# Status of ERC's Direct Carbonate Fuel Cell Program

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## OBJECTIVE

Under the cooperative agreement DE-FC21-95MC31184 with DOE/FETC, Energy Research Corporation (ERC) has been developing its Direct Carbonate Fuel Cell (DFC) power plants for stationary power applications. The objective of the program is to develop and demonstrate a cost-effective, market-responsive DFC power plant design(s).

## Progress Made to Date

Significant progress has been achieved to date under this program:

- Based on experience gained from the Santa Clara proof-of-concept test, cell and stack designs have been refined to provide stability, reliability and thermal cycling capability consistent with commercial goals.

- Cell area has been scaled up to 9,000 $cm^2$, and verified in seven subscale stacks achieving a power rating of >1kW/cell.

- One-year endurance testing of the scaled-up commercial entry design cell has been completed (test is continuing), showing performance stability exceeding market entry goals (Figure 1).

- The previous 100kW power plant facility has been upgraded to test stacks up to 400kW size. Its operation has been successfully verified with two full-size stack tests.

- A "hot box" concept has been developed for better packaging of stacks and to reduce piping requirements. Five months of comprehensive testing of the first full-size 250kW stack with this "hot box" was completed in 1998. The stack met all, in fact, in most cases exceeded the goals for this mechanical test. The test sequence included thermal cycles, planned and unplanned plant trips, very fast load ramps, other normal operating events as well as simulated stress conditions such as an uncontrolled thermal cycle, an oxidizer trip, and an emergency plant trip with no deliberate action taken for five hours. This full-size stack indicated excellent robustness to these tests events (only 0.4% decay per 1000h over the entire test

period). The stack converted pipeline natural gas to DC power with a 47% efficiency, which equates to an estimated ~50% efficiency in commercial operation.

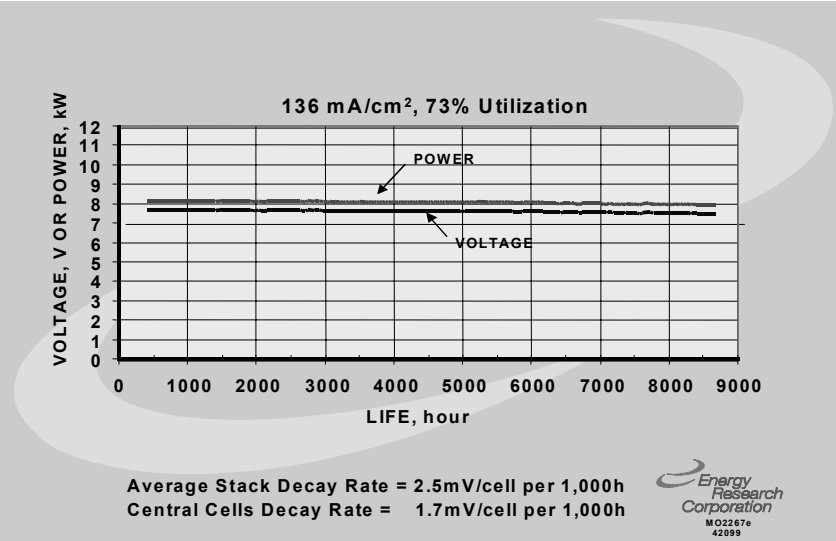


**Figure 1. Subscale Stack (10-cell, 9,000 cm$^2$ cell area) Endurance:**
Stable Performance has been Demonstrated in the One-year Life Test

- The second full-height stack representative of our commercial product building-block stack design, is currently on test for >3500 hours (Figure 2). The power plant has produced over 500,000kWh of energy, powering the Danbury facility with any excess fed to utility grid. This stack has ~9% higher power output compared with the first full-height stack (Figure 3). The stack has already been subjected to one stressed thermal cycle, without any deleterious effects.

- Manufacturing process development was continued at the Torrington, CT facility with the addition of an automatic cathode production line, a rolling mill to substantially improve component dimensions and tooling for the 9000 cm$^2$ commercial design. 1MW cell packages of the commercial design manufactured to date.

- Present manufacturing capacity is over 5 MW/year (one shift basis), and will be upgraded to 50 MW/year in steps to meet projected demand.

- In parallel with ERC's effort on megawatt-class power plant, ERC's technology partner, MTU Friedrichshafen GmbH, an affiliate of Daimler-Chrysler, developed and demonstrated an innovative 300kW (nominal) cogeneration system utilizing cell components purchased from ERC. A second field test in Europe has been planned for 1999.

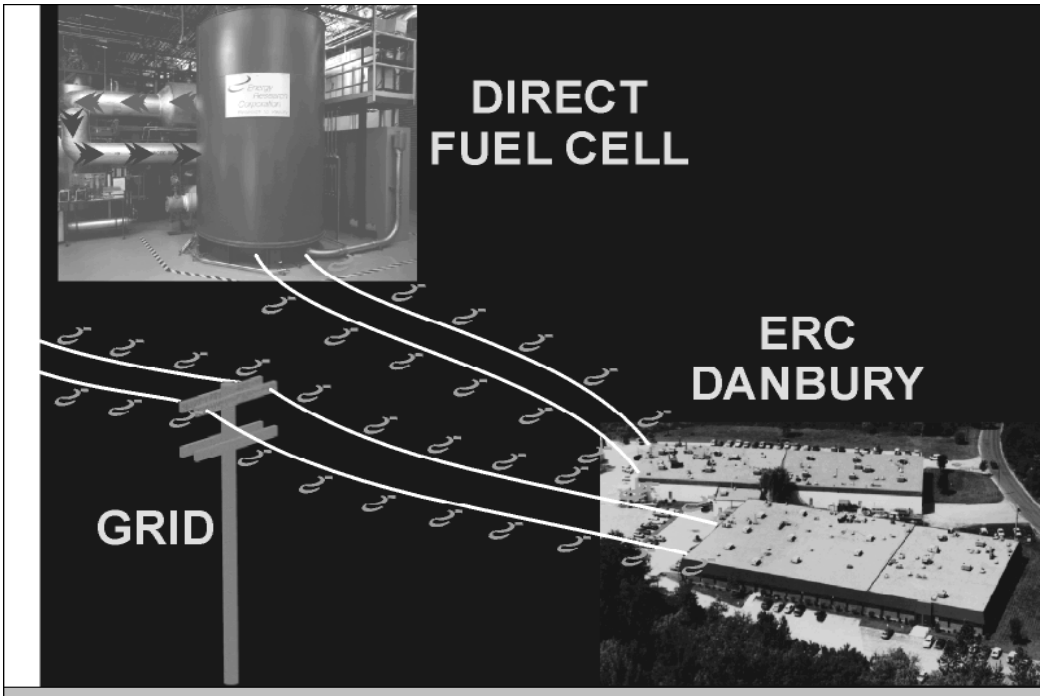


**Figure 2. A Submegawatt Demonstration with a Product Building-Block Stack:**
Over 500,00kWh of Electricity Produced

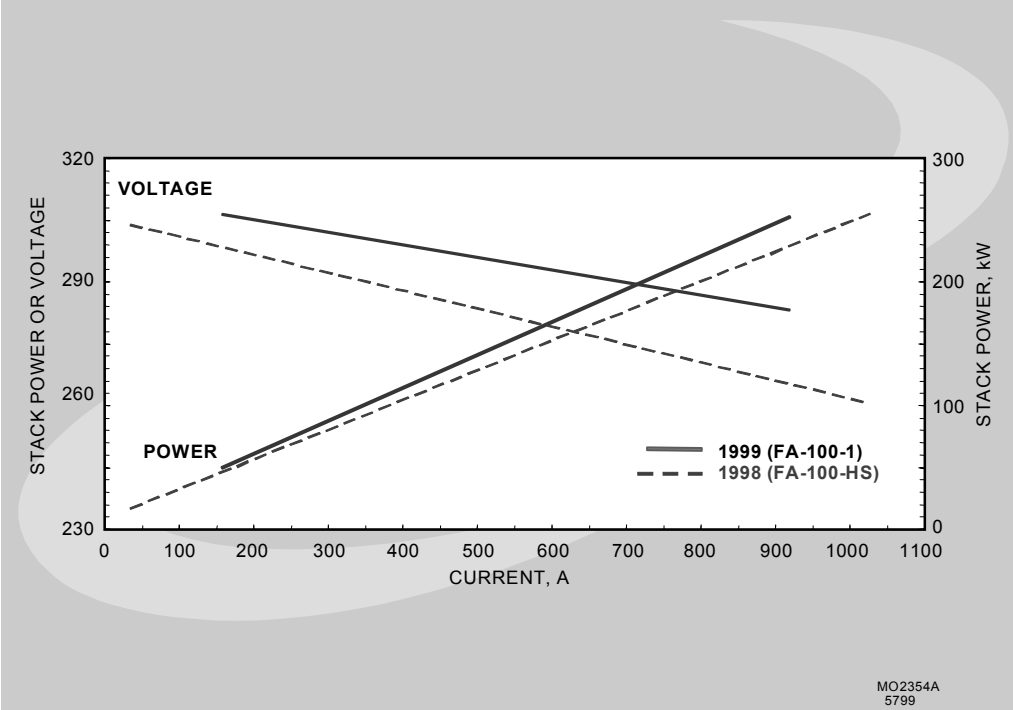


**Figure 3. Building-Block Stack Performance:**
The 1999 Stack Achieved 9% Higher Performance Than the 1998 Stack

- ERC cross-licensed 300kW and MW-Class products with MTU-expanding the potential market for the DFC.

- A compact, cost-effective power plant has been designed based on the "hot-box" stack module concept and substantial experience from Santa Clara proof-of-concept demonstration. The power plant will have $1/9^{th}$ the footprint of Santa Clara plant and is estimated to cost $1140/kW (1995 dollars) to the customer.

- Significant effort was mounted to gather market intelligence and to organize precommercial demonstrations. There is an emerging consensus that 200kW to 3000kW fuel cell units represent a significant size range for dispersed generators. ERC has therefore selected three distinct products for a wide market penetration at the earliest possible date (Figure 4).

- Under a separate program ERC designed a hybrid system using a non-combustion turbine that can achieve >70% system efficiency. This is expected to be the basis for second generation DFC products with significantly lower $/kW cost.

## Future Plan

With the objective of demonstrating market-responsive, reliable power plant(s), ERC has the following verification/demonstration plans:

1. Continue qualifying tests on subscale and product building-block stacks.

2. Build a conditioning/quality assurance facility to check out a 4-stack module at full power for 1000 hours. This facility will also allow stack module developmental testing and checkout testing for modules to be used in plant demonstrations.

3. Field test in the U.S. an operating 300kW (nominal) packaged power plant based on MTU hot-module concept. A test in Europe is scheduled for fourth quarter of 1999.

4. Conduct a field test on a megawatt-class prototype power plant(s) at a host site. Upon satisfying field test criteria, supply a market-entry megawatt-class plant. Discussions with several potential customers and hosts are currently in progress.

## Acknowledgement

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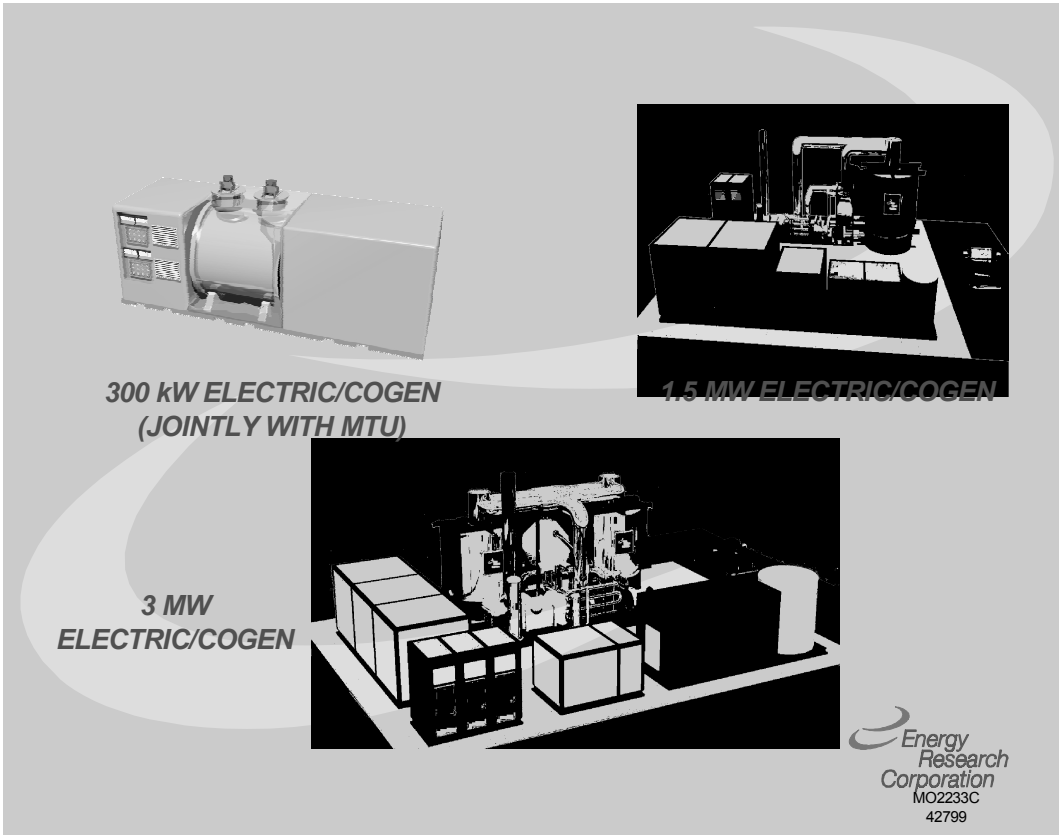


**Figure 4. ERC Direct Fuel Cell Products:**
A Range of Submegawatt and Megawatt Products are Planned to be Offered