The Strategic Value of Industrial SEM in Limiting Climate Pollution

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ABSTRACT

The Paris Agreement established at the United Nations Framework Convention on Climate Change in 2015 sets a two-fold goal for the world's nations: to hold the increase in global average temperature to below 2 degrees C above pre-industrial levels and to pursue efforts to limit the increase in temperature to 1.5 degrees C.

Stopping climate change at 2 degrees C requires strong policies on energy efficiency—a main contributor to greenhouse gas emission reductions—as well as on other zero- or near-zero-emitting energy sources. Since efficiency is cheaper than many other clean energy technologies, it makes sense to prioritize aggressive efficiency policies and measures.

Numerous studies have looked at the potential energy savings at national and multi-national levels. This paper draws on U.S.-focused studies to look at the role of efficiency in deep decarbonization scenarios. In many analyses, one of the largest remaining sources of emissions in the post-2030 period is fossil fuel use in the industrial sector. This paper discusses why existing estimates of industrial efficiency potential likely underestimate achievable savings due to the newness of the techniques of strategic energy management (SEM), along with incomplete information on efficiency measures to industrial energy users. Underestimating industrial efficiency potential can result in decarbonization studies underestimating the emission reduction contributions from industry. This paper qualitatively explores the emissions impact of more aggressive industrial efficiency, focusing on how wider use of SEM-based incentive and information policies could be a major contributor to reducing greenhouse gas pollution in both the 2 degree and 1.5 degree C scenarios.

Introduction

In December 2015, countries came together in Paris to draft an agreement to both combat climate change and provide assistance to adapt to its effects. This was the first, successful agreement under the UN's Framework Convention on Climate Change, calling on the global community to strengthen and deploy measures to limit climate change to a 2 degree C rise above pre-industrial levels. A secondary goal of the Paris Agreement was to pursue further efforts to limit climate change to a 1.5 degree C rise above pre-industrial levels (UNFCC 2015).

In less than a year, the Paris Agreement reached the threshold for entry, officially entering force on November 4, 2016. As of February 2017, 132 parties have ratified the agreement, representing over 80 percent of the world's greenhouse gas (GHG) emissions (UNFCC 2016). As part of the Agreement, the U.S. submitted a near-term, public commitment to reduce total GHG emissions to 26-28 percent below 2005 levels by 2025. The U.S. government has cited a long-term reduction target of 80 percent by 2050. However, this is not part of the official submission to the UN. This 2050 target has been in reference to both 2005 levels and 1990 levels in different materials. (The White House 2015, 2016).

An 80 percent reduction by 2050 is in line with a 2-degree C target and has been well researched and modeled by several parties, including government agencies, academics, non-profits, and even private energy companies. Achieving a 1.5-degree C target has not received the same attention or analysis, and thus, the emissions trajectory is less clear. However, a 1.5-degree C target will require emission reductions that are significantly deeper, and, even more importantly, reductions that are realized in a shorter amount of time (Goldstein 2017). These two criteria imply that efficiency will play an even larger role in meeting the 1.5-degree C goal, because most supply-side near-zero-carbon resources take longer to deploy than efficiency.

While there is greater uncertainty, preliminary analysis of a 1.5-degree C scenario indicates that global GHG emissions will likely needed to achieve net zero by 2060-2080 (Climate Analytics 2015). For contrast, a 2-degree scenario will likely need to reach global net zero emissions between 2080 and 2100. For developed countries, a 1.5-degree target will also likely require achieving net zero emissions, at least for CO_2, by 2050 (Climate Analytics 2015).

Under a 2-degree scenario, a disproportionate portion of reductions come from the residential, commercial, and electric power sectors. Zero-carbon, clean electricity sources are already as cheap, or cheaper, than fossil fuel- generated electricity, and while variable resources, like wind and solar, may pose operational challenges from a grid perspective, recent progress on integrating high levels of renewables and developing a more flexible grid are optimistic signs of the feasibility of a clean, reliable, and low-cost electric system. In 2016, California was already successfully integrating 67 percent renewables into its generation mix instantaneously (California ISO 2017). Housing and commercial floor space cannot only be made much more efficient, but these spaces can also easily be largely, if not fully, electrified.

Deep decarbonization strategies typically depend on a combination of efficiency improvements, zero-carbon electricity generation, electrification of buildings and vehicles, and lower-carbon fuels and fuel switching. Given the relative technological maturity and lower costs of energy efficiency and renewables, as compared to the other measures, the efficiency and electrification potential of buildings provides easier, least costly decarbonization opportunities.

The industrial sector and heavy-duty transportation present much harder sectors to fully decarbonize. These sectors also cover a less homogenous set of end-uses and needs. As such, decarbonization strategies for these sectors are much less complete, and these sectors contribute a disproportionately smaller share of emission reductions in many 2-degree C scenario analyses.

Given the more expansive and robust analysis that has been completed on a 2-degree C warming scenario, this paper starts by describing what measures are available for the U.S. to achieve a 2-degree C target. From this starting point, the paper then discusses the remaining opportunities to achieve more ambitious emission reductions. This discussion focuses on the remaining opportunities in the industrial sector, exploring both the cost-saving and carbon-reducing potential of strategic energy management (SEM) across the U.S. industrial sector. The potential energy and emissions savings from SEM programs have largely been ignored in most decarbonization analyses, due to less robust data on the effectiveness of SEM. This paper's discussion is largely qualitative, given the current lack of quantitative data on these issues.

What Does It Take to Meet a 2 Degree C Target?

The common consensus of 2-degree C modeling is that an 80 percent reduction in U.S. GHG emissions can be achieved at relatively low cost using technically-proven solutions. All modeling efforts rely on four decarbonization strategies, to varying degrees:

1) Deploying all cost-effective energy efficiency to reduce energy demand in buildings, energy, and transportation;

2) Deploying significant levels of renewable and other zero-carbon electric generation to greatly decarbonize electricity;
3) Deploying a deep and broad electrification of buildings, industry, and vehicles;
4) Decarbonizing remaining fuel use in industry and transportation, specifically, through low-carbon fuels and carbon capture and sequestration.

These analyses also implement measures to reduce non-CO2 emissions, like methane and HFCs, from energy production, agriculture, and refrigerants (E3, PNNL, and LNBL 2014). Several analyses also rely on carbon sink enhancements and other measures to sequester carbon from the atmosphere back underground to reduce net GHG emissions (White House 2016).

For the rest of this section, the authors explore the findings of the Natural Resource Defense Council's (NRDC) forthcoming "Paving the Pathway to Zero Carbon" report (NRDC 2017). The modeling was conducted in partnership with Energy + Environmental Economics (E3), which completed similar analysis with the U.S. national laboratories (E3, PNNL, and LNBL 2014). The NRDC analysis used E3's PATHWAYS model, which is a scenario-based platform built on a bottom-up representation of the U.S. energy system. In this model, portfolios of measures, such as the electricity supply mix and the make-up of transportation fuels, are chosen as inputs by the user. (See E3, PNNL, and LNBL 2014 for a complete methodology). Given the more theoretical purpose of this paper, the underlying data outputs behind the NRDC pathways conclusions will largely not be referenced in this paper.

NRDC's pathway relies primarily on energy efficiency and renewable energy to decarbonize the U.S. economy—an even heavier reliance than other studies because of the organization's assumptions showing greater, but supported, potential energy savings across the U.S. economy than in many other studies (Laitner et al. 2012). NRDC also included less optimistic assumptions on the economic, environmental, and regulatory feasibility of other zero-carbon sources, such as nuclear and biomass. Given these two assumptions, NRDC's analysis relies less on these other zero-carbon sources than other deep decarbonization approaches.

Energy efficiency plays a critical role in reining in energy use and mitigating the costs and challenges of transitioning to a clean energy system in NRDC's modeling. Overall, the entire U.S. economy sees a 45 percent reduction in energy use compared to the reference case by 2050 (EIA 2013). The scenario also includes an expansive deployment of renewable electricity, which both directly and indirectly displaces emissions from fossil-fuel combustion. Non-hydro renewables grow to around 75 percent of the nation's electricity mix, providing a low-carbon fuel source for buildings, some industry, and passenger vehicles. Excess renewable generation is also used to create synthetic fuels, which in addition to biofuels, helps decarbonize those sectors and end-uses that may still rely on liquid or fossil fuels (e.g., aviation, long-distance trucking, certain energy-intensive industrial processes).

Residential and commercial buildings see the bulk of efficiency gains, reducing energy consumption by around 50 percent and 40 percent, respectively, through improved efficiency of building shell and appliances, as well as the deployment of lighting controls and grid-enabled devices that help optimize and reduce consumption. Building energy use and carbon emissions are further reduced by switching heating end-uses, as well as cooking, from gas to electricity. This provides additional energy savings, as electric heaters are more thermodynamically efficient than natural gas heaters. In total, the residential and commercial sectors see a reduction of almost 70 percent and 60 percent compared to business-as-usual, respectively, due to efficiency and electrification. Combined, these sectors reduce their carbon footprint by close to 95 percent from the reference case in 2050. These two sectors see early and significant emission reductions, achieving a 15 percent reduction in carbon emissions from reference case in the first 5 years (2020) and more than a 55 percent reduction in carbon emissions from reference case by 2030.

The transportation sector achieves emission reductions through several measures, specific to the mode of transportation. Passenger vehicles see the greatest emission reductions in the transportation sector, with a 60 percent reduction from reference case by 2050. The reductions come from a wide-scale deployment of electric vehicles (to be ~70 percent of the total fleet in 2050), coupled with additional reductions in vehicle-miles-traveled due to changes in personal vehicle driving behavior. Transportation options like aviation, shipping, and long-distance trucking reduce emissions mainly through energy efficiency measures, such as fuel efficiency improvements and more optimized scheduling. Large-scale modal shifts, such as personal car, air, or long distance truck to rail, were not considered within the model. However, these modal shifts may provide opportunities for further emission reductions in the transportation sector. In addition, while less significant than efficiency measures, additional emission reductions come from an infusion of both bio-diesel and synthetic gas into the transportation fuel line.

Like transportation, the method of decarbonization in industry varies greatly between sub-sectors. The modeling implements efficiency improvements across all sectors, through a combination of operation and maintenance (O&M) improvements and increased efficiency of boilers and industrial processes. Industry-wide, the sector achieves a total *energy intensity* reduction of 55 percent by 2050, equivalent to a 33 percent decline in total *energy consumption* compared to reference case. NRDC assumed the industrial sector achieved annual *energy intensity reductions* of 3 percent in the first decade, declining gradually to 1 percent by 2050, which results in annual *absolute energy* reductions of about 1.1% between 2015-2050. The actual modeled energy reductions vary among sub-sectors, driven by the underlying modeling architecture (e.g., motor choice, retirement rates, technology possibility curves).

While efficiency is implemented to a similar degree across the industrial sector, the electrification potential varies much more significantly between sub-sectors. The costs and effectiveness of using electricity versus lower-carbon fuels vary greatly between sub-sectors and the model accounts for this. A little more than 40 percent of all industrial boilers and industrial processes are electrified, with a substantial portion of the remaining 60 percent of industrial end-uses transitioned to lower-carbon fossil and renewably derived fuels. Industries that use fossil fuel-derived feedstocks, such as chemicals and refineries, also deploy carbon capture and sequestration (CCS) as a strategy to decrease emissions from industrial production, though this only accounts for 2.4% of the total emission reductions achieved by the industrial sector.

While not modeled, there may also be broader innovative strategies that more drastically alter and improve the process in which input materials are used and how final products are made and sold. These strategies may also uncover solutions to further reduce fossil fuel use or further electrify industry. Following sections will delve into this potential in further detail.

The fundamental conclusion of this modeling is that the U.S. can achieve an 80 percent reduction in GHG emissions by relying primarily on energy efficiency and renewable energy. Like many other studies, the pathway underscores that achieving a 2-degree C limit can be done with technically-proven technologies that are deployed at commercial scale today, and that can be accommodated without insurmountable challenges to the energy system.

At the same time, NRDC's analysis indicates that reducing carbon emissions in the industrial sector, freight, and air transportation sub-sectors may be more difficult than for the buildings sector. Projected emissions in the year 2050 are more heavily weighted to the industrial and transportation sectors than they had been historically, with these two sectors contributing 89 percent of total carbon emissions in 2050, up from 64 percent in 2015. This is partially a result of a lack of literature on deep savings in the industrial sector, either in the form of case studies or in terms of analysis of the engineering basis for deep savings. This lack of data is in stark contrast with the buildings sector, where both theoretical analyses and case studies of net zero buildings have been available for over a decade (NAS 2010). Because of data limitations on efficiency and electrification potential in industry and transportation, it is likely that these decarbonization studies underestimate industrial decarbonization opportunities. This may result in the 2-degree C modeling relying on more expensive alternatives to meet emission goals than necessary if more measures were taken in industry and transportation.

Since a 1.5-degree C approach will require much more aggressive, innovative emission reduction strategies, broader industrial efficiency and electrification could be of substantial value in achieving the additional, necessary emissions reductions. We explore this issue next.

Going Further: The Role of SEM in a 1.5 Degree C Scenario

SEM is a relatively new concept in industrial energy efficiency policy in most countries. It was developed as an international standard over the period of about ten years, culminating in the issuance of the International Organizations for Standardization’s Standard 50001 in 2011 (ISO 2011).

Some of the roots of this concept date back to the 1970s, when Japan responded to the energy crisis of the 1970s by requiring industrial enterprises above a given size to hire an energy manager and report back to the government on the progress their organization had made in saving energy. After two decades, the energy intensity of Japanese industry had decreased dramatically to a level lower than that of almost any other country (NAS 2010).

SEM programs are based on an Energy Management System (EnMS) that directs change in an organization’s culture (DOE 2014). The EnMS directs management to provide resources and staff to continuously improve the organization’s energy use over the years. Since the performance indicators used to measure and track compliance with the organization’s energy performance improvement goals are often based on whole-facility energy consumption, the types of improvements credited include major process changes, smaller equipment performance improvements, and improvement in O&M and conservation behaviors. SEM offers a new tool to reduce emissions from the industrial sector, helping overcome some of the barriers to industrial energy efficiency that other programs may not address effectively (DOE 2015a).

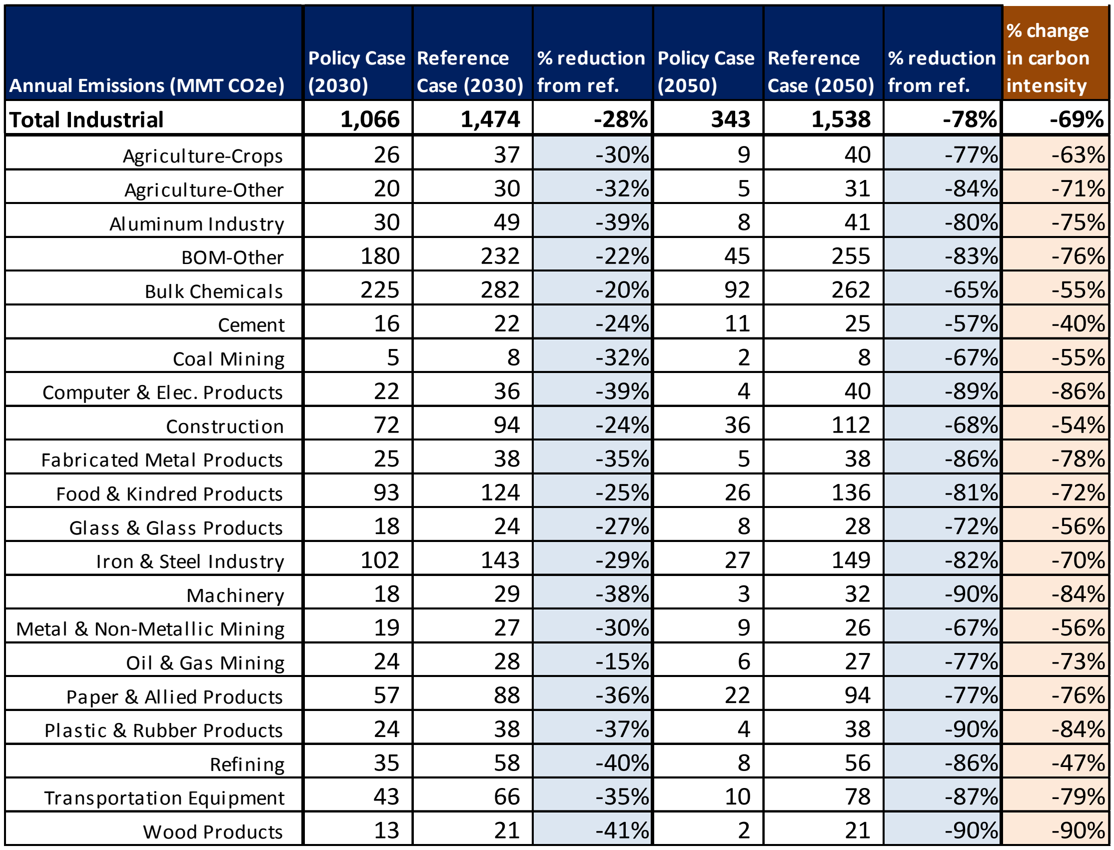
Before discussing this opportunity, we review the contributions by industrial sub-sector in the NRDC 2-degree C scenario. Table 1 shows the change in emissions between the reference case and the NRDC policy case in 2030 and 2050. Table 2 shows the change in energy consumption between reference case and the NRDC policy case in 2030 and 2050. The reduction in emissions and energy are due to several measures, including efficiency improvements, electrification, fuel-switching, bio- and synthetic fuels, and a small amount of CCS.

Emission reductions are lowest in bulk chemicals, construction, cement, and mining – all sectors that continue to rely on fossil fuels. On average, across the entire industrial sector, around 70 percent of observed fuel switching is from fossil fuels to electricity by 2050, with the other 30 percent of switching from higher carbon fossil fuels (e.g., coal, coke) to lower-carbon liquid fuels (e.g., diesel and gas). Among sub-industries with the lowest reductions in emissions, this split is closer to 30 percent switching from fossil fuels to electricity and 70 percent switching from higher to lower carbon fuels. This not only has a significant impact on the emission reductions achieved, but also on the changes in carbon emissions intensity. Mining, cement, construction, and bulk chemicals all see smaller than average reductions in emission intensity by 2050 (see Table 1, last row). A smarter, more holistic approach to manage energy consumption of these sectors provide the greater opportunities to further reduce industrial emissions, as efficiency improvements in those sectors would result in the largest reductions in emissions per unit of energy saved. As will be discussed more below, preliminary reviews of strategic energy management (SEM) programs indicate that participants can maintain annual energy savings rate between 2.5 and 5 percent over a multi-year period (Therkelsen et al. 2015), substantially higher than the absolute energy savings achieved under the NRDC 2-degree scenario.

The greatest emission reductions come from wood products, machinery, computer & electronic products, as well as plastic & rubber products. These industries all largely use electricity (or on-site wood waste CHP for wood products) which results in higher than average reductions in both emissions and emissions intensity.

Generally, there is not a great variation between sectors in emissions savings projected—they are mostly in the 30-40 percent range for 2030 and 70-90 percent for 2050. There is much greater variation in energy reductions between sub-industries (see Table 2). Emission savings are also much greater than energy savings, which are reduced by only a third overall. This is due to industries fuel-switching and using bio- and synthetic fuels, in addition to reducing energy consumption.

Table 1. Emissions and Emissions Intensity by Case by Industrial Sub-Sector



Annual Emissions (MMT CO2e)	Policy Case (2030)	Reference Case (2030)	% reduction from ref.	Policy Case (2050)	Reference Case (2050)	% reduction from ref.	% change in carbon intensity
Total Industrial	**1,066**	**1,474**	**-28%**	**343**	**1,538**	**-78%**	**-69%**
Agriculture-Crops	26	37	-30%	9	40	-77%	-63%
Agriculture-Other	20	30	-32%	5	31	-84%	-71%
Aluminum Industry	30	49	-39%	8	41	-80%	-75%
BOM-Other	180	232	-22%	45	255	-83%	-76%
Bulk Chemicals	225	282	-20%	92	262	-65%	-55%
Cement	16	22	-24%	11	25	-57%	-40%
Coal Mining	5	8	-32%	2	8	-67%	-55%
Computer & Elec. Products	22	36	-39%	4	40	-89%	-86%
Construction	72	94	-24%	36	112	-68%	-54%
Fabricated Metal Products	25	38	-35%	5	38	-86%	-78%
Food & Kindred Products	93	124	-25%	26	136	-81%	-72%
Glass & Glass Products	18	24	-27%	8	28	-72%	-56%
Iron & Steel Industry	102	143	-29%	27	149	-82%	-70%
Machinery	18	29	-38%	3	32	-90%	-84%
Metal & Non-Metallic Mining	19	27	-30%	9	26	-67%	-56%
Oil & Gas Mining	24	28	-15%	6	27	-77%	-73%
Paper & Allied Products	57	88	-36%	22	94	-77%	-76%
Plastic & Rubber Products	24	38	-37%	4	38	-90%	-84%
Refining	35	58	-40%	8	56	-86%	-47%
Transportation Equipment	43	66	-35%	10	78	-87%	-79%
Wood Products	13	21	-41%	2	21	-90%	-90%

Source: NRDC 2017.

Table 2. Energy Use by Case by Industrial Sub-Sector

Annual Energy Consumption (Exajoules)	Policy Case (2030)	Reference Case (2030)	% reduction from ref.	Policy Case (2050)	Reference Case (2050)	% reduction from ref.
Total Industrial	**22.8**	**24.8**	**-8%**	**18.2**	**27.1**	**-33%**
Agriculture-Crops	0.5	0.5	-11%	0.36	0.61	-40%
Agriculture-Other	0.35	0.40	-13%	0.23	0.43	-47%
Aluminum Industry	0.42	0.45	-8%	0.28	0.42	-32%
BOM-Other	2.99	3.26	-8%	2.48	3.72	-33%
Bulk Chemicals	6.16	6.70	-8%	4.56	6.67	-32%
Cement	0.20	0.21	-2%	0.17	0.25	-32%
Coal Mining	0.08	0.09	-9%	0.06	0.09	-32%
Computer & Elec. Products	0.35	0.35	-1%	0.28	0.44	-37%
Construction	2.43	2.49	-2%	2.09	3.08	-32%
Fabricated Metal Products	0.40	0.44	-10%	0.27	0.45	-41%
Food & Kindred Products	1.76	1.97	-10%	1.46	2.22	-34%
Glass & Glass Products	0.31	0.36	-13%	0.26	0.42	-37%
Iron & Steel Industry	1.42	1.59	-11%	0.98	1.74	-44%
Machinery	0.27	0.30	-8%	0.20	0.34	-40%
Metal & Non-Metallic Mining	0.33	0.37	-10%	0.26	0.37	-32%
Oil & Gas Mining	0.41	0.44	-7%	0.35	0.43	-19%
Paper & Allied Products	2.45	2.51	-2%	2.57	2.84	-9%
Plastic & Rubber Products	0.37	0.38	-5%	0.24	0.38	-38%
Refining	0.52	0.82	-36%	0.21	0.79	-74%
Transportation Equipment	0.69	0.74	-8%	0.54	0.91	-40%
Wood Products	0.39	0.42	-5%	0.38	0.47	-18%

Source: NRDC 2017.

How much farther can we go in reducing emissions to meet the 1.5-degree C goal? Climate pollution is cumulative: it doesn't matter much how many tons of carbon equivalent we emit in 2050 but rather how much we have emitted during the whole of the next 33 years (and however longer it takes to get to net zero). An approach to 80 percent reduction along a straight-line path will lead to more cumulative emissions (and less cumulative emission reductions) than front-loading the savings. Thus, Table 1 and Table 2 show that increased energy and emissions savings in the decade 2040-50 will not be nearly as effective as increased savings before 2030.

Globally, we are already very slightly beyond 1 degree C of warming. Thus, stopping at 1.5 degrees C means reducing *cumulative* global emissions by about one-half compared to 2 degrees C. (Because if you want temperature increase to be only half a degree below the 2-degree C level, that is half the emissions of a 1-degree C rise.) (Climate Analytics 2015) This reduction has not been allocated across countries, but one way to do it would be to start with national plans to stop warming at 2 degrees C and then cut the cumulative emissions by half. Cumulative CO_2 emissions from 2015-2050 in the NRDC scenario are 107 gigatons (GT), indicating a budget of roughly 50-55 GT of CO_2 emissions for a 1.5-degree C scenario.

SEM programs can provide substantial financial incentives and/or mandatory savings requirements, which would address several key barriers to industrial sector efficiency that existing incentive programs do not (DOE 2015a). Most existing government programs, such as SEP and Energy Star, rely on purely voluntary commitments, devoid of financial incentives, and on the provision of technical information (often with insufficient budget to meet client demand).

Most utility SEM programs as of 2017 focus solely on behavioral change and improvements to O&M. While they encourage interest in equipment upgrades indirectly through improved energy planning, they do not offer more innovative, custom programs that encourage deeper savings, such as thorough process-engineering approaches that consider redesigns of whole systems or fundamental processes. Instead, to date, they have merely referred customers to pre-existing, generally widget-based, industrial efficiency incentives.

Analyses of how to realize additional savings from the industrial sector are constrained by two major factors: first, there is a dearth of efficiency program design concepts for this sector. This failure is even more apparent when considering the buildings sector, where there are decades of research on the energy and emissions impact of building energy codes, equipment efficiency standards, normative labeling (e.g., Energy Star, LEED) (USGBC 2016), informative labeling (e.g., HERS ratings) (RESNET 2017), financial incentives, financing reform, and behavior change programs. For industrial SEM, the number of utilities or government agencies running programs in North American is fewer than 30, and many of these programs are small or non-incentivized (DOE 2015b). Thus, there is relatively little operational experience with SEM.

The second constraint from fully capturing the role of industrial efficiency is the fact that efficiency potential studies almost exclusively rely on data available outside the factory fence. The details of production techniques and processes that would be needed for an in-depth analysis are unavailable to researchers in most cases, and could violate non-disclosure agreements were they to be used to guide more in-depth studies.

Even the more aggressive potential studies of the industrial sector project no more than about 20 percent savings over about 20 years compared to business-as-usual (NAS 2010). In contrast, a study of the DOE program on SEM—Superior Energy Performance (SEP)—found savings averaging 14 percent compared to the baseline (or 11 percent compared to BAU) in just one year (Therkelsen et al. 2015). The range of variation in that study was large: one review of SEP participants cited in the study found an average of almost 30 percent savings over the three-year DOE cycle. These case studies speak to a much greater savings opportunity than efficiency potential studies indicate.

The role of SEM in meeting the more aggressive 1.5-degree C target will require significant expansion in both the breadth and depth of SEM. The vast majority of industrial facilities will need to participate to meet U.S. emissions goal. This is an expansion of several orders of magnitude. However, it is not infeasible. Strong financial incentives in Germany have led to many ISO 50001 certifications quickly. One potentially straightforward approach would be to add more utilities or efficiency program administrators to programs like SEP and to provide much more substantial funding for these critical programs. Scaling up existing efforts has an advantage from the perspective of limiting cumulative climate emissions. Current published literature, some of which is cited above, as well as informal reports from conferences and SEM planning meetings, shows that large savings can be achieved in the initial 1-3 years of the program. Roughly half of the reported savings has come from operational improvements that cost very little and, more importantly, have not been addressed by previous financial incentive programs.

The programs should also seek to maintain the high rates of progress seen initially over a longer period. Organizations engaged in SEM have been able to maintain near-constant rates of annual energy performance improvement for the length of their participation (Therkelsen et al. 2015). This is supported by the experience of a senior manager of a larger SEM incentive program, who suggested that a reasonable 10-year target for program participants was 25-40 percent energy savings. At least one pilot program has achieved 5 percent annual savings (3M 2012). If industrial partners achieved savings in line with these experiences, industry could obtain energy savings at substantially higher levels than indicated in Table 2. Industrial energy use is only reduced by 8 percent in the first 15 years under the NRDC scenario, substantially less than the 25-40 percent savings over 10 years. Assuming the same changes in emissions intensity, achieving a 25 percent energy reduction in 2030 (compared to reference) would reduce carbon emissions by another 176 MMT in 2030; achieving instead a 40 percent reduction would reduce carbon emissions by 370 MMT in 2030 – more than the annual emissions of the industrial sector under a 2-degree C scenario in 2050. These energy savings can yield even greater emission savings when combined with cleaner fuels, electrification, and fuel-switching measures.

Expanded SEM programs should also focus more intensively on whole-system improvements that go beyond the widget-based programs that currently dominate the financial incentives world. This will likely necessitate stronger interpersonal relationships between the program administrator and the top management of the industrial organization, both to maintain the program long-term and to encourage staffing that includes the engineering talent needed to make fundamental changes in process (Vetromile and Grossman 2008). It is harder to do process engineering changes when the management not only lacks the engineering resources to do the analytic and design work in-house, but also lacks the experience to write a good Request for Qualifications for someone from outside to do the work.

There are four time scales on which SEM can work:

- Day-by-day, which includes behavioral changes to improve energy performance;
- Monthly, such as changes in O&M procedures;
- Annually, such as retrofits of equipment;
- And over decade-long timescales, which includes some capital projects (Vetromile 2011).

Engaging management, such as Board of Directors, C-suite, or plant managers, may be helpful in assuring continuity of SEM efforts and in making sure that the once-in-ten-year upgrade cycle includes energy performance considerations and that the efficiency dimension is not forgotten over the intervening years.

This continuing top-management engagement—indeed, enthusiasm—is important for several reasons. First, it turns out to be common for changes in top management commitment to lead to withdrawal from SEM programs: in one study the mean retention time in SEM programs was only 4.5 years (Vetromile 2015).

Second, if we want to move beyond payback periods of 1.5 years or so typically used to evaluate efficiency investments (Therkelsen et al. 2015), to a present-value based criterion, it will require top management intervention to free up the necessary capital. The authors have never found an analytically satisfying explanation of why efficiency projects face hurdle rate of several times the true cost of capital to an industrial firm, and have argued that psychological factors such as risk aversion, or peer pressures generated by a management perspective that favors next-quarter results to long-term results, provide a stronger explanation than anything based on economic rationality (Goldstein 2007). But top management commitments can add a decision-making rule that that compensates for risk-averse behavior (Kahneman 2011).

Thirdly, it takes significant strategic planning and budgeting efforts, as well as strong attention from operational managers and financial planners, to set up and execute plans for significant process improvements during the once-in-a-decade capital project cycle (Pierett

2012). In the past, such opportunities have been lost due to predictable problems, such as change in staffing at the plant manager or chief engineer (if there is one) level at the host facility, or at the customer representative level for the utility serving the plant

The level of expansion proposed here has effects that cannot be modeled robustly at this time due to lack of experience: how broadly and deeply can SEM participation be expanded, and are there any unanticipated side effects? For the buildings sector, we have had, over the past 40 years, numerous pilot projects testing the hypotheses of much deeper and broader savings based on whole-system or whole-building perspectives, as well as pilots that included behavioral improvements as well as engineering improvements. For the industrial sector, in contrast, we should ask the question: "how strongly can industry leaders and government and utility policy-makers encourage results that we have never seen systematically before?" The framing of the question suggests that we cannot know the answer based on observation or modeling.

Conclusions

SEM is included to some extent in the 2-degree C scenarios, but its success is predicted to be no larger than outcomes that have already been achieved and documented in the literature. Yet the experience to date in the U.S. has been limited to programs relying only on recognition (nationally) or on modest enhancements of pre-SEM industrial programs (regionally).

Additional large savings could be achieved if the observed savings seen in these voluntary programs were applied to a much larger fraction of the industrial sector. As discussed, if the entire industrial sector was to achieve annual energy savings in-line with those achieved by SEM participants, the sector could reduce carbon emissions by another 150-350 MMT by 2030 compared to NRDC's 2-degree C scenario. Not only are these emission reductions significant, but these savings could occur in the near-term, when their value in reducing cumulative emissions is highest, not only because the emissions reductions occur more quickly, but also because the overall supply of electricity (and to a lesser extent gas as well) is dirtier than it will be in future decades.

Another source of large additional savings is the prospect that capital projects can be designed from a more systematic perspective. This includes the creation of corporate plans and policies that ensure that actions will be taken during future capital upgrade cycles and that they will look creatively at fundamental process changes (including fuel switching), as well as incremental improvements; and without the constraint of unjustifiably short payback periods.

It is hard to define quantitative assumptions that will allow the prediction of emissions savings because the experiential base does not exist: ambitious and strongly incentivized SEM has not been done. But the inability to defensibly choose any specific numerical value for additional savings also rules out one assumption that is implicitly (and often unwittingly and unrecognizably) made in virtually all models: that the additional savings in emissions (beyond those in 2-degree C scenarios) are zero.

SEM offers the opportunity to encourage innovation in industrial energy efficiency in ways that we have never seen before, and can be a key component of a successful global program to limit climate change to 1.5 degrees C.

References

California ISO. 2017. "Renewables Watch." May 13, 2017. http://content.caiso.com/green/renewrpt/20170513_DailyRenewablesWatch.pdf.

Climate Analytics. 2015. *Timetables for Zero emissions and 2050 emissions reductions: State of the Science for the ADP Agreement*. Berlin: Germany.

DOE (Department of Energy). 2014. "DOE eGuide". Accessed March 2, 2015. www.energy.gov/eere/amo/articles/doe-eguide.

DOE. 2015a. "Barriers to Industrial Energy Efficiency—Report to Congress." Washington, DC: U.S. Department of Energy

DOE. 2015b. "Industrial Superior Energy Performance (SEP) Ratepayer-Funded Accelerator". www.energy.gov/sites/prod/files/2015/09/f26/Factsheet.pdf.

EIA (Energy Information Administration). 2013. *Annual Energy Outlook 2013 with projections to 2040*. April 2013.Washington, DC: EIA. www.eia.gov/outlooks/aeo/pdf/0383(2013).pdf.

E3, PNNL, and LNBL. 2014. U.S. 2050 Report: Pathways to Deep Decarbonization in the United States. http://unsdsn.org/wp-content/uploads/2014/09/US-Deep-Decarbonization-Report.pdf

Goldstein, D. B. 2007. *Saving Energy, Growing Jobs: How Environmental Protection Promotes Economic Growth, Profitability, Innovation, and Competition*. Bay Tree Publishing, Point Richmond, California.

Goldstein, D. B. 2017. "A Jobs and Infrastructure Program to Arrest Climate Change." *Electricity Policy*, February.

ISO (International Organization for Standardization). 2011. *Win the energy challenge with ISO 50001*. ISO 2011-06/3 000, ISBN 978-92-67-10552-9.

Kahneman, D. 2011. *Thinking, Fast and Slow*. New York: Farrar, Straus and Giroux.

Laitner, J. A., S. Nadel, N. Elliott, H. Sachs, A. S. Khan. 2012. *The Long-Term Energy Efficiency Potential: What the Evidence Suggests*. Washington, DC: American Council for an Energy-Efficient Economy. aceee.org/research-report/e121.

NAS (National Academy of Sciences). 2010. *Real Prospects for Energy Efficiency in the United States*. Washington, DC: The National Academies Press. doi:https://doi.org/10.17226/12621.

NRDC (Natural Resources Defense Council). 2017. "Paving the Pathway To Zero Carbon: Deep Decarbonization Strategies for the U.S. Energy System". Forthcoming June 2017.

Pierett, Steve. 2012. *Volvo Certification of an Integrated ISO 14001 and ISO 50001/SEP System Presentation*. Department of Energy.

RESNET 2017. "What is the HERS Index?". www.resnet.us/hers-index.

The White House. 2015. “Fact Sheet: U.S. Reports its 2025 Emissions Target to the UNFCCC.” Available at: www.whitehouse.gov/the-press-office/2015/03/31/fact-sheet-us-reports-its-2025-emissions-target-unfccc.

The White House. 2016. “United States Mid-Century Strategy for Deep Decarbonization”. https://obamawhitehouse.archives.gov/sites/default/files/docs/mid_century_strategy_report-final.pdf

Therkelsen, P., A. McKane, R. Sabouni, Y. Tamm, P. Rao, and P. Scheihing. 2015. “Development of an Enhanced Payback Function for the Superior Energy Performance Program.” In *Proceedings of the ACEEE 2015 Summer Study on Energy Efficiency in Industry*. Washington, DC: ACEEE.

Trabish, H. 2016. “SPP notches back-to-back wind generation records”. Utility Dive, March 9. www.utilitydive.com/news/spp-notches-back-to-back-wind-generation-records/415279/.

UNFCCC (United Nations Framework Convention on Climate Change). 2015. *Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015*. See C.N.63.2016.TREATIES-XXVII.7.d of 16 February 2016 (Opening for signature) & C.N.92.2016.TREATIES-XXVII.7.d of 17 March 2016 (Issuance of Certified True Copies). unfccc.int/resource/docs/2015/cop21/eng/10.pdf#page=30.

UNFCCC. 2016. *The Paris Agreement*. unfccc.int/paris_agreement/items/9485.php.

USGBC (U.S. Green Building Council). 2016. “Benefits of Green Building”. www.usgbc.org/articles/green-building-facts.

Vetromile, J. and M. Grossman. 2008. “The Role of Process Engineering in Reducing Greenhouse Gas Emissions.” Air & Waste Management Association’s Annual Conference and Exhibition, Paper # 636. Presented 6/26/08 Session ES-4b(2).

Vetromile, J. 2011. “Powering Up Existing Tools to Accelerate Efficiency in Industry.” In *Proceedings of the ACEEE 2011 Summer Study on Energy Efficiency in Industry*. Washington, DC: ACEEE.

Vetromile, J. 2015. “What Gives SEM Staying Power?” In *Proceeding of ACEEE 2015 Summer Study on Energy Efficiency in Industry*. Washington, DC: ACEEE.

3M. 2012. *ISO 50001/SEP Case Studies Presentation*. Department of Energy.