Energy Code Applicability for Industrial Facilities

Natalie Hildt, Energy & Resource Solutions, Inc.
Brian McCowan, Energy & Resource Solutions, Inc.
Gary Epstein, Energy & Resource Solutions, Inc.

ABSTRACT

During the past few years there has been considerable interest in development of more aggressive commercial energy codes. Codes that have been adopted by various states represent slight modifications from ASHRAE/IES 90.1 (1999), or the IECC model energy code. These codes generally contain prescriptive and systematic requirements for building envelope, HVAC systems, and electrical and lighting systems. The new energy codes were originally developed for the commercial sector, but in state adoptions of energy codes industrial facilities are generally directly included and fall under the jurisdiction of the code. Unfortunately, there are numerous industrial facilities where the energy intensity of the facility can be increased by prescriptively following new code requirements. For example, in highly energy intensive industrial process facilities that are subject to space cooling, addition of high levels of code-required insulation can dramatically increase air conditioning energy. Beyond such unexpected problems, the reality of commercial energy codes is that they do not significantly address the energy efficiency of the process equipment that is dominant in a manufacturing facility.

This paper will first describe the general requirements of the predominant new energy codes, focusing on the appropriateness of applying code measures originally designed for commercial buildings to industrial spaces. We will then discuss other approaches to address the general efficiency of energy use in industry. Advantages and limitations of each approach will be clearly described. In the end, the overall objective of the paper will be to comment on the applicability of commercial energy codes in the industrial sector, and to begin a discussion on approaches to systematically improve the base level of US industrial energy efficiency.

Introduction to Recent Trends with Energy Codes

During the past several years, a considerable broad-based effort has taken place to introduce new, more aggressive building energy codes. For commercial buildings (the focus of this paper) in general, the new energy codes are primarily based on ANSI/ASHRAE/IESNA Standard 90.1, and Chapter 8 of the 2000 International Energy Conservation Code (IECC). The IECC has become a model to which many states interested in new energy codes modify to create a code suitable for their jurisdictions. Several states have already adopted new energy codes, and many others are in the process of making modifications to ASHRAE 90.1 or the IECC as they develop their specific code. New energy codes present a number of new requirements for buildings and building systems that will result in a higher level of energy performance.

Technically, most of the new state energy codes have a number of requirements that many in the design community believe will be a challenge for compliance. Commercial code requirements address building envelope, HVAC systems, and electrical /lighting systems.

Their appropriateness for industrial buildings have fallen under considerable scrutiny, with many firms that design effective industrial facilities raising serious questions about the relevance of the primary components of commercial codes to manufacturing operations.

Commercial Energy Code Technical Focus

Essentially all recent energy codes are focused on three primary technology areas. First, is the building envelope. In this section of energy codes, the primary focus is on insulation, glazing, door, and foundation requirements. Such requirements vary depending on the construction type (masonry, steel frame, wood frame, etc.) and the local weather region. In certain states, requirements are more aggressive and the codes have mandates for air and vapor barriers.

In the building mechanical systems (or HVAC) sections of energy codes, the focus here is on the load determination and design of HVAC systems; the minimum efficiencies for equipment; and associated auxiliary systems (fans, pumps, piping, ducts, etc.). There are a number of typical requirements that limit the amount of horsepower allowable for fan and pumps systems. There are also requirements that may mandate outside air economizing, heat recovery ventilation, and demand control ventilation.

For building lighting systems, the focus is on lighting design and specification. In these code sections, there is specification of maximum allowable lighting power densities and application of automatic controls for shut-off of lighting systems during unoccupied hours.

The fundamental initial observation is that there is limited to no address of industrial type energy systems. As described in the next sections of this paper, the focus of the new energy codes are clearly not consistent with the typical primary energy end use systems in industry.

How Industrial Buildings are Different

Although industrial buildings and commercial buildings are generally covered by the same energy code requirements, the buildings are quite different in their energy usage profiles. These differences affect building envelope concerns, HVAC design considerations, safety factors, usage patterns, and lighting issues.

Energy codes essentially deal with *building system* energy usage and not with the energy used for processes conducted within the building. The largest energy consumers associated with the non-industrial commercial building are without question building system components. Space heating, space cooling, ventilation, lighting, and domestic water heating are all major energy users, typically eclipsing the usage of plug loads including office machinery.

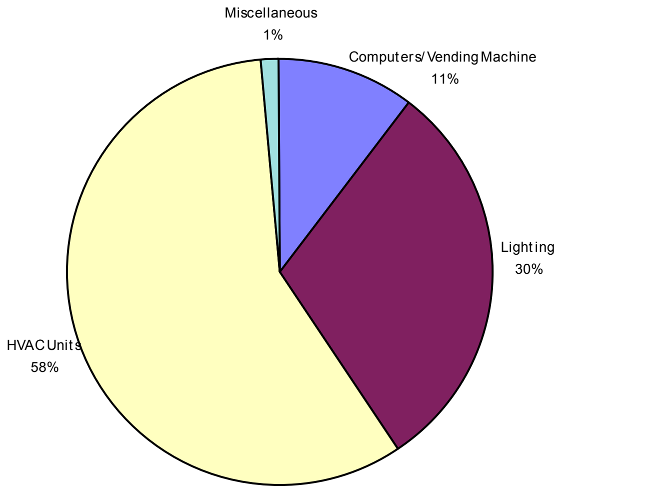
Differences in Industrial End Use Patters

The authors of this paper have performed hundreds of end-use studies for commercial and industrial buildings throughout the Northeastern United States. Figure 1 presents an electrical end-use pie chart for a medium size office building in New England.

As the chart illustrates, HVAC and lighting loads combine for 88% of the electrical load. For fossil fuel use, 100% of this load is dedicated for building systems.

Industrial buildings have an entirely different end-use breakdown, as building system usage may play a significantly smaller part when compared to process loads. Although the usage profiles differ for different types of manufacturing facilities, in all cases process loads heavily dominate the energy usage. Figure 2 illustrates the actual end-use breakdown for a modern high tech manufacturer of semiconductor computer components. The next chart (Figure 3) illustrates the end-use breakdown for a traditional manufacturing plant that produces injection molded plastic goods.

Figure 1. Energy Use Breakdown for Current (Computer Intensive) Commercial Office Building



These charts demonstrate a much different scenario with only a small percentage of the electrical load dedicated to building systems, while the great majority of the electricity is consumed by compressed air systems, process motors and other process equipment.

The consumption of fossil fuels in industrial building is also often heavily skewed toward process usage, with the heating of process water, or the direct heating of materials typically using much more energy than that for comfort heating. Material handling, especially when propane powered vehicles are used, can also eclipse comfort conditioning uses of fossil fuels. Chart 4 illustrates the end-use breakdown for natural gas for a traditional manufacturing facility in Ohio.

As the various end-use charts illustrate, industrial building experience far different usage patterns than do typical commercial buildings. Their dominant energy usage is dedicated to the production of products, and not to the comfort of the occupants. Energy codes, as they exist today, deal almost exclusively with energy end-uses associated with occupant comfort.

Figure 2. Energy Use Breakdown for High Tech Manufacturing Facility (Sapphire Crystal Growth Operation)

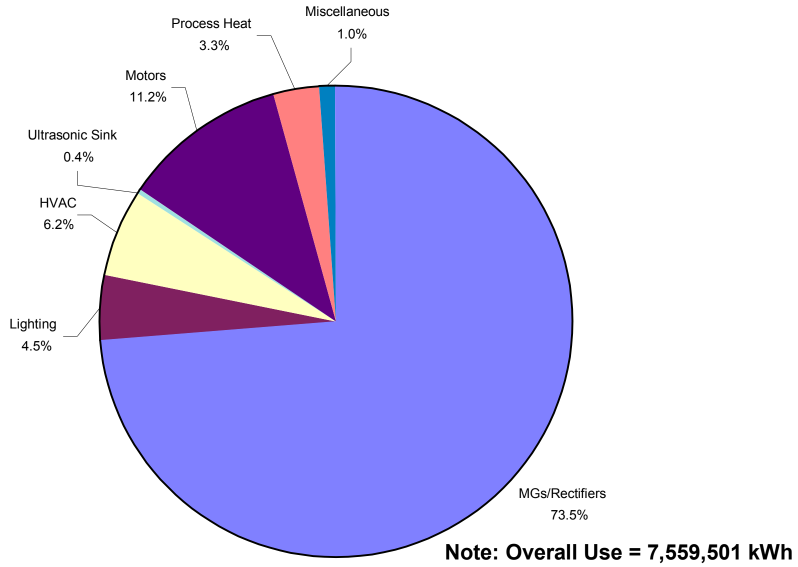
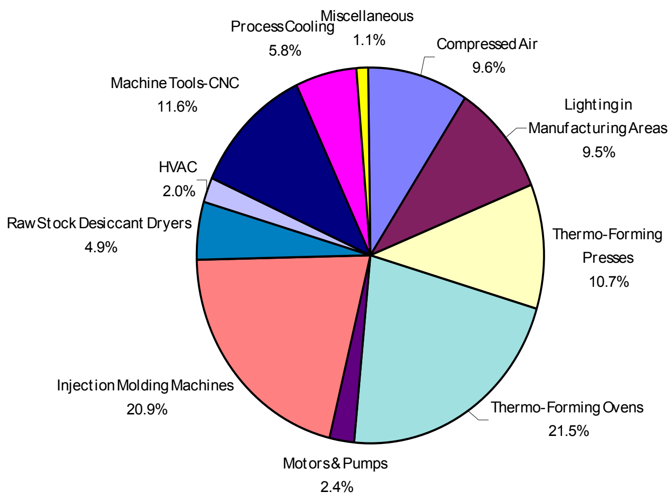
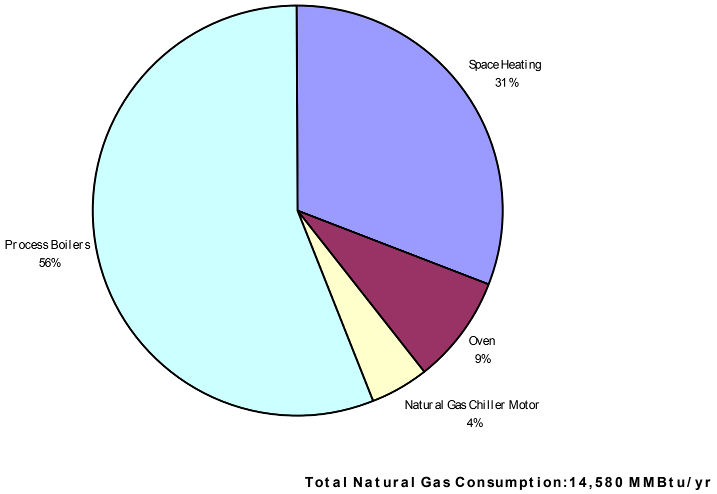


Figure 3. Energy Use Breakdown for Injection Molding Manufacturing Facility



Note: Overall Use = 4,553,000 kWh

Figure 4. Natural Gas Use Breakdown for General Manufacturing Plant



Other Differences

Another major difference between the two styles of business has to do with the sources and performance of the comfort heating/cooling and how it interfaces with the building envelope and HVAC equipment. Commercial buildings receive only a small percentage of their internal heat gains from equipment not intended for space heating. Computers, lighting, convenience refrigeration, occupants, etc. contribute only a relatively small amount of heat to the space. In climatic areas of the country that are dominated by space heating needs, the percentage of the heating/cooling demand supplied/created by this equipment is usually less than 20%. Industrial buildings, by contrast, receive a far greater amount of heat from process equipment that is not intended, nor controlled, for space heating. Depending on the processes involved, a typical industrial building might receive 50 – 200% of its space heating requirements from waste heat generated by process equipment. Given this situation, even in the coldest climates, many industrial buildings experience year-round space cooling loads.

In terms of lighting, commercial buildings have very predictable lighting needs, with very consistent visual task demands from building to building within each space type. Lighting for industrial processes however is very process specific. The amount and quality of the lighting needed for a particular process is often determined by process engineers who specify all parameters involved in the operation of process equipment. Additionally, worker safety is a dominant factor in industrial lighting. For commercial lighting, safety usually involves the ability to navigate within the building to locate exits in the case of an emergency. For industrial machine operators, lighting-based safety often involves real threat to limbs and/or life under conditions of lighting failure or even inadequate lighting.

A final distinction between commercial and industrial buildings is that the manufacturers of process equipment often specify certain aspects of building construction. For instance, many manufacturers of heaving machinery specify the exact construction of concrete slab floors on which that equipment is placed. Often this specification emphatically excludes insulation that the code may require. Equipment warrantees often hinge on these requirements, and in the case of lighting requirements, building owners may face lawsuits if accident investigation shows non-compliance with a process equipment manufacturer's lighting requirements.

Typical Energy Code Jurisdiction

Although industrial buildings are demonstrably different from the commercial building that energy codes have been designed around, industrial buildings are certainly fully covered by ASHRAE based energy codes. The following section was taken from Chapter 13 (energy section) of the Massachusetts Building Code.

> **Scope:** (Energy Code) sets forth requirements for the effective use of energy in structures other than *low rise residential buildings*, which shall be designed and constructed to comply with the requirements of (the Energy Code).
>
> **Exception:** As an alternative to the provisions of (the Energy Code), buildings with total floor area not greater than 10,000 square feet may be designed and constructed using the envelope requirements of (the Energy Code).
>
> **1301.7 Exempt buildings:** The following buildings are exempt from the further provisions of (the Energy Code), with the exception of (the Energy Code sections) dealing with lighting requirements.
>
> 1. Buildings and structures or portions thereof whose peak design rate of energy usage is less than one watt per square foot or three and four tenths (3.4) Btu/h per square foot of floor area for all purposes;
> 2. Buildings and structures or portions thereof which are neither heated nor cooled;
> 3. *Greenhouses* that are free-standing, or attached to a building and separated by a wall having the same thermal value as an exterior wall, and provided with a separate temperature control system;
> 4. Buildings with less than 100 square feet of gross floor area.
> 5. Portions of aircraft hangars where aircraft are housed or stored and/or aircraft servicing, repairs or alterations may occur. Such hangars are also exempt from the lighting requirements of (the Energy Code).

Code Requirements with Limited Applicability for Industrial Sites

Although industrial buildings and commercial buildings are covered by the same energy code requirements, the buildings are quite different in their energy usage profiles. These differences affect building envelope concerns, HVAC design considerations, safety factors, usage patterns, and lighting issues. The following sections of this paper discuss some of the key code requirements that may be inappropriate for industrial sites, and associated recommendations

Lighting Problems

Unlike other sections of ASHRAE- or IECC-based energy codes, the lighting section of the code is written as system performance requirements, rather than minimum component technical specifications. Instead of specifying specific lamp or ballast types, the codes specify a certain lighting watts per square foot (lighting power density) that may be installed; the technology used to achieve this is left to the designer's discretion. This type of code requirement is welcomed by lighting designers and architects as the freedom it allows encourages creativity in lighting design. However, this approach does present some difficult problems for industrial buildings.

A review of the lighting power densities (LPD) requirements for the Massachusetts Energy Code reveals the following maximum LPDs related to industrial buildings as shown in Table 1 below.

Table 1. Maximum LPDS/Industrial Buildings

Industrial Spaces	
Automobile Garage Service/Repair	1.4
Detailed Manufacturing	6.2
Manufacturing Control Room	0.5
Manufacturing Corridor/Transition	0.5
Manufacturing Equipment Room	0.8
Manufacturing General High Bay	3
Manufacturing General Low Bay	2.1
Workshop	2.5

The first thing noticed, is that although there is a very wide variety of manufacturing spaces, there are very few types recognized by the code requirements. This likely explains the very wide range of LPDs allowed. From 0.5 (manufacturing control room) to 6.2 (detailed manufacturing). The problems are obvious here. Who decides what is "general manufacturing" and what is "detailed manufacturing" and on what do they base their decision. This could be a critical decision as the allowed LPD differential is as high as 3-to-1.

The limit of 0.5 watts per square foot for manufacturing control room is a good example of a potential problem area. Many manufacturing control rooms are predominantly video display terminal dominated. For this type of room, 0.5 watts is wholly adequate. However, some manufacturing control rooms house analog electro mechanical equipment that is operated by workers equipped with clipboards and handwritten charts. For this type of control room 0.5 LPD is likely inadequate, as for example, the maximum LPD for private offices is 1.3 watts.

At the other end of the scale, an LPD of 6.2 is allowed for "detailed manufacturing" while the next less energy intensive lighting category for industrial building is at an LPD of 3. For some very detailed manufacturing, an LPD of 6.2 might be necessary if a very bright and/or lighting of a special spectral quality is needed. However, utilizing any reasonably efficient light source, an LPD of 6.2 will produce an excessively bright work area. As an example, a calculation of a sample room with 10' ceilings, typical T-8 recessed fluorescent fixtures, and average reflectivity of surfaces, reveals a work-plane illumination level of approximately 240 foot-candles. This would be a severely over-lit space for all but the most intricate detail work. Of course, the 6.2 figure is the maximum LPD allowed for this type of space and designers and contractors are free to choose lower values, however designers tend to see the code requirements as "reasonable" targets. The authors of this paper have served as the code "circuit riders" in Massachusetts for the past two years providing technical assistance to the architectural and engineering communities regarding energy code compliance. It has been our experience that most design professionals, with the possible exception of highly qualified lighting designers, feel compelled to design at, or just below, code allowed LPD levels. A typical quote from an electrical engineer, from one of our actual sessions is, "that can't possibly be enough light; it's only 1.1 watts per square foot and the code says that I need 1.6." Given these circumstances it is easy to see that the code can actually promote energy waste than energy conservation.

Another lighting code issue involving industrial buildings concerns worker safety and automatic lighting controls. Most energy codes require the automatic shut-off of lighting during normally unoccupied times. This can be done with timer based systems or occupancy sensing. Mandatory egress lighting is excluded from this requirement for safety reasons. Industrial facilities, however, may have very different safety considerations. Employees working with dangerous machinery and/or dangerous chemicals are at risk when lighting fails unexpectedly. Naturally lighting may fail because of a utility power failure, but many facilities with critical safety needs provide back-up power to continue illumination for short or long term. Although most codes allow for safety concerns, they typically state that a competing safety code or law must "trump" the energy code provisions. No automatic lighting controls are 100% reliable, and safety must be considered when designing lighting control systems for industrial facilities.

Lighting power density recommendations. It would be virtually impossible for the writers of any code to cover all types of industrial spaces in order to establish fair and accurate maximum lighting power density levels. As an alternative, we would suggest a formula that the design team could use to establish the maximum allowable LPD for the particular space in question. This formula or formulas would be based on the target illumination level (foot-candles) for the space, ceiling height, and the approximate overall efficacy of the typical technologies used for such spaces. The target foot-candle levels could be supplied by the manufacturers of the process equipment to be used, lighting designers, and/or IESNA recommended illumination levels. A simple calculation from this formula would establish the maximum LPD for the space. Table 2 illustrates a sample formula.

Table 2. Sample Proposed LPD Compliance Formula

Space Type	Target Illumination Level*	Ceiling Height Factor (Table A)	Technology Factor (Table B)	Maximum LPD**
Final Assembly Small Parts	75	1.2	1	1.8

*Provide source of target illumination level: Machinery manufacturer recommendation

** Result from Code Compliance Software

Table - A Ceiling Height Factors	
Below 10'	1
10' - 14'	1.1
14' - 20'	1.2
20' - 25'	1.3
25' - 30'	1.4
Above 30'	1.5

Table - B Technology Factors	
Linear Fluorescent	1
Linear Fl. Over 90 CRI	1.2
Compact Fluorescent	1.2
HID	1

With a formula approach such as the one illustrated above, maximum allowable LPD levels could be more closely and accurately assigned to particular industrial spaces and tasks, assuring that adequate illumination is provided, while energy is not needlessly wasted.

Industrial safety and automatic lighting control recommendations. In order that worker safety is not compromised, a safety exclusion for industrial spaces should be allowed, beyond the existing exclusion that requires the citing of a specific health/safety regulation. Building designers would be required to describe in the code compliance narrative a rationale for seeking this safety exclusion. This explanation would include a description of the work performed and the specific hazard exposure.

Building Envelope/HVAC Design Issues for Spaces with Minimal or No Heating

Building envelope requirements that are articulated in current commercial building energy codes are generally intended to minimize energy use for buildings for which the dominant factor in determining the loads are weather related. In such spaces, heating is generally required during winter-like weather when the temperatures are significantly lower than desired indoor conditions. Similarly, cooling is required during summer-like weather when the outdoor temperatures (and humidity or enthalpy) are (somewhat) higher than desired indoor conditions. Some industrial buildings are consistent with the load patterns found in commercial spaces. This may include such low internal gain manufacturing operations such as assembly plants.

Most industrial sites differ considerably from the basic weather-dominated commercial building. More typically, manufacturing equipment and operations lead to a building that is internal gain-dominated. In such a space, heating may never be required, or at least not until outside temperatures are quite low – near freezing or below. In such spaces, there is either no space cooling in the manufacturing area or there is cooling that can occur during much of the year.

Whether or not the space is cooled, the energy code building envelope requirements can result in a considerable energy use penalty. In fact, most insulation requirements will provide the greatest benefit during the heating season. In contrast, when there is either mechanical space cooling or a desire to minimize the temperature in the space without such cooling, additions of insulation can result in increased energy use or decreased occupant comfort.

During comfort cooling operations, insulation, which reduces the propensity for heat transmission to the space from a higher temperature ambient environment, can be a major benefit. However, if cooling is occurring when ambient temperatures are significantly lower than the indoor temperature, insulation or other heat loss mitigation aspects of the envelope will reduce the ability of heat to escape via transmission through envelope structures. The inability for heat to escape effectively increases the net cooling load and will result in either decreased comfort or increased energy use by the cooling system.

Insulation is not the only code requirement factor that can have this potentially adverse impact on cooling load, operations, and energy use. Restrictions on glazing are at least partially based on heating loads. For industrial buildings these restrictions discourage glazing for daylighting and natural ventilation that would provide energy savings and enhanced productivity.

Similarly, in the HVAC sections of many energy codes, there are requirements to limit the quantity of outside air ventilation. While standards such as ASHRAE 62 (and associated legislated requirements) state minimum outside air ventilation rates, it is often prudent to provide far more than stated levels for purposes of addressing space-cooling needs. The economizer sections of certain energy codes, where present, do often address this deficiency, however, for certain industrial buildings it would be far more efficient to facilitate development of fan systems that just continually introduce copious quantities of outside air to minimize mechanical cooling needs.

Finally, many new codes mandate the installation of heat recovery systems in spaces where there are very high ventilation rates. Unfortunately, such HRV systems can again result in an energy penalty when one fundamental objective design for high ventilation rates is to eliminate heat from the space.

Cooling load recommendations. There are several considerations for mitigating the potentially adverse energy impacts of cooling systems discussed above. First, we believe that insulation and other heating system energy savings based requirements should be excluded when a new facility design demonstrates that the baseline internal gains demonstrate minimal heating energy requirements and that overall loads are dominated by these internal gains.

Many codes also facilitate an alternative compliance approach for meeting requirements when the various prescriptive requirements are inconsistent with a designer's objectives or desires. In ASHRAE 90.1, this is referred to as the Energy Cost Budget method. In other state codes it may referred to as the Systems Analysis Approach. While these alternative compliance paths are indeed suitable for a custom, energy-optimized design, it is a very challenging route that requires simulation modeling with 8,760 hours of calculations. Many facility designers are not versed in such approaches. Further, in an internal gain dominated industrial environment, 8,760 hours of calculations, intended to capture weather variations, is inappropriate. We believe that there should be code exceptions to facilitate more simplified analyses for industrial facilities or other gain dominated buildings. In such facilities, the commercial building prescriptive requirements may result in an unanticipated energy penalty or a facility that is unduly uncomfortable for occupants.

Slab Insulation Requirements

A number of new energy codes have requirements for under slab insulation. Such requirements have two primary objectives. First, from an energy perspective, the under slab insulation can minimize heat loss to the environment. Second, from an indoor air quality perspective, the insulation can minimize the potential of condensation on carpeting or other flooring materials directly on the slab. This would in turn minimize the likelihood of mold growth and associated health consequences.

In industrial spaces, however, practices are much different and these problems are not as relevant. Mold-based IAQ problems are less significant than other potential air quality issues, which are frequently mitigated through high exhaust ventilation rates. Further, industrial slab floors are seldom covered, or are just covered with composite vinyl tiles. In either case, these do not represent a very effective medium for mold growth.

Further, under slab insulation requirements are inconsistent with the placement of large process systems. While insulation can certainly handle the stress of commercial loads and weights, factory floors are usually designed to handle very large focused loads. These are incompatible with the placement of under slab insulation, and may adversely affect equipment warranties and recommended installation practices for certain manufacturing systems.

Conclusions

As has been demonstrated in this paper, the new generations of energy codes that are being adopted in many states are far more aggressive than previous requirements. For industrial facilities, many of the requirements are inconsistent with the energy usage patterns of these sites. In fact, there may indeed be energy penalties (increased usage) due to direct implementation of some of the prescriptive requirements in the codes. States should carefully consider the applicability of the codes for industrial site. In consideration of usage patterns that are not dominated by traditional commercial sector usage, it may be prudent to fully or partially exclude industrial sites from certain code requirements. At the very least, simplified analytical techniques should be allowable for compliance and for demonstrating facility energy performance at a lower usage level than a code-prescriptive approach.

Further study may be warranted in order to quantify the potential energy use penalties associated with use of commercial-based energy codes in certain industrial facilities. Such energy penalties may be concurrently associated with higher construction costs, and incremental funds could have otherwise been directed to specification and installation of other energy efficient systems. Due to the considerable variability in industrial stock there is a wide range of impacts for specific industrial facilities and an effort towards quantification of impacts would be challenging. Still, understanding the potential energy and cost impacts of using commercial-based energy codes for industrial sites may be a valuable exercise in justify a new approach that results in codes that are better focused for industrial facilities.

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