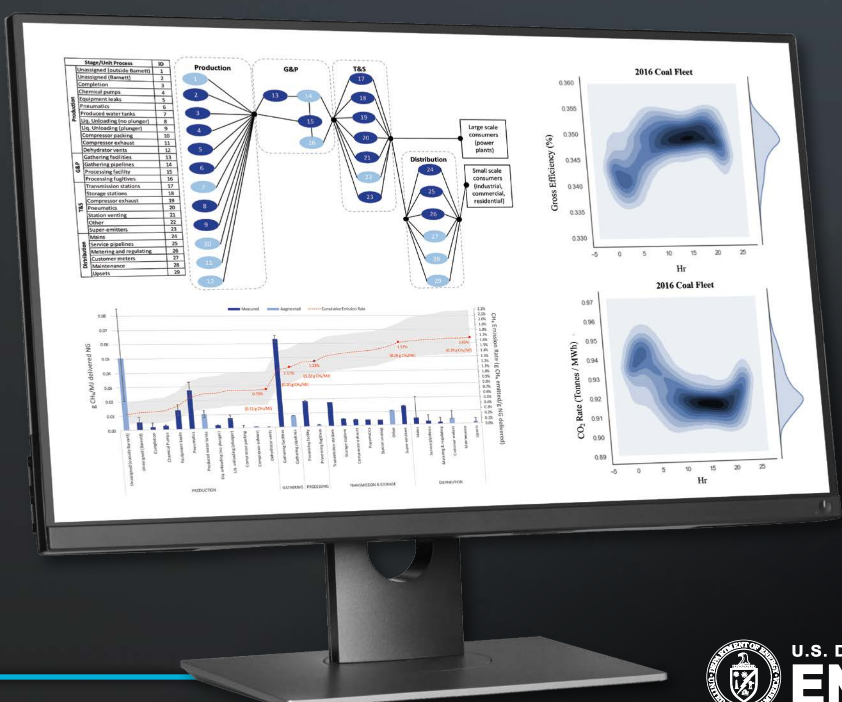
SYSTEMS ENGINEERING & ANALYSIS

Development of Multi-scale Approaches to Modeling & Analysis of Technology, Processes & Markets

The discovery, design, and operation of energy systems benefit from systematic decision-making techniques to examine the often-competing goals of maximizing profits, minimizing costs, and meeting environmental and technical constraints. The capabilities of Systems Engineering & Analysis (SEA) allow comprehensive evaluation of the most complex energy systems from the sub-process to the global scale and their related technical, economic, resource, policy, environmental and market risks along their entire value chain and throughout their life cycle, and the identification of effective R&D investment choices. Development and application of the Lab's multi-criteria and multi-scale decision tools and approaches include process systems engineering research, process and cost engineering, resource and subsurface analysis, market and infrastructure analysis and environmental life cycle analysis. These provide insights into the potential for new technology ideas; identify new energy concepts; and analyze how energy systems interact at plant, regional, national, and global scales.



U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

1

COST ESTIMATION

DEVELOP CAPITAL & OPERATIONS COSTS FOR CONVENTIONAL & ADVANCED ENERGY TECHNOLOGIES

Cost is a critical metric when evaluating competing technologies in the energy space. The SEA directorate has access to resources with design/build experience of conventional energy technologies like natural gas combined cycle and pulverized coal power plants. Cost estimates are rooted in near-term projects that accurately reflect current market conditions. These estimates, in reports such as the NETL Bituminous Baseline, provides reference capital and operations costs for a wide range of fossil power plants. These costs establish a basis for evaluating and comparing alternative novel technologies as well as a basis for research and development goal setting and measuring progress towards those goals. Gap analyses are performed to identify the data necessary to more fully assess the technology, and to guide technology developers in their research and development efforts.

2

OPTIMIZATION OF ADVANCED ENERGY SYSTEMS

SYSTEMATIC & RIGOROUS ENERGY CONCEPT EVALUATION

Researchers use advanced process modeling, simulation, and optimization tools to maximize the learning rate and accelerate technology validation and deployment. The framework developed represents an innovative approach for the design and optimization of innovative steady state and dynamic processes. The modular framework enables rigorous large-scale mathematical optimization and leverages the SEA capabilities in the areas of conceptual design, steady state and dynamic optimization, multi-scale modeling, surrogate model development, uncertainty quantification, automated development of thermodynamic physical property, and kinetic submodels from experimental data. SEA capabilities in this area range from customized and first principle models to simplified and shortcut models developed using open source platforms such as Pyomo and commercial software platforms such as Aspen®, MATLAB, and Simulink. SEA applications range from supporting the U.S. power industry to developing the U.S. energy systems of the future.

3

PROCESS ENGINEERING

FLOWSHEET DEVELOPMENT & PROCESS SIMULATION

Using rigorous engineering fundamentals and the latest performance information available, the SEA directorate develops process flow diagrams for a wide range of energy technologies, including conventional technologies like Natural Gas Combined Cycle (NGCC) and Pulverized Coal (PC) plants as well as developing technologies like pre- and post-combustion carbon capture, chemical looping combustion, and supercritical CO_2 power cycles. Process simulation software is used to generate process material and energy balances, which enable equipment sizing and cost estimating. Combined with cost estimation, process engineering is used to provide the framework for research and development metric evaluation.

4

ENERGY MARKETS ANALYSIS

ADVANCED TECHNOLOGY IN A GLOBAL ENERGY MARKET CONTEXT

Energy Markets Analyses evaluate the potential role of advanced technologies, being developed by NETL R&D, to be competitive in the future U.S. energy landscape, under varying factors including market forces, macroeconomic trends, or government regulations. Scenario analyses use platforms such as the National Energy Modeling System (NEMS), Market Allocation (MARKAL), and MarketBuilder, with regional, national, or global focus. Characterization of the upstream resources (e.g., coal, natural gas, and water) critical to energy production also form a vital part of these analyses.

5

R&D BENEFITS ANALYSIS

QUANTIFYING ECONOMIC BENEFITS OF SUCCESSFUL R&D

The SEA team conducts studies to evaluate potential benefits of its programs to ensure that the R&D investments not only contribute to the achievement of US DOE missions but do so with a significantly positive economic impact regionally as well as nationally. In addition to custom model development, SEA capabilities include utilization of input-output (IMPLAN) models and an in-house developed Econometric Input-Output model (ECIO) to assess regional/national economic impacts including those on employment and GDP.

6

ENVIRONMENTAL IMPACTS QUANTIFICATION

METRICS TO COMPREHENSIVELY ASSESS IMPACTS OF ENERGY SYSTEMS

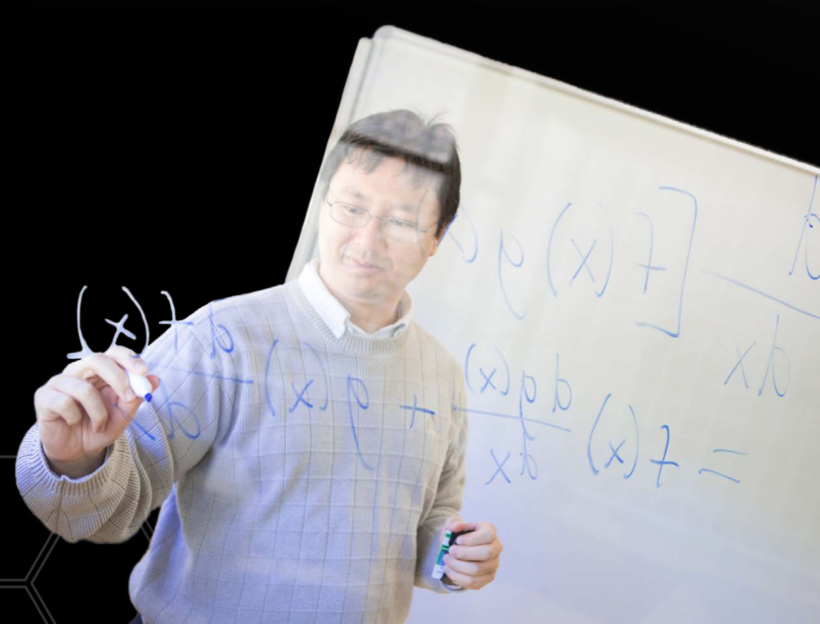
ESAT assesses environmental impacts using systematic approaches, like life cycle analysis (LCA) to ensure that comparisons are made on equivalent bases. LCA allows decision makers to evaluate the consequences of policy, guides research, and identifies opportunities for improvement. Environmental burdens comprise emissions to air and water, water use, and land use – these burdens are normalized using a common framework understand common impacts.

7

SUPPLY CHAIN MODELING

PROCESS-BASED APPROACH FOR CHARACTERIZING SUPPLY CHAIN BEHAVIOR

The Energy Systems Analysis Team models supply chains using a "bottom-up" approach wherein the inputs and outputs of individual supply chain nodes ("unit processes") are connected as a network that allows modeling of supply chain interactions. These unit processes are developed using open-source, engineering-based modules. This modular approach allows for incorporation into other projects and allows detailed analysis of scenarios, contributions, and uncertainty.



Dr. Byron Soepyan Frits, Process Engineering Research team member

8

ENERGY INFRASTRUCTURE MODELING

ECONOMIC DISPATCH MODELING & INFRASTRUCTURE EXPANSION MODELS

The goal of R&D is to improve existing plant performance and develop new power plants to meet changing market needs. Understanding how technology translates to market penetration depends on the plant's ability to acquire fuel and dispatch into its regional electricity market. Using economic dispatch and infrastructure forecasting models allow the Energy Market Analysis Team to provide feedback to researchers on cost targets. Additionally, economic dispatch modeling is used to predict grid reliability issues as more culpable energy is retired and replaced by renewables and natural gas, which has some regional infrastructure constraints. Answers to these questions result in a more resilient energy infrastructure network as the system continues to transition.

9

SUBSURFACE RESOURCE APPRAISAL

ASSESSING FOSSIL RESOURCES & CO_2 STORAGE POTENTIAL

Successful utilization of the majority of subsurface U.S. energy resources (including unconventional oil and gas reservoirs, depleting oil and gas formations, residual oil zones, saline-bearing reservoirs, and potential geothermal zones) fundamentally hinges on locating and characterizing them. Prominent geologic interpretation and geospatial software combined with custom economic evaluation tools, machine learning and data analytics approaches enables SEA to locate and appraise subsurface energy resources in a fashion that aligns with NETL's overall mission. These appraisals include techno-economic evaluation of fully-integrated energy systems evaluating the deployment of emerging technologies to more effectively utilize domestic subsurface energy resources. Brought together, these approaches have the potential to completely change the way that oil and gas and other subsurface fields are operated.

SYSTEMS ENGINEERING & ANALYSIS

- Carbon Capture Simulation Initiative – *Albany, Morgantown, Pittsburgh*
- Simulation-Based Engineering to Support Advanced Energy Systems – *Pittsburgh*
- Environmental Life Cycle Analysis – *Pittsburgh*
- Process & Cost Engineering – *Morgantown, Pittsburgh*
- Energy Markets & Infrastructure Analysis – *Morgantown, Pittsburgh*
- Subsurface Resource Assessment – *Morgantown, Pittsburgh*

CONTACTS

Randall Gentry
Deputy Director & Chief Research Officer, Science & Technology Strategic Plans & Programs
Randall.Gentry@netl.doe.gov
412.386.7302

BUSINESS INQUIRIES

Jessica Lamp
Technology Transfer Program Manager
Jessica.Lamp@netl.doe.gov
412.386.7417

MEDIA INQUIRIES

Shelley Martin
Media Relations Manager
Shelley.Martin@netl.doe.gov
304.285.0228

TECHNICAL INQUIRIES

Peter Balash
Systems Engineering & Analysis Associate Director
Peter.Balash@netl.doe.gov
412.386.5753

LOCATIONS

Albany, OR
1450 Queen Avenue SW
Albany, OR 97321-2198

Morgantown, WV
3610 Collins Ferry Road
Morgantown, WV 26507-0880

Pittsburgh, PA
626 Cochrans Mill Road
Pittsburgh, PA 15236-0940

Visit us: **www.NETL.DOE.gov**

@NationalEnergyTechnologyLaboratory

@NETL_DOE

@NETL_DOE

Program staff are also located in Houston, TX and Anchorage, AK

05.2020.2000