Economic Evaluation of Residential Air Conditioner Designs for Hot and Dry Climates

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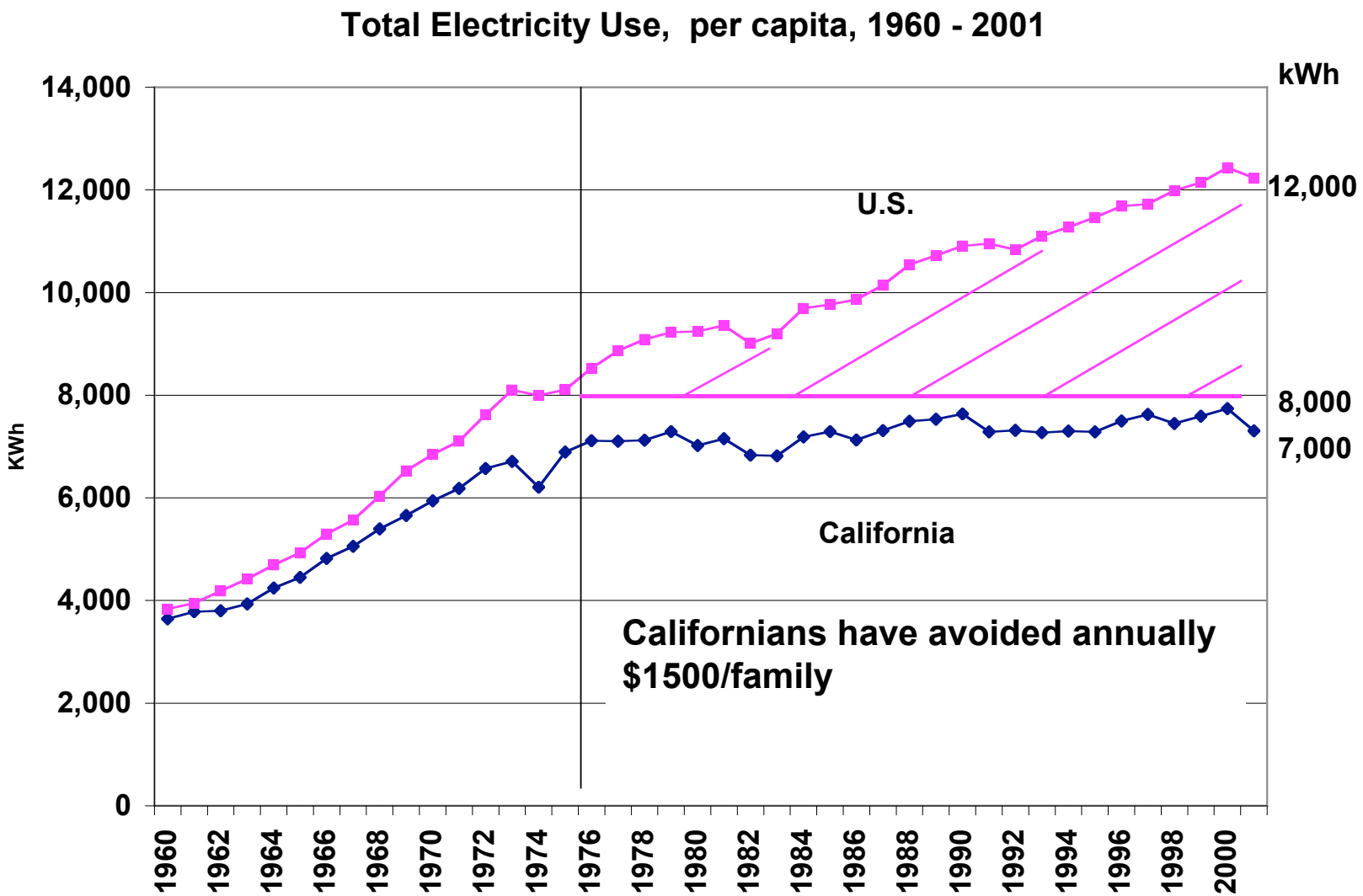
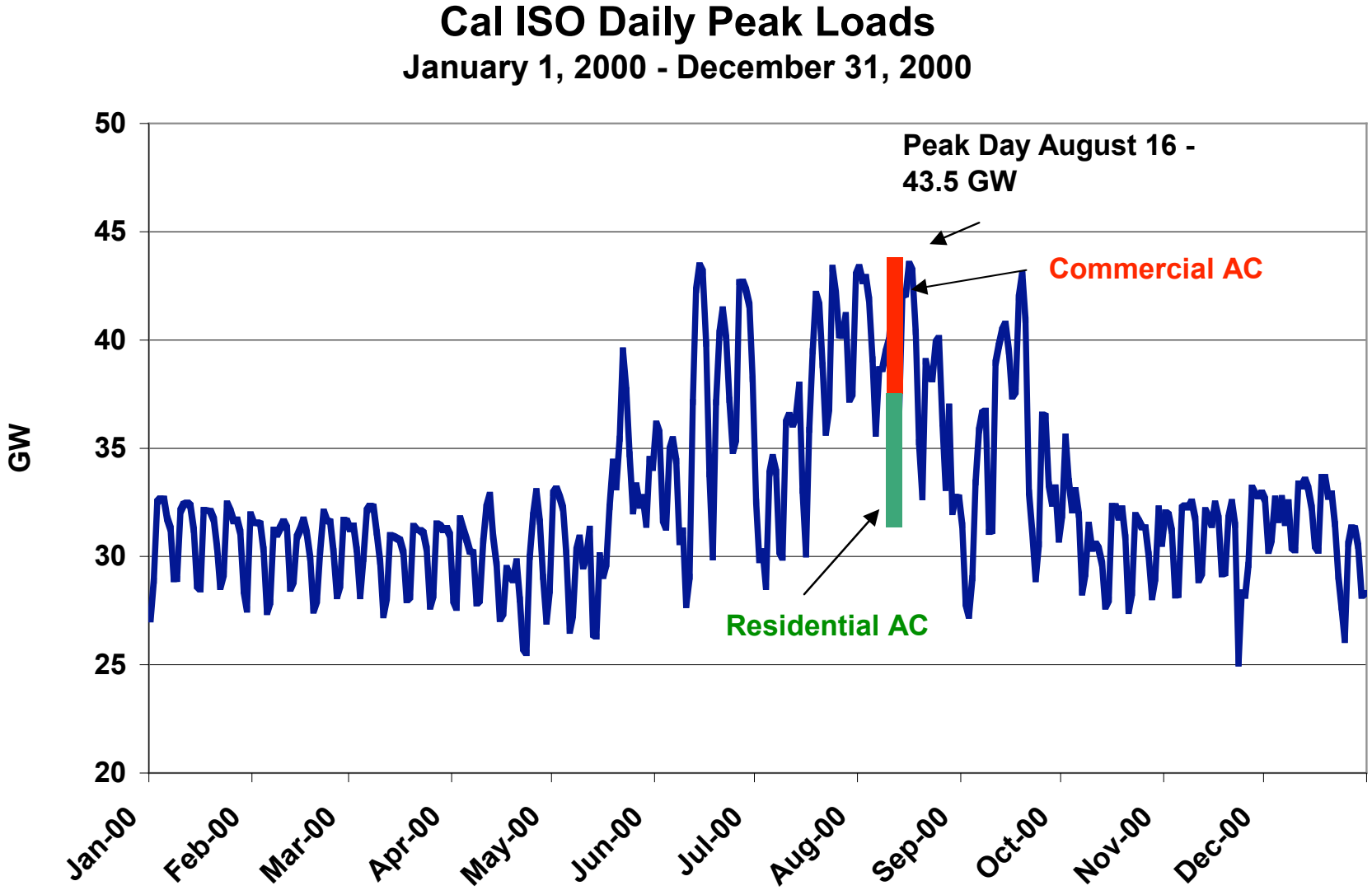
California has lower per capita electricity use than the rest of the country



Daily peak loads in California are highest during the summer



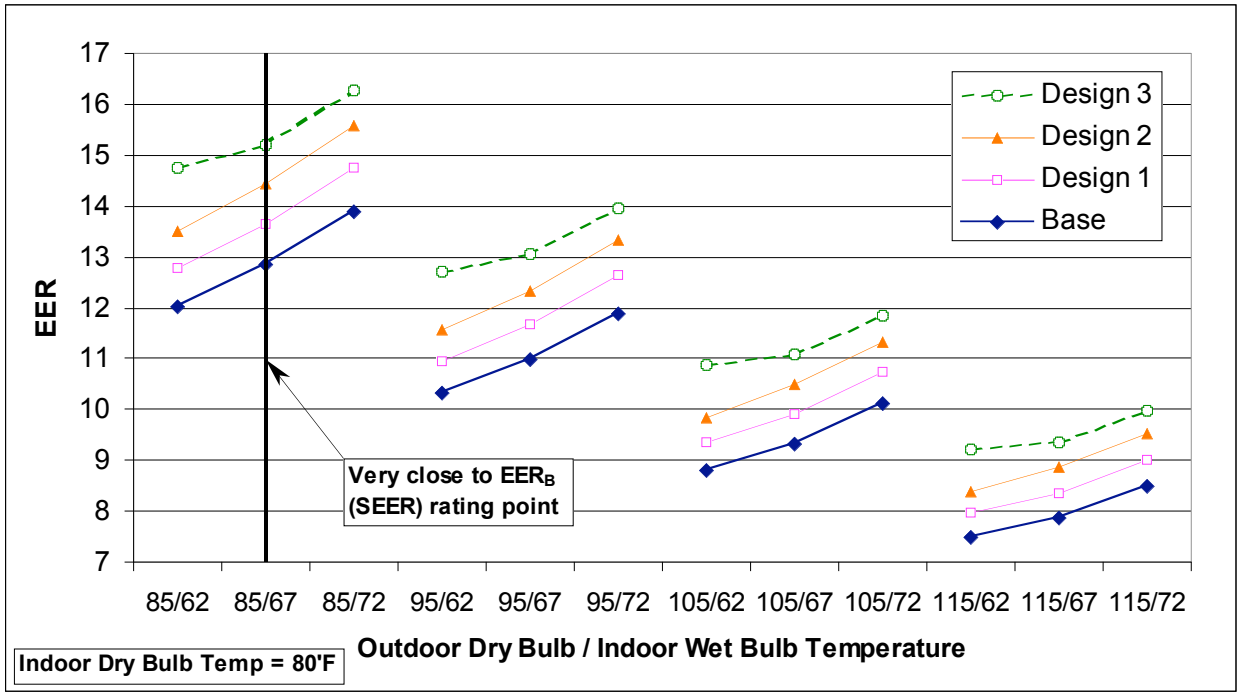
DOE has funded research at ORNL to develop A/C designs for hot/dry climates

- **Several Hot/Dry designs were developed by ORNL relative to a conventional baseline design**
- **Three Hot/Dry designs were adapted for economic evaluation**
  - **Baseline design: 13 SEER, R-410A**
  - **Hot/Dry designs**
    - **Design 1: 1.4X Evap HX surface area**
    - **Design 2: 1.4X Evap HX surface area; ECM Blower Motor**
    - **Design 3: 1.4X Evap HX surface area; ECM Blower Motor; Rated Ducts**

	System		Evaporator				Compressor	Ducts
Design	**SEER**	**Hot/Dry EER** Out: 115°F In: 80°F/62°F	**Face Area** *Sq.ft.*	**Flow** *CFM*	**Fan Power** 115°F; 80/62°F *Watts*	**Evap Temp** Out: 95°F In: 80°F/67°F	*Percent of Baseline Displacement*	**Type / Ext. Static** *Inches H_2O*
Baseline	13.1	7.5	5.0	1200	355	48°F	-	Typical / 0.5"@1200 CFM
Design 1	13.8	8.0	7.2	1200	330	52°F	94%	Typical / 0.5"@1200 CFM
Design 2	14.6	8.4	7.2	1200	265	52°F	91%	Typical / 0.5"@1200 CFM
Design 3	15.4	9.2	7.2	1500	250	55°F	84%	Rated / 0.15" fixed

Designs evaluated at multiple temperatures for purposes of modeling in a typical house

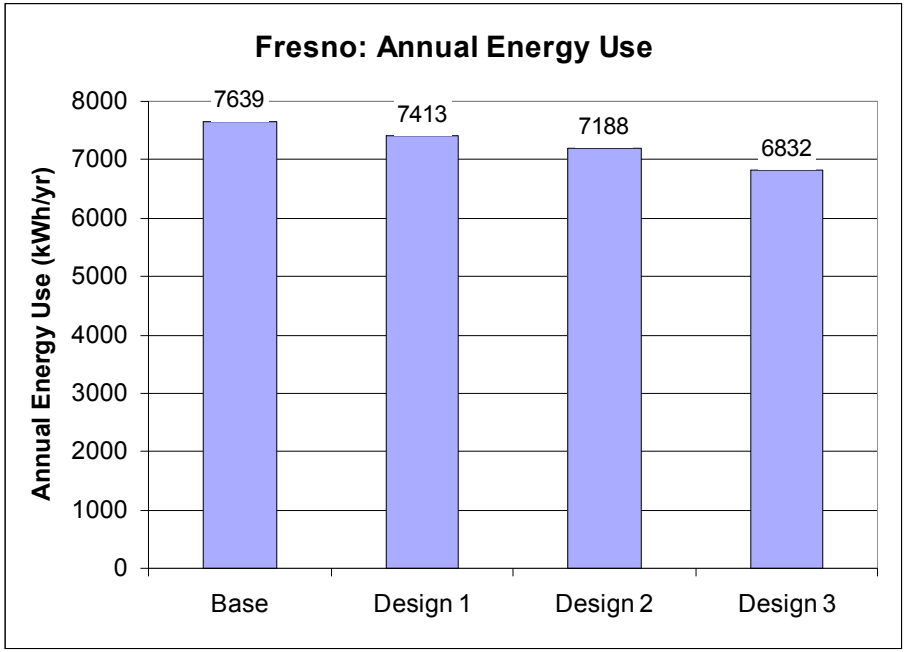
- **Baseline and three Hot/Dry designs were simulated with the ORNL Heat Pump Design Model, Mark VI, at four sets of outdoor dry bulb/indoor wet bulb temperature conditions**
  - **More efficient designs maintain their efficiency advantage regardless of temperature conditions**
  - **Compressor downsized to match baseline capacity-- hot/dry design condition**

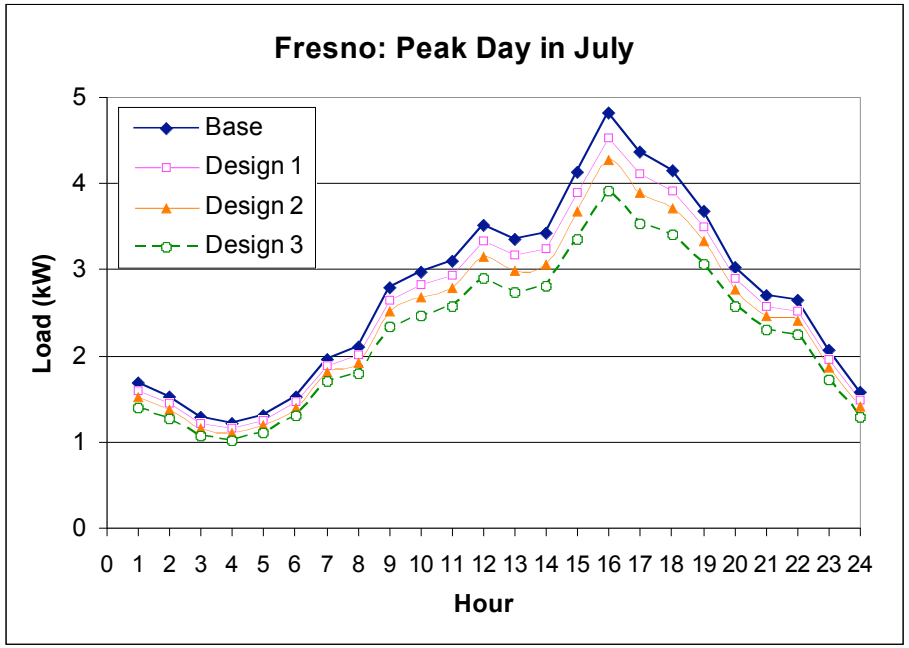


Prototypical house chosen for two hot/dry locations: Fresno, CA and Phoenix, AZ

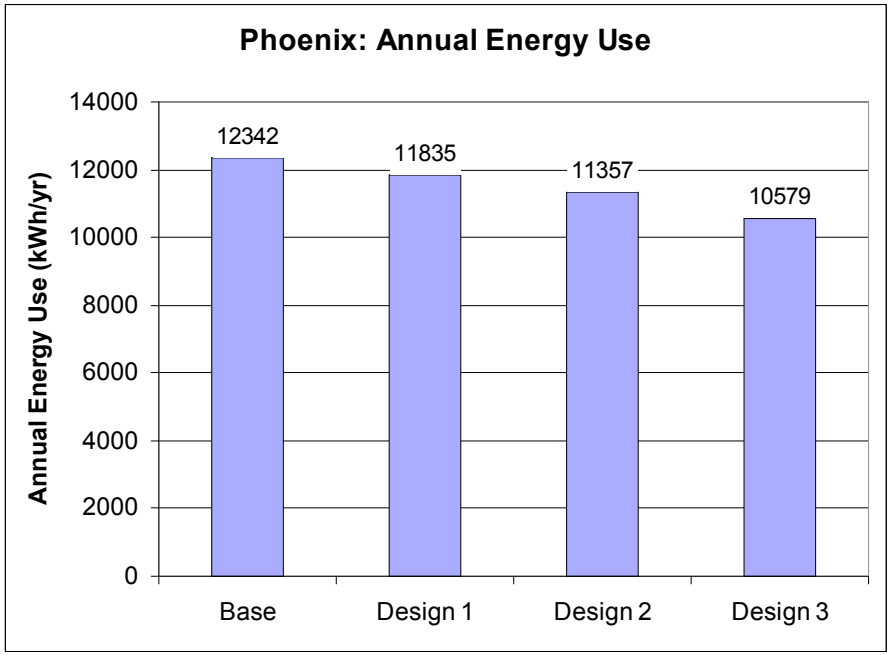
- California prototypical house for Fresno
- Fresno house modeled in Phoenix (only weather changed)
- Both locations modeled with DOE-2
  - Square footage: 2258 sq.ft.
  - Number of floors: 2
  - Floor type: Slab-on-grade
  - Exterior wall
    - Area: 1584 sq.ft.
    - Insulation: R-13
  - Ceiling insulation: R-30
  - Windows
    - Area: 251 sq.ft.
    - Window-to-Wall Ratio: 16%
    - R-value: R-1.2 (double-glazing)

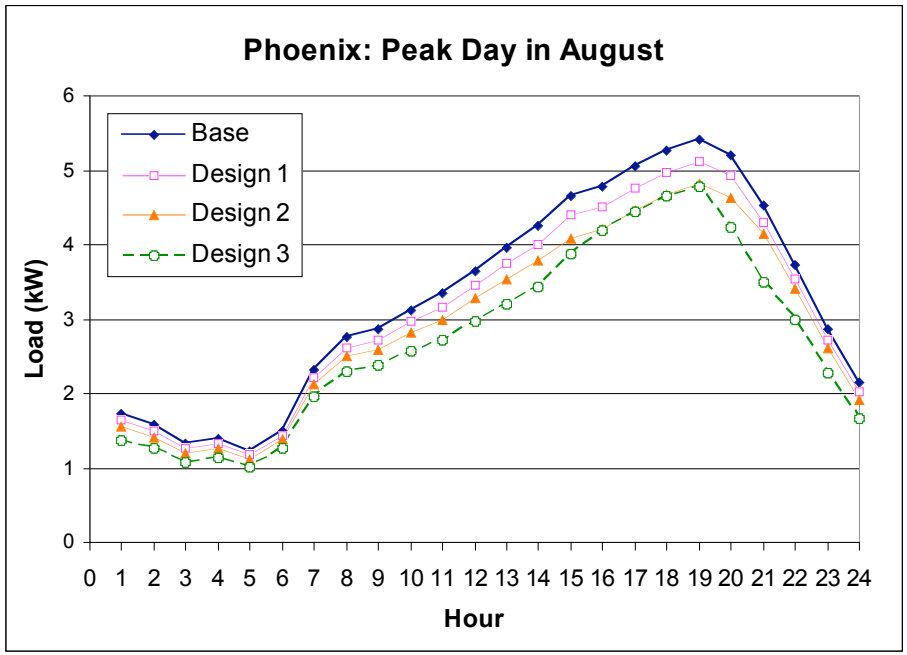
Designs yield both annual energy and peak demand savings in Fresno





Designs yield both annual energy and peak demand savings in Phoenix





CEC-PIER Hot-Dry a/c Proof of Concept Project

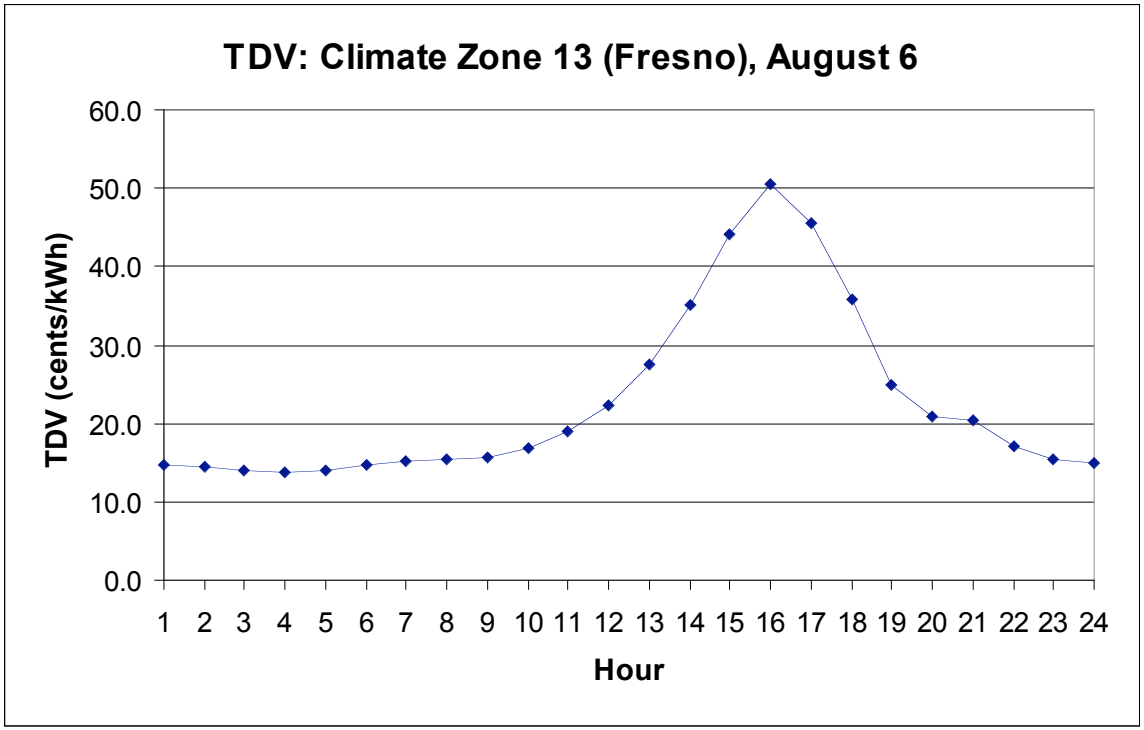
- **Proctor Engineering et al. have modified Keith Rice's Designs and built two early prototypes optimized for California a/c loads, one 3-ton residential split system, one 5-ton commercial package unit. Actual measurements to date support the calculations provided in earlier slides**
- **See http://www.hdac-des-pier.com/project.html**

Residential electric utility tariffs used to calculate bills

- **Fresno: Pacific Gas & Electric Co.**
- **Schedule E-1 – Residential Service (Zone R) (Effective March 1, 2004)**
  - **Monthly Summer Charges**
    - 0 to 534 kWh: 12.59 ¢/kWh
    - 534 to 694 kWh: 14.32 ¢/kWh
    - 694 to 1068 kWh: 18.15 ¢/kWh
    - 1068 to 1602 kWh: 21.43 ¢/kWh
    - Remaining kWh: 21.43 ¢/kWh
  - **Monthly Winter Charges**
    - 0 to 387 kWh: 12.59 ¢/kWh
    - 387 to 503 kWh: 14.32 ¢/kWh
    - 503 to 774 kWh: 18.15 ¢/kWh
    - 774 to 1161 kWh: 21.43 ¢/kWh
    - Remaining kWh: 21.43 ¢/kWh
  - **Fixed Charges**
    - Monthly Charge: $5.00
- **Phoenix: Arizona Public Service Co.**
- **Residential Service E-12 (Effective July 1, 2003)**
  - **Monthly Summer Charges**
    - 0 to 400 kWh: 7.38 ¢/kWh
    - 400 to 800 kWh: 10.28 ¢/kWh
    - Remaining kWh: 11.99 ¢/kWh
  - **Monthly Winter Charges**
    - All kWh: 7.39 ¢/kWh
  - **Fixed Charges**
    - Basic Service Charge: $7.50

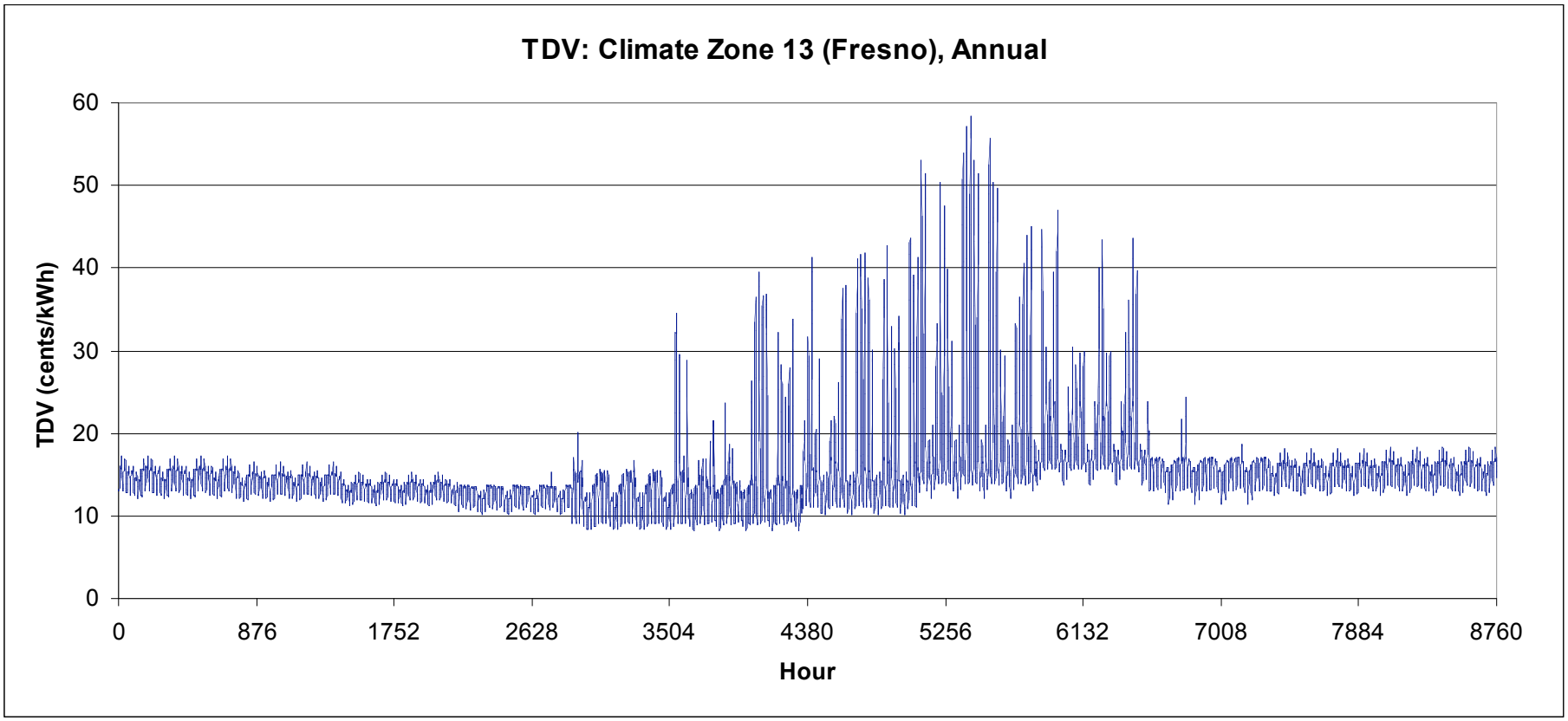
Time dependent valuation (TDV) prices are also used to calculate bills

- TDV prices are incorporated into California appliance standards (Title 20) and building standards (Title 24)
- TDV prices, or avoided costs, are independent of the idiosyncrasies of utility tariffs
- TDV prices incent efficient air conditioners

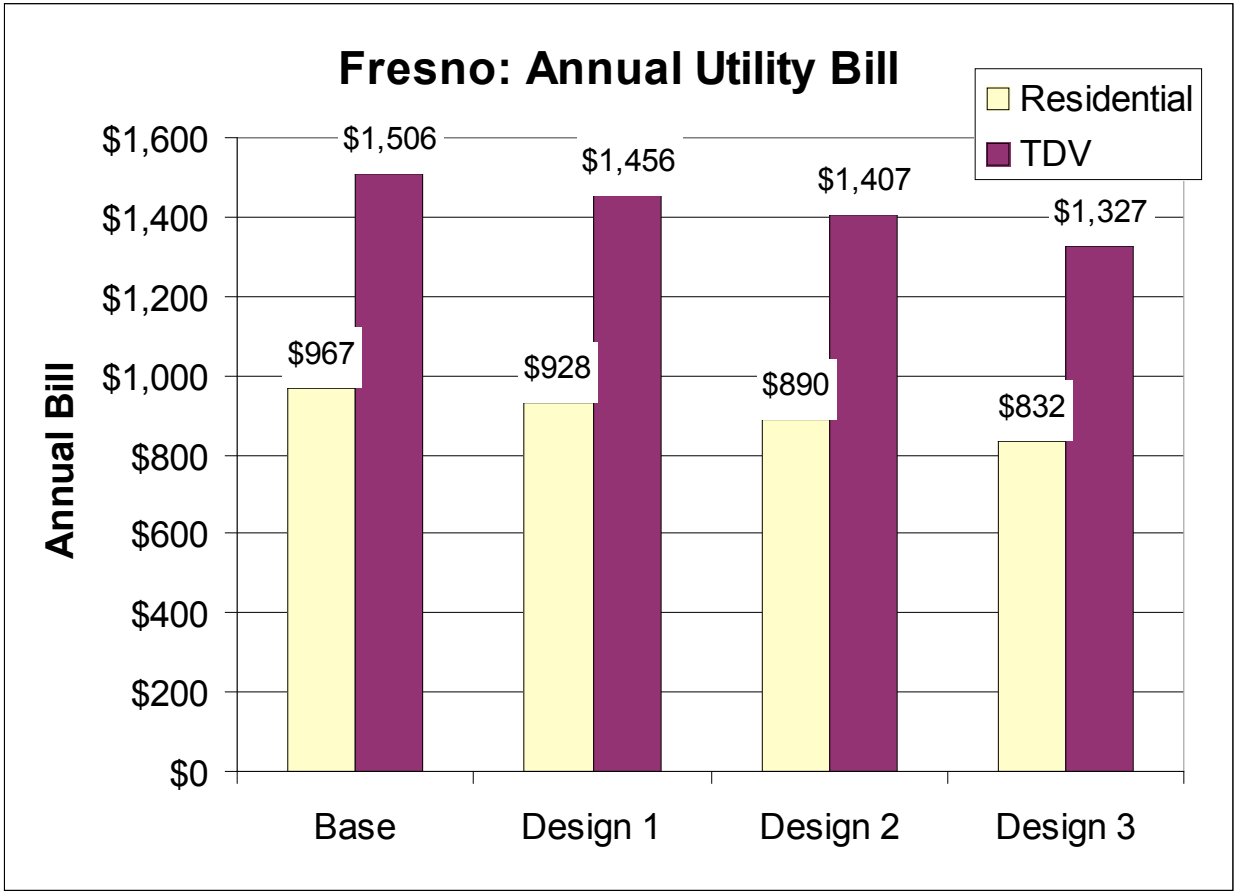


Time dependent valuation (TDV) prices vary over the year

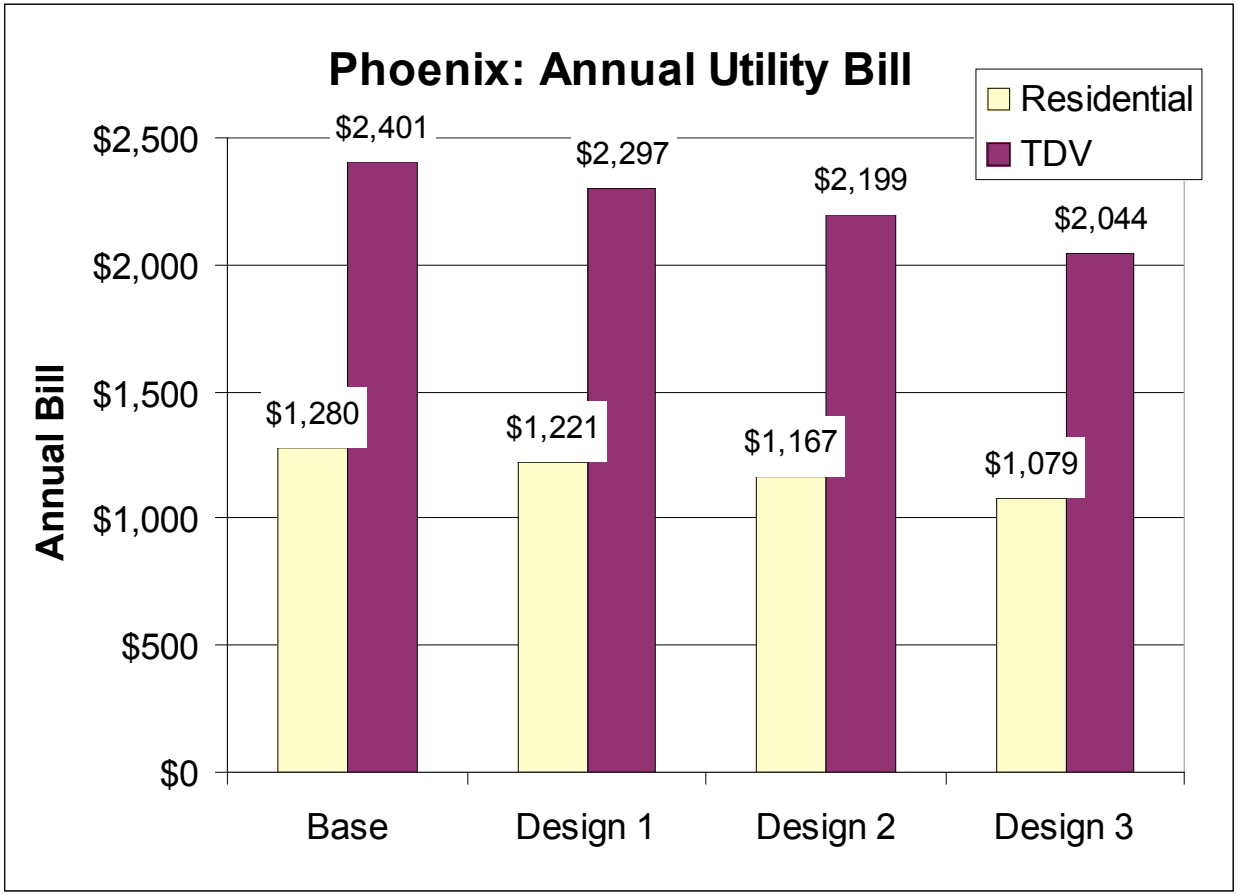
- **Although TDV prices in some hours exceed 50 ¢/kWh, annual average TDV price equals 15 ¢/kWh**



Fresno A/C energy use can now be expressed as utility bills – PG&E and TDV



Phoenix A/C energy use can now be expressed as utility bills – APSC and TDV



Consumer price of more efficient designs increase with efficiency

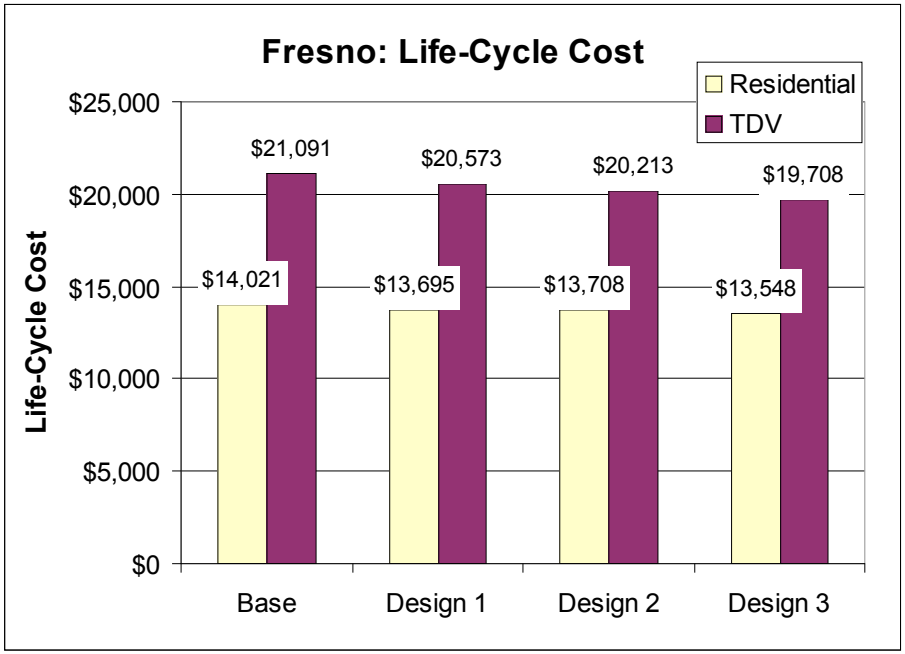
	Manufacturer Cost					Δ Consumer Price		
	Compressor	Evap Coil	Evap Motor	Total	Δ Cost	Δ Price	Δ Ducts	Δ Total
Baseline	$168	$113	$61	$342	-	-	-	-
Design 1	$158	$172	$61	$391	$49	$101	-	**$101**
Design 2	$153	$172	$185	$510	$168	$348	-	**$348**
Design 3	$141	$172	$185	$497	$155	$322	$500	**$822**

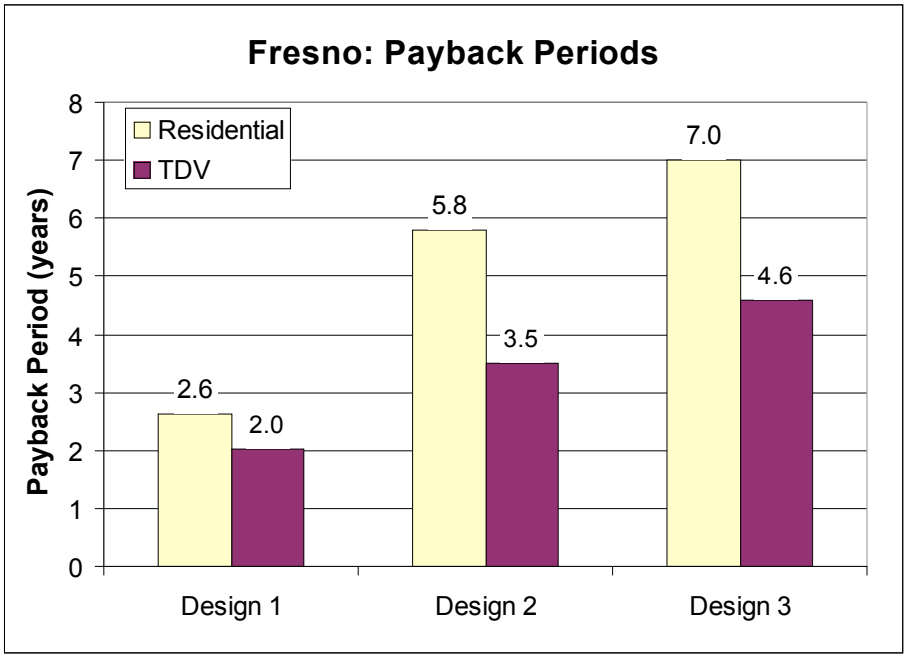
- **Manufacturer cost estimates from 2001 DOE Technical Support Document**

Cost-effectiveness of designs based upon LCC savings and payback

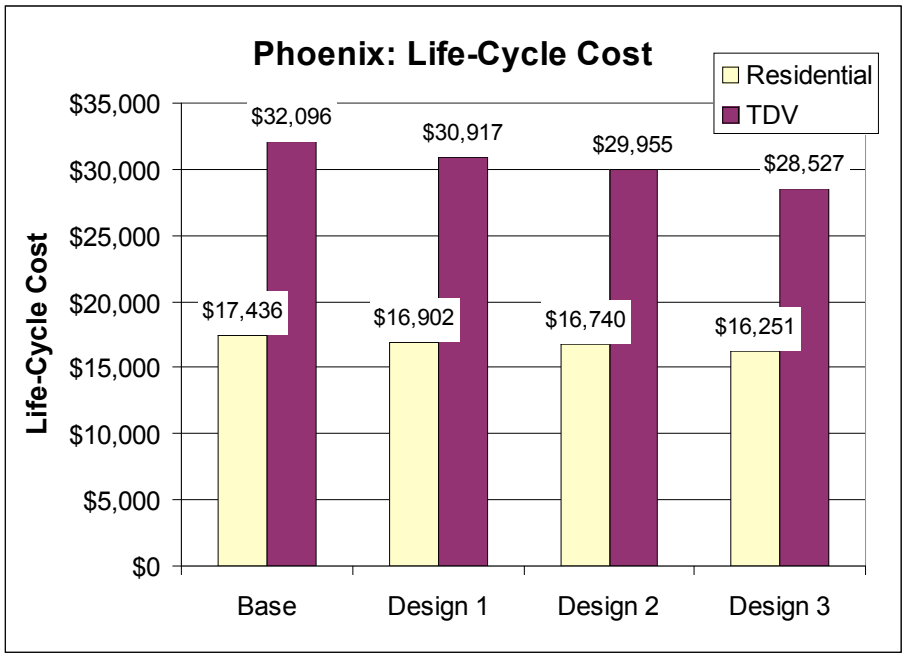
- **Life-cycle cost (LCC) is the sum of the total installed cost plus the present value of the lifetime operating cost savings**
  - **For residential tariff calculations, present value of future operating cost savings calculated with a 5.6% real discount rate**
  - **Equipment lifetime set to 18.4 years**
  - **Future electricity price trends based upon DOE-EIA's 2004 Annual Energy Outlook**
  - **Both the discount rate and lifetime are taken from DOE's central air conditioner rulemaking analysis**
- **Payback period is the increase in total installed cost divided by the annual operating cost savings**

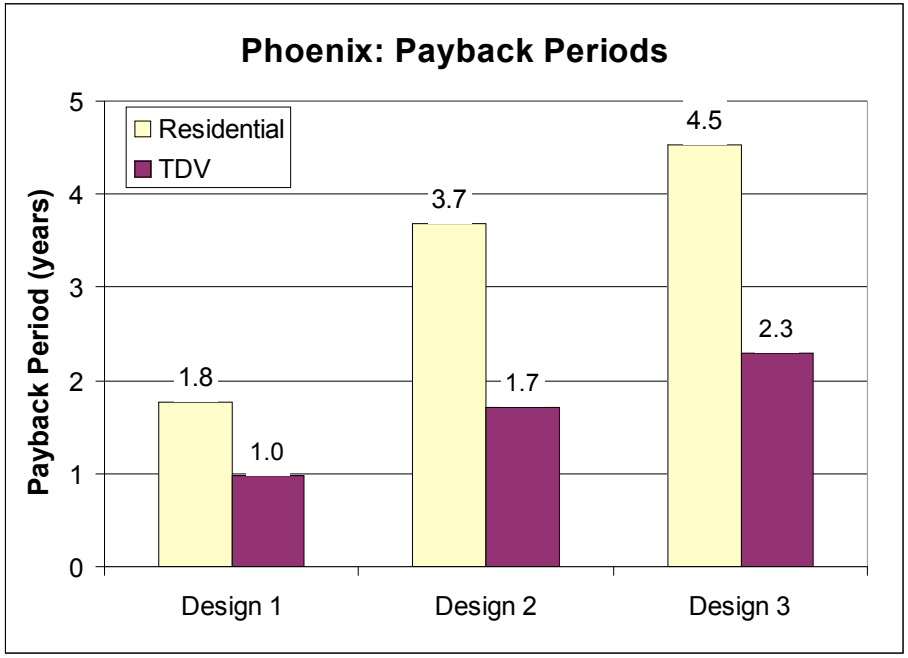
All designs provide both LCC savings and short payback periods in Fresno





All designs provide both better LCC savings and shorter payback periods in Phoenix

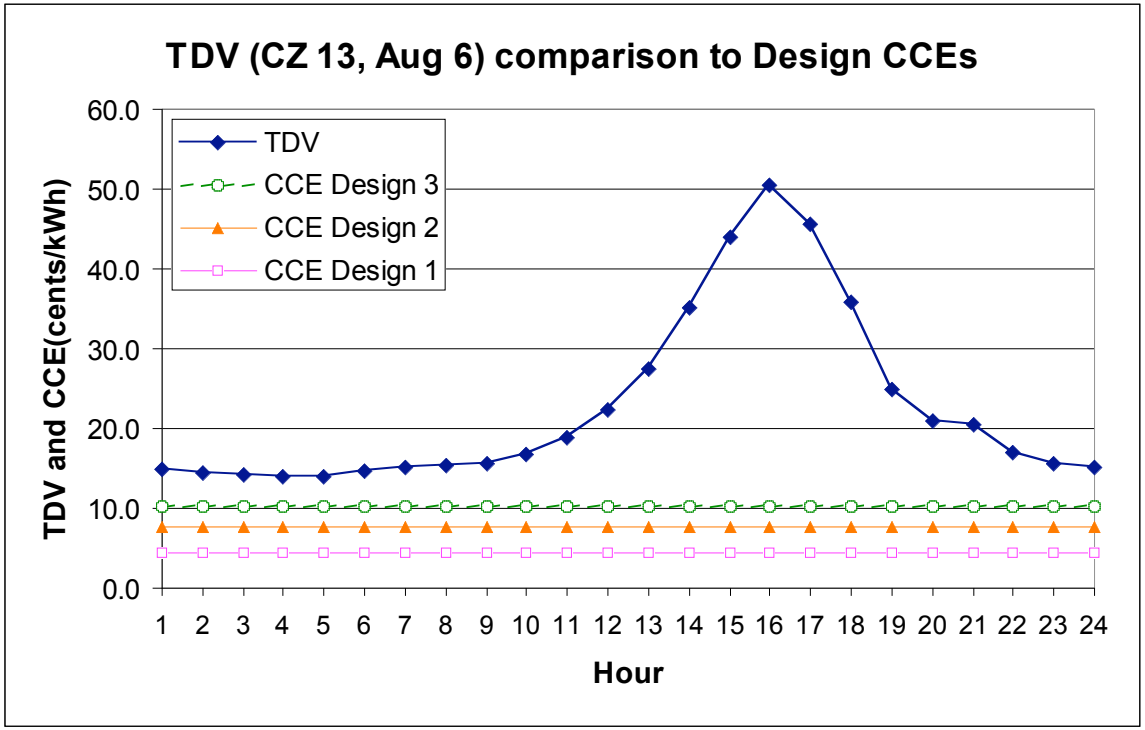




Cost of Conserved Energy (CEE) can also be used to evaluate designs

$$CCE = \frac{\Delta\$_{AC} \cdot CRR}{\Delta kWh_{per\ year}}$$

CEE	**= Cost of Conserved Energy**
$\Delta\$_{AC}$	**= Consumer price increase due to hot/dry AC design**
CRR	**= Capital recovery rate; set at 10% per year**
$\Delta kWh_{per\ year}$	**= Annual energy savings due to hot/dry AC design**



Summary of Analysis

- **All three Hot/Dry A/C designs developed by ORNL provide LCC savings and relatively short payback periods**
  - **LCC savings range from:**
    - **~$300 to ~$1200 based on residential electric utility tariffs**
    - **~$500 to ~$3500 based on TDV prices**
  - **Payback periods range from 2 to 7 years**
  - **LCC savings and payback periods are relative to a 13 SEER baseline design**
- **To exploit full savings potential:**
  - **Manufacturers need to offer equipment designed for Hot/Dry climates**
  - **California needs to revise building standards to ensure good ducts**