2009 BFRL Project Description

Project Title: Development of a Rating Methodology for Micro-Cogeneration Technologies

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Co-Investigator(s):

BFRL Program: Healthy and Sustainable Buildings

Objective: Develop the enabling measurement science needed to capture the performance of micro-cogeneration systems.

Problem:

What is the problem? Micro-cogeneration systems, also known as micro-combined heat and power (mCHP) systems, provide energy and cost savings for residential or small commercial applications through the effective utilization of the excess heat made available from on-site electricity production. The systems, which use engines or fuel cells as the primary energy conversion device, can convert more than 80 % of the fuel to useful energy at its point of use. This conversion rate is a significant improvement over the average 30-35% fuel to electricity conversion efficiency for coal power plants, thereby moving the building industry towards net-zero energy buildings by reducing source energy consumption.

Market acceptance of mCHP can be accelerated by helping potential consumers understand the potential energy and cost savings. When discussing ways to accelerate market acceptance, the U.S. Department of Energy's *The Micro-CHP Technologies Roadmap*[1] states that "Defining measurable benchmarks for efficiency, emissions, payback, reliability, and installed cost would help consumers understand the performance and costs of mCHP units." A Measurement Need has been submitted to the US Measurement System program office that addresses this particular issue. Unfortunately, the measurement science to translate simple system efficiency into consumer energy savings (or payback) is lacking.

Why is it hard to solve? A consumer's energy savings from installing a micro-cogeneration system are not simply a function of a single electrical and thermal efficiency measure, but are also highly dependent upon the size of the thermal and electrical load of the application and the mCHP system's ratio of thermal to electrical energy output. Additionally, as mCHP devices are sized to meet only part of the application's thermal load, their interaction with

[1] http://www.eere.energy.gov/de/pdfs/micro_chp_roadmap.pdf

ancillary devices such as a supplemental furnace/boiler or a thermal storage tank will affect the energy and cost savings for the consumer. Measurement science must be developed that effectively accounts for these influences in the prediction of a mCHP device's energy consumption and production and the use of the energy generated for a specific application.

How is it solved today, and by whom? The measurement science needed to capture the installed performance of mCHP systems has not been developed. The United Kingdom and The Netherlands are currently developing rating systems for mCHP, and the EU is just beginning its own effort. In particular, Publicly Available Specification 67 (PAS 67) in the UK, which is about to be published, generates a chart of seasonal efficiencies for a mCHP device with respect to various heat loads[2]. It is expected that commercially available mCHP systems for sale in the UK will be tested according to PAS 67 in the future. While efforts abroad will aid in the development of a rating methodology in the U.S., differences in electrical and thermal loads between the regions and the preponderance of forced air heating in the U.S., as opposed to Europe's predominance of hydronic heating, necessitates a different procedure.

Why NIST? The development of a rating methodology for mCHP systems is directly related to the BFRL mission and vision, as it requires the development of the measurement science to create performance metrics for the promotion of U.S. innovation and competitiveness in the building energy sector. As it is focused on enabling innovative building energy technologies, the project fits within BFRL's "Measurement Science for Net Zero Energy, High-Performance Buildings" strategic priority and BFRL's core competency of "measurement science for building energy technologies." Additionally, because this work is closely related to the rating methodology for residential fuel cells, BFRL's experience in this area will ensure success.

Approach:

What is the new technical idea? A rating methodology will be developed that measures the performance of micro-cogeneration systems under typical conditions experienced in the U.S. It must account for the performance of the co-generator and the electrical and thermal loads of the application. The methodology must specify a limited number of tests that will effectively determine the performance of a wide variety of prime-movers (internal combustion engines, Stirling engines, fuel cells, etc.). A rating procedure must subsequently be established that can approximate the energy consumption, energy delivery, and operational cost of the units and concisely communicate the results to the consumer.

The technical idea is directly related to previous BFRL efforts undertaken to develop a rating methodology for residential fuel cell systems, which are a subset of the broader micro-cogeneration market. The test methodologies and rating procedures documented for residential fuel cells will be used as a starting point for the development of a more inclusive rating methodology. Significant additional work must be completed to characterize the performance of other types of generators, as the heat to power ratio for other technologies could strongly affect the systems' overall performance in integrated heating systems, especially forced-air systems.

[2] The Carbon Trust, "Micro-CHP Accelerator". 2007, London, UK.

Why can we succeed now? Interest in mCHP is expanding quickly in the United States. In 2007, the Partnership for Advanced Technology in Housing (PATH) listed mCHP as one of its "Top Ten Technologies," and EPA included mCHP in its National Action Plan for Energy Efficiency: Vision for 2025[3]. In March 2008, the new Climate Choice program from DOE and EPA, which is an Energy Star-like program for emerging technologies, includes mCHP as one of its first candidate technologies[4]. The recent entry into the U.S. market of commercially available mCHP systems will make a thorough investigation of the technologies feasible at this time. Recent efforts by the International Energy Agency's (IEA) Annex 42 have produced computational models that will complement the test program and help assess the performance of systems under loads expected in the U.S.

What is the research plan? To reach the goal of developing a rating methodology for mCHP systems, NIST plans to model mCHP behavior under various loads, measure the performance of representative systems, and develop rating procedures that effectively and equitably communicate real-world performance to potential customers.

A preliminary assessment of mCHP systems in US applications will be carried out to evaluate the potential energy and cost savings arising from their use and to better understand the factors influencing their performance. This assessment will be comprised of a modeling effort and an experimental evaluation of actual systems. First, the installed performance of representative systems will be investigated using predictive performance models developed by IEA Annex 42 for internal combustion and Stirling engines. The mCHP devices will be modeled in six climate zones throughout the U.S., representing a large spectrum of thermal loads. The investigation will also help identify key parameters to examine during the test phase of the project.

The second step of this assessment will entail measurements of the electrical and thermal efficiency of these systems under different environmental, electrical, and thermal loads. During FY09, testing will focus on systems that supply thermal energy by heating water, which could then be used for domestic hot water or hydronic heating systems. Devices integrated with forced-air heating systems will be tested.

Beyond FY09, generic empirical models will be developed for each of the system technologies tested at NIST. The models will capture the electrical and thermal efficiency as well as the control strategy employed. To validate the models and aid the rating methodology development, partnerships with mCHP manufacturers and state and local jurisdictions will be sought to enable the monitoring of mCHP devices installed in residential applications. While the models will be used to update the preliminary performance assessment, their primary purpose is for use in development and evaluation of the rating methodology.

The measured data and model predictions will be used to draft a proposed rating methodology. The document will distinguish between control schemes or generator types as needed. A test methodology will be clearly described, and a rating procedure will be shown that

[3] http://www.epa.gov/cleanenergy/documents/vision.pdf
[4] http://www.epa.gov/cppd/climatechoice/technology.htm

results in a simple, consumer-oriented metric that effectively communicates the potential energy and cost savings for a micro-cogeneration device.

Recent Results: While this is a new project, it follows closely from the development of a rating methodology for residential fuel cell systems, which are a subset of mCHP systems. In that project, a proposed test methodology and rating procedure[5] were documented. The document was the result of comprehensive testing of three residential fuel cell systems. The proposed rating methodology will serve as an excellent starting point for a mCHP rating methodology.

Standards and Codes: The project outcome will include a proposed rating methodology for mCHP devices, which may result in the development of a performance standard. Currently, there are no standards activities in the mCHP industry, but project staff will pursue any appropriate opportunities as they become available.

[5] Davis, M.W., Ellis, M.W., Dougherty, B.P. (2006) "Proposed Test Methodology and Performance Rating Standard for Residential Fuel Cell Systems." NISTIR 7131