National Cooling Initiative: What Are We Waiting For?

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ABSTRACT

All climate change is global; all cooling is local. Every new air conditioning system installed in residential and small commercial buildings adds to electric utility peak demand and greenhouse gas emissions from increased power production. The entire supply chain encompassing the HVAC industry, its products, its contractors, related efficiency/performance test methods, the federal efficiency standards setting process, does not support national, state and local goals to reach net zero energy/emissions building energy use in 2030. And neither does the current utility regulatory and utility energy efficiency framework. With HVAC manufacturers noting the rapidly approaching thermodynamic limits of compressor-based cooling efficiency, the nation requires an immediate, comprehensive, coordinated approach to achieve and maintain optimal mechanic cooling performance across all product and market segments. This necessitates a 'disruptive' strategy to replace the business as usual approach for improving HVAC efficiency and field performance supported by the HVAC industry, ASHRAE, energy efficiency advocates, mandated through federal statutes and tasked to the US Department of Energy. The current national efficiency standards setting process needs to move outside the current federal framework and the HVAC industry, with cooling efficiency research, development and deployment resources reallocated and scaled up toward high efficiency cooling approaches that are tailored to regional and local climate, and utility-specific conditions. The National Cooling Initiative (NCI) will be established to quickly mobilize the research, technical, market and financial resources to drive a rapid transition to high performance cooling for both vapor-compression and evaporative cooling approaches across equipment sizes, types and markets.

Background

"Problems cannot be solved by the same level of thinking that created them." -Albert Einstein.

Market demand for mechanical cooling systems is reaching all time highs in the residential sector nationally. In the commercial sector, rooftop unitary equipment suffers from variety of energy performance degradation conditions that begin with manufacturing/engineering design, result from system sizing errors, and are compounded through installation, operation and maintenance deficiencies. Electric utility peak demand growth in virtually all areas of the country is being driven primarily by residential and commercial air conditioning growth.

U.S. population and housing growth projections point to larger homes with fewer people in them. Extrapolating growth trends out to the year 2030 puts the U.S. population at 365,590,000, with 51,527,000 new housing units The percentage of homes installing air conditioning has increased from 42.8% in 1972 to 89.2% in 2006, with 95% reported in California.

Further extrapolating from the growth assumptions presented above, using published AHRI efficiency ratings, the increase in demand for residential central air conditioning alone between 2008 and 2030 would require 120 gigawatts (GW) of additional generation capacity, and more likely 140 GW to 168 GW of additional capacity based on the actual HVAC equipment operating efficiencies observed from numerous field studies around the country.

Significantly, HVAC and related compressor manufacturers are stating that the thermodynamic limits of vapor-compression cooling are being reached in both single- and multiple-compressor systems. This implies the need to look beyond incremental SEER-EER efficiency related improvements to a comprehensive assessment of new and existing tools, techniques and products that could be applied in a more integrated approach to improve vapor compression- and evaporative-based cooling equipment efficiency across all equipment lines and sizes at least up to 20 tons. Advanced evaporative cooling product developments show great promise. While efficient technology development is advancing, there is a more fundamental need for new approaches to integrated, whole building design and function. Establishing these parameters is central to establishing the conditions for creating buildings that require little or no mechanical or evaporative cooling at all, in addition to further optimizing mechanical cooling equipment.

Analysis of AHRI shipment data shows that the average rising efficiency of equipment jumped in 1992 after the first standard was established, but then stagnated with the average growth rate resulting in little or no acceleration of shipped efficiency for nearly ten years after its adoption. Chart 1 shows AHRI reported unitary efficiency averages for the period from 1976 to 2003 with projected trends. No data was available from 2003 on. The baseline was reset to 13 SEER for the purposes of illustrating the effect on the growth curve the underlying national codes might have. Chart 2 indicates that mandated efficiencies might actually create a rebound affect in the market and does not affect the long-term natural progression in shipped efficiency of equipment. However, it does bring the lower SEER level projections up. The point of the charts is that to substantially influence the average shipped and installed efficiency curves, there needs to be an increase in the percentage of the required improvement over minimum standards or the frequency of establishing new standards or better yet, both. These are the major objectives of the National Cooling Initiative (NCI). The charts do not account for regional/climate-based differences, flaws in the rating system, nor the well-known quality problems nationally with system sizing, installation practice, and system maintenance.

Chart 1. Projected Trends Using ARI Shipped Data for Unitary <65,000 Btu/h

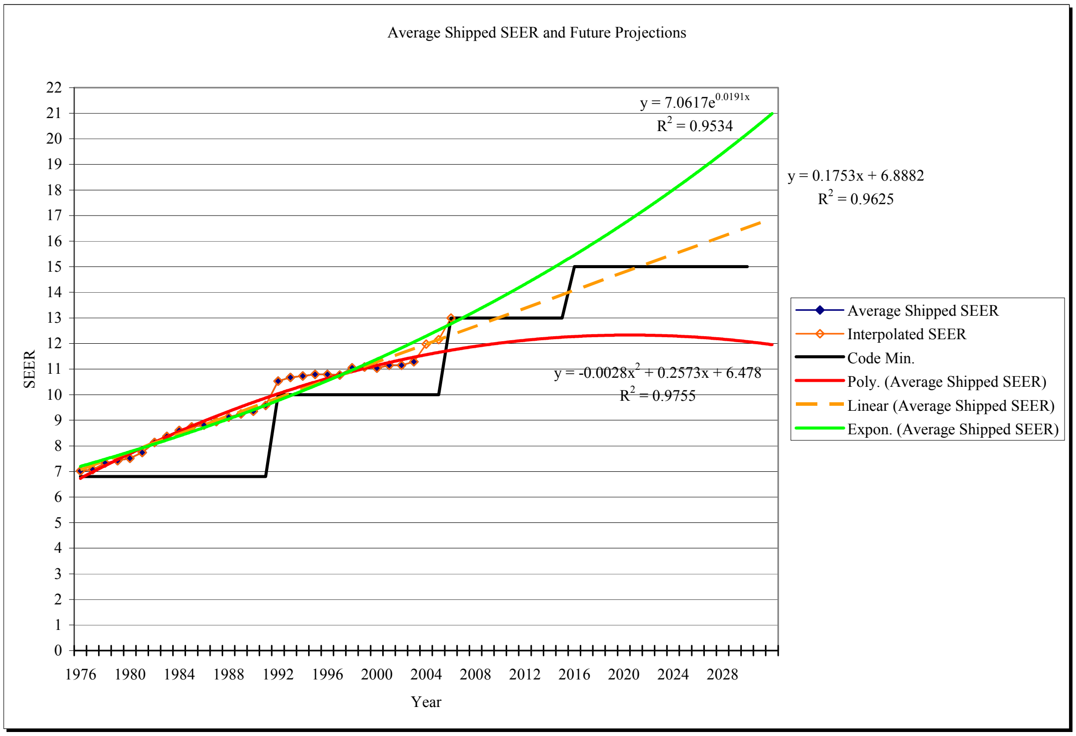
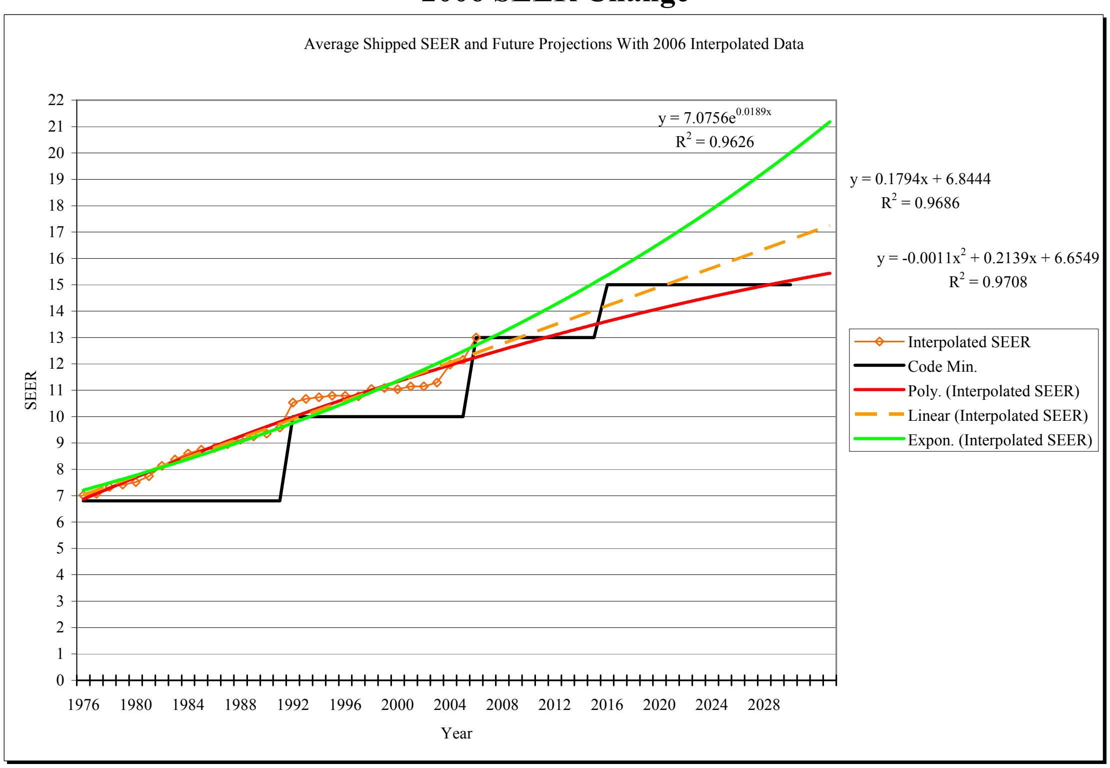


Chart 2. Projected Trends Using ARI Shipped Data and Interpolated Data: 2006 SEER Change



What's Not Working?

HVAC Industry Leadership and Business Model

"...Some on Capitol Hill are advocating a return of a confusing patchwork of state standards-a move that would make American industry less productive, less...able to provide good-paying jobs...American industry can provide a wide range of quality when allowed to manufacture to one national efficiency standard...." (ARI Magazine, 2007).

The ARI statement is especially troubling since it is dismissive of the serious and growing impacts of HVAC energy inefficiency on greenhouse gas emissions as utility peak demand climbs, driven in most areas of the country by increased air conditioning use. Responsible leadership cannot dismiss the fact that laboratory and field research results show 29-37% reductions in energy and demand from residential HVAC equipment optimized and controlled for hot dry climates. (Pacific Gas & Electric, 2008). Serious corporate leaders in the HVAC industry must come to grips publicly with the need for making meaningful and accelerated progress in energy efficiency without resorting to tired, empty rhetoric. Due to lack of industry leadership thus far, along with a history of industry foot dragging on higher efficiency standards, the proposed NCI must be driven largely from outside the industry, with appropriate industry involvement in specific technical areas, but not at a strategic level in terms of direction or standards.

Generally, the HVAC industry's business model provides three tiers of equipment to the market. These tiers are often labeled as 'good/better/best.' The good units meet minimum nationally mandated efficiency levels, which is a part of the problem, with ASHRAE continually debating, "Should our standards try to advance best practice, or focus on minimum levels of performance?" (ASHRAE, 2008), and always coming out supporting minimum performance. The lead on increasing efficiency levels nationally never comes from the industry. Leadership on efficiency is driven primarily by efforts of energy efficiency advocacy community often in concert with electric utilities, state and regional efficiency organizations. A notable exception to this dynamic involves the efforts of Wal-Mart Corporation to specify and procure a rooftop package HVAC unit that was at least 25% more efficient than the minimum standard. A single manufacturer (Lennox) stepped up to the challenge after more than a year's negotiations with several manufacturers, but only because Wal-Mart went to them with the efficiency interest for its private benefit.

The lowest efficiency units are a commodity product with an estimated 80% market share. The 'better' equipment tier enjoys approximately 10-15% market share, with the 'best' units having less than a 10% market share. In order to meet global, national, regional and local greenhouse gas emissions reductions goals, this market share split needs to be reversed with the best units becoming the commodity mass market unit providing the highest efficiency as well as the most robust performance. Only such a major market shift can lead to significant energy and demand savings from mechanical cooling. Dealing with the financial requirements to flip the market share of efficiency is a primary challenge faced by the NCI and the nation.

Federal Overlay: Test Protocols/Efficiency Standards Rulemaking Process/R&D Priorities

In the 1970's federal legislation established the testing methods by which air conditioning equipment receives a Seasonal Energy Efficiency Rating (SEER) rating, primarily for marketing purposes. Plain and simple, the legislated, mandated testing and certification system currently in place is broken. It does not represent how systems work in the field (and never did), is based on a single point test rating, is most often used as a surrogate method for equipment selection (and utility financial incentives), which was never the intended purpose of the rating and does not meet the conditions for optimizing climate-based efficiency standards. In the residential sector, SEER is largely seen as the efficiency of the condenser and not about selecting the correct combination for a given house and its design requirements. It is all about selling the highest SEER number or having it to sell down from to save the customer money upfront, and not providing the unit that will actually deliver the best comfort and efficiency for a given application.

From the formulation and through adoption of the SEER methodology, there have been a growing chorus of critics of the SEER method voicing continuing concern about the poor indicator of efficiency of this rating methodology due in part to the unrealistic assumptions about the conditions under which equipment operates in the field. A compelling argument for the needed changes in SEER test conditions for both climate optimized standards and more useful national standards, was made in an ACEEE paper (Sachs, et al. 2007).

Currently, the federally legislated process for rulemakings to establish HVAC efficiency standards has locked the HVAC industry, the electric and gas utilities, and efficiency advocates into a six to eight year long process from the start of a standards rulemaking to the time when equipment is available to the market. The idea that this process can lead to equipment efficiencies and performance enhancements that support zero or very low energy buildings by 2030 is misguided at best and at worst, as it is currently, directly counterproductive to reaching future high efficiency/low energy building performance goals.

As noted above, the established rulemaking process also ensures that no innovations in efficiency and robust field performance can enter the market quickly other than at 'best' tier levels with limited mass-market penetration. There are also issues with the Federal Trade Commission that only allows the promotion of SEER as the indicator for efficiency to consumers regardless of the real shortcomings in the rating method.

U.S. DOE is in the process of examining priorities among 25 technologies and approaches for improved efficiency in space cooling (and some heating) for consideration in its Building Technologies program. DOE is not considering any of the equipment performance issues note below, although many of them significantly impact the expected efficiency gains forecast in the DOE process. This further illustrates the need for comprehensive and cohesive direction for improving cooling efficiency nationally outside the usual industry and federal channels.

One can describe the overall federal (and HVAC industry) framework as profoundly dysfunctional and conclude that it should be abandoned for the purposes of a strategic acceleration of cooling efficiency research, development and deployment nationally.

Backlog of Equipment Performance Issues

In addition to a test protocol redesign, the following list of issues that active HVAC contractors, engineering consultants, researchers, utility program operators and efficiency advocates believe need addressing now, represent in part the justification for proposing the NCI.

The list is not is exhaustive. However, it is indicative of the lack of attention to fundamentals that characterizes the current environment in the HVAC industry and is related to ASHRAE's inhibited process for reaching for higher efficiency sooner. The range of topics is instructive as to the need to move the efficiency bar forward more quickly.

The current approach to system optimization would be substantially enhanced if HVAC manufacturers would publish performance curves in an industry standard format. This would allow contractors, designers, utility program operators, efficiency advocates and anyone interested, to optimize cooling equipment selection for any location. While this is a potentially powerful and relatively straightforward approach, there appears to be a lack of leadership inside the industry to aggressively champion this approach and make it happen quickly.

Standards

- Revision of the DOE/ASHRAE/ARI test pressure conditions for furnaces and air handlers, with the addition of required measured blower power.
- Creation of a minimum national standard for onboard fault detection and diagnostics functionality and reporting for all equipment, residential and small commercial.
- Creation of a national standard for the specification of designated sensor mounting (applications) locations for service work.
- An industry standard methodology for the use of superheat and subcooling measurements. A review and revision as needed, of the current superheat/subcooling tables along with evaporator and condenser performance charts.
- Provision of an industry-wide standard mounting location for data labeling via stickers, plates, or potentially an RFID tag, with enhanced data sets such as updated superheat/subcooling tables for a wide range of indoor/outdoor conditions permanently affixed to each unit.
- Industry standard locations for service pressure and temperature measurements.
- Industry standard labeling of equipment for the purposes of identifying capacities, metering devices, refrigerant charge and other appropriate metrics.
- Industry standard definition and methods for determining refrigerant charge.
- Testing and certification of third party coils.

Benchmarks, Diagnostics and Information Access

- Creation of national benchmark standards for existing diagnostic and repair protocols
- Development of a prioritization of in-field diagnostic approaches based on benefit-cost of the energy savings, cost to diagnose/repair, and the frequency of occurrence of faults.
- Creation of a definition of a clean coil and how to measure it, including quantification of the return on investment for coil cleaning, equipment life, energy performance and reliability.
- A web-based, technical repository where protocols and measured/certified/lab test data could be posted for public and professional review. The collection of data should allow researchers and practitioners to examine the quality of the data including sensor and instrument types, accuracies, measurement uncertainties, and testing methods. Data from field research and utility program results would be posted and archived.

- Operational performance curves.
- Alternative, non-invasive, measurement techniques.

Equipment Design and Operation

- Updated and expanded range of in-field unit refrigeration charge diagnostic protocols down to 50°F outside temperature, 40°F degree wet-bulb with an upper limit of 115°F outside.
- Equipment housings – air tightness.
- Equipment size and configuration issues.
- Inefficient fan aerodynamics.
- Operational sequences – fans, staging, ventilation, variable speeds.
- Implementation of the 36 features of the Advanced Package Rooftop Unit (Architectural Energy Corporation, 2005) that enhance the field performance and serviceability migrated to all commercial rooftop units.

HVAC Contractors

Within the last five years, due to rising concern over substandard HVAC contractor work throughout the residential and small commercial buildings sectors, leading national organizations representing businesses related to HVAC work and led by the Air Conditioning Contractors of America (ACCA) have made a determined push to improve the quality of system sizing, component selection, installation and maintenance practices across the industry. Unfortunately, much of the industry is still not listening.

Efforts by ACCA have produced an "HVAC Quality Installation (QI) Specification" that has been formally recognized by the American National Standards Institute (ANSI) as a national standard. A national standard provides all contractors with a common set of guidelines to start from, but it is voluntary and there is little to no oversight of contractor field quality by any third party with the exception of utility programs that do not yet reach many contractors.

Verification and enforcement protocols are being developed for the new ANSI standard. The new protocols will allow for actual field inspections by auditors where funds are available such as through local utility conservation programs, but not outside a funded framework. There is no effective, uniform national approach to verify quality practice in the contractor base.

The issue of maintenance and service of systems is also a factor negatively compounding other problems in the supply chain. In fact, too many contractors are not providing even scheduled services to units. Contractors lack cost effective tools and the related knowledge to understand and effectively measure and evaluate static pressure airflow, duct leakage and the related performance relationship to fan power. Proper air balancing is rarely practiced.

The service contracts usually consist of a technician visiting a site and going through a checklist of items to make sure the unit will run. These service agreements do not provide for corrections or even identification of potential problems such as duct leakage or airflow and capacity issues, except when a technician is individually oriented or specifically tasked to assessing these items. A larger percentage of commercial equipment appears to receive at least annual servicing, but the level of service is typically limited and may easily miss performance degradation conditions. One major indicator of commercial equipment service quality problems is the widespread incidence of poor or failed economizer operation.

Utility-supported HVAC maintenance programs throughout the country report the same types of barriers and issues to getting technicians to do their jobs correctly. Program operators are finding inaccurate tools, un-calibrated tools, improper methods, improper interpretation of data collected, lack of proper measurement techniques, and missing key data collection steps. Furthermore, many technicians are never given the time to collect measurements properly, so they are forced to act on too little information and are under pressure to get to the next job.

Local Codes and Enforcement

There have been many model National Energy Code improvements over the past decade with numerous annual revisions, updates and addendum. These energy codes require builders to build buildings that are responsive to the conditions in which the buildings will operate. Energy codes require certain measures concerning air sealing, insulation R-values and may provide trade-offs and performance modeling to allow builders to take credit for higher than minimum efficiency mechanical equipment in order to meet code provisions. At first glance this seems like a good way to allow builders and designers to remain flexible with their designs, but it does not in any way guarantee higher energy efficiency.

Projects are designed that fail the building envelope requirements by 30% or more, yet pass code requirements because of credit provided by installing high efficiency HVAC equipment. The problem is further exacerbated by the poorly executed installation of the mechanical system due to improper duct design, poor commissioning and lack of code inspection. California, with some of the toughest efficiency standards in the nation, acknowledges code compliance rates under 10% for HVAC permits in new and existing construction. Code officials there bear the brunt of customer complaints due to poor installation quality that could have been discovered through routine and required permit inspections.

National Cooling Initiative (NCI)

There is discussion in product development circles about 'disruptive' technologies, products or approaches that seem to spring on to the market and create new market niches or take over a product niche, sometimes very quickly, such as fax machines and the Apple iPod. Given concerns about global warming and managing utility demand growth, the timing is right for a 'disruptive strategy' to accelerate the delivered improvements in cooling technologies (both vapor compression- and evaporative-based). The proposed NCI is the disruptive strategy that is necessary for an acceleration of cooling efficiency nationally.

NCI Structure

The NCI, national, public non-profit organization, without HVAC industry affiliation, will be responsible for setting up all necessary approaches needed to move away from the current broken paradigm and develop the appropriate mechanisms for establishing higher in-field equipment and system efficiencies, tackling the performance and quality issues in the HVAC contracting field, educating homeowners and business owners, and developing the financial mechanisms needed to deploy high efficiency equipment to the mass market.

The main components of the NCI include:

A. Technology R&D: The NCI will establish a public interest approach to the design of advanced, high efficiency equipment and related components. NVI will accelerated technology research, development, and through an aggressive R&D effort that will necessarily take place outside the HVAC industry infrastructure since HVAC industry personnel cannot participate openly in the development of new technology due to confidentiality and proprietary issues within the companies they work for. Currently, industry reports that its R&D capabilities are booked dealing with the upcoming changes related to new refrigerants and new efficiency standards scheduled to be implemented in 2010. Additional R&D testing will be supplied through a network of national laboratories, university and other private laboratory and research facilities equipped for this work. Engineering talent from the private sector, retired HVAC industry personnel and researchers from a variety of disciplines will be brought to bear on developing next generation technology. NCI will develop new energy efficiency indicators to rate the expected performance and energy use of cooling systems that more accurately predict system power demands related to local climate conditions. New equipment will have standardized, embedded automated diagnostics with communications protocols for smart thermostats (way beyond a change filter light) and for web-based equipment performance monitoring for both residential and commercial buildings owners. Centers of Technical Excellence will be established through existing institutional arrangements. For example, the Western Cooling Efficiency Center, established at the University of California at Davis, is already leading the hot dry climate optimized approach with active utility and state support. The Center has released a challenge to cooling companies in the form of a specification for a unit that meets Western hot dry climate needs. The performance specification implies a hybrid unit combining compressor cooling with advanced evaporative cooling. Similar R&D technology challenges will be initiated for hot humid and other climates. The NCI will partner with a closely linked national initiative to create innovation in the design/build community that would seek to optimize building designs that would reduce utility peak load electricity demands from residential and commercial buildings. NCI would establish a publicly accessible information archive for researchers, utility programs operators, design engineers and policy makers. NCI would provide commentary on the posted information.

B. HVAC Contractor Quality: Given the central importance of managing electricity growth and use nationally and locally, there is a compelling need for a large cadre of trained and licensed professionals to deal with all aspects of energy use including HVAC. The NCI will work with national professional organizations representing the HVAC industry, higher education institutions at all levels, and licensing boards, to establish professional credentials for anyone directly involved with HVAC in the field. The credentialing framework and process will have the same force of standard practice, related public law and levels of professional compensation that are related to the training and licensing of doctors, engineers, attorneys, commercial airline pilots and other similarly skilled professionals. Practicing ‘cooling without a license’ will have financial penalties attached. HVAC manufacturers will only be able to sell to licensed distributors. Licensed distributors will have the capacity, authority and legal requirement to check and verify the sizing calculations of HVAC contractors before equipment can be sold and permitted. Intensive technical training, not simplified book learning followed by self-administered testing, will be required. This will require the introduction of a new compliance system designed to track the status of HVAC equipment from the sale to contractors at the distributor office to the final quality check performed by trained and licensed third parties in the field. This approach can be integrated with local code inspection to further insure quality control. A single national training, certification and licensing platform will be established with the verification protocols being developed by ACCA and allied trade organizations. HVAC manufacturers will have legal responsibility to make sure their equipment is installed and operated to the highest standard. As with many professions, ongoing continuing education requirements will be necessary to maintain HVAC contractor certification.

C. Consumer Education: The NCI would be responsible for the development and implementation of education and promotion programs aimed at informing homeowners and business owners of what is at stake in maintaining cooling equipment efficiency and related goals for quality installation and maintenance. A national campaign, "Cool Star," similar to what has proved successful in establishing public awareness of the benefits of the Energy Star™ brand might be launched. This campaign would involve well-funded mass media marketing and the participation of educational institutions at all levels in every community. The effort will reach down to the high school level, where energy literacy would become a required part of the graduation curriculum.

D. Federal Legislation: The NCI will make a set of legislative recommendations to the US Congress covering all aspects of a national framework for cooling efficiency in all its aspects. This framework will accelerate the timetable for establishing higher efficiency standards and deployment of new equipment. National legislation would embed climate optimized efficiency standards as a minimum requirement in all regions and take into account climate differences at the sub-state level, unlike current federal legislation. Legislation will also provide substantial tax credits and direct financial incentives to individuals and businesses to further leverage the financing of high efficiency cooling products. NCI will design and propose a federal levy on air conditioner sales that will provide funding for the NCI and for consumer education and incentives.

E. Local Code Enforcement: The NCI will reach out to the International Conference of Building Officials and the International Code Council to reposition nationally, energy-related permitting and inspection procedures as an integral part of the fire/life/safety framework that currently represent the actual priorities of local code officials. Appropriate professional training curriculum will be developed and added to the fundamental responsibilities of the local code officials. Federal funding would be available to support the local training efforts.

F. Utility Regulatory Policy: The NCI will partner with the Regulatory Assistance Project to coordinate with the National Association of Regulatory Utility Commissioners to establish uniform, national regulatory approaches that address the need for utility DSM programs to implement optimized, high efficiency cooling equipment with ratepayer funds. A level of national consistency must be achieved on the issue of utility marginal cost effectiveness for efficiency investments. Ratepayer financial incentives through utility DSM programs for cooling equipment must be based on projected 'national' marginal costs of electricity supply. This marginal cost will be based on an economic framework that includes global warming mitigation needs and the eventual limits on fossil fuel supply [primarily natural gas] for power generation. National efforts will be initiated to establish the cost of serving peak air conditioning loads through mechanisms such as the Time Dependent Value method being introduced in California.

NCI Initiation Process

One option for establishing the NCI could be to approach the Consortium for Energy Efficiency (CEE) to facilitate the startup phase and provide a hand-off to an independent organization when appropriate. CEE, which represents a number of utilities, efficiency advocates and national laboratories throughout the US and Canada, also works closely with allied industry partners to advance energy efficiency goals nationally. CEE members are likely to be supportive of a framework that provides an independent assessment of cooling technologies and performance. However, CEE industry partners are unlikely to be enthusiastic. CEE membership would have to determine if this comprehensive approach was a priority and justifiable from the organization's strategic perspectives as well as national needs.

CEE staff would identify and convene an initially self-identifying working group of technical experts, researchers and efficiency advocates to establish the overall framework for the NCI and identify specific tasks. An action plan to address the issues would be developed, financial resource options identified and a schedule set to deliver what is required. The NCI organization would establish appropriate working groups to deal with technology, testing/certification, contractor issues, local needs, market needs and financial approaches to deal with the inevitable increase in costs of the more efficient equipment, along with substantial education efforts to inform all consumers about the underlying principles that are being promoted.

If CEE cannot take on this task for whatever the reason, other national energy advocacy groups including ACEEE, will be approached to take on the NCI. While this mission may not fully fit with current advocacy group positions, it is time for a change in advocacy approach to a more aggressive, comprehensive and perhaps hands on initiative.

The overall NCI process would be guided by a compensated board made up of engineering professionals, utility regulators, researchers, efficiency advocates and utility representatives.

Summary

This paper is meant as a conceptual action plan to dramatically accelerate efficiency gains in cooling buildings. It is a brief summary illustrating the current trends and issues that drive the need to convene the NCI to plot an appropriate course of corrective and integrated actions across the HVAC industry spectrum. The NCI staff and board will be challenged to address the real issues of equipment efficiency, the ability to deliver and maintain cooling efficiency in the field, how to create useful efficiency metrics to help local policy makers make better informed decisions as well as give consumers a more complete picture of expected equipment performance. The sooner we get started on this path, the better.

“Problems cannot be solved by the same level of thinking that created them." ~Albert Einstein

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