Comprehensive Life-Cycle Analysis for Energy and Environmental Systems

Argonne's Environmental Science Division (EVS) analyzes the life-cycle impacts of energy systems and processes on the environment. Improved understanding can assist decision makers in developing solutions that optimize performance, sustainability, and response to global climate change.

PROBLEM/OPPORTUNITY

The United States faces increasing challenges to meet the energy, water, and transportation needs of its citizens while simultaneously reducing its carbon and water footprints. The development and integration of analysis tools can evaluate technologies and practices to comprehensively understand their capabilities and effects on the environment and global climate change.

EVS staff members analyze environmental and economic impacts across the life cycle of technology development and deployment to assist sponsors making policy development and implementation decisions. These analyses provide an objective, scientific basis for decisions related to energy and environmental policy concepts, the development of regulatory requirements, and the acceptance and use of new technology.

ANALYSIS CAPABILITIES

Connecting life-cycle analysis with environmental and economic models assists decision makers in a variety of planning scenarios, which include the following.

Life-Cycle Assessment

Life-cycle assessment (LCA) inventories relevant inputs and outputs of a system, evaluates potential environmental impacts associated with those inputs and outputs, and interprets the results to assess the environmental impacts associated with a system. EVS staff members conduct these assessments to identify opportunities for system optimization, to inform decision makers or planners of associated environmental impacts, and to assess the environmental performance of a system.

Cost-Benefit Analysis

EVS staff members conduct cost-benefit analyses to evaluate policy options for technology or management practices. The initial upfront cost of sustainable or environmentally preferable technology often exceeds the upfront cost of conventional technology.

An extensive green roof on a Washington, D.C., office building (Source: C.E. Clark, Argonne National Laboratory)

Cost-benefit analyses can evaluate the costs and benefits over the lifetime of the technologies, revealing the true cost to the owner. While the upfront costs for a green roof are higher than those for a conventional roof, the costs over the lifetime of the roof are considerably lower.

Environmental Analysis

EVS staff members consider the benefits that ecosystems provide to energy and water management. Integrating natural systems into the fabric of a city can provide a multitude of benefits, from stormwater management to reduction of the urban heat island. Quantification of these benefits informs decision makers in developing and deploying policies and programs.

ANALYSIS APPLICATIONS

EVS staff members assess the regulatory, economic, and environmental feasibility of innovative environmental and energy technologies. Results are disseminated to decision makers in industry and government and to other stakeholders and provide the basis for regulatory and policy change. Recent examples include green infrastructure, enhanced geothermal systems, and green remediation.

Green Infrastructure

Green infrastructure refers to wet-weather management approaches and technologies that infiltrate, evapotranspire, capture, and reuse stormwater to maintain or restore natural hydrologies such as rain gardens, green roofs, green walls, infiltration planters, or trees and tree boxes. Such systems provide beneficial impacts to cities and watersheds that include reductions of (1) stormwater runoff volume, pollutant loads, and temperatures; (2) air emissions due to decreased demand from reduced heat loss and heat gain in buildings; and (3) urban temperatures and the urban heat island effect (UHIE) through evaporative cooling and increased surface albedo. The benefits of green infrastructure can extend well beyond the city, as decreased cooling needs reduce the demand for power during peak loading periods, resulting in fewer greenhouse gas emissions and less water consumption for power generation.

As increased temperatures and changing precipitation patterns are already impacting the United States, understanding and quantifying the benefits of green infrastructure can assist planners in designing cities to manage energy and water appropriately as climate change alters the future. Previous EVS work includes the development of quantitative multimedia engineering and economic models, computer simulations, analysis, and policy recommendations for integrating green roofs as a mitigation strategy to improve emissions management from energy generation and improve the quality of stormwater runoff.

Enhanced Geothermal Systems

Current estimates that enhanced geothermal systems (EGS) technology is capable of providing at least 100,000 MW of electricity within 50 years suggest substantial opportunity for its widespread adoption. Energy and environmental analyses are critical to the development and deployment of a robust set of geothermal technologies, especially EGS. EVS, in collaboration with Argonne's Energy Systems Division, is developing an LCA to quantitatively assess the energy and environmental benefits of EGS by closely examining proximity to infrastructure, resource availability, and tradeoffs associated with well depth and resource temperature.

In particular, Argonne is analyzing life-cycle emissions and energy issues so that reductions in fossil energy use, petroleum use, greenhouse gas (GHG) emissions, and criteria air pollutant emissions by EGS will be thoroughly examined. Water consumption and water quality impacts of EGS are also being quantified. Eventually, techno-economic analysis will be conducted to assess the economic viability of EGS relative to conventional geothermal technologies, conventional power generation, and conventional district heat/power generation.

Green Remediation

The practice of "green remediation" takes into consideration all of the environmental effects of remedy implementation in an effort to maximize the net environmental benefit of cleanup actions. Maximizing the net environmental benefit requires understanding the full extent of impacts across the life cycle of the cleanup actions from initial site characterization to release or transfer of the site. EVS provides technical assistance on best management practices for site investigations and bioremediation activities. Other assistance activities focus on applying a life-cycle framework to green remediation that begins with the initial site investigation and sampling activities, includes remedial action and cleanup, and ends with the reuse or redevelopment of the site. Such an approach involves an assessment of the environmental debt associated with remediation activities including the raw material and energy consumption of the investigation, and the emissions produced from the investigation and remedy selection process.

FUTURE

EVS will continue to refine and develop life-cycle tools that aid policy formation and implementation related to new energy resources, efficiency in the development and use of energy and related resources, and responsible management of energy byproducts.