ground heat exchangers*



# GPCE Research Portfolio

## *New Technologies*



- ☐ Optimal performance
- ☐ High energy efficiency
- ☐ Low carbon footprint



# GPCE Research Portfolio

## *New Technologies*



- ☐ Optimal performance
- ☐ High energy efficiency
- ☐ Low carbon footprint



**Industrial Sector**



# Summary

- *CENTER FOR INTEGRATED BUILDING SYSTEMS (CIBS)*
  - *Applies basic research results to create better building systems*
- *GREAT PLAINS CENTER OF EXCELLENCE (GPCE)*
  - *Applies better building systems to the industrial sector*







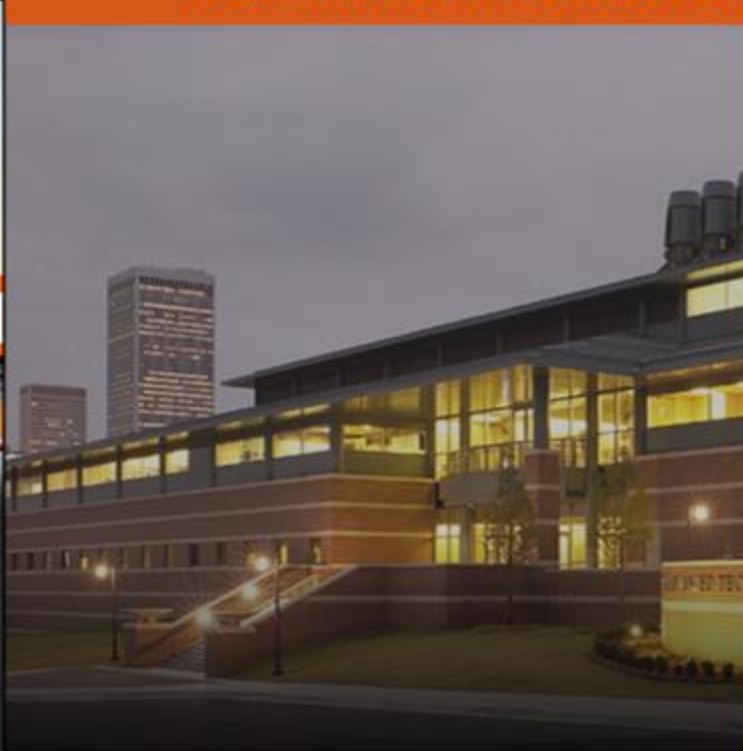
SOUTH CENTRAL REGION  
**SUN GRANT PROGRAM**

ABOUT REGIONAL AWARDS FUNDING OPPORTUNITIES

**GREAT PLAINS CENTER OF EXCELLENCE**

**Helmerich Research**

**CENTER FOR INTEGRATED BUILD**



**RURAL ENERGY ASSESSMENT CENTER**

**HAMM INSTITUTE FOR AMERICAN ENERGY**  
at Oklahoma State University

**OSU**  
**RESEARCH**



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# Questions?



**RESEARCH**



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# Thanks for joining us in Cowboy Country!



RESEARCH