HVAC Technologies for Building Energy Efficiency Improvements

2013 National Symposium on Market Transformation

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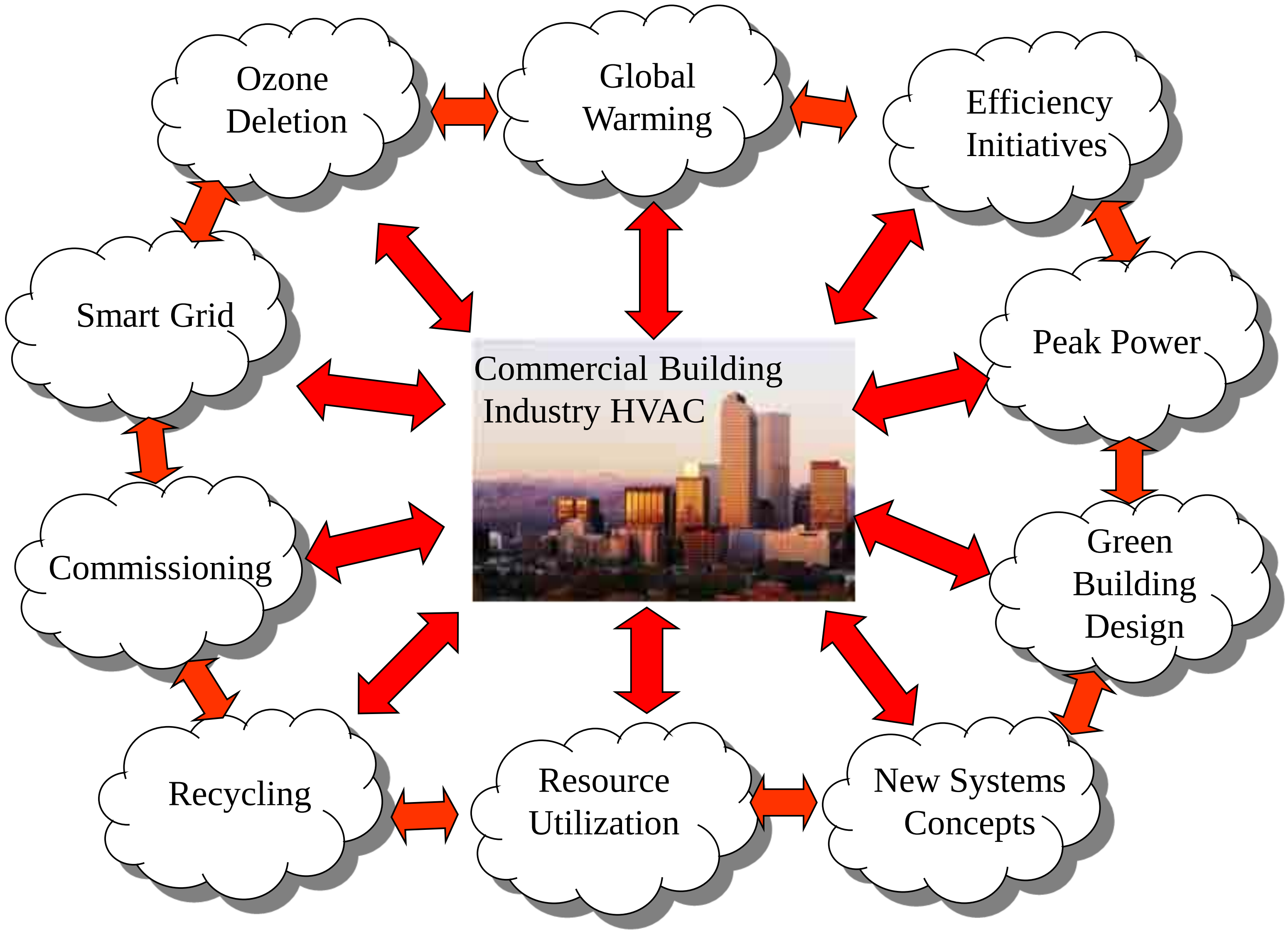
HVAC Industry Challenges and Issues



Many of these are interrelated

Major Industry Challenges and Drivers

- In the 2011 AHRI Strategic plan two of the key drivers for consideration were ***"Climate Change"*** and ***"Energy Efficiency"***
- Today most legislative and regulatory changes focus on *climate* and *efficiency* as a separate topic and develop proposals to address each separately.
- *Climate* and *efficiency* are actually strongly linked, and in fact should be treated together.
- Focus on the environmental and **energy issues** has intensified and likely will continue now that we are thru the election cycle.
- The approach in the US has been to focus on **prescriptive component** requirements, most of which are at **full load**, using conventional metrics like EER, COP and SEER and do not consider annual operation and interactions with the building and are approaching ***"Max Tech"***
- A historical approach is used to continue to raise the current metrics incrementally every 6 to 10 years and this is done at a national level with the same approach for all regions

As an industry we face significant challenges and the old approaches used since the 1970's may not be the best approach and likely will not deliver significant energy reductions

Changing Customer Demands and Drivers

At the same time we see new demands and requirements from customers

- More efficient system and environmentally friendly solutions
- Peak load reductions (utilities)
- Pre-packaged solutions with more options
- Regional solutions (high latent, hot-dry, etc)
- More reliable systems that can be properly commissioned and continue to function over extended periods, often with poor maintenance
- Flexible systems that can meet changing building requirements and demands
- More information on our unit ratings including certification of other rating points as well as full certification of the complete operating map
- Better interface with building design tools used to evaluate and optimize buildings
- Interface with building automation systems, the smart grid, and advanced service tools
- Expanding global markets and solutions, but with regional specific requirements

But at the same time they want lower costs (less 3 year payback), more factory installed options, and configurable units

Historical Efficiency Improvements

Significant progress has been made in improving the energy efficiency of buildings and HVAC Equipment

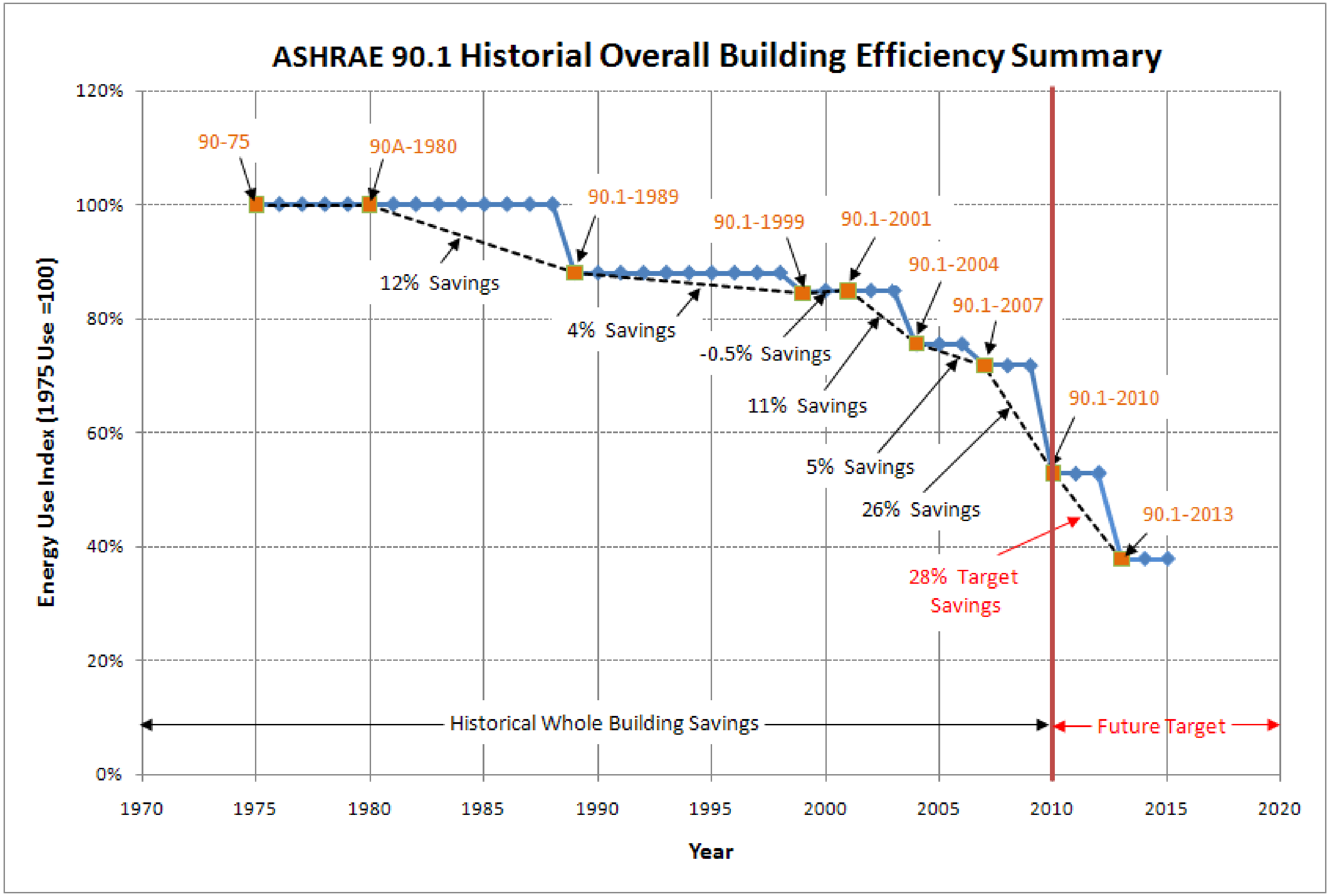


Chart based on PNNL ASHRAE 90.1 Determination Study and new 2013 Addendums

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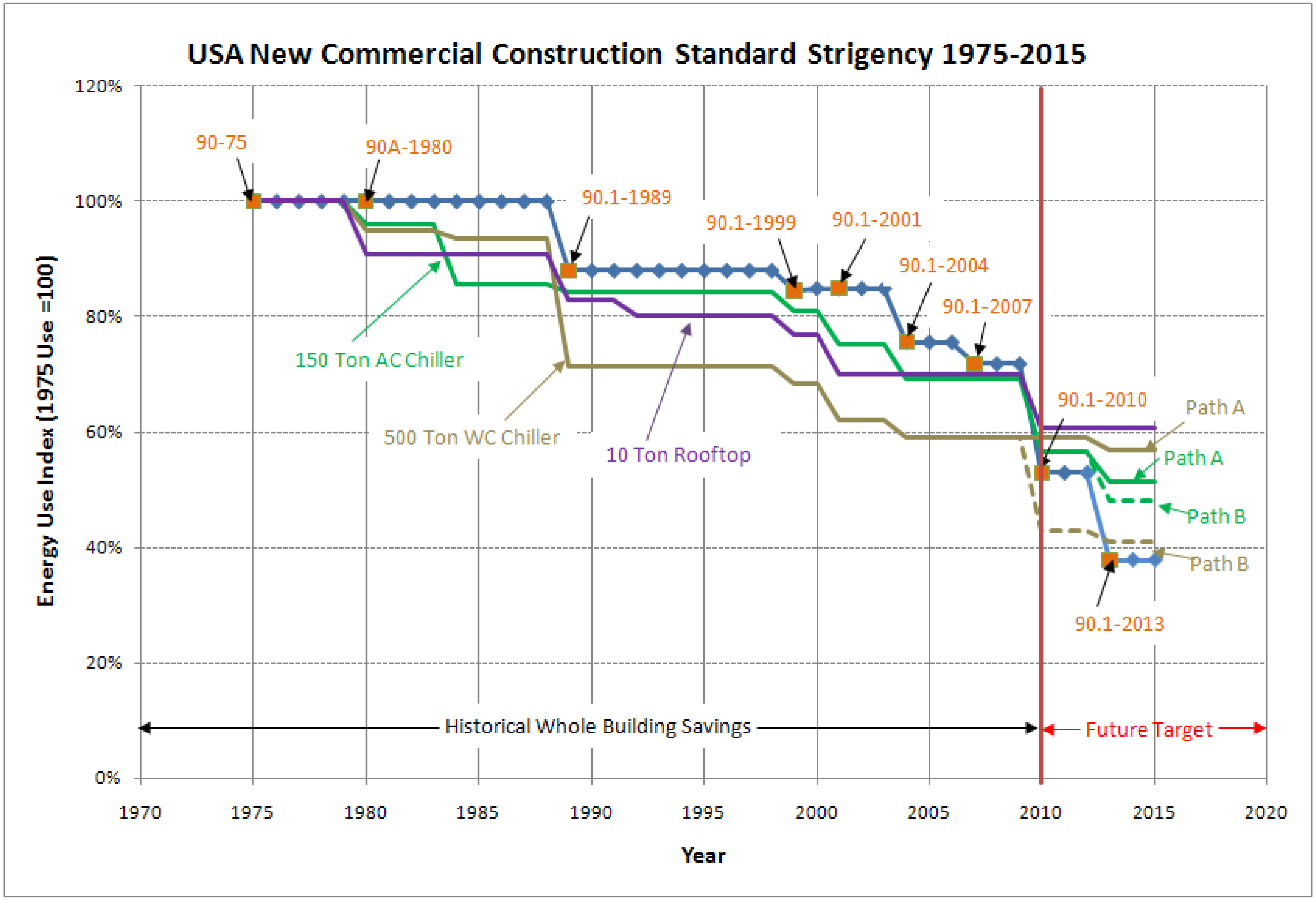

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Possible Future Roadmap

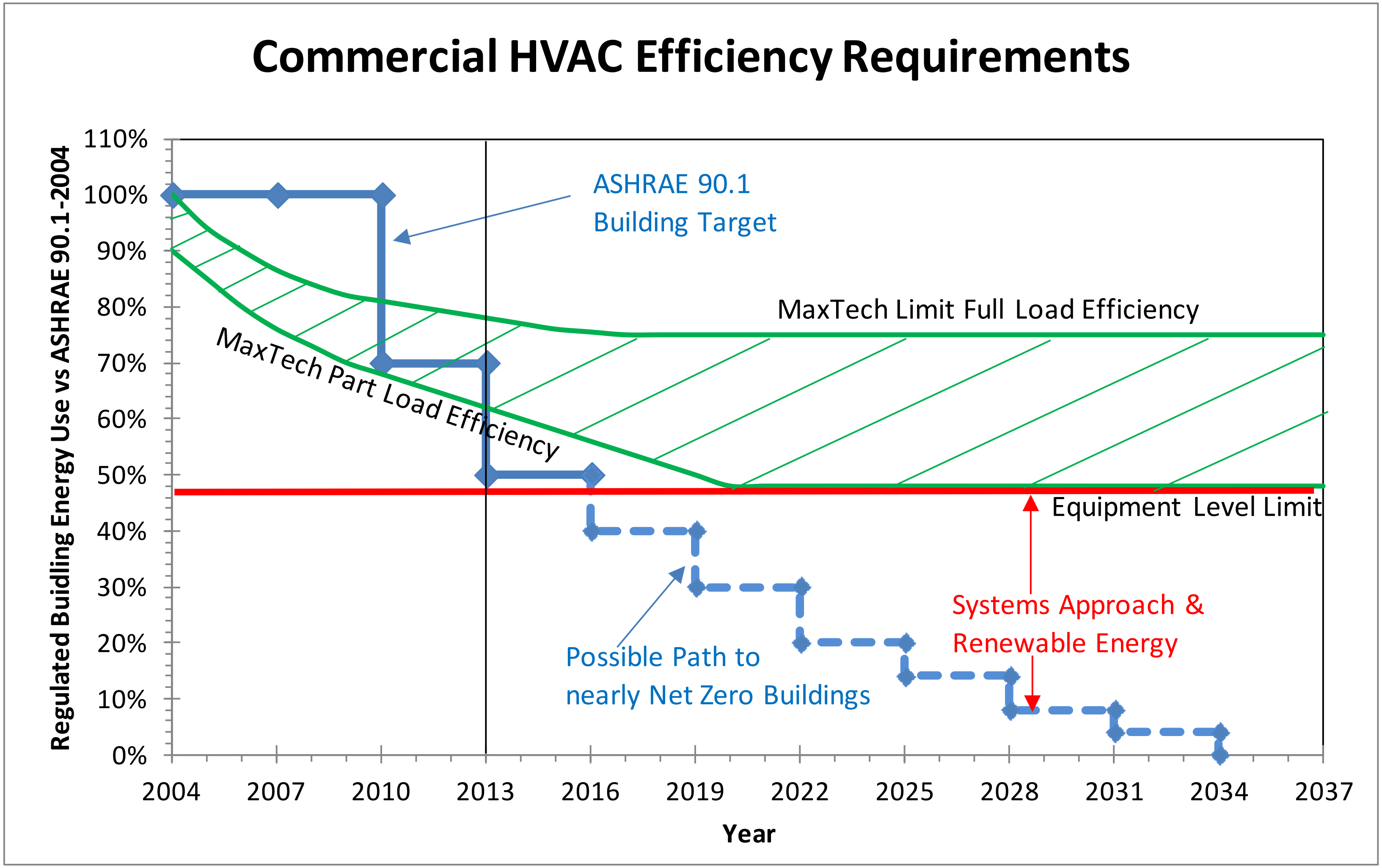


Chart is an estimate of possible future regulations to achieve Near Net Zero by 2034 and studies done by Carrier on technical limits of HVAC equipment

Potential Future Roadmap

Historical Approach *(Business as usual)* - Full Load Improvements

- We are approaching ***"Max-Tech"*** on many products and significant improvements in base product full load efficiencies will be limited and often not cost effective
- We also face issues with the phase down of the HFC refrigerants that are used today, and will have to evolve to new lower GWP refrigerants that may not be as efficient and could be more expensive to apply

Necessary Approaches for Increased Energy Efficiency

- Switch to new ***part load*** or annualized metrics like IPLV for chillers and IEER for rooftops, splits, and VRF
- ***Hybrid system*** with rating approaches like AHRI guideline V
- ***Subsystems approaches*** (Europe and Canada) (very active)
- ***Whole Building System*** approaches (ASHRAE Building Energy Quotient)
- Defined ***commissioning and continuous commissioning*** requirements to make sure equipment runs correctly coupled with smart systems using ***diagnostics and prognostics***

Part Load and Annualized Focus

- For many products like chillers, packaged products, and VRF systems AHRI has adopted new part load metrics to supplement the full load metrics
- The part load metrics are based on a **weighted USA average** models of typical commercial buildings.
- They are intended to be a better representation of the efficiency of a product over the annual operation but have their limitations.
- They are just a metric for the energy use of the equipment and do not factor in regional weather and the system energy and impact from components like air side economizers, water economizers, hybrid systems, cooling towers, pumps, and in some cases the indoor air handling equipment
- They add considerable testing to certification programs, and tolerances and uncertainty of measurement are a challenge
- They are **not intended to predict the energy** of a building and are intended to be just a means to compare equipment at other than a full load design point
- Adoption has been slow and often do not fit the old regulatory environment which is an **appliance based approach**
- We still have many products that have not adopted a part load or annualized metric

Why should we focus on part load?

Buildings ***do not*** run at full load

Typical Commercial Office Building

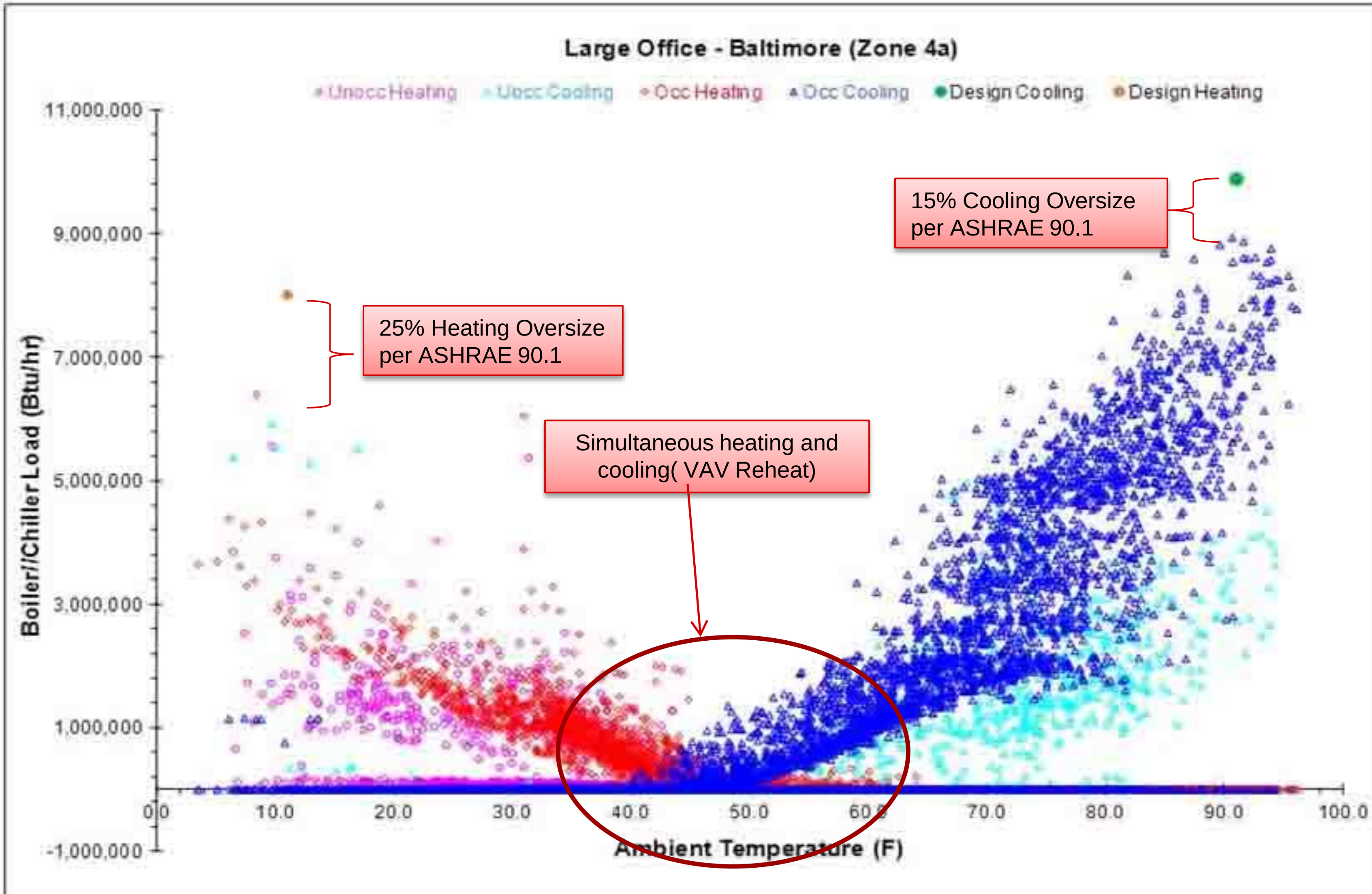


Chart based on data obtained by the ASHRAE 90.1 determination benchmark Large Office Model

Typical Commercial Hospital

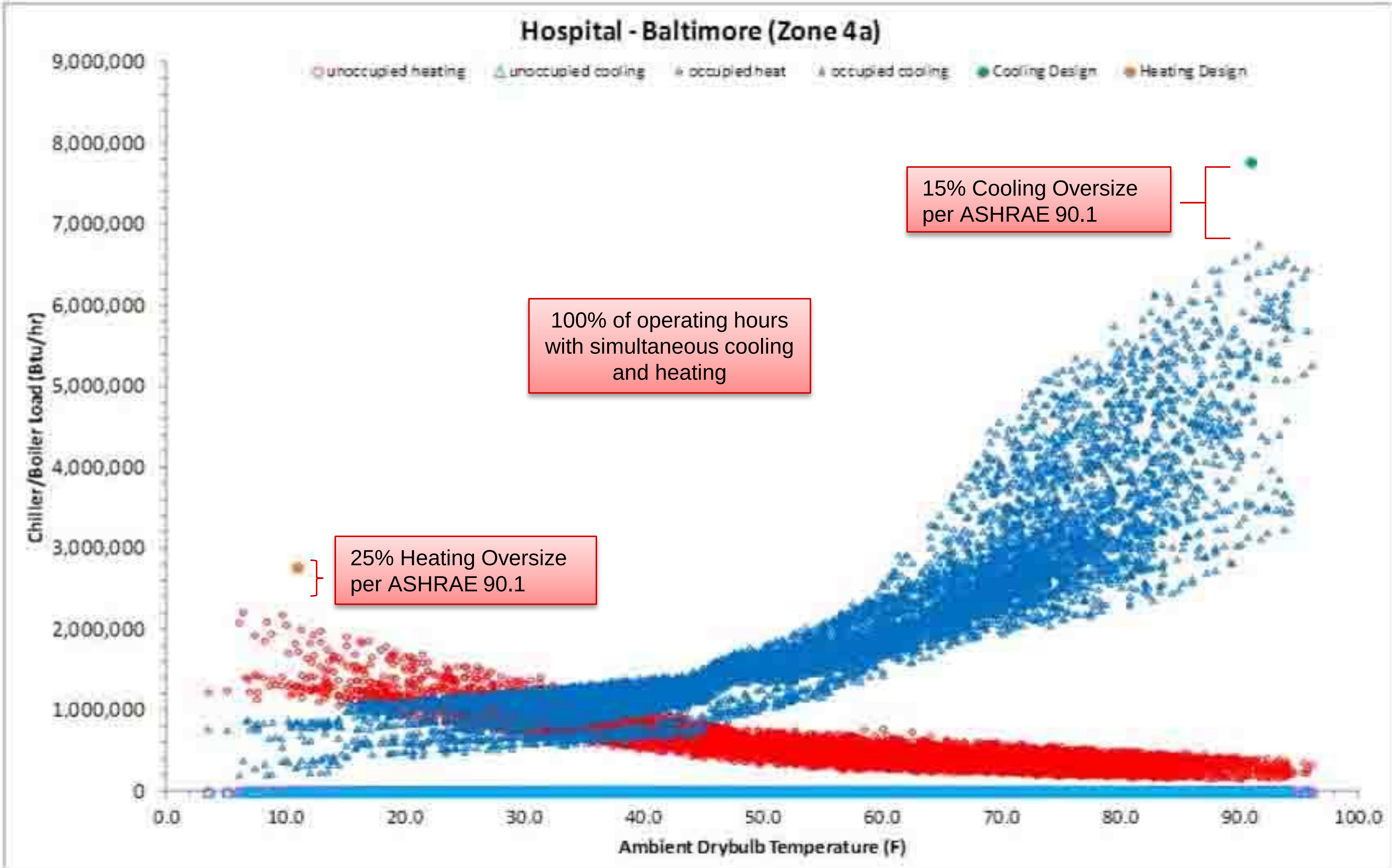


Chart based on data obtained by the ASHRAE 90.1 determination benchmark Large Office Model

Why should we focus on part load?

- Studies have shown the average equipment is oversized by 10% to 20% and in fact ASHRAE 90.1 Appendix G recommends modelers to assume 15% over sizing for cooling and 25% for heating

- Most buildings are designed based using the 1% or 0.4% weather design data which means with no over-sizing they run 99% of the time at part load and reduced ambient conditions

- Studies have also shown that loads in buildings are also over estimated (i.e. plug loads) and occupancy is never 100%

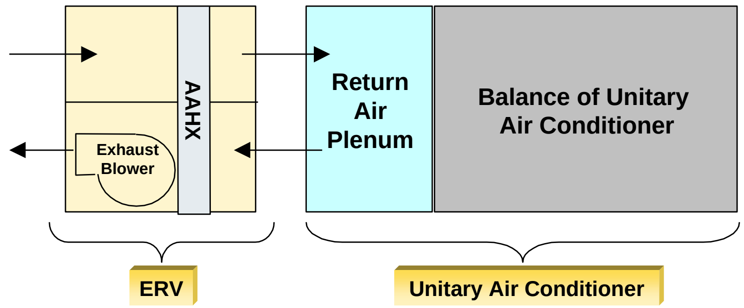
- Bottom line is that commercial units **never run at the AHRI full load** rating points, so improvement in full load efficiency may not actually save much energy in a real building if the part load does not also improve

Hybrid Systems Technology

- The concept for a hybrid system approach is to take two or more technologies and combine them together utilizing some type of combined rating.
- During the annual operation each hybrid technology is used where it delivers the most benefit
- Some examples are;
  - Airside economizer (significant technology improvement in design and controls)
  - Hydronic economizer
  - Free Cooling refrigerant cycles
  - Integrated Heat Recovery
  - Multiple chiller units with one being a heat pump water to water chillers
  - Integrated Exhaust Air Energy Recovery
  - Dual fuel heat pumps
  - Thermal Storage
  - Electrical Energy storage
  - Desiccant dehumidification and cooling systems
  - Evaporative pre-cooling condensers (new technology for hot dry climates)
  - Evaporative outdoor air coolers, direct and indirect
  - Desuperheaters and integrated hot water heaters

Note that none above are reflected in current prescriptive minimum Equipment rating metrics

Example Combined Efficiency



ERV Recovered Energy Efficiency Ratio

$$\text{RER} = \frac{\text{Net conditioning recovered by ERV}}{\text{Total electrical power consumed by ERV}}$$

RTU Energy Efficiency Ratio

$$\text{EER} = \frac{\text{Net conditioning capacity of RTU}}{\text{Total electric power by RTU}}$$

RER **EER**

CEF = Combined Efficiency Factor

Example:

Rooftop	+	ERV	=	System CEF (30 ton system)
EER	&	RER	=	CEF
12.0	**&**	**124.69**	**=**	**17.19**

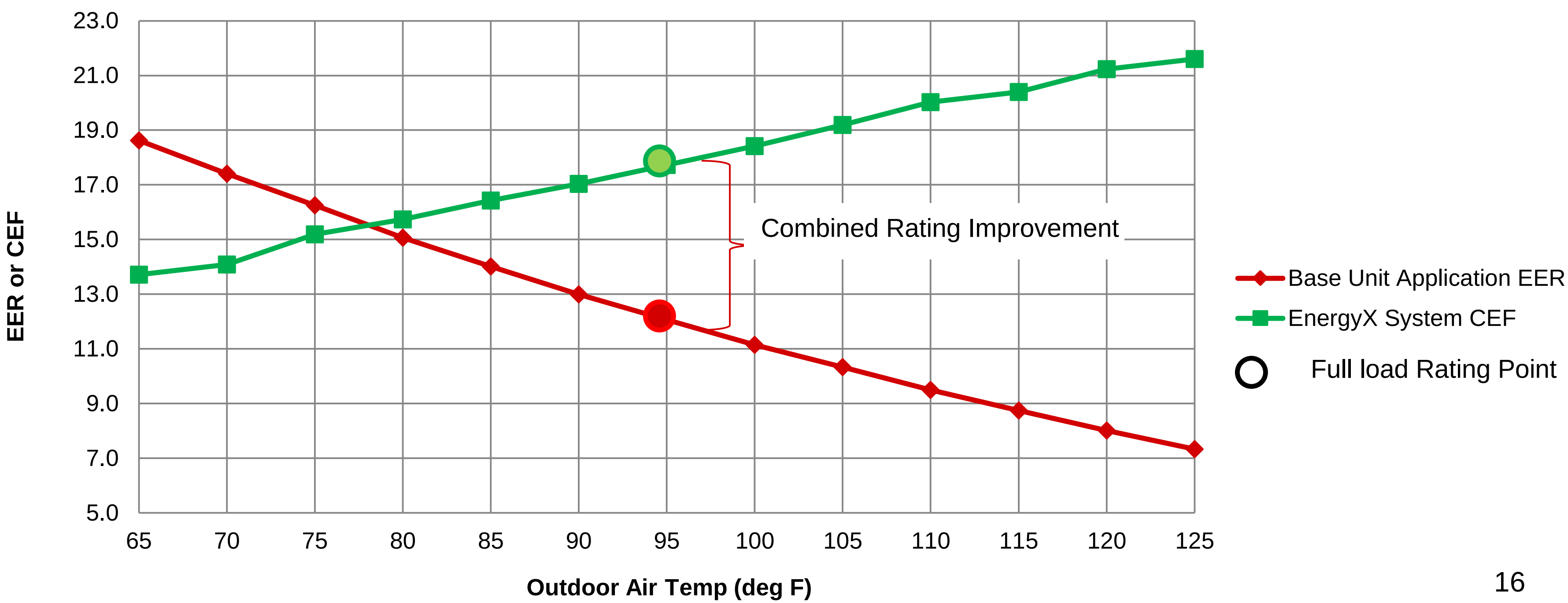
17.19 System EER for a 30 ton total system

Efficiency Comparison (ERV Example)

Example shows how over the operating range a hybrid unit like an ERV/Rooftop can have further improvements at non standard rating conditions

	Base Rooftop Unit	**EnergyX**
Model:	Rooftop	**ERV**
Location:	Tampa, FL	**Tampa, FL**
Altitude (ft)	0.0 ft	**0.0 ft**
CFM	3500	**3500**
Ext static press:	0.75"	**0.75"**
Ventilation Air:	50% or less (economizer)	**50% OA (1750 cfm)**

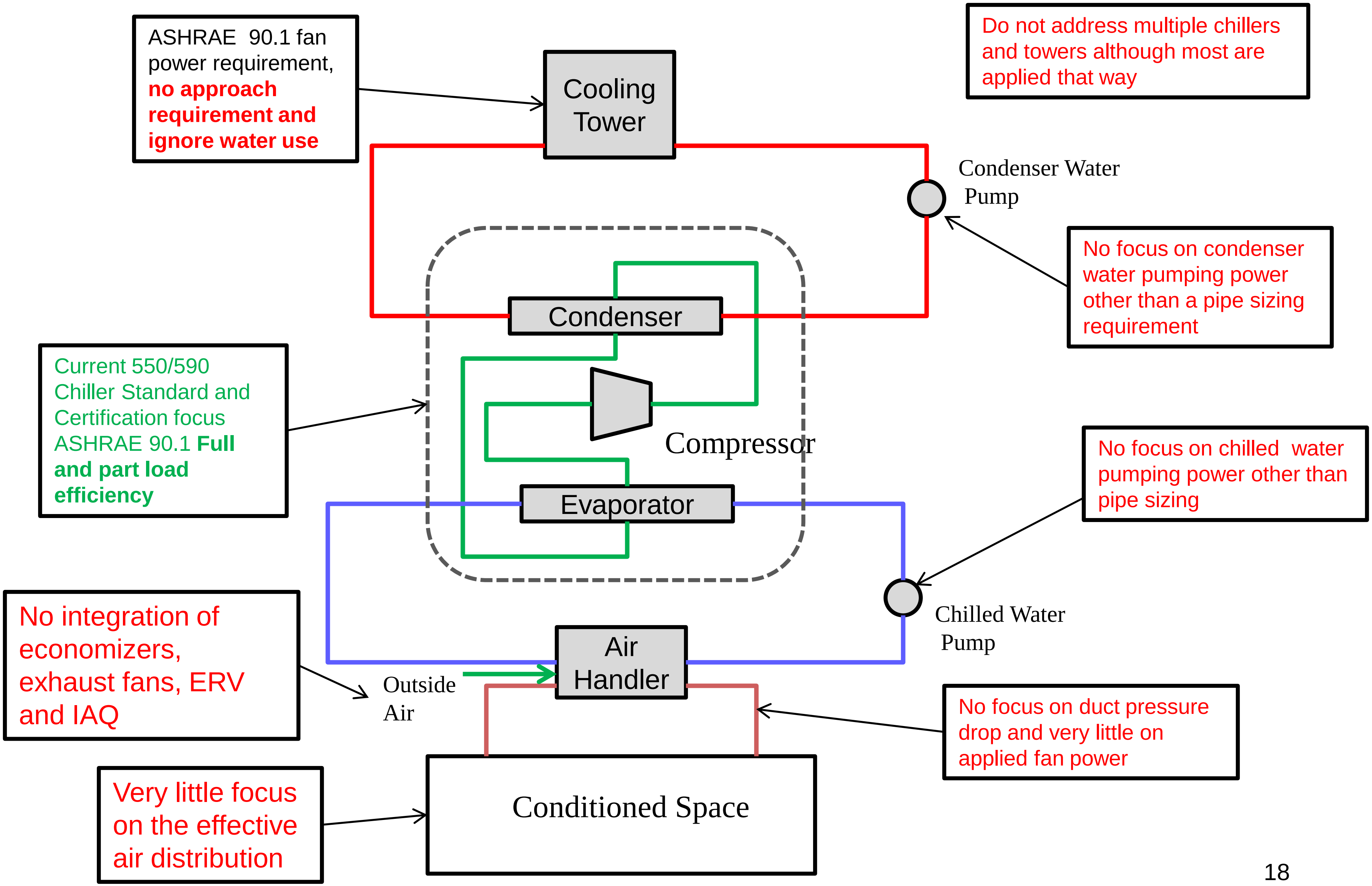
CEF vs Application EER



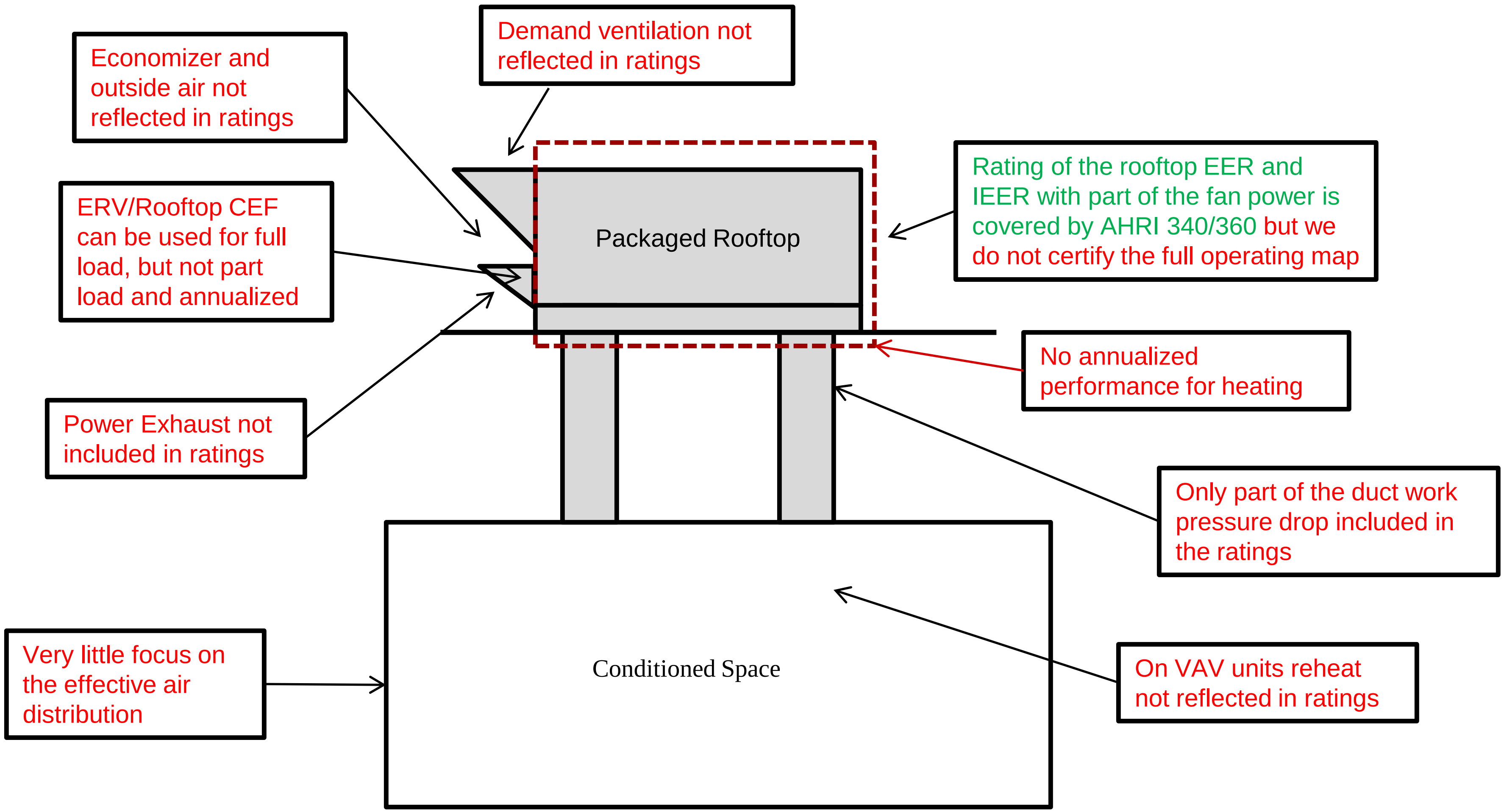
Subsystem Approaches

- Today, the focus of AHRI Standards and regulations are at the equipment level at standard ratings conditions and typically at full load.
- There is no direct tie to environmental performance
- Metrics on performance often do not cover the applied energy use of the system when installed in a building, so the overall performance is not determined and it may not be the optimal system configuration
- Often additional power is used in the application, conditions are different than the standard rating conditions, and additional hardware is added to complete the system
- Commercial equipment regulations assume equipment is an appliance, but most are highly configured systems
- So the concept of a subsystems approach is to expand the scope to cover the HVAC subsystem and not just the components and to focus on annual operation and not just full load equipment sizing metrics

Chiller Water "System" Example



Packaged Ducted Rooftop “System” Example



The Basic Approach to Subsystem Efficiency

Efficiency = output/input

So, another way of looking at this is

Efficiency = $\sum$ outputs/ $\sum$ inputs

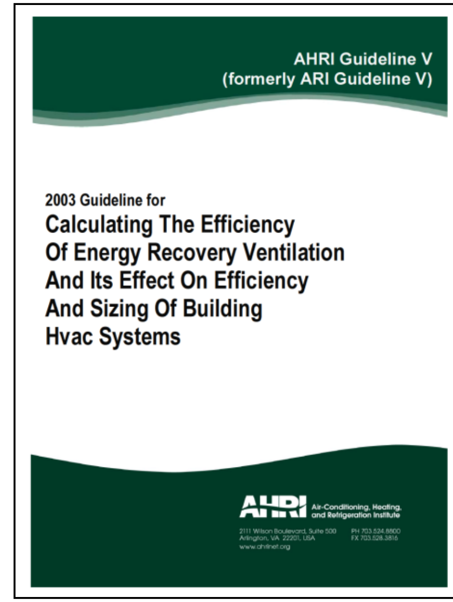
A key to the effective use of this is to get acceptance of using certified components and then combine them without adding another certification program

Subsystem Ratings

- AHRI has started to do some subsystem ratings guidelines like the Energy Recovery and Rooftop Combined Efficiency but the use and acceptance has been limited

- Recently CEE (Consortium for Energy Efficiency) has expressed interest in the concept and work is underway to develop some trial rebate programs.

- Overseas thru ISO and in Canada thru CSA, the use of subsystem ratings is growing quickly and is a high priority


AHRI Guideline V
(formerly ARI Guideline V)

2003 Guideline for
Calculating The Efficiency
Of Energy Recovery Ventilation
And Its Effect On Efficiency
And Sizing Of Building
Hvac Systems

AHRI Air-Conditioning, Heating, and Refrigeration Institute

National Research Council Canada

$$HVAC_{TOI} = \sum_{i=1}^{34}\left(\alpha_i * ToV_i + \beta_i * ToV_i^2\right) * \gamma_i - \sum_{i=1}^{34}\left(\alpha_i * BaV_i + \beta_i * BaV_i^2\right) * \gamma_i$$

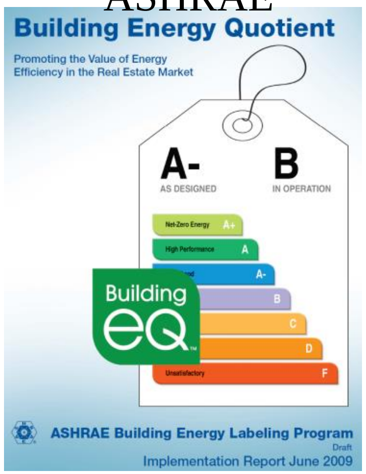
Overall Building Energy Metrics

- Various whole building rating systems have been developed and are being developed
- These are a good approach, as they allow one to consider the complete building as a system and to optimize the energy and cost and avoid wasted energy
- But the tools to reliably predict the energy of buildings are inaccurate at this point, expensive to run and are used on less than 20% of buildings
- Technology development work is underway to provide better HVAC support to that overall building energy systems approach
  - Provide detail model data for simulation correlations thru efforts like *ASHRAE 205 - Standard Representation of Performance Simulation Data for HVAC&R and Other Facility Equipment*
  - Develop new improved correlations and model methods for equipment
  - Provide complete certified operating map data for equipment in formats that can be used with simulations tools
- In Canada and in Europe overall building simplified analysis tools are also being developed to support whole building analysis and legislation

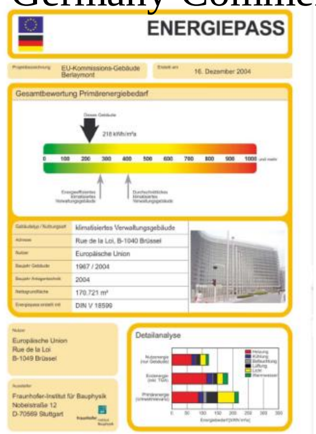
Whole Building Metric

- Globally there are initiatives underway to implement whole building metrics as well as policies involving the use of the metrics

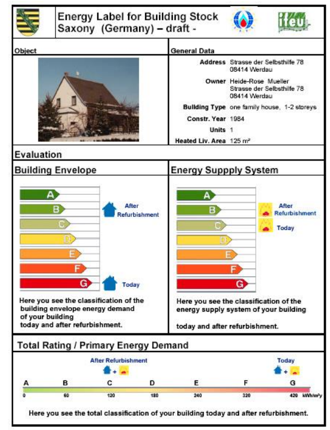
ASHRAE



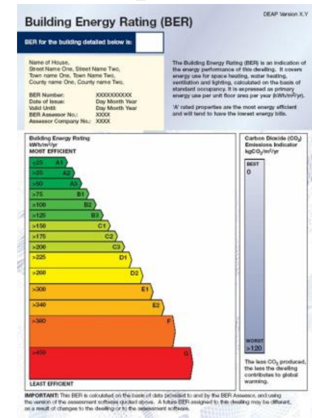
Germany Commercial



Germany Residential

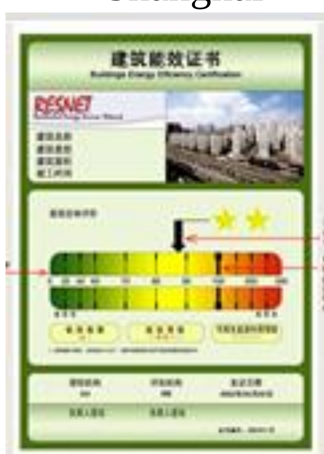


European Union



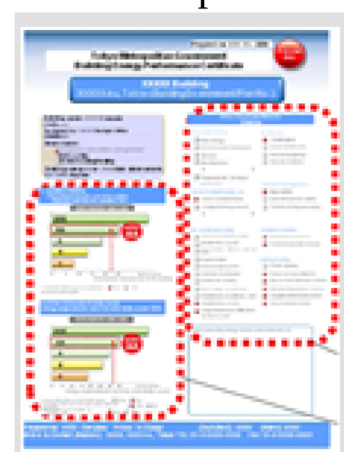
China

Shanghai



Turkey

Japan



Key Enablers to Systems Approach

- To address HVAC&R as a system requires tools and procedures that are not fully developed
  - New Modeling Tools
  - New Equipment Models and Standards
  - Verification of Equipment Performance
  - Automated ways to transfer data
  - Acceptance as a Compliance Path

Commissioning and Re-commissioning

- Another opportunity to significantly reduce building energy use is commissioning and re-commissioning of units and systems to make sure they continue to run as designed

- Most energy regulations and standard focus on the design of the units but very little attention is paid to the installation and operation

- Studies have shown that significant energy can be saved by proper installation and maintenance of units

- Efforts in this would reduce the overall energy of a building as well as reduce refrigerant leaks by routine maintenance of the units

- Also as part of this new technologies in Diagnostics and Prognostics and integrated building controls systems are developing

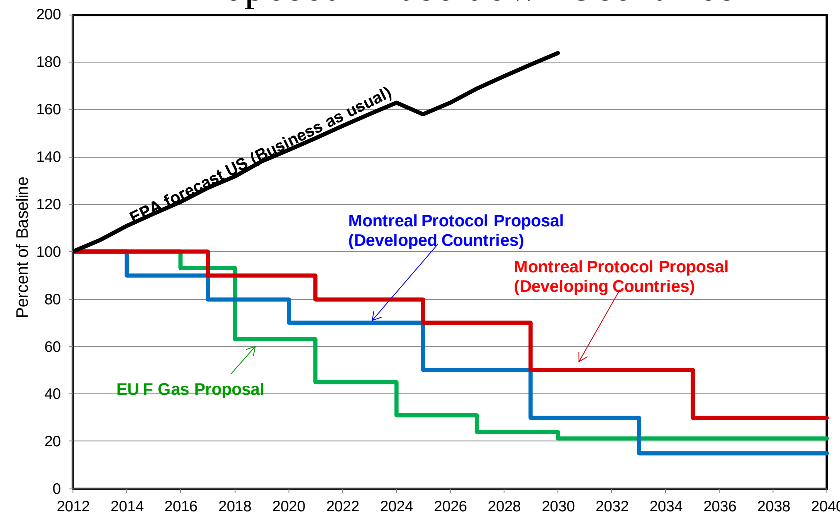
AHRI Systems Working Group

- AHRI has formed a new *Systems Working Group* that will focus on systems approaches to building efficiency
- This was done because the historical approach to improving HVAC efficiency is reaching the limits of technology an alternate approaches need to be explored
- The group was formed early this year with a cross function team of experienced experts covering most of the HVAC disciplines and systems
- Goal is to save energy in buildings while enabling new technologies and approaches to savings energy to be used
- Primary focus is be to put together a packages and technological solutions to change the path of national energy policy for buildings as well as AHRI rating standards
- This will also likely include the development of new systems analysis tools.

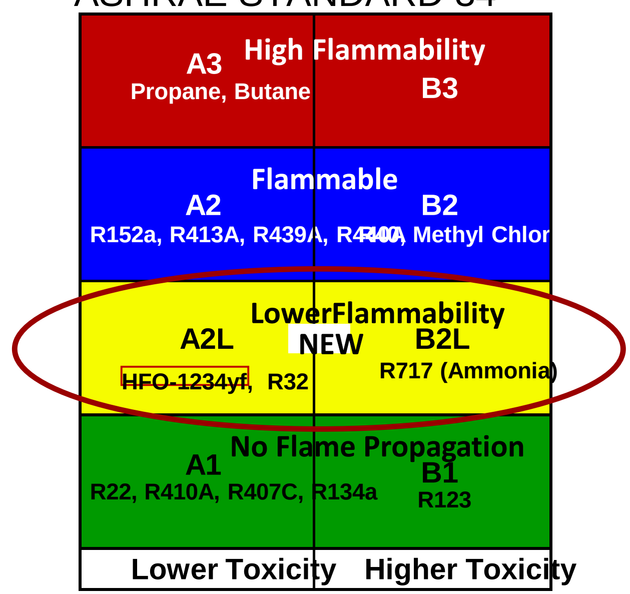
Refrigerants

- Due to the high global warming impact of the refrigerants used in HVAC products a phase down and change in refrigerants may be required
- Current refrigerants have GWP levels at 2088 (R410A), 1430 (R134a), and 3922 (R404A)
- Final phase down levels will likely require GWP levels below 150 to 300
- Below about 600 GWP will require the use of the new 2L refrigerants which are semi-flammable
- This will require significant changes to regulations and designs
- Also the changes will result in the use of lower pressure refrigerants and larger compressors

Proposed Phase down Scenarios



ASHRAE STANDARD 34



Other New Technology Trends

- Greater use of indoor fan volume control
  - Constant volume units by 2016 will have minimum of 2 fan speeds
  - Almost all VAV units are using variable speed indoor fans
  - New concepts like single zone VAV and thermal displacement packaged units have been introduced
- Units with more stages of capacity and variable speed with optimization for part load.
- New economizer controls
  - Improved economizer integration
  - New high limit changeover sensors
  - Diagnostics
  - Commissioning (Title 24 2014)
- Heat Pump Chillers used for building Energy Recovery
- Greater use of dedicated outside air units (DOAS)
- Latent control technologies (humid climates)
- Evaporative cooling (dry climates)

QUESTIONS