Could Building Energy Codes Mandate Rooftop Solar in the Future?

H.E. Dillon, C.A. Antonopoulos, A.E. Solana, and B.J. Russo,
Pacific Northwest National Laboratory
J. Williams, US Department of Energy

ABSTRACT

As model energy codes are expanded to reach efficiency levels 50% greater than current codes, onsite renewable energy systems could become a code requirement. These requirements may be necessary as envelope, mechanical and lighting efficiency gains are maximized. Code development for both the commercial and residential sector is likely, with some examples already in existence. This leads to many questions about the requirement structure, shading, solar installation levels, and compliance issues.

This paper explores existing requirements and compliance options for both commercial and residential code structures. Common alternative compliance options are discussed including renewable energy credits (RECs), green-power purchasing programs, shared solar programs and other community-based renewable energy investments. Compliance options are analyzed to consider building lifespan, cost-effectiveness, energy trade-offs, enforcement concerns and future code development. Existing onsite renewable energy codes are highlighted as case studies for the code development process.

A proposed level of 6 watts/square foot of roof area in the commercial sector is discussed in light of the economic analysis indicating the requirement may not yet be cost effective. Existing analysis by the authors will be used as a catalyst for a discussion about the potential market transformation opportunity presented by increased onsite renewable energy deployment. A cost-effectiveness analysis is presented to illustrate the connection between PV system market pricing over time and stringency of future onsite renewable energy requirements.

Background

Research has been conducted to determine the mechanism for implementing a future energy code requirement (Kaufmann et al., 2011). Kaufmann et al. suggested that an appropriate maximum for the requirement in the commercial sector would be 4 W/ft^2 of roof area or 0.5 W/ft^2 of conditioned floor area.

As with all code requirements, there must be an alternative compliance path for buildings that may not reasonably meet the renewables requirement. This might include conditions like shading (which makes rooftop PV arrays less productive), unusual architecture, unsuitable roof pitch or building orientation, or other issues. In the short term, alternative compliance paths including high performance mechanical equipment, substantial envelope improvements, or advanced controls may be feasible. As the stringency of the code continues to increase however, efficiency trade-offs will be fully exploited, requiring alternative compliance options focused solely on renewable electricity trade-offs or equivalent programs.

Current model energy codes (IECC and ASHRAE 90.1) do not have prescriptive requirements for onsite renewable energy systems. Recently, ASHRAE Standard 189.1, *Standard for the Design of High- Performance Green Buildings*, was developed by the American

National Standards Institute (ANSI), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), United States Green Building Council (USGBC) and Illuminating Engineering Society of North America (IESNA). On-site renewable energy systems are included in the provision that addresses energy efficiency. The IGCC (*International Green Construction Code)* is also developing requirements for on-site renewable energy generation.

The mandatory requirement for on-site renewable energy systems in ASHRAE Standard 189.1 focuses on roof-integrated PV systems capable of producing at least 6.0 kBtu/ft^2/year of energy based on conditioned space. This requirement is reduced to 4.0 kBtu/ft^2/year if heating, ventilation and air conditioning (HVAC) systems and appliances have efficiencies exceeding the Energy Policy Act of 2005 (EPAct), National Appliance Energy Conservation Act (NAECA) and Energy Independence and Security Act (EISA) standards (ASHRAE, 2010). The alternative compliance option available for buildings that cannot comply with the requirement includes purchase of Green-e certified RECs (Green-e Energy, 2011) of at least 7 kWh/ft^2 of conditioned space per year until 70 kWh/ft^2 has been reached (10 years).

7.4.1.1 On-Site Renewable Energy Systems. Building projects shall contain on-site renewable energy systems that provide the annual energy production equivalent of not less than 6.0 kBtu/ft^2 (20 kWh/m^2) of conditioned space. The annual energy production shall be the combined sum of all on-site renewable energy systems.

Exception: Buildings that demonstrate compliance with both of the following are not required to contain on-site renewable energy systems:

1. An annual daily average incident solar radiation available to a flat plate collector oriented due south at an angle from horizontal equal to the latitude of the collector location less than 4.0 kWh/m^2-day, accounting for existing buildings, permanent infrastructure that is not part of the building project, topography, and trees, and

2. Purchase of renewable electricity products complying with the Green-e Energy National Standard for Renewable Electricity Products of at least 7 kWh/ft^2 (75 kWh/m^2) of conditioned space each year until the cumulative purchase totals 70 kWh/ft^2 (750 kWh/m^2) of conditioned space.

Renewable Energy Credits (RECs)

RECs, also commonly referred to as green tags, are the environmental attributes of energy produced from renewable energy sources that can be sold separately from the actual energy. The separation of the energy from its environmental attributes is referred to as unbundling. One REC is equivalent to 1 MWh per the standard market definition.

There are two types of REC markets in the United States: compliance and voluntary. *Compliance* markets are driven by renewable portfolio standards (RPS) or other state or utility mandates dictating that a portion of delivered energy must come from renewable resources. *Voluntary* markets allow consumers to buy RECs to support green power whether or not they have access to green power through their local utility. The voluntary market is any purchase of RECs performed in the absence of an RPS or other mandate.

Case Studies

Although few agencies/jurisdictions have adopted ASHRAE Standard 189.1, there are examples of commercial and residential onsite renewable code developments that have implemented renewable energy generation requirements. These examples represent the best insights about how compliance with RECs has evolved for different requirements, and each example is discussed in more detail in other documents (Dillon et al., 2011).

The City of Seattle, Washington

In 2010, Seattle amended the city's 2009 energy code to include an on-site renewable energy system requirement for commercial buildings. Chapter 16 of the energy code adds a renewable energy requirement for new buildings and additions of more than 5,000 ft^2 through partial adoption of ASHRAE Standard 189.1-2009 (WSL, 2011). To meet the renewable energy requirement, building projects will need to add renewable generation systems that provide annual energy production equivalent to 500 Btu/ft^2 (0.15 kWh/ft^2) of gross conditioned floor area (WSL 2011). Annual renewable energy production is the sum of all on-site renewable energy systems, including solar thermal systems. The following is the language of the Seattle code:

> Chapter 16 On-Site Renewable Energy Systems
> **1620 Prescriptive Option for On-Site Renewable Energy Systems**.
> **1621 Annual Production of On-Site Renewable Energy Systems**. Building projects shall contain onsite renewable energy systems that provide the annual energy production equivalent of 500 Btu/ft^2 of gross conditioned floor area. The annual energy production shall be the combined sum of all on-site renewable energy systems.
> **EXCEPTION**. Purchase of renewable electricity products complying with the Green-e Energy National Standard for Renewable Electricity Products of at least 7 kWh/ft^2 of conditioned space each year until the cumulative purchase totals 70 kWh/ft^2 of conditioned space (WSL, 2011).

While the Seattle code is modeled closely after ASHRAE Standard 189.1, the electricity production requirements are lower and the REC trade-off is higher. REC purchases are more expensive because they are required to be purchased at the time of construction. This fact contributes to the energy and price equivalency discussed later in this paper.

Two alternative methods of compliance include increased mechanical system efficiency or purchase of RECs that comply with the Green-e Energy National Standard for Renewable Electricity Products. The first option requires installation of high efficiency space heating and cooling equipment equivalent to 1.10 times the minimum efficiency requirements of the Washington State Energy Code. The second alternative includes purchasing one year of RECs in compliance with the Green-e Energy Standard of at least 70 kWh/ft^2 of conditioned space. This amount will increase to 125 kWh/ft^2 after July 1, 2012. RECs are required to be purchased and paid in full before a building permit will be issued.

The City of Aspen, Colorado

To promote energy efficiency and renewable energy, the City of Aspen and Pitkin County, Colorado, enacted the Renewable Energy Mitigation Program (REMP) in the residential and commercial building code in 2000. The code places a limit on energy consumption in residential and commercial buildings by mandating an "energy budget" for new construction and significant building additions. Property owners who wish to consume energy beyond the energy budget for exterior uses such as pools, spas and heated driveway snow removal systems must install on-site renewable energy systems or pay a one-time energy mitigation fee. Details about this program are provided in prior work (Dillon et al., 2011).

Requirement Structure

To perform the requirement analysis, several inputs for the described equivalences are summarized in this section. One subtle aspect of the alternative compliance path is motivation. It is important that the requirement encourage the construction and development of new renewable energy generation. The code requirement developed by Kaufmann et al. (Kaufmann et al. 2011) is structured to encourage this via rooftop solar arrays, and it is important that the alternative compliance paths do not undermine the objective of renewable energy system development. For the purpose of this report, the following requirement structure assumptions have been made:

- The structure of the requirement wording will be similar to that of the current City of Seattle code or ASHRAE 189.1 requirement, based on either conditioned floor area or roof area. The requirement will be close to 4 W/ft^2 of roof area or 0.5 W/ft^2 of conditioned floor area (Kaufmann et al., 2011).
- The REC compliance will be represented in the same units (either conditioned floor area or roof area).

To determine equivalence for the RECs alternative compliance option, the following assumptions were made:

1. The REC requirement should be designed to be energy-neutral or energy-positive compared to the renewable requirement. This means that the RECs requirement should never be structured for less equivalent energy to be purchased over the life of the building than actual electricity the required PV system would generate.
2. The REC requirement should be structured to be cost-neutral to the PV array requirement if possible. This means that the REC procurement option should not be less expensive than that of the required PV system. If off-site renewable energy is purchased rather than installing a PV array or equivalent renewable energy generation system, it may reduce the probability that the building will install a system retroactively. This represents a lost opportunity for reducing the building load.
3. The REC requirement should be relatively easy to enforce. This implies that some reasonable amount of documentation may be required but should not be burdensome over the life of the building.

Other factors to consider regarding prescriptive on-site renewable energy systems, including PV arrays and alternative compliance options, include enforcement issues, building life considerations, and the price of compliance. An overview is provided here, and these issues are explored in detail in prior work (Dillon et al., 2011):

- Enforcement of a REC compliance path has several potential issues. Documentation of the RECs purchase becomes difficult if a building is constructed and then sold by the developer. Also, REC prices may change over time and make it difficult for a developer to determine the best option for a specific building.

- Structuring an on-site renewable requirement in a manner that accounts for building lifespan will be an important consideration for both the commercial and residential sectors. The lifespan of PV systems is another factor, but like the HVAC system in a traditional building code it is assumed in this analysis that the system would be replaced by an equivalent PV array at the end of life.
- A key factor when defining alternative compliance option requirements for on-site renewable energy systems and RECs is related to the difference in cost for each compliance option. The National Renewable Energy Laboratory (NREL) has given a range of PV electricity cost of 0.20-0.80 $/kWh as a national average (Price, 2010). A separate study investigated the price to use for the cost of installed PV systems in detail based on current installation estimates. Results from that study indicate that a levelized cost of producing electricity from an array would be approximately 0.25 $/kWh given the array size and current installation costs (Russo et al., 2011).

RECs Alternative Compliance Calculation

To determine the correct RECs alternative compliance amount for a given region or jurisdiction, a calculation methodology has been developed to align the objectives of energy neutrality and cost equivalence. The analysis methodology is based on the assumption that most buildings would use photovoltaic systems to comply with a renewable energy generation requirement. The range of possible inputs for the calculation is given in Table 1 and assumptions are documented in Dillon et al. (2011).

The purpose of the calculation is to determine the correct trade-off level for RECs (Y) based on the proposed energy code requirement for renewable energy (X). The units of X and Y may be either W/ft^2 or kWh/ft^2 but they must both be assigned consistently. It is important that the REC alternative compliance option be weighted so the code user is encouraged to install PV or another renewable energy technology on-site rather than simply buying RECs because they are the low-cost option. This will help keep compliance with the requirement focused on reducing the energy load of a specific building, which is the purpose of the building energy code. To determine the weighting, (E_w), the levelized cost of a PV array (PV_p) should be considered along with the levelized cost of purchasing RECs (R_p). In essence, E_w is a measure of the incentive to pursue offsite RECs as opposed to developing on-site renewable energy systems. When the ratio is 1.0, there is no incentive to pursue one route over another. When the ratio is greater than 1.0, there is an incentive to pursue off-site RECs; when it is less than 1.0, the opposite is true.

The price factor (*Pf*) is the ratio of the levelized REC and PV system purchasing costs as shown in Equation 1. The RECs alternative compliance option level is then calculated from Equation 2.

$$Pf = \frac{R_p}{PV_p} \qquad (1)$$

$$Y = \frac{X}{Pf \cdot E_w} \qquad (2)$$

The calculation methodology is not appropriate for a code requirement; rather it is proposed as a technique for determining appropriate code requirements as possible energy code development moves forward in the IECC or ASHRAE consensus process. It could also be used by local jurisdictions as future codes are adopted to adjust the requirement levels at the local level.

Table 1. Description of Calculation Inputs and a Range of Typical Values

Variable Name	Description	Units	Typical Values	Sources
X	Energy code renewable requirement	W/ft^2 roof area or W/ft^2 conditioned floor area	≤4 or ≤0.5	Kaufmann et al. 2011
Y	Energy code REC alternative compliance option level	W/ft^2 roof area or W/ft^2 conditioned floor area	$Y \geq X$	
R_p	Cost of REC in local or national market	$/kWh	0.002-0.06 (0.019 this analysis)	Dillon et al. 2011
PV_p	Levelized cost of PV array electricity	$/kWh	0.2-0.8 (0.25 this analysis)	Russo et al. 2011
E_w	Offsite incentive percent for RECs		≤1	

RECs Alternative Compliance Calculation Based on Present Prices

To investigate the current level of alternative compliance options in existing codes, a 10,000 ft^2, one-story building that is 100% conditioned is considered as an example. In this example, it is assumed that the PV array is installed, maintained, and replaced as needed over a 70 year period. The results of this building complying with ASHRAE 189.1 and the City of Seattle requirements are shown in Table 2 using Equations 1 and 2 and solving for E_w.

If this building complies with the ASHRAE 189.1 requirement the RECs purchase is only 10,000 kWh/year of renewable energy, close to 57 percent of the energy output of the PV system. This requirement is not price-equivalent, meaning that the offsite incentive (E_w) is greater than one. The same building constructed in Seattle would be required to install a smaller system and this requirement also provides a slight incentive for purchasing RECs rather than installing the renewable onsite.

Table 2. Existing RECs Alternative Compliance Option Levels for an Example Building of 10,000 ft^2 Assuming a Building Lifespan of 70 Years. The First Two Columns Were Calculated Using Equations 1 and 2 and Solving for E_W

Description	ASHRAE 189.1	City of Seattle	Recommended (Kaufmann et al. 2011)
Renewable Requirement	0.37 kWh/ft^2/year	0.15 kWh/ft^2/year	0.72 kWh/ft^2/year (based on 0.5 W/ft^2)
RECs Alternative compliance option	70 kWh/ft^2 over 10 years	70 kWh/ft^2	663 kWh/ft^2 over 70 years
Renewable Requirement for Sample Building (X)	3,700 kWh/year	1,500 kWh/year	7,200 kWh/year
RECs Alternative compliance option for Sample Building (Y)	10,000 kWh/year	10,000 kWh/year	94,748 kWh/year
Offsite Incentive (E_w)	4.9	2.0	1.0

This comparison indicates that based on current estimates for REC and PV systems levelized costs, electricity, and building lifespans, the ASHRAE 189.1 alternative compliance option for RECs is low relative to the renewable generation requirement. The City of Seattle trade-off levels are more reasonable based on current market conditions, but the renewable generation requirement may be lower than the optimum level for the region.

Estimate of Requirement Impacts

It is estimated that a maximum of 4,701 MW of solar PV arrays would be installed on new commercial buildings in the U.S. in the year 2012 if a building code was adopted requiring renewable energy generation of 4 W/ft^2 of roof area to be installed. This would be a significant increase in installed PV systems in the U.S. The Energy Information Administration (EIA) estimated that only 640 MW of solar generation capacity (including both solar PV and solar thermal projects) were installed in 2009 (EIA, 2011a). BP estimated that 1,642 MW of PV arrays were installed in 2009, and that 2,520 MW were installed in 2010 (BP, 2011). These estimates have a large variation, but the highest estimate still shows that commercial building PV array installations could nearly triple the net capacity of installed PV arrays in the U.S. in the first year of implementation.

In future years, commercial building construction is expected to continue to increase. Forecasts presented in EIA's Annual Energy Outlook (EIA 2011a,b) were used to estimate potential PV system installations on new commercial building rooftops through 2035. Assuming 4 W/ ft^2 of roof area are installed on each building, the number of installed MW per year was estimated by Dillon et al. (2011) and is shown in Figure 1.

Using the assumptions documented in prior reports (Dillon et al., 2011), it is estimated that about 2,959 MW could be installed on new residential construction in the U.S. in the year 2012 if the building code required 4 W/ft^2 of roof area to be installed on each new building. This is not as much renewable generation capacity as could be contributed by new commercial buildings, but is significant and still greater than current PV array capacity in the U.S. Figure 2 shows the projected PV system installations, in MW of capacity, through the year 2035 based on a revised version of EIA's residential construction forecast. Data for the first few years of the EIA forecast were revised because they were found to not be representative of recent recession construction. Note that the potential capacity installed each year almost doubles once the housing industry fully recovers from the recession.

Impact of Commercial Buildings RECs

As discussed, the REC alternative compliance option could be structured in a number of ways, and the possible impact to the future REC market is summarized in Table 3. This is a maximum calculation assuming that compliance with the requirement is met only using REC purchases.

The amount of electricity that could be generated if PV arrays were installed (to determine energy equivalence) was determined using a national average capacity factor of 16.5%. The national average capacity factor was calculated on a weighted-average basis, with more weight given to capacity factors in climate zones expected to see more buildings growth. The analysis assumed flat roofs for all commercial buildings. Additional assumptions are documented in prior reports (Dillon et al., 2011).

A 2005 report on REC markets estimated that in 2010 the compliance and voluntary markets would each be about 46 million MWh (Holt & Bird, 2005). While this data is out of date, it provides an order-of-magnitude comparison to the potential impact of an alternative compliance path to a renewable energy requirement in commercial building codes.

Figure 1: Newly Installed MW by Year on Commercial Buildings, Assuming 4 W/ft^2 of Roof Area. Assumptions for this Projection Are Documented in Dillon et al. 2011

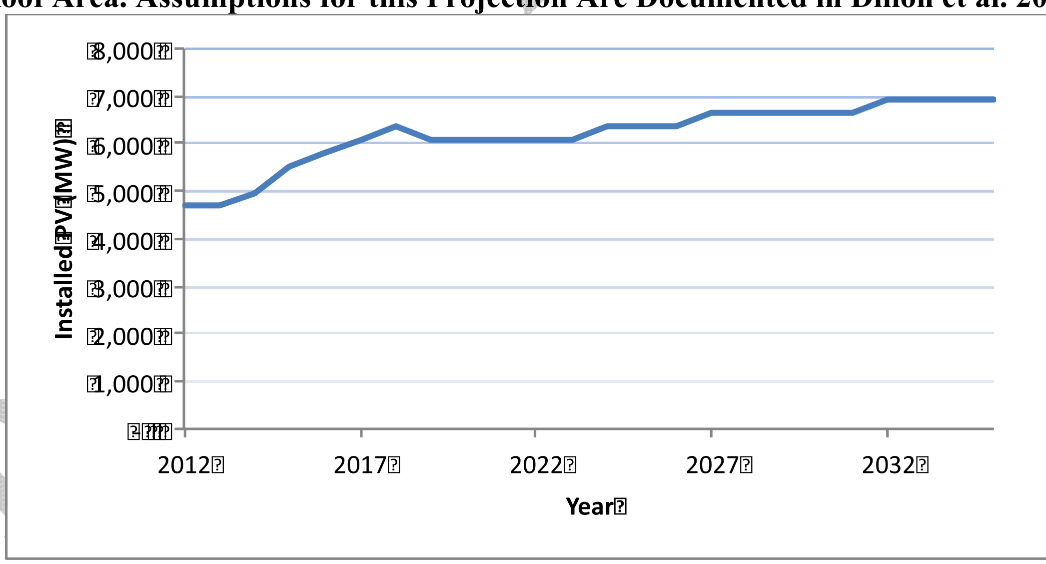
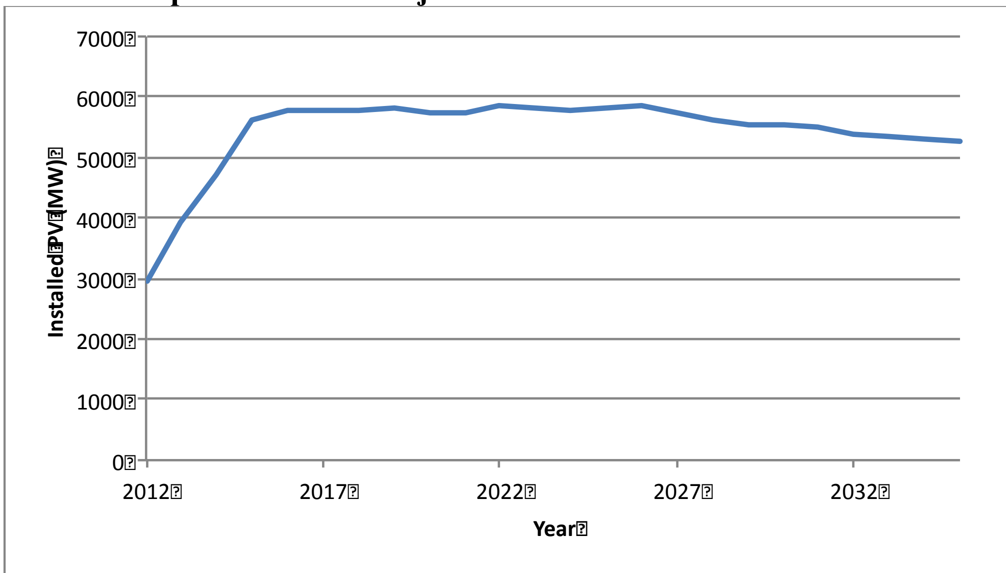


Figure 2: Newly Installed MW by Year on Residential Buildings, Assuming 4 W/ft^2 of Roof Area. Assumptions for this Projection Are Documented in Dillon et al. 2011



Regardless, the impact to the REC markets would be overwhelming even if only 30% of the buildings comply using RECs (21.8 million to 1.88 billion RECs, depending on the code requirements as shown in Table 3). This is still at minimum half the estimated 2010 voluntary market, and at maximum 12 times more than the estimated 2015 voluntary market. This analysis highlights the need to provide proper incentives for buildings to install onsite renewable generation rather than complying with the requirement using RECs. Additional compliance measures like community solar may be needed to offset the possible impact in the REC markets. Using a price-equivalent code requirement may offer additional danger for the REC market impact, but it should reduce the possibility of 100% compliance via RECs and should be implemented.

Table 1: Summary of Highest Impact (100% compliance via RECs) to the REC Markets in 2012 for Different Code Scenarios Using E_w=1 with Equations 1 and 2. For Reference, the Current REC Market is Estimated to be 63-157 Million MWh (Bird et al., 2010)

	100% of buildings use RECs compliance			
Renewable Energy Generation Requirement	4 W/ft^2 of roof area	0.5 W/ft^2 of conditioned floor area	4 W/ft^2 of roof area	0.5 W/ft^2 of conditioned floor area
RECs Alternative Compliance Option	Energy Equivalent	Energy Equivalent	Price Equivalent 5,334 kWh/ft^2	Price Equivalent 663 kWh/ft^2
2012 Projected REC market impact for one year of energy equivalent purchases	6.8 million RECs	1.0 million RECs	89 million RECs	13.6 million RECs
2012 Projected REC market impact for building life purchases	476 million RECs	72.6 million RECs	6.2 billion RECs	950 million RECs

Code Language Recommendations

Although on-site code requirements can apply to both the commercial and residential sectors, the structure of the requirement, compliance options and enforcement should be handled differently.

In general, the language and structure of the renewable requirement in the commercial sector should use ASHRAE 189.1 wording, but the basis for the requirement and the requirement levels should be adjusted as shown below. The energy requirement should be structured based on W/ft^2 because panel wattage is provided and vetted for most PV modules sold on the U.S. market. Therefore, most contractors, regardless of sophistication, can typically be assured that they are meeting the requirement if they follow a W/ft^2 code requirement. This format for the requirement will avoid the need for PV array output modeling, which may be especially important in the residential housing construction industry for simplicity. Sample language is proposed in the box below based on the conclusions from Kaufmann et al. (2011) and the addition of the RECs compliance levels from this work.

On-Site Renewable Energy Systems. Building projects shall contain on-site renewable energy generation systems with an installed power density of no less than 4 W/ft^2 of roof area or 0.5 W/ft^2 of conditioned floor area.

Exception: Buildings that demonstrate compliance with the following are not required to comply with the on-site renewable energy systems:

Purchase of renewable electricity products complying with the Green-e Energy National Standard for Renewable Electricity Products of at least 5,334 kWh/ft^2 of roof area or 663 kWh/ft^2 of conditioned floor area at the time of permitting.

On the residential side, the requirement structure could be similar to the commercial requirement, but the high-performance equipment trade-off should remain in place in the code for longer since residential scale renewable systems will not be as cost-effective as commercial systems. In addition, a compliance option via community renewable generation should be provided in light of the successes of the existing programs.

Conclusions

After review of existing renewable requirements, an analysis technique has been proposed to evaluate the incentive for a builder to choose either an on-site PV array or REC purchases. Using this technique the present ASHRAE 189.1 and City of Seattle code requirements were evaluated.

- For a commercial building with a 70-year life, the ASHRAE 189.1 requirement is not energy or price-equivalent for the REC alternative compliance path. This may be by design due to the wording of the requirement which restricts the use of RECs for buildings where the renewable energy generation requirement is not reasonable.
- For a commercial building with a 70-year life, the Seattle requirement is close to energy-equivalent and price-equivalent for the REC alternative compliance path.

- A proposed maximum level REC alternative compliance path based on the Kaufmann et al. (2011) findings is evaluated using current market conditions and a price-equivalent REC trade-off is proposed.
- These results indicate that, based on current market conditions, additional incentives are needed to encourage PV array installation and to make the REC compliance option appropriate for the building energy codes.

Several follow on conclusions are possible from this analysis effort:

- Due to the current levelized cost of solar electricity (roughly \$0.25/kWh) and the low price of RECs (\$0.02/kWh), a requirement for on-site renewable energy based only on energy equivalence will result in no new construction of building integrated PV arrays. An energy equivalence arrangement will dramatically favor purchase of RECs, and builders will follow the lowest price compliance option.
- To address this issue, the code requirement should be based on price equivalence rather than energy equivalence. An analysis technique for this calculation is proposed to aid future code development work and code adopters.
- The impact on the solar PV array and REC markets from a requirement of this type will be dramatic. Additional economic research about market impact should be performed once a draft requirement has been established.

This paper provides a maximum case estimate for impact to the PV array market and the REC market based on the Kaufmann et al. (2011) proposed requirement levels. If all new buildings in the commercial sector complied with the requirement to install rooftop PV arrays, nearly 4,700 MW of solar would be installed in 2012, a major increase from EIA estimates of 640 MW of solar generation capacity installed in 2009. The residential sector could contribute roughly an additional 2,300 MW based on the same code requirement levels of 4 W/ft^2 of roof area.

For the REC market, the largest impact estimate is based on all new construction complying with the code by purchasing RECs instead of installing renewable energy systems like PV arrays (maximum possible result). For an energy equivalent requirement, this could result in 72.6-476 million RECs purchased in 2012 depending on the code requirement, while the current RECs markets may be closer to 92 million RECs. If a price equivalent REC requirement is in place, the market impact is larger. The repercussions for the market could be dramatic, and this analysis indicates the need to design the code requirement carefully to incentivize on-site PV systems so the REC market does not become volatile.

Long-term adoption of on-site renewable systems in building energy codes will require further market, technology and policy analysis. While major issues and preliminary recommendations have been identified both in this paper and in a previous study (Kaufmann et al., 2011), further steps should be taken to ensure proper structure of future code implementation.

Acknowledgements

Funding for this work was provided by the US Department of Energy with leadership from Jeremy Williams and Bob Dewey. The authors appreciate the comments and support provided by Doug Elliott and Anne Manning.

References

American National Standards Institute, American Society of Heating, Refrigeration and Air-Conditioning Engineers, United States Building Council, Illuminating Engineering Society of North America (ASHRAE). 2010. *Standard 189.1: Standard for the Design of High-Performance Green Buildings.* Atlanta, Ga.: American Society of Heating, Refrigeration and Air Conditioning Engineers.

Bird, L., Holt, E., Sumner, J., Kreycik, C. 2010. *Voluntary Green Power Market Forecast Through 2015*. http://www.nrel.gov/analysis/newsletters/2010_june.html. NREL/TP-6A2-48158. Golden, Colo.: National Renewable Energy Laboratory.

BP. 2011. *Solar Capacity: Solar Power Starts to Show up at Scale*. Accessed August 24, 2011 at http://www.bp.com/sectiongenericarticle800.do?categoryId=9037190&contentId=7068638.

Dillon, HE., CA Antonopoulos, AE Solana, and BJ Russo. 2011. *Renewable Energy Requirements for Future Building Codes*. PNNL-20727. Richland, Wash.: Pacific Northwest National Laboratory.

[DOE] Department of Energy. 2011a. *Buildings Energy Databook. Chapter 3: Commercial Sector. Table 3.2.7: Commercial Building Median Lifetimes (Years)*. http://buildingsdatabook.eere.energy.gov/TableView.aspx?table=3.2.7. Washington D.C.: U.S. Department of Energy, Energy Efficiency and Renewable Energy.

[EIA] Energy Information Administration. 2011a. *Annual Energy Outlook 2011: Commercial Sector Key Indicators and Consumption, Reference Case*. http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2011&subject=0-AEO2011&table=5-AEO2011&region=0-0&cases=ref2011-d020911a. Washington D.C.: Energy Information Administration.

[EIA] Energy Information Administration. 2011b. *Annual Energy Outlook 2011: Residential Sector Key Indicators and Consumption, Reference Case*. http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2011&subject=0-AEO2011&table=4-AEO2011&region=0-0&cases=ref2011-d020911a. Washington D.C.: Energy Information Administration.

Green-e Energy. 2011. *National Standard Version 2.1*. http://www.green-e.org/getcert_re_stan.shtml. San Francisco Calif.: Green-e Energy.

Price, S., Margolis, R. et al. 2010. *2008 Solar Technologies Market Report*. http://www.nrel.gov/analysis/market_re_data_solar.html. Golden, Colo.: National Renewable Energy Laboratory.

Holt E and L Bird. 2005. *Emerging Markets for Renewable Energy Certificates: Opportunities and Challenges*. http://www.eere.energy.gov/greenpower/resources/pdfs/37388.pdf. NREL/TP-620-37388. Golden, Colo.: National Renewable Energy Laboratory.

Kaufmann, J.R., Hand, J.R., Halverson, M. 2011. *Integrating Renewable Energy Requirements Into Building Energy Codes.* PNNL-20442. Richland, Wash.: Pacific Northwest National Laboratory.

[NREL] National Renewable Energy Laboratory. 2011. *Insolation for Flat-Plate Collectors at Latitude Tilt Map*. http://www.nrel.gov/gis/images/map_pv_national_hi-res.jpg. Golden, Colo.: National Renewable Energy Laboratory.

Russo BJ., Weimer, M. Dillon, HE. 2011. *Draft report: Renewable Energy Requirements for Future Building Codes: Energy Generation and Economic Analysis.* Richland, Wash.: Pacific Northwest National Laboratory.

Taylor, Z.T., Lucas, R. 2011. *Draft RFI for Economic Assessment of Residential Building Energy Codes*. Richland Wash.: Pacific Northwest National Laboratory.

U.S. Census Bureau. 2011. *2011 Statistical Abstract*. Construction & Housing: Housing Units and Characteristics.http://www.census.gov/compendia/statab/cats/construction_housing/housing_units_and_characteristics.html. Washington D.C.: U.S. Census Bureau.

Washington State Leglislature. 2011. *Washington State Administrative Code, Title 51: General Administration. Chapter 51-11: Washington State Energy Code 2009 Edition. Chapter 16:On-Site Renewable Energy Systems*. http://apps.leg.wa.gov/wac/default.aspx?dispo=true&cite=51-11. Seattle Wash: Washington State Leglislature.