the ENERGY lab

PROJECT FACTS

Carbon Sequestration

Novel Oxygen Carriers for Coal-Fueled Chemical Looping Combustion

Background

Increased attention is being placed on research into technologies that capture and store carbon dioxide (CO_2). Carbon capture and storage (CCS) technologies offer great potential for reducing CO_2 emissions and, in turn, mitigating global climate change without adversely influencing energy use or hindering economic growth.

Deploying these technologies in commercial-scale applications requires a significantly expanded workforce trained in various CCS specialties that are currently under-represented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCS technologies.

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has selected 43 projects to receive more than $12.7 million in funding, the majority of which is provided by the American Recovery and Reinvestment Act (ARRA) of 2009, to conduct geologic sequestration training and support fundamental research projects for graduate and undergraduate students throughout the United States. These projects will include such critical topics as simulation and risk assessment; monitoring, verification, and accounting (MVA); geological related analytical tools; methods to interpret geophysical models; well completion and integrity for long-term CO_2 storage; and CO_2 capture.

Project Description

NETL is partnering with Western Kentucky University (WKU) to develop a series of advanced oxygen carriers for coal-fueled chemical looping combustion (CLC) to yield a high purity carbon dioxide stream available for CO_2 capture for CCS applications. CLC is a flameless combustion technology where there is no direct contact between air and fuel. The CLC process utilizes oxygen from metal oxide oxygen carriers for fuel combustion. The products of CLC are CO_2 and water vapor (H_2O). Thus, once the steam is condensed, a relatively pure stream of CO_2 is produced ready for sequestration. The many benefits of this combustion process include minimizing production of oxides of nitrogen (NO_x), production of a CO_2 stream ready for sequestration that does not require additional CO_2 separation units, and thus there is no energy penalty or reduction in power plant efficiency.

In conventional combustion systems, a low CO_2 partial pressure in the flue stream results in a significant energy penalty due to added capture and compression costs of such low concentration and pressure CO_2 streams. Roughly one-fifth of the electricity produced will be lost to CO_2 separation and compression efforts. Among all available proposed carbon management technologies, CLC, as shown in Figure 1, is the only process using oxygen carriers to indirectly combust fossil fuels with simultaneous production of highly concentrated CO_2, without energy penalty,

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PARTNERS

None

PROJECT DURATION

Start Date

12/01/2009

End Date

11/30/2012

COST

Total Project Value

$300,000

DOE/Non-DOE Share

$300,000/$0

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

and with enhanced combustion efficiency. Emission control of other major air pollutants in the CLC process is generally more cost-effective than conventional post-combustion treatment because of the higher concentrations of air pollutants in the flue gas and the lower mass flow rate of the flue gases.

WKU is developing a CLC process model to optimize the performance of the selected oxygen carriers. WKU will screen chemical formulas and investigate preparation methods of three categories of copper oxide oxygen carriers and their characterization using thermo-gravimetric analysis and temperature program reduction methods. The modification of the three categories of oxygen carriers will be continuously evaluated in a scale-up facility and a CLC process model will be built-up to optimize the performance of the selected oxygen carriers. This modification will focus on improving the oxygen-transfer capability, achieving favorable thermodynamics to generate high purity of CO_2, increasing the reactivity and the attrition-resistance, and improving the thermal stability in redox cycles. Final formulation of selected oxygen carriers will be demonstrated in a 10 kW integrated coal-fueled CLC facility. Graduate and undergraduate students will assist WKU with the research effort.

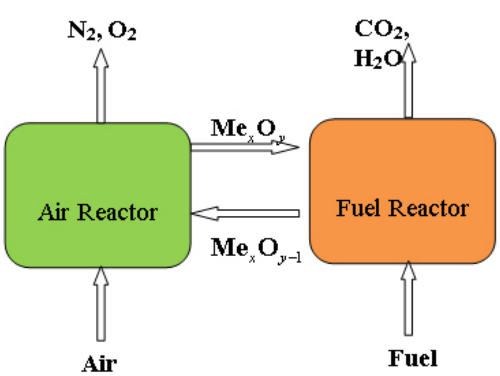
Goals/Objectives

The objective of the project is to develop a series of advanced oxygen carriers for CLC looping combustion. The development of the advanced oxygen carriers will focus on improving overall physical and chemical characteristics and test carriers in an actual CLC facility. Project goals include:

1. Developing attrition-resistant and thermally stable oxygen carriers to achieve an auto-thermal heat balance of the processes for generating high purity CO_2 with favorable kinetics.
2. Evaluating the impacts of scale-up methods and application of inexpensive raw materials (copper-based minerals and widely-available inexpensive clays) for preparation of oxygen carriers on reaction performance in testing within hot-model conditions.
3. Preparing multi-metal or free-oxygen-releasing oxygen carriers and exploring their optimal formula and reaction mechanisms.
4. Evaluating the adaptability of prepared oxygen carriers to diversified coal types in the hot-model tests and investigating methods for eliminating carbon deposits on oxygen carriers.

Benefits

The overall project will make a vital contribution to the scientific, technical, and institutional knowledge necessary to establish frameworks for the development of commercial-scale CCS. The development of more efficient CO_2 capture technologies can reduce overall electricity costs and make CCS more economically feasible. The experience gained from this research will contribute to the development of other innovative oxygen carrier concepts, as well as offer graduate and undergraduate student research opportunities of practical training.



Oxidation: exothermic

$$Me_xO_{y-1} + \frac{1}{2}O_2 \rightarrow Me_xO_y$$

Reduction: endothermic

$$(2n+m)Me_xO_y + C_nH_{2m} \rightarrow (2n+m)Me_xO_{y-1} + nCO_2 + mH_2O$$

Me_xO_y : Metal oxide, Me_xO_{y-1} : the reduced compounds

Figure 1: Conceptual schematic of CLC