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Optimization of Novel Networks of Distributed Combined Heat and Power Fuel Cell Systems to Reduce Greenhouse Gas Emissions and Energy Costs

Stationary combined heat and power (CHP) fuel cell systems (FCS) can provide electricity and heat for buildings, and can reduce greenhouse gas (GHG) emissions significantly if they are configured with an appropriate installation and operating strategy. The Maximizing Emission Reductions and Economic Savings Simulator (MERESS) optimization tool was developed and deployed to allow users to evaluate different strategies for installing and operating CHP FCS in buildings and towns. The MERESS model examines unique strategies that commercial industry has typically overlooked. It incorporates the pivotal choices made by FCS manufacturers, building owners, emission regulators, competing generators, and policy makers, and empowers them to evaluate the effect of their choices directly. The choice of operating strategy results in trade-offs among three important, but often competing goals: 1) GHG emission reductions, 2) cost savings to building owners in procuring electricity and heat, and 3) FCS manufacturer profitability. The MERESS model allows users to evaluate these design trade-offs and to identify the optimal control strategies and building load curves for installation based on either 1) maximum GHG emission reductions or 2) maximum cost savings to building owners.

The research team deploys the MERESS model to show the impact of installing FCS in a California town. This town achieves the highest 1) GHG emission reductions, 2) cost savings to building owners, and 3) FCS manufacturer profitability with three different operating strategies. It achieves its maximum CO_2 emission reduction, 37% relative to a base case of no FCS installed, with operating Strategy V: stand alone operation (SA), no load following (NLF), and a variable heat-to-power ratio (VHP) [SA, NLF, VHP]. The town's building owners gain the highest cost savings, 25% relative to a base case with no fuel cells and under full incentives and a $100/tonne CO_2 tax, with Strategy I: electrically and thermally networked (NW), electricity power load following (ELF), and VHP [NW, ELF, VHP]. FCS manufacturers can be expected to have the highest profitability and sales with Strategy III: NW, NLF, with a fixed heat-to-power ratio (FHP) [NW, NLF, FHP]. Strategy III is consistent with the way that FCS manufacturers design their systems today, primarily as SA and NLF. Strategies I and V are avant-garde for the fuel cell industry, in particular, in their ability to operate FCS with a VHP. Without any state and federal incentives or carbon tax, Strategy I is economical, although marginally so, with 3% cost savings, and a 29% reduction in CO_2 emissions. No particular building type stands out as consistently achieving the highest CO_2 emission reductions or cost savings. However, buildings with load curves similar to a particular wet laboratory building (Mudd Chemistry) achieve maximal cost savings (1.5% with full federal and state incentives but no carbon tax) and maximal CO_2 emission reductions (32%)

Keywords: Maximizing Emission Reductions and Economic Savings Simulator (MERESS) optimization tool, fuel cell system (FCS), greenhouse gas emissions (GHG), carbon dioxide (CO_2) emissions, networks, cogeneration, combined heat and power (CHP), cost, profitability, thermal distribution networks, low-voltage electricity distribution networks, optimization, heat recovery, distributed energy systems, operating strategy, stand alone (SA), networked (NW), heat load following (HLF), electricity load following (ELF), no load following (NLF), variable heat-to-power ratio (VHP), fixed heat-to-power ratio (FHP).