the ENERGY lab

Radically Engineered Modular Systems (REMS)

BREAKING THE COAL CONVERSION MOLD

Mission

The National Energy Technology Laboratory (NETL) aims to radically innovate how we conceptualize, design, and build coal conversion reactors and plants to make them economically attractive, create new coal market opportunities, and significantly reduce the global warming impact of fossil energy use.

> *No challenge poses a greater threat to future generations than climate change.*
>
> —President Barack Obama

Electricity and liquid transportation fuels will be the primary products; coal will be the primary feed. However, co-production of high-value chemicals, creation of high-value carbon storage products, and use of biomass, municipal solid waste—and perhaps low-cost natural gas—are all part of the vision.

General Approach

The general Radically Engineered Modular Systems (REMS) approach is to create distributed, cost-competitive coal conversion plants by: (1) using a modular approach to increase plant availability, (2) using recent advances in manufacturing to reduce capital costs, (3) optimizing the whole plant (not just the reactors), (4) using simulations to reduce the reactors' and plants' development time and cost, (5) leveraging both technical breakthroughs and amenable commercial technologies (6) making greenhouse gas emission reduction an integral part R&D and plant design, and (7) ensuring the first small-scale field test facilities will be useful to the local community.

To keep costs reasonable, and the necessary diverse work efforts focused, specific locations will be determined for the first REMS projects. Each REMS plant design will be unique—focused on locally available coal; other opportunity inputs such as biomass, natural gas, or solar power; infrastructure; weather impacts; product markets; etc. The most economically competitive products will be considered, and techno-economic systems analyses will be performed periodically as the REMS concept matures to ensure economic viability and to show where more development work is needed.

Reducing the cost and global warming impact of coal conversion to useful products is the primary goal of the REMS Initiative—first in niche applications and/or small markets. However, this initial work will create a "tool box" for REMS development including new computational toolsets; reactor characterization techniques; advanced manufacturing methods; and research and development (R&D) on alternative energy use, flexible feed technologies, solid carbon capture, co-product optimization, catalyst technologies, and system analysis optimization. After the initial niche applications, these developed tools, knowledge, and expertise can be applied to mainstream applications, greatly reducing the cost and risk of larger-scale REMS plant development.

To control the cost of "tool box" development, and to ensure efficient execution of the initial REMS activities, the focus will be on holistic pilot-plant development in a few relatively specific locations. Whole pilot plants, not only the reactors, will be designed with focus on how advanced manufacturing, modularization, and

simulations can improve all aspects of the pilot plant, including, integration of reactors, balance of plant equipment, and more market-competitive products. Ideally, the pilot plants will be able to provide a useful function beyond the project test phase.

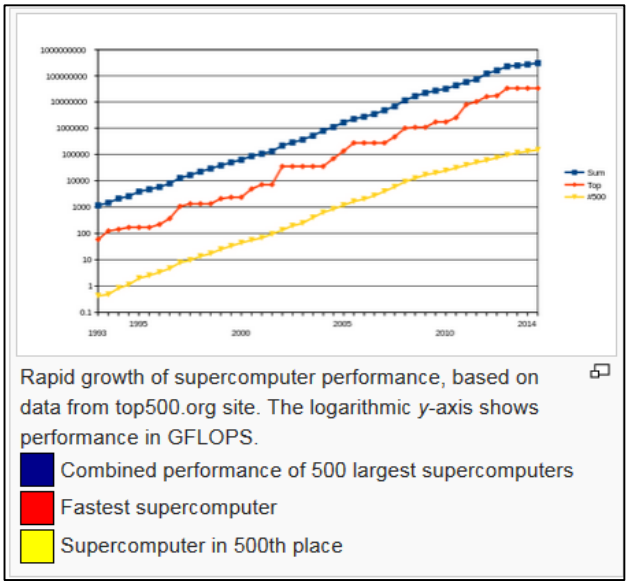
Background and Technical Details

Traditional reaction and chemical process engineering starts at laboratory scales, and gradually builds up to larger systems. The typical R&D development cycle for the conception of a new chemical process and its industrial-scale deployment is approximately 20–30 years in length, occurs in several stages, and requires enormous capital investment. Furthermore, these long cycles force the developer to incur large financial risks during this process due to the potential for technologies to fail during scaling.

Simulation-based reactor design will be used to better predict reactor behavior and results, and advanced manufacturing techniques will enable rapid prototyping of concepts. This approach should lead to significantly reduced times for new reactor development.

NETL's Multiphase Flow Modeling Team

Once perfected, multiphase and kinetic modeling, plus supporting data, will provide accurate predictions of where in the reactor desired and undesired reactions occur, and allow researchers to virtually test feed- and product-specific reactor designs. Furthermore, as computing power continues to increase, these reactor simulations will become increasingly fast and realistic, while reducing in cost. A physical example is the desktop computer of the early 1990s compared to smart phones of today.



Rapid growth of supercomputer performance, based on data from top500.org site. The logarithmic *y*-axis shows performance in GFLOPS.

- Combined performance of 500 largest supercomputers
- Fastest supercomputer
- Supercomputer in 500th place

Rapid prototyping, such as inexpensive 3D plastics printing of cold flow reactors, will be used to quickly test the unique reactor designs. Additive manufacturing and other advanced manufacturing techniques for metals and ceramics will be utilized to rapidly translate cold-flow proven unique reactor designs into reactors for hot-flow validation, and for final manufacturing of coal conversion reactors for deployment.

Metal additive manufacturing using a laser

The REMS reactors will:

- Have optimal configuration and size for conversion of specific coal type and other feedstock (biomass, municipal solid waste, etc.) to the target product(s).
- As much as practical, combine multiple chemical reactions and separation systems into one reactor or process.

- Be, as much as practical, amenable to modular deployment.

REMS technical breakthroughs, combined with a modular approach, should be able to overcome the traditional economies of scale. Academic research on the economics of smaller and more modular systems cite a variety of contributing factors for these changing economic and business models:

- Small, modular reactors and plants with common components can be mass produced quickly, prefabricated, and dropped in at a desired site, which reduces build and maintenance costs in comparison to the construction of a traditional coal conversion plants.
- Modular plants will have higher availability, since equipment failure will only slow production, rather than halt it—often the case in conventional plants with limited equipment redundancy.
- The "right-sizing" of reactor systems by coupling several small, prefabricated, modular, reactors can allow one to effectively service markets that were previously too small to be economically attractive for large, traditional plants.

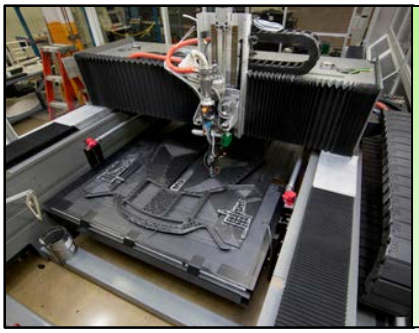
Another advantage, having to do with global warming rather than cost: smaller systems will enable a higher proportion of biomass use, since biomass transportation costs are too high to support use in large power or coal-to-liquids plants bound by economies of scale. This same principle is true for other opportunity fuels, such as municipal solid waste.

Two NETL programs are actively pursuing the REMS approach:

Gasification Systems

Coal and Coal Biomass to Liquids

The REMS approach is actively seeking technologies that can lower greenhouse gas (GHG) emissions without the need to geologically store CO_2. While small, distributed plants favors the use of biomass, it's likely these small plants will be the last to have geological CO_2 storage available and affordable. Therefore, co-feeding of biomass to reduce the net GHG emissions is both more feasible, and important, than in larger coal conversion or power plants.



Carbon fiber additive manufacturing

Institute for Advanced Composites Manufacturing Innovation

Other methods being explored to reduce CO_2 emissions include carbon removal from coal. For instance, excess carbon can be removed in char or heavy coal tars, which could then be converted into high-value products with near-permanent capture. This solves two problems at one time: increasing plant market competitiveness while storing GHG before it becomes a gas.

Outreach and communication to foster collaboration on R&D and manufacturing techniques, and using commercial technologies applicable to REMS plants will be an active and ongoing part of the REMS initiative.

CONTACTS

Jenny Tennant, Portfolio Manager
Science & Technology Strategy Planning and Programs
304-285-4830
jenny.tennant@netl.doe.gov

John Wimer, Associate Director
Science & Technology Strategy Planning and Programs
304-285-4124
john.wimer@netl.doe.gov