



Evaluation of Field Performance of Residential Fuel Cells

Subcontract Number: AAD - 1 - 30605 - 12

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NREL Technical Monitor: Holly Thomas

Electric Distribution Transformation Program

2004 Annual Program and Peer Review Meeting,
October 28-30, 2003, Coronado (San Diego), California

Relevance to Problems and Needs

DoE Vision and CRN Demo Program

Grid 2030 Vision

- Three major elements:
- * national backbone...
 - * regional interconnections...
 - * local distribution mini-grids ...

Targets

- 2010: 100% of distribution systems allow DG ...fully integrated...
- 2020: Customer total energy systems for power, heating...
- 2030: Stationary power systems for customers
Decrease fossil fuels by 30%



Directly
Applicable

CRN RFC (*Residential Fuel Cell*) Demonstration Program:

- Evaluate the barriers to, and value of, RFC DG
- Install, collect, assess installation and field performance
- Investigate regulatory and institutional issues
- Make information available to co-op and DG community

DoE Roadmap and CRN Demo Program

CRN Co-op RFC Demo direct applicability to Roadmap:

Targets

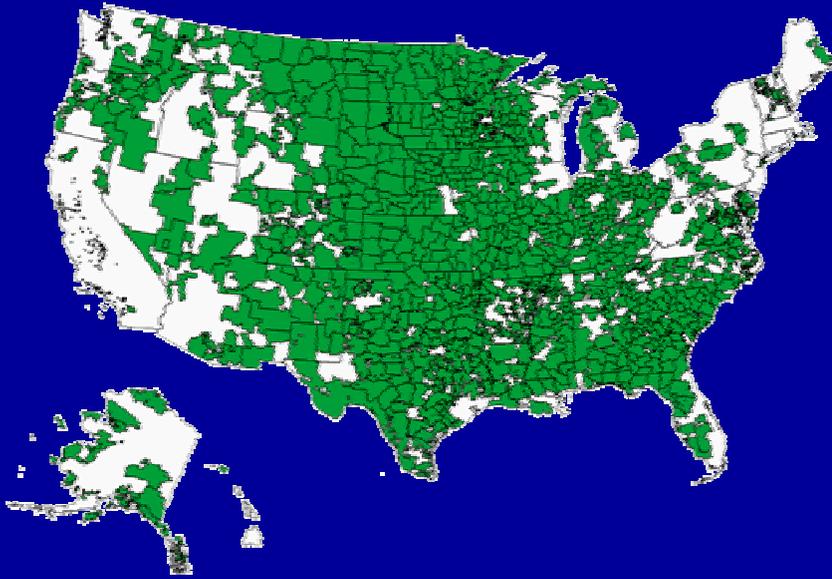
- T&D Losses 7%→ 4%
- Improve Efficiency by 3%
- Halving Losses
- Penetration on-site generation w CHP
- High efficiency DG devices

Challenges *receiving at least six votes*

- Increased power thru ROW's
- Collaborative...protocols market integration of DG
- Modeling of distribution systems
- Network integration of DG
- Standards for DG integration
- Low cost fuel cell
- Adequate operational and planning models
- RDD&D resulting in deployment of advanced technologies

This CRN Demonstration directly applies to these Roadmap targets and challenges

DoE Vision - Roadmap and Co-ops



- 36 million customers in 47 states
- 75 percent of nation's area with 45% of line miles
- 6 customers per line mile vs 33 for IOU's



Co-op growth rate twice that of IOU's



Consumer owned, responsiveness



View DG as needed solution; not as a 'problem'

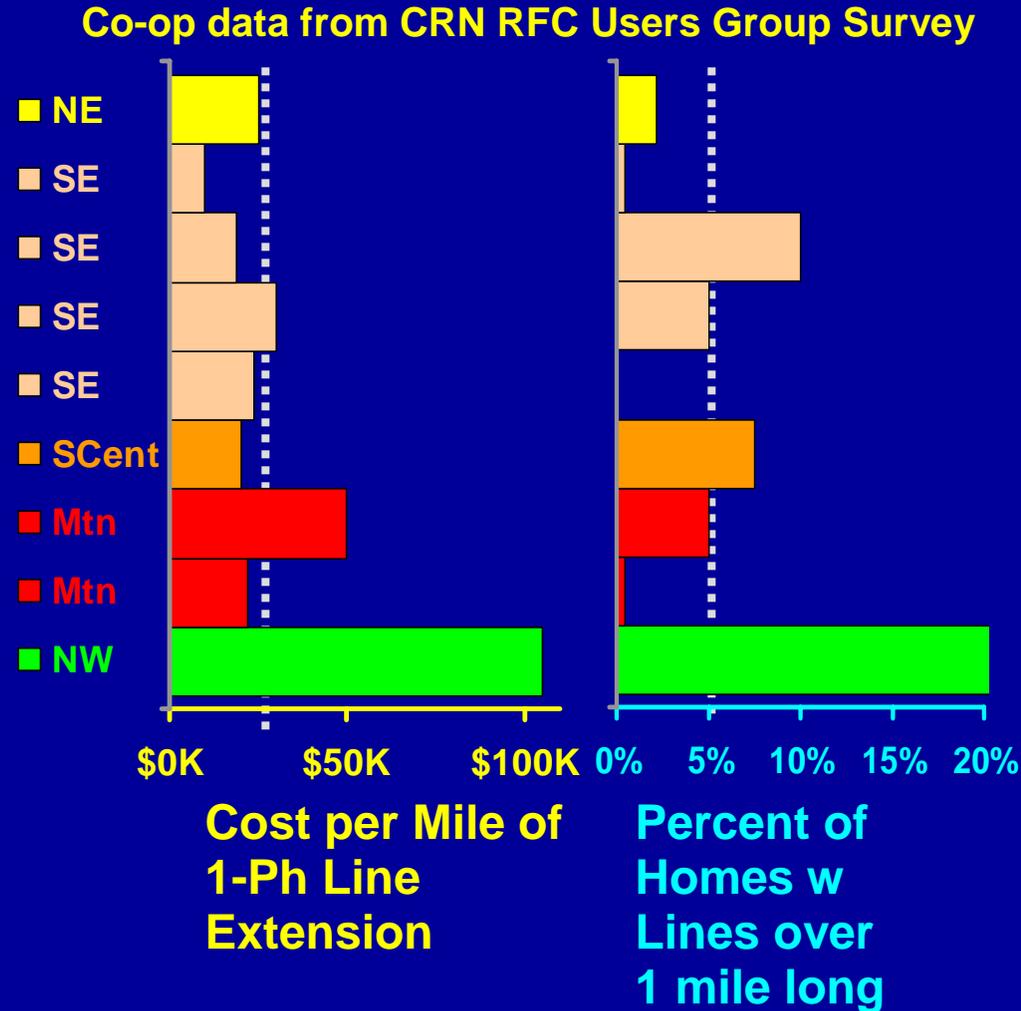
DoE Vision - Roadmap and Co-ops (cont'd)



Edge-of-the-Grid profile favors DG



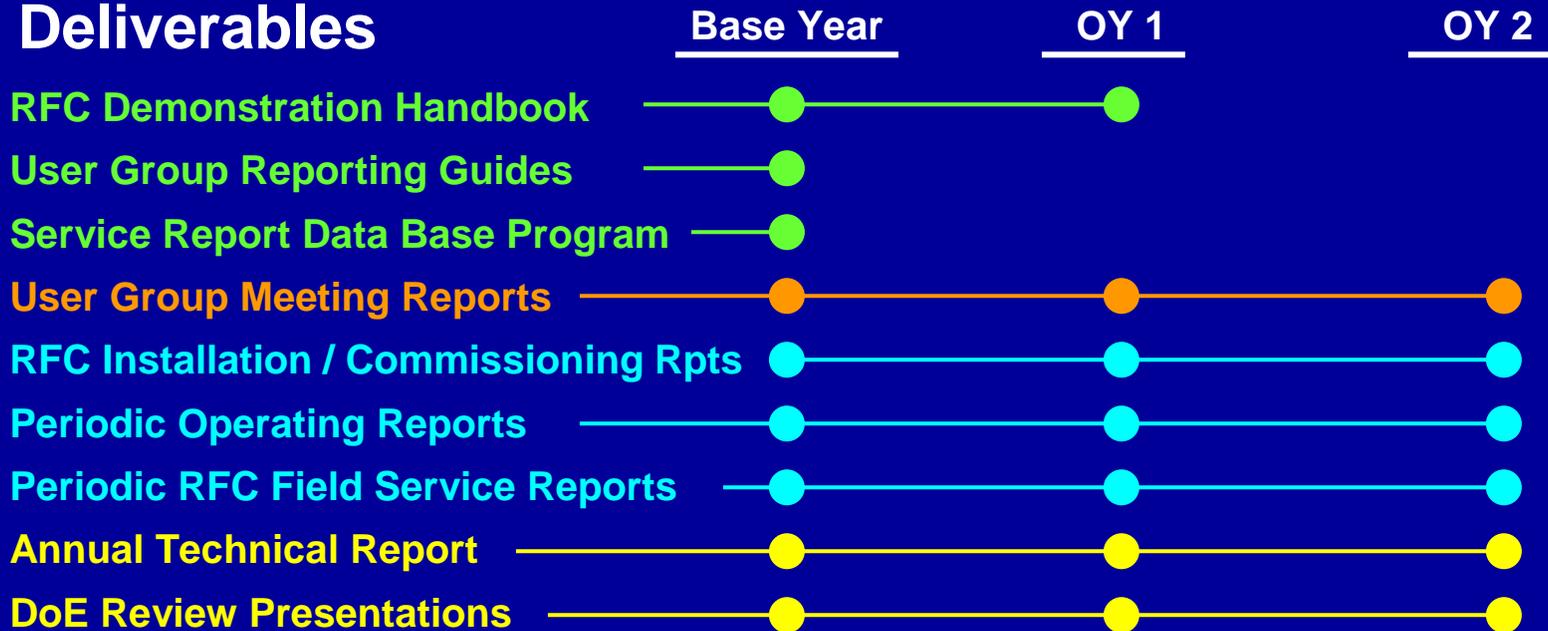
Remote Residence early-entry RFC market



Budget, Timeline and Deliverables

Life-Cycle Project Timeline

Deliverables



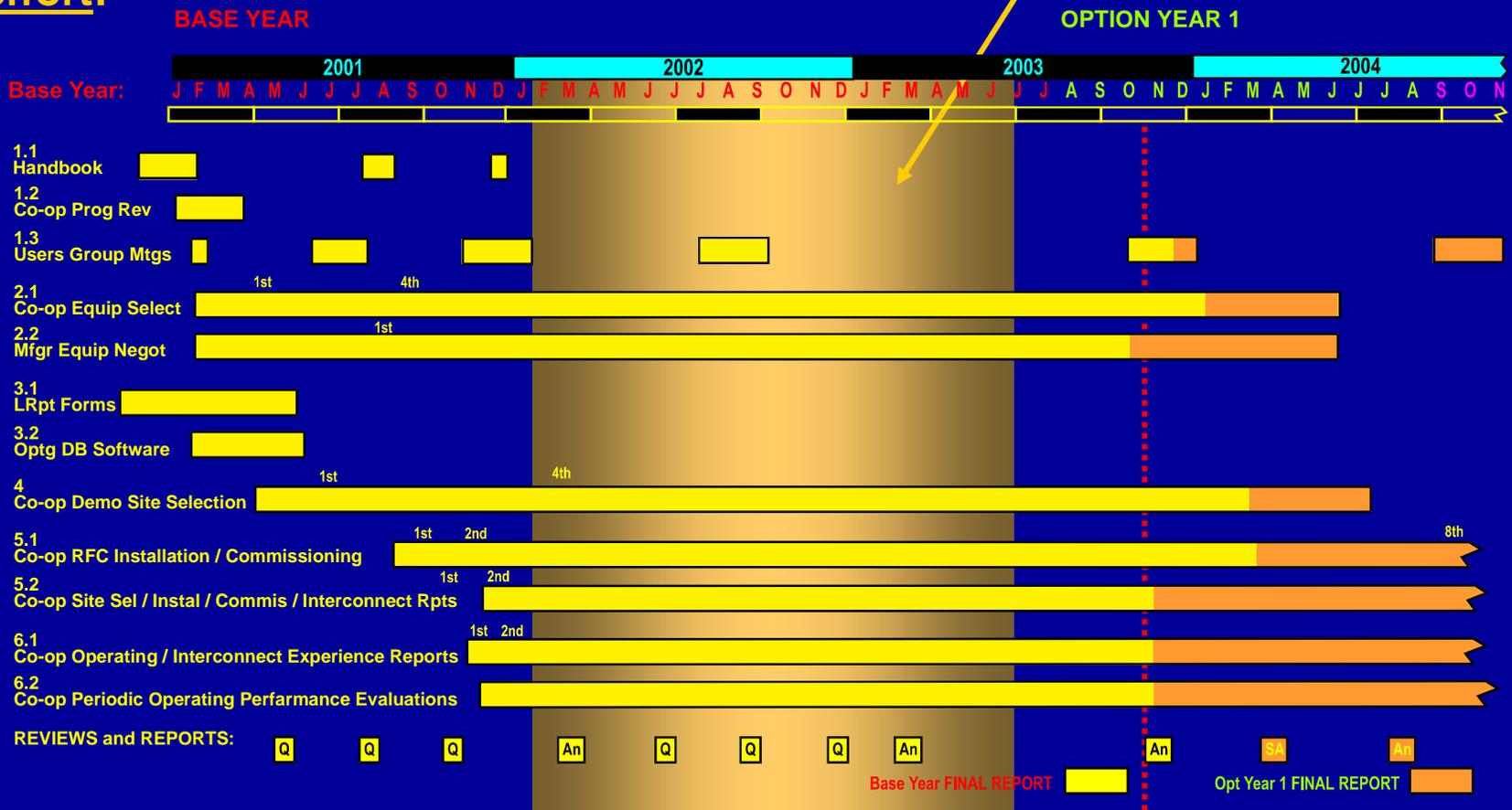
Budgets

	Total (\$K)	DOE/NREL	CRN
Base Year (Date-Date)	\$306	\$99	\$207
Option Year 1 (Date-Date)	442	93	349
Option Year 2 (Date-Date)	248	112	136
Total	\$996	\$304	\$692

CRN-DoE Demo Program Timeline

- Two units already installed and others now ramping up after initial manufacturer's delay.

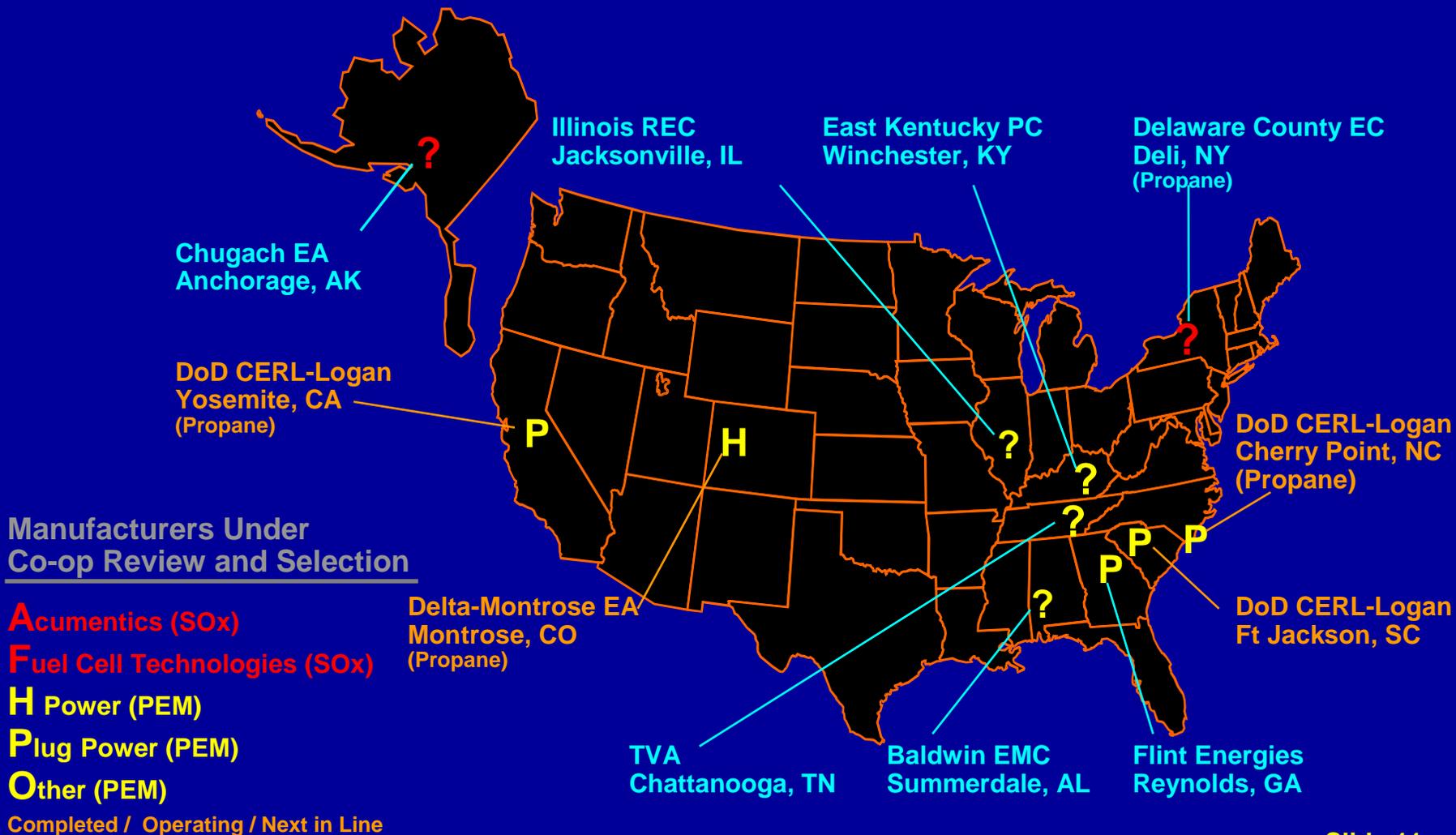
Manufacturer Roll-out Delay Issue (Now Over).
 Pause was in installations; not CRN Visioneering effort!



Technical Approach

Broad Demonstration Program Scale

- Wide range of sites, climates, electric interconnects, and manufacturers



Technical Approach

BASE YEAR

OPTION YEAR 1



Target Visioneering:

What do we have?
What do we need to get to RFC DG?

- ✓ Co-op Seminar on technology / needs
- ✓ RFC Demonstration Handbook
- ✓ NRECA DG Interconnection Handbook
- ✓ DG and other interconnect guides
- ✓ Extensive cost estimating spreadsheets
- ✓ Thermal recovery analysis
- ✓ RFC equipment needs
- ✓ Knowledge needs and data resources
- ✓ Market and sensitivity issues
- ✓ etc.

Protocols

RFC Users Group:

**Analysis, Seminars, Reviews,
and Reports**

What are the issues?
How do we solve them?
Are grid interconnects acceptable?
What is the mature DG market size?
What is the DG entrance strategy?

Analysis

Issues
and
Needs

Feedback

Co-ops Apply
RFC Distributed
Generation

Installation and field experience:

Did interconnects work well?
Did mfgs meet specifications?
What went right? What went wrong?
What can we improve?
What can we do to reduce customer costs?

Technical Approach (cont'd)

- **CRN RFC Demonstration Tool Kit**

Available to CRN Members, RFC Demonstration Participants, and to Manufacturers in overall demonstration program.

METERING AND INSTALLATION GUIDELINES 68 pages

REPORTING INSTRUCTIONS 52 pages

USER GROUP SPREADSHEET TOOLS:

- Detailed System Selection and Installation Cost Estimates
- MarketView Analysis Software
- Water and Space Heating Thermal Recovery Analysis
- etc.

USER GROUP ANALYSIS / REVIEWS Over 50 presentations and reviews

- Electrical grid interconnect and metering
- NRECA DG interconnection guidelines and status
- Electrical interconnect for Customer Critical Loads
- RFC laboratory testing protocols
- Thermal recovery issues and implementation
- Market size, sensitivity, catalog issues
- Remote market size and comparative technology cost analysis
- PEM versus SOx features and dispatch cost issues
- etc.



**Progress
and
Accomplishments**

Results and Deliverables: Base Year

- **CRN RFC Demo Handbook**

168 pages:

Program, Elect interconnect, Fuel incl methanol,
Instrumentation, Thermal recovery, Markets, etc.

Supplements: Motor start, Thermal recovery

NREL version at: <http://www.nrel.gov/docs/fy02osti/32455.pdf>

- **CRN RFC Demo Program Annual Report**

127 pages:

Overview, Key deliverables and results, Grid interconnect,
Fuel, Thermal issues and resolution, Key market results, etc.

Full Version will be posted on NREL site

- **User Group Meeting Reports**

- **Demo Participant Letter Report Guides**

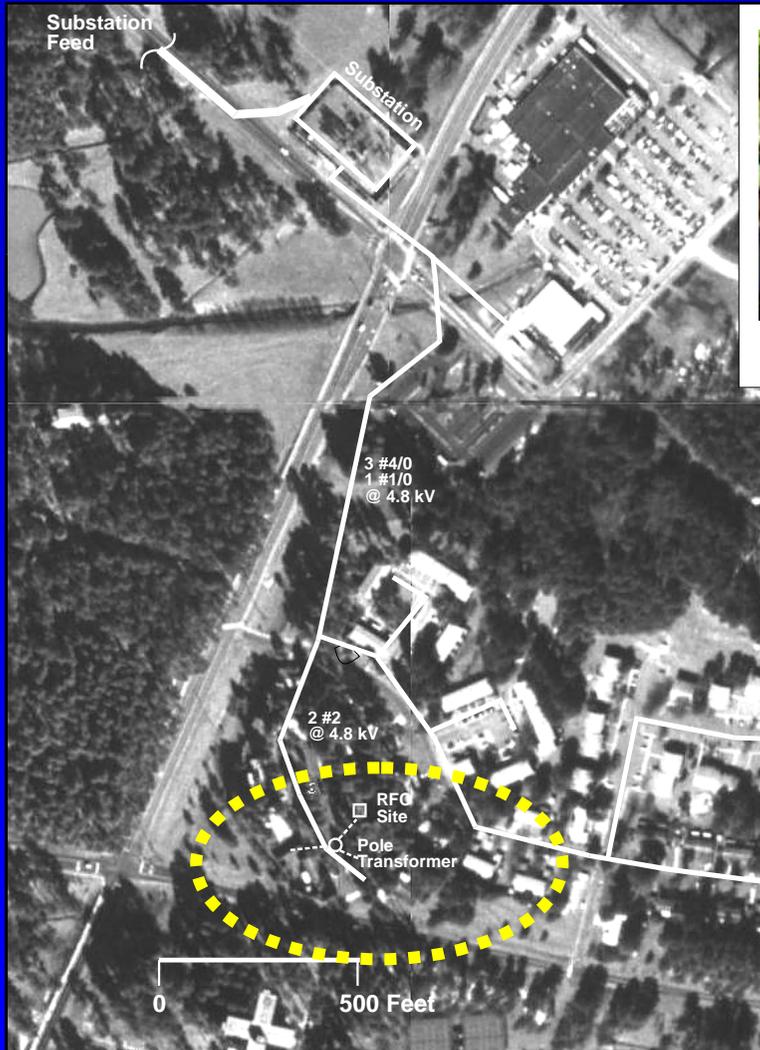
- **Service Reporting Data Base Setup**

- **Installation Reports**

- **DoE Reporting Presentations**



Grid Parallel Interconnect: Typical Analysis



RFC Installation



Site Interconnect Pole Transformer

Fort Jackson Grid Parallel Interconnect

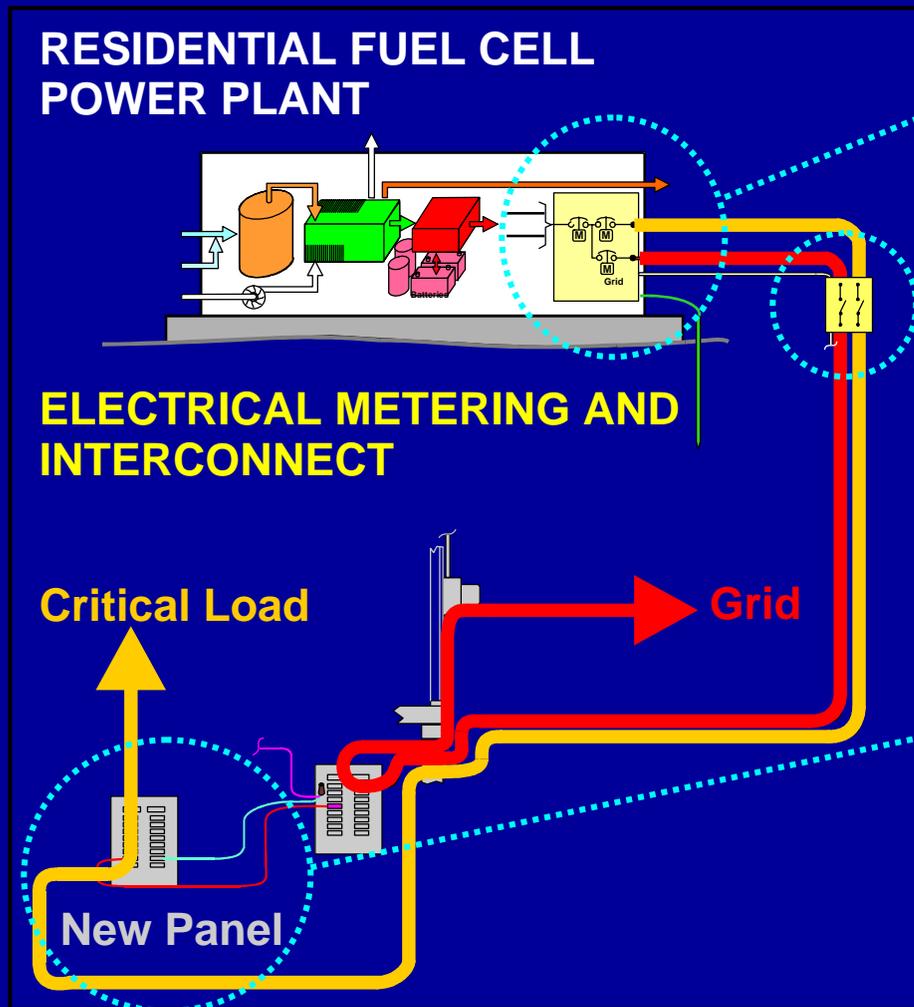
- Typifies co-op
- 2100' from substation
- Plug Power RFC
- 2.5 to 5 kW output
- 3 homes on pole side

Initial Results:

exported power to other homes, and exported to grid through pole Xfmr without any issues.

Over 125 Plug RFCs have more than 1.1 million hours operation without interconnect issues.

Grid Parallel Interconnect: Barrier Efforts



1. Reviewed manufacturer grid interconnection system. ✓OK

2. \$12 A/C pullout disconnects.
• Potential \$320 savings



X 2 = DPDT

3. Prefab Customer Critical Load interconnect.

- Saves \$185 of installation labor
- User friendly



Grid Parallel Interconnect: Dispatch Barrier

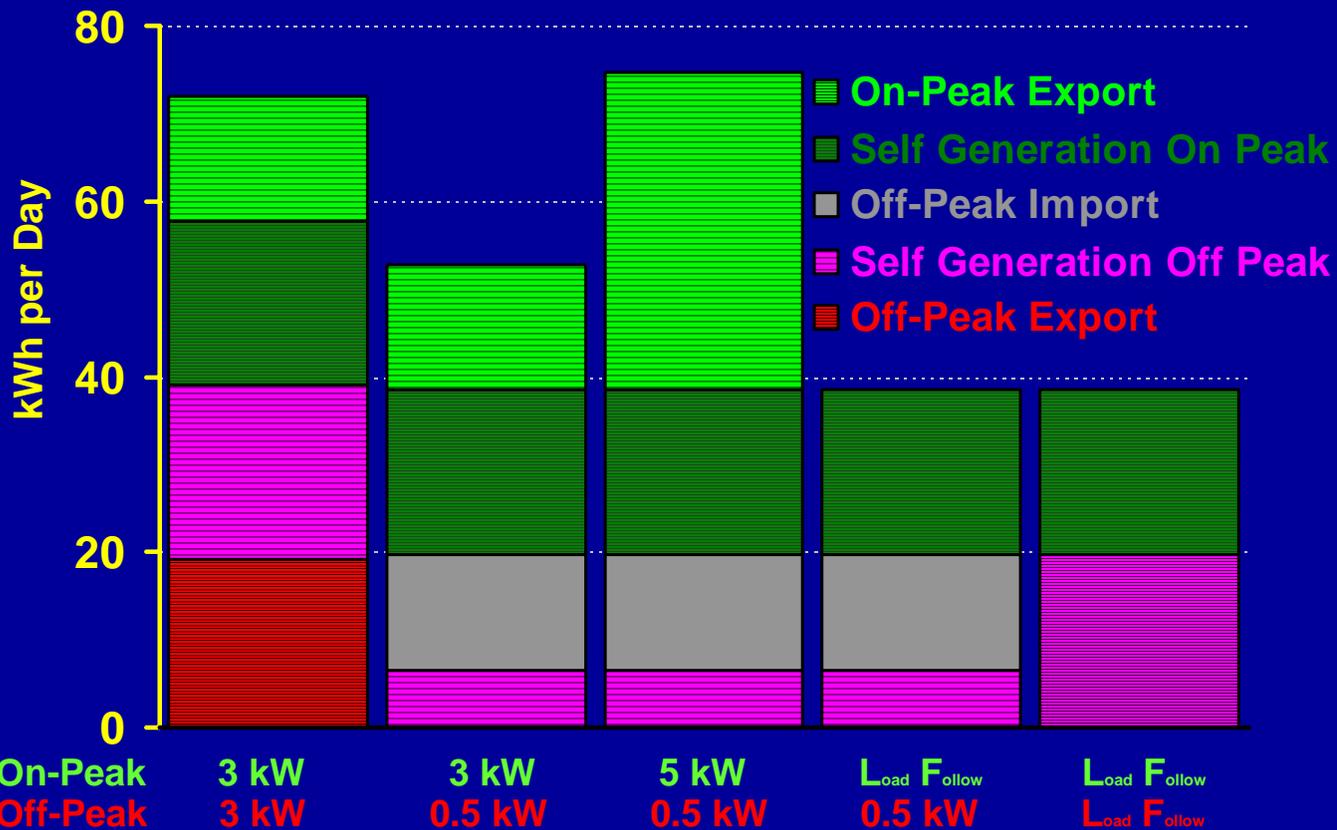
RFC Dispatch and Import-Export Estimator



Site Data

Incremental Annual Customer Cost of Running Fuel Cell at Dispatch versus Not Running RFC

PEM Natural Gas	\$295	-\$80	-\$165	\$5	\$150
Propane	\$1,805	\$815	\$1,195	\$625	\$1,015
SOx Propane	\$905	\$240	\$345	\$200	\$465



Catalog Size Impact

Catalog is only “large” RFC unit:

5 kW unit = \$5,000 + \$1,500 installation

If add a “small” RFC unit

5 kW unit = \$5,000 + \$1,500 installation

+

2.5 kW unit = \$3,800* + \$1,500

* Calculated by Economy of Scale modeling

If decide to make only “small” RFC units

Dual 2.5 kW = \$5,600 + \$2,000 installation

+

2.5 kW unit = \$2,800 + \$1,500 installed

* Calculated by Partial Economy of Production modeling

RFC Economic Market
per 1,000 Dwellings

2.4

8.7

17.2

Note: Electric Prices: Year 2000 w 10% Increase
Propane Price: 115 ¢/Gallon Average
Annual Maintenance: \$300 per year
Customer Intangible Benefits: \$30 / Month

Natural Gas Prices: Year 2000 less \$1.00 / Mil Btu
Low Region = 87¢ High Region = 138¢
Propane Tank if required: \$1,325
Heat Pump Duct Heater is available: \$900

RFC Installation Cost: Barrier Resolution

RFC System and Installation Cost Estimator



Typical Residential Fuel Cell Installation

Site Pad, etc	\$1,150
Natural Gas Fuel	850
Electrical Interconnect	2,280
Thermal Recovery	3,630
Water Makeup	1,130
TOTAL	\$9,040

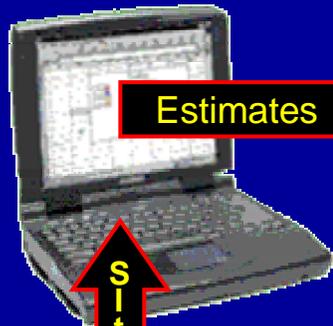
\$ / kW at 3 kW = \$3,010

Extensive barrier resolutions underway:

- ✓ Modeling to improve concepts
- ✓ Field data to confirm estimator
- ✓ Alternate materials to reduce cost or labor
- ✓ Standardized installation concepts
- ✓ Clearer installation guidelines
- ✓ Simple installation sketches for contractors
- ✓ Presupply of parts to reduce field labor
- ✓ Prefabrication to reduce field labor

Thermal Recovery: Economic Barriers

RFC Thermal Recovery Estimator



Estimates

Site Plan

Water Heating

NGas Water Heater

\$283 \$ per Year Credit

Propane Water Heater

\$486

Electric Water Heater

\$385

Columbus, OH Space Heating: NGas Furnace

\$323

Propane Furnace

\$555

Heat Pump

\$263

Atlanta, GA Space Heating: NGas Furnace

\$198

Propane Furnace

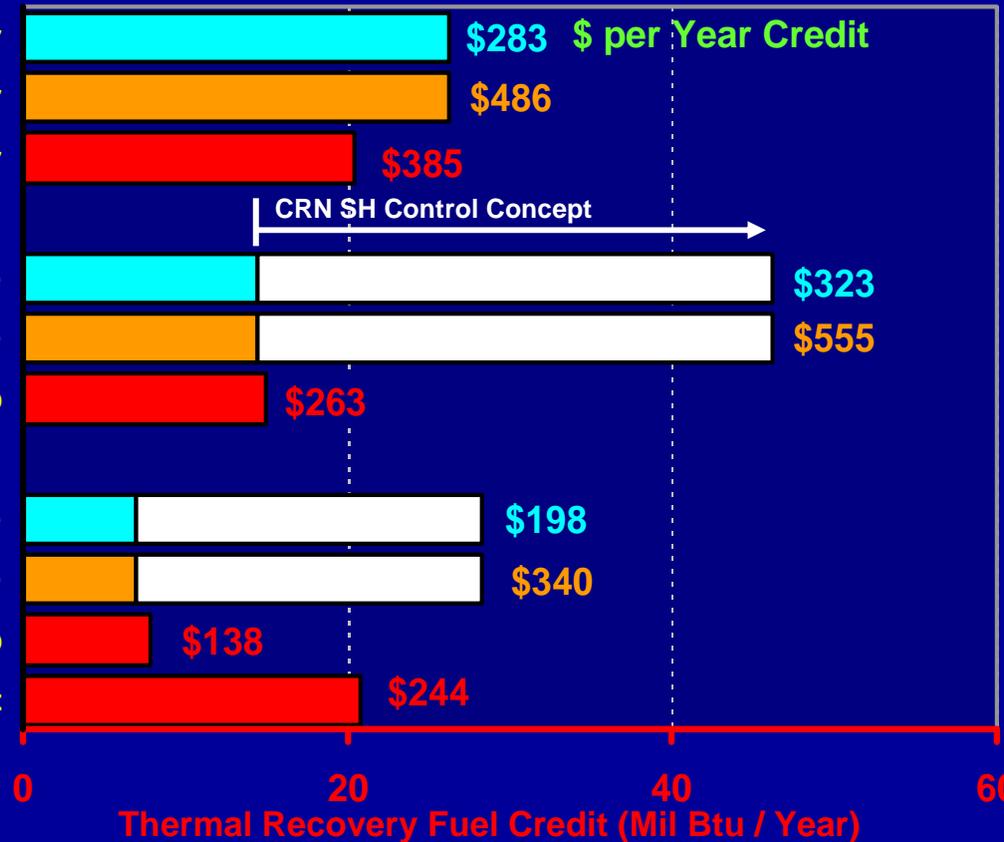
\$340

Heat Pump

\$138

Resistance Heat

\$244



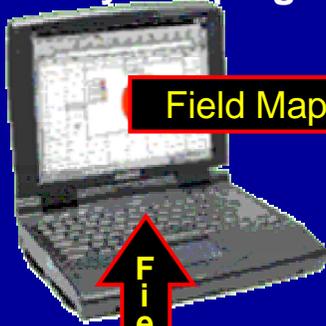
- Thermal Recovery can yield significant fuel savings

$$\text{Fuel After Thermal Recovery} = \$1,050 - \$283 - \$323 + (0.16 \times \$\text{TherRcvyInstalled}) \quad 1.5 \text{ kW Natural Gas}$$

- CRN system concepts greatly increase RFC Space Heating potential

Thermal Recovery: Water Heating Mapping

RFC Field Thermal Recovery Mapping



Field Map

Field Data



Courtesy LoganEnergy

Chart 1
Thermal Recovery Inlet and Outlet Temperatures

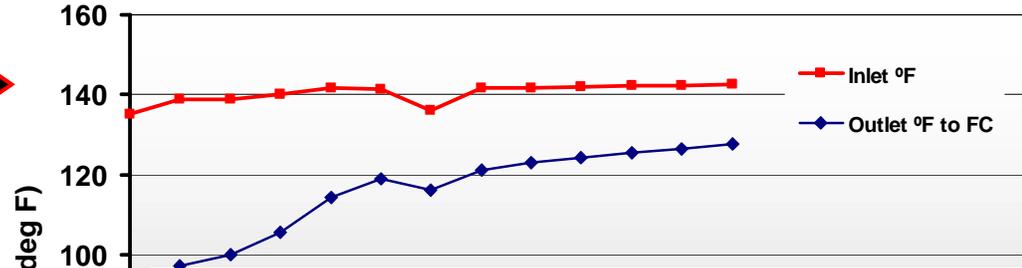
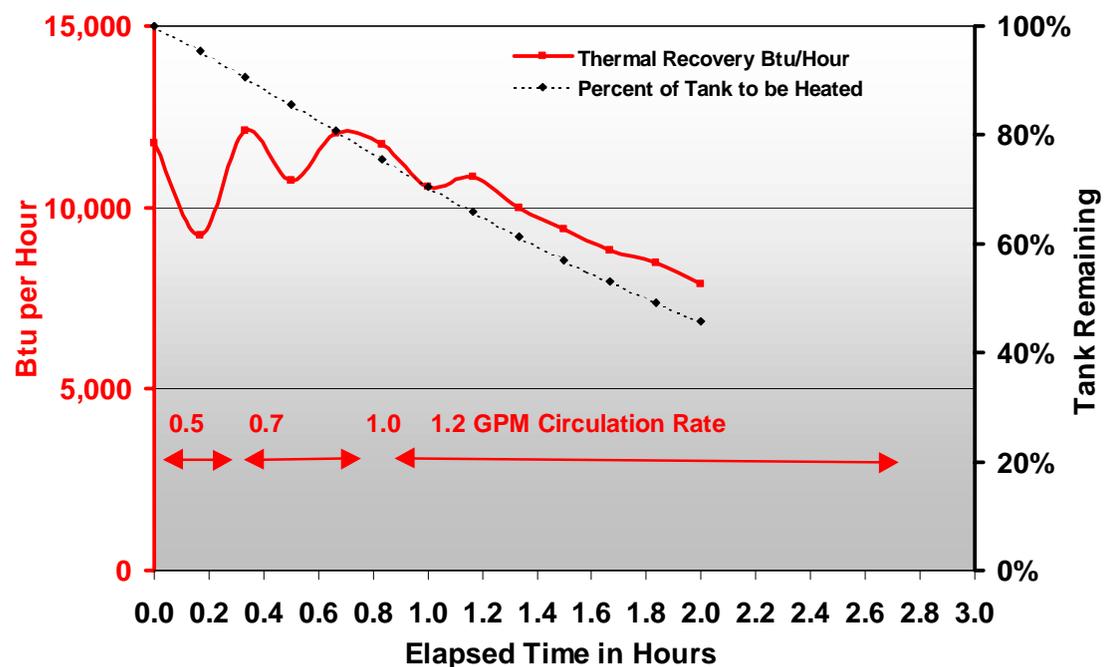


Chart 2
Thermal Recovery Heat Transfer in Btu per Hour



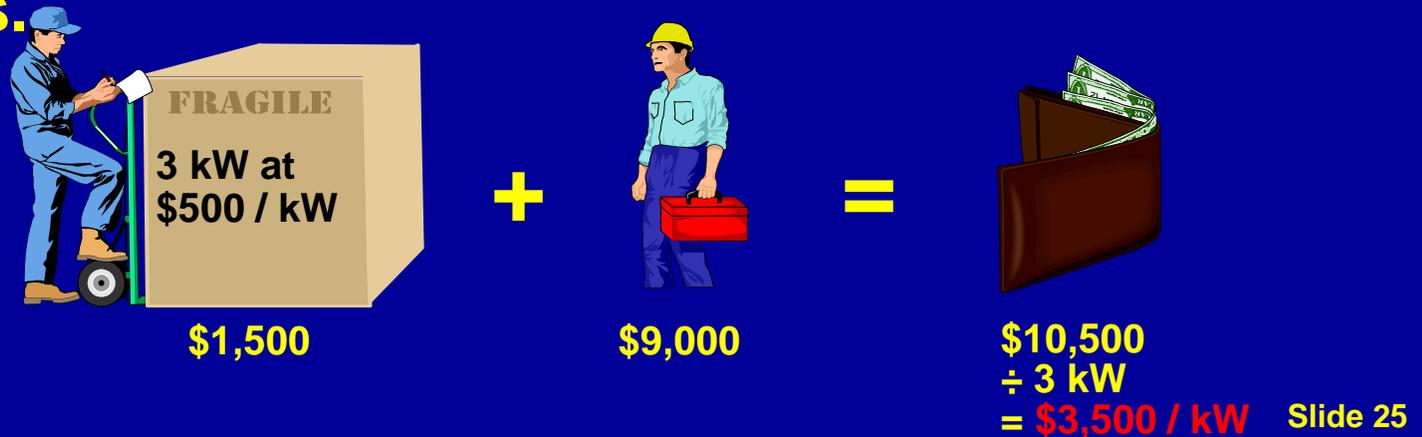
Planned FY04 Activities

- **Continue RFC field installations**
 - Collect, analyze Installation Costs
 - Monitor grid Parallel field performance
 - Monitor RFC performance and actual busbar Efficiencies
 - Examine differing types of Thermal Recovery systems
 - Accumulate and process Service Experience
- **Continue RFC barrier efforts**
 - Implement alternate grid disconnects
 - Implement less expensive Customer Critical Load Panel
 - Review and improve Thermal Recovery installation practices
 - Develop prefabricated loop for Thermal Recovery sites
 - Work propane Btu and Odorant issues
 - Continue interface with manufacturers re catalog, etc.
- **Continue User Group efforts**
 - Increase attention on Installation Cost issues
 - Implement a Space Heating thermal recovery site
 - Increase attention to Early Entrance DG Market planning
- **Continue collaborative outreach**

Impacts and Benefits:
Affordability
Reliability
Security

Vision and Roadmap CRN RFC Metrics

- Each kW of RFC DG capacity eliminates equivalent T&D line losses. *10% RFC DG = 220,000 MW*
- RFC CHP incremental-fuel-to-electric efficiencies readily reach 60+ percent.
- RFC Dual Mode freedom from grid outages is a key consumer benefit. *Ice storms, hurricanes, etc.*
- Customers buy an installed Black Box. Installation experience just as important as \$/kW technology targets.

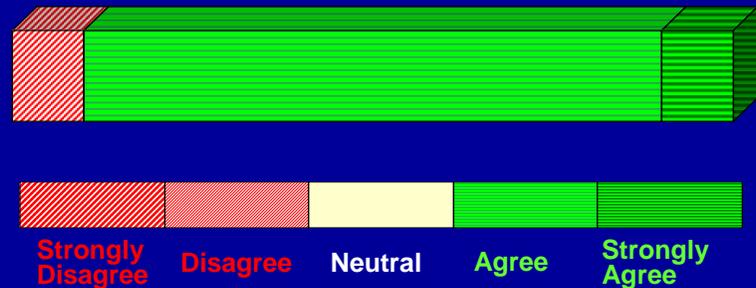


Vision and Roadmap CRN Metrics (cont'd)

- RFC's can make an excellent grid storage device, under study in CRN demo program.

CRN RFC Demo Program: RFC User Group Co-op Survey

OK for RFC to RELY on grid for BATTERY CHARGE power during NIGHT-TIME?



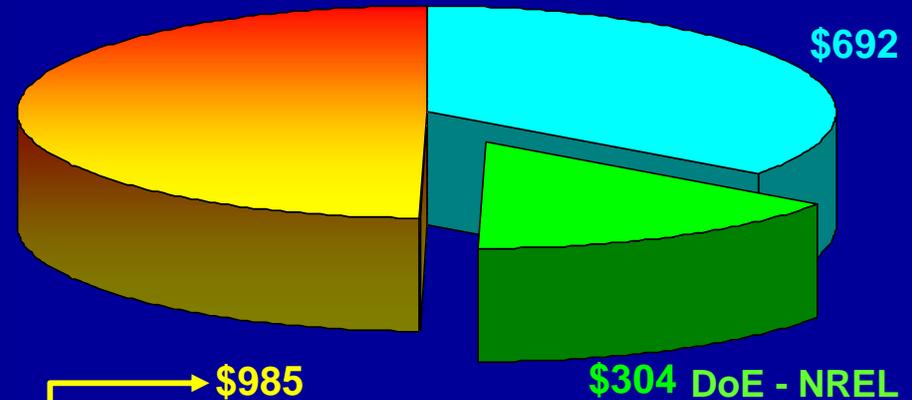
Collaboration, Interactions and Outreach

CRN Program Collaboration

State SOx Site Funding	\$150 K??
DoD Mil Base Sites	\$240
DoD CERL ConcurTech RFC Testing	\$160
EPRI RFC UG + Data	\$100
NRECA DG Interconnect Handbook	\$100
CRN Customer DG Focus Groups	\$80
CRN, etc Added Funding to Date	\$145
Additional Co-op Site Funding	\$160

\$985 K

- CRN Contract
- DoE - NREL
- Collaboration & Supplements



**DoE-NREL Substantial Leveraging:
15% of \$1.98 Million Total**

Collaboration and Outreach

- **Co-op demos include a broad range of public awareness programs and outreach** (*commissioning ceremonies, open houses, local group presentations, site tours, brochures, bill mailers, etc.*)
- **Presentations to: co-op and industry working groups, DoE meetings, Joint Co-op/EPRI meetings, Fuel Cell Manufacturers Group, etc.**
- **RFC User Group meetings with manufacturers**
- **Significant joint effort with DoD-CERL**
- **Applicable information posted on NRECA - CRN websites**
- **NRECA Annual Meeting displays/presentations reach over 5,000 senior co-op management and Directors**

Collaboration and Outreach (cont'd)

- **NRECA DG Interconnect Handbook**

105 pages:

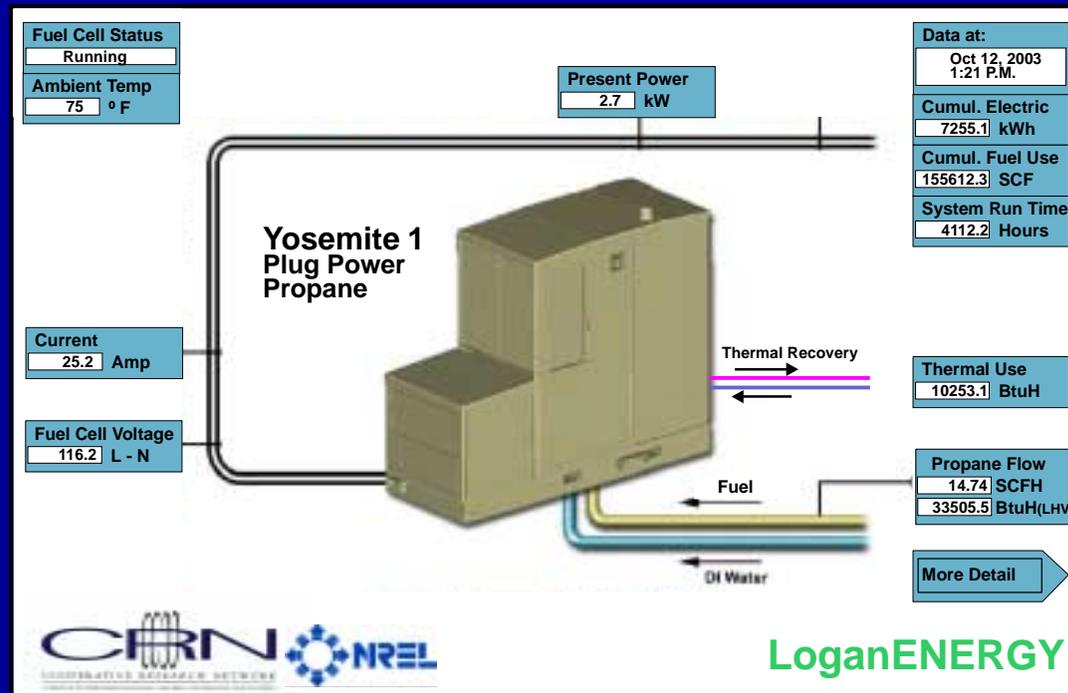
P1547, Explanation, Why needed, Safety importance, How to implement, etc.

Full Version at: <http://www.nreca.org/nreca/Policy/Regulatory/DGToolkit/DGApplicationGuide-Final.pdf>

Application Guide for Distributed Generation Interconnection
The NRECA Guide to IEEE 1547



- **Real-time internet access to some field units**



A satellite image of Earth at night, showing city lights and a grid overlay. The image is dark blue with bright yellow and white lights representing cities and urban areas. A grid of white lines is overlaid on the image, likely representing a coordinate system or a specific region of interest. The text "Thank You" is written in large, bold, yellow letters on the left side of the image.

Thank You