Commercial HVAC and service water-heating equipment minimum energy efficiency standards in the U.S.

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1. SYNOPSIS

This paper describes policy and recent developments in the U.S. linking a commercial building energy efficiency standard to mandated manufacturing minimum commercial HVAC equipment efficiency standards.

2. ABSTRACT

Commercial HVAC and service water-heating equipment efficiency is mandated in the U.S. through a strong linkage to ASHRAE Standard 90.1. ASHRAE recently updated Standard 90.1 in 1999, triggering rulemaking processes undertaken by the U.S. DOE to set mandated manufacturing minimum efficiency levels for covered equipment at Standard 90.1 levels or higher if technologically feasible and economically justified. This paper describes the history of this policy, current activities and decisions, and the technical, economic, and policy issues arising out of them.

3. INTRODUCTION

The U.S. has established what is perhaps a unique relationship between a building energy efficiency standard for commercial buildings and mandated manufacturing minimum equipment efficiency standards. As many countries have in place or are considering one or both of these policy instruments, this approach of linking the two presents policy makers with potential synergies and pitfalls.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the main professional organisation representing the building heating, ventilating, and air-conditioning (HVAC) industry, has established Standard 90.1—a building energy efficiency standard covering all buildings except low-rise residential buildings. Standard 90.1, which was updated in October 1999, has served as the basis for building energy codes promulgated at the state level in the U.S., and in many other countries. Legislation in 1992 mandated that the U.S. Department of Energy (DOE) set efficiency levels in the then-current Standard 90.1 as mandatory minimums for HVAC and service water-heating equipment sold in the U.S. market. It also established a process for revising the minimum equipment efficiency standards when Standard 90.1 is updated. With the recent Standard 90.1 update, DOE is now undertaking its first rulemaking processes for these equipment categories. The rulemaking process is based on establishing technologically feasible and economically justified criteria for revising the manufacturing standards.

This paper briefly describes the 1992 legislation establishing the link between the building energy efficiency standard and manufacturer minimum equipment efficiency standards, and the recent history of ASHRAE's update process for Standard 90.1. We then present the process by which the efficiency levels in the updated Standard 90.1 are either adopted or revised upwards by DOE for the purpose of the manufacturer minimum equipment efficiency standards. We describe activities and decisions taken to date, and the technical, economic, and policy issues arising from them.

4. BACKGROUND

Legislation Establishing Link

The Energy Policy and Conservation Act (EPCA) of 1975, as amended by the Energy Policy Act (EPACT) of 1992, establishes that the DOE regulate efficiency levels of certain commercial HVAC and SWH equipment categories. Initial minimum efficiency levels for products falling under these categories were established in EPACT, based on the requirements in *ANSI/ASHRAE/ IES Standard 90.1-1989* (ASHRAE 1989). EPCA requirements state that, if ASHRAE amends efficiency levels prescribed in Standard 90.1-1989, then DOE must establish an amended uniform national manufacturing standard at the minimum level specified in amended Standard 90.1. However, DOE can establish higher efficiency levels if it can show through clear and convincing evidence that a technologically feasible and economically justified higher efficiency level would produce significant additional energy savings. EPCA restricts DOE from prescribing a higher standard if it is likely to result in the unavailability of the products with performance characteristics, features, sizes, capacities, and volumes substantially the same as those available in the U.S. at the time. Further, it prohibits DOE from lowering the existing requirements that increase energy use or decrease minimum energy efficiency. Tables 1 and 2 list the covered products and corresponding EPCA efficiency levels for air-conditioners and heat pumps, and for furnaces, boilers, water heaters, and unfired hot water storage tanks.

Table 1. Standard Levels for Air Conditioners and Heat Pumps

Product Category	**Product Subcategory**	**Efficiency Level[a]** EPCA	**Efficiency Level[a]** Standard 90.1-1999
Small Commercial Packaged Air Conditioning and Heating Equipment	3 Phase, Central, Split System, Air-Cooled AC, HP <65 kBtu/h	SEER: 10.0 HSPF: 6.8	SEER: 10.0 HSPF: 6.8
	3 Phase, Central, Single Package, Air-Cooled AC, HP <65 kBtu/h	SEER: 9.7 HSPF: 6.6	SEER: 9.7 HSPF: 6.6
	Central, Air-Cooled AC, HP _65 kBtu/h and <135 kBtu/h	EER[b]: 8.9 COP[c]: 3.0	EER[b]: 10.3 COP[c]: 3.2
	Central, Evaporatively-Cooled AC <65 kBtu/h	EER[b]: 9.3	EER[b]: 12.1
	Central, Water-Cooled AC <65 kBtu/h	EER[d]: 9.3	EER[d]: 12.1
	Central, Water-Source HP < 17 kBtu/h	EER[d]: 9.3	EER[c]: 11.2
	Central, Water-Source HP _ 17 kBtu/h and <65 kBtu/h	EER[d]: 9.3	EER[c]: 12.0
	Central, Evaporatively-Cooled AC _ 65 kBtu/h and <135 kBtu/h	EER[b]: 10.5	EER[b]: 11.5
	Central, Water-Cooled AC _ 65 kBtu/h and <135 kBtu/h	EER[d]: 10.5	EER[d]: 11.5
	Central, Water-Source HP, _ 65 kBtu/h and <135 kBtu/h	EER[d]: 10.5	EER[e]: 12.0
	Central, Water-Source HP < 135 kBtu/h	COP[f]: 3.8	COP[g]: 4.2
Large Commercial Packaged Air Conditioning and Heating Equipment	Central, Air-Cooled AC, _135 kBtu/h and <240 kBtu/h	EER[b]: 8.5	EER[b]: 9.7
	Central, Air-Cooled HP, _135 kBtu/h and <240 kBtu/h	EER[b]: 8.5 COP[c]: 2.9	EER[b]: 9.3 COP[c]: 3.1
	Central, Water-Cooled, Evaporatively-Cooled AC, _135 kBtu/h and <240 kBtu/h	EER [h]: 9.6	EER [h]: 11.0
Packaged Terminal Air Conditioners and Heat Pumps	PTAC/PTHP (Air-Cooled)	EER and COP vary by capacity (different formulas)	EER and COP vary by capacity (different formulas)

[a] Heating efficiency levels do not apply to cooling only air conditioners.
[b] At 95_ F Dry-bulb temperature.
[c] At 47 F dry-bulb temperature.
[d] At 85_ F entering water temperature.
[e] At 86_ F entering water temperature.
[f] At 70_ F entering water temperature.
[g] At 68_ F entering water temperature.
[h] According to ARI Standard 360.

Table 2. Standard Levels for Furnaces, Boilers, Water Heaters, and Unfired Hot Water Storage Tanks

Product Category	Product Subcategory	Efficiency Level	
		EPCA	Standard 90.1-1999
Warm Air Furnaces	_225,000 Btu/h	Thermal Efficiency[a]: 80% Gas, 81% Oil	Thermal Efficiency[a]: 80% Gas, 81% Oil
Packaged Boilers	_300,000 Btu/h	Combustion Efficiency[a]: 80% Gas, 83% Oil	Thermal Efficiency[a]: 80% Gas, 83% Oil
Storage Water Heaters	Electric	Standby Loss[b]: 0.3 + 27/V_a (%/h) (V_a=Measured Storage Volume in Gallons)	Standby Loss[c]: 20 + 35_V (Btu/h) (V=Rated Storage Volume in Gallons)
	Gas	Thermal Efficiency: 78%, Standby Loss[b]: Varies by Volume	Thermal Efficiency: 80%, Standby Loss[c]: Varies by Volume
	Oil	Thermal Efficiency: 78%, Standby Loss[b]: Varies by Volume	Thermal Efficiency: 78%, Standby Loss[c]: Varies by Volume
Instantaneous Water Heaters	V<10 gallons	Thermal Efficiency: 80%	Thermal Efficiency: 80%
	V _10 gallons, Gas-fired	Thermal Efficiency: 77%, Standby Loss[b]: Varies by Volume	Thermal Efficiency: 80%, Standby Loss[c]: Varies by Volume
	V _10 gallons, Oil-fired	Thermal Efficiency 77%, Standby Loss[b]: Varies by Volume	Thermal Efficiency 80%, Standby Loss[c]: Varies by Volume
Unfired Hot Water Storage Tanks	All	Heat Loss[b]: _ 6.5 Btu/hr/ft^2	R-12.5 Insulation

[a] At the maximum rated capacity.

[b] Storage water heaters and hot water storage tanks having more than 140 gallons of storage capacity need not meet the standby loss or heat loss requirement if the tank surface area is thermally insulated to R-12.5 and if a standing pilot light is not used.

[c] Water heaters having more than 140 gallons of storage capacity are not required to meet the standby loss requirement if the tank surface is thermally insulated to R-12.5, if a standing pilot light is not installed, and gas- or oil-fired storage water heaters have a flue damper or fan-assisted combustion.

ASHRAE Standard 90.1 Recent Update

On October 29, 1999, ASHRAE approved the amended Standard 90.1 (Standard 90.1-1999) (ASHRAE 1999), which increases the minimum efficiency levels for some of the commercial HVAC and SWH equipment covered by EPCA 92. ASHRAE issued ANSI/ASHRAE/IESNA Standard 90.1-1999, *Energy Standard for Buildings Except Low-Rise Residential Buildings* at the Winter meeting in Dallas in February 2000. This new version of Standard 90.1 represents ten years of effort on the part of the project committee that completely revised the previous 1989 version of the standard. The new standard is designed for ease of use, is written in code language to simplify enforcement, has separate publications in IP and SI units to serve the international communities, and was expanded to include existing buildings in its scope. To address concerns raised by reviewers of the 1989 version of the standard, the project committee decided to ensure that the basis of the new standard would be well founded and documented, and that economics would be used in helping to establish the criteria. Also, the number of locations with climate data for use with the standard was expanded for the U.S. and Canada. In addition, for the first time, 64 international countries are included in the standard. These changes will make the standard more applicable for a wider audience in both the U.S. and other countries.

The scope of Standard 90.1-1999 provides minimum energy efficiency requirements for the design and construction of: 1) new buildings and their systems; 2) new portions of existing buildings and their systems, and; 3) new systems and equipment in existing buildings. It also provides criteria for determining compliance with the requirements.

The provisions of this standard apply to:

- The envelope of buildings provided the enclosed spaces are: 1) heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h.ft^2 (10 W/m^2) or; 2) cooled by a cooling system whose sensible output capacity is greater than or equal to 5 Btu/h.ft^2 (15 W/m^2)
- The following systems and equipment used in conjunction with buildings:
  - Heating, ventilating, and air conditioning
  - Service water heating
  - Electric power distribution and metering provisions
  - Electric motors and belt drives
  - Lighting

The provisions of the standard do NOT apply to:
- Single-family houses, multi-family structures three stories or fewer above grade, manufactured houses (mobile homes), and manufactured houses (modular),
- Buildings that do not use either electricity or fossil fuel, or
- Equipment and portions of building systems that use energy primarily to provide for industrial, manufacturing, or commercial processes.

An important difference between this scope and the scope of previous ASHRAE commercial building energy standards is the emphasis on new systems and equipment in existing buildings. Also, the philosophical bent on the updates of the Standard 90.1 has changed over the years. From a building energy "design" Standard (90.1-1989 edition), the new Standard (90.1-1999 edition) has been transformed to a minimum building code. In the Standard 90.1-1999, the "cost effective" criteria have resulted in the final energy savings being much lower than the target levels that the Committee started off with at the start of the revision process.

Consensus Process

The process used in the development of all ASHRAE standards is termed a consensus process. The ASHRAE Manual for Processing ASHRAE Standards (ASHRAE 1994) defines consensus as "substantial agreement, in the judgement of a duly appointed authority, reached by directly and materially affected interest categories. Substantial agreement means more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that an effort be made toward their resolution. It does not require that each separate interest subcategory reach consensus on the standard. For ASHRAE standards projects and any jointly sponsored standards projects that use ASHRAE procedures, the project committee is the consensus-forming body. 'Duly appointed authority' means the Board of Directors of ASHRAE, and in the case of jointly sponsored standards, the Boards of Directors of ASHRAE and the joint sponsor(s). For American National Standards, 'duly appointed authority' means the ANSI Board of Standards Review."

The essential features of consensus that apply to Standard 90.1-1999 are the inclusion of various interest categories as members of the SSPC, extensive public review of draft requirements, revision of draft requirements in response to comments, spirited debate and presentation of opposing viewpoints during committee meeting times, and final approval by the various technical subcommittees, the full standing standards project committee, various ASHRAE Standards subcommittees, ASHRAE Standards Committee, ASHRAE Technology Council, and the Boards of Directors of ASHRAE and IESNA. Since this standard has also been submitted as a potential American National Standard, the procedures used to develop the standard (but not the technical content) are subject to review by ANSI.

Economically Based Criteria

Standard 90.1-1999 is based on economic criteria tempered with professional judgement. Using economic-based criteria in this standard led to several interesting results, including the "backing off" of several envelope requirements from previous versions of ASHRAE Standard 90.1. These requirements were found to be too stringent when subjected to the simple economic analysis used by the committee. After years of increasing envelope stringency in successive versions of ASHRAE Standard 90.1, this was an unwelcome outcome for those parties interesting in saving energy at any cost. Use of economic criteria also precipitated great debate on fuel prices (e.g., should they be national or regional or local?, should they be seasonal?), and how differences in fuel prices should translate into differences in envelope or mechanical requirements. Another unforeseen result of the use of economic based criteria was the loss of a number of requirements whose benefit tended to go to tenants of buildings, while the cost was borne by the owner of the building.

The economic approach chosen by ASHRAE SSPC 90.1 was to use minimum life cycle costing. Life cycle costing was based on the total cost of the efficiency versus the total benefit. Thus, for envelope requirements, the base case was an un-insulated assembly, and various levels of insulation were competed to determine the minimum cost. This approach is used, as opposed to assuming the existing requirements in previous versions of ASHRAE Standard 90.1 as baseline and looking at incremental costs and incremental performance.

A key concept in the development of this version of Standard 90.1 was that of economic scalar (McBride, 1995). The economic scalar is a term that combines the effect of fuel price escalation rates, discount rates, and measure lifetimes into a single term that can be used in a life cycle costing. (Mathematically, the scalar ratio is the quotient of the uniform present worth factor and the present value of annually recurring operating costs over the lifetime of the measure). Rather than spend time haggling in committee over individual rates, all economic rates were bundled into a scalar ratio and the appropriate scalar ratio chosen by examination of estimated national energy savings versus scalar ratio used. The estimation of national energy savings was done using a National Energy Model developed by the committee (not to be confused with the National Energy Modelling System (NEMS) used by DOE). The model took a simple look at the impacts of various measures on office and retail buildings in eleven locations representing a range of climates around the U.S. Ultimately, the committee chose scalar ratios of 8 and 18 after extensive examination of the results of the National Energy Model. These two scalars represented visible breakpoints on a plot of national energy savings versus scalar ratio.

Implicit in the decisions made early on in the ASHRAE process was the idea of multiple sets of requirements. Original thoughts indicated that possibly three tiers of requirements would be developed, but this was pared to down to two tiers – one for voluntary national standards and one of higher stringency for use in utility incentive programs. The scalar ratios of 8 and 18 were selected to represent Tier I and Tier II levels of energy savings criteria, corresponding to the assumed fuel escalation rates, discount rates and a 30-year lifetime for the building envelope. The current draft of the ASHRAE standard contains a single set of requirements that correspond to the original Tier I requirements. A set of requirements corresponding to the original Tier II, plus procedures for generating additional sets of requirements will be found in the Standard 90.1-1999 Guideline.

For this minimum life cycle cost (LCC) approach, some sort of fuel costs were needed. Heating and cooling may both be provided by electricity or natural gas, with natural gas more common in heating applications and electricity dominant in cooling applications. Early on in the process, a decision was made to use national average fuel prices to simplify the requirements of the standard. This was subjected to great debate and comment during public review, but the decision to base requirements on a national average fuel prices has survived, albeit with the inclusion of procedures in the guideline for calculation of requirements based on other costs determined by an adopting jurisdiction. National average fuel prices for electricity and natural gas were set at 8 cents per kWh for electricity and 56 cents per therm for natural gas. Again, this was subject to considerable comment and debate, but requirements are still based on these costs.

Another issue that stimulated much debate was the HVAC equipment cost data. The relative cost-efficiency relationships used in the ASHRAE analysis were those supplied by the industry trade associations following a survey of their member companies. The “smoothed-out” curves provided by the cooling products industry represented 90th percentile data, meaning that 90% of the companies responding to the survey felt they could manufacture products at or below the relative cost specified by the curve. This of course produced conservative single-point cost figures, with none of the underlying data on actual costs revealed.

The technical analysis performed by ASHRAE also focused exclusively on energy savings impacts for office and retail building types. These two building types had the largest fractions of the new commercial building construction in 1994. However, analysing only these two building types may have skewed the energy savings impacts and cost-effectiveness results, and resulting stringency levels chosen on these bases. Indeed, subsequent analyses of the overall impact of Standard 90.1-1999 over 90.1-1989 has shown little or no improvement in energy efficiency (DOE; 2001a; GRI, 2000).

The mechanical sections of the standard (Sections 6 and 7) include the updates made to the HVAC and water heating equipment efficiency levels. The HVAC-related requirements are presented in order of complexity, beginning with the simplest, most common building design options. In addition, a new “simplified approach” was added to the mechanical section to address the needs of smaller commercial buildings. The analysis methodology and the engineering assumptions were essentially the same as for the Screening Analysis (described in following sections). As a result of the ASHRAE LCC analysis, significant increases in stringency levels resulted for space cooling equipment, while the space heating and water heating equipment efficiencies, in general, remained relatively flat. The mandatory provisions of the standard include the equipment efficiency requirements, similar to those in the 1989 version of the standard.

Updated efficiency levels in Standard 90.1-1999 for the mechanical equipment covered under EPCA are listed in Tables 1 and 2. Note that the EPCA levels are identical to and were adopted from the previous version of the standard, Standard 90.1-1989. For most products, efficiency levels were increased in the 1999 update, although a few were unchanged (*e.g.* the 3-phase <65 kBtu/h package and split system AC and HP products), and one was lowered (*i.e.* electric water heaters).

Adoption of Standard 90.1 by States

ASHRAE Standard 90.1 by itself has no legal standing as an enforceable part of building codes. In the U.S., building codes are adopted at the state level, which applies to building energy efficiency codes as well. Most U.S. states adopt Standard 90.1 or slight variations of it in their state building codes covering commercial buildings (BCAP 2001). The only authority exercised by the federal government in this area of state building energy efficiency codes is an advisory “determination” role of DOE’s that requires states to consider updating their commercial building codes when Standard 90.1 is updated. States are not required to adopt the revised standard or revise theirs in response; they are only required to consider doing so. However, states recognise ASHRAE as representing a broad spectrum of building industry stakeholders (including code officials) and generally follow suit with their building codes when ASHRAE updates 90.1

ASHRAE Standard 90.1 Addendum Process

ASHRAE has initiated a “continuous maintenance” process for revising and updating Standard 90.1. Rather than conduct periodic major revisions, as was done between 1989 and 1999, Standard 90.1 will in the future be continuously updated through proposed changes, called “addendum” which anyone can submit for consideration by the standing standards project committee for 90.1. Proposed changes must be submitted as specific changes in text or values and must be substantiated. Proposals are generally considered on an annual cycle.

5. RULEMAKING ACTIVITIES AND DECISIONS

Screening Analysis

To decide whether to adopt efficiency standards contained in Standard 90.1-1999 or to initiate the process of developing and analysing more stringent standards for particular product categories, DOE performed a simplified screening analysis and evaluated other information (DOE 2000). This process was used to identify products covered by EPCA for which it was unlikely that a more detailed analysis would reveal evidence sufficient to justify more stringent requirements, and also to identify products for which it was reasonably possible such evidence would be revealed by further analysis. The screening analysis estimated the annual national energy savings (from 2004 to 2030) that would result if the EPACT-covered products were required to meet the Standard 90.1-1999 efficiency levels, and additional energy-savings potential for these products if they were to exceed these efficiency levels. The screening analysis looked at 25 different categories of air-conditioners, heat pumps, water heaters, boilers, and furnaces of various sizes and fuels covered in EPACT.

Methodology

The magnitude of HVAC and SWH loads imposed on equipment depends on the physical and operational characteristics of the building in which the equipment is used, as well as the prevailing climatic conditions. To address this variation in energy use, we estimated coil loads for 7 representative building types at 11 climate locations based on a whole-building simulation. Seven of the top 8 building types (with the largest annual energy use according to Commercial Building Energy Consumption Survey (CBECS) data (EIA 1995)) were chosen for the analysis because they represent 78.4% of the cumulative total energy consumption of all commercial buildings[1]. The seven building types are office, mercantile and service, education, lodging, public assembly, food service, and warehouse. The 11 climate locations, which were selected to represent their influence on energy use in commercial buildings, are Providence, Rhode Island; Detroit, Michigan; Minneapolis, Minnesota; Knoxville, Tennessee; Shreveport, Louisiana; Tampa, Florida; Denver, Colorado; Phoenix, Arizona; Seattle, Washington; Fresno, California; and Los Angeles, California.

For each equipment category, we estimated the energy usage of a given piece of equipment based on a characteristic equipment size for each combination of representative building type and climate location. The unit energy use was estimated using a full-load equivalent operating hour (FLEOH) and adjusted for each nominal equipment efficiency level.

The FLEOH is effectively the number of hours a system would have to run at full capacity to serve a total load equal to the annual load on the equipment. FLEOH is calculated as:

$$\text{FLEOH} = \frac{\text{Annual Load}}{\text{Equipment Capacity}} \quad (1)$$

FLEOH is strictly defined as being related to the equipment capacity, not the peak load on the system. Because FLEOH is used to generate annual heating and cooling loads irrespective of equipment size, an assumption is required on how the equipment is typically sized that must be used consistently. For this analysis, we assumed that the equipment is sized based on the design day[2] peak equipment load with no explicit oversizing:

$$\text{Equipment Capacity} = \text{Design Day Peak Load} \quad (2)$$

Substituting Eq. (1) into Eq. (2) yields:

$$\text{FLEOH} = \frac{\text{Annual Load}}{\text{Design Day Peak Load}} \quad (3)$$

The FLEOH for a piece of equipment is a function of the relative annual load to the peak building load. In general, this ratio will vary depending on building construction, building internal loads, building schedules, and orientation and exposure of the zone that the equipment serves. We assumed that for any given building type, the internal-load characteristics and building schedules are constant across the building.

Estimating Annual Building Space-Heating And Space-Cooling Loads

To create the building-level weighted FLEOH, we first used a generic three-story, 15-zone prototype building, with characteristics that represent a particular building type to estimate the coil loads. The generic building coil loads were estimated for each building type and at each climate location. Cooling and heating loads were obtained using the Building Loads and System Thermodynamics (BLAST) simulation tool. In addition to the variation in building characteristics, the use of airside economisers and setback (setup) schedules can significantly affect the space loads. To account for these variations, we estimated four sets of the generic building coil loads: 1) with economiser and setbacks; 2) with economiser and without setbacks; 3) without economiser with setbacks; and 4) without economisers and setbacks. We scaled the generic coil loads for each simulation (308 total runs, corresponding to 7 building types, 11 climate locations, and 4 combinations) to represent an average building.

From the scaled results, FLEOH were generated for heating and cooling equipment for each representative building. Because multiple building zones existed in the scaled building, the FLEOH from each zone was weighted by the design loads in the zone and summed up to determine an average weighted FLEOH for that building. The weights account for higher influence by zones having larger peak loads and a corresponding larger number of units serving the zone. This aggregation results in a single FLEOH for a particular building type and climate location. FLEOH were calculated for each class of equipment (heating and cooling) and for each representative building type and climate location simulated.

Translating Annual Loads To Annual Energy Use

Equipment efficiency is used to translate annual equipment loads to energy use as shown in Eq. (4). We used seasonal energy efficiency ratio (SEER) or energy efficiency ratio (EER) for cooling equipment and thermal efficiency for heating and water-heating equipment as the efficiency rating because it is readily available across equipment categories; hence,

$$\text{Annual Energy Use} = \frac{\text{FLEOH x Equipment Capacity}}{\text{Efficiency Rating}} \qquad (4)$$

Economic Impact Analysis

We also conducted a life-cycle cost (LCC) analysis to determine the economic impacts of alternative efficiency levels. For each of the equipment types, the LCC analysis requires estimates of equipment price at various efficiency levels, annual energy consumption, lifetimes of equipment, region-specific energy prices, and discount rate (7% real). National net present value (NPV) was based on an aggregation of the LCC estimates for each market segment, using the estimated distribution of shipments by market segment.

The Energy Information Administration (EIA) *Annual Energy Outlook* (AEO) provided the projected energy prices used in the screening analysis (EIA 2000). Based on the AEO, the national average natural gas price for 2010 was $5.53 per million Btu. In order to account for the electricity demand charges and for higher summer electric peak loads, electricity prices in the screening analysis were uniformly adjusted upward by 5%. The resulting national average price of electricity in 2010 was 6.7 cents per kWh.

Estimating National Energy Savings

We estimated the national energy impacts of higher efficiency equipment by 1) mapping climate locations onto regions and 2) estimating the fraction of each year’s national equipment shipments (by product category) within market segments, as defined by a representative building type within a particular region of the United States. Because detailed statistical information related to where and in what types of buildings the equipment is currently being installed is generally unavailable, an allocation process was developed. The estimated allocation of national shipments to market segments was primarily based on information from the CBECS (EIA 1992, 1995) related to floor space and saturations of generic equipment types for each market segment. We then estimated national energy consumption for each equipment category at each efficiency level by multiplying the annual unit energy use in each market segment with the annual shipments expected for that market segment.

Screening Results

The screening analysis provided estimated national energy savings from 2004 through 2030 for all of the efficiency levels analysed including the Standard 90.1-1999 efficiency levels for space-cooling, space-heating, and water-heating equipment, as well as the reduction in carbon emissions for the same time frame. Table 3 shows the estimated national energy savings relative to Standard 90.1-1999 for the lowest life-cycle cost efficiency levels analysed over the 27-year timeframe in the screening analysis. The table is arranged in descending order of national energy savings. The products showing the greatest savings potential include the 3-phase AC & HP <65 kBtu/h, central air source AC & HP 135-240 kBtu/h, PTAC & PTHP, gas boilers and tankless instantaneous gas water heaters.

Table 3. Energy Savings Relative to Standard 90.1-1999 for Energy Efficiency at Lowest Life-Cycle Cost from 2004 to 2030 and DOE Actions

Product Subcategory	Efficiency Level at Minimum Life-Cycle Cost	National Energy Savings (TBtu)	DOE Actions
3 Phase, Central, Single Package, Air-Cooled AC <65 kBtu/h	12.0	1412.7	Propose ASHRAE Addendum
Central, Air-Cooled AC, 135-240 kBtu/h	10.4	428.8	Study Further/Rulemaking
PTAC	10.5	311.7	Study Further/Rulemaking
3 Phase, Central, Split System, Air-Cooled AC <65 kBtu/h	11.0	278.6	Propose ASHRAE Addendum
PTHP	9.9	249.0	Study Further/Rulemaking
Small Gas-Fired Boilers <2.5 MMBtu/h	78.7%	200.0	Study Further/Rulemaking
3 Phase, Central, Single Package, Air-Cooled HP <65 kBtu/h	12.0	183.6	Propose ASHRAE Addendum
Tankless Gas Instantaneous Water Heaters	81.5%	102.0	Study Further/Rulemaking
Large Gas-Fired Boilers >2.5 MMBtu/h	85.3%	79.0	Study Further/Rulemaking
3 Phase, Central, Split System, Air-Cooled HP <65 kBtu/h	12.0	66.4	Propose ASHRAE Addendum
Central, Water-Source HP 17-65 kBtu/h	12.5	65.0	Adopt Standard 90.1-1999
Central, Air-Cooled HP, 135-240 kBtu/h	10.4	31.4	Study Further/Rulemaking
Electric Water Heaters	1.0	6.6	Reject 90.1-1999
Central, Water-Cooled AC 65-135 kBtu/h	12.4	2.7	Adopt Standard 90.1-1999
Central, Water-Cooled AC 65-135 kBtu/h	11.5	2.5	Adopt Standard 90.1-1999
Central, Air-Cooled AC 65-135 kBtu/h	10.3	0.0	Study Further/Rulemaking
Central, Air-Cooled HP 65-135 kBtu/h	10.1	0.0	Study Further/Rulemaking
Central, Water-Cooled AC <65 kBtu/h	12.1	0.0	Adopt Standard 90.1-1999
Central, Water-Source HP < 17 kBtu/h	11.2	0.0	Adopt Standard 90.1-1999
Central, Water-Source HP, 65-135 kBtu/h	12.0	0.0	Adopt Standard 90.1-1999
Gas-Fired Warm Air Furnaces >225 kBtu/h	77.5%	0.0	Adopt Standard 90.1-1999
Gas Storage Water Heaters <155 kBtu/h	80.0%	0.0	Adopt Standard 90.1-1999
Gas Storage Water Heaters >155 kBtu/h	80.4%	0.0	Adopt Standard 90.1-1999
Gas Instantaneous Water Heaters with Tanks	80.0%	0.0	Adopt Standard 90.1-1999
Small Oil-Fired Boilers <2.5 MMBtu/h	NA	NA	Study Further/Rulemaking
Large Oil-Fired Boilers >2.5 MMBtu/h	NA	NA	Study Further/Rulemaking
Evaporatively-Cooled AC Products	NA	NA	Adopt Standard 90.1-1999
Central, Water-Source HP 135-240 kBtu/h	NA	NA	Adopt Standard 90.1-1999
Oil-Fired Warm Air Furnaces >225 kBtu/h	NA	NA	Adopt Standard 90.1-1999
Oil Storage Water Heaters <155 kBtu/h	NA	NA	Adopt Standard 90.1-1999
Oil Storage Water Heaters >155 kBtu/h	NA	NA	Adopt Standard 90.1-1999
Tankless Oil Instantaneous Water Heaters	NA	NA	Adopt Standard 90.1-1999
Oil Instantaneous Water Heaters with Tanks	NA	NA	Adopt Standard 90.1-1999
Unfired Hot Water Storage Tanks	NA	NA	Adopt Standard 90.1-1999

Final Rule on Products Accepting Standard 90.1-1999 Values

DOE published a final rule on 12 January 2001 establishing: 1) which commercial HVAC products to accept Standard 90.1-1999 levels as uniform national standards; 2) which to evaluate further to determine whether a higher standard is justified and/or recommend addendum to Standard 90.1-1999; 3) and which to reject revised ASHRAE levels (DOE 2001b). In this rule, it adopted the ASHRAE levels for 18 product categories of commercial air conditioners, heat pumps, furnaces, water heaters, and hot water storage tanks. The effective date manufacturers must comply with this rulemaking is 29 October 2003 for most products, and one year later for the rest. Between 2004 and 2030, these higher standards are expected to save 1.1 Quads of energy nationwide.

Four products of residential-scale (<65 kBtu/h) air-conditioning and heat pump products employing 3-phase motors are proposed for consideration of an addendum to Standard 90.1-1999. EPCA legislation stipulates that DOE can adopt or further consider only updated Standard 90.1-1999 levels, and ASHRAE did not update these from the 90.1-1989 levels. The reason the levels were not updated is because these products are essentially the same as the residential-scale products using single-phase motors that are covered under different legislation and rulemakings that were ongoing at the time of ASHRAE's decision. Industry expressed a strong preference to make the mandated efficiency levels the same between the single-phase and 3-phase products in the same size categories, and ASHRAE apparently decided to heed that preference in postponing updated levels for the 3-phase products. If ASHRAE does not update levels contained in the revised standard, then DOE cannot act unilaterally to impose regulation. Instead, DOE can propose to ASHRAE that it consider updating the efficiency levels of these categories of products. The single-phase central air-conditioning and heat pump rule was published 19 January 2001 and DOE will propose to ASHRAE that the 3-phase equipment levels contained in the rule be adopted in Standard 90.1-1999, and then DOE could in turn accept those levels as a mandated national standard in a subsequent rule, or conduct further study and establish higher levels.

DOE rejected the standard for electric water heaters that would increase energy use over the existing EPCA level, and left the EPCA level in place.

Finally, DOE signalised its intention of considering more stringent standards than those adopted by ASHRAE for 11 categories of commercial products. DOE determined through its screening analysis that more stringent standards than those found in Standard 90.1-1999 may save significant additional energy and be technologically feasible and economically justified. For instance, if all 11 products were to have their efficiency levels set at minimum life-cycle cost as estimated in the screening analysis, an additional 1.4 Quads could be saved over the 2004-2030 timeframe.

Further Analysis on Products Showing Significant Potential Savings

DOE is conducting formal rulemaking processes as the means of considering whether more stringent standards are warranted for the 11 products mentioned above (and listed as "Study Further/Rulemaking" under DOE Actions in Table 3). The rulemaking process entails a series of steps and activities carried out over an approximately three-year period, that enables public and stakeholder participation, review, and input, rigorous engineering and economic analysis, and public notice at various stages of DOE inclinations and decisions regarding new efficiency levels. Rulemakings are generally conducted on a product-by-product basis, although similar categories of products are often combined into a single rulemaking. Considerable resources are required to conduct formal rulemaking processes. This requires DOE to prioritise and select the highest priority products to conduct rulemakings. Currently, for the commercial HVAC products described in this paper, DOE has initiated two rulemakings as the highest priorities covering PTAC and PTHP in one, and Central Air-Cooled AC and HP 65-135 kBtu/h and 135-240 kBtu/h in the other. The remaining four products are medium priority and will be included in future rulemakings as resources permit or priorities shift. The analyses from the two high priority rulemakings are just getting underway, with the first preliminary results from the Advanced Notice of Proposed Rulemaking scheduled for early 2003.

One unique aspect of the rulemakings on these products is the possibility of "short-circuiting" the process by ASHRAE taking action through its continuous maintenance process, to adopt efficiency levels DOE finds acceptable. Should this occur, DOE could suspend further analysis and issue a final rule accepting the revised ASHRAE levels. Indeed, DOE has signalised its intent to propose addendum to ASHRAE in order to affect just such an outcome, while continuing rulemaking activities in parallel. Specific addendum proposals from DOE are likely to come out of preliminary analyses in the first year or so of the rulemaking.

The major activity of a rulemaking process is the analysis, which is used to justify DOE decisions. The major elements of the analysis are:

- Market and Technology Assessment
- Engineering Analysis
- Building Simulation and Energy Savings
- Manufacturing Costs and Retail Prices
- Forecasted Energy Average and Marginal Prices
- Life-Cycle Cost and Payback Analysis
- Forecasted Product Shipments
- National Energy and Environmental Impacts
- Consumer Impacts
- Manufacturer Impacts
- Employment Impacts

6. POLICY IMPLICATIONS

The unique link between a professional society's building energy efficiency standard, and government-mandated manufacturer minimum energy efficiency standards for commercial HVAC equipment holds implications for how these two powerful policy instruments are applied in practice. In the U.S., building codes are applied at the state or local levels, while equipment standards are applied at the federal level to all manufacturers and importers. Depending on how states adopt the revised Standard 90.1 in their building codes, and how the federal government adopts or conducts rulemakings for the revised HVAC equipment efficiency levels, can create a complex juxtaposition of code and standard content and timing to which industry and the market must respond. Managing this is outside the control of any one entity.

Timing issues are particularly important. Manufacturers need many years of lead-time to adjust their production capacity to different product mixes necessitated by new efficiency mandates. When the building standard is updated, there is some lag time before it is adopted by states. Rulemakings also take several years. For products undergoing rulemaking processes leading to possibly higher efficiency levels, this puts manufacturers in a quandary. They can decide to adjust manufacturing capacity to the building standard updated levels, only to have to adjust again a few years later to new, higher equipment standard levels, or they can try to guess where the equipment standard levels are likely to be set and adjust to those, but run the risk of "overshooting" the market if actual mandated levels are lower.

The consensus process used by ASHRAE in updating its building standard has advantages and disadvantages. The main advantage is that the resulting standard theoretically reflects broad agreement among the stakeholders. The disadvantages are that the levels agreed to are essentially least common denominator values. Equipment manufacturers wield considerable influence on the process and managed to wear down efficiency advocates seeking more stringent provisions. Another disadvantage is the extremely long period of time it took to come to consensus; it took a decade, which was twice as long as the goal set at the outset of the update process.

Tying government policy to industry-driven professional body decisions ends up influencing those decisions. ASHRAE in updating Standard 90.1 was well aware that the levels they struck for commercial HVAC equipment could become "the floor" mandated by law, and probably influenced manufacturers to stridently argue for lower efficiency levels than they otherwise might have accepted. It also likely contributed to the delays in updating the standard, as equipment manufacturers sought to put off the day of reckoning of facing stiffer mandates. Whether it was intended or not, putting this much leverage on government policy in the hands of a private interest group probably has shifted the balance of power away from public interest in this area, in the manner of "the fox guarding the hen house."

Finally, with the internationalisation of building energy efficiency standards and the global market for HVAC equipment, the influence of these linked policies becomes enormous. Standard 90.1 has spawned many other countries' building energy efficiency codes, and updates are likely to carry similar weight. Manufacturers facing mandated higher efficiencies for their equipment could respond by marketing higher efficiency equipment outside the U.S. or they could "dump" the orphaned lower efficiency equipment on markets without (or with more relaxed) manufactured or imported equipment efficiency standards. For these reasons it behooves energy policy makers around the world to be aware of this unique policy circumstance from the U.S. and take appropriate measures.

7. ACKNOWLEDGEMENTS

This work was supported by the Office of Building Research and Standards of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

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9. END NOTES

[1] An eighth building type not considered in the Screening analysis was the inpatient health care buildings (primarily hospitals). Outpatient healthcare facilities (e.g. clinics) about half of the square footage of the entire health care category) were included in the analysis through the consideration of the office building type. The main reason for not including the 24-hour hospitals was because these buildings do not typically use the type of unitary cooling and heating equipment covered by the analysis.

[2] A design day is defined by winter low-temperature based on ASHRAE 99% dry-bulb temperature and summer high-temperature on ASHRAE 1% dry-bulb and the corresponding mean coincident wet-bulb temperature (ASHRAE 1997).