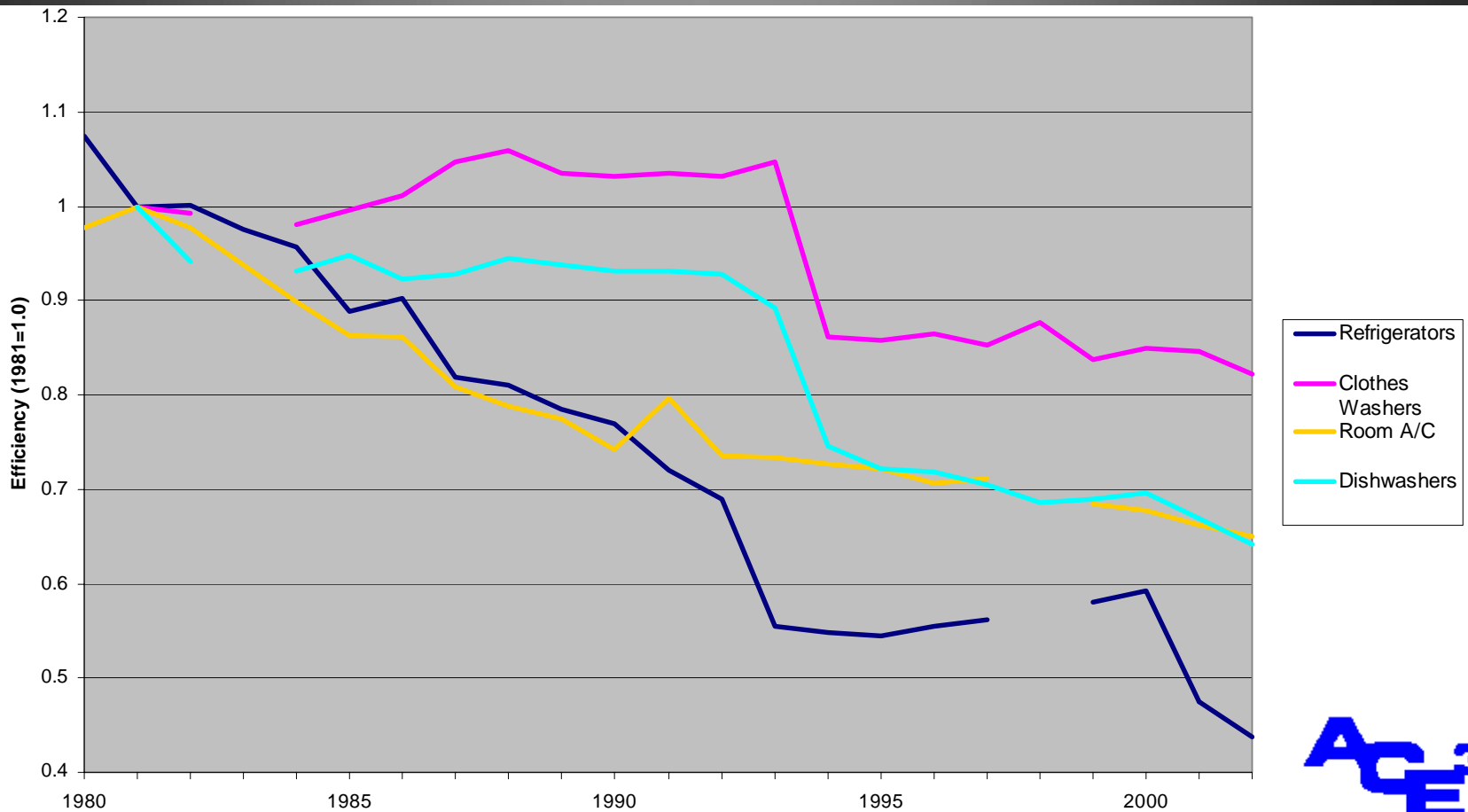


Increasing Appliance Energy Savings by Looking Beyond the Current Energy Star

Steven Nadel, ACEEE
2004 Energy Star Appliance
Partner Meeting



Appliance Efficiency Trends



Source: AHAM 2003 Factbook



Efficiency Levels in 2004

Product	Federal Standard	Energy Star	Best Available
Refrigerator	520 kWh avg in 2002	15% better (~440 kWh)	>20% better
Clothes washer	1.04 MEF (1.26 in '07)	1.42 MEF	>1.8 MEF (some >2)
Room air conditioner	9.7-9.8 for <20kBtuh	10.7-10.8	>11 EER
Dishwasher	.46 EF	.58 EF	>.70 EF (some >1)

Dehumidifiers – Current and Proposed Energy Star Specs

Category	Pints/ day	Liters/ day	Current E* (L/kWh)	Consensus Proposal
IA	≤ 25	≤ 11.8	1.0	1.2
IB	25-35	11.8-16.6	1.2	1.3
IIA	>35-45	>16.6-21.3	1.3	1.4
IIB	>45-54	>21.3-25.6	1.3	1.5
III	>54-<75	>25.6- <35.5	1.5	1.6
IV	≥ 75	≥ 35.5	2.25	2.5

CEE SEHA Levels

- Refrigerators – 20, 25 and 30% better than federal standard
- Clothes washers – 1.42, 1.60, and 1.80 MEF (9.5, 8.5, 7.5 and 5.5 WF)
- Room a/c – 15% & 20% better than federal standard (e.g. 11.2-11.3 & 11.6-11.8 EER for units <20kBtuh)
- Dishwashers – nothing beyond Energy Star at present



Pending Federal Tax Credits

- Included in Senate bill, not House bill
- Conference may be completed this week
- Tax credits to manufacturers for 2005-2006
- \$100 for Energy Star refrigerators and clothes washers with $\text{MEF} \geq 1.5$
- \$150 for refrigerators that save 20% relative to current federal standards (\$100 in 2007)
- Sen. Smith (R-OR) has proposed incentives for 2008-2010 (including dishwashers)



Refrigerators Exceeding Federal Standard by at Least 21%

Brand	Model	Configuration	Defrost Type	Compact	Ice	Volume	Adjusted Volume	kWh/year	Percent Better
Sun Frost	R-19	Refrigerator Only - Single Door	Automatic	No	No	16.14	16.14	204	53%
Sun Frost	RF-12	Top Freezer	Partial	No	No	10.12	11.41	171	51%
Sun Frost	RF-16	Top Freezer	Partial	No	No	14.31	16.77	254	36%
Avanti	BCA902W	Refrigerator Only - Single Door	Automatic	No	No	8.87	8.87	247	32%
Avanti	RM901W	Refrigerator Only - Single Door	Manual	No	No	8.70	8.70	230	29%
General Electric	ZIS420NR	Side-by-Side	Automatic	No	Yes	26.01	32.13	565	23%
General Electric	ZISS420NRS	Side-by-Side	Automatic	No	Yes	26.01	32.13	565	23%
LG Electronics	LRSC2696#**	Side-by-Side	Automatic	No	Yes	25.51	31.31	565	22%
Avanti	1201W-1	Refrigrator/Freezer - Single Door	Manual	No	No	11.00	11.69	277	21%
Kenmore	7420*40*	Top Freezer	Automatic	No	No	21.64	25.72	417	21%
Kenmore	7421*40*	Top Freezer	Automatic	No	No	21.64	25.72	417	21%
Kenmore	7490*40*	Top Freezer	Automatic	No	No	18.79	21.94	387	21%
Kenmore	7491*40*	Top Freezer	Automatic	No	No	18.79	21.94	387	21%

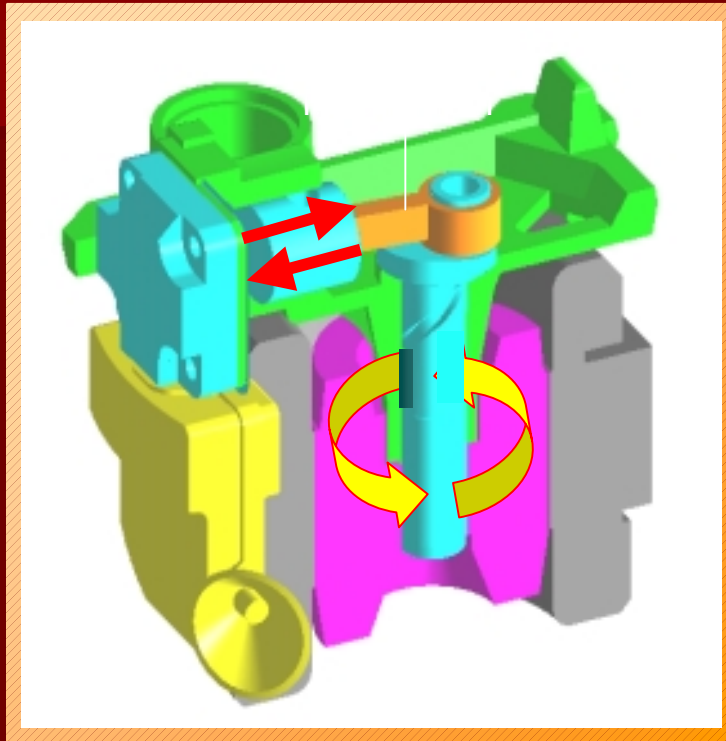
Based on Energy Star database, 9/30/04; units less than 7.75 cf not included.



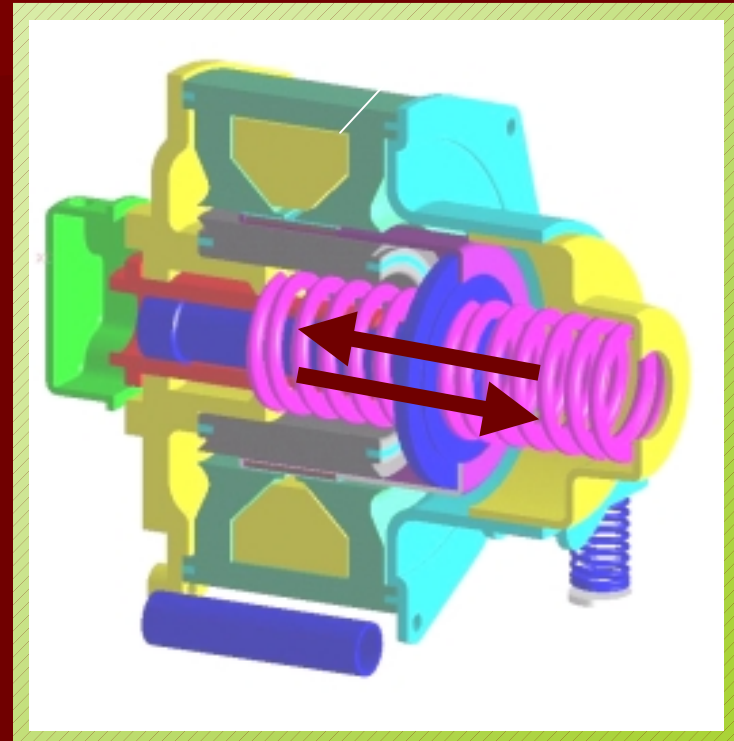
Linear Compressor

What's difference?

Recipro. Compressor



Linear Compressor



Crank mechanism

Motor

Linear motion

*Direct
Transmission*

Piston

Linear Compressor



High efficiency

Low Energy Loss

Total Loss of Compressor

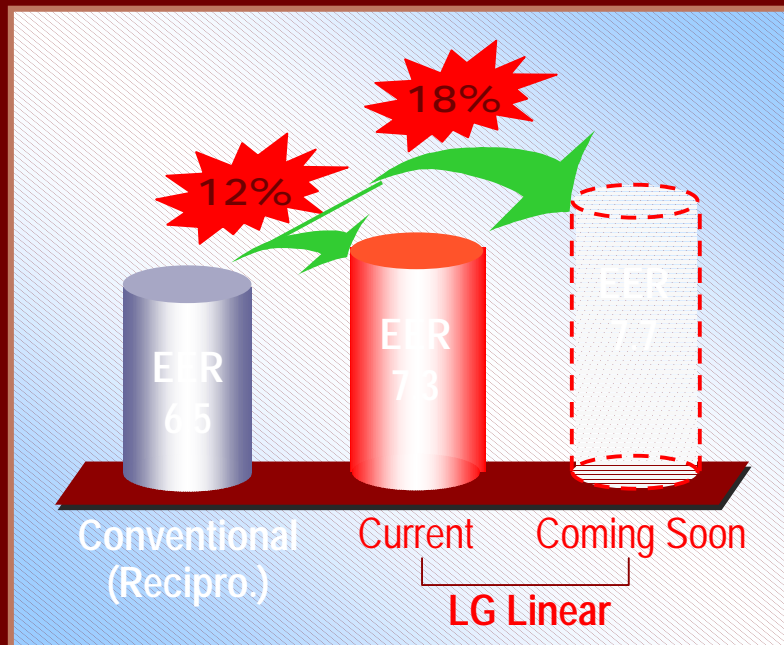
Motor Loss
+
Friction Loss
+
Flow Loss
+
Heat exchange Loss

- Super Efficient Linear Motor
- No Crankshaft Mechanism
- Direct Suction & Straight Flow Path
- Free Piston System

High
Efficiency

Linear Compressor

Compressor Efficiency for **R134a** Refrigerant



Compressor Efficiency for **R600a** Refrigerant

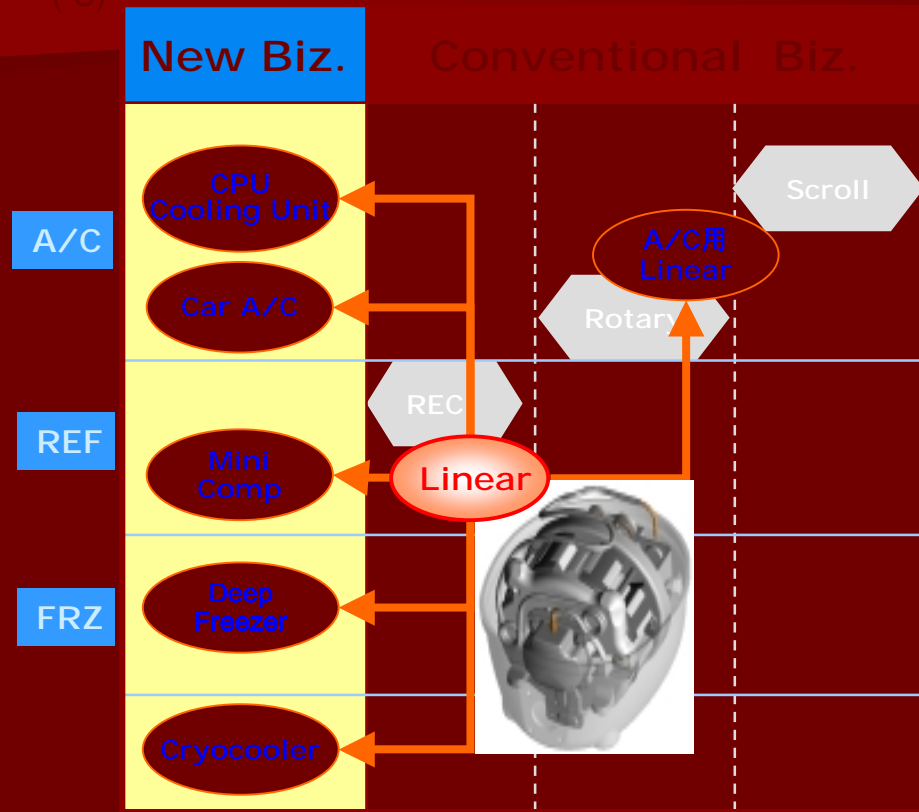


Test condition : LG Ref condition
(Condenser temperature = 33°C)
(Evaporator temperature = -26°C)

Linear Compressor

Eva.Temp
(°C)

Application Domain



Application to New Biz.

■ For Household A/C

- ❑ Energy Improvement : 20% (Heat Pump, 2.8kW)
- ❑ Under Development,
- ❑ Plan to release to Market in '05



■ For Car A/C

- ❑ For Eco-Friendly Electric Car
- ❑ Under Research



■ For Cryocooler

- ❑ Oil Free Mechanism is essential
- ❑ Development already Finished
- ❑ On sale of Samples



EPA Multiple Pathways Study

- From 1993 so somewhat dated
- Identified multiple pathways to reduce the energy use of an 18cf R/F to 230-430 kWh/yr at incremental consumer cost of \$35-201/unit.
- Technology options included:
 - Advanced insulation – vacuum, carbon black
 - New cycles – Lorenz, dual-loop
 - Better compressors – linear, advanced rotary and reciprocating
 - Thicker walls



Multiple Pathways – Incremental Costs and Savings

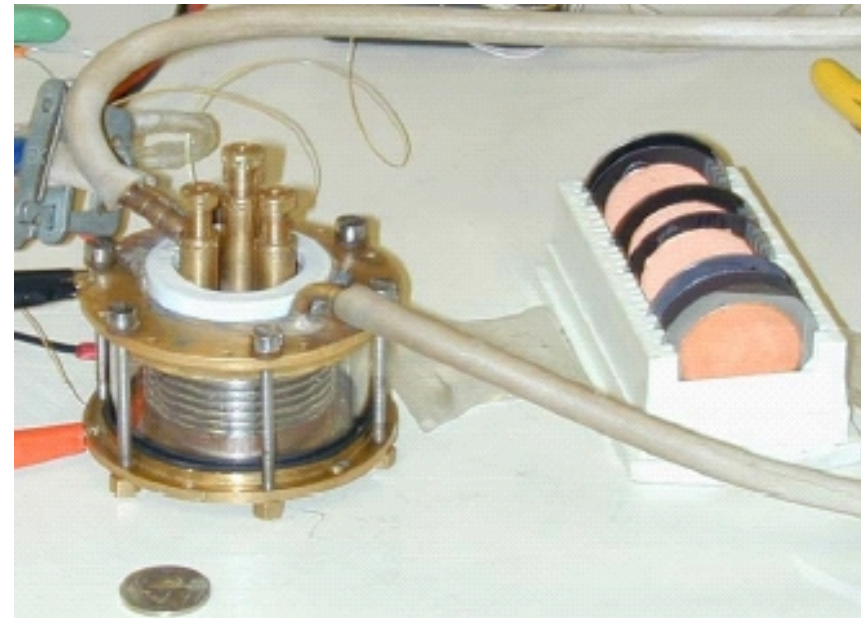
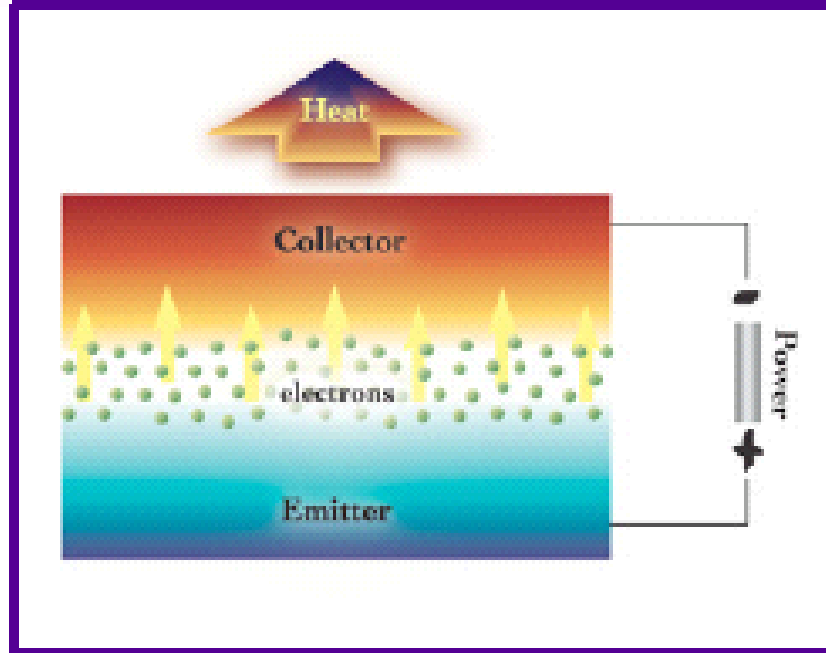
Option	kWh Saved	Consumer Cost
Linear compressor	~50	\$14
Carbon black insul.	~20	\$4
Vacuum panel insul.	~100	\$64
Lorenz cycle	~60-90	\$15-30
Dual loop	~10-20	\$79-86
Thick walls (2.5 cm)	~80	\$16
Thick walls (5cm)	~130	\$35

Cool ChipsTM

- Thermoelectric cooling device
- Uses electric current to move high-energy electrons (& associated heat) across a semiconductor junction
- With recent developments, claim COP can be double that of conventional systems
- Need to go from lab demos to production scale – high risk, potentially high payoff R&D
- Leading developer thinks will be modestly less expensive than standards compressor system



Cool Chips™



ACE³

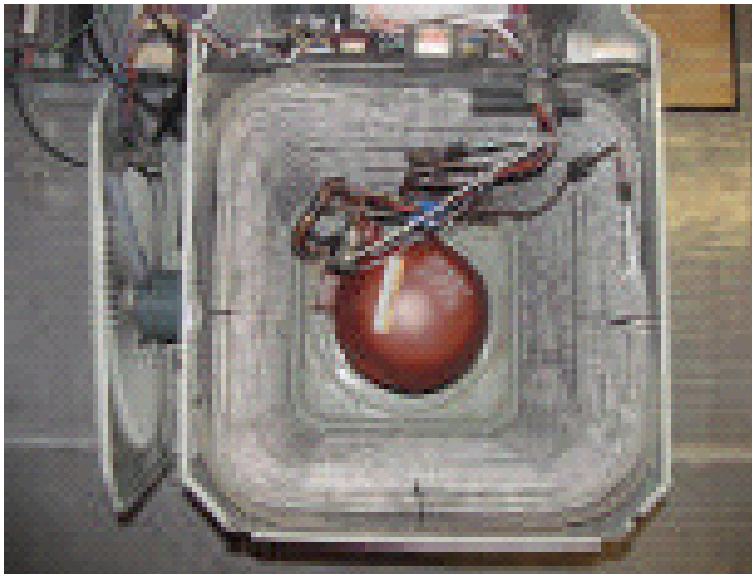
Room Air Conditioner Options

- Better compressors
- Increase heat exchange area (larger units or use microchannel heat exchangers)
- Mini-splits instead of window units
- Improved controls (TXV, computer controls) – primarily saves in shoulder periods



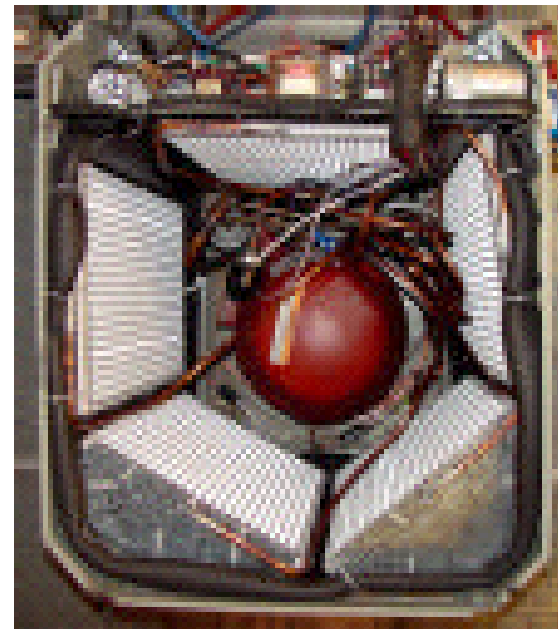
Microchannel Heat Exchanger

- Baseline, Spine fin-and-tube HX



33.25" H x 26.5" W x 30" D

- MV20 HX



33.25" H x 26.5" W x 30" D

Microchannel Heat Exchangers

- Use multiple flat tubes to increase heat exchange surface in limited space
- Permit higher efficiency for same unit size
- Used in radiators; research underway on applying to room and central AC
- Issue – designing evaporators to shed condensate
- Perhaps \$100 incremental cost now – needs to come down



Mini-Split Air Conditioners



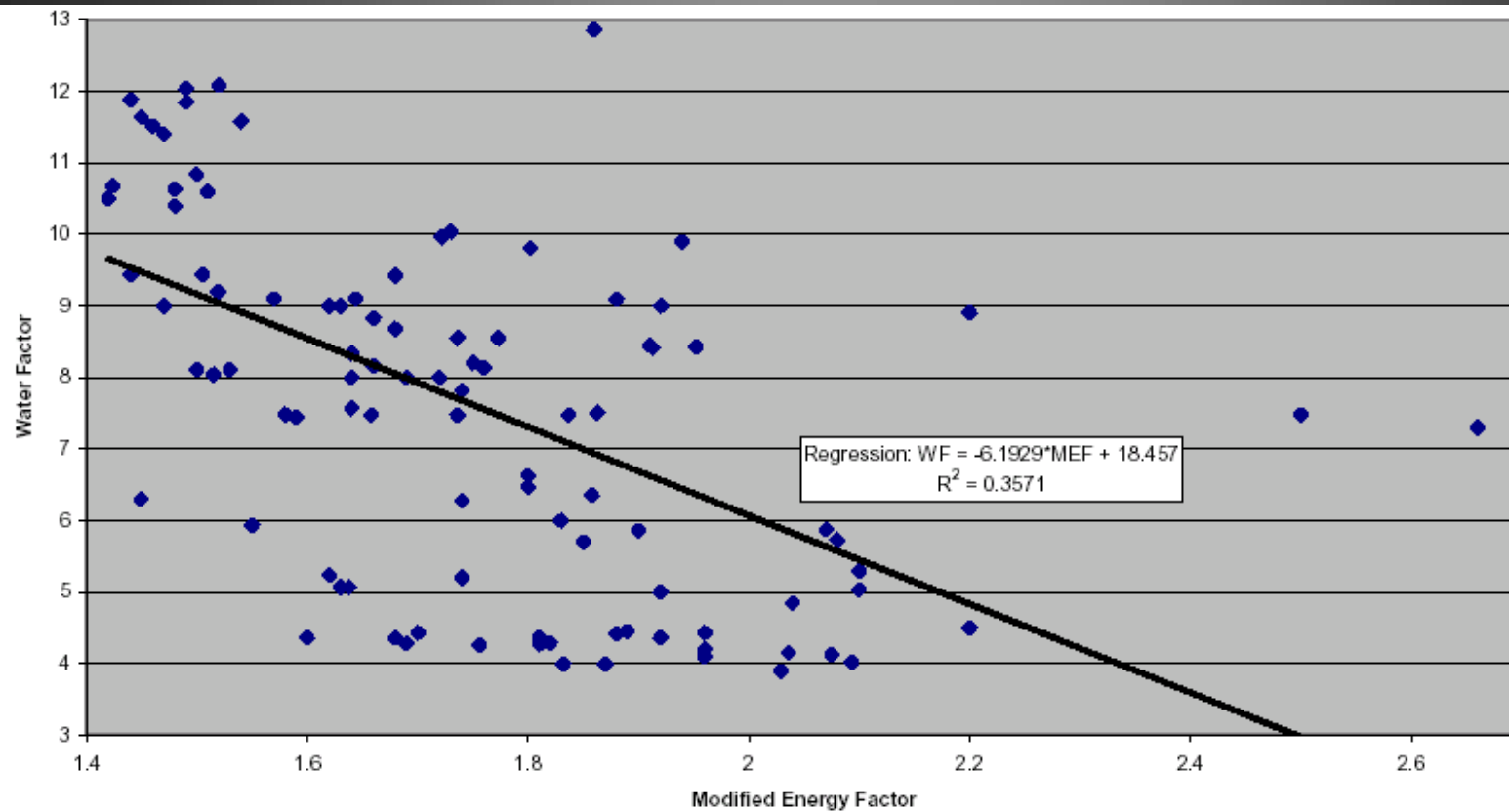
ACE³

Mini-Split Air Conditioners

- Separate indoor and outdoor units
- Quieter
- Doesn't block window; out of the way
- More efficient (EERs can be >12)
- More expensive
- Very popular in Asia; increasingly popular in Europe
- In U.S. classified with central AC



Clothes Washer Efficiencies



Source: DOE "Market Impact Analysis" 8/04

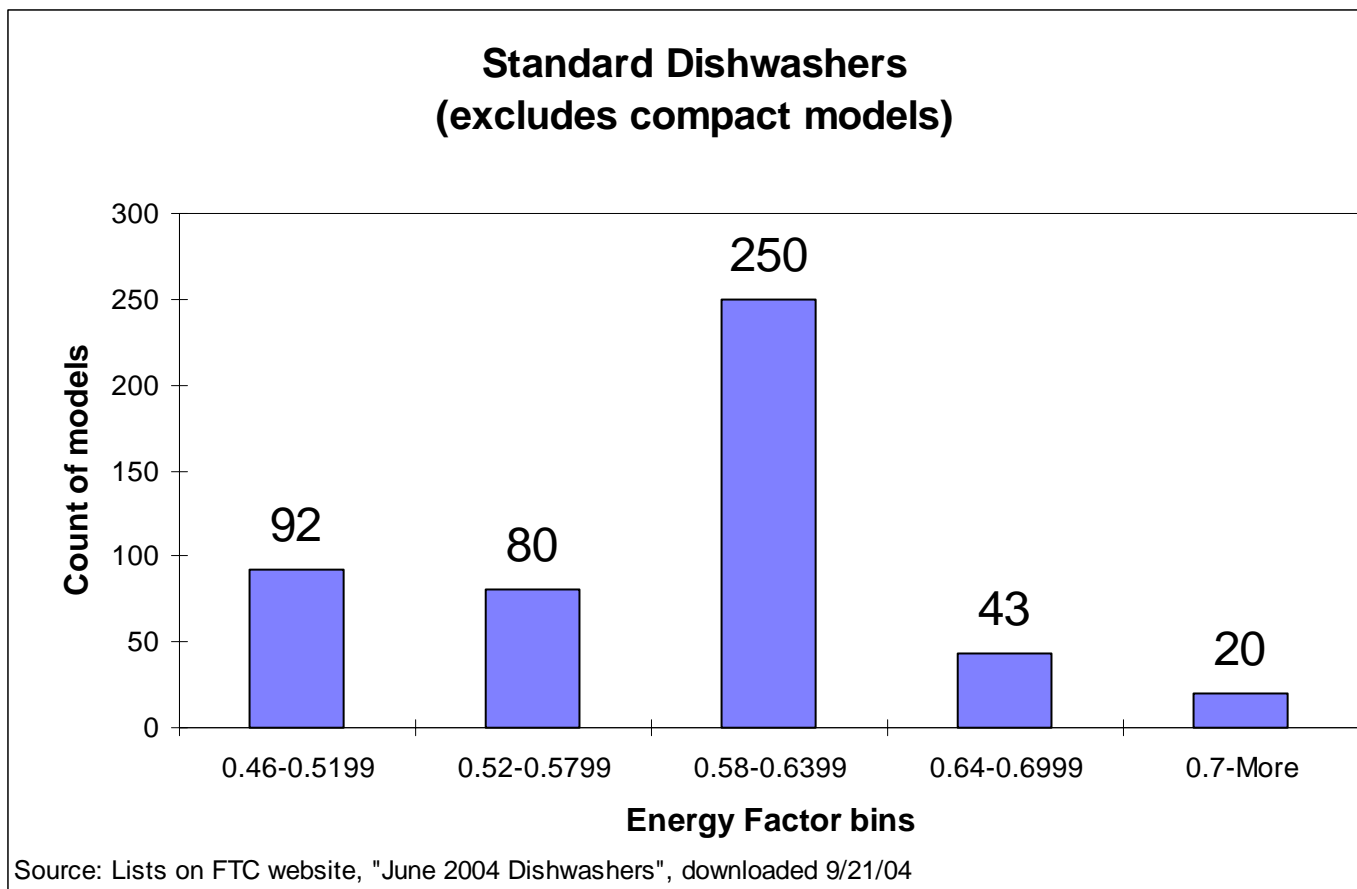


Technologies in Efficient Clothes Washers

- Partial fill (H-axis or sophisticated V-axis)
- High spin-speeds
- Improved motors (e.g. brushless DC)
- Sophisticated controls (e.g. fabric and soil sensors)



Dishwasher Efficiencies



Technologies in Efficient Dishwashers

- Soil sensor
- Better motors
- Less water – smaller sumps, improved spray patterns, less rinses
 - But cut water too much and affect cleaning performance



Conclusions

- Refrigerators with 25%+ savings relative to current standard very feasible
- Use of microchannels, improved compressors or mini-splits needed for substantial room AC savings
- Efficiencies of best CW and DW unlikely to improve but expect more models, better performance

