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Environmentally beneficial electrification: The dawn of 'emissions efficiency'☆,☆☆

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1. Introduction

The nature of the electricity grid is changing dramatically, as are our nation's environmental goals, so our policy thinking needs to change profoundly, too. Mounting research suggests that aggressive electrification of energy end uses – such as space heating, water heating, and transportation – is needed if the United States and the world are to achieve ambitious emission reduction goals for carbon dioxide. This concept, the electrification of energy end uses that have been powered by fossil fuels (natural gas, propane, gasoline, diesel, or fuel oil) in order to reduce greenhouse gas emissions, is called "environmentally beneficial electrification."[1]

Achieving the greenhouse gas emissions reductions possible through environmentally beneficial electrification will require routinely revisiting and updating prevailing energy efficiency metrics and accounting methodologies in order to maximize gains. Specifically, it is timely to consider whether reduced electricity consumption (i.e., kWh) is the optimal compass with which to navigate the path to a low-carbon future when, in fact, substitution of electricity for fossil fuels may in some cases *increase* electricity consumption.

Policy goals are shifting from the simple energy conservation focus of yesteryear toward achieving greenhouse gas (GHG) reductions. Therefore, we need to assess the GHG emissions associated with various ways to power end uses, as opposed to simply the number of kilowatt-hours consumed. To that end, we submit that "emissions efficiency"[2] may be as or more important than "energy efficiency" moving forward.

Beyond ensuring that our efficiency metrics and policies promote positive environmental outcomes and produce less CO_2, it is also imperative that they not create *disincentives* to achieving GHG emissions reductions through the electrification of loads that are less carbon-intensive than existing practices. Replacing a fuel oil heating system in a single-family residence with electric heat pump technology, for example, would typically reduce emissions, improve comfort, and save the owner money. But such replacements may not be encouraged under the Clean Power Plan (CPP) due to the statutory constraints the U.S. Environmental Protection Agency (EPA) faces implementing it under section 111(d) of the federal Clean Air Act (CAA). This article expands upon environmentally beneficial electrification, introduces the concept of emissions efficiency, and considers how the design of the CPP could impede opportunities for environmentally beneficial electrification. Because environmentally beneficial electrification is necessary to achieve our nation's GHG emission reduction goals, states must find ways to encourage it. Notwithstanding the uncertain judicial future of the CPP at this time, several steps to boost environmentally beneficial electrification reflect "no regrets" strategies that should be encouraged and implemented even in the absence of a clear regulatory regime.

2. Growing consensus for environmentally beneficial electrification

Consensus is growing that meeting aggressive GHG reduction goals will require electrification of end uses such as space heating, water heating, and transportation. A recent report by Environmental and Energy Economics (E3) states that "critical to the success of long-term GHG goals" is "fuel-switching away from

☆As the U.S. works to meet carbon reduction goals, 'environmentally beneficial electrification' will be required. Rather than focusing solely on reducing energy consumption, we must generate electricity using more resources that emit little or no CO_2 and power more end uses with electricity. To this end, 'emissions efficiency' may be an important and effective metric for the electric sector moving forward.

☆☆This article and the opinions within are the responsibility of the authors and do not necessarily represent the opinion of their respective organizations.

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[1]Dennis, K. 2015. "Environmentally Beneficial Electrification: Electricity as the End-Use Option." Electricity Journal 28(9): 100–112.

[2]The term "emiciency" could be used as a newly coined word and applied as a short-hand term for "emissions efficiency." Greater emissions efficiency reflects fewer emissions created per unit of useful output of an energy-consuming service. For example, fewer pounds of CO_2 emitted per mile traveled by a car or fewer pounds of CO_2 emitted per gallon of hot water provided by a water heater.

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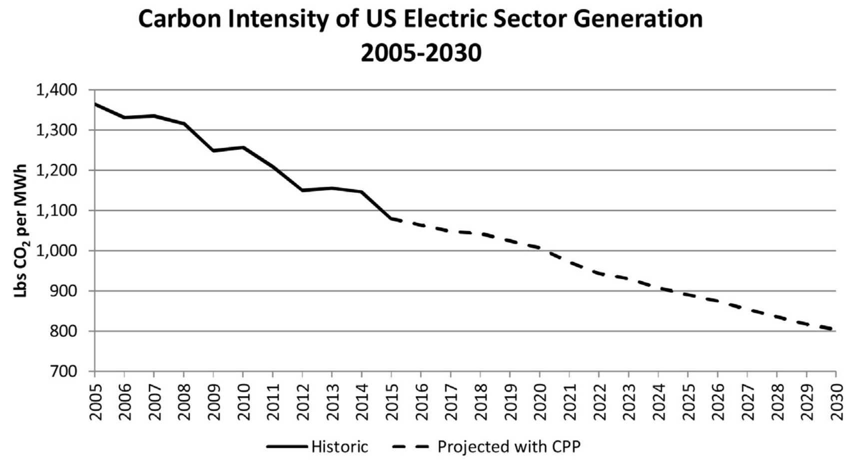

Fig. 1. Carbon intensity of U.S. electric generation, 2005–2030.[13]

fossil fuels in buildings and vehicles."[3] Lawrence Berkeley National Laboratory similarly concludes that "widespread electrification of passenger vehicles, building heating, and industry heating" is essential for meeting California's GHG reduction goals.[4] Work at Stanford University also indicates that "one potential way to combat ongoing climate change, eliminate air pollution mortality, create jobs and stabilize energy prices involves converting the world's entire energy infrastructure to run on clean, renewable energy."[5]

The United Nations Sustainable Development Solutions Network's *Deep Decarbonization Pathways Project*, the California Council of Science and Technology,[6] the Acadia Center's *EnergyVision report*,[7] experts like Jeffrey Sachs of Columbia University,[8] and even Bill Nye the Science Guy have all added to this chorus.[9] Many other researchers around the globe are echoing the same conclusions. The consensus on environmentally beneficial electrification, it seems, is in.

3. What's behind the trend toward environmentally beneficial electrification?

Our earlier article, *Environmentally Beneficial Electrification: Electricity as the End-Use Option*,[10] outlined major trends in the electric power industry that are enhancing the opportunity to electrify end uses as a means to reduce GHG emissions. They are worth revisiting here.

First is **the adoption and implementation of public policy goals to achieve GHG emissions reductions**. In 2009, the U.S. established a national goal to reduce overall GHG emissions approximately 17% below 2005 levels by 2020. Many states have also adopted individual GHG reduction goals.[11] Minnesota and California, for example, have set an 80% GHG reduction goal by 2050. The nine states comprising the Regional Greenhouse Gas Initiative (RGGI) originally imposed a cap on GHG emissions from their electric generation units in January 2009, then further reduced that cap from 165 million short tons to 91 million tons in 2014 with an additional 2.5% annual reduction until 2020. These targets have significantly impacted the Northeast electricity grid, producing a lasting impact on that region's GHG emissions profile.

The second trend is **the lowering of GHG emissions rates of the U.S. electric sector overall due to technology advances and cost reductions of cleaner electric generation**, as well as policy goals. Fig. 1 shows the actual and projected carbon intensity of U.S. electric generation from 2005 to 2030. The reduction shown is unprecedented in history. According to EIA, non-emitting renewable and nuclear sources provided about 33% of U.S. electricity production in 2015, the highest share on record.[12]

This trend has major implications: end uses that traditionally would have created more emissions if powered by electricity are at or near a tipping point where their electrification would create fewer emissions than if they were powered using fuel oil, natural gas, propane, or gasoline. Furthermore, the environmental performance of end-use electric equipment will improve over the lifetime of the product, assuming the trend shown in Fig. 1 continues. The same cannot be said for end-use products that directly burn fossil fuels; their emissions are constrained by the laws of thermodynamics, and will remain constant (or possibly worsen due to degradation) over their lifetime.

The third trend generating abundant opportunity for environmentally beneficial electrification is **the significantly increased efficiency of end-use equipment itself**. The availability and performance of heat pump technology, for instance, which is often

[3] Borgeson, Sam. Haley, Ben. Hart, Elaine. Mahone, Amber. Price, Snuller. Ryan, Nancy. Williams, Jim. 2015. "California PATHWAYS: GHG Scenario Results." *Energy + Environmental Economics*.

[4] LBNL. 2013. California's Carbon Challenge Phase II Volume I: Non- Electricity Sectors and Overall Scenario.

[5] Jacobson, Mark Z. 2015. "Stanford Engineers develop state-by-state plan to convert U.S. to 100% clean, renewable energy by 2050". *Stanford News*.

[6] California Council on Science and Technology. 2013. Policies for California's Energy Future - Electricity Pricing and Electrification for Efficient Greenhouse Gas Reductions.

[7] Acadia Center. "A Pathway to a Modern, Sustainable, Low Carbon Economic and Environmental Future." 2014.

[8] Johan Rockström and Jeffrey D. Sachs, "Sustainable Development and Planetary Boundaries," Background paper for the High-Level Panel of Eminent Persons on the Post-2015 Development Agenda.

[9] Rodriquez, Ashley. 2015. "Science Guy Bill Nye's radically simple blueprint for ending Climate Change." Quartz.com.

[10] Dennis supra note 1.

[11] Thirty-seven states have adopted binding or voluntary renewable energy requirements or goals. These and other policies to increase renewable electric generation in order to reduce GHG emissions continue. The U.S. recently set a goal of 20% non-hydro renewables by 2030 up from 7%, which was achieved in 2014.

[12] Wiman, Channele. 2016. "Carbon Dioxide emissions from Electricity generation in 2015 were lowest since 1993". *Independent Statistics and Analysis, U.S. Energy Information Administration*.

[13] "Project level" GHG accounting, as opposed to "organizational level" GHG accounting, seeks to quantify, monitor, and report the results of actions to reduce or avoid increases in GHG emissions no matter where they occur. Because environmentally beneficial electrification reduces emissions outside the traditional "boundary" of the electric sector, project accounting is needed to account for its emissions reductions.

200% to 300% efficient at converting electricity into heat and hot water for homes and businesses,[14] offers great opportunity for electrified loads to reduce emissions compared to fossil powered alternatives.

The fourth electrification trend is **the growing need for "flexiwatts"[15] to enable greater integration of renewable energy into the electric grid**. Historically, utilities created reliable electricity grid systems by building and operating supply-side resources (e.g., coal, nuclear, and natural gas) to match the energy demand consumers placed on the system. Grid operators exercise far less control, however, over renewable energy resources, specifically when wind and solar resources are available to the system. Because electricity cannot yet be economically stored at grid scale, variability of supply must be balanced with the ability to vary demand. It thus becomes far more important – and far more valuable – to control the load side of the equation by managing the operation of electric loads that possess energy storage capabilities (e.g., electric water heaters, electric vehicles).[16] These "flexiwatt" loads can be called upon to "absorb" the power generated by renewable, non-emitting electricity when the sun is shining or the wind is blowing, and can be quickly shed when they are not. Optimization of demand-side resources will be crucial to keeping electricity reliable and affordable as large amounts of renewable generation are added to the grid. Thermal loads, such as space conditioning and water heating, are excellent candidates for storage (in the form of ice, chilled water, and hot water), allowing loads to operate when power is available, and still deliver end-use energy services when heating or cooling are desired.

4. Revisiting 'energy efficiency' as a metric to drive GHG emission reduction strategies

Whether a matter of policy or strategy, maximizing GHG emissions reductions hinges on the development of easy-to-use metrics that capture the cross-sector emission reductions associated with environmentally beneficial electrification.

Environmentally beneficial electrification is not only essential to meeting GHG reduction goals, it also provides a significant economic opportunity, and we need to consider pathways, policies, and actions to foster it. Of paramount importance initially is to identify how progress should be measured.

Consider the "energy efficiency" of an electric water heater in terms of gallons of hot water produced per kWh, or an electric vehicle in terms of miles driven per kWh. Typically their energy efficiency will not change significantly over their operating lifetimes: an electric vehicle produced today will operate with roughly the same miles-per-kWh in 10 years as it does now. Due to the declining carbon intensity of the grid as shown in Fig. 1, however, these devices will become more "emissions efficient" over time; the electric vehicle will emit *less* CO_2 per mile in 10 years than it does today. Moreover, both electric vehicles and electric water heaters can be flexibly managed to charge when low-cost or renewable energy is available, providing additional opportunity to secure economic and environmental benefits.

Traditionally, state and federal energy efficiency efforts for electricity have focused on reducing kWh consumed by electricity end-users, and separately, on reducing therms consumed by natural gas end-users and gallons consumed by petroleum end-users. Motivated largely by the oil shocks of the 1970s, early policies essentially sought to conserve primary energy, including shifting loads from electricity (typically produced from fossil fuels at less than 40% efficiency) to direct use of natural gas (at efficiencies of 60% to 80%). More recently, as climate threats have become evident, the goal of reducing GHG emissions has become as important as primary energy conservation. This change in focus – from seeking fewer kWh used to fewer tons of CO_2 emitted – has also been paralleled by increased natural gas generation (which emits about half as much CO_2 as coal) and greater penetration of renewable energy resources (which typically emit no greenhouse gases).

Despite this change in focus, kWh saved through energy efficiency is regularly applied as a proxy for GHG emission reductions because it's the "way we have always done it." This is another case where conventional wisdom lacks wisdom: energy efficiency is an inadequate metric to measure technology performance when it comes to GHG emissions.

Energy efficiency ratings of electric products have been based on the amount of kWh used per unit of service, such as amount of heat or hot water produced per kWh consumed. This is important, of course, but an equally important – and often overlooked – driver of emissions is what generation source produced those kWhs. Today, it matters less how *much* electricity is used than how that electricity is generated. Generation, in turn, depends heavily on *when* the electricity is used, because grid operators often dispatch higher-emitting generation resources to meet higher system loads.

In short, a kWh of energy savings reported by an energy efficiency program or consumed by an electric product might have been produced by a number of generation sources, be it wind, solar, nuclear, gas, hydro, or coal. These savings may be cost-effective and desirable, because all electricity has a cost, but the direct economic cost is only a part of the *emiciency* picture. ("Emiciency" is a new proposed shorthand term for "emissions efficiency"). Kilowatt-hours from different sources have vastly different emissions profiles, ranging from as much as 2 pounds of CO_2[17] to as little as no CO_2 at all. Because traditional "energy efficiency" metrics ignore this dramatic variability, it would seem that "emissions efficiency" is as materially relevant a metric as "energy efficiency" for managing GHG emissions.

Metrics matter. If policies like energy efficiency resource standards, appliance efficiency standards, rebates, and other incentives are measured simply with kWh consumption metrics, we may miss out on many cost-effective GHG emission reduction opportunities from fuel conversions. We stand on the verge of massive opportunities for environmentally beneficial electrification, but recognizing and realizing those opportunities will not be achieved through an indiscriminate focus on reducing kWh consumption.

5. Will the Clean Power Plan discourage environmentally beneficial electrification?

Renewable energy features prominently among the options available for states and sources to comply with the CPP. EPA has

[14] Heat pumps use electricity to move heat from one place to another instead of generating heat directly. To move the heat, heat pumps work like a refrigerator in reverse. By using electricity to move heat out of surrounding air, it can deliver two to three times more heating energy than the electricity it uses, thus the technology is 200–300% efficient at heating space and water. For additional information on heat pumps, see two 2016 reports by ACEEE: "Comparative Energy Use of Residential Gas Furnaces and Electric Heat Pumps (Research Report A1602), and "Opportunities for Energy and Economic Savings by Replacing Electric Resistance Heat with Higher-Efficiency Heat Pump" (*Research Report A1603*).

[15] Dyson, Mark. Mandel, James. 2015. "The Economics of Demand Flexibility." *Rocky Mountain Institute*.

[16] For a quick explanation of how this works, see the April 2016 Popular Science article and video Deaton, Jeremy. 2016. "Your Water Heater Can Become a High-Power Home Battery." PopularScience.com.

[17] Based on 2000 pounds of CO_2 per MWh, an emissions rate typical of coal generation.

also indicated that energy efficiency can be used as a compliance option. It is not clear that environmentally beneficial electrification will enjoy similar standing, however, potentially risking one of the most consequential GHG emission reduction opportunities available. As noted earlier, achieving the GHG reductions necessary to address climate change will require that significant amounts of space heating, water heating, and transportation be electrified. Adding these electric loads to an increasingly clean grid will reduce overall emissions compared to their fossil-fuel-burning counterparts. Such additions could be discouraged, however, by the source-specific focus of CAA section 111(d) and, correspondingly, the CPP. Section 111(d) requires emissions reductions from electricity generating sources only, thus discouraging the addition of new electric loads even when overall GHG emissions drop. As a result, electrification measures may be discouraged that would create net emissions reductions from chimneys, flues, and vehicle tailpipes, but could increase power sector emissions marginally. This could happen, for instance, if natural gas generation were used to balance the system when renewable resources do not produce sufficient power at certain times or places.[18]

To illustrate this potential CPP disincentive, consider a hypothetical electric service territory with a population of 100,000 consumers. Assume the electricity mix serving this hypothetical territory is 50% coal-fired, 40% combined-cycle gas turbine, and 10% gas-fired combustion turbine. Like most populations throughout the U.S., the residents of this territory use a mixture of fuel oil, electric resistance heaters, electric heat pumps, propane, and natural gas to heat their homes and water, and gasoline and diesel to power their cars. In this example, the population undertakes environmentally beneficial electrification projects in which 65,000 (65%) of the consumers upgrade their heating systems to electric heat pumps, 74,000 (74%) upgrade their water heaters to electric heat pumps, and 14,234 (14%) switch to an electric vehicle. The technology used by the consumers both before and after these environmentally beneficial electrification activities is shown in Table 1.[19]

As a result of the technology changes toward greater electrification shown in Table 1, the number of kWh consumed in the service territory would remain constant, but CO_2 emissions from space and water heating and transportation would drop by 25%. Basically, the electricity savings from improving the efficiency of existing electricity end uses is redirected to displace existing uses of natural gas, propane, and petroleum. Prior to and after the change, the utilities serving the territory would sell the same number of kWh, which could be generated by the same power plants, and conveyed over the same distribution lines. The total number of warm houses, hot showers, and miles driven would also unchanged, but 25% fewer emissions would be produced, by reducing emissions from fossil fuels used for space and water heating and for transportation. Thus, the "emissions efficiency" of meeting the space, water, and transportation needs of the community would improve by 25% as a result of environmentally beneficial electrification. These emissions results are outlined in Table 2.

This example illustrates the complementary nature of traditional energy efficiency and environmentally beneficial electrification. Gas, propane, and natural gas water and space heating is switched to heat pump electric technology, which lowers direct emissions from combustion of fossil fuel and increases kWh consumption. Similarly, gasoline and diesel vehicles are switched to electric vehicles, which also lower direct emissions from combustion of fossil fuel while increasing kWh consumption. Electric resistance space in water heating is also switched to heat pump technology, which reduces kWh and lowers emissions. In this case the kWh consumption before and after the transformation are set equal for illustrative purposes, while GHG emissions are reduced 25% across the community. If additional gas- or diesel-powered vehicles were switched to electric vehicles or additional fossil-fuel-fired water heaters were switched to heat pump water heaters in this example, the kWh consumption would increase as would emission reductions.

Under this scenario, the service territory would not comply with the Clean Power Plan as a "rate-based" area, because its CO_2 emission rate per MWh would not change. Similarly, the territory would not comply as a "mass-based" area because tons of *electric system* CO_2 emissions would also be unchanged. Yet the underlying climate objectives of the CPP would be well served by its 25% reduction in emissions. Further, the presence of new, controllable electric loads would help ensure that the grid system balance would remain equal or better than in the baseline case, there would be no incremental dispatch or reliability challenges, and the utilities would face no adverse revenue impact from the efficiency shifts introduced by the environmentally beneficial electrification scenario. Regardless of any changes to federal policy that might address this conundrum, states have substantial ability to incorporate economy-wide environmentally beneficial electrification in their plans to address future federal GHG emission limits.

Table 1
Technologies used by consumers before and after environmentally beneficial electrification example.

		Thousands of Consumers	
		Prior to Electrification	After Electrification
Space Heat	Oil	20	5
	Electric Resistance	35	10
	Electric Heat Pump	10	75
	Natural gas	35	10
Water Heat	Propane	5	2.5
	Electric Resistance	49	10
	Electric Heat Pump	1	75
	Natural Gas	45	12.5
Vehicles	Electricity	0	14.2
	Gasoline	90	80.8
	Diesel	10	5

Table 2
Emissions efficiency results of environmentally beneficial electrification example.

	CO_2 Emissions (Thousands of Short Tons)	
	Prior to Electrification	Results
Electricity	533	533
Oil	111	28
Propane	8	4
Natural Gas	244	69
Gasoline	238	213
Total	1134	847
CO_2 Emissions Reduction		25%

[18] As noted earlier, there is hope that environmentally beneficial electrification can be pursued by states through the flexibility the Clean Air Act offers states in developing their CPP compliance plans should the plan survive legal challenges.

[19] This simplified analysis was designed by Jim Lazar using standard assumptions for various technologies and fuel conversions. Details of the analysis are available in the accompanying "Supplementary materials and Calculations for the Research Article: Environmentally Beneficial Electrification: The Dawn of 'Emissions Efficiency'.

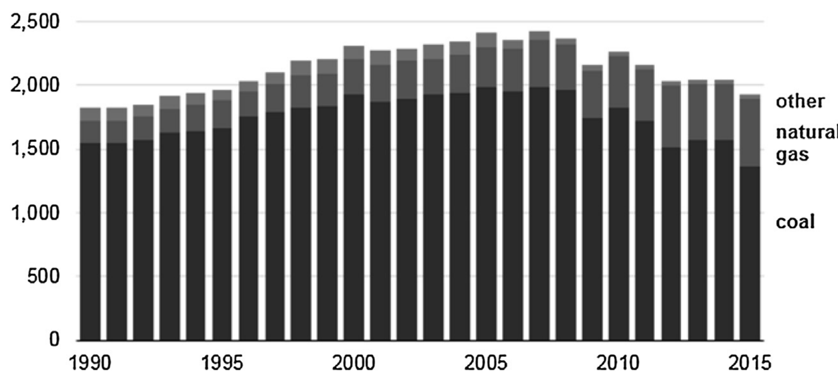

Fig. 2. Total mass carbon dioxide emissions from the U.S. electric power sector, 1990–2015 (million metric tons).[21]

6. Electric sector emissions and environmentally beneficial electrification

How we analyze and present emissions from the electric power sector is critical to understanding the role it will play in the broader landscape of a carbon-constrained world. Fig. 2 is a chart released by the U.S. Energy Information Administration (EIA) in May 2016 showing that total carbon dioxide emissions from the electric power sector returned to 1993 levels in 2015, the lowest they have been in more than two decades. Such graphs are often used to depict power sector emissions trends, in such documents as the U. S. Department of Energy's (DOE) Quadrennial Energy Review (QER) briefing materials.[20]

Unfortunately, like the rate-based chart in Fig. 1, this mass-based graphic also fails to recognize the impact of environmentally beneficial electrification. Fig. 1, which illustrates the declining carbon intensity of U.S. electricity generation, certainly provides a more encouraging picture of the electricity grid's GHG emissions progress. But both figures omit any consideration or quantification of the benefits of environmentally beneficial electrification. Neither metric captures the amount of services provided by the electric sector nor the emissions impacts of electrifying those services instead of combusting oil, gasoline, propane, or natural gas to meet those energy needs.[22]

The electric sector emissions data presented in Fig. 2 can be readily misinterpreted as suggesting that power sector emissions have not improved significantly since 1993. Yet, as NRDC notes in a May 2016 blog post, "since 1993—the last time power sector emissions were this low—U.S. GDP (real) has grown at a healthy clip of 2.5% [per year] on average."[23] According to EIA, the U.S. power sector produced 28% more electricity (or 890 billion more kWh) in 2015 than it did in 1993–with the same amount of emissions.[24]

Our current emissions metrics do not provide a clear picture of either the impact of producing this much more electricity without increasing emissions or of the additional energy services that could be provided at the same level of emissions through environmentally beneficial electrification. To illustrate this point, if the U.S. power sector could replicate its past performance and produce yet another 890 billion kWh without increasing mass carbon emissions, it could electrify the 253 million vehicles currently powered by gasoline and diesel. This would trim about 1.3 billion short tons from U.S. CO_2 emissions,[25] more than 60% of the 2.1 billion short tons of CO_2 emissions released by the electric sector in 2015. In this hypothetical illustration, mass CO_2 emissions from the electric sector itself (as shown in Fig. 2) would not decline, but its emissions intensity would decrease roughly 18% (as reflected in Fig. 1). The annual carbon savings associated with this environmentally beneficial electrification would be well over 60%, however, and the "emissions efficiency" of the entire system (i.e., everything powered by the grid plus the amount of the transportation sector electrified) would increase dramatically.

7. The potential of environmentally beneficial electrification

According to EIA, "electric generating facilities expect to add more than 26 gigawatts (GW) of utility-scale generating capacity to the power grid during 2016. Most of these additions come from three resources: solar (9.5 GW), natural gas (8.0 GW), and wind (6.8 GW), which together make up 93% of total additions. If actual additions ultimately reflect these plans, 2016 will be the first year in which utility-scale solar additions exceed additions from any other single energy source".[26]

What if the new generation EIA anticipates is used to power electric vehicles, including public buses and trains, or air conditioning? Using reasonable capacity factor assumptions and emissions rates,[27] this new generation could produce 92.5 MWh per year at an emissions rate of about 0.19 short tons of CO_2 per MWh.[28] If operating at average capacity, the share of this generation from natural gas and other combustion would emit about 17.8 million short tons of CO_2 per year. These results are summarized in Table 3.

As estimated above, this new generation capacity could power over 26 million electric vehicles, reducing emissions from

[20] US DOE, QER 1.2: An Integrated Study of the U.S. Electricity System, Stakeholder Briefing Memo. February 4, 2016.

[22] Figs. 1 and 2 are both examples of GHG accounting at the "organization level" in the parlance of energy efficiency evaluation, measurement, and verification (EM&V) professionals. Emission reductions that occur outside the electricity sector (such as those from vehicle tailpipes or flue vents exhausting emissions from gas, propane, and fuel oil furnaces and water heaters in homes and businesses) are not included in this data. GHG emissions reduced through environmentally beneficial electrification of transportation and buildings do not show up.

[23] Steinberger, Kevin. "EIA: U.S. Power Sector Carbon Emissions Reach 22-year Low in 2015." NRDC blog April 22, 2016.

[24] According to EIA, the U.S. produced 3197 billion kWh in 1993, 4055 billion kWh in 2005 and 4087 in 2015. In 2015, 890 billion more kWh were produced than in 1993.

[25] LA Times, "253 million cars and trucks on U.S. roads; average age is 11.4 years," June 2014. Assuming 3500 kWh per year per vehicle. Using EPA's emissions estimate of about 4.7 t of CO_2 per vehicle per year from their "Green Vehicle Guide: Greenhouse Gas Emissions from a Typical Passenger Vehicle."

[26] EIA. Today in Energy. March 1, 2016.

[27] EIA. Frequently Asked Questions: How much carbon dioxide is produced per kWh when generating electricity with fossil fuels? (https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11). Note that this value is an average and is based on data from February 2016. New power plants are typically more efficient, so this number improves further as the generation fleet turns over.

[28] This could be considered the "incremental" emissions factors associated with adding new electric loads to the grid.

Table 3
Estimated MWh generation and emissions from expected 2016 generation additions.

Type	New Capacity (GW)	2015 Average Capacity Factor	Estimated Generation (MWh)	Emissions Rate (Short Tons/MWh)	Emissions (Short Tons)
Solar	9.50	28.6%	23,800,920	0.00	0.00
Natural Gas	8.00	56.3%	39,455,040	0.45	17,754,752
Wind	6.80	32.5%	19,359,600	0.00	0.00
Nuclear	1.10	92.2%	8,884,392	0.00	0.00
Petroleum and Other	0.30	1.3%	34,164	1.09	37,068
Hydro	0.30	35.9%	943,452	0.00	0.00
Total	26.00	40.6%	92,477,568	0.19	17,791,820

displaced gasoline and diesel use by roughly 137 million short tons of CO_2 emissions annually. Factoring in the 17.8 million short tons of increased emissions shown in Table 3, the net result would be an overall reduction in U.S. CO_2 emissions of more than 119 million short tons per year. Using the mass-based metric (tons, as shown in Fig. 2), emissions from this new 2016 generation would increase power sector CO_2 emissions by approximately 0.8%. Applying the carbon intensity metric (emissions rate or CO_2-per-MWh, as shown in Fig. 1), it would decrease power sector CO_2 emissions intensity by 1.4%. Incorporating the impacts of the environmentally beneficial electrification of 26 million vehicles, however, would decrease overall U.S. mass CO_2 emissions by 5.6% of current electric sector emissions.[29] This again reinforces the importance of finding a way to capture the benefits of electrification as a matter of policy.

8. Implementing and accounting for environmentally beneficial electrification: a "no regrets" strategy

The Clean Power Plan has been criticized for potentially discouraging the pursuit of environmentally beneficial electrification. The U.S. Supreme Court's stay of the CPP in February 2016 provided states and utilities with greater opportunity to identify, implement, and quantify GHG emissions reductions associated with environmentally beneficial electrification as part of an overall "no regrets" strategy. The following steps could be taken today to support implementation of environmentally beneficial electrification.

8.1. DOE and EPA should consider updating the "source" energy factor

As detailed by Dennis (2015),[30] the "source" energy metric[31] employed by DOE and EPA in energy efficiency policies and tools may warrant updating in light of the technology advancements and changing system mix characteristics noted earlier in this article. In joint comments responding to a DOE request for information[32] on this topic, the Natural Resources Defense Council (NRDC), National Rural Electric Cooperative Association (NRECA), Edison Electric Institute (EEI), and American Public Power Association (APPA) offered one possible route, outlining an approach through which EIA would annually develop and disclose a "fossil fuel source energy" metric and its calculation methodology. Whatever methodology is ultimately selected, its goal should be to provide an accurate and level playing field among all energy alternatives.

8.1.1. When accounting for emissions associated with the addition of new electric load, recognize that the emissions intensity of the grid is changing with time

Current emissions accounting methods typically reflect existing generation, often with outdated data. Such static approaches do not reflect the impacts of the grid's continuing fuel mix and technology improvements that reduce emissions over time. In calculating power sector emissions on a going-forward basis, state air quality agencies, energy efficiency program administrators, and other interested parties should apply emissions factors that reflect the changing nature of the generation fleet that will be serving the new electric loads.

8.1.2. As environmentally beneficial electrification is implemented, account for the emissions impacts that result from displaced direct combustion of fossil fuel

Accounting for environmentally beneficial electrification should include the impact of the entire project. Overall emissions reductions can be quantified by comparing emissions of the "project" scenario (i.e., the emissions associated with the electricity used post-electrification) to a "baseline" scenario (i.e., the emissions that would have occurred with the use of the traditional fossil-fuel combustion alternative).[33] Although electrification is focus of this article, state officials could broaden this approach to ensure that emission reductions associated with all fuel conversions (e.g., from distillate oil to natural gas as a heating fuel) are similarly recognized (e.g., through a BTU-oriented all-fuels program). Quantification should, of course, be mindful to balance the need for accuracy with the cost of measurement and verification. State air quality agencies, partnering with state energy offices, energy efficiency program administrators, and other interested parties should develop and apply "deemed emissions reductions" just as "deemed kWh savings" are often applied today in the evaluation, measurement, and verification (EM&V) of energy efficiency programs.

8.2. Move towards "emissions efficiency" in addition to energy efficiency (i.e., kWh saved) as a metric for projects targeting GHG emissions reductions

As noted earlier, a heat pump water heater may reduce kWh by 50% compared to a resistance water heater, but a heat pump water heater controlled so as to have its load met by PV during the middle

[21] Shenot, John. April 14, 2016. "It's Already Happening: New EIA Numbers Show a Utility Sector in Transformation." Available at www.raponline.org/its-aready-happening-new-eia-numbers-show-a-utility-sector-in-transformation/?sf_action=get_results&_sft_topic=climate-and-public-health.

[29] Details of the analysis are available in the accompanying "Supplementary materials and Calculations for the Research Article: Environmentally Beneficial Electrification: The Dawn of 'Emissions Efficiency'."

[30] Dennis supra note 1.

[31] The idea behind the "source" energy metric is to represent the total amount of raw fuel that is required to operate a building. It incorporates all transmission, delivery, and production losses associated with electricity use in buildings.

[32] In March 2016, DOE issued a request for information on "Accounting Conventions for Non-Combustible Renewable Energy Use" which may be a first step in updating the "source" energy metric. See DOE Docket ID EERE-2016-OT-0010 for details about DOE's request.

[33] "Project level" GHG accounting, as opposed to "organizational level" GHG accounting, seeks to quantify, monitor, and report the results of actions to reduce or avoid increases in GHG emissions no matter where they occur. Because environmentally beneficial electrification reduces emissions outside the traditional "boundary" of the electric sector, project accounting is needed to account for its emissions reductions.

hours of the day may reduce emissions 75% or more. The energy efficiency of the former is good, but the "emissions efficiency" of the latter is far better. It is important, particularly to state air quality agencies, to capture this "emiciency" opportunity in future program and policy planning.

9. Conclusion

Significant progress in reducing GHG emissions from the power sector is already underway,[34] but far greater progress is readily achievable – both economically and practically – by aligning public policies to reinforce this positive trend. Technological advances to reduce the number of kWh necessary to perform a service, for example, along with public outreach to increase uptake of such advances, are essential and certainly merit greater attention. The electricity thus freed up can be used to displace fossil energy use, further reducing GHG emissions.

Traditional energy efficiency metrics are increasingly obsolete, however. Staunch adherence to efficiency measured by energy savings alone (i.e., kWh saved), for instance, overlooks numerous opportunities to also reduce emissions through fuel conversions from fossil energy to efficient electric technologies powered by an increasing clean generation fleet (or from higher-emitting to lower-emitting fossil energy sources). The electric system is dynamic, and evaluating the impacts and benefits of electricity use is not a simple task. Metrics matter greatly, and it is important that they are effective and accurate. But no single metric can be pursued in isolation, whether it is energy efficiency, emissions efficiency, or any other individual metric. It is necessary to look at the system broadly, develop priorities (including safety, reliability, affordability, compliance environmental regulations, and economic development), and optimize the integrated system accordingly.

Without promptly addressing the challenges of finding appropriate metrics to measure emissions efficiency and environmentally beneficial electrification, we risk diminishing progress toward the very goals we seek. In order to simultaneously maximize cost savings and GHG emissions reductions, new metrics must incorporate not only energy-saving technologies – increasing the performance-per-kWh of devices – but also the processes, procedures, and policies governing how and when those devices use electricity and which of them currently powered by fossil fuel combustion might instead be electrified. There is at least as much promise in reducing emissions via the latter efforts as the former. Our economy and our climate demand that we use both, by pursuing optimal "emissions efficiency" strategies.

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[34] Shenot, John. April 14, 2016. "It's Already Happening: New EIA Numbers Show a Utility Sector in Transformation." Available at www.raponline.org/its-aready-happening-new-eia-numbers-show-a-utility-sector-in-transformation/?sf_action=get_results&_sft_topic=climate-and-public-health.