Introduction to DER and the CERTS Microgrid

talk presented at the

Ernest Orlando Lawrence Berkeley National Laboratory

BERKELEY, CA

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by

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Outline

- Introduction to DER Seminar Series
- Why distributed energy resources?
- CERTS Microgrid development
- Distributed Energy Resources
  Customer Adoption Model (DER-CAM)
- DER-CAM Case Studies
- Conclusion & Future Work

I. Intoduction to DER Seminar Series

Berkeley Lab DER Seminar Series
Winter 2002

Conference Room 90-3148, 12-1 unless otherwise noted

	date	speaker	title
1	Tue, 3 Dec.	*Chris Marnay*	Introduction to Distributed Generation and the CERTS Microgrid
2	Thu, 5 Dec.	*Francis Rubinstein*	An Embedded Device Network for Lighting and Building Equipment Control
3	Tue, 10 Dec.	*David Littlejohn*	The Role of Combustion Research in Developing Quality DER Systems
4	Thu,12 Dec.	*Tim Lipman*, CIDER	Vehicles as Mobile Sources of Generation and Ancillary Services
5	Tue, 17 Dec. (Room 90-3075 @ 12:30pm)	*Dimitri Curtil*	DER Simulation by Linking SPARK with EnergyPlus
6	Thu, 19 Dec.	*Hugh Outhred*, U. of N.S.W., Australia	An Australian Perspective on DER

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II. Why DER?

small scale (< 500-1000 kW)
electricity generation close to loads using a
significant share of output

History of U.S. Electricity Sector

phases of centralization

1. isolated developments (pre 1900)
2. consolidation and monopolization (1900-1933)
3. fossilization and total centralization (1933-1980)

phases of decentralization

1. independent investment (avoided cost) (1980-1995)
2. wholesale (and some retail) competition (1995-)
3. decentralization and full competition? (2000-)

Meeting Future Electricity Demand: The Conventional Wisdom

- according to the *Annual Energy Outlook 2001*
  - to 2020 U.S. electricity demand:
    - will grow at only 1.8%/a (GDP at 3.0)
    - but with retirements, that's almost 400 GW of new capacity
    - that's 92% natural gas fired, tripling NG use for power
- roughly equivalent to 1000 new generating stations plus associated transmission and distribution
  (an investment of ~ $400 billion)
- NG prices increase at only 2%/a real
- electricity prices fall at 0.5%/a real
- share of electricity passing through high voltage grid almost unchanged

Limits of Current Power System

- restrictions on power system expansion
  - siting, environmental, right-of-way, etc.
- failure of centralized power system planning
- heterogeneous power quality requirements
  - extreme customer requirements (digital power)
  - high cost of reliability?
- volatile bulk power markets (investment cycle)

  & lack of transmission investment incentives
- economic drive to operate power system closer to limits efficiency limits (losses, carbon, CHP?)
- security (vulnerability of centralized systems)

Benefits (& Costs) of DER 1

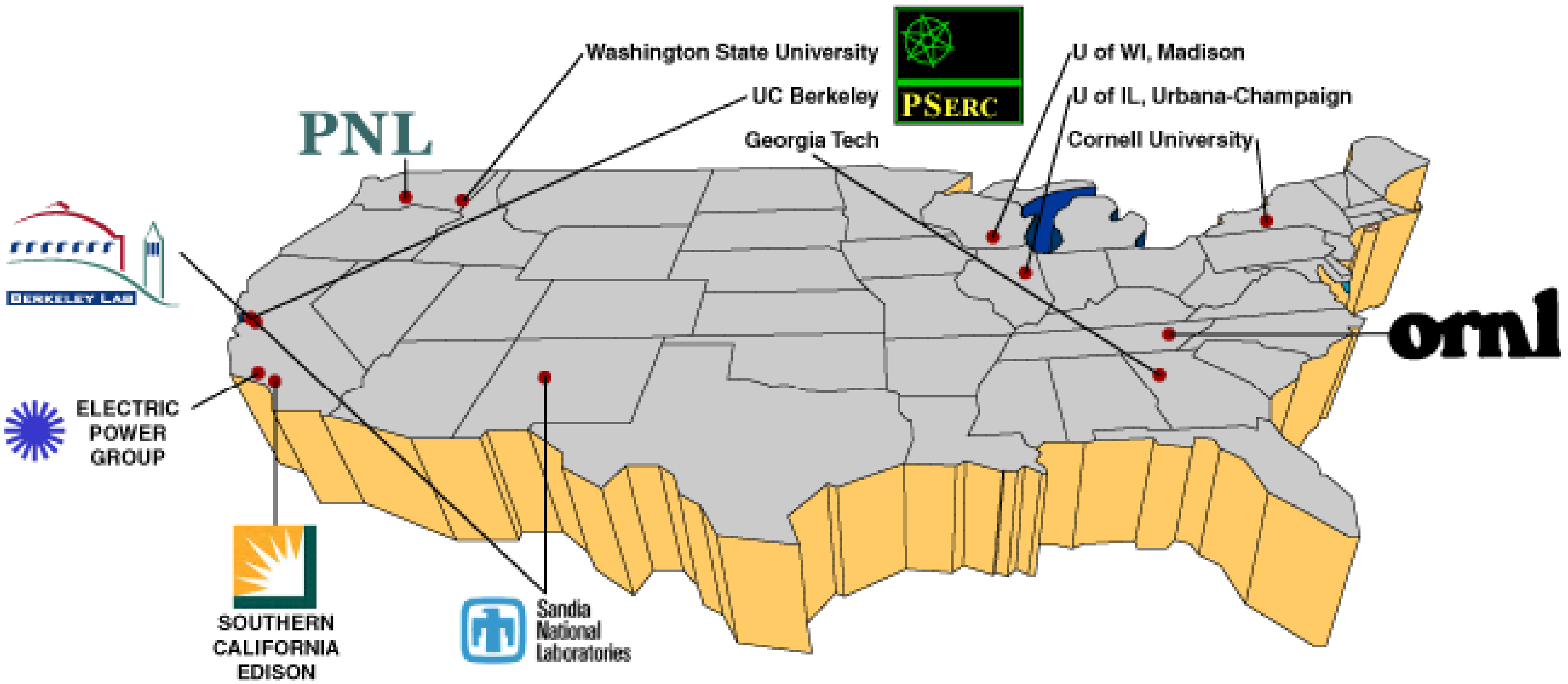
	Benefit/Cost	Economic Size	Market Liklihood	Tracta-bility
1	Lower Cost of Electricity	2-3	3	3
2	Consumer Electricity Price Protection	1-2	3	2
3	Reliability & Power Quality (DER adopter) (other customers)	3 & 1-2	3 & 1	2 & 1
4	Combined Heat and Power/Efficiency	3	3	3
5	Indoor Emissions	1	1	2
6	Noise Disturbance	1	1	2
7	Consumer Control	1	3	1
8	T & D Deferral and Congestion Relief	3	2	2
9	Capacity Deferral/Standed Assets	2-2	1	2

Benefits (& Costs) of DER 2

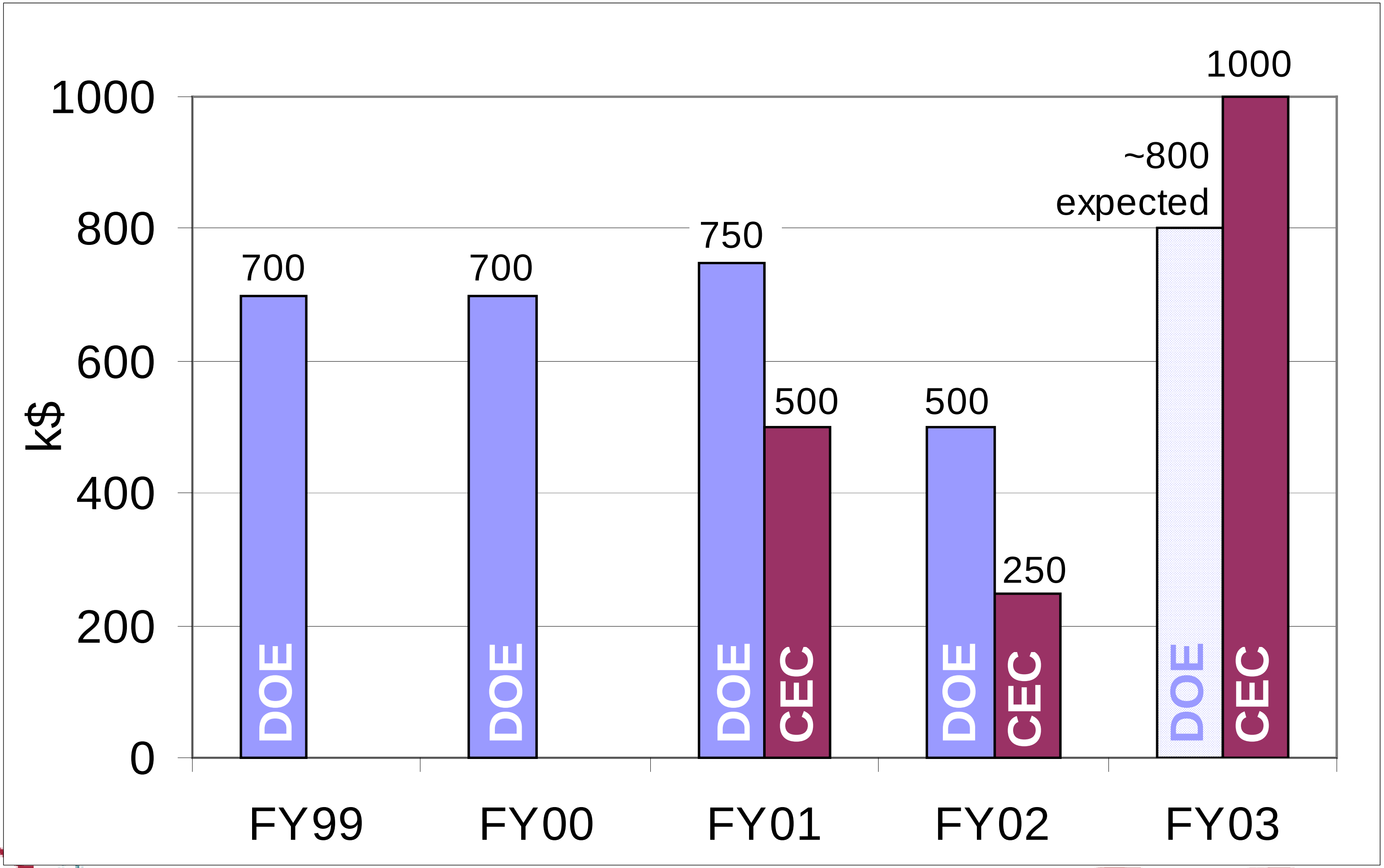
	Benefit/Cost	Economic Size	Market Liklihood	Tracta-bility
10	Reduced Transmission Losses	1	1	2
11	Voltage Support to Electric Grid	1-2	1	1
12	Reduced Security Risk to Grid	2	1	1
13	Enhanced Electricity Price Elasticity	2-3	1	1
14	Airborne or Outdoor Emissions	2-2	1	2
15	DER Fuel Delivery Challenges	1-2	2	2
16	NIMBY - BANANA	1	1	1
17	Land Use Effects.	1	1	2

III. CERTS Microgrid Development

Consortium for Electric Reliability Technology Solutions



CERTS Funding for MicroGrid Development and Testing

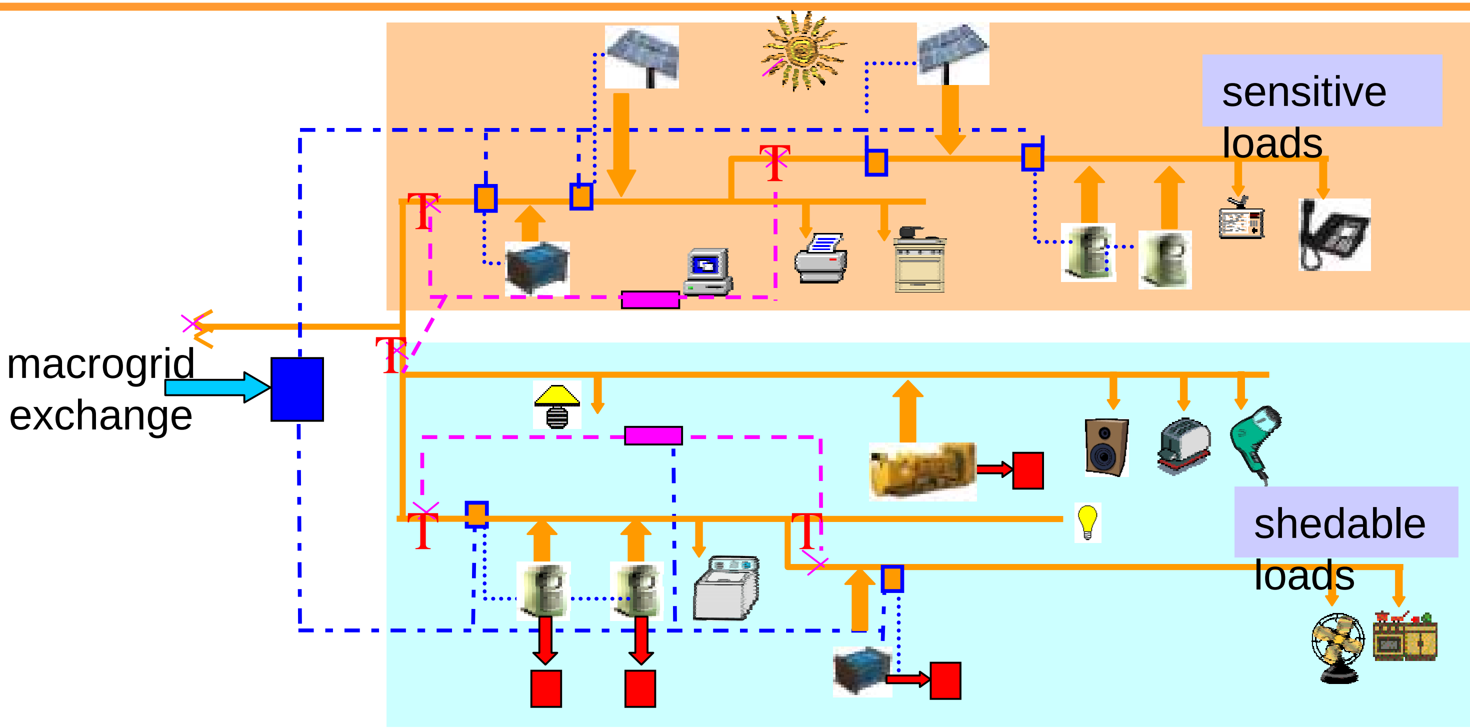


* U.S. Federal fiscal years (FY) are 1 Oct - 30 Sep

The CERTS Microgrid is ...

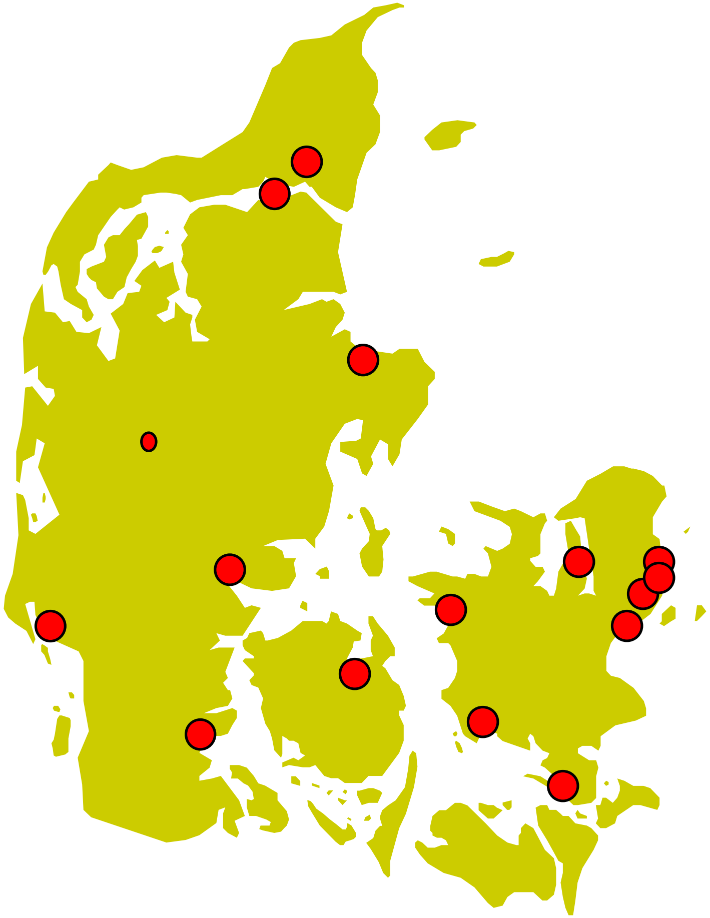
- controlled by *customers* based on internal requirements subject to the technical, economic, and regulatory opportunities and constraints faced.
- designed and operated to jointly provide heat and power and heterogeneous power quality and reliability.
- a cluster of small (e.g. < 500 kW) sources, storage systems, and loads which presents itself to the grid as a legitimate entity, i.e. as a *good citizen.*
- interconnected at one interface with the familiar wider power system, or *macrogrid,* but can island from it.
- controlled by local intelligent power electronic devices, such as enhanced inverters.

An Example CERTS Microgrid



Energy Manager
Power Flow Controller
circuit
Breaker
Protection Coordinator
heat load
EM communication
protection communication
PV panel
fuel cell
micro turbines
reciprocating engine

Development of Danish Power System (1980-2000)



source: Eltra (grid operator of western Denmark)

CERTS Microgrid Development

- CERTS Microgrids viability shown in simulation
- 3 microturbine bench test planned for 2003
  - test bed design with Northern Power Systems
  - demonstration of connected and islanded operation
  - minimal control scheme
- full field demonstration in 2004
  - protection scheme implemented
  - economic operation to demonstrated
  - within environmental & other constraints
  - full control scheme

Capstone Microturbines at Irvine

Installation at Harbec Plastics

Two Irvine Microturbines with CHP British Bowman & Japanese Takuma

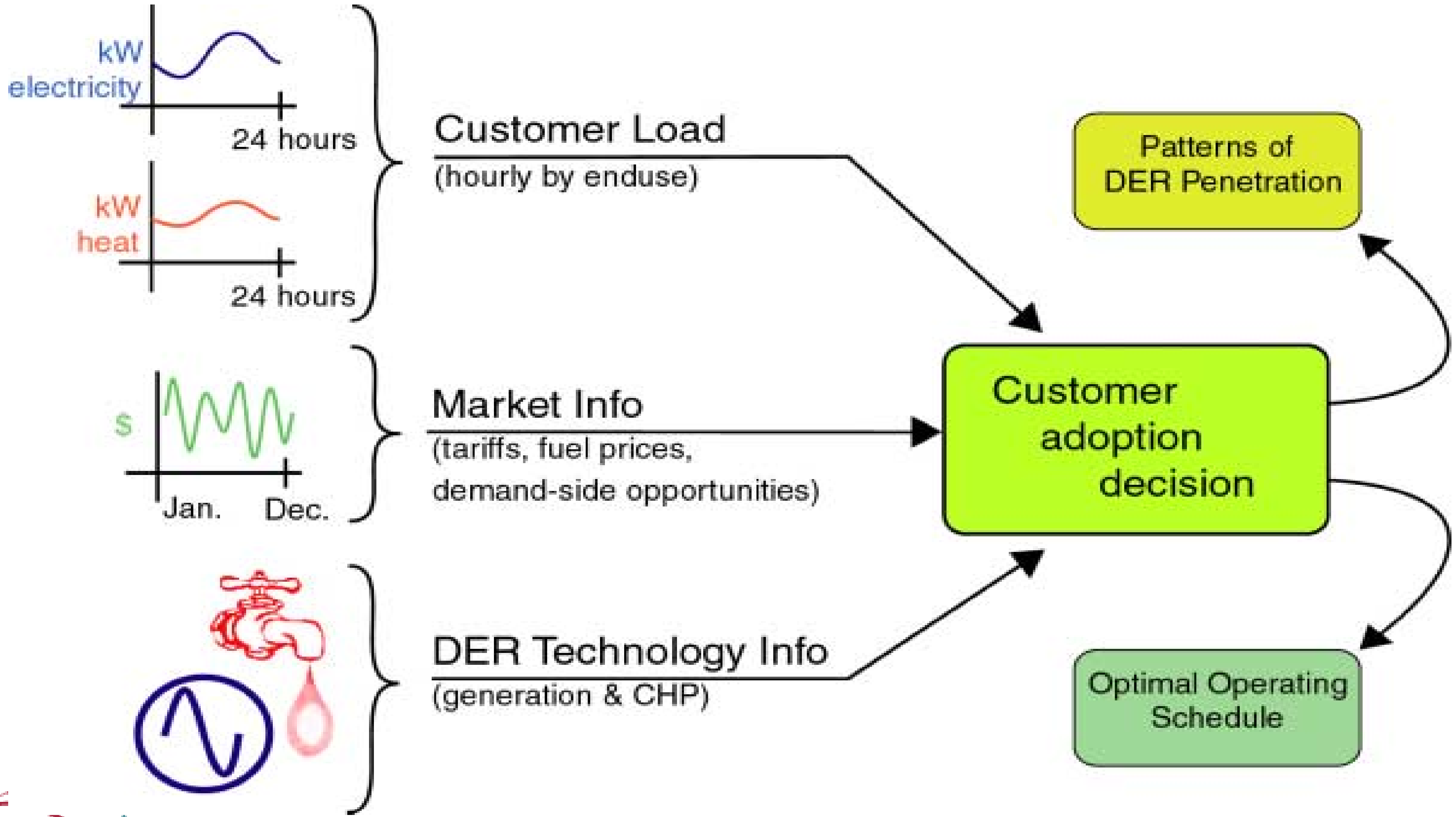
Plug Power 5 kW PEM Fuel Cell

IV. The Distributed Energy Resources Customer Adoption Model (DER-CAM)

Electricity Markets & Policy Work

- CERTS Program Administration
- policy analysis of power system reliability
- analysis of competitiveness of renewable technologies
- review of electricity markets
  - electricitymarketdata.lbl.gov
- ESCo data base

DER Customer Adoption Model (DER-CAM)



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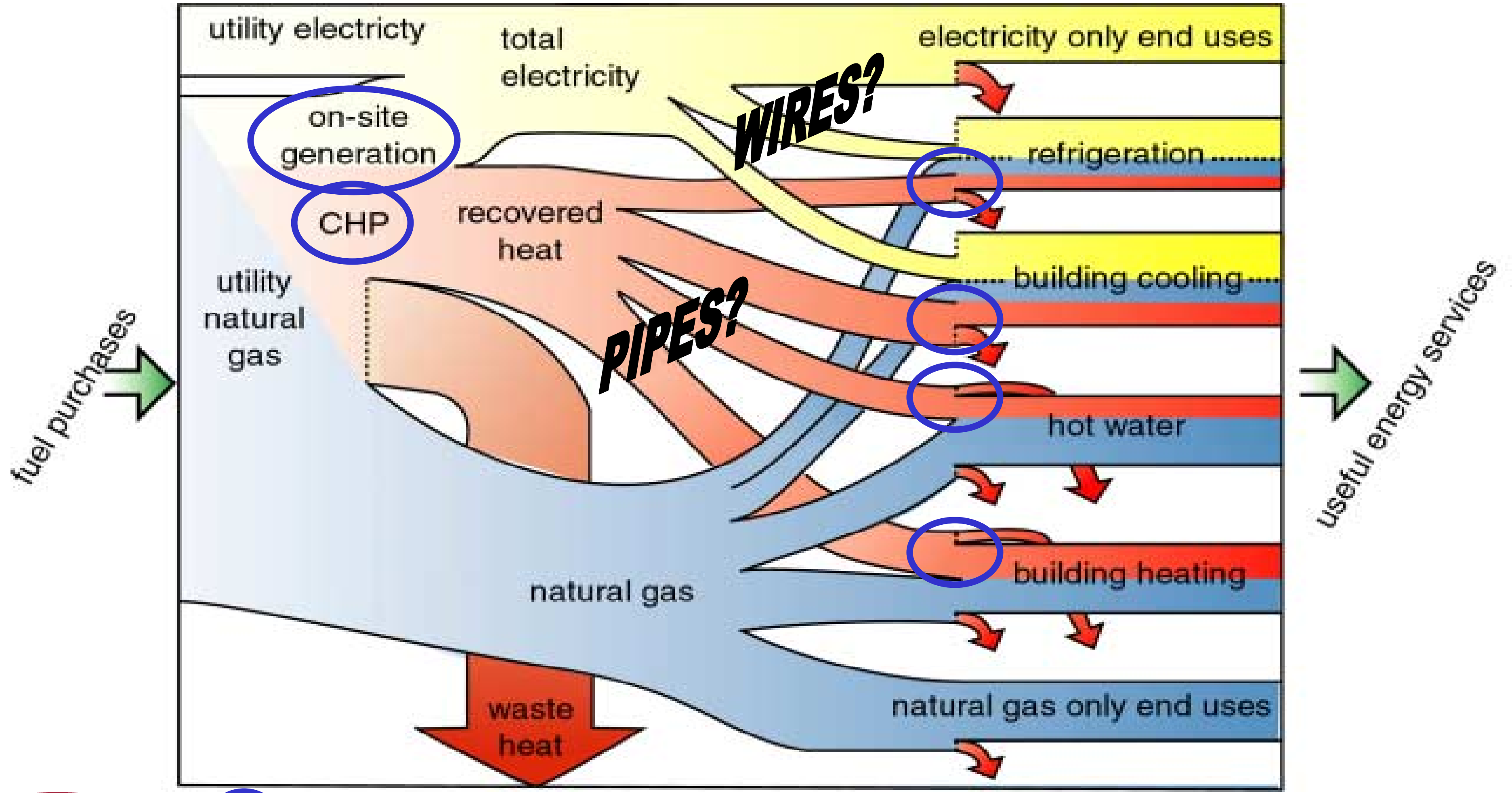
Energy Flows Incorporating CHP



technology adoption decisions

V. Case Studies

Case Study Results 1

(site selected DER installations vs. DER-CAM results)

	site	DER chosen	DER-CAM result
1	A&P Super-market	60 kW Microturbine (60 kW) with CHP	No DER installation
2	Guarantee Savings Building	600 kW Fuel Cells 600 kW capacity: (3 x 200 kW) with CHP and absorption chiller	765 kW PV (1 x 100 kW), natural gas engines (3 x 55 kW) with CHP, and natural gas engine (1 x 500 kW) with absorption chiller
3	The Orchid	800 kW Propane engine (4 x 200 kW) with CHP and absorption chiller	900 kW Propane engines (2 x 200 kW) with CHP, (1 x 500 kW) with absorption chiller

Case Study Results 2

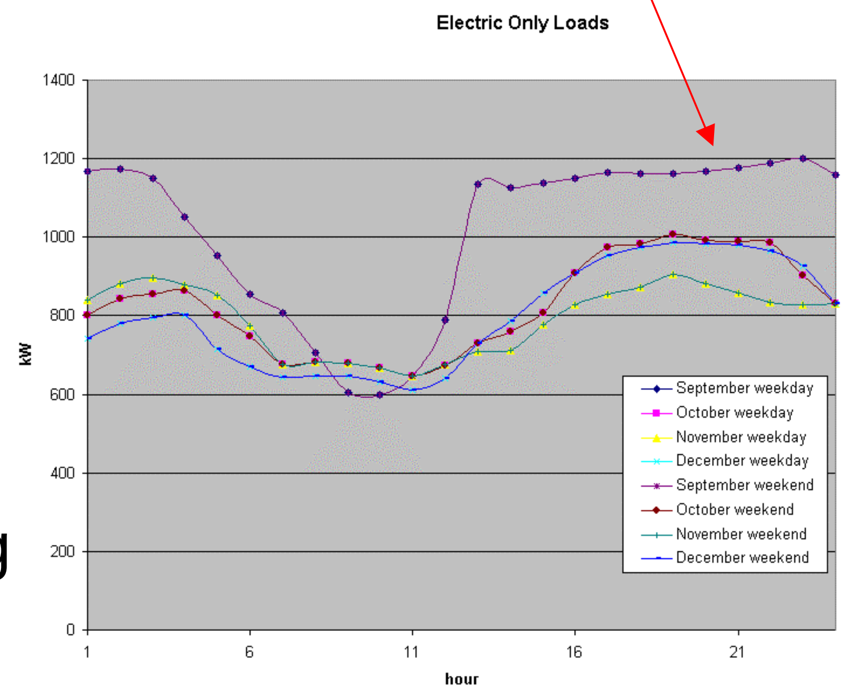
(site selected DER installations vs. DER-CAM results)

site	DER chosen	DER-CAM result
4 Pharmingen	300 kW Natural gas engines (2 x 150 kW) with CHP	500 kW Natural gas engine (1 x 500 kW) with CHP
5 USPS San Bernardino	500 kW Natural gas engines (1 x 500 kW) no CHP, electric chiller, perhaps additional absorption chiller	1120 kW Natural gas engine (2 x 500) kW with absorption chiller, and microturbines (2 x 60 kW) with absorption chiller

San Bernardino USPS

Redlands, CA Mail Handling Facility

equipment runs mostly in evening and night



large cooling load due to handling equipment

San Bernardino USPS

- site manager was confident about nat. gas engine decision based on visits to other recip. engine CHP sites
- solar panels unattractive based on perceived poor track record
- microturbines too new – haven't proved themselves yet

25 000 m^2 of rooftop in the desert!

will install 500 kW natural gas reciprocating engine – waste heat use undecided

Pharmingen San Diego, California

manufacturer of protein based reagents for life sciences

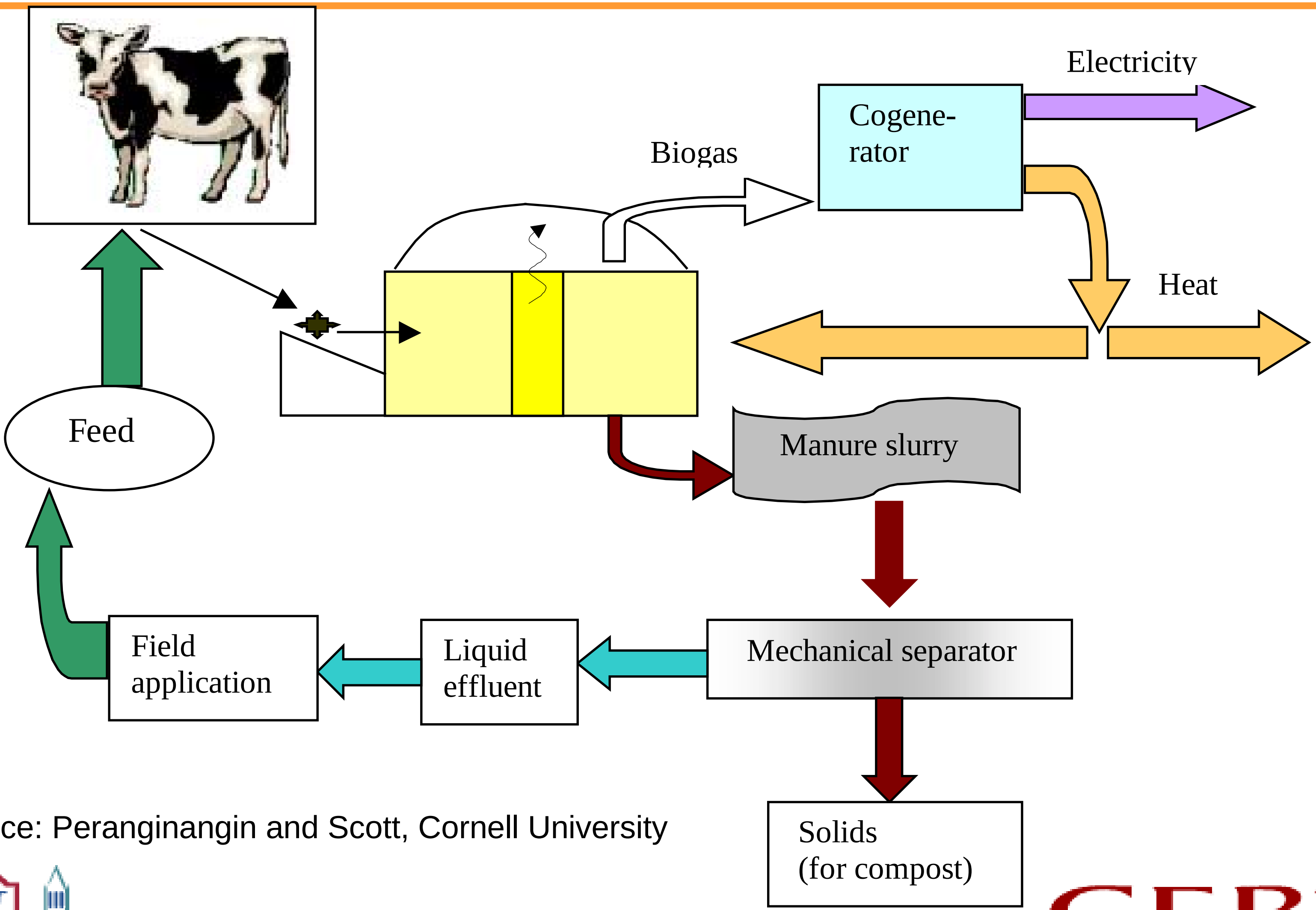
- constant air replacement
- year-round heating load
- 24/7 cooling load for chemicals and products
- 200 kW base load
- 600 kW peak load

Desired an "alternate utility" to provide electricity at a flat rate (per kWh)

Guarantee Savings Bank,
Fresno CA

- historic landmark
- 12 Story Office Building: IRS, INS tenants
- 3 x 200 kW PAFC in parallel with grid
- charging $0.35/kWh to GSA for electricity
- perceived problems with combustion tech. permitting
- major remodel in progress

AA Dairy Farm, Candor NY



source: Peranginangin and Scott, Cornell University

AA Dairy Farm, Candor NY

Conclusions

- rethinking highly centralized power grid systems is underway
- Microgrids are components of decentralized power systems
- CERTS Microgrids
  - are controlled by electronics local to generators, storage, & load
  - operate connected to or disconnected (islanded) from the macrogrid
  - control heterogeneous reliability and power quality close to end-use
  - produce “waste heat” close to potential uses and enable CHP
  - optimize over compatible electrical and heat requirements
- CERTS planning bench and field demonstrations
- DER-CAM finds jointly optimal combinations of on-site power generation, waste heat capture, and utility purchases of electricity and natural gas

Future DER-CAM Work

- develop into a tool for assessing real-world sites
  - perhaps by establishing benchmark cases
  - many directions for enhancements (incorporating end uses)
- policy and market assessment analysis
  - market potential for thermally activated cooling
- Energy Manager
  - controls for CERTS field demonstrations
  - and beyond