Taking the (Fuel) Blinders off Energy Codes

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ABSTRACT

Amidst a backdrop of the Arab Oil Embargo of 1973 and a perception of physical limits on energy resources, the obvious policy imperative of a new generation of energy codes was to reduce the use of all types of energy. These energy codes emphasized reductions in the use of all fuel and energy types, and it was generally accepted that one type of fuel should not be favored over another type of fuel. This paper examines those direct links between fuel types referenced by energy codes and climate policy, and how upcoming energy codes can address emission impacts of building designs. These policy developments illustrate that existing site, source and cost metrics only partially work to reduce carbon emissions from the building sector. The paper explores the application of the "emissions efficiency" concept to national and state codes, and how code developers can consider the critical technical questions that need to be addressed – such as time-of-use emission rates, updated electric grid source multipliers, and the net effect of electricity exports from the site. This paper proposes a shift towards emissions efficiency that should lead to more building designers, owners, and operators applying standardized carbon calculations to their buildings; with the objective that design choices, equipment selection, and operations will begin to bend towards reduced emissions impact.

Introduction and Problem Statement

When the current generation of building energy codes was born in the 1970s and 1980s, the obvious policy imperative was to reduce the use all types of energy. This occurred amidst a backdrop of the Arab Oil Embargo of 1973 and the perception of the limits of physical energy resources on the planet. These energy codes emphasized efficient use of fuel and energy in buildings. Because of the political divisiveness associated with mandated fuel switching, it was generally accepted that energy codes should not favor one type of fuel over another. If, however, the goal is for energy codes to reduce carbon emissions from the building sector it is clear that fuel needs to be taken into account. Fatih Birol, executive director of the International Energy Agency, said building energy codes are "...the single most important step (in tackling climate change) I want governments to take, and they can take it tomorrow" (Harvey 2016). This paper examines how climate policy now impacts energy code policy, and examines the long-held taboo of favoring one type of fuel over another in these regulatory mechanisms.

Metrics, Codes, and Zero Energy Buildings

Back in 2007, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) convened a workshop on carbon emissions from buildings. Harvey Sachs stated its purpose as follows:

> "The ultimate goal of the process initiated through this workshop is to design a tool with which heating, cooling and ventilation engineers could estimate the carbon "footprint" of

> a building during the design phase, so that decisions could be made which would improve building performance and reduce greenhouse gas (GHG) emissions, as well as energy costs, over the lifetime of the facility. Residential, commercial, and industrial buildings represent roughly one third of total global greenhouse gas emissions; improved energy design may be able to reduce the contribution of new buildings by 50 - 80% over the next few decades." (ASHRAE 2007)

Mahone, Mahone, and Hart (2016) came to a similar conclusion in examining the role of California's Title 24[1] energy codes:

> "If one of the primary goals of encouraging energy efficiency in buildings is to reduce the GHG emissions associated with buildings, then it is important to incorporate the carbon content of the electricity and natural gas that buildings use into decision making; both at the time that the building is designed, and when the building is in operation."

Still, many years after the emergence of carbon emissions as a primary policy driver, the current metrics that are at the foundation of today's International Energy Conservation Code (IECC), ASHRAE, and California Title 24 codes do not directly account for carbon emissions, and are as follows:

1. Energy: kWh, Therms, BTUs (IECC 2018)
2. Energy Cost (ASHRAE 90.1)
3. Time-Dependent Value (TDV) (California Title 24)

Each of these is generally applied on a "site" basis (energy used at the building site), and only indirectly measures the environmental impact of the fuel use to the extent that emissions are correlated to the measured units. However, in the rules for modeling commercial buildings and for calculating the residential Energy Rating Index, on-site renewable energy generation is subtracted from the total "site" energy use of the building.(IECC 2018) Because the use of these energy sources is subtracted from total energy use, these fuels are clearly favored by those codes over the other fuel types.[2] However, to the extent they are subtracted from total energy use, total building energy use is allowed to increase – meaning that there is some level of trade-off between energy efficiency and renewable energy.

It is evident that the treatment of different fuel types has been done on an ad hoc basis rather than being part of a comprehensive approach to achieving explicit policy objectives. Making fuel selection an integrated component of energy codes is now becoming critical, as primary policy drivers are shifting toward climate change mitigation and Zero Energy Buildings (ZE Buildings; also often referred to as Zero Net Energy or Net Zero Energy Buildings), and as renewable energy prices drop exponentially. In addition, new building features and components such as electric vehicles, battery and other storage contribute to the need to rethink the energy metrics currently used.

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[1] California's energy codes, often referred to collectively as Title 24, were established by the California Building Standards Commission in 1978 to reduce energy consumption. These codes are now updated every three years.

[2] For instance, ASHRAE 90.1 Appendix G states "onsite renewable energy … shall be subtracted from the proposed design energy consumption prior to calculating the proposed building performance." (ASHRAE 90.1 2016)

To provide a framework for the new emissions metric, the authors agree with Harvey Sachs' summary of the objectives of carbon tools discussed at the ASHRAE workshop in 2007:

- To enable meaningful carbon accounting for the energy side of the building industry
- To provide building architects and designers with predictive information and benchmarks regarding lifetime GHG emissions
- To provide guidance for designers in reducing the carbon footprint of new buildings

These objectives now need to be extended to our model energy codes. At the same time, while carbon emissions associated with energy consumption are a key driver of the policy, the increasing share of renewable energy production options means they will play a greater role in the future. While energy conservation codes should not become just "energy generation" codes, there needs to be a path to a codes approach that accounts for both generation of clean energy and significantly reduced consumption.

The Concept of Emissions Efficiency

> "Policy goals are shifting from the simple energy conservation focus of yesteryear toward achieving greenhouse gas (GHG) reductions….
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> To that end, we submit that *emissions efficiency* may be as or more important than *energy efficiency*" moving forward." (Dennis, Colburn, and Lazar 2016)

Greenhouse gas emissions reduction increasingly has become a driver in discussions of energy code policies. Because energy codes are ranked among the most cost-effective means to reduce emissions (Creyts et al. 2007) and are referenced in almost every climate action plan, it has become evident that a primary purpose of these codes is to reduce GHG emissions. If building energy codes are to address GHG emissions, then how do we shift the primary objective from "energy efficiency" to "emissions efficiency"? Dennis, Colburn, and Lazar state plainly that "energy efficiency is an inadequate metric to measure technology performance when it comes to GHG emissions." This is because a kilowatt-hour used by a building could have been produced by a coal plant or a wind farm, each with its own carbon profile. Two buildings with equal energy consumption could have wildly different GHG emissions. Thus, energy efficiency is well suited to measuring the total amount of energy used at the building site, but poorly suited to measuring the total GHG impacts of the energy used.

The implications of using the most suitable metric to match policy objectives are large. That is because the policy drivers for saving energy are increasingly driven primarily by climate impacts – and secondarily by grid impacts. The emphasis on resource depletion has diminished. Diane Gruenich, former California Public Utility Commission (CPUC) Commissioner, asserts that "energy efficiency outcomes must be integrated with a carbon reduction framework". She notes that it is an accident of history that carbon policies (e.g. AB 32) came into existence 20 years after the first energy codes (e.g. Title 24). Gruenich notes that "Compensation (utility rebates, customers' bill savings) for successful energy efficiency efforts is similarly allocated according to benefits to the energy system rather than larger carbon mitigation goals" (Gruenich 2015). This further exacerbates the misalignment between energy programs and carbon policy objectives.

Zero Energy Buildings and the Challenge of Moving From an Energy Focus

to a GHG Focus

Of course, many people will say, “That is the way we have always done energy codes – why change now?” They will ask, “Is a carbon code an energy code?” These type of fuel source questions are already being addressed in the debate over how to define ZE buildings. Let’s take a look at how that debate can inform the transition of codes from energy to emissions efficiency.

A lengthy saga could be written about the “The Definition of Zero Energy” – a saga with no final chapter in sight. In September 2015 the US Department of Energy released a common definition and stated that a Zero Energy Building (ZEB) is “an energy-efficient building where… the actual annual delivered energy is less than or equal to the on-site renewable exported energy” (DOE 2015). Almost every agency or organization that has tried to define ZE has been drawn into a series of lengthy, almost philosophical, discussions about objectives and outcomes of differing ways to define ZE. Many of them revolve around how to account for the emission impacts of on-site consumption of grid-delivered electricity and how to balance those impacts with on-site electricity generation and direct combustion of fossil fuels.

Generally, ZE is defined on an annual basis using either site or source energy. Historically, site energy was the most commonly used metric, but many entities (including the US Department of Energy (DOE) and Environmental Protection Agency (EPA)) have determined that source energy is a more equitable and accurate unit of evaluation (DOE 2015, EPA 2018). The fundamental difference is that source energy accounts for impacts beyond the building, including fuel used to generate and transmit electricity to the building, while site energy refers to only the energy used within the building or site boundary. There are many details that influence why one kWh delivered to a building is not the same as the next kWh delivered to that same building. The difference largely has to do with *when* and *where* that electricity is generated and used.

- *When:* Solar PV panels tend to produce the most energy when the sun is at the highest point in the sky: solar noon. Wind turbines produce energy when the wind is blowing strongly, which varies by hour and season. Both these resources are intermittent by nature. However, peak demand on the grid is often mismatched with this renewable production. In California, for instance, system peak demand is moving later and later in the evening while renewable production typically peaks mid-day. In a scenario like this, conserving (or curtailing) energy during those evening peak hours is more important than reducing energy usage during the middle of the day.
- *Where:* Certain technical aspects of the transmission and distribution grid impose physical limits on the production, transmission, delivery, and consumption of electricity, whether from renewable sources or from fossil-fuel sources. Electricity-bearing wires are rated to carry a certain current capacity at their designated voltage, which limits the power (kW) these wires can deliver. Similarly, substations are rated for certain kW capacities. The increasing adoption of distributed energy resources (e.g. solar PV panels on buildings) means that two-way energy flows are becoming much more common. But many pieces of equipment on the grid were not built to accommodate this. For instance, some transformers were designed to detect electricity backflow and physically cut the wire when backflow occurs, which then requires a service call from the utility to restore power. This presents obvious challenges to ZE buildings served by such equipment;

technical constraints like this can limit the absorption of renewable energy at the local and the societal levels.

Thus, Zero Energy does not necessarily mean net zero carbon. While a ZE building does, over the course of a year, generate as much clean renewable energy as it consumes, during nearly every hour of the year the building is either consuming more energy than it generates or vice versa. It is common for a ZE building to be an electricity consumer from the grid when the sun is not shining and has a higher carbon emission profile. That consumption from the grid is offset with onsite generation when the grid is relatively lower-carbon overall. This means that many ZE buildings are not, in fact, net zero carbon.

In California, the concept of Time Dependent Valuation (TDV) also comes into play; TDV takes into account varying energy values during each hour of the year. The calculation of TDV includes only a minor factor for the cost of carbon of the fuels consumed. And the TDV framework is intended to guide energy simulation modeling and code compliance calculations - it is not easily applicable to real-world buildings with actual performance data. But TDV is a first step to evaluating performance on an hourly basis for an annual period. The California Energy Commission uses a TDV definition for its energy codes, and in the current code cycle intends to apply it to the nearly ZE residential code (Title 24-2019).

But there are limits on the usefulness of TDV for project teams (e.g. designers, owners, operators, etc.) and for national codes:

- Project teams often don't understand clearly how TDV calculation results can influence building operation costs and thus may not factor the TDV framework into design.
- TDV is not a direct surrogate for carbon emissions – thus Title 24 does not directly target climate goals.
- National codes: Implementation of a TDV framework relies on regional grid characteristics. To implement this framework on a scale beyond any one grid region would require careful and in-depth research and decision-making about how to effectively and fairly account for the differences in grid regions. This would add substantial complexity to national-scale model codes.

Outside of California, the general statement is that a building will reach ZE status if the total energy consumed over a year's period is less than the total renewable energy produced onsite over that year. This has the advantage of being easy to apply, but complications arise with different scales, such as portfolios, and with choosing between different metrics, such as source energy, site energy or energy cost. As an example, ASHRAE Standard 105 defines boundary conditions for energy consumed and generated on site on an annual basis. This Standard also contains conversion tables to calculate source energy, if preferred. Moving towards a source energy metric can help account for gross impacts at the grid level, or at the societal level, and in some sense extends the boundaries beyond the building site. But moving to a more precise hourly carbon metric would present a universal yardstick that transcends boundary conditions.

The upshot of the when and where of grid-delivered energy is this: the CO_2 emitted to produce and deliver one kWh of energy varies by place and time. Perfect tracking of the CO_2 content associated with every kWh delivered is challenging and is not generally considered feasible. However, new tracking and controls systems are being developed[3] and major improvements are being made towards accounting for emissions rather than energy.

A Path to Align a New Code Focus on Emissions

Aligning energy codes with emissions will require modifications to the current metrics and code language. Both of these issues are addressed in this section. For the code language, the focus is on changes needed in ASHRAE 90.1 and IECC.

Emissions Impacts: Metrics and Measurement

Measuring the impact of CO_2 emissions will require more information about building performance than simply tracking the total energy used per year. The most common metric for tracking building energy performance today is Energy Use Intensity (EUI), which measures total annual energy consumption per square foot, combining electricity, gas, and other sources, denoted in kBtu/ft^2-year. This metric is common across the industry, and targets for building performance are often defined using EUIs. While both site and source EUIs are common, neither can tell us the emissions associated with that energy consumption. We need new metrics to move beyond EUI and energy cost and be able to answer these key questions:

How does your building's electricity demand correspond to the grid's marginal carbon emissions factors?

How do these compare to the emissions of other fuel choices?

How should codes incorporate these impacts?

8760 Profiles: At the Building Level

As explained in the previous section, it is important to consider when and where a kWh used in a building is consumed. In terms of metrics and measurement, annual hourly demand profiles (often called "8760 profiles" because there are 8,760 hours in a year) are a key data point in describing emissions impacts. An 8760 profile of a building is typically generated when a building designer completes a building energy simulation model and can be used to inform the design selection process. Actual 8760 data can be collected from a smart meter (e.g. an Advanced Metering Infrastructure, or AMI, compliant device). A building's 8760 profile can vary enormously due to design choices.

8760 Profiles: At the Grid Level

The electricity grid's emissions impacts of electricity consumption can be described by annual hourly emissions factors (lbs. CO_2 and other pollutants emitted per kWh delivered) for the local electricity grid (eGrid subregion or similar)[4]. This set of hourly emissions factors is

[3] For example, WattTime, a subsidiary of Rocky Mountain Institute, enables real-time carbon impact estimates and controllability in devices such as thermostats, battery chargers, and building controls systems. www.watttime.org.

[4] In some cases electricity does flow between eGrid regions, reducing the difference in emissions factors between neighboring eGrid regions, but the effect in this case is typically relatively small.

referred to here as the 8760 grid emissions factors. These factors vary substantially depending on the extent to which the electricity production mix is dominated by baseload plants, peakers, or renewable generation sources (naturally, emissions factors during most hours in the year contain combinations of these sources). The availability and granularity of these data varies by grid operator (ISO).

- *Baseload hours:* During baseload hours, the emissions factor will most closely approximate the emissions factor of the baseload plant(s) in that region. Historically, baseload hours have tended to be during the night. In regions whose baseload energy is predominantly supplied by coal-fired steam power plants, this may approach 2 lbs. CO_2 emitted per kWh delivered (a typical emissions rate in a coal fired power plant). In regions where the baseload is predominantly supplied by nuclear or hydropower, this emissions factor will be substantially lower as the CO_2 emissions from these sources approach zero lbs. CO_2 emitted per kWh delivered. In most regions, a mix of sources provides baseload power and the overall regional emissions factor will be calculated as a weighted average of these sources.
- *Peak hours:* During peak hours, the overall grid emissions factor will be representative of a weighted average of all the generation sources on the grid. These will include baseload sources, whether coal-fired, oil-fired, nuclear, or hydropower, as well as mid-peak sources (often oil or combined cycle natural gas turbines) and peak energy sources such as simple cycle gas turbines and gas or oil engines (e.g. dispatchable distributed generation). The emissions factor for a simple cycle gas turbine may be around 1 lb. CO_2 per kWh delivered; for a combined cycle gas turbine the factor is somewhat lower. It is important to note that during peak hours the *marginal* emissions factor will be equal to that of the last dispatched plant.
- *Renewable-dominated hours:* During certain hours of the year in some parts of the country, the electricity on the grid is predominantly produced by solar PV panels, wind turbines, and other renewable sources. These may be distributed (e.g. rooftop PV) or centralized (e.g. wind farms). Generally, these hours will be around noon in areas with high solar penetration and regular daytime winds, or during the nighttime hours in areas with high wind farm penetration and strong nighttime winds. Naturally, this can vary significantly by area and is changing quickly as more renewable capacity is installed.

Though an off-the-shelf application of 8760 emission factors is not available nationwide today, it is being considered in certain locations and certainly falls within the range of technical feasibility should national model codes choose to move in that direction.

8760 Profiles: When the Cost of Renewable Energy is "Free"

In an increasing number of regions of the United States, the penetration of both distributed and centralized renewable energy has resulted in energy oversupply when periods of high production are coincident with lower demand. There is a zero or negative cost of electricity during these "curtailment" hours – and reducing consumption has no impact on emissions as the marginal emissions are zero. This is particularly evident in California and Hawaii which are actively attempting to reduce the number of periods when excess renewable generation must be curtailed. If code metrics tracked CO_2 emissions, codes could be structured to encourage <u>less</u> energy conservation at those hours of the year relative to other periods.

Once these key data sets related to building and grid 8760 profiles are known, significant use case possibilities arise. For instance, this data could be used by a building designer as follows (note that this is only one potential application and that broad access to this information by the design community could well enable more innovation):

1. Building energy simulation model based on proposed design generates the building's 8760 profile.
2. The total CO_2 emissions over the course of a year are calculated as the sum of the hourly products of the building's 8760 profile and the 8760 grid emissions factors.
3. The emissions impact of design choices are evaluated by performing parametric simulations using this methodology. Passive and active design choices that result in lower emissions can be properly valued.

Pathways for Code Development

> **"C101.3 Intent.** This code shall regulate the design and construction of buildings for the use and conservation of energy over the life of each building." (IECC 2018)

The national model energy codes, IECC and ASHRAE 90.1, explicitly and solely aim to reduce the amount of energy a building is designed to consume. For the purposes of switching to a direct emissions objective, it is likely that the Intent or Purpose sections of both documents would need to be expanded or altered. Subsequent code cycles would then need to review and modify existing provisions in the code such that emissions, rather than energy, were the focus of the code changes. For the performance approach, the modeling rules in ASHRAE 90.1 Appendix G, which are used by many projects modeled for code compliance, seem well suited to accommodate new calculations of emissions impacts. Modeling software allows for inputs of cost and/or source energy factors. The largest challenge appears to be designing tables or algorithms to account for the location-variant and time-variant emission factors for grid-based electricity. For the prescriptive approach in 90.1 and IECC, code provisions can be based on the best emissions performance among equipment types and efficiency levels, such as mini-split heat pumps and gas furnaces, which would take into account the consumption, time of day and grid location characteristics of the project.

It should be noted that both national model green codes, the 2019 International Green Conservation Code (IgCC) and ASHRAE Standard 189.1-2018, are intended to achieve broader objectives, such as environmental responsibility. As such, they each have an additional compliance requirement that does require projects to account for CO_2 emissions alongside their respective energy metrics. IgCC and ASHRAE 189.1, along with ASHRAE Standard 105, do provide vetted methodologies and technical values for several of the parameters that will be necessary in developing "emissions efficiency" compliance requirements.

It should also be noted that federal law requires that stringency of each cycle's version of ASHRAE 90.1 and IECC-residential be "determined" by the Department of Energy on an energy basis (EPCA 1975). Changing the intent of the code will not conflict with DOE's ability to meet that statutory requirement, while at the same time it will provide states and cities new carbon-based policy mechanisms.

Mahone, Mahone, and Hart (2016) consider two options for California to pursue in moving towards a carbon-based Title 24. The first would set carbon budgets that "would reflect the expected 'lifecycle' carbon content of grid electricity, on-site fuel combustion, and on-site electricity generation." The second option would take a half-step toward this goal by modifying TDV calculation methodology: "Rather than changing the building code to be entirely based on carbon savings, the current code could be simply modified to more directly encourage carbon reductions and carbon-based trade-offs using the current cost effectiveness framework."

Pathways for Project Teams

As more building designers, owners, and operators become familiar with the emissions impacts of their buildings and as codes and policies begin to account for overall CO_2 emissions, there may be impacts on building design and measure selection. These impacts may appear in any of several decisions they make on every project:

- *Use of grid-delivered electricity vs. onsite generation and storage*: Building owners today are almost exclusively connected to the grid and rely on the grid to absorb surplus generation from onsite renewables. However, regulatory changes may change this equation for instance, the major changes to new net metering installations as implemented in Nevada in late 2016 (Pyper 2015)) and the technology is changing rapidly. The costs of both PV panels and onsite battery storage have fallen very rapidly over the last few years and battery storage in particular looks likely to continue this trend. Building owners may begin to consider more carefully the cost and carbon impacts of their grid connection choices, and some may choose to rely more heavily (or even exclusively) on onsite generation and storage as these technologies continue to evolve.
- *Mechanical Equipment Selection:* Design choices such as HVAC system type have major impacts on the building's 8760 profile. Consideration of emissions in codes and policies may drive designers and building owners to install equipment that optimizes the building's emissions profile. For example, radiant space conditioning can shift the load on a chiller or boiler either earlier or later, which may reduce emissions by enabling reductions in high-emissions peak energy usage or shifting load toward low-carbon times.
- *Electric Lighting vs. Daylighting:* A building that uses electric lighting throughout the day will have higher electric usage during daylight hours than one that harvests daylight when possible and turns off electric lights during those hours. Consideration of emissions impacts of these design choices will be helpful to building lighting and daylighting designers.
- *Water Heating:* Emissions considerations may impact choices related to the fuel used (gas vs. electricity) and the technology type (condensing or noncondensing gas unit, electric resistance or heat pump unit, and tank vs. tankless unit). Some utilities are piloting programs[5] to use electric tank water heaters as grid storage units, by restricting the usage of the element during peak times and relying on the full tank's stored latent heat to deliver sufficiently hot water until the peak time has passed.
- *Onsite vs. Cloud Computing:* Buildings can choose to install servers and other data processing equipment onsite or can outsource much of that electric load by taking advantage of cloud computing services. If those centralized cloud computing data centers are located in places with lower emissions factors and favorable climates, the overall

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[5] For example, in 2017 Bonneville Power Administration funded a smart water heater demonstration project to install demand response control modules on 600 electric resistance and heat pump tank water heaters.

emissions impacts can be reduced. However, the opposite will be equally true if the cloud data centers are in areas with higher emissions.

- *Electric Vehicles as Energy Storage:* While electric vehicles (EVs) have not yet reached full-scale market penetration, their potential to play a role in energy storage at the building level is significant. While the owner of the EV must decide whether to allow its use as a dispatchable grid asset, design teams can choose to include building features that enable this EV use case.
- *Distributed Generation: Onsite Use of Generators and Fuel Cells:* Some buildings, including those with critical loads such as hospitals and data centers, need to have backup generation onsite for resiliency. Other buildings may choose to have these systems available as well. In many cases, these facilities already have arrangements with utility companies or demand response aggregators to help manage peak loads. A more complete picture of carbon emissions would further inform these design and operational decisions. If generators can be run on Green-e certified biofuels that changes the emissions picture in yet another dimension.
- *District Energy:* The decision to meet space heating and/or cooling needs through a district system as opposed to a dedicated single-building system will impact the load profile of that building significantly. To get a complete picture of the emissions impact of this basic choice, the emissions impacts of the building's marginal load on the district system will need to be compared to the emissions impacts of that building's marginal load on the grid.

Future Research: What is Most Needed?

This is just the beginning of the research on this important topic. Several topic areas will require further examination and research.

Grid Emissions Factors: Regional Differences

Code stakeholders will need to agree on 8760 profiles to define grid emissions factors at the regional level. The eGrid subregions could be a way to account for the differences between different regions of the national electric grid. These 8760 profiles will need to be updated regularly as new resources come online, especially in states and regions where coal plant retirements, Renewable Portfolio Standards, and other factors are driving rapid changes in the generation mix.

Energy Simulation Models vs. Building Prototypes

Most every building is not required to produce energy simulation models to comply with the energy code. For instance, office buildings under a certain size typically do not undertake an expensive simulation model, but can instead rely on a prescriptive approach to meeting code. We must consider how to accommodate the prescriptive compliance path in energy codes. One way to do this would be to create prototype building 8760 profiles and conduct a sensitivity analysis to define the key factors influencing these profiles, and then use adjusted prototype profiles to apply a carbon-adjusted 8760 profile for these buildings.

Conclusion

"Five trillion tonnes of carbon emissions…is often cited as an estimate of total cumulative emissions" if current global fossil fuel reserves are burned in a business-as-usual scenario (Tokarska et al. 2016). Given worldwide acceptance of the need to avoid this catastrophic level of carbon emissions, building sector policies are increasingly mandating low- and zero-carbon emission new buildings as additions to jurisdictional building stocks.

With the turn to requirements for low or zero carbon emission in buildings, energy codes need to adapt to the reality that specific fuels used to power buildings, and their specific emission characteristics, can be as critical as total energy use. The declared intent of energy codes is falling further out of alignment with climate policy. By making carbon the prime metric, the implicit goal for many participants could align with the explicit intent of climate policies. To adapt to these new implicit features of carbon codes, current model code organizations need to begin this transition as soon as practicable. Written and unwritten rules that call for energy codes to be "fuel-blind" are outdated. Current policy drivers call for explicit emissions performance criteria in the development of energy codes. It is time to align the efforts of code developers and code users with climate policies at local, state, and federal levels.

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