PNNL-28578

Considerations for Commercial Building Participation in a Transactive Energy - Additional Information on Commercial Buildings

April 2019

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TD Hardy

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

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The research done in FY 18[1] found that there were many factors particularly relevant to the commercial setting that would impact participation and should be considered when evaluating the effectiveness of a Transactive Energy (TE) system. One factor that became a major focus was the ownership and lease structures, commercial real estate databases were used to estimate the percentage of commercial space that may be subject to a lease arrangement that inherently removed the incentive to participate in TE. Other major factors that were discussed were the impacts that participation could have on the production and revenue of a commercial space and how the state of the building and the equipment within it would effect the potential participation. The research on other factors was not discussed at the same level of detail; this addendum aims to analyze some of the other important factors on commercial participation in a TE system with similar rigor.

The end use equipment and condition of the building directly impact the possible savings opportunities that a TE system can offer a commercial customer, and therefore the incentive to participate. Data from the 2012 Commercial Building Energy Consumption Survey (CBECS) completed by the US Energy Information Agency (EIA)[2] can be used to identify the amount of commercial building space that has potential for high levels of participation in a TE system. This identification can be done by examining the end use equipment and building characteristics that exist in the CBECS data that provide an increased opportunity to save by participating in TE while factoring in the square footage of the commercial building with said equipment installed. The combination of square footage and end use loads provides a general idea of the total electrical energy consumption involved when using these particular loads. Additionally, this information can be organized by commercial activity and used to identify if any commercial building types stand out in terms of opportunities.

Table 1 is a compilation of data from CBECS that highlights specific factors that would be of interest in implementing TE systems that include commercial buildings. These present data on loads that have high potential for TE system integration, existing on-site generation, and implications of the use pattern of the commercial building. The data is broken out by building type (i.e. its primary end-use) and presented as a percentage of total floor space rather than by number of buildings. As energy usage is typically proportional to floor space, this provides a good estimate of the total opportunity for impacting power system energy consumption in the commercial building space via TE systems.

Table 1 Percentage of Total Floorspace with TE System Opportunities by Building Type
(Percentages based on total commercial floor area of 87,093 million square feet)

	All buildings	Office	Warehouse / Storage	Service	Mercantile	Religious worship	Education	Public assembly
Total Floorspace	100%	18%	15%	5%	13%	5%	14%	6%
Has new lighting and HVAC*	67%	81%	45%	44%	63%	51%	78%	78%

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[1] Bender S.R., J.M. Niemeyer, M.R. Weimar, and T.D. Hardy. 2018. "Considerations for Commercial Building Participation in a Transactive Energy System." In *IEEE - ISGT*. PNNL-SA-137666.
[2] https://www.eia.gov/consumption/commercial/

Electricity Primary Space Heating Energy Source	30%	38%	27%	21%	34%	32%	24%	21%
HVAC Building Automation System	43%	52%	13%	13%	55%	23%	71%	48%
Lighting Building Automation System	14%	17%	4%	NA	42%	NA	12%	15%
Buildings with Electricity Generation	29%	38%	18%	9%	20%	NA	34%	34%
Buildings with Water Heating	91%	98%	77%	81%	97%	95%	97%	96%
Buildings with Space Heating	92%	99%	76%	90%	95%	99%	99%	96%
Buildings with Cooling	91%	100%	77%	81%	98%	94%	97%	94%
Under 50 Workers During Main Shift	58%	35%	74%	87%	56%	94%	41%	69%
Open Continuously	20%	14%	14%	NA	10%	NA	3%	14%

	Food service	Food sales	Lodging	In-patient	Out-patient	Public Order and Safety
Total Floorspace	2%	1%	7%	3%	2%	2%
Has new lighting and HVAC	49%	46%	71%	137%	56%	44%
Electricity Primary Space Heating Energy Source	38%	37%	48%	7%	37%	NA
HVAC Building Automation System	14%	36%	39%	93%	48%	43%
Lighting Building Automation System	NA	NA	5%	14%	NA	NA
Buildings with Electricity Generation	NA	31%	48%	95%	39%	82%
Buildings with Water Heating	100%	100%	100%	100%	100%	93%

Buildings with Space Heating	97%	96%	98%	99%	98%	97%
Buildings with Cooling	94%	95%	98%	100%	100%	96%
Under 50 or 10* Workers During Main Shift	52%	47%	26%	NA	20%	19%
Open Continuously	6%	22%	98%	100%	NA	66%

NA indicates there was not enough data available to calculate a value
*Includes floorspace constructed after 2008 or floorspace that has had HVAC or lighting remodels

In examining the data in Table 1 there are a few items of particular note. Across all building types the percentage of buildings with cooling systems (air-conditioning, largely) installed is very high. Though the use of these devices will be highly dependent on the climate in which they were installed, air-conditioning is typically a driving force in energy consumption during peak summer days when load management via TE systems would offer significant benefit. The use of electric heating systems across building types varies much more from single digit up to almost 50% which again presents a large TE opportunity. Interestingly, most commercial building types do have some form of water heating, but it can be assumed that many of those will have natural gas versus electrical water heating and thus present a lower opportunity for TE systems to have an impact on electrical load.

Given the significance of cooling on a building's energy consumption during hot days (including peak load days when the power system is reaching its limits), more specific data related to cooling across the building type was assembled and presented in Table 2. This data pertains to both space cooling (as in traditional air-conditioning) as well as the use of temperature-controlled storage spaces (such as refrigerators and walk-in freezers).

Table 2 Percentage of Floorspace with Cooling and Refrigeration by Building Type

(Percentages based on total commercial floor area of 87,093 million square feet)

	All buildings	Office	Warehouse and storage	Service	Mercantile	Religious worship	Education	Public assembly
Residential-type central air conditioners	17%	14%	20%	25%	22%	36%	7%	17%
Heat pumps	14%	18%	9%	9%	15%	16%	19%	12%
Individual air conditioners	14%	14%	12%	15%	7%	16%	17%	11%
District chilled water	5%	7%	NA	NA	NA	NA	11%	16%
Central chillers	20%	32%	4%	NA	4%	NA	34%	19%

Packaged air conditioning units	52%	50%	49%	40%	80%	49%	48%	48%
Swamp coolers	2%	NA	NA	NA	4%	NA	NA	NA
Other Cooling	0%	NA	NA	NA	NA	NA	NA	NA
Any refrigeration	85%	88%	66%	78%	91%	93%	92%	89%
Walk-in units	33%	21%	6%	NA	54%	NA	58%	28%
Cases or cabinets	33%	25%	8%	NA	61%	18%	47%	32%
Large cold storage areas	5%	NA	7%	NA	11%	NA	NA	NA
Commercial ice makers	38%	34%	13%	NA	49%	23%	50%	39%
Residential-type or compact units	72%	81%	58%	68%	78%	83%	73%	78%
Vending machines	50%	55%	38%	37%	62%	10%	63%	49%

	Food service	Food sales	Lodging	In-patient	Out-patient	Public Order and Safety
Residential-type central air conditioners	26%	29%	13%	NA	20%	17%
Heat pumps	10%	NA	19%	22%	13%	NA
Individual air conditioners	11%	NA	40%	23%	NA	NA
District chilled water	NA	NA	NA	20%	NA	NA
Central chillers	NA	NA	28%	79%	32%	29%
Packaged air conditioning units	52%	60%	41%	58%	56%	56%
Swamp coolers	5%	NA	NA	NA	NA	NA
Other Cooling	NA	NA	NA	NA	NA	NA
Any refrigeration	100%	100%	98%	100%	95%	96%

Walk-in units	84%	82%	54%	93%	NA	NA
Cases or cabinets	70%	87%	47%	80%	20%	NA
Large cold storage areas	NA	23%	NA	13%	NA	NA
Commercial ice makers	74%	55%	74%	97%	34%	36%
Residential-type or compact units	51%	40%	78%	87%	91%	84%
Vending machines	11%	54%	74%	97%	53%	66%

In terms of device type providing air-conditioning for commercial buildings, the packaged units (often roof-top installations) are a significant fraction of all cooling device types across all commercial building types. As compared to the split units, these units provide cold air directly the conditioned space and may or may not feed ductwork inside the building. In large big-box installations they may all feed a common area; this presents an opportunity for TE systems to reduce the number of operating units while still providing some degree of cooling to the space. That is, such installations allow a response to the TE signal that is more continuous in nature than strictly binary (all air-conditioning on or off); such responses are more desirable for TE systems.

Also of note is the large amount of refrigeration installed across all building types. The opportunity for TE systems to utilize this load is highly dependent on the purpose of the refrigeration. In retail sales spaces the ability to adjust the storage temperature of refrigerated or frozen good storage may be possible within certain limits (particularly for food items), but that opportunity could be reduced in food service establishments that face food health and safety requirements and may be even more tightly regulated in medical buildings where some portion of the refrigeration is used for storage of medicines.

Commercial ice makers provide a particularly unique TE system opportunity as, like other electrical cooling devices, the energy intensity of such operations can be very high but the produced product can be safely stored for long periods of time. With relatively modest changes to the size and effectiveness of the storage area for the ice, the ability to move the operation of the ice maker in time in response to TE signals could provide energy cost reductions with little to no loss of amenity (total volume of ice produced).

Lastly, Table 3 provides an overview of the energy consumption by load type versus building type. Examination of the CBECS data in this way shows where the biggest energy-consuming loads are in the various commercial building types and, consequentially, where the greatest opportunity for load management via TE mechanisms exists.

Table 3 Percentage of Electricity Consumption by End Use by Building Type

	Space Heating	Cooling	Ventilation	Water Heating	Lighting	Cooking	Refrigeration	Office Equipment	Computers	Other
Education	2%	20%	15%	1%	17%	1%	9%	5%	17%	14%
Food sales	1%	3%	6%	0%	8%	5%	71%	1%	1%	6%
Food service	2%	11%	11%	1%	7%	16%	41%	3%	1%	8%
Health care	1%	19%	22%	0%	17%	2%	5%	5%	9%	19%
Inpatient	1%	23%	18%	0%	16%	3%	6%	5%	8%	20%
Outpatient	2%	10%	32%	0%	18%	1%	4%	4%	11%	18%
Lodging	3%	13%	16%	1%	13%	3%	11%	14%	2%	24%
Mercantile	2%	13%	17%	1%	20%	1%	27%	3%	3%	13%
Retail (other than mall)	2%	14%	17%	0%	26%	1%	19%	2%	4%	16%
Enclosed and strip malls	2%	12%	18%	2%	16%	1%	33%	3%	3%	12%
Office	2%	13%	25%	0%	17%	0%	3%	4%	19%	15%
Public assembly	3%	30%	9%	0%	13%	1%	9%	3%	6%	27%
Public order and safety	1%	21%	7%	1%	21%	1%	4%	4%	11%	27%
Religious worship	4%	19%	16%	0%	11%	1%	5%	4%	4%	35%
Service	2%	13%	11%	0%	29%	0%	4%	3%	6%	31%
Warehouse and storage	1%	12%	5%	0%	30%	0%	17%	2%	6%	27%
Other	2%	14%	8%	0%	19%	0%	8%	1%	21%	27%

As previously stated, the cooling load is generally very significant and when combined with the ventilation load that would also run when cooling a building, the two combined generally provide the largest consumption of energy as compared to the other load types. Peak electrical load days often have a significant fraction of their load from cooling systems and thus the TE system potential is often significant.

Lighting is also a very large energy consumer but is more of a challenge from a TE system stand-point. Lighting loads are a “forfeit” type of TE load. That is, anytime lighting is changed in response to a TE signal the amenity is forfeited; there is no such thing as “pre-lighting” in the same way that a building can be “pre-cooled”. Given the large amount of energy used for lighting in commercial spaces, there has been a lot of discussion of how it might be leveraged for TE systems. It is clear that energy efficiency measures (lighting upgrades) would be effective in reducing the total energy consumption but more dynamic operations in response to TE signals may or may not be implementable due to this loss of amenity.

Organizing the available data from CBECS in this way allows for a clear identification of the areas within the commercial building space where there is ample opportunity for TE. This not only can inform where additional research would have the most impact, but also lays the foundation for future valuation studies. Understanding which actors in the commercial building space have what values to offer to a TE system is one of the first steps in creating a value model for a use case that includes an in depth look at commercial buildings.

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