



# Evaluation of Field Performance of Residential Fuel Cells

Subcontract Number: AAD - 1 - 30605 - 12

Principal Investigator: Edward Torrero, CRN Arlington, VA  
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

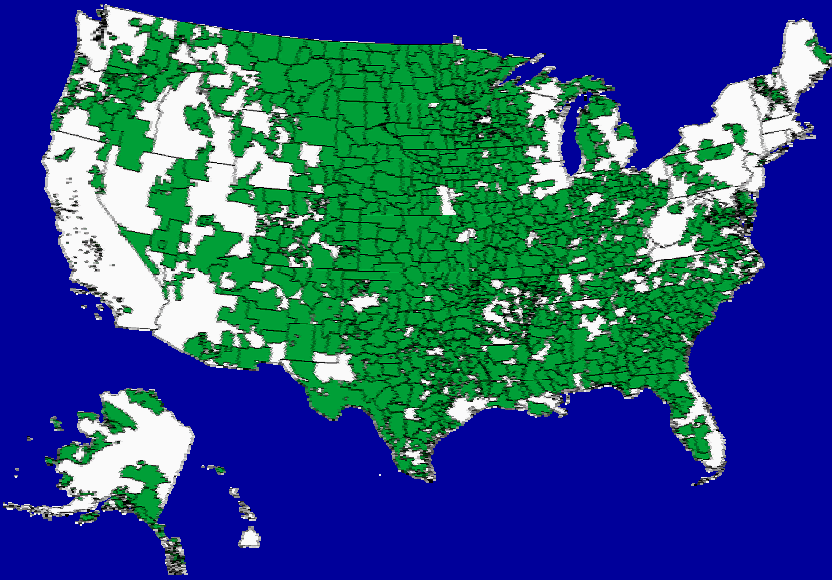
- T&D Losses 7%→ 4%
- Improve Efficiency by 3%
- Halving Losses
- Penetration on-site generation w CHP
- High efficiency DG devices

## 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'**

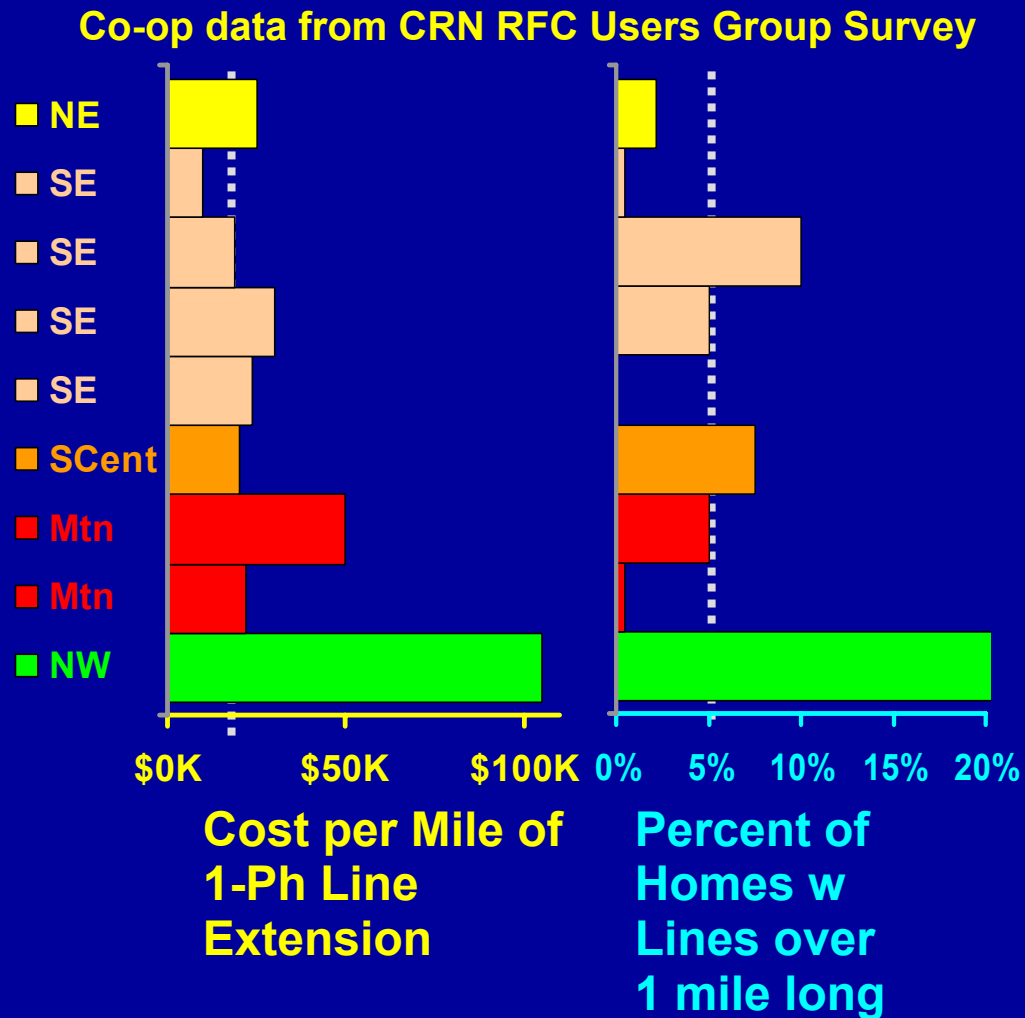
# DoE Vision - Roadmap and Co-ops (cont'd)



**Edge-of-the-Grid profile favors DG**



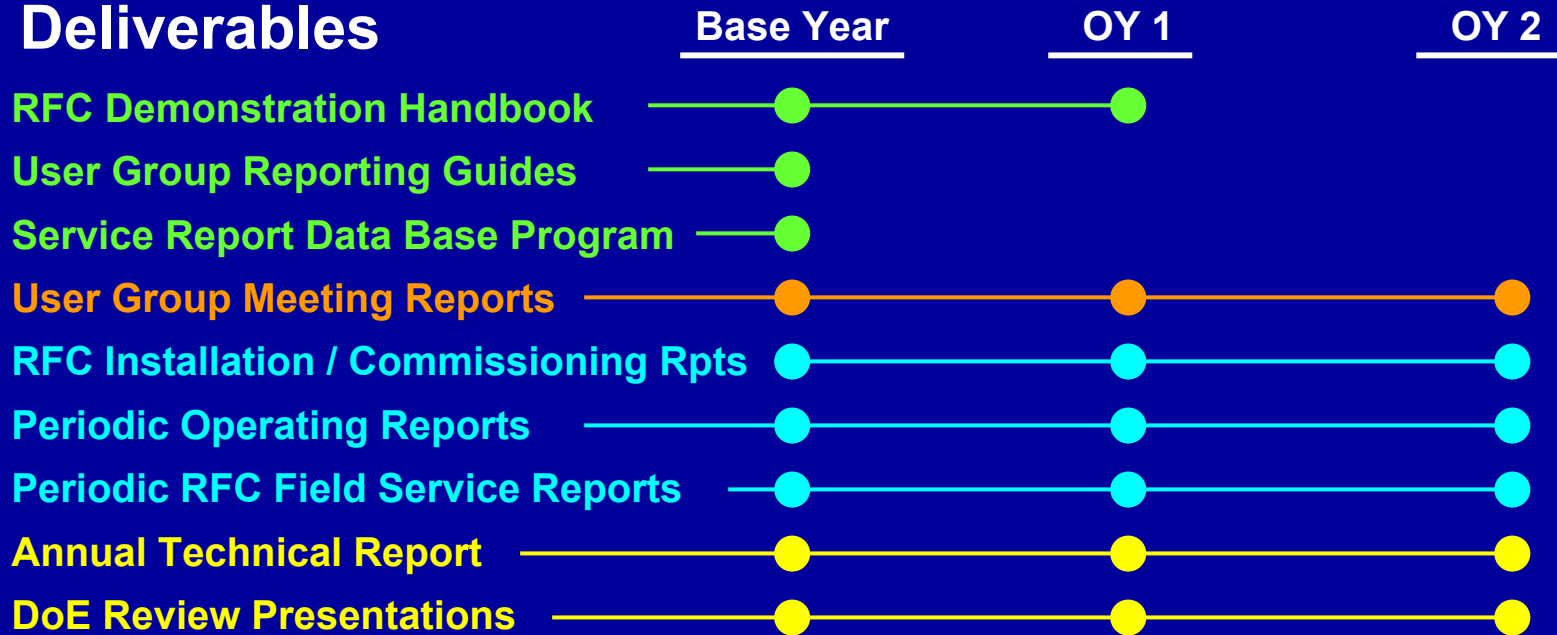
**Remote Residence early-entry RFC market.**



# **Budget, Timeline and Deliverables**

# Life-Cycle Project Timeline

- Deliverables**



- Budgets**

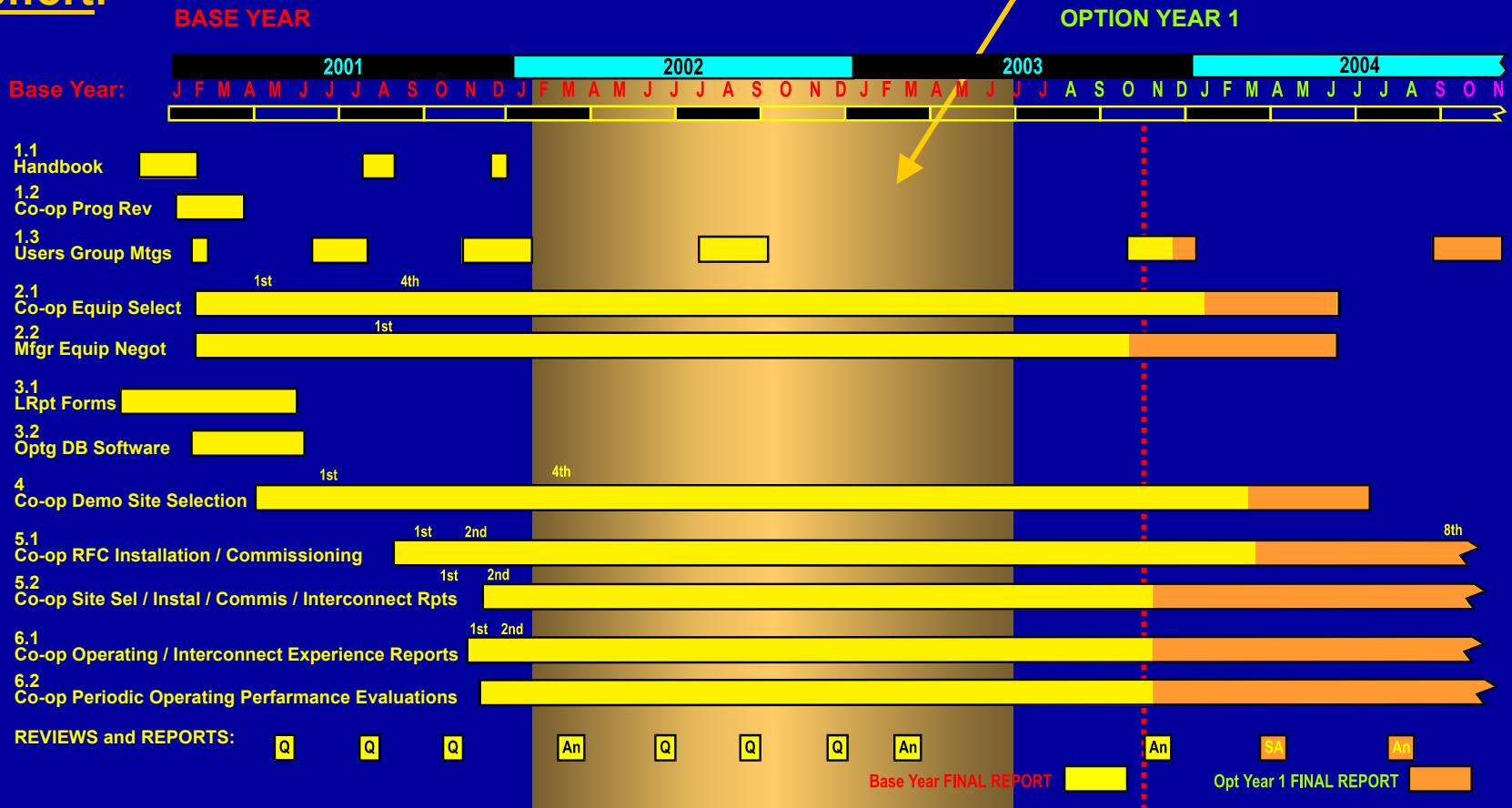
	Total (\$K)	DOE/NREL	CRN
Base Year (Date-Date)	\$306	\$99	\$207
Option Year 1 (Date-Date)	442	93	349
Option Year 2 (Date-Date)	248	112	136
<b>Total</b>	<b>\$996</b>	<b>\$304</b>	<b>\$692</b>



# CRN-DoE Demo Program Timeline

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

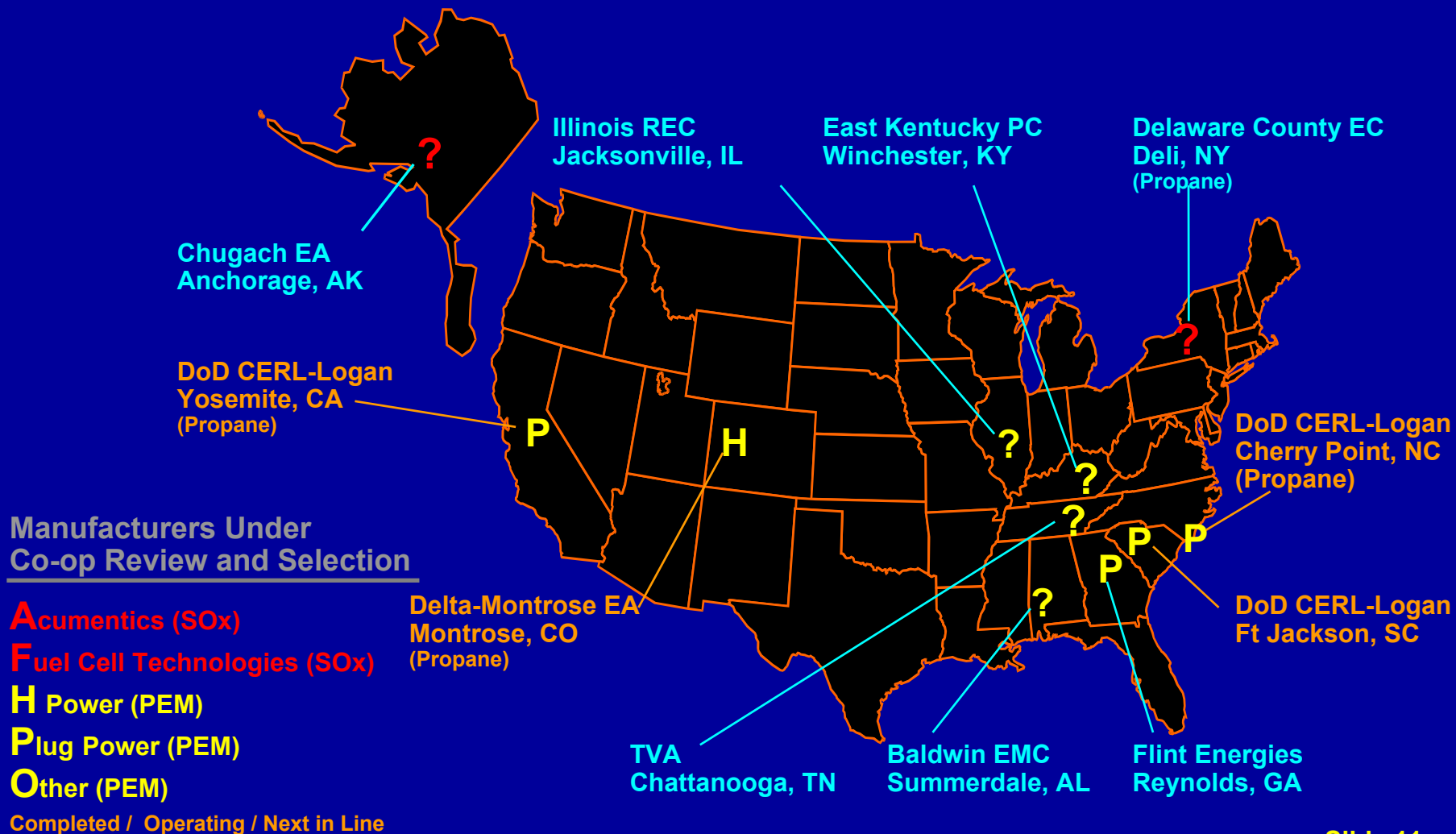
Manufacturer Roll-out Delay Issue (Now Over).  
 Pause was in installations; not CRN Visioneering effort!



# 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

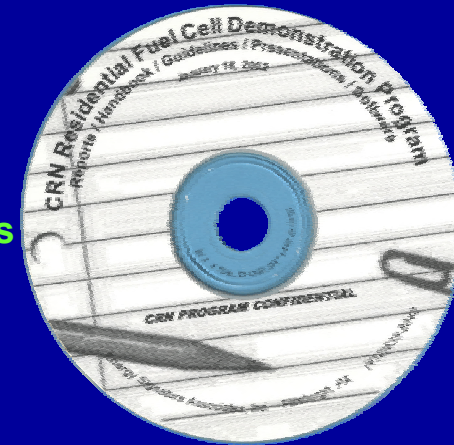
**REPORTING INSTRUCTIONS** 52 pages

**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**

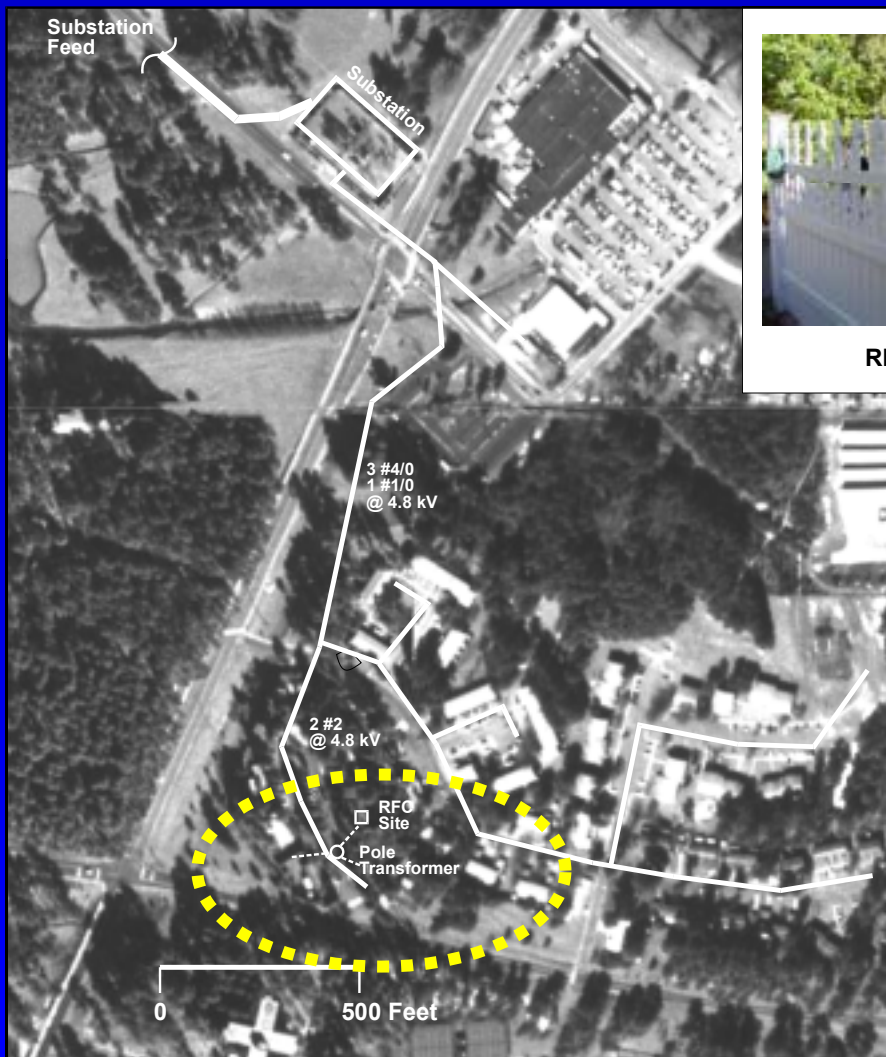
- **Service Reporting Data Base Setup**

- **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

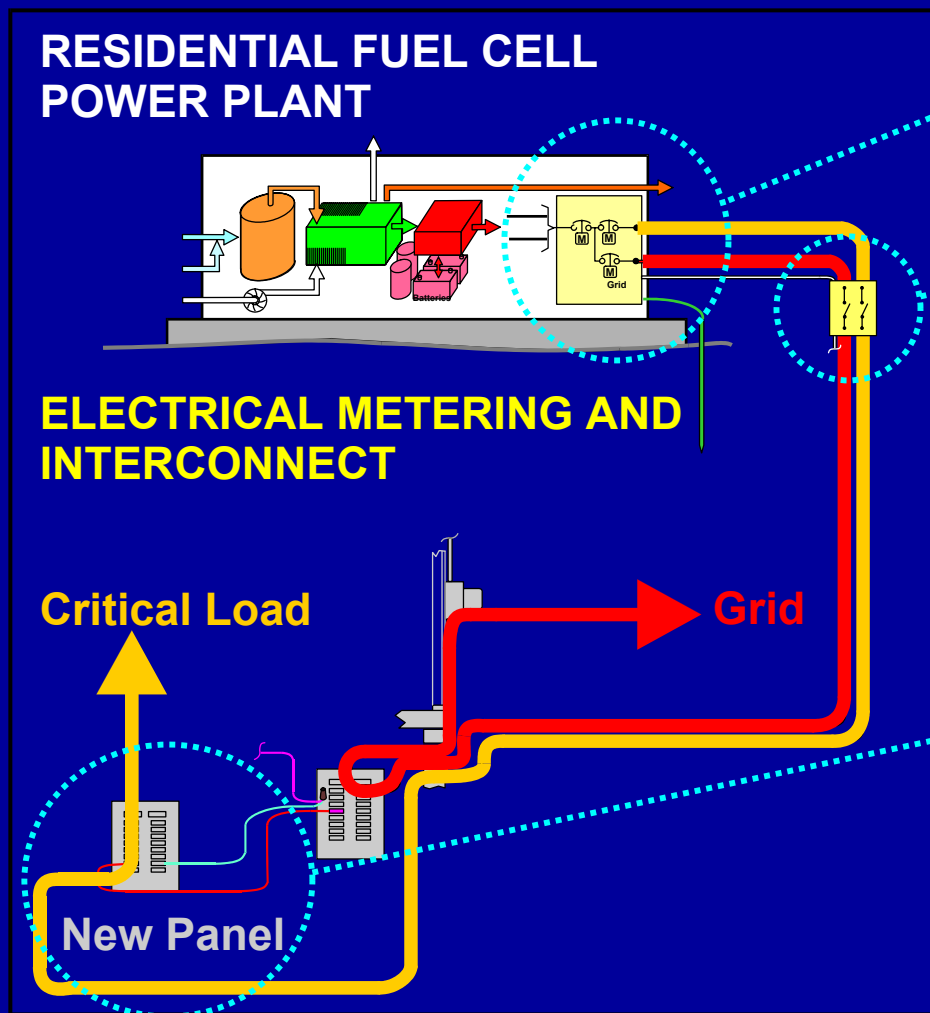
## Initial Results:

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

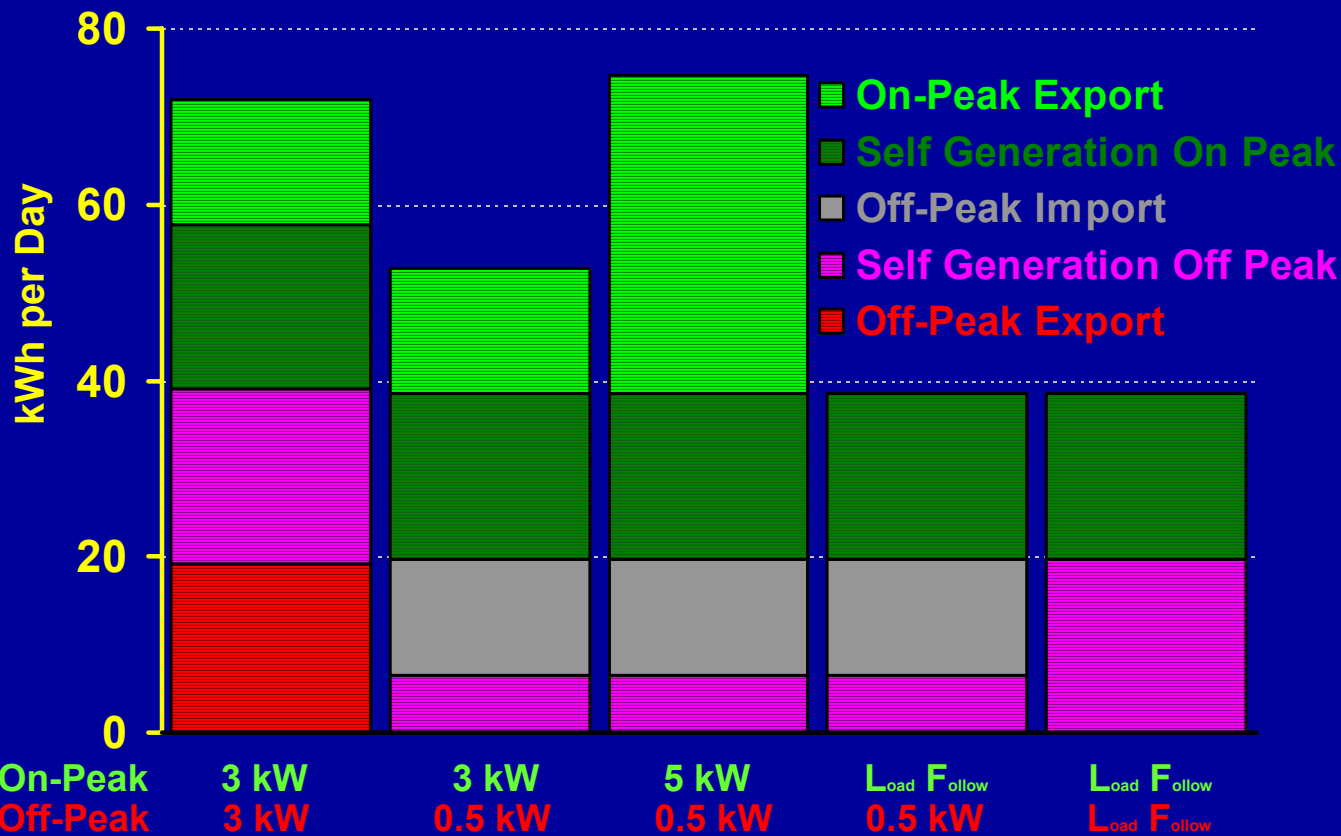
RFC Dispatch and Import-Export Estimator



Site Data

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

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

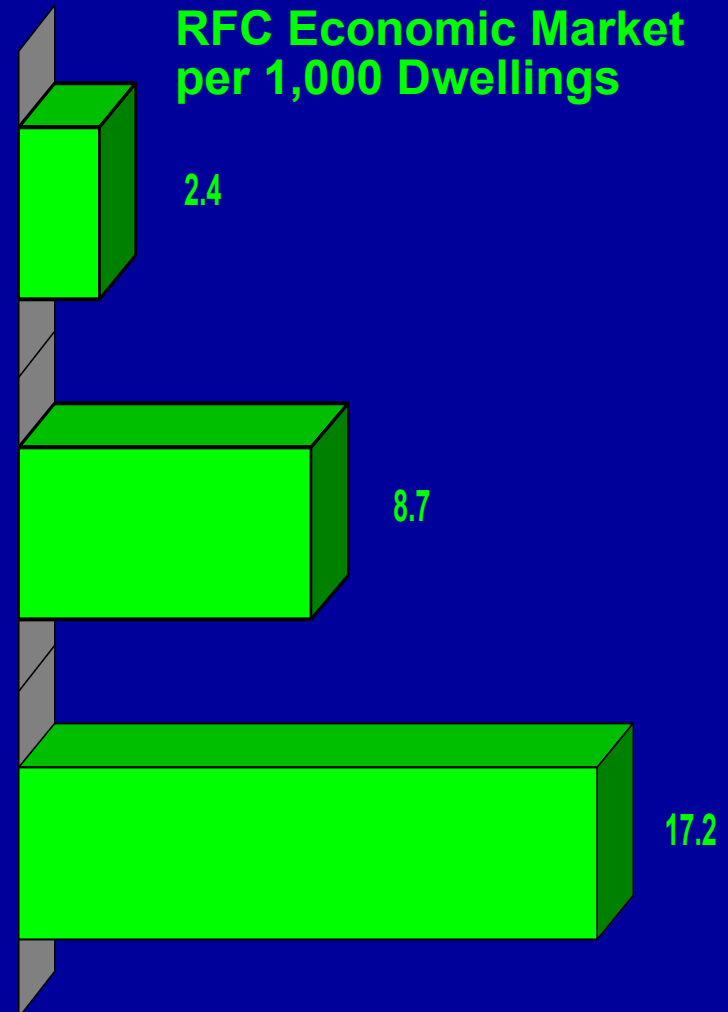
Dual 2.5 kW = \$5,600 + \$2,000 installation

+

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

\* Calculated by Partial Economy of Production modeling

RFC Economic Market  
per 1,000 Dwellings

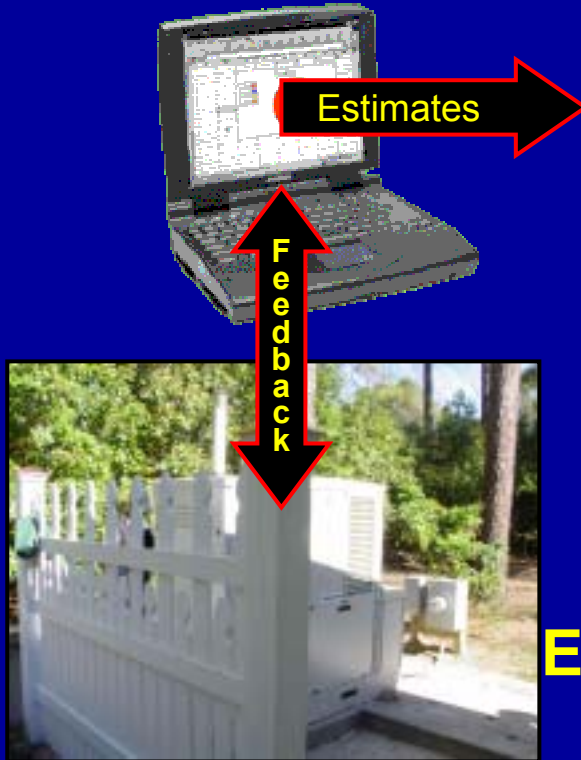


Note: Electric Prices: Year 2000 w 10% Increase  
Propane Price: 115 ¢/Gallon Average  
Annual Maintenance: \$300 per year  
Customer Intangible Benefits: \$30 / Month

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
<b>TOTAL</b>	<b>\$9,040</b>

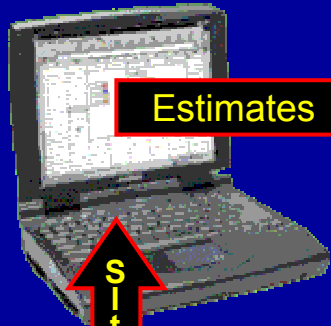
**\$ / kW at 3 kW = \$3,010**

## 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

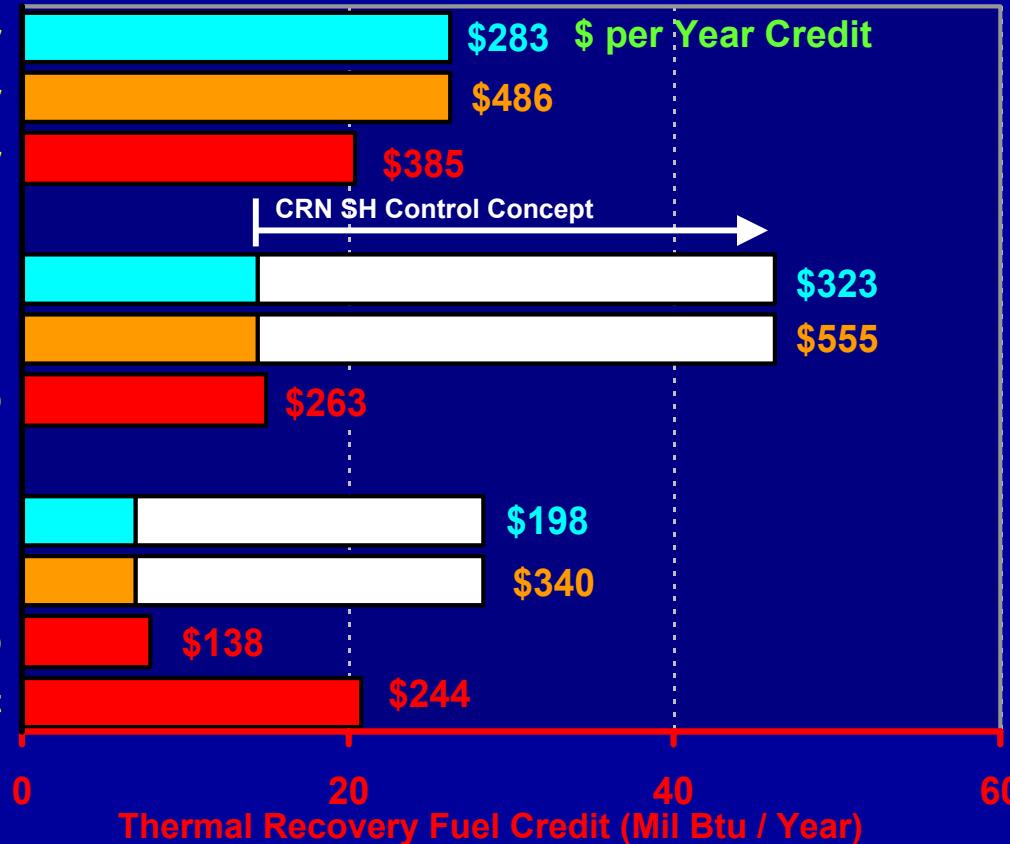
\$340

Heat Pump

\$138

Resistance Heat

\$244



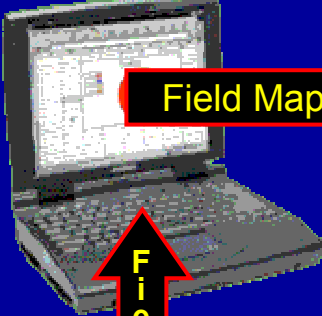
- Thermal Recovery can yield significant fuel savings

$Fuel\ After\ Thermal\ Recovery = \$1,050 - \$283 - \$323 + (0.16 \times \$TherRcvlyInstalled)$  1.5 kW Natural Gas

- CRN system concepts greatly increase RFC Space Heating potential

# Thermal Recovery: Water Heating Mapping

RFC Field Thermal Recovery Mapping

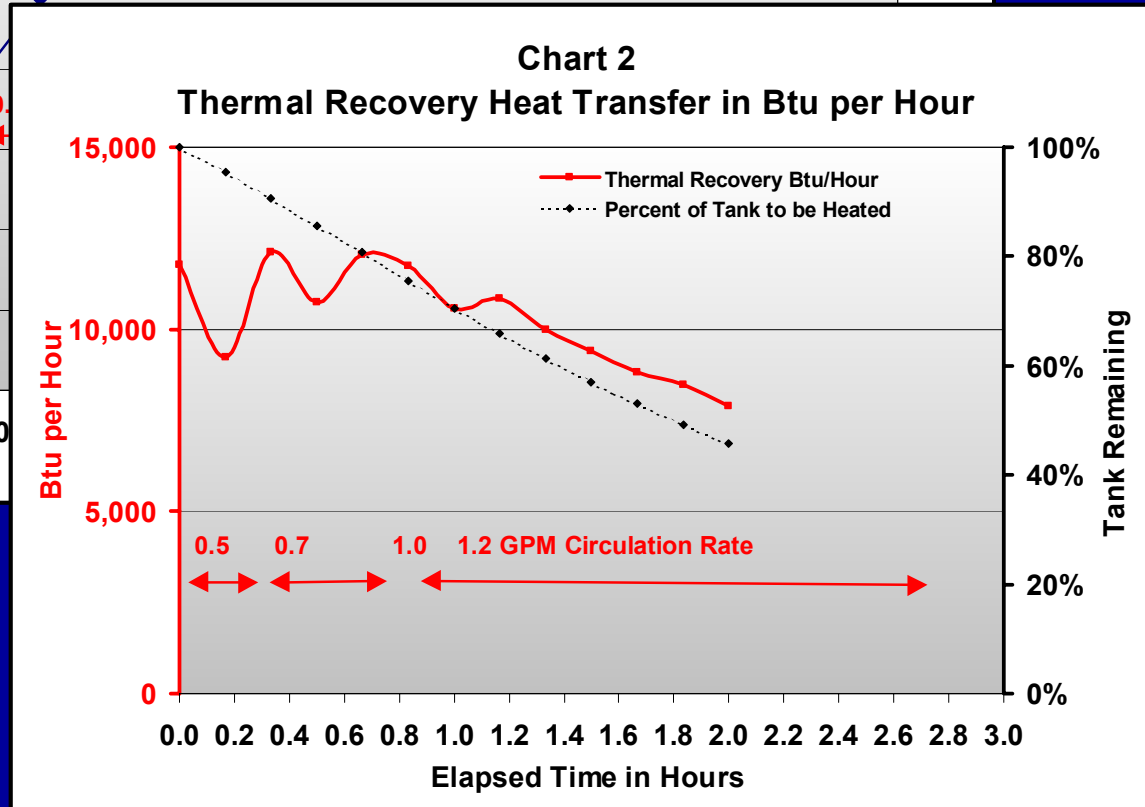
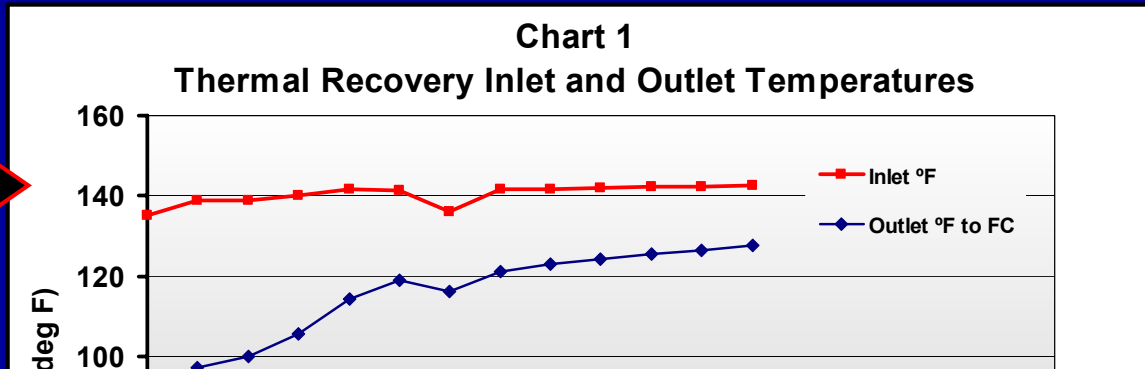


Field Map

Field Data



Courtesy LoganEnergy



# Planned FY04 Activities

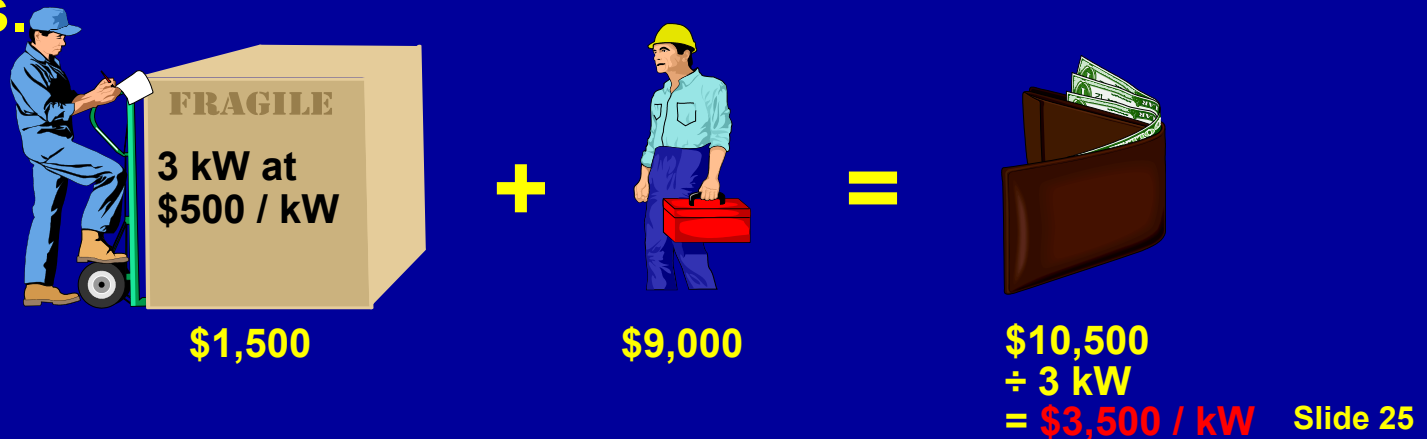
- **Continue RFC field installations**
  - Collect, analyze Installation Costs
  - Monitor grid Parallel field performance
  - Monitor RFC performance and actual busbar Efficiencies
  - Examine differing types of Thermal Recovery systems
  - Accumulate and process Service Experience
- **Continue RFC 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.

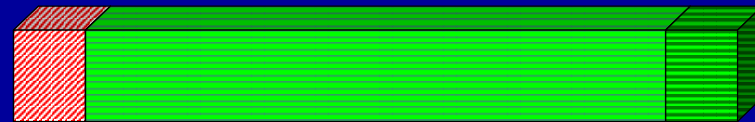


# Vision and Roadmap CRN Metrics (cont'd)

- 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?

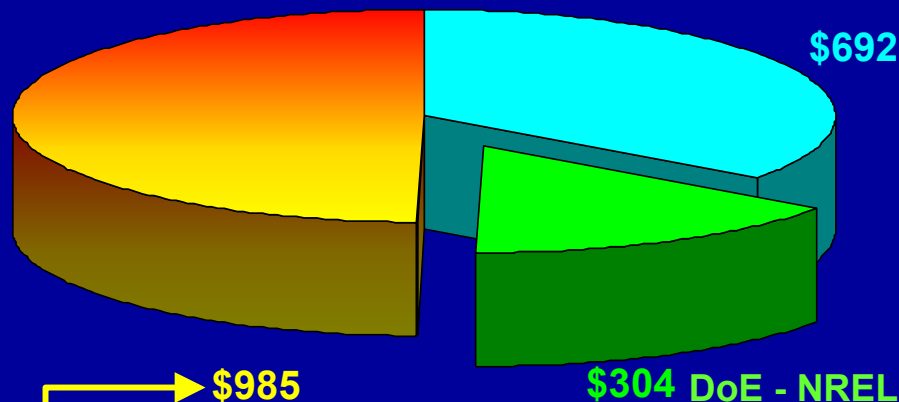


# **Collaboration, Interactions and Outreach**

# 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**

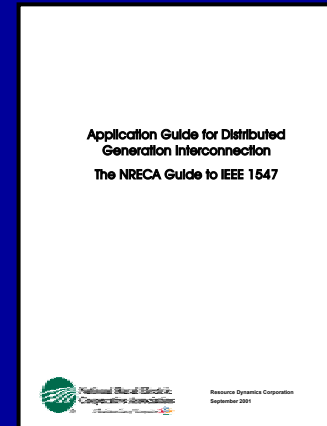
# Collaboration and Outreach (cont'd)

- **NRECA DG Interconnect Handbook**

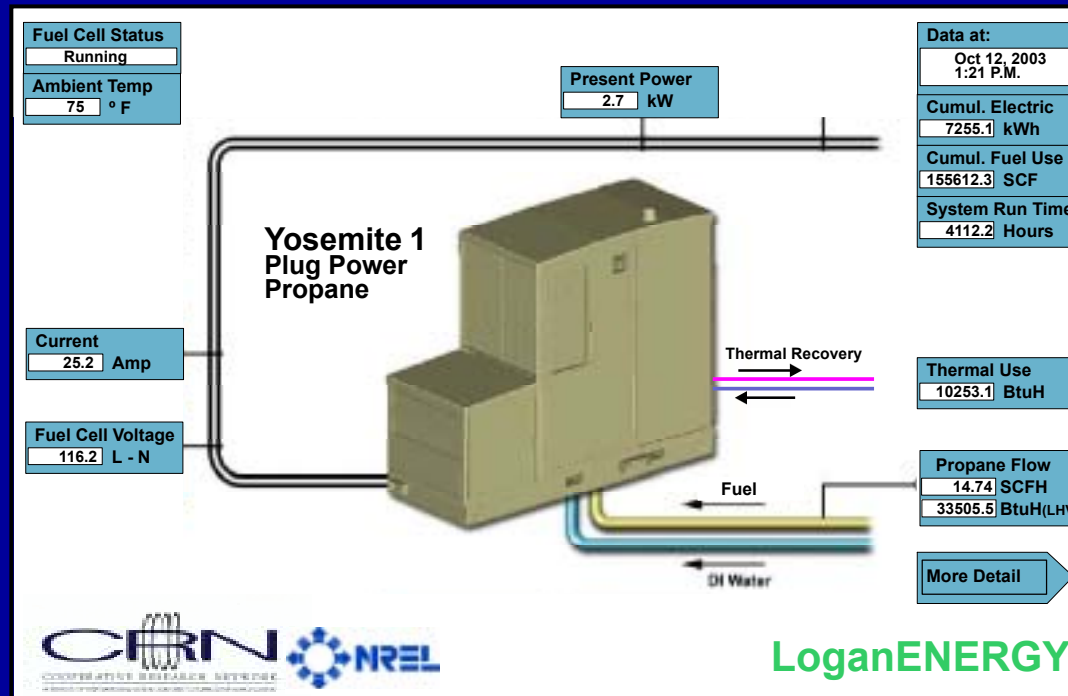
105 pages:

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

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



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





**Thank You**