Mass Producing Industrial Energy Efficiency through Building Energy Codes

Jon McHugh, McHugh Energy Consultants
Doug Naaf & Patrick Eilert, Pacific Gas & Electric Company
Mike McGaraghan & Amanda Gonzales, Energy Solutions

ABSTRACT

Historically the most common method of promoting industrial energy efficiency was through individualized industrial energy assessments and educational outreach. Industrial energy assessments were streamlined by developing "canned" calculation methodologies for frequently found measures. These popular measures have been incorporated into deemed savings utility efficiency programs and are the topic of industrial technology briefs. Historically buildings energy codes have steered clear of "process energy end-uses." The ASHRAE 90.1-2010 and the 2013 California Title 24 building energy efficiency standards have, however, increased regulation of process loads. Title 24 has increased coverage to the following process areas: lighting in factories, refrigeration systems for commercial and industrial storage, cooling of data centers, fume hood ventilation systems, industrial boilers and compressed air. The paper estimates the statewide energy impacts from industrial and commercial processes covered by the building code.

Background

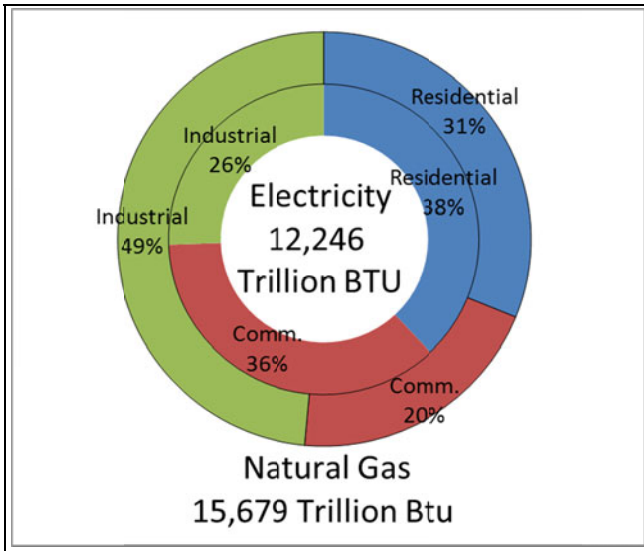


Figure 1: Electricity and Natural Gas Consumption by Sector (EIA 2013)

As shown in Figure 1, the industrial sector consumes approximately 26% of electricity and 49% of natural gas sold in the United States. Over time, the production efficiency of the industrial sector has increased. In 2010, for every Million Btu's of energy consumed, the California industrial sector produced $204 of products. This is more than twice as much value per Million Btu than the rest of the United States. In comparison the average cost paid by California industrial user for natural gas is $6.57/Million Btus or approximately 3% of the value of production. Similarly California industry produced approximately $7.22 worth of product for each kWh of electricity consumed by the industrial sector – approximately twice the financial productivity per kWh as the country as a whole. In comparison the average cost paid by California industrial user for natural gas is $0.099/kW or approximately 1.4% of the value of production. [1]

Increasing the energy efficiency and cost efficiency of the industrial sector has been important to wide range of groups:

- Government – an efficient industrial sector is more competitive globally and able to hire more workers and increase the balance of payments. In addition pollution and greenhouse gases per unit of production are reduced.
- Utilities – the industrial sector has a higher load factor and is typically lower cost to serve per unit of energy. Bringing energy expertise to these customers helps utilities understand their clients' needs and enhances loyalty. Industrial efficiency programs are typically the lowest cost method resource acquisition – a kWh or therm saved in industrial efficiency is significantly less expensive than operating other efficiency programs and is less expensive than purchasing more supply capacity. A subset of the industrial sector has been a key participant in demand response (load shifting) programs.
- Industry – participating in an energy management program increases competitiveness and profitability. Side benefits can include reduced maintenance and environmental compliance costs.
- Consultants and equipment suppliers – there is money to be made selling consulting and design services to industry as well as selling the products that are part of the efficiency upgrade.

Industrial energy efficiency assessments combination of applying common repeatedly applied efficiency measures and developing custom energy efficiency solutions for the particulars of the process and the particular plant. The repeatable common efficiency measures can be summarized as:

- Reducing utility rates (fuel switching, special rates, demand response, power factor adjustment etc.)
- Common efficiency measures that would apply to the operation of any building such as lighting and HVAC measures.
- Repeatable measures for systems providing general support services to the process such as compressed air, steam, chilled water etc.
- Repeatable process measures that incorporate the improved production technology that are typically specific to a class of industries such as improved coating technologies, improved clean-room operation etc.

The custom efficiency solutions for a particular industrial plant typically involve evaluating potential improvements to the manufacturing process. This type of process recommendations are occasionally part of a broad based technical assessment. The skill developed in evaluating repeatable industrial efficiency improvements are frequently used to

[1] Data on productivity per Million Btu and per kWh from Energy Efficiency and Renewable Energy (EERE) webpage: *Energy Consumption in California Industry* http://apps1.eere.energy.gov/states/industrial.cfm?state=CA&dollars=1#energy.

evaluate specific ideas that plant staff have identified but have not had the time or capability to quantify the benefit.

Energy Analysis and Diagnostic Centers (EADC) and Industrial Assessment Centers (IAC)

Since its inception in 1976 under the sponsorship of the US Department of Commerce, the Energy Analysis and Diagnostic Centers (EADC) provided industrial energy efficiency assessments to small and medium sized manufacturers. The scope was limited these smaller companies that may not have the resources to have their own in-house energy manager. These assessments were conducted by Engineering Schools which simultaneously transferred high levels of expertise from some of the leading engineering schools to small manufacturers while undergraduate and graduate students received hands-on training on industrial energy efficiency. With the creation of the US Department of Energy in 1978, USDOE took over sponsorship of the program. (Kirsch 1995) In 1988, the Environmental Protection Agency (EPA) sponsored three universities under the Waste Minimization Assessment Center (WMAC) pilot program to provide the waste minimization assessments to small and medium sized manufacturers. With both of these programs successfully serving small and medium sized manufacturers, in 1993 these two programs were reorganized into an Industrial Assessment Center (IAC) Program under US DOE sponsorship. In 1996, productivity enhancement assessments were included to the industrial energy efficiency and waste minimization assessments provided by the IAC's. (Buchanan, 1999) Currently the IAC program has 24 participating universities.

Besides the direct benefit provided by the IAC's to their participating companies, the IAC program has sponsored several generations of energy efficiency engineers and has been bringing useful energy efficiency measures into the public domain and a mapping of these measures to the types of industries that are likely to make use of these measures. The Industrial Assessment Centers (IAC) Database contains all the publicly available assessment and recommendation data that has been gathered from 15,000+ site assessments. This includes information on each assessment including facility size, SIC or NAICS industry type code and details of resulting recommendations. As of 2013, the IAC database contains the results of most of the site assessments including a description of over 119,000 energy efficiency, pollution prevention and process efficiency recommendations (on average approximately 8 recommendations per site).

As mentioned earlier, industrial energy assessments typically contain repeatable recommendations that are common to most industries within a given industrial sector as well as custom measures that make use of similar types of thermodynamic analyses as the repeatable recommendations but are specific to the particular process or are related to advances in industrial process equipment efficiency. Some custom measures over time are repeatedly applied and become a standard measure.

Repeatable Industrial Measures as Code Candidates: Examples from the IAC Database

In Table 1, we have tabulated the top 20 most frequently recommended measures by the IAC program. The most frequently recommended efficiency measure has been to replace lower efficiency lamps or ballasts with higher efficiency versions. This measure has been recommended over 11,000 times out of the 15,000 assessments or approximately 73% of the time. Also included in table 1, the average simple payback of the measures as calculated in the assessment report and how frequently the measures were implemented as reported by facilities staff. It should be noted that those measures with the highest implementation rates were those that required changes to maintenance procedures or required little capital investment. All of the top 20 measures had average simple paybacks less than 3 years. The last column of table 1, is appended to the IAC database search results by the authors of this paper and contains a code commentary of which of the frequently occurring industrial efficiency measures have been adopted into the various energy efficiency codes.

Table 1. IAC Database Top 20 Recommended Measures[2] and Code Commentary

#	Description	Times Rec'd	Average Payback	Imp Rate	Code Commentary
1	utilize higher efficiency lamps and/or ballasts	11,321	2.9	56.34%	Fed appliance stds. CA T-24
2	eliminate leaks in inert gas and compressed air lines/ valves	7,337	0.4	81.14%	CA 2016 T-24 proposal
3	use most efficient type of electric motors	5,071	4.1	64.25%	Fed appliance stds
4	install compressor air intakes in coolest locations	4,881	0.9	47.90%	Climate dependent
5	utilize energy-efficient belts and other improved mechanisms	3,990	0.8	55.62%	Equipment dependent
6	reduce the pressure of compressed air to the minimum required	3,863	0.5	49.47%	Application specific
7	install occupancy sensors	3,514	1.4	35.68%	Building standards
8	use more efficient light source	3,388	1.9	53.24%	Building standards
9	insulate bare equipment	3,356	1.2	47.73%	Equipment specific. Opportunity
10	analyze flue gas for proper air/fuel ratio	2,275	0.6	68.57%	CA 2013 T-24. Parallel positioning and O2 trim control
11	install timers and/or thermostats	1,904	0.7	55.16%	Building standards
12	reduce illumination to minimum necessary levels	1,736	0.4	50.79%	Building standards
13	use multiple speed motors or VFD for variable pump, blower and compressor loads	1,704	2.1	29.34%	CA 2013 T-24
14	turn off equipment when not in use	1,486	0.4	59.32%	Operations
15	recover heat from air compressor	1,444	1.1	32.58%	CA 2013 T-24 supermarket refrigeration
16	replace electrically-operated equipment with fossil fuel equipment	1,430	2.0	27.68%	Fuel switching. T-24 space heating no elec resistance
17	optimize plant power factor	1,396	2.0	38.67%	Appliance efficiency Standards
18	insulate steam / hot water lines	1,276	2.4	61.07%	CA 2013 T-24
19	reschedule plant operations or reduce load to avoid peaks	1,248	0.4	40.68%	Operations.
20	eliminate or reduce compressed air used for cooling, agitating liquids, moving product, or drying	1,178	0.8	45.98%	Equipment selection

[2] Updated the top ten search to top 20 measures ranked by number of times recommended at: http://iac.rutgers.edu/database/topten/ Code commentary is added.

This code commentary has identified the following trends of commonly recommended industrial efficiency measures: some of these measures are already addressed by building codes as they are common to other nonresidential end-uses (space conditioning, lighting), others are addressed by the Federal appliance efficiency regulations, some of these commonly applied measures are related to operational patterns of control and finally some are measures which have not been regulated or not until recently. Some products such as lamps, lighting ballasts, electric motors etc. are regulated by the Federal appliance efficiency regulations (NAECA, EPAct, EISA etc). Measures such as designing to the Illuminating Engineering Society (IES) standards, installing occupancy sensors, and setback thermostats are already embedded in most building energy codes such as ASHRAE 90.1, the International Energy and Conservation Code (IECC) and most state building efficiency codes. Improved control of boiler air fuel ratio, variable speed drives on air compressors and reducing compressed air leaks are all measures that traditionally not been part of an appliance standard because they are application specific and have not been part of traditional building energy codes as they are not generally applied to commercial building end-uses but to the processes within supermarkets or factories.

DOE Industrial Technologies Program

The DOE's Energy Efficiency & Renewable Energy (EERE) group has partnered with industry trade organizations and other stakeholders to develop training materials and software tools for building engineers and managers to be able to identify and analyze energy system savings opportunities. MotorMaster and the Compressed Air Challenge are two such programs that have paved the way for code ready measures, adopted at the Federal level and in California, respectively.

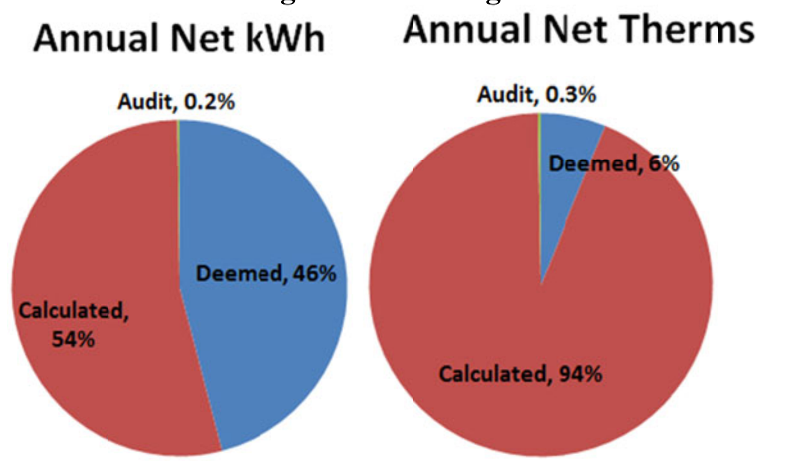
MotorMaster+, a software tool for motor system optimization, has been credited with nationwide annual savings of more than $2.4 million and 50.7 Gigwatt-hours (GWh) as of 2000 (EERE 2010). The software tool, MotorMaster+ takes in a series of facility specific inputs such as motor load, efficiency point at load, annual energy use, and annual operating cost, identifies inefficient or oversized facility motors, and computes the savings that can be achieved through retrofit. The tool makes use of a database of more than 20,000 motors as well as technical data to help optimize drives. The Consortium for Energy Efficiency (CEE) used MotorMaster to prescribe specifications for a motors efficiency program, which also became the basis of the DOE Rulemaking on Motors for which national standards became effective in 2010.

The Compressed Air Challenge (CAC) is a voluntary collaboration of industrial users including manufacturers, distributors, energy efficiency organizations, and other utilities. Like MotorMaster, CAC offers a software component for identifying energy efficiency savings opportunities unique to a given facility, as it related to compressed air. As a part of CAC, there is also a publication of "Best Practices for Compressed Air Systems". Compressed air measures adopted in the 2013 version the California Title 24 building energy efficiency standards were based partly on CAC data. As was the case with many commercial building best practices that ultimately became part of the minimum efficiency code, whether it was Title 24, ASHRAE 90.1 or IECC, we expect that other industrial best practices similar to the Compressed Air Challenge may be incorporated into future codes.

Utility Industrial Energy Efficiency

Utility incentive programs have traditionally been designed to transform the market with energy efficient technology and processes, and to develop code-ready measures. Industrial energy consumption can be due to complex technologies, processes, and use-cases, making identifying and crafting code-ready measures more challenging. Nonetheless, there are ample opportunities to leverage existing utility industrial energy efficiency measures into codes.

Figure 1. PG&E Annual Net Savings from Core Industrial & Agricultural Programs



Source: PG&E 2013

The two pie charts in Figure 1, show the percentage of process (sum of industrial & agricultural) savings associated with deemed, calculated, and audit Core[3] PG&E programs.

Deemed programs are programs that have prescriptive measures and are the most code ready. Calculated programs rely on facility level detail, and with innovation could be turned into a deemed program. The small energy savings associated with audit programs is somewhat misleading as the audit program essentially markets the deemed savings and calculated savings programs thus the energy savings recorded for audit programs are the measures uncovered during the industrial audit that do not fit into either of the other two programs . In terms of electrical savings 46 percent of process savings come from deemed programs, which are the closest to being code ready (PG&E 2013). In terms of net therms, only about 6 percent come from Deemed Programs. Moreover, for electricity savings, 64 percent of savings associated with calculated and deemed programs is from new construction (PG&E 2013), which in theory are most primed for code. Measures include installation of new pumps, variable frequency drives (VFDs), waste water aerators and controls, compressors, and motors. Natural gas savings measures are largely due to efficiency improvements associated with boilers and hot water systems.

The levelized cost (total resource cost basis including the incremental cost of the measure itself, program overhead and incentives paid to free-riders) for the program are $0.076/kWh and $0.399/therm. The overall Total Resource Cost (TRC) benefit cost ratio for the program is over 2 to 1.Thus operating the program is cheaper than building more capacity or buying more power and delivering it to the site. As another point of comparison the average retail rate for electricity to California industrial customers is $0.0991/kWh[4] and the average retail rate of natural gas to

[3] Core refers to programs run directly through PG&E, as opposed to third-party programs, which are operated and administered by entities outside of PG&E, though PG&E can still claim their savings.

[4] USEIA March 2012 Industrial rate in Table 5.6.A. *Average Retail Price of Electricity to Ultimate Customers by End-Use Sector.* **Electric Power Monthly Data for March 2013** Release Date: May 21, 2013 http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

California industrial customers is $0.657/therm.[5] The low levelized costs of the industrial efficiency program signal that the industrial sector represents a prime opportunity for reducing the effective cost of energy for industrial customers. The State of California is motivated to operate these efficiency programs as it increases the competitiveness of California businesses while helping to achieve the State's environmental goals.

Process Measures in California Building Codes

Traditionally building energy efficiency codes only covered building energy consumption and all other end-uses were not considered in scope of the code. Energy consumption considered to be out of scope included outdoor lighting, lighting in unconditioned spaces, plug loads, refrigeration and "process loads" including mechanical cooling that was keeping equipment cool such as data center cooling.

In response to the California power crisis of 2001, Senate Bill SB 5X (Sher, Chapter 7, 1st Extraordinary Session, Statutes of 2001) was passed which had the effect giving the California Energy Commission the authority to adopt lighting for all outdoor lighting applications, including all non-conditioned areas. "Such lighting includes but is not limited to lighting in unconditioned buildings, lighting that is mounted on the exterior of buildings, lighting that is exterior to buildings but controlled from the electrical panel of the building, and lighting that is not controlled from a building."[6] For the 2005 Title 24 standards, this led to the development of California lighting zones for the establishment of outdoor lighting power allowances, efficiency and control requirements for lighted signs and lighting power density requirements and minimum skylight area requirements in unconditioned warehouses and in "industrial work buildings."

As part of the development of the 2008 Title 24 standards, the California Energy Commission made a determination that there was no legislative obstacle to regulating process loads only traditional practice and what was currently an administrative scope of the standard which could be changed administratively. Refrigerated warehouse refrigeration measures were selected as the first process area to regulate. The refrigeration equipment is often installed at the same time as the warehouse is built. The refrigerated warehouse design and construction market was a significant target of market transformation activities by the California statewide nonresidential new construction program called Savings By Design (SBD). SBD market interventions included design assistance, whole building energy simulation to predict energy savings and cost-effectiveness and demonstration projects.

In discussions with the technical author[7] of the Codes and Standards Enhancement (CASE) report for Refrigerated Warehouses, the starting point for developing the new standard was to evaluate the code worthiness of the energy efficiency measures promoted by the Savings By Design program. Code worthiness incorporates a broad range of attributes including enforceability, feasibility, cost-effectiveness and can be broadly applied without relying on any single proprietary technology. The ASHRAE Refrigerated Warehouse Guidelines were also evaluated so the new code could be harmonized with this industry sponsored document. A

---

[5] USEIA March 2012 costs in Table 22. Average price of natural gas sold to industrial consumers, by state, 2011-2013 **Natural Gas Monthly**: April 2013. http://www.eia.gov/naturalgas/monthly/pdf/ngm_all.pdf

[6] CEC Background Information on SB 5X Outdoor Lighting Standards. http://www.energy.ca.gov/title24/2005standards/archive/outdoor_lighting/background.html

[7] Personal communication with Pete Jacobs of Design Builders.

phone survey was administered to refrigerated warehouse designers, owners and operators to evaluate common practice and efficiency measures they would recommend. This effort preceded the technical analysis of selected measures and the results vetted with industry stakeholders. The outcome was a broad ranging proposal that included minimum insulation levels, variable speed control of evaporator and condenser fans, floating head controls and condenser sizing. Overall this package of measures was calculated to save 10 GWh/yr for each year of new construction and reduce peak demand by 1.7 MW. As we will discuss later on, refrigerated warehouses were the subject of additional energy efficiency measures adopted in the 2013 standards.

California's aggressive greenhouse reduction goals as contained in Assembly Bill 32 and supported by the Governor and the State Legislature set the stage for taking a more comprehensive approach towards process energy efficiency in the 2013 Title 24 building standards. The California Public Utilities Commission had increased funding to the California Investor Owned Utilities so the IOUs could sponsor more CASE reports and advocate for more measures including a significant increase in industrial and process measures.

Table 2. 2013 Title 24 - Energy Savings and Life Cycle Energy Cost Savings for One Year's New Construction in California

	Elec Savings	Demand Savings	Gas Savings	Life Cycle Cost Savings
Code Measure Description	GWH/yr	MW	Million therms	PV $ (Millions)
Compressed air VSD and optimal staging controls	23.2	4.2		43.0
Industrial Boiler: Flue damper			0.03	0.4
Ind. Boiler VFD combustion air fan	0.7	0.1		1.3
Ind Boiler Parallel Position Controls			0.47	6.8
Ind Boiler O2 Trim Controls			0.61	8.8
Laboratory HVAC Variable Air Volume	TBD	TBD	TBD	TBD
Data Center Cooling Systems	51.7	1.5		98.7
Refrigerated warehouse efficiency	1.1	0.2		2.9
Supermarket refrigeration efficiency and heat recovery	18.0	1.5	1.89	68.5
Parking Garage Ventilation Control	13.9	3.2		10.6
Kitchen Ventilation Control	TBD	TBD	TBD	TBD
Total	**108.6**	**10.7**	**3.00**	**$241.0**

Similar to the 2008 standards, the 2013 standards built upon a variety of efforts including a market for industrial energy efficiency that had been primed and characterized by energy efficiency training and incentive programs. As an example, one of the authors of the Compressed Air CASE report indicated that in advance of selecting the compressed air measures for evaluation, they interviewed a number of key players in the market for efficient compressed air systems. This included one of the developers of the compressed air simulation software, Air Master, one of the trainers for the Compressed Air Challenge, and utility industrial efficiency program staff. In addition they found the USDOE Compressed Air Sourcebook to be an outstanding resource. In short the combined efforts of many organizations and people were leveraged to take this measure into the California building energy efficiency code. As shown in Figure 1, the projected savings from industrial and process measures in the 2013 standards for one year's new construction accounted for approximately 109 GWh/yr of electricity savings and 3 Million therms per year of natural gas savings. This is approximately one fifth the savings for the rest of the residential and nonresidential building standards. If these measures were applied to the entire United States the savings would be approximately tenfold.

Process Measures in other Energy Codes

According to the 1992 Energy Policy Act, all states are supposed to certify that the state nonresidential energy code saves as much or more energy than the ASHRAE 90.1-2010 *"Energy Standard for Buildings except Low-Rise Residential Buildings."* This standard has requirements for: data center cooling equipment efficiency, kitchen and laboratory exhaust systems, parking garage ventilation controls. Additional date center and computer room cooling efficiency measures are being added to the 2013 version of ASHRAE 90.1. ASHRAE is also adding a new energy standard dedicated to high risk data centers (such as those designed by ANSI/TIA942 as Tier II or greater or mission critical data centers having mechanical cooling system redundancy), Standard 90.4P, *Energy Standard for Data Centers and Telecommunications Buildings*.

The State of Washington amendments to the 2012 IECC (International Energy Conservation Code) cover the areas listed above for the ASHRAE 90.1 standard. In addition the State of Washington amendments also include requirements for: refrigerated warehouses, walk-in refrigerators and freezers, refrigeration condenser heat recovery. The parking garage ventilation controls in the Washington code require both Carbon Monoxide and Nitrogen Dioxide sensors whereas most of the other codes require only Carbon Monoxide sensing.

The 2010 Oregon Energy Efficiency Specialty Code covers most the same process elements as the ASHRAE 90.1 Standard. Both the Washington State and Oregon energy codes also require economizers for computer room cooling systems greater than 20 tons.

Impact of Codes on Industrial Efficiency Incentive Programs

The energy savings that are claimed by utility industrial energy efficiency programs are relative to a baseline. For the new construction programs in the state, the baseline used is the current energy code at the time of the project. The level of efficiency chosen for many of the measures adopted into the 2013 Title 24 energy code are equivalent to the level of efficiency promoted by utility energy efficiency incentive programs. With the baseline reset these new construction programs must find even higher levels of efficiency for a given type of measure or develop new types of measures. Thus for new construction programs adoption of tried and true measures into codes speeds up the process of innovation; new construction programs must keep searching for the next big efficiency measure. In the time lag (typically 2 years) between code adoption and the effective date when the code is enforced, new construction program can help smooth the market transition to the new code by specifically marketing the soon to be code measures while communicating to these market participants of the upcoming code requirements.

Of the industrial efficiency programs delivered by Pacific Gas and Electric, 97% of the natural gas savings were due to retrofits and only 3% of savings were associated with new construction activity. Thus the key impacts on the industrial programs are how the retrofit portion of the program is affected. When a new code is adopted, especially a code that has efficiency requirements for equipment replacement, the baseline is unclear. Is the baseline the system efficiency that is upgraded, or should the baseline be the current code requirements? As explained in McHugh et al. (2010), the code baseline for retrofits is a convenience baseline; it is easy to define but is often misleading for retrofits projects even if the retrofit measure is something that triggers the energy code. The key question for evaluating the baseline is to estimate what would have happened without the efficiency program intervention. In some cases, nothing would have happened and the equipment in place at the time of the energy assessment would be operating for years to come and depending upon the particulars of the site, the equipment might be repaired rather than replaced resulting in the equipment lasting longer than its expected useful life. In summary, a significant fraction of the total industrial efficiency opportunity is in existing industrial facilities. The level of impact that bringing industrial measures into codes has on retrofit programs is dependent on the rule sets that regulators, evaluators and program managers place on how energy savings is calculated.

If the regulatory environment is supportive of industrial retrofit programs co-existing with industrial energy codes, the synergies are significant. As described earlier, repeatable industrial efficiency measures that are proven to regularly save energy under most circumstances without negative repercussions to the process quality or longevity of equipment are potential candidates for future energy codes. Industrial programs are well suited to systematically collect the energy, cost, and feasibility information so these measures can be documented for consideration as a code measure. Once the efficiency measure is in the energy code, it enhances the credibility for that measure and rightly so as each measure in the code must undergo a series of hearings during which all stakeholders can hold the measure up to scrutiny in regards to is feasibility and cost-effectiveness. As a result, the industrial efficiency retrofit program has an easier job of convincing the program participant that the recommended measure is viable as it is required for all new factories. In addition the argument can be made that implementing the new code measures now yields near term energy savings for a cost outlay that has to be incurred anyway at some later date.

Future Process Opportunities in Energy Codes

Given the fairly significant savings realized from the Process and Industrial energy efficiency measures in the 2013 Title 24 building efficiency standards, we have been developing a list of potential industrial and process efficiency measures that would be evaluated for inclusion in the 2016 standards. These measures can be characterized as either consolidating energy savings in areas pioneered by the earlier standards or an expansion of scope into new areas of process or industrial energy efficiency.

Table 3. Potential 2016 Title 24 Process and Industrial Measures with Statewide Energy Savings Estimates for One Year's Construction Activity

Code Measure Description	GWH/yr	Million therms
Evap fan speed control for supermarket walk-ins	2.5	
Lab fume hoods: Occupancy sensing control of sash, occupancy + time control general AC setback, no reheat, system sizing	8.1	1.2
Compressed air: Pipe sizing and leak testing	4.5	
Compressed air: Air dryer efficiency	TBD	
Compressed air: Capacity controls for centrifugal compressors	4.5	
Requirements for steam traps including networked fault detection and diagnostics		2.9
Total	**19.5**	**4.1**

Table 3 contains a rough estimate of electricity and natural gas savings that would result from one year's construction activity after a code being adopted with these proposed measures. The estimates here are crude; if these measures are proposed a Codes and Standards Enhancement (CASE) report would document the feasibility, cost-effectiveness and statewide impact with greater detail and accuracy.

Measures to consolidate earlier efficiency measures include:

- Compressed air – expand the variable speed swing compressor requirement also to centrifugal compressors (conduct enough research to eliminate or reduce the number of applications where the requirement is exempted)
- Evaporator fan speed controls – expand this measure from refrigerated warehouses to smaller evaporators including those found in supermarket walk-in coolers and freezers.

Measures that expand the scope of the standards:

- Compressed air piping– test for systems leaks when installing a new system or a new air compressor
- Laboratory fume hoods - occupancy sensing near fume hood to close sash when no one is present, reset general room airflow rate and setpoint when unoccupied after hours, max W/cfm at peak air flow, eliminate simultaneous heating and cooling (dual duct, chilled beam, 4 pipe fan coil etc.,), sizing calculated, exhaust duct sealing.
- Steam traps - Sizing of steam traps, required installation of a strainer and purge valve upstream. On-board Fault Detection and Diagnostics (FDD) of steam trap failure and remote monitoring of steam traps on large systems.

Conclusions and Recommendations

The expansion of the scope of building efficiency codes to process and industrial efficiency measures increases the possible savings opportunities from advanced building codes. Typically the types of measures that are incorporated into energy codes are those measures that impact support equipment such as compressed air, steam and pumping systems. In the case of the 2013 Title 24 energy code, approximately one fifth of the total energy savings is due to process measures. If these measures were implemented in the United States on a nationwide basis, the added energy savings for each year's construction activity would be approximately

1,100 GWH/yr of electricity savings and 30 Million therms/yr of natural gas or other fuel savings.

A well designed and executed energy efficiency portfolio can take advantage of the potential synergies between industrial incentive programs and industrial energy codes. Industrial incentive programs can collect real world information on energy savings, costs, and unforeseen impacts (positive and negative) from industrial efficiency measures. These incentive programs are also well connected with the industry and thus are well-positioned to: solicit input on potential code measures, identify resources for code compliance training and identify key market players who should be contacted for code training.

For new construction, adoption of repeatable measures into code increases energy innovation as those providers of enhanced efficiency must develop new measures to differentiate themselves. In addition, with standard efficiency measures addressed by code, efficiency programs can focus on providing detailed industry or plant specific customer measures that are beyond the purview of the regularly applied efficiency features that are the basis of advanced energy codes.

Measures that are adopted into energy codes are easier for incentive programs to sell to their participants as providing dependable savings and being compatible with other processes and other building codes. This is a reasonable perception as the code proposal had to be vetted and the code organizations had to develop a standard that is internally compatible with other codes. However regulators, program evaluators and managers must be able to articulate an energy baseline structure that does a good job of estimating what the energy baseline would be without the program. Provisions for excluding free-ridership must be based on more sophisticated methods than using code as a convenience baseline.

Other code bodies are encouraged to evaluate the basis of the new industrial efficiency measures in the 2013 version of California's Title 24 building energy efficiency standards and consider if these measures would provide comparable benefits in other jurisdictions. We think the benefits are compelling as it creates the frame work for implementation of key industrial efficiency measures on a state by state basis rather than on a factory by factory basis.

References

ASHRAE. 2010 ASHRAE 90.1-2010 *"Energy Standard for Buildings except Low-Rise Residential Buildings.* American Society of Heating, Air-conditioning and Refrigerating Engineers. https://www.ashrae.org/resources--publications/bookstore/standard-90-1

Belzer D, M Halverson, and S McDonald. 2010. A Retrospective Analysis of Commercial Building Energy Codes: 1990-2008. December 2010. Building Energy Codes Program, Pacific Northwest National Laboratory, Richland, Washington. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-19887.pdf

Buchanan, Laura M. 1999, "The Industrial Assessment Center (IAC) Program: Industrial Manufacturing Providing Practical Experience for Engineering Students" (1999). *University of Tennessee Honors Thesis Projects*. http://trace.tennessee.edu/utk_chanhonoproj/288

California Energy Commission (CEC) 2013. *Title 24, part 6. Building Energy Efficiency Standards*. Publication No. CEC-400-2012-004-CMF. http://www.energy.ca.gov/title24/

[EERE] Energy Efficiency and Renewable Energy Program. 2010. "Industrial Technologies Program: MotorMaster+". http://www1.eere.energy.gov/manufacturing/tech_deployment/pdfs/motormaster_fs.pdf

Energy Information Administration, 2013 Monthly Energy Review: February 2013. http://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

Kirsch, William.F., William J. Clark, Merritt C. Kirk 1995. *The EADC Program DOE Helping Small and Medium-Size Manufacturers.* Proceedings 1995 ACEEE Summer Study on Energy Efficiency in Industry.

McHugh, J. and C.B Winn, 1992. *The Energy Conservation CD-ROM: TMY Weather data for 234 Cities and The EADC Industrial Energy Conservation Database*, US Department of Energy

McHugh, J. and C.B Winn, 1992. *CSU-ECOs Colorado State University - Energy Conservation Opportunities Software*, US Department of Energy

McHugh, J., D. Mahone, M. Bruceri, and P. Eilert. 2010. A New Class of Retrofits: "Repair Indefinitely" *Proceedings of the 2010 ACEEE Summer Study of Energy Efficiency in Buildings*. Washington, D.C.: American Council for an Energy-Efficient Economy http://www.aceee.org/files/proceedings/2010/data/papers/2079.pdf

Muller, M, & K. Papadaratsakis. 2003. *Self-Assessment Handbook for Small Manufacturers* Version 2.0. http://iac.rutgers.edu/redirect.php?rf=selfassessment

[OEESC] 2010 Oregon Energy Efficiency Specialty Code. http://www.cbs.state.or.us/bcd/programs/energy.html

[SBCC] Washington State Building Code Council. State of Washington amendments to the 2012 International Energy Conservation Code. https://fortress.wa.gov/ga/apps/SBCC/Page.aspx?cid=2284