Advanced Oxy-fuel Boilers for Cost-Effective CO_2 Capture

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Presentation Outline

- Program goal and background
- Conceptual design of the Advanced Boiler
- Economic advantages
- Present laboratory-scale tests
- Summary

Program Goal

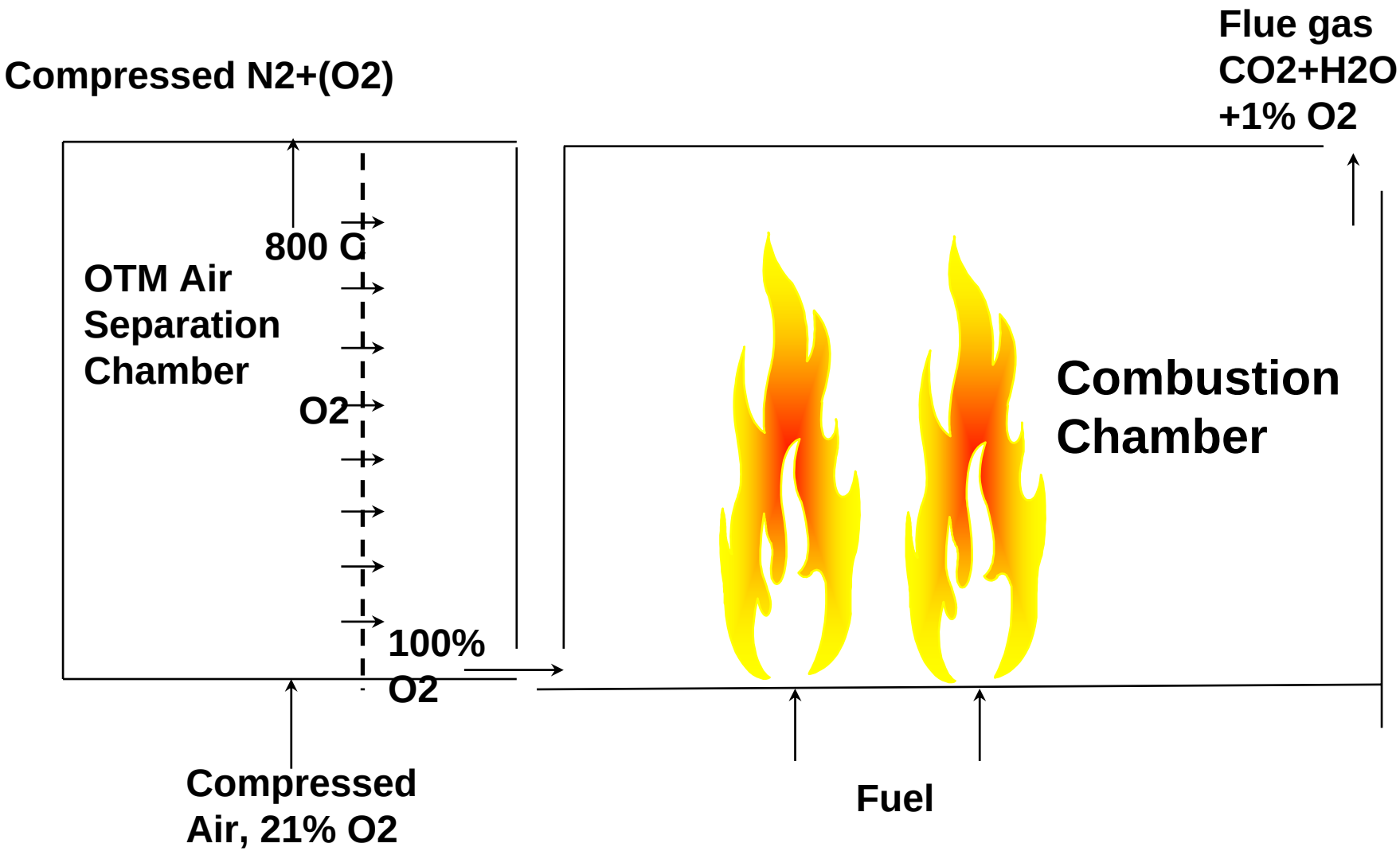
Develop and commercialize a novel high efficiency boiler or process heater that can provide a CO_2-rich product stream that can be inexpensively purified and compressed for sequestration

Program Background

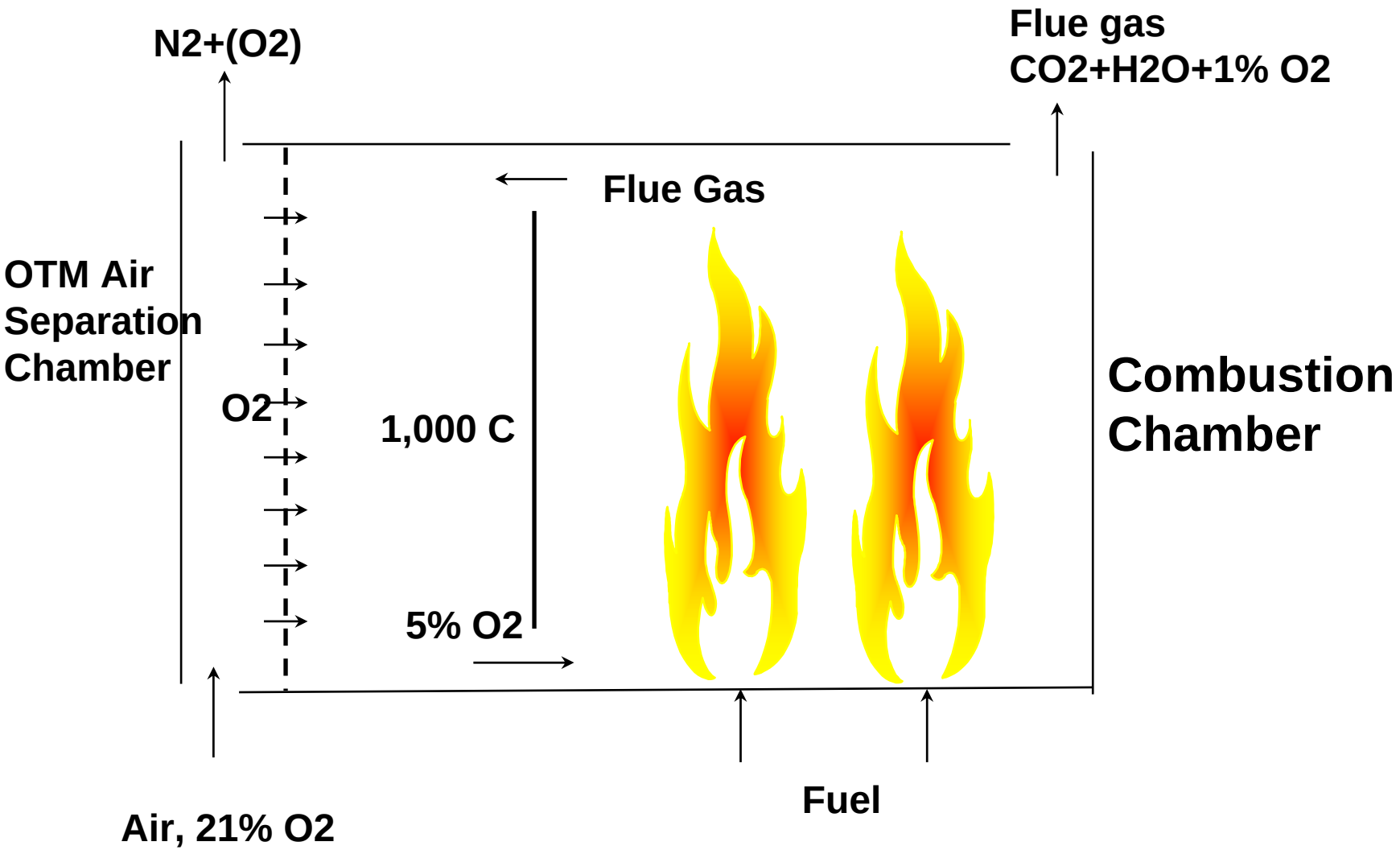
- **Oxy-fuel fired boiler**
  - improve thermal efficiency
  - increase fuel savings
  - simplify and reduce the cost of CO_2 capture
  - ultra-low NO_x emission

- **Oxygen source**
  - traditionally by external air separation unit — high cost
  - Oxygen Transport Membranes (OTM)
    - thermal integration of O_2 separation with the boiler
    - reduced operating and capital costs for oxy-fuel system

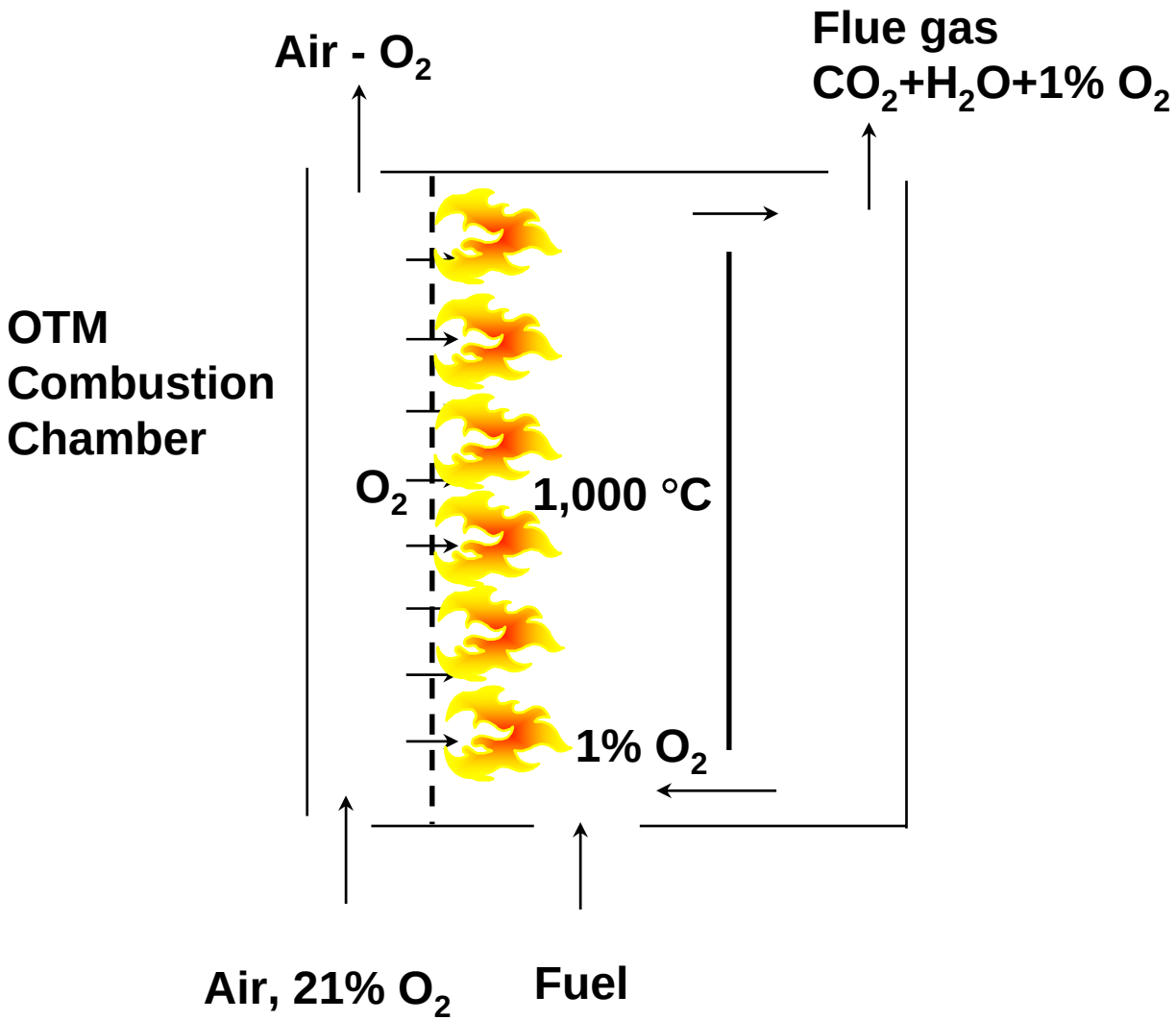
Conventional OTM Process



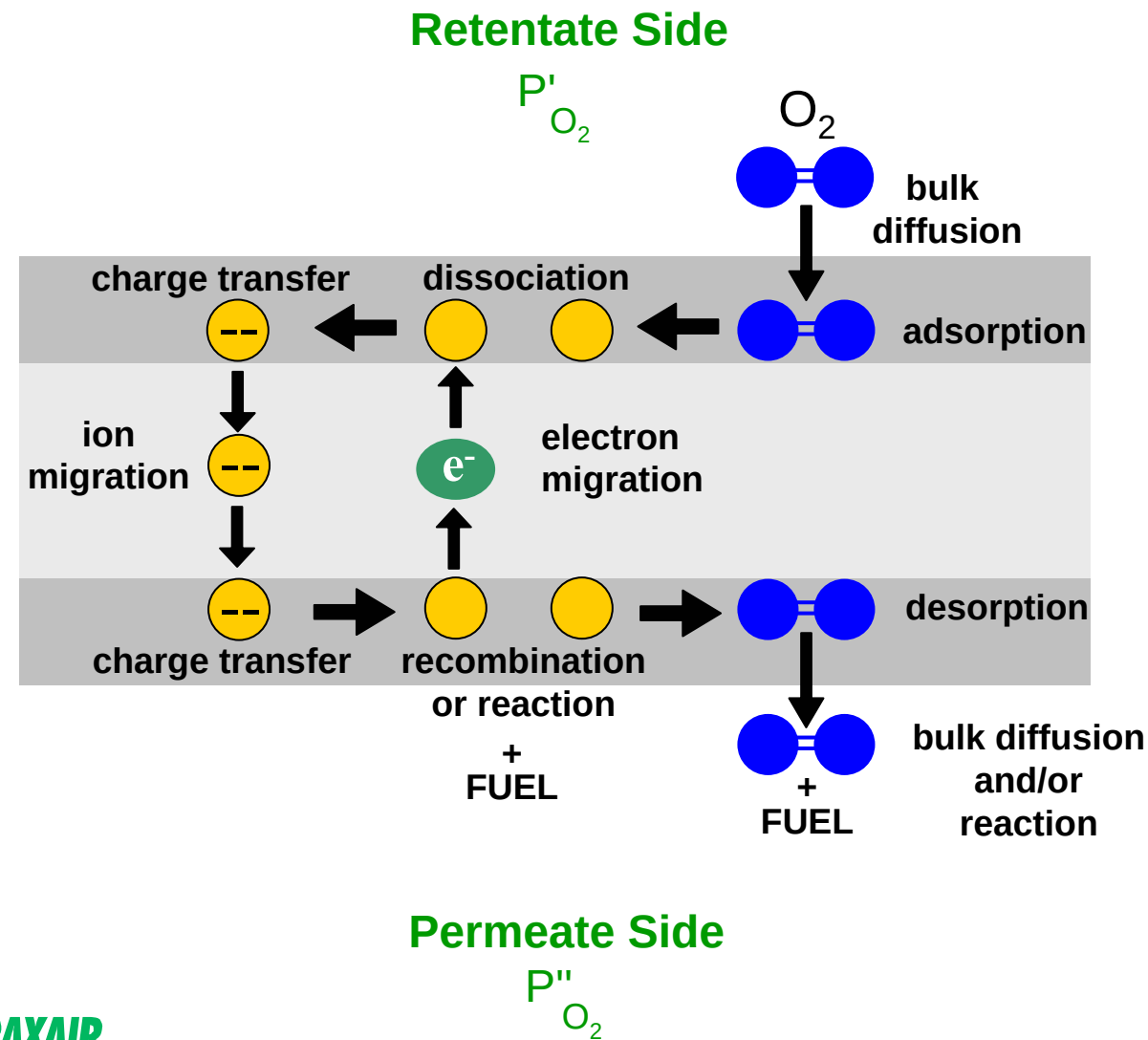
OTM-Dilute Oxygen Combustion Concept



OTM-Reactive Purge Combustion Concept

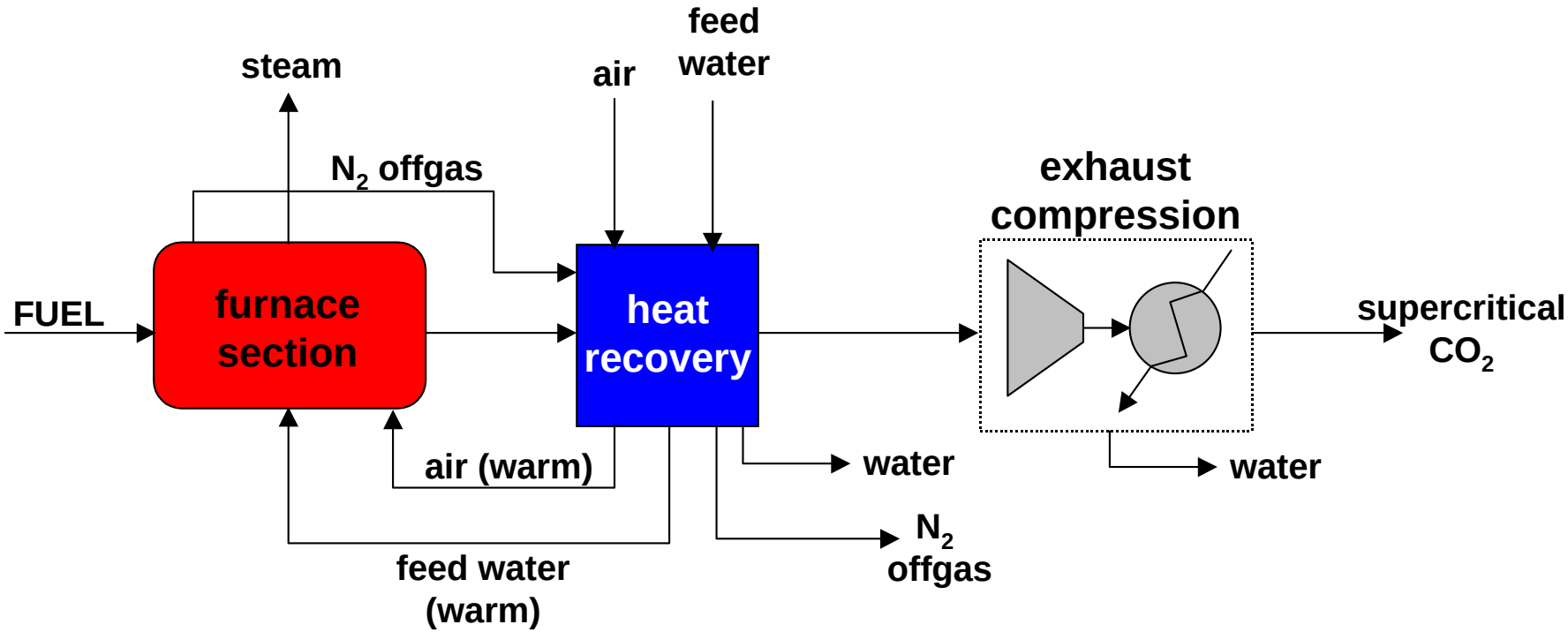


OTM Principles



$$Flux \propto \ln\left[\frac{P'_{O_2}}{P''_{O_2}}\right]$$

Conceptual OTM Boiler Process



Economics Case Study

	Conventional Boiler	Advanced OTM boiler
Capital Cost		
Boiler	$6,000,000	$9,000,000
Annualized capital cost	$1,026,000	$1,539,000
Operating Costs		
Annual Fuel @$5/MMBTU	$29,300,000	$26,300,000
Annual Power @ $0.045/kWh	$53,000	$1,500,000
Annual Cost of Oxygen		
Total Operating Costs	$29,353,000	$27,800,000
Combined annual Cost	$30,379,000	$29,339,000

- **Oxy-fuel fired boiler**
  - improve thermal efficiency
  - 2 year payback

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Economics Case Study

	Conventional Boiler	Advanced OTM boiler
Capital Cost		
CO_2 Capture System	$30,500,000	$6,000,000
Annualized capital cost	$5,215,000	$1,026,000
Operating Costs		
Annual Steam @$5/MMBTU	$5,857,000	
Annual Power @ $0.045/kWh	$2,100,000	$775,000
Annual Chemicals	$1,500,000	
Total Operating Costs	$9,457,000	$775,000
Combined annual Cost	$14,672,000	$1,801,000
Net Supercritical CO_2 Cost	$41/ton	$5/ton

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Laboratory-scale Tests

- **OTM material development**
  - thermal and mechanical stability
  - long-term operation reliability
  - high oxygen transport flux
  - cost effective OTM tube manufacturing

- **Thermal integration of OTMs with fuel combustion – Multi-tube OTM reactor**
  - temperature control and heat transfer
  - complete and efficient combustion
  - very low NO_x
  - more detailed capital cost estimate to meet requirements for cost effective CO_2 capture

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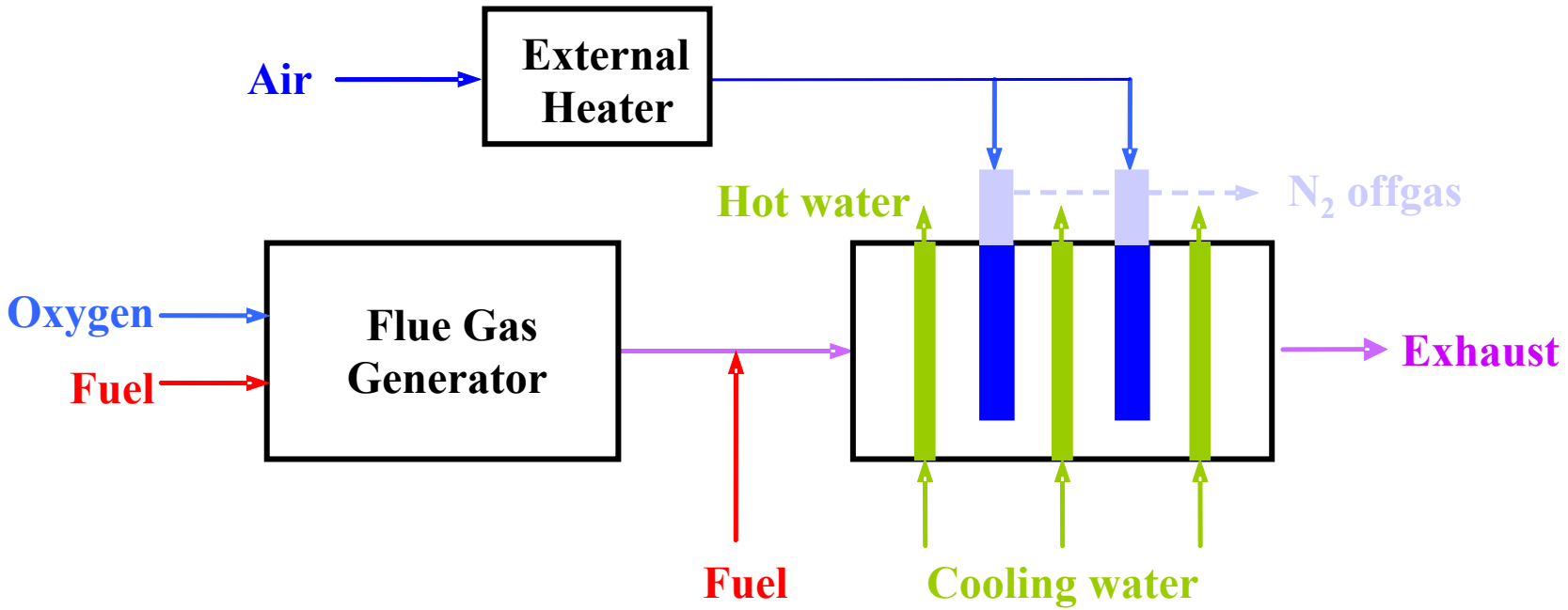
OTM Material Development

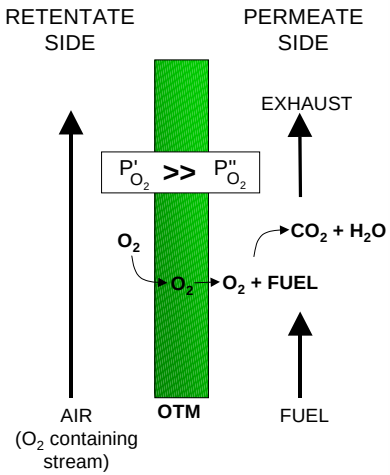
- Ceramic membrane is key to program success
- Membrane performance tests occur at severe operating conditions
- Membrane material optimization in progress
- Robust porous support
  - no tube failures when exposing to fuel
  - no tube failures during thermal cycles
  - no tube failures despite events with rapid cool down

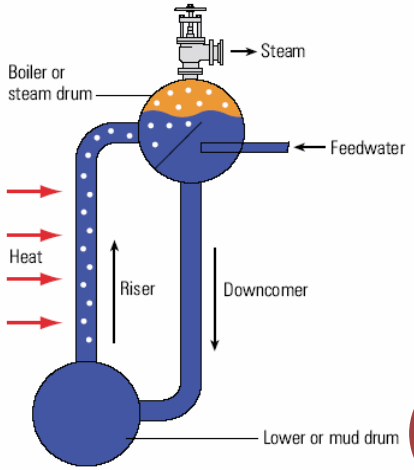
Multi-tube OTM Reactor

Flow Diagram of Multi-tube OTM Reactor



Technology Roadmap





CO_2 Capture & Sequestration & EOR >120 MMBtu

Demonstration (20 MMBtu)

Pilot Boiler (0.5-1 MMBtu)

Proof of Concept

2005 2006 2007 2008 2009 2010 2011 2012

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Summary

- **Advantages of thermally integrated OTM boiler**
  - Utilize OTMs to supply oxygen for combustion, eliminating the need of an external air separation unit.
  - Produce high purity CO_2 exhaust, significantly reducing the cost of CO_2 capture.
  - Improved efficiency provides economic incentive for commercialization.
- **Current laboratory-scale tests**
  - OTM material development to demonstrate material stability and sufficient oxygen flux
  - Multi-tube OTM reactor experiments to understand the thermal integration of OTMs with fuel combustion

Any Questions?

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