MAKING MODERN LIVING POSSIBLE

Evaluating the Merits of Variable Speed

CEE presentation- Sept 30, 2009

Mogens Rasmussen

Major Market Trends

- Demands for greater comfort
  - Rising standard of living
  - Concerns about noise pollution
- Energy efficiency
  - Increasing energy prices
- Environmental concern
  - Climate change (global warming)
  - Carbon emissions

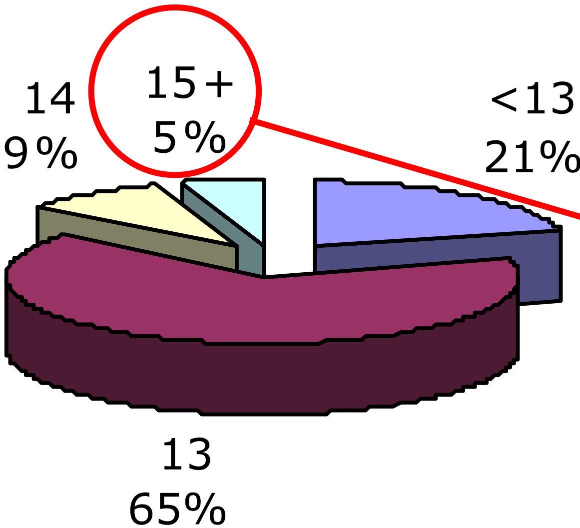
Higher Efficiency Systems

HVAC
Regulatory and Legislative Trends

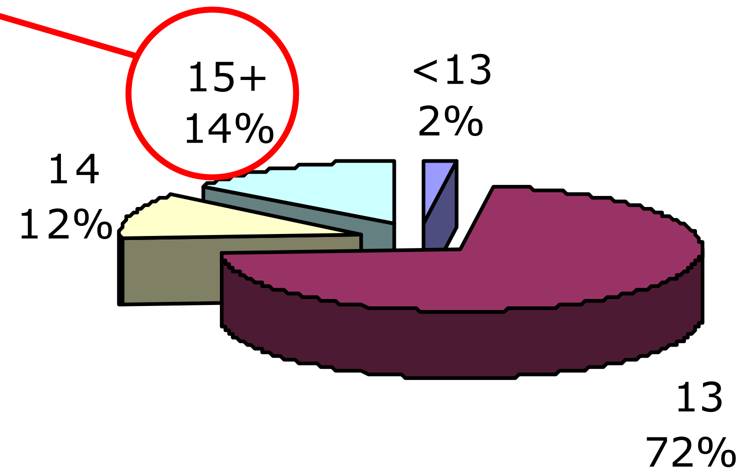
- New SEER levels for residential units
- IEER standard for light commercial units
- Stimulus bill (Tax credits)
  - Geothermal HP
  - Residential HVAC
- Montreal Protocol (focus on ODP)
- Kyoto Protocol (focus on GWP)
- Waxman-Markey House Energy and Climate Bill
- Reduction in System Refrigerant Charge

Market Evolution

2006 Residential Market SEER Split

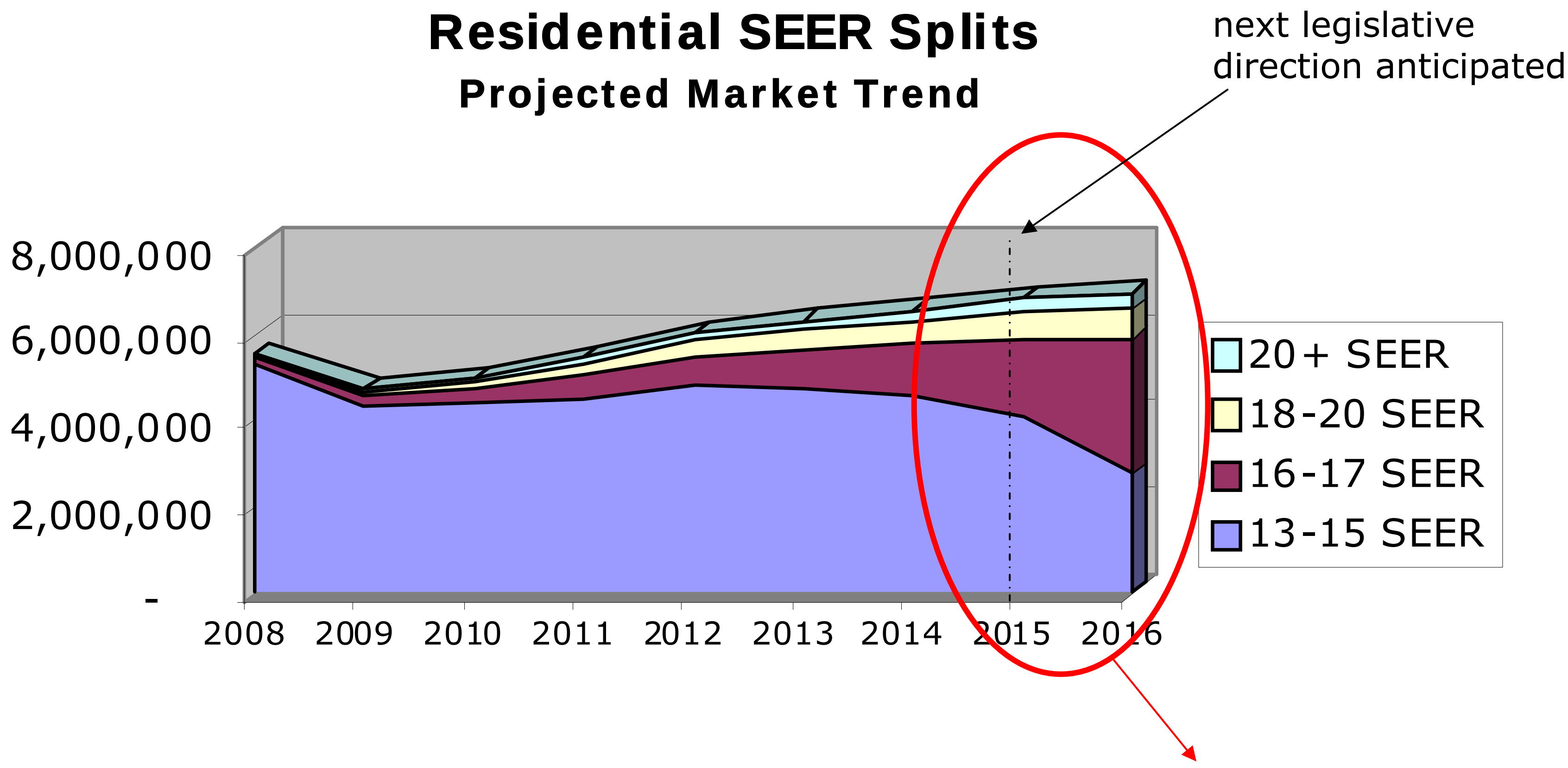


2009 (thru July) Residential Market SEER Split



Based on ARI Statistics

Projected Market Development



13-15 SEER: ~ 30%
16-17 SEER: ~ 55%
18+ SEER: ~ 15%

Opportunity to Improve Efficiency in Residential Systems

System Coefficient of Performance

Ratio of Heat Removed / Energy used in removing it

Theoretical maximum *COP*:

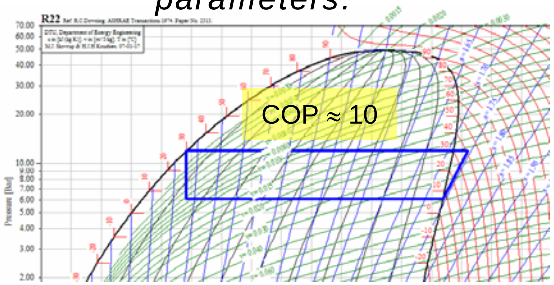
$$COP_{max} = \frac{(T_{cold} + 273.15)}{(T_{warm} - T_{cold})}$$

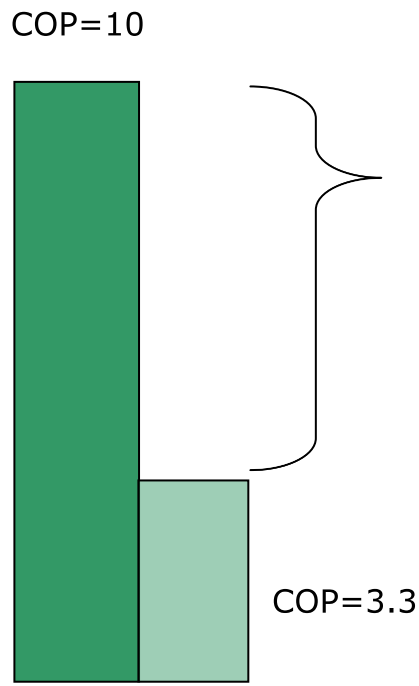
T_{cold} = 6°C (43°F); T_{warm} = 30°C (86°F) ⇨ COP_{max} = **11.6**

Practical COP's are ≈ 1 / 3 of the max. theoretical value

What Causes the Gap?

Standard cycle with ideal parameters:



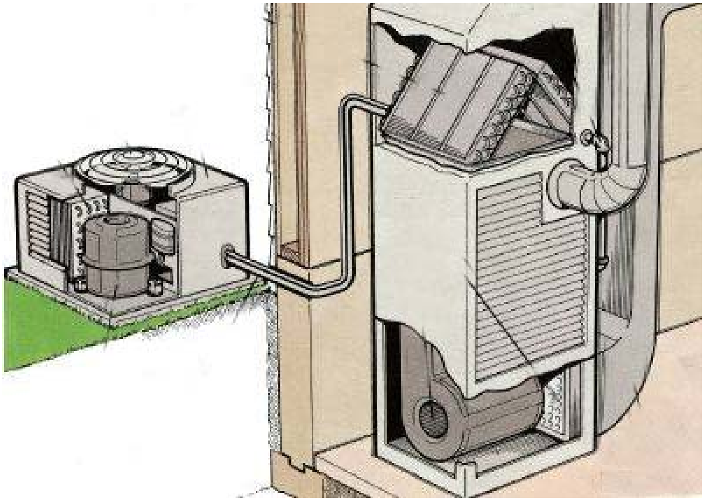


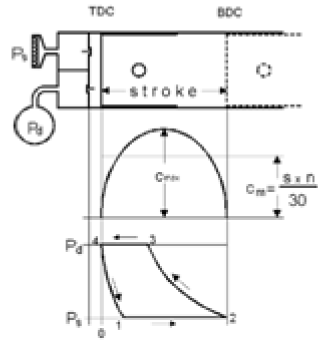
- Cycle inefficiencies
- Component inefficiencies
  - ΔT at heat exchangers
  - Δp in tubes
  - losses in compressors → η_{is} <<1)
- Dynamic behavior
  - fluctuation in pressures

There is a great efficiency potential applying better components and smoother control.

Improving Efficiency in Residential

Examples of Prior Areas of Optimization





Optimization of compressor efficiencies

Advancement in compressor technologies

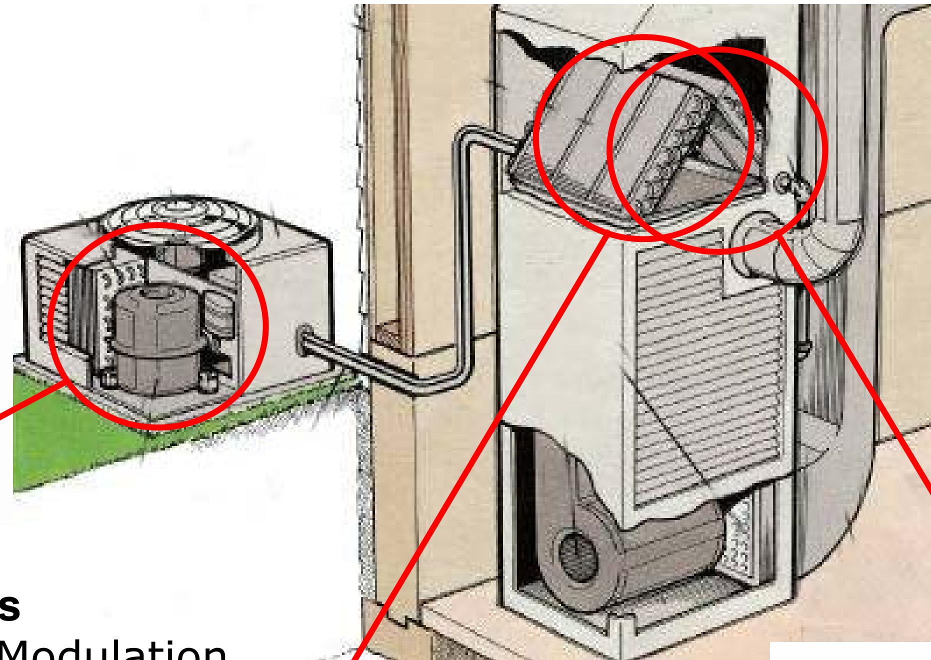
Increased Coil Surface Area

Advancement in coil technologies

Use of mechanical expansion devices

Next Level of Optimization

Examples



Total System Control

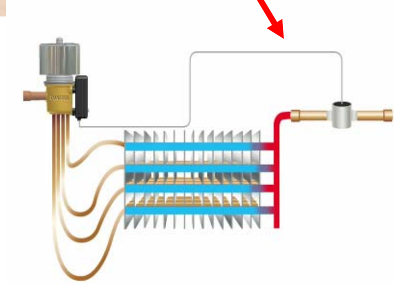
- Diagnostics/maintenance
- Optimization
- Communication

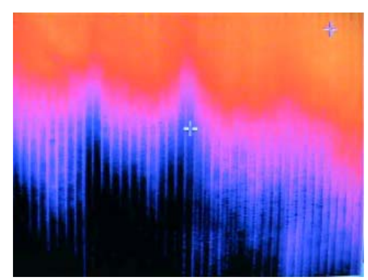
Compressor Technologies

- Mechanical Modulation
- Variable capacity

Heat Exchanger Technologies

- Micro-channel
- All aluminum



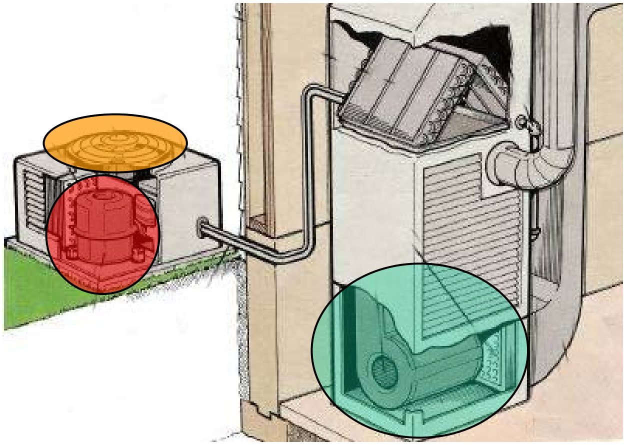


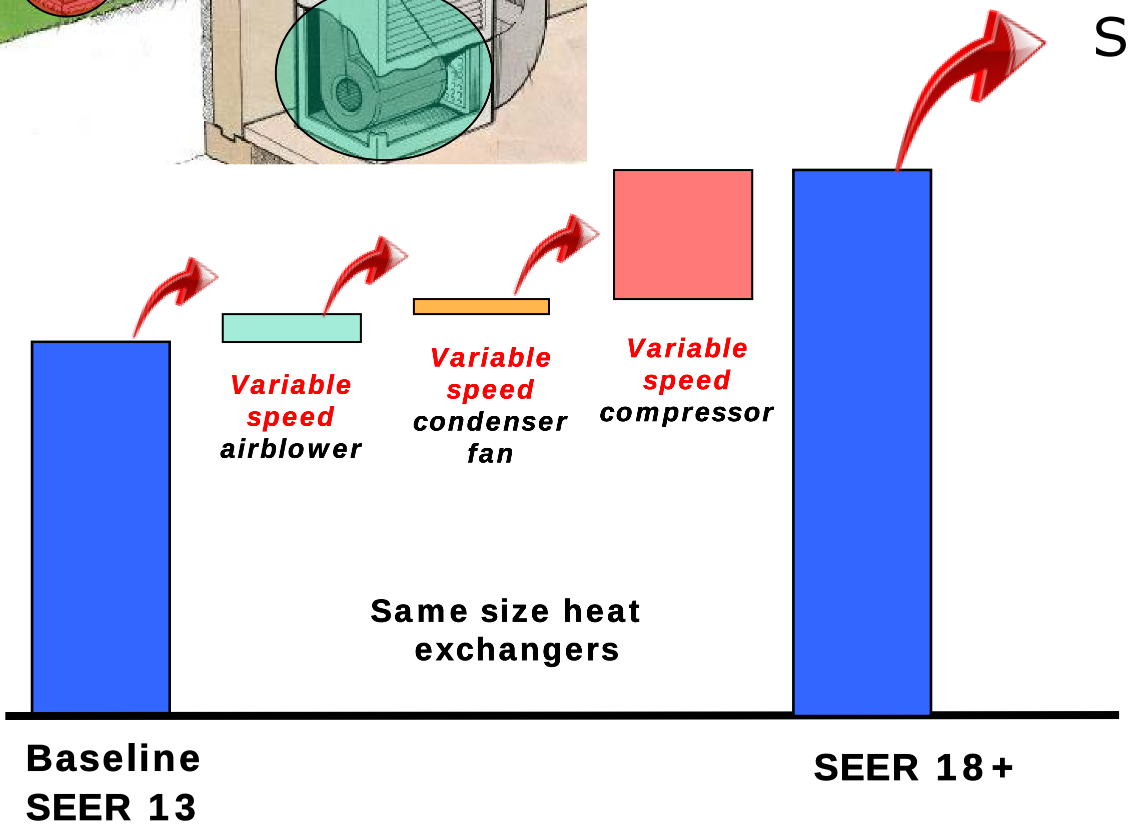
Evaporator Control

- Superheat optimization
- Refrigerant and airside distribution improvement

Variable Speed Technology

A Quantum Leap



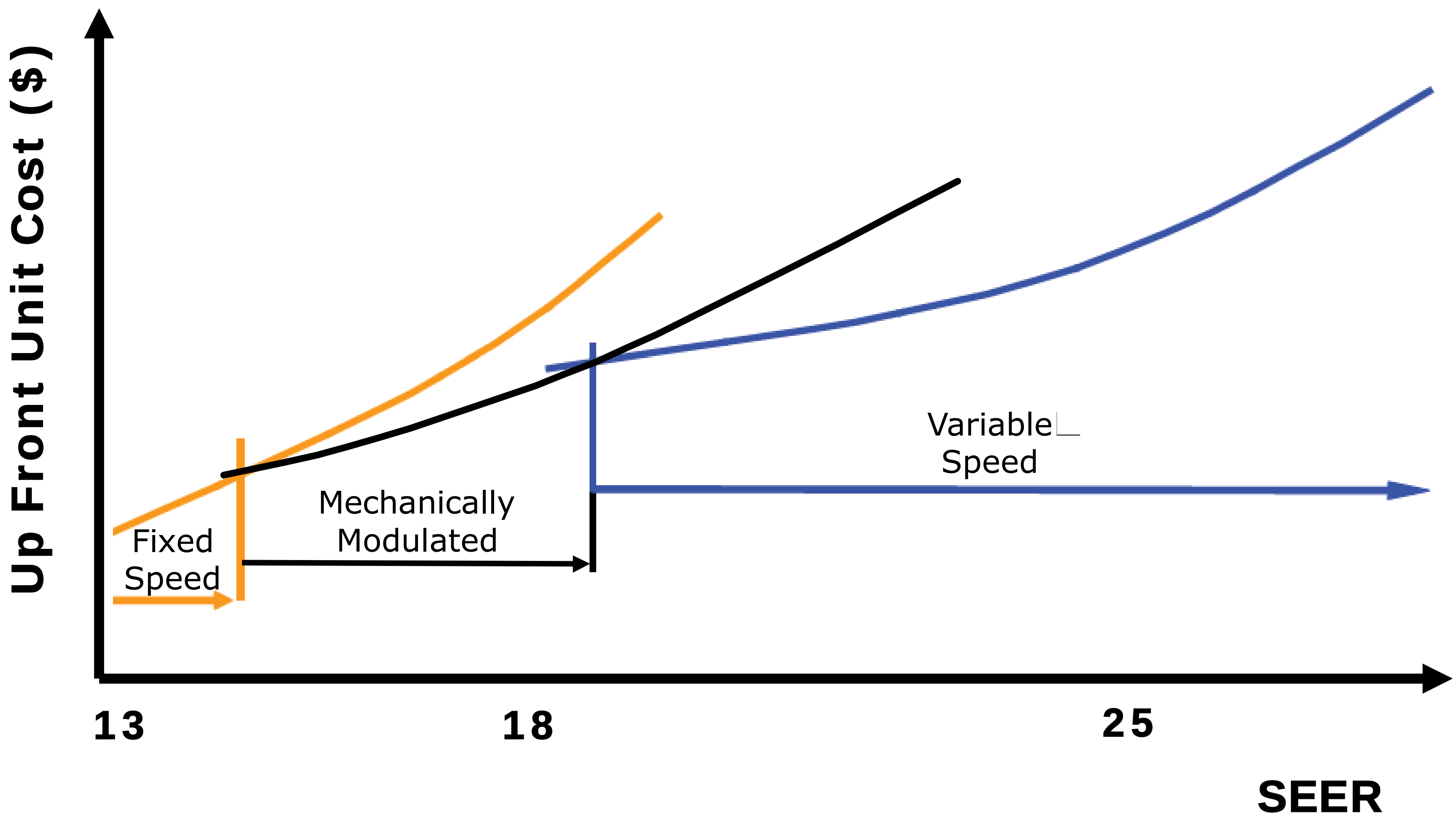


SEER 20+

- Improved heat exchangers
- Improved liquid distribution
- Total system optimization

VS Compressor

A Cost Efficient Proposition for High SEER Solutions

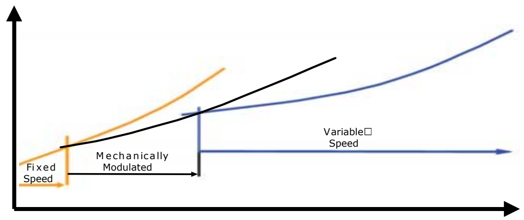


Variable Speed Compressor
Design Benefits

- **Improved System Efficiency**
  - Load matching
  - Motor technology (permanent magnet vs. induction motor)
  - Enables optimized fan control (condenser fan, air blower)

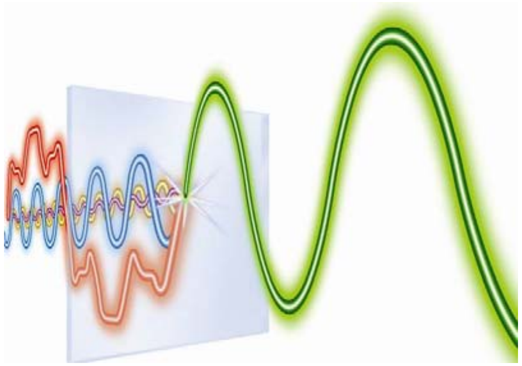
- **Compressor Protection**
  - Operating envelope
  - Continuous operation (less cycling)
  - Current monitoring
  - Diagnostics

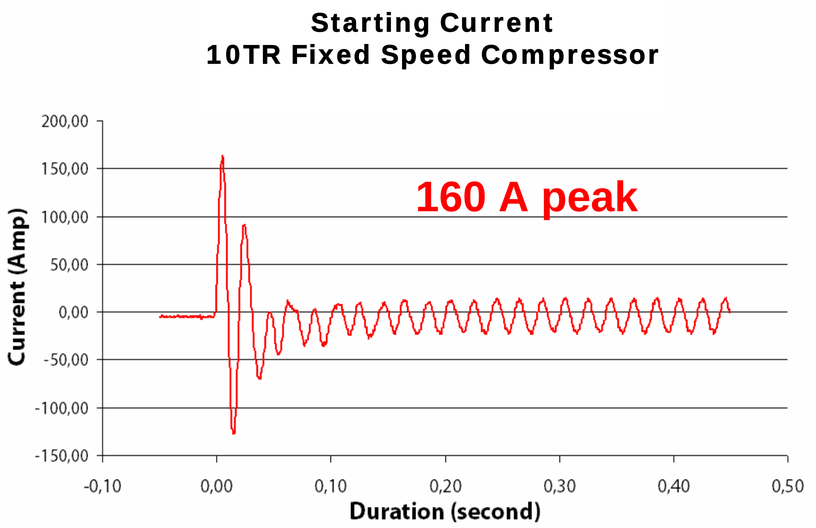
- **Up Front Cost**
  - Unit footprint (i.e. smaller heat exchangers)
  - Consolidation of system electronics



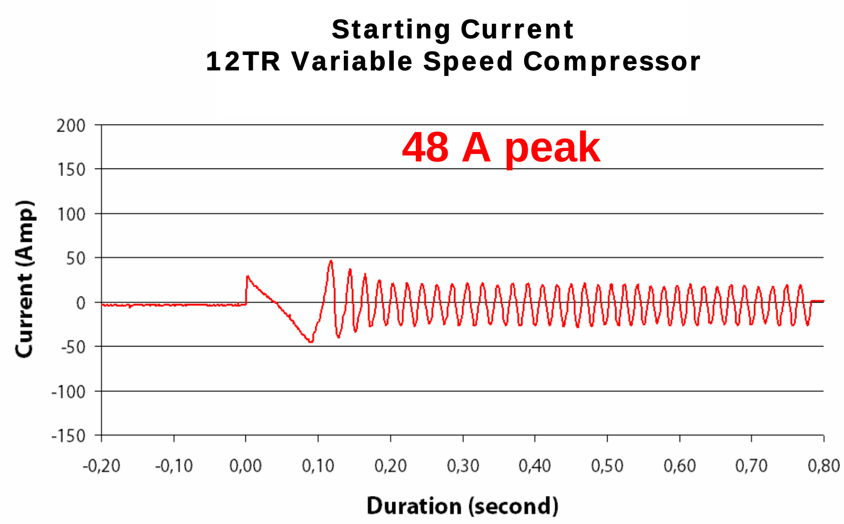
New Generation Inverter

Benefits

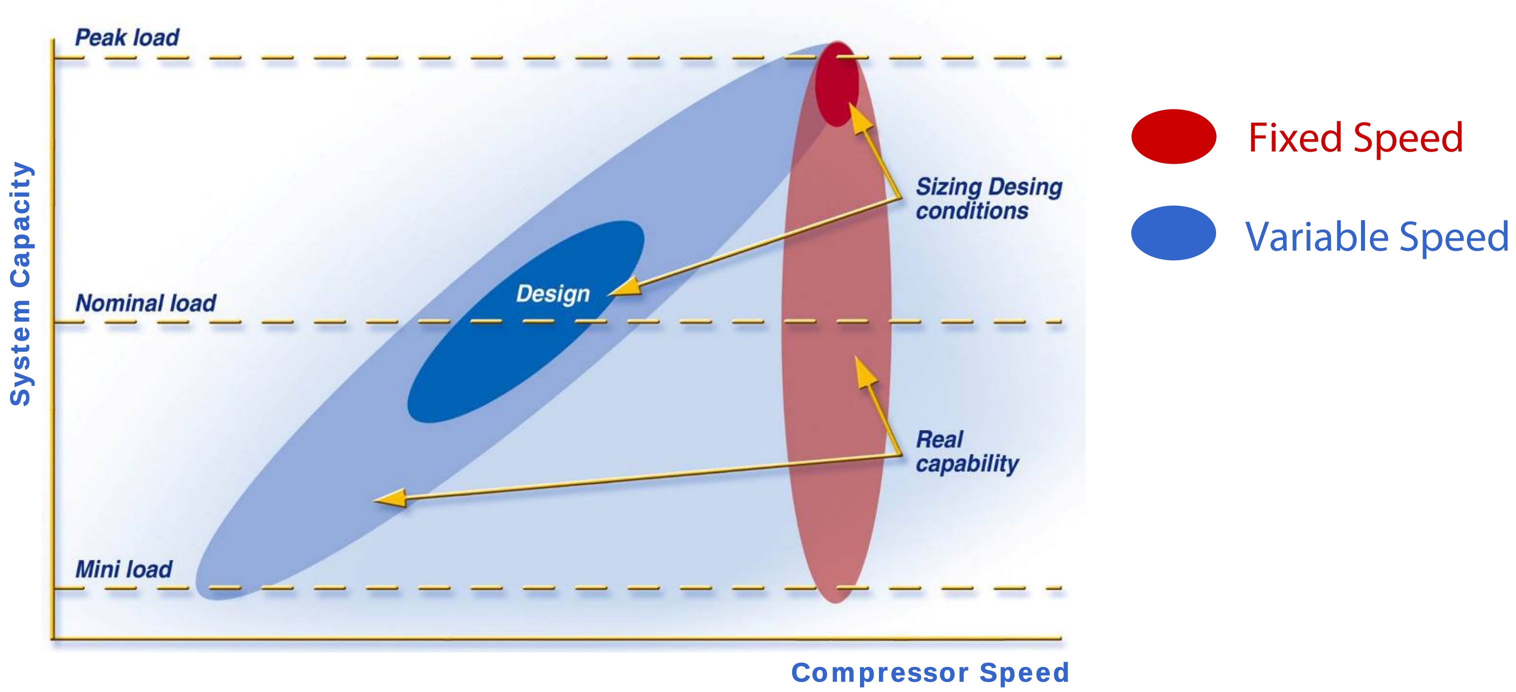




- Near elimination of in-rush current
- Clean inverter
  - near 0 harmonics
- Power factor correction
  - Above .98
- Dynamic load demand control
  - Smart Grid

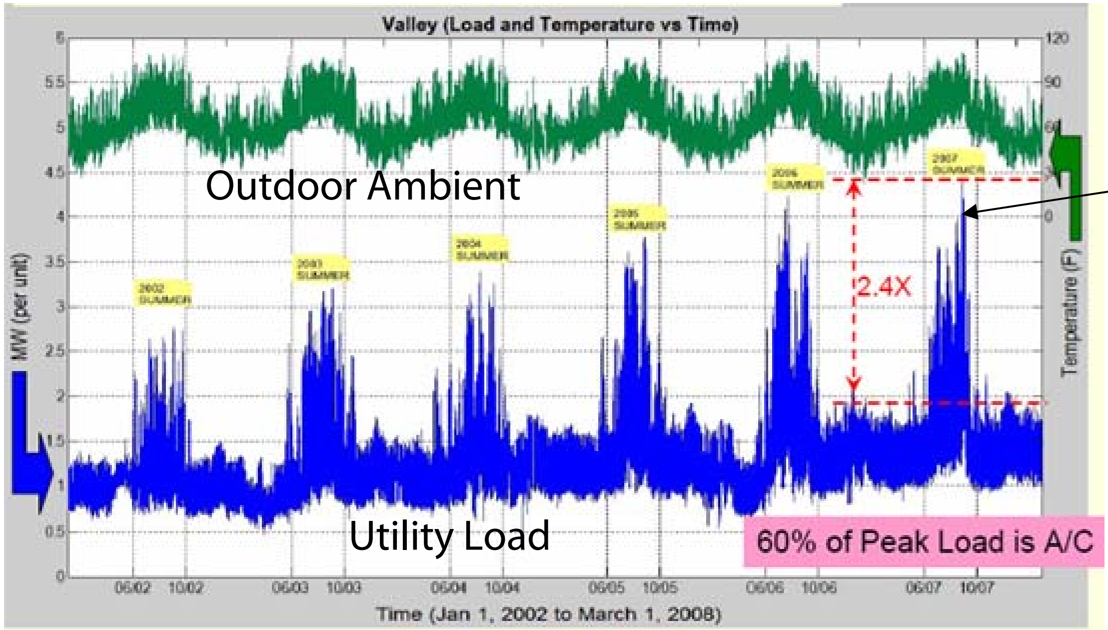


Variable Speed Compressor
System Benefits



- By matching load and capacity, the compressor runs below full speed more than 95% of the time, resulting in:
  - Highest efficiency
  - Greater comfort (i.e. humidity control)
  - Lower noise level (up to 20 dB reduction)
- Significantly smaller heat exchangers for the same efficiency level

Power Grid Benefits



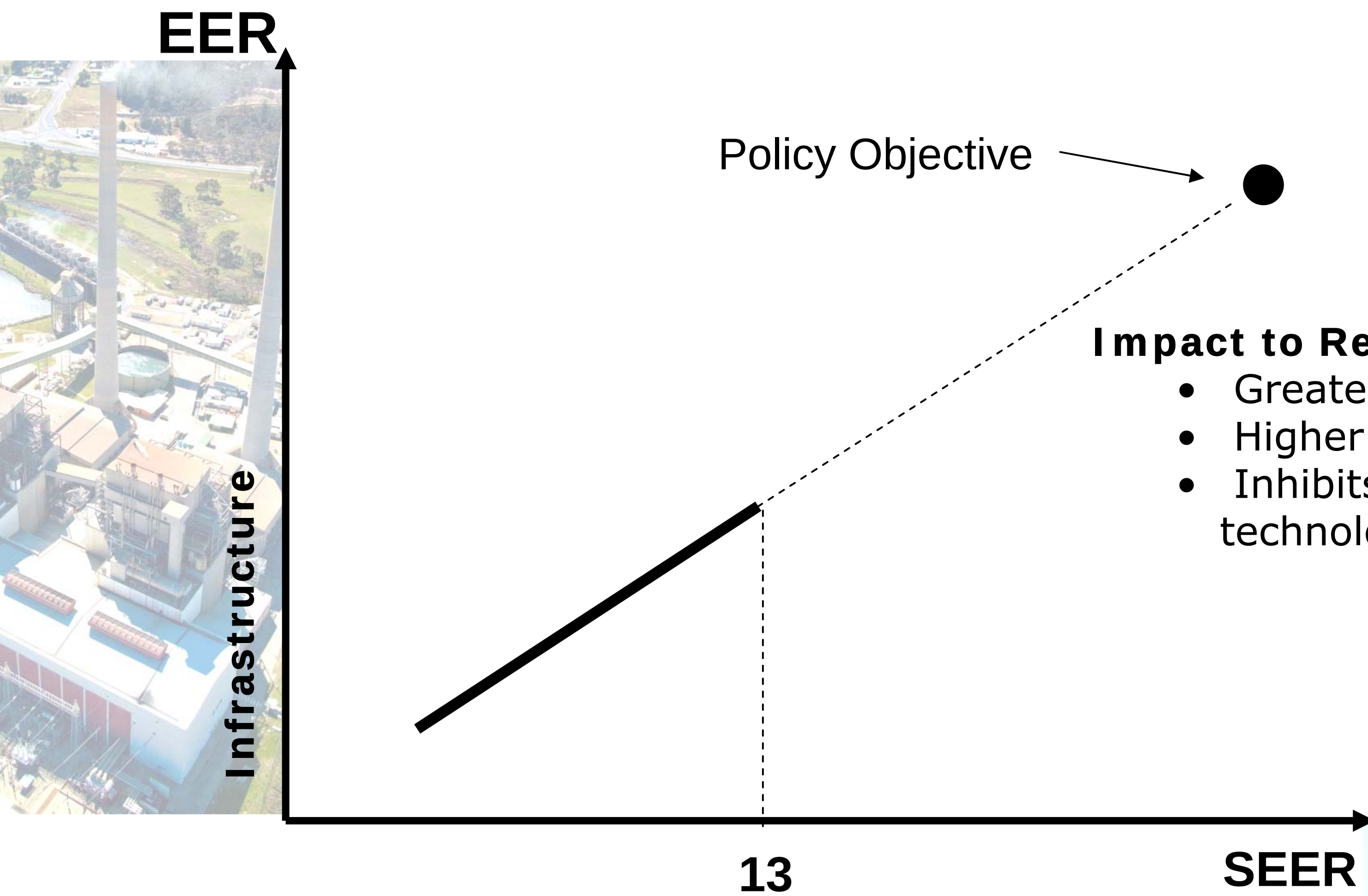
Source: DOE workshop, Southern California Edison, 4/22/2008

- Peak load levels are growing each year
- Peak loads represent a small part of the total load profile

- Solutions for peak load demand control with smart grid technology and dynamic pricing
- Power factor correction
- Low voltages events will not stall air conditioning units

Residential Air Conditioning

Public Policy Direction

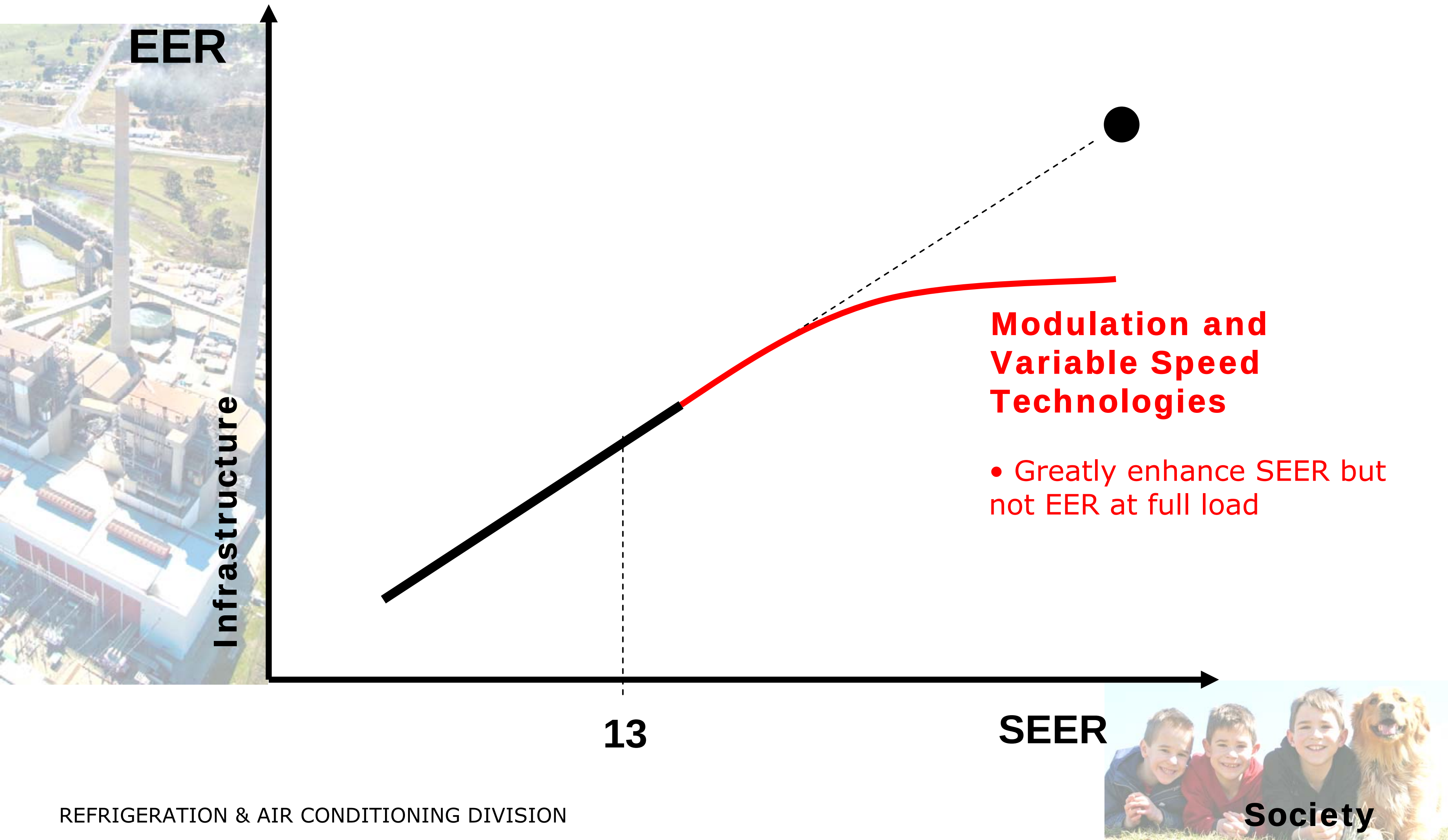


Impact to Residential Systems

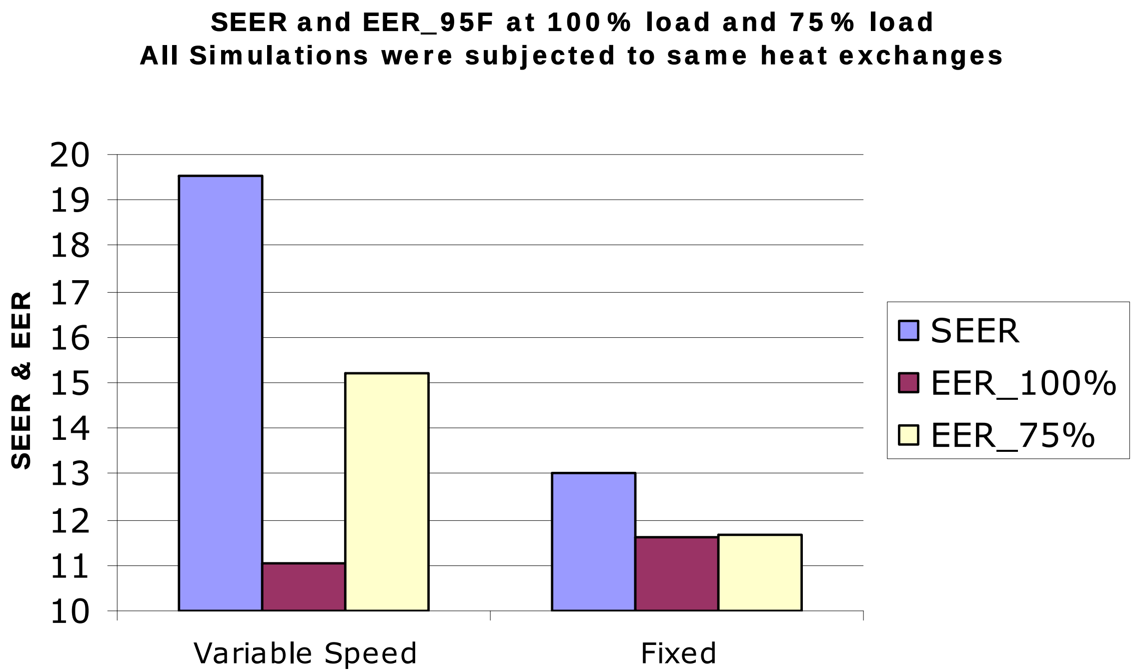
- Greater Physical Size
- Higher Unit Cost
- Inhibits emerging technologies

Residential Air Conditioning

Public Policy Direction



How Variable Speed Compressor Technology Addresses EER



Peak load demand control through Smart Grid Technology

- Very high EER during unload (signal from Utility Co.)
- No stalling compressors with locked rotor current
- Maintain operation during low voltages
- Active power factor correction (raises distribution and transmission utilization)
- No inrush current
- Ideal solutions for dynamic pricing with unloading capability

Recommendations

We should consider a different approach maximizing total benefit of new technologies:

- Specify peak load reduction capability for variable speed systems
- Specify maximum inrush current
- Specify power factor near 1.0

- **The problem is not the efficiency at peak load – it's the load**
- **Metrics need to be aligned to the real issue**
- **Reduce the load and improve efficiency**

Danfoss

MAKING MODERN LIVING POSSIBLE