# Distributed Generation

*talk presented at the*

## Western Underground Committee

***Stanford University, Stanford CA***

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by


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CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

# Outline

I. Distributed Generation: A Site and a System

II. The CERTS Microgrid

III. Distributed Energy Resources

Customer Adoption Model (DER-CAM)

IV. Redlands Postal Facility

V. Limitations of the Macrogrid

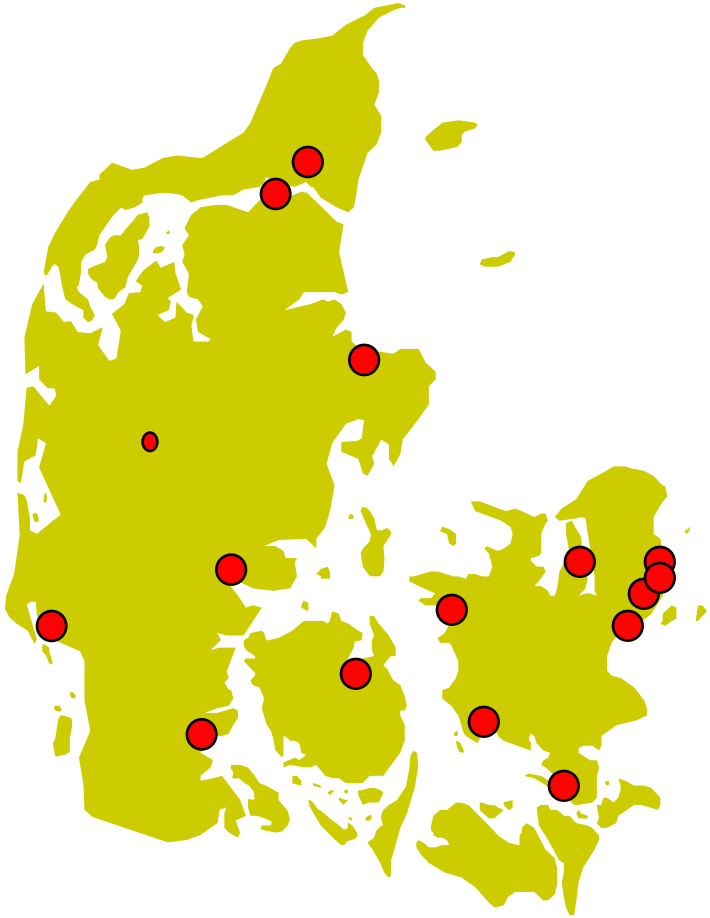
VI. "The" Correct Level of Reliability

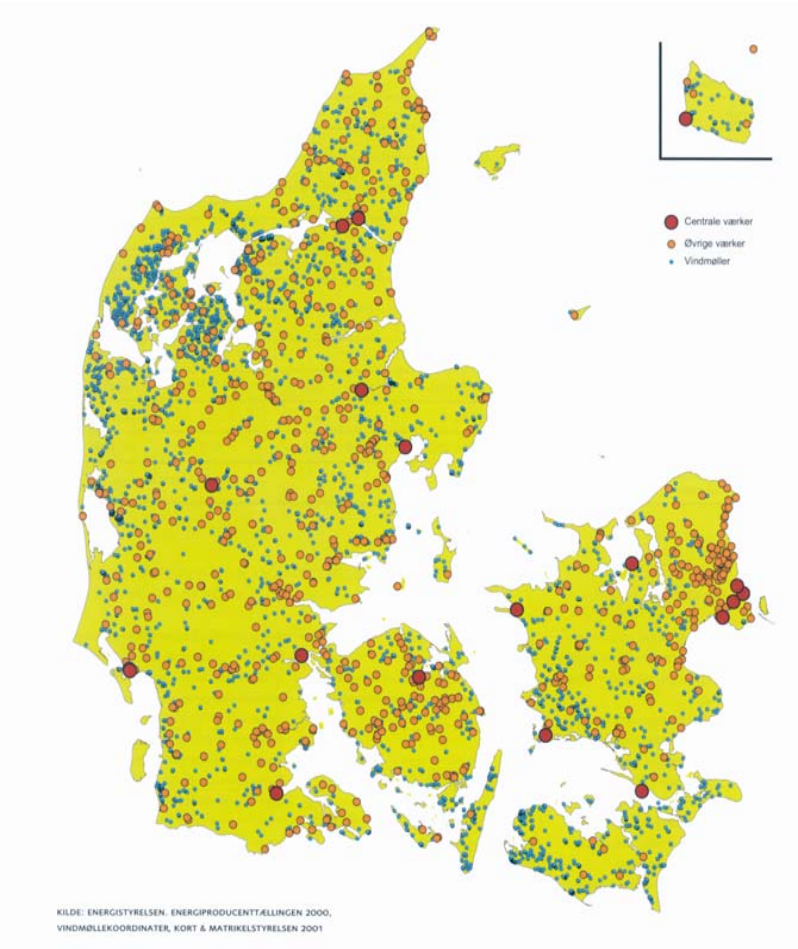
VII. Conclusion

combined heat and power (CHP) (the missing 27%) (cooling!)
& reliability and power quality (PQR)
CERTS Microgrid is only one potential model for DER deployment
can/should we make a paradigm shift to a more dispersed power system?

# Garden City L.I. Telephone Exchange

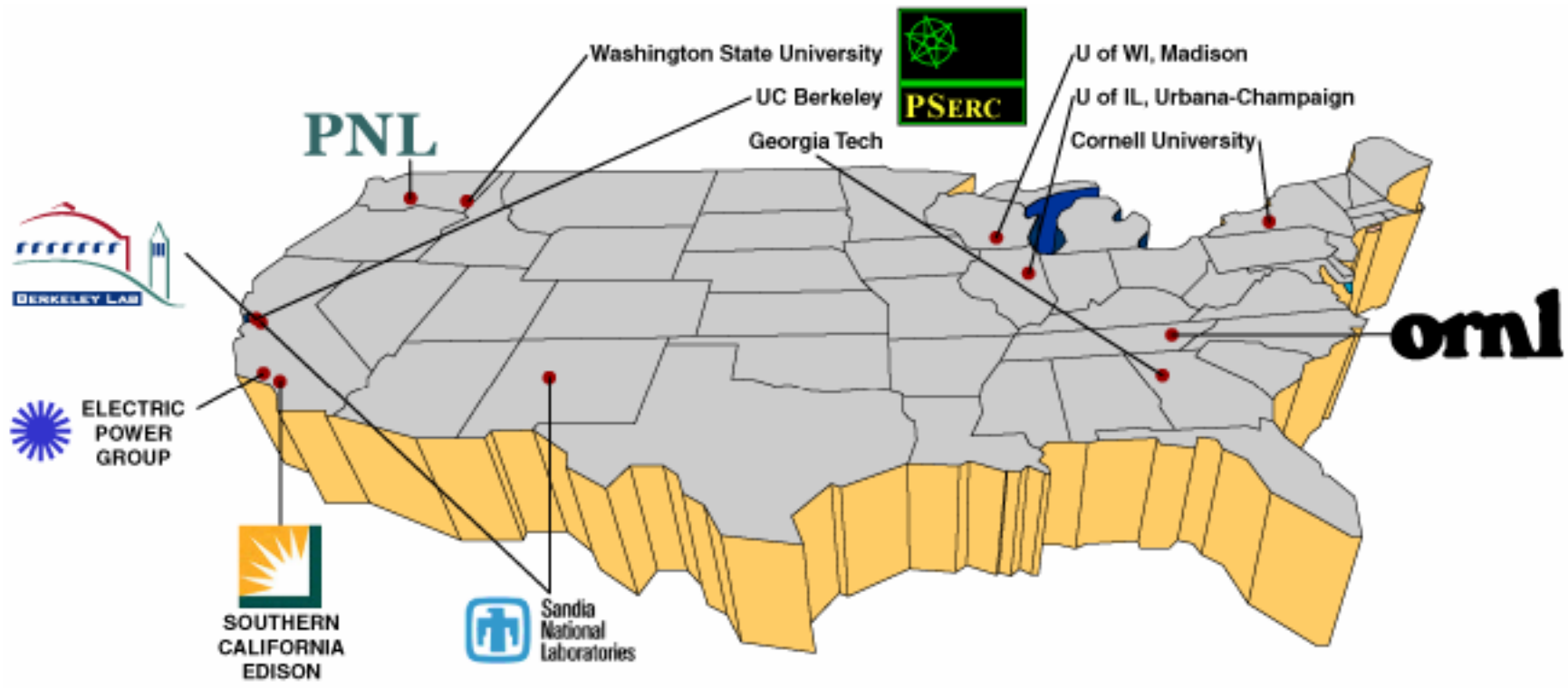
# Development of Danish Power System (1980-2000)






source: Eltra (grid operator of western Denmark)

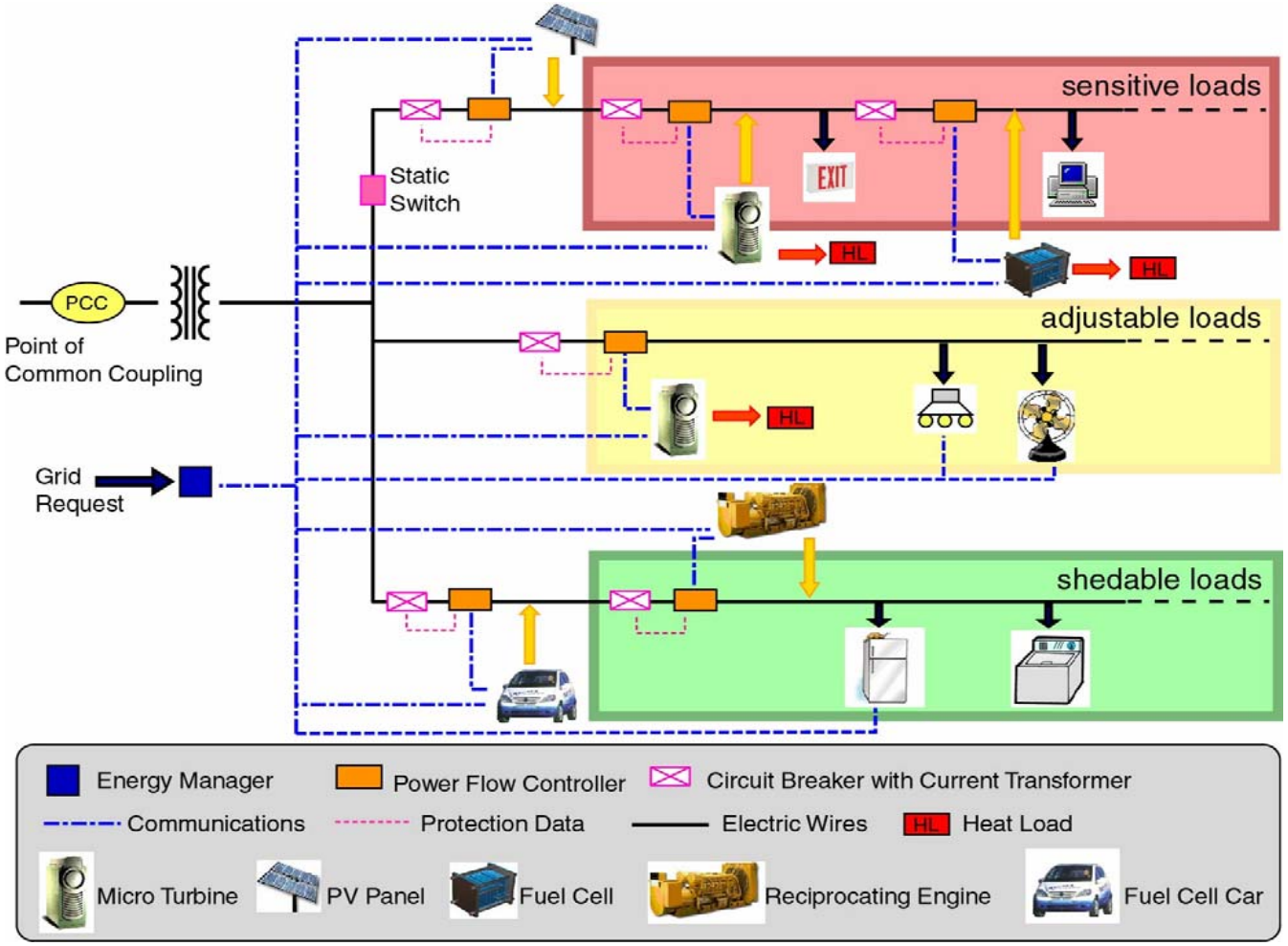
# Consortium for Electric Reliability Technology Solutions



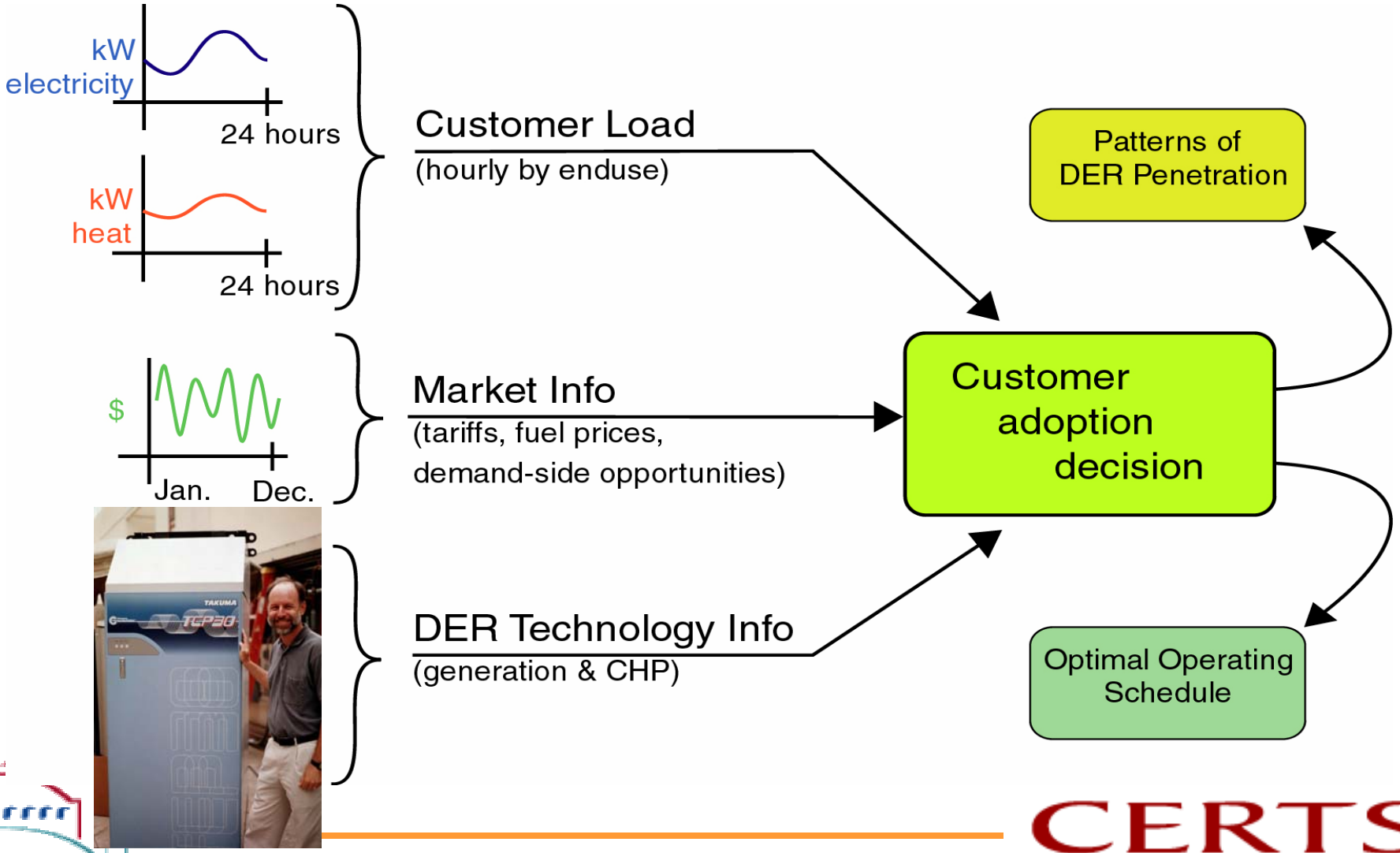
# The CERTS Microgrid is ...

- 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 with the familiar wider power system, or *macrogrid,* but can island from it.
- controlled by local intelligent inverter like power electronic devices.

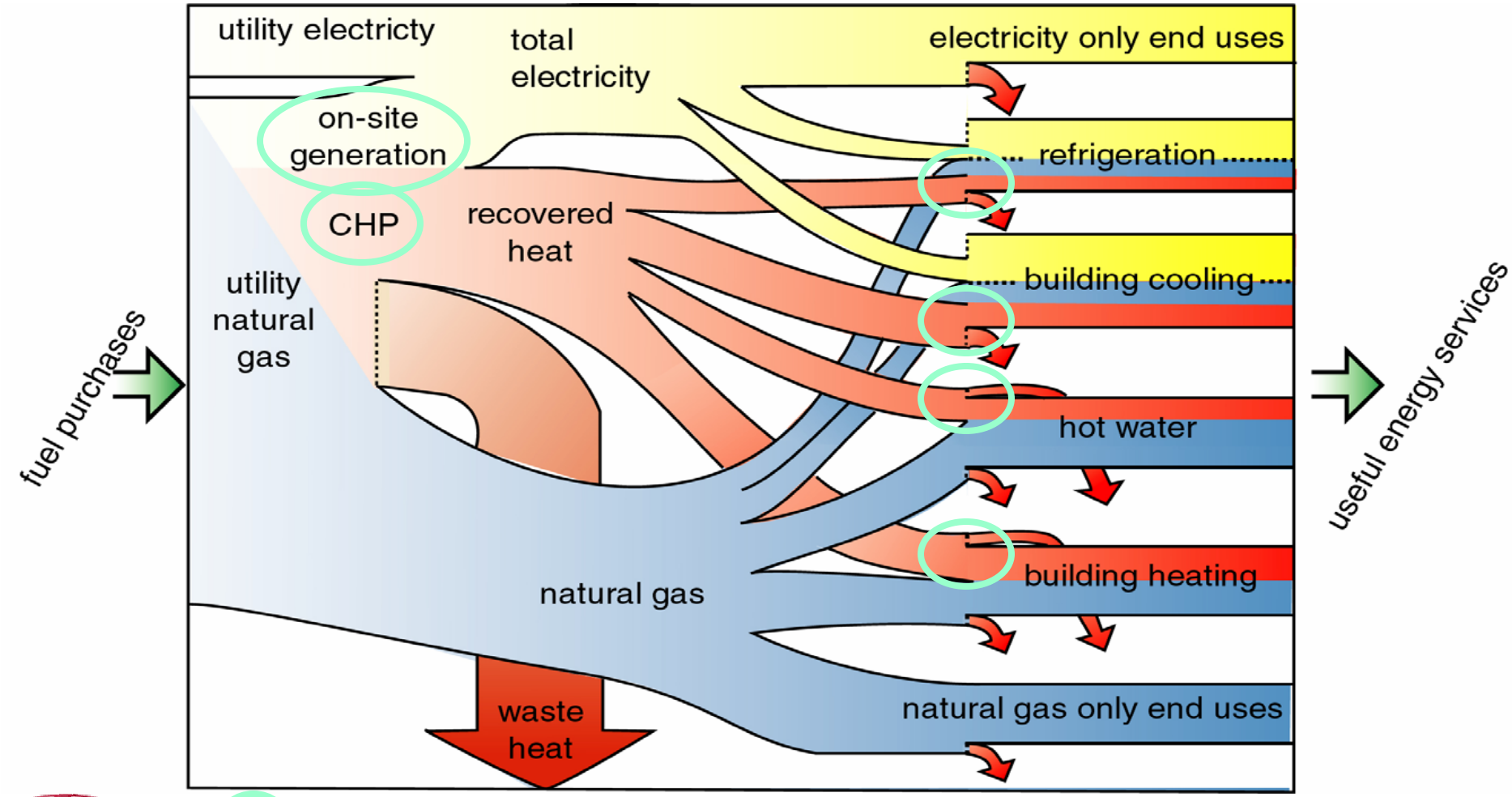
# Example CERTS Microgrid



# DER Customer Adoption Model (DER-CAM)



# Energy Flows Incorporating CHP

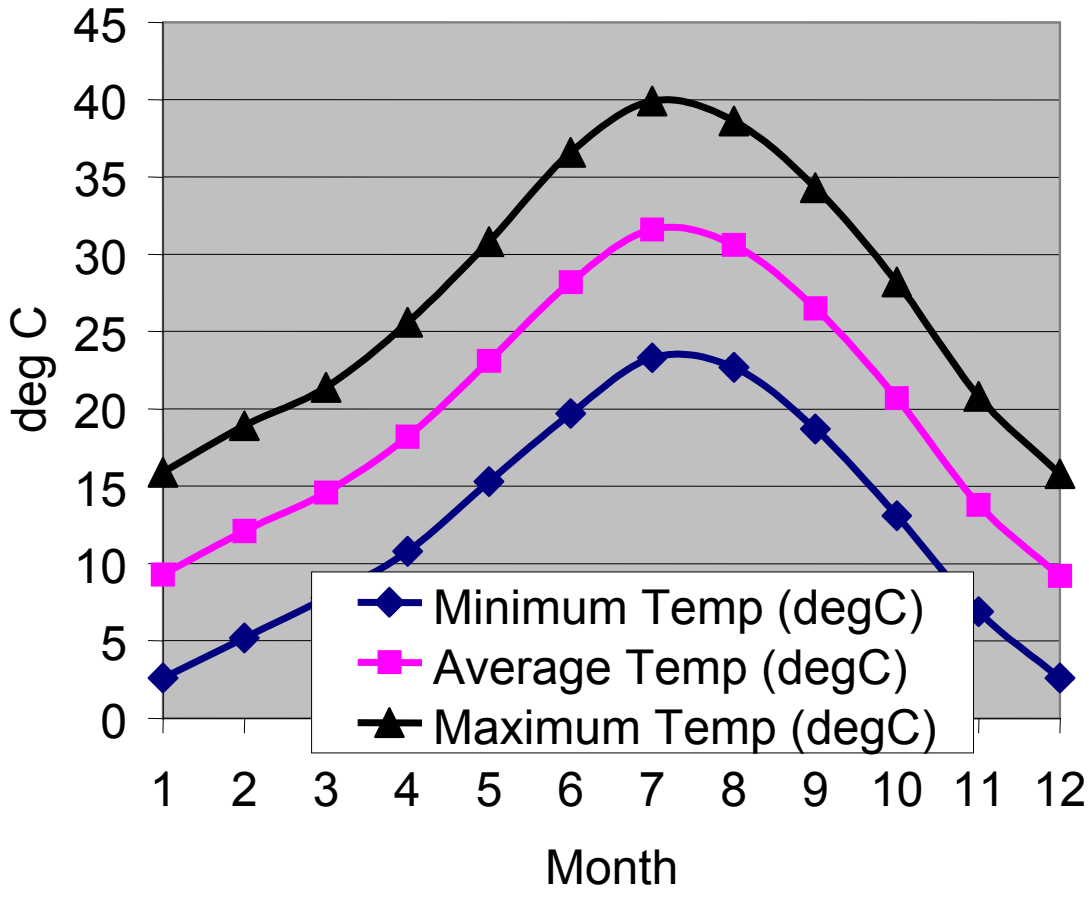



technology adoption decisions

# San Bernardino USPS, Redlands CA

Redlands, California

# San Bernardino USPS: Temperature




source: Renewable Resource Data Center, National Renewable Energy Laboratory, http://rredc.nrel.gov/

# San Bernardino USPS, Redlands, CA

equipment runs mostly in evening and night

32,000 $m^2$ single-story facility

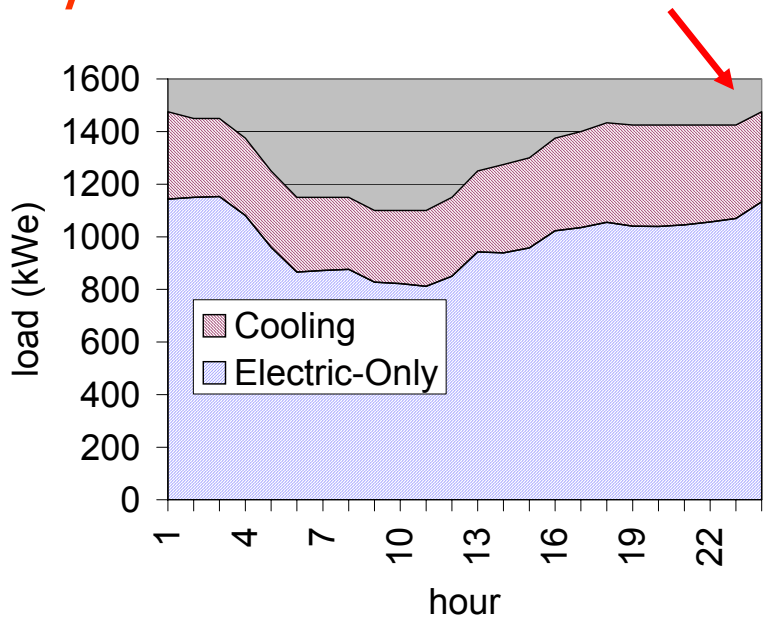
# Summary Table of Results

| CASE | Capacity Installions | Equipment | Investment Costs | Annual Utility Bills | | | Total Energy Costs | Bill Savings Over Do-Nothing Case |
|---|---|---|---|---|---|---|---|---|
| | | | | Electricity | Gas | Gas | | |
| | (kW) | | (k$) | (k$) | for DER (k$) | for direct enduse (k$) | (k$) | (%) |
| Do Nothing | | | 0 | 1260 | 0 | 1 | 1261 | |
| DER without CHP | 1165 | 3x 55 kW NG engine<br>2x 500 kW NG engine | 358 | 50 | 579 | 1 | 988 | 22% |
| DER with CHP | 1120 | 2x 60 kW Microturbine with abs. Cooling<br>2x 500 kW NG engine with abs. cooling | 353 | 32 | 526 | 1 | 912 | 28% |

peak electric load without DER : 1500 kW

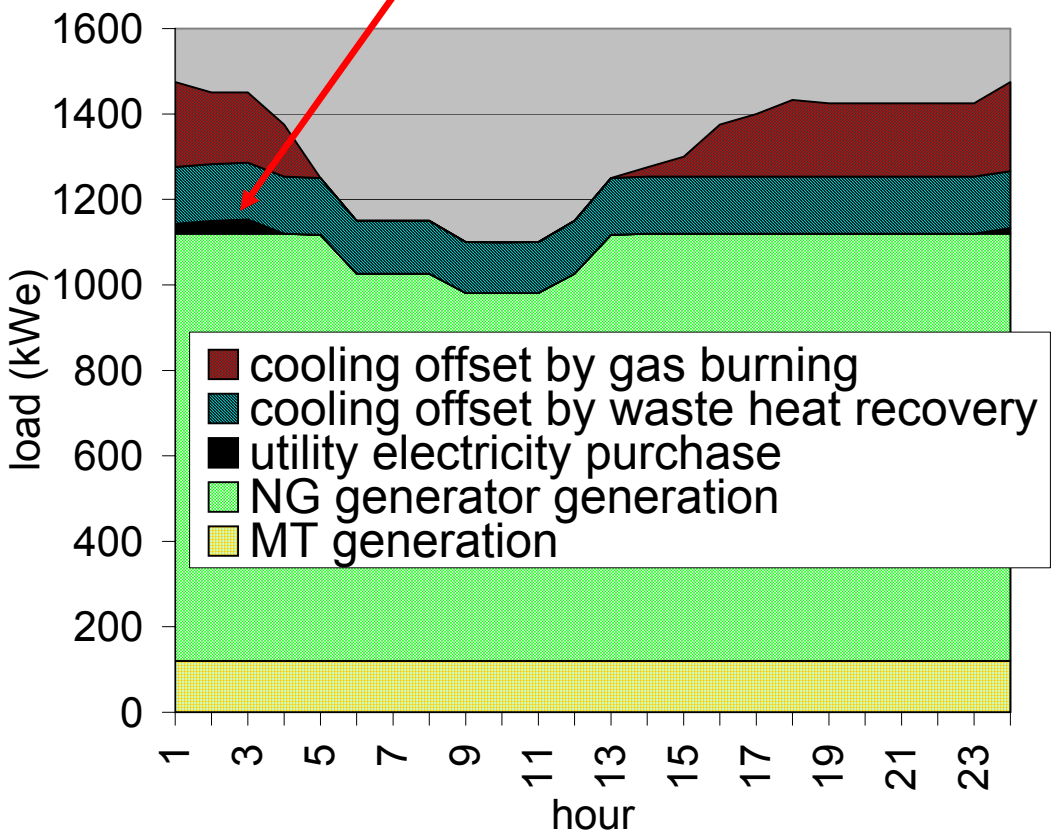
# USPS July Weekday Electric Loads

*peak load = 1500 kW*




site electric loads

*peak load = 1150 kW*




How site electric loads are met.

# Summary

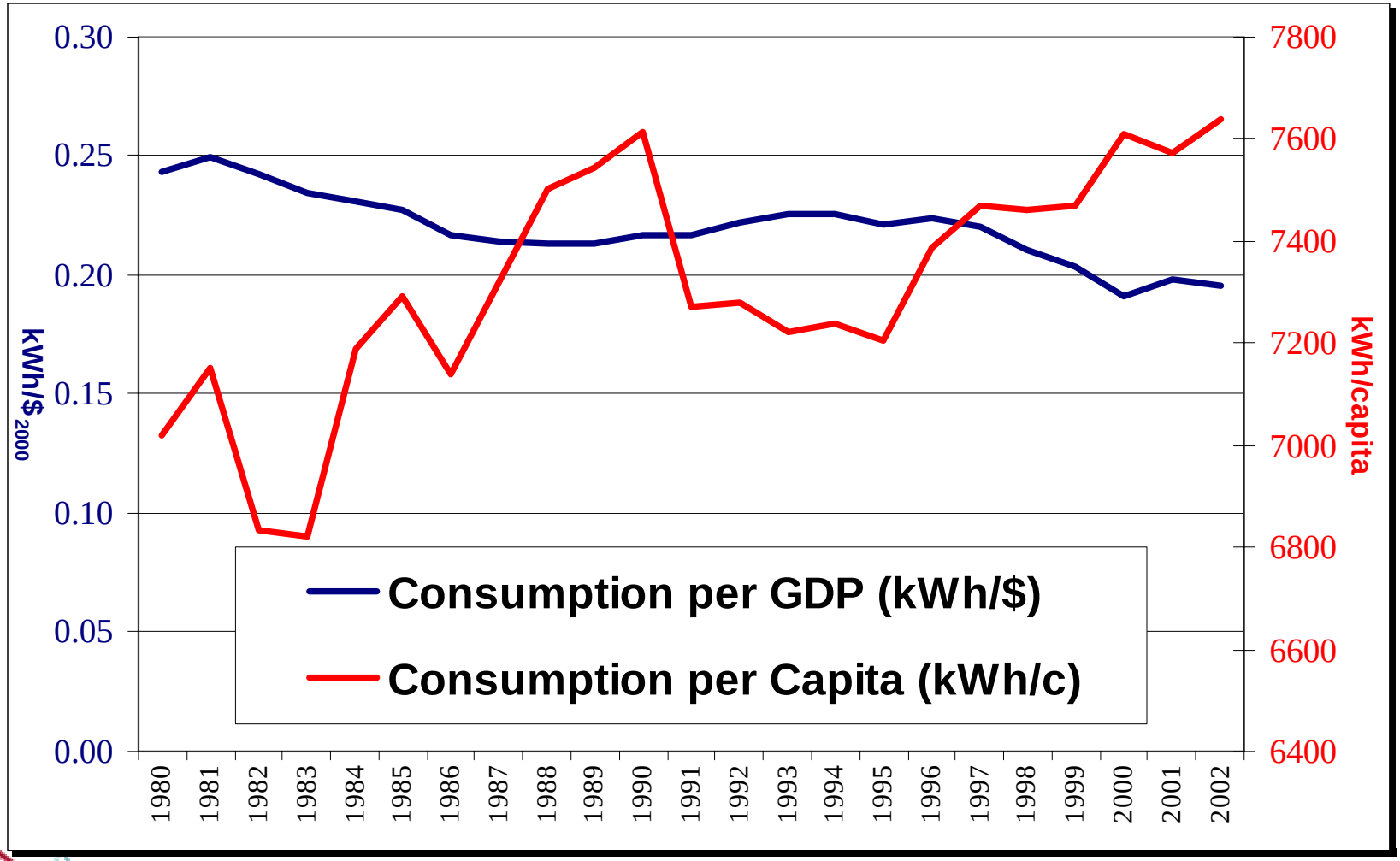
- even without heat loads, continuous cooling load year-round makes CHP economic
- max. bill savings of 28% indicated
- without DER, high dependence on electricity prices
- DER-CAM optimal system, high dependence on natural gas prices
- DER economic up to double NG prices, or $16/kW standby charge

further analysis possible with SESU

# Meeting Future Electricity Demand: The Conventional Wisdom

- according to the EIA Annual Energy Outlook 2004
  - 2002 to 2025 U.S. electricity demand:
    - will grow at only 1.8%/a (population at 0.8 & GDP at 3.0)
    - a total 1942 TWh (51%) increase in energy,
      and a 283 GW (31%) increase in capacity
    - but with retirements, that's almost 345 GW (38%) new capacity
    - that's 55% natural gas fired, NG use for power increasing at 1.8%/a
- roughly equivalent to ~1000 new generating stations
  plus associated transmission and distribution
- electricity prices fall at 0.3%/a real
- NG prices increase at only 1.2%/a real
- share of electricity passing through high voltage grid almost unchanged

# California Electricity Use



# Limits of Current Power System

- volatile bulk power markets
- centralized power system planning
- economics drives operates closer to limits
- insecure system

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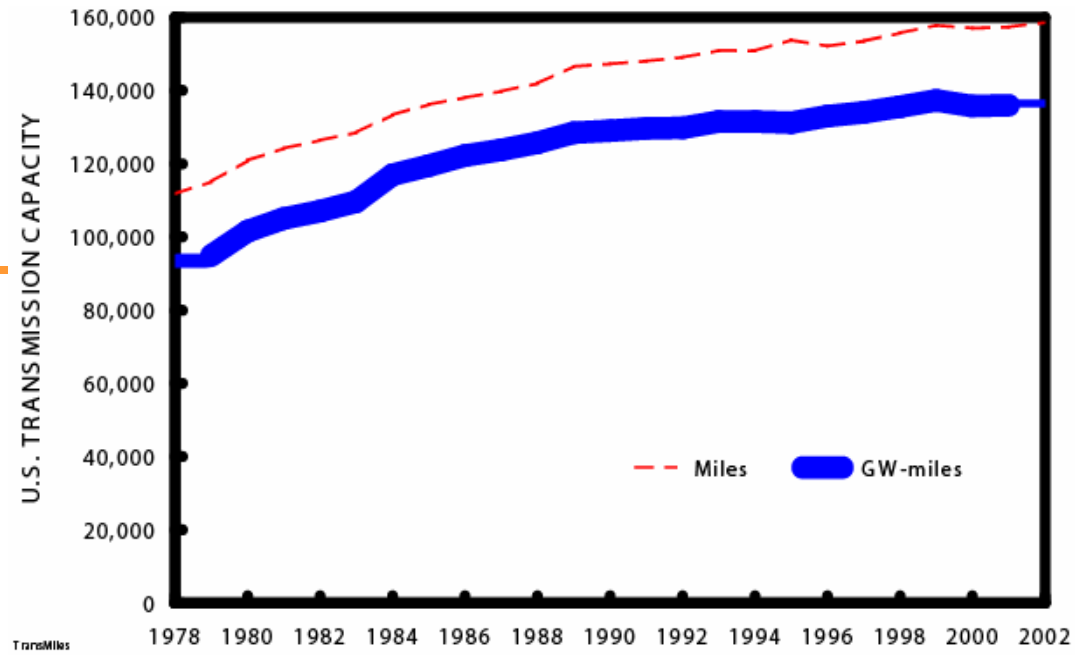
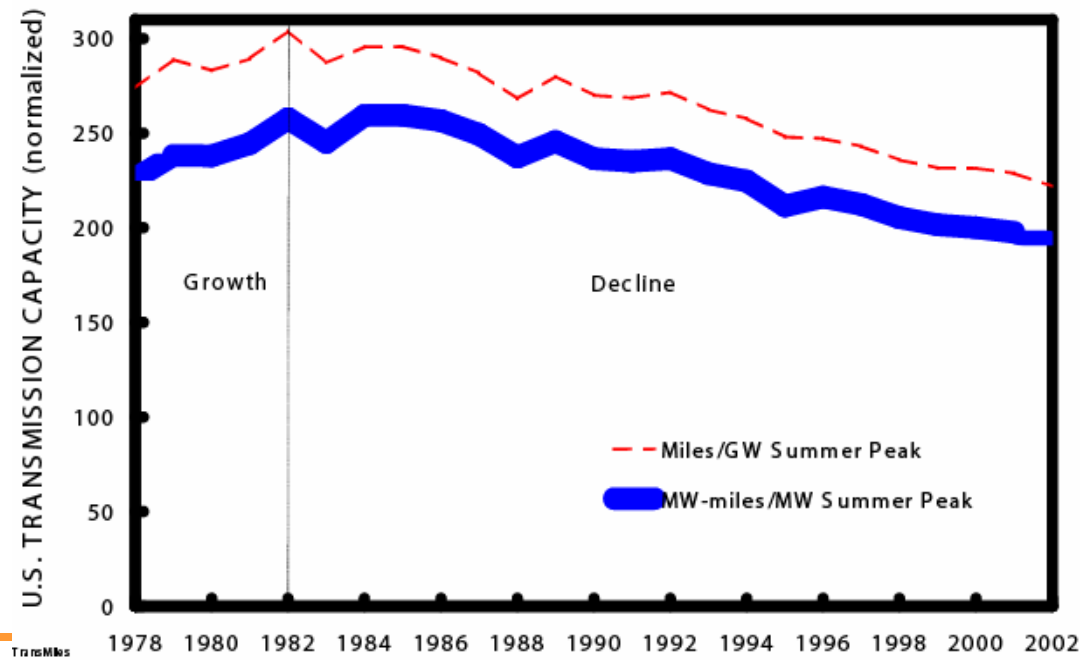
- efficiency limits (losses, carbon, CHP)
- restrictions on power system expansion
  - siting, environmental, rights-of-way, etc.
  - declining investment
- multiple infrastructure interdependencies
- roller coaster investment cycle
- heterogeneous power quality and reliability (PQR)

# U.S. Transmission Capacity 1978-2002

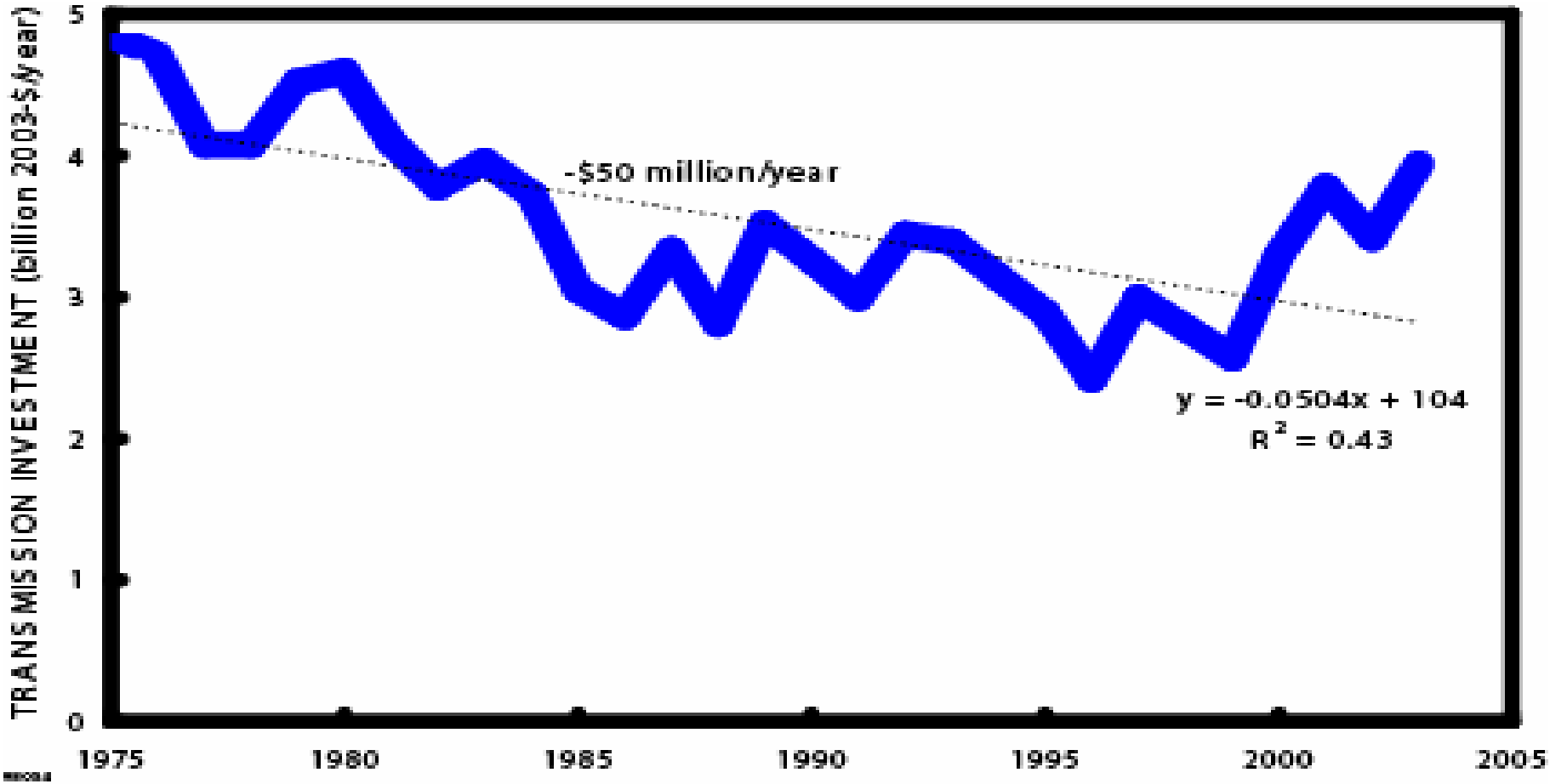
[miles and GW–miles (top) and normalized by summer peak demand (bottom)]




source: Hirst, Eric, *U.S. Transmission Capacity: Present Status and Future Prospects*, Consulting in Electric_Industry Restructuring, Bellingham, WA, June 2004, pg. 6.

# Annual Transmission Investments
## (Investor-Owned Utilities 1975-2003)




source: Hirst, Eric, *U.S. Transmission Capacity: Present Status and Future Prospects*,Consulting, Bellingham, WA, June 2004, pg. 7.

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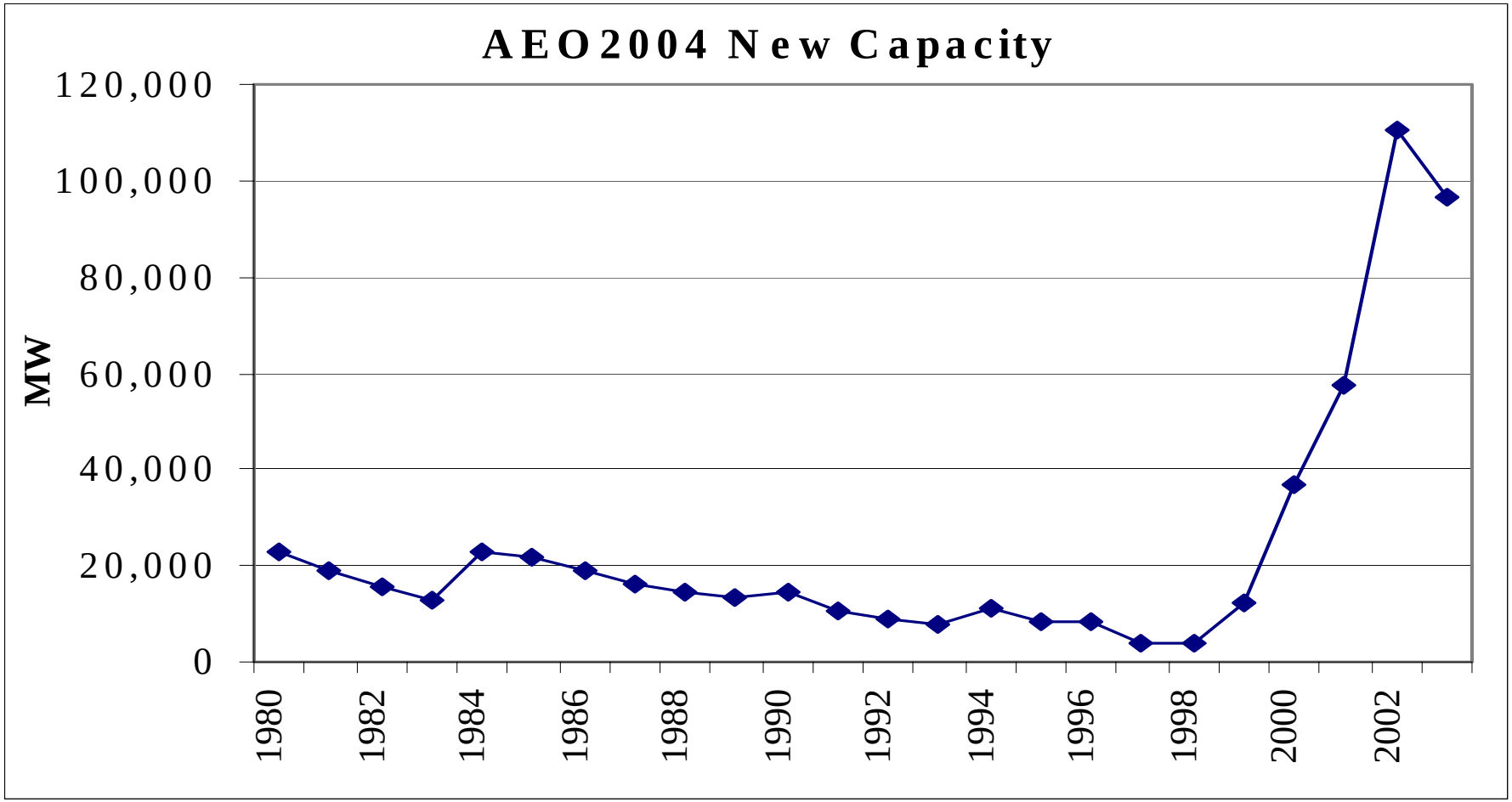
# AEO-2004 New Generating Capacity




source: NEMS AEO-2004 data file

# Lessons from 2003 Blackouts

- summer of 2003 saw a series of outages: northeastern U.S. and Canada, Italy, London, Sweden
- U.S.-Canada blackout left system intact
- yet 3 days for full Toronto subway service
- interdependent systems are vulnerable (e.g. telecom network)

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# Phone System's Weak Link

## Storms Cause Greater Outages In New Fiber-Optic Networks As BellSouth Races to Recover

AP/Wide World Photo

**By PETER GRANT**
**Staff Reporter of THE WALL STREET JOURNAL**
**September 17, 2004; Page B1**

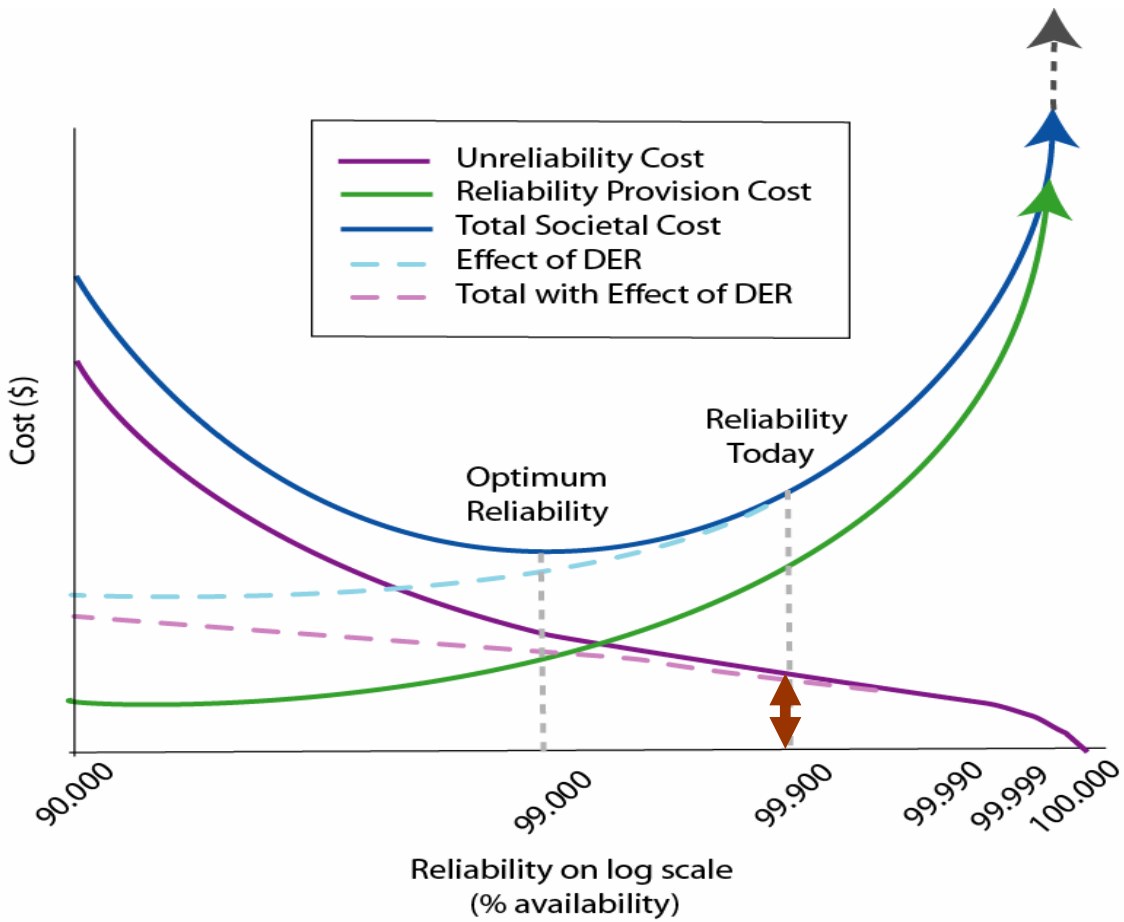
CHARLOTTE, N.C. -- Ron Royster stepped out yesterday for only a few minutes from **BellSouth** Corp.'s command center here, where technicians closely monitor the havoc Hurricane Ivan is wreaking on its phone network. But as soon as Mr. Royster, the center's director, returned, he could tell conditions had deteriorated.

Furthermore, because of fiber optics and other new technologies BellSouth has added to upgrade its networks over the past decade, the systems are, ironically, more vulnerable to disasters. The key problem: Many phone networks that used to rely on their own electricity now depend partly on commercial power. That means that when the utility company's power lines go down, the phones may go down, too.

But in the past decade, phone companies added fiber optics and devices known as "digital loop carriers," small file-cabinet-sized pieces of equipment, between central offices and homes. The devices have greatly boosted the capacity of the lines, cutting costs and making new services including high-speed Internet connections possible.

The digital-loop devices also run on electricity from the local power company's network, however. While they are equipped with batteries, that backup lasts only about eight hours -- and less if there's a lot of Internet traffic over the network. Once the batteries run out, phone and Internet service goes dead unless a backup generator can be installed. While some digital-loop carriers have a generator, BellSouth says it would be economically unfeasible to put a generator at all 65,000 of them.

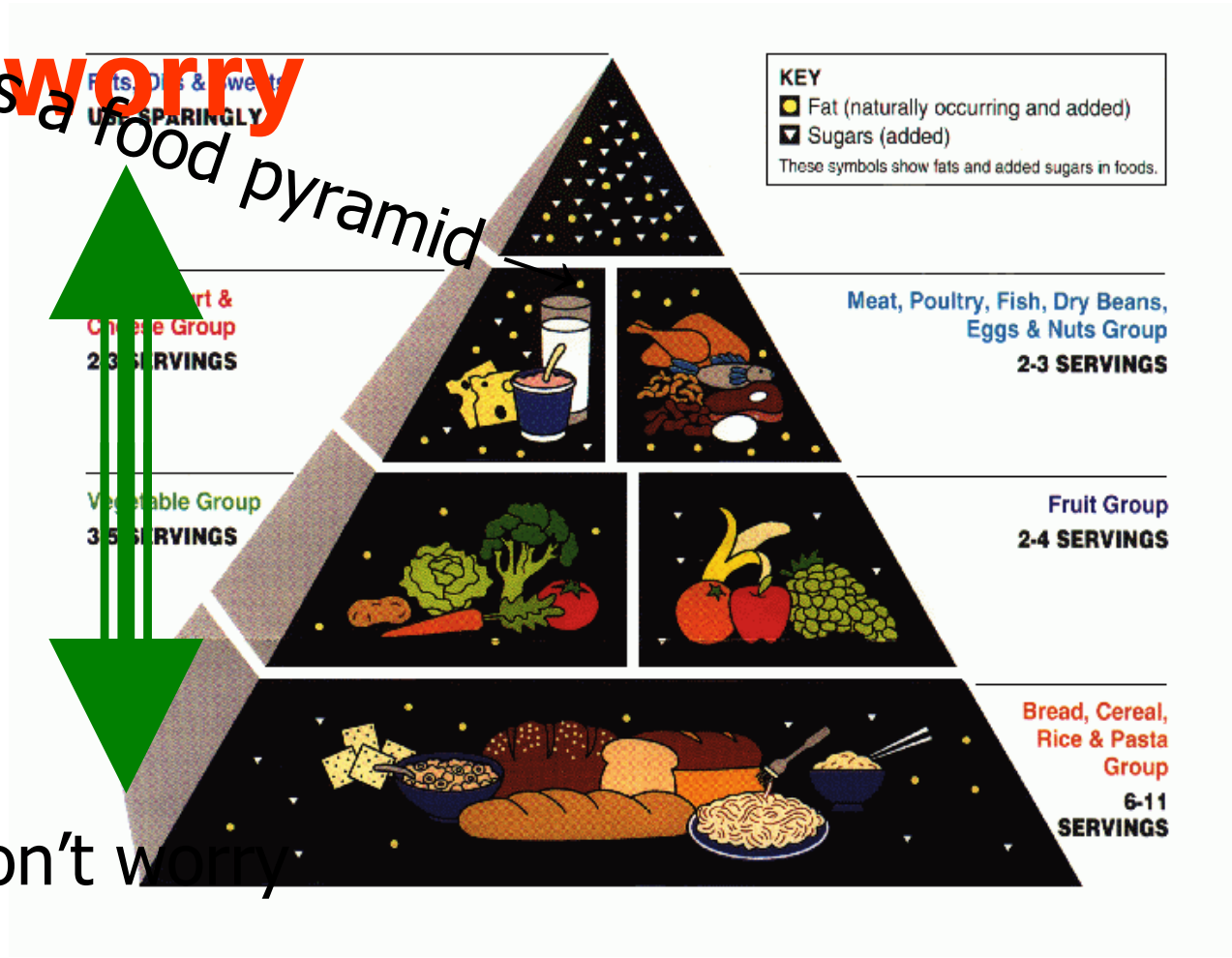
# The Optimal Universal Level of Electricity Supply Reliability



# Why a Pyramid?

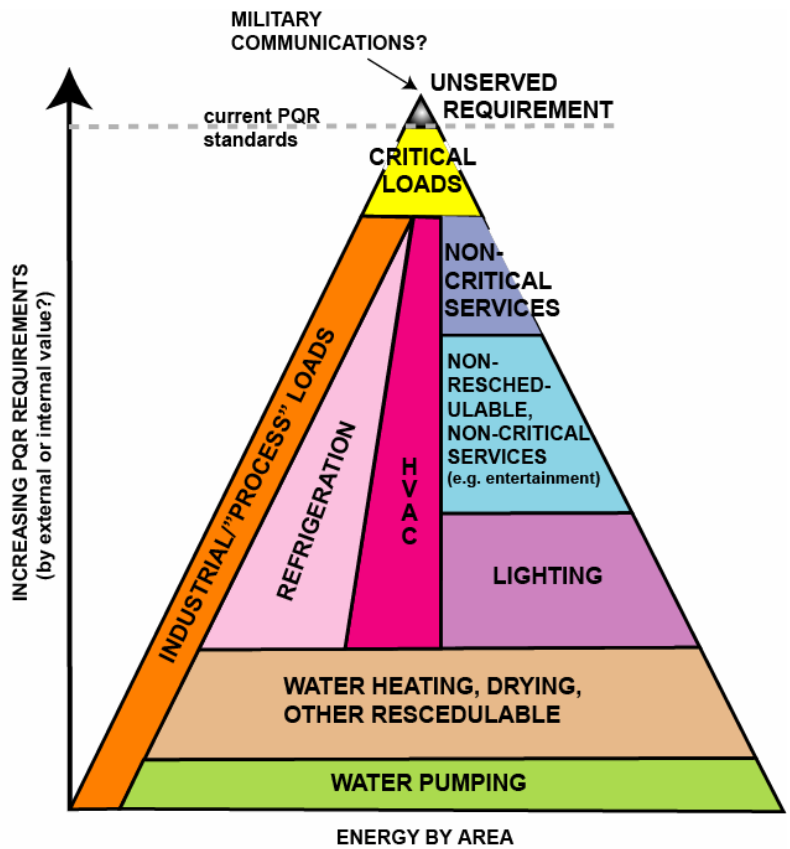
This is a food pyramid

worry



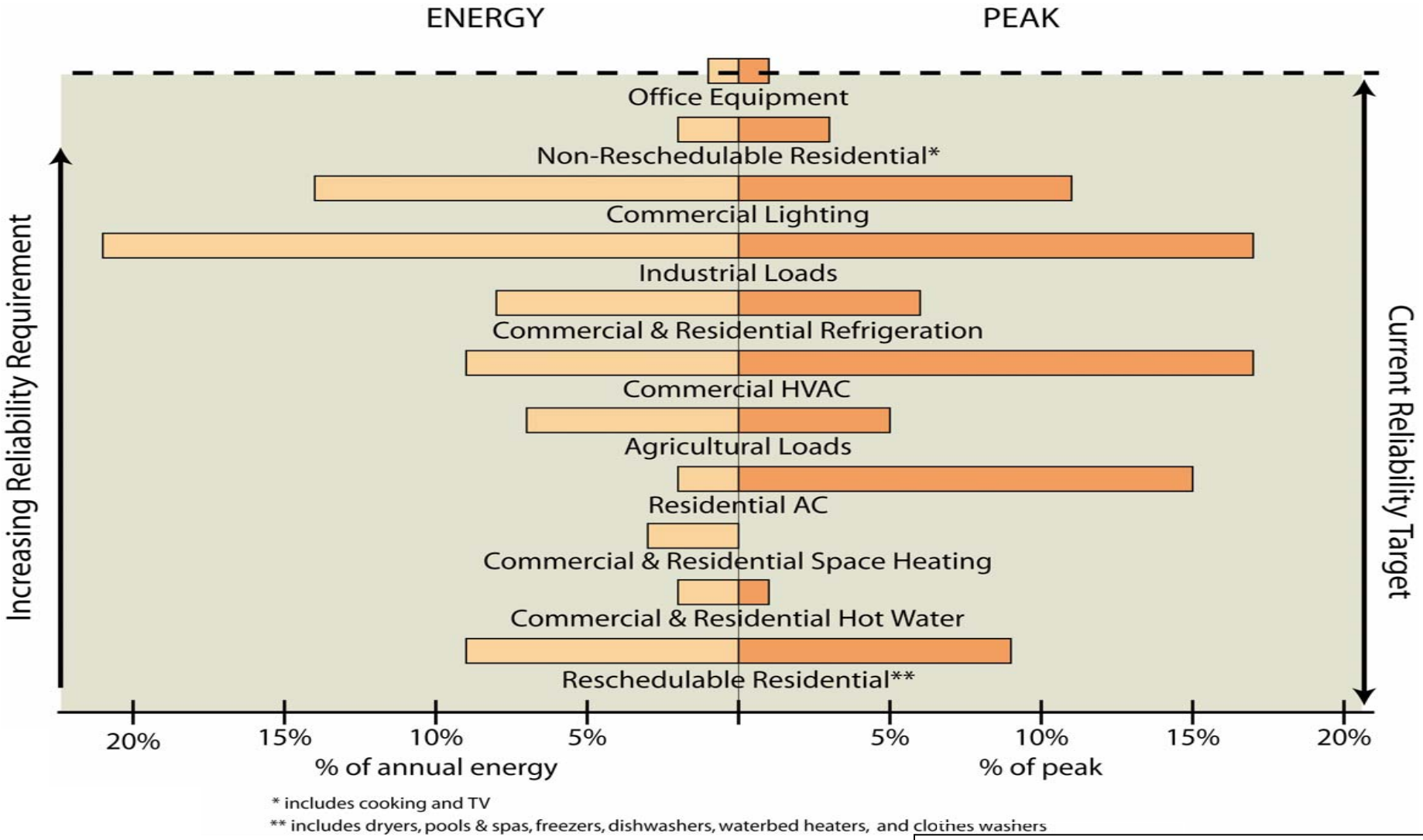

don't worry

# A First Energy Pyramid




- highly sensitive loads are small
- most demanding PQR requirements are not met
- categories cover a range of PQR requirements
- need new categories

# 1999 California Electricity Consumption by End-Use




* includes cooking and TV

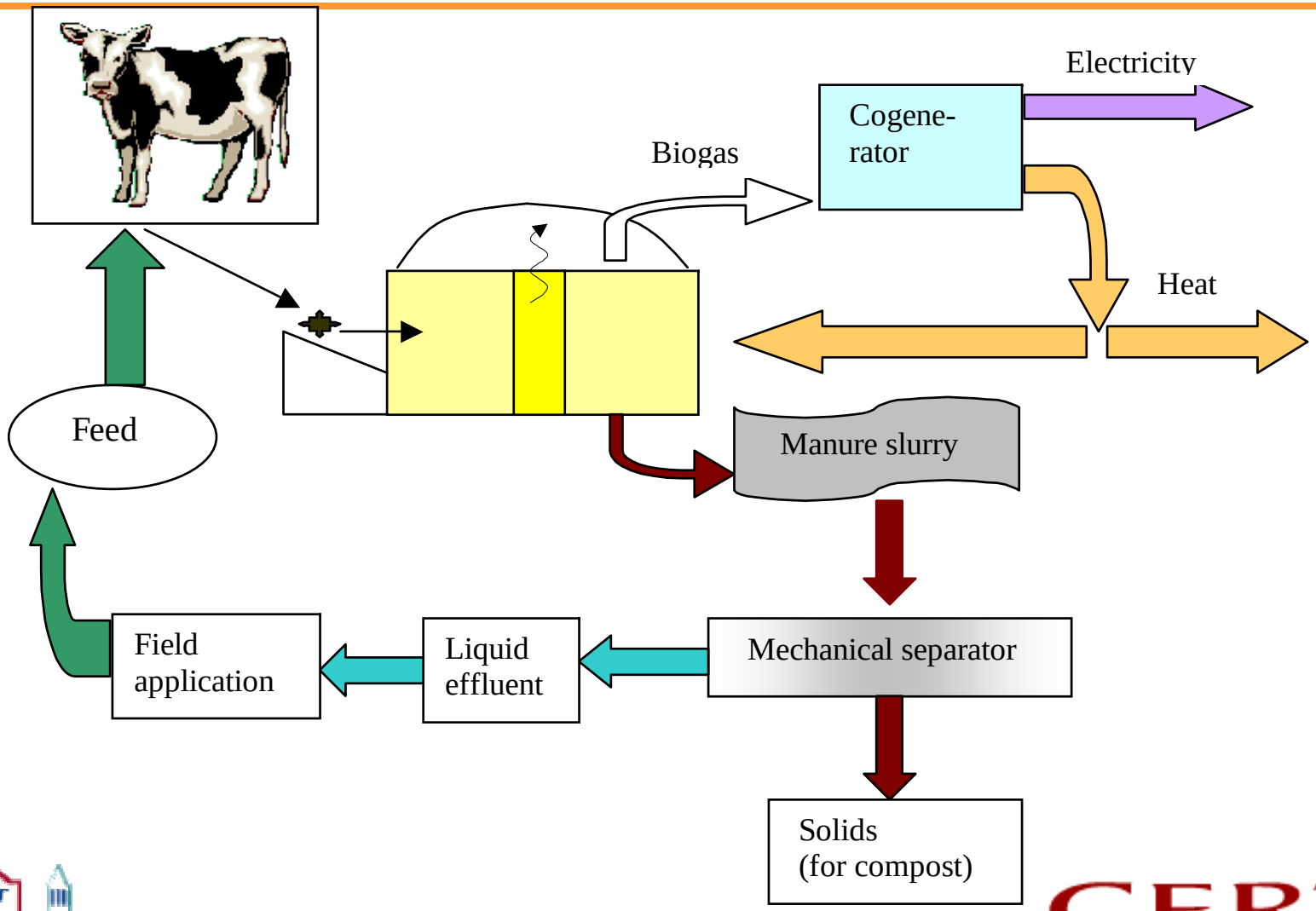
** includes dryers, pools & spas, freezers, dishwashers, waterbed heaters, and clothes washers

*source: Brown & Koomey, Energy Policy 2003*

# V. Conclusions

- expansion of the macrogrid is constrained
- power conversion local to loads in microgrids
  (e.g. CERTS Microgrid) can deliver a cost, efficiency (CHP), and reliability gain
- DER-CAM systemically analyzes building energy systems, i.e. directly considers CHP (& efficiency)
- our understanding of other issues, notably heterogeneous reliability is rudimentary
- multiple building power systems one possibility
- interdependent systems create vulnerability
- CERTS Microgrid going to lab testing in 2005

# AA Dairy Farm, Candor NY




source: Peranginangin and Scott, Cornell University

# AA Dairy Farm, Candor NY

# Moscone Center, San Francisco

# Guarantee Savings Building, Fresno CA

- 3 x 200 kW PAFC in parallel with grid
- charging $0.35/kWh to GSA for electricity
- DER-CAM optimal NG engines 500 kW + 2 x 55 kW CHP + 100 kW PV
- perceived cost of combustion permitting
- FC economic to spark spread increase of 140% (to 5) or standby charge of $8/kW