Direct Current in Buildings
A look at current and future trends

National Electrical Manufacturers Association

About the National Electrical Manufacturers Association

The National Electrical Manufacturers Association (NEMA) represents nearly 350 electrical equipment and medical imaging manufacturers that make safe, reliable, and efficient products and systems. Our combined industries account for 360,000 American jobs in more than 7,000 facilities covering every state. Our industry produces $106 billion shipments of electrical equipment and medical imaging technologies per year with $36 billion exports.

Report Authors

Brian Marchionini

Senior Program Manager, NEMA

Shuyu Zheng

Research Analyst, NEMA

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EXECUTIVE SUMMARY

Trends in the energy industry are helping to fuel the debate about the advantages and disadvantages of direct current in buildings. Examples of these trends include the growing deployment of distributed energy resources (DER) such as solar photovoltaics and energy storage and end use loads are becoming more natively based on direct current due to the proliferation of electronics and light-emitting diodes (LED). These trends can open the opportunity to deploy direct current (DC) systems in buildings, which can potentially lead to benefits such as improved energy efficiency, more flexible configurations, reduced installation costs, and improved reliability.

However, there is still uncertainty about the rate of proliferation DC in buildings. There are a number of scenarios that could occur such as:

a. Continuing the status quo where the AC infrastructure remains the dominant delivery source of electricity
b. DC in buildings primarily as niche applications such as data centers and remote area systems
c. DC in new building construction or even building retrofits

The National Electrical Manufacturers Association (NEMA) conducted a survey with vendors, technical experts, research laboratories, standards development organizations, and other stakeholders to explore the existing landscape and future scenarios for DC in buildings. This paper summarizes the results from the survey and provides background on the primary drivers for DC systems. It also highlights potential benefits of using DC in buildings and opportunity areas in next five to ten years.

Figure 1 summarizes respondents' thoughts on what the key benefits were for using DC in buildings. Respondents were able to choose as many benefits as they thought were appropriate. More flexible and simple designs and improved energy efficiency were two of the top rated benefits. While these and other benefits may be disputed, technical and economic information is being developed by national laboratories and trade associations to help stakeholders with decision making.

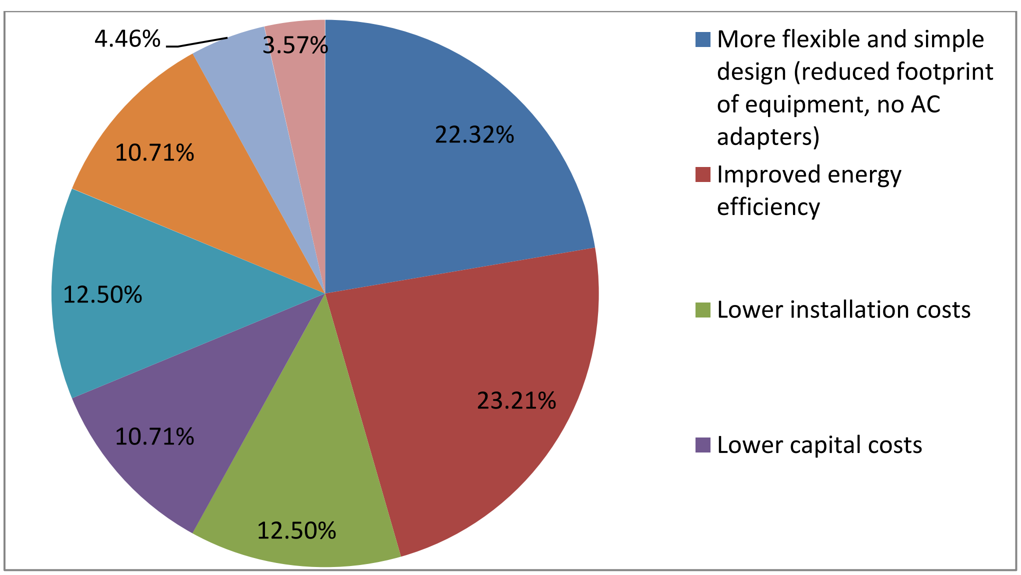

Figure 1: Examples of Benefits from DC in Buildings

If stakeholders are interested in achieving these benefits on a broad scale, there are several barriers that need to be overcome. Figure 2 highlights some of the barriers and recommendations for overcoming them.

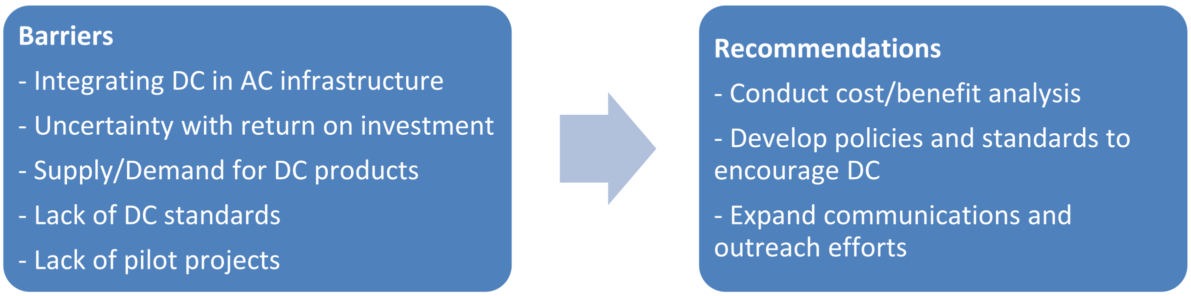

Figure 2: Examples of Barriers and Recommendations from Increased Deployment of DC in Buildings

Since today's electric grid is almost exclusively built on a reliable and well established AC system, converting to DC based system(s) can be challenging. A shift from AC to DC could occur when products can be made cheaper, smaller, or more efficient and with reduced total cost of ownership for buildings. There is also a lack of pilot projects and lessons learned that are available for stakeholders to understand the value proposition and best practices. Communications and outreach activities to stakeholders are important for broadening the understanding of DC in buildings. Examples of these stakeholders can be found in Figure 3. Conducting an economic analysis of the costs and benefits for several use cases would also be useful for stakeholders to better understand capital costs and expected payback.

Figure 3: Examples of the Stakeholders that should be Engaged to Promote DC in Buildings

INTRODUCTION

Alternating current (AC) has been the dominant means of power distribution and transmission since Thomas Edison lost the War of the Currents in the 1890s. However, in the last several decades, the advent of new generation sources and end-use technologies has increased interest in direct current (DC) systems. On the generation side, the growing deployment of distributed energy resources such as solar photovoltaics and energy storage systems could affect DC in buildings. On the consumption side, the portion of native DC loads continues to grow with the proliferation of electronics and LEDs giving rise to a higher DC end-use demand. These drivers help enable a future where there could be more widespread use of DC in buildings and other applications. However, DC systems could continue to have limited penetration to niche applications and pilot projects until widespread adoption and implementation take hold.

Electricity used in today's buildings is imported from the electric grid as AC and transformed to the appropriate voltage level for many end use devices. However, devices such as electronic equipment with an external or internal power supply require the AC power to be converted to DC. With new AC/DC hybrid solutions, energy efficiency can be improved; however, the quantity is influenced by several factors that include building types and size, the number and efficiencies of power conversion components (DC/AC, AC/DC, DC/DC), DC voltage level and associated line losses and power system configuration (Alliance to Save Energy, 2017). Figures 4 and 5 show the EMerge Alliance estimates energy loss on the end-use side can reach 20% for some devices and with DC systems this can be reduced to 6% or lower.

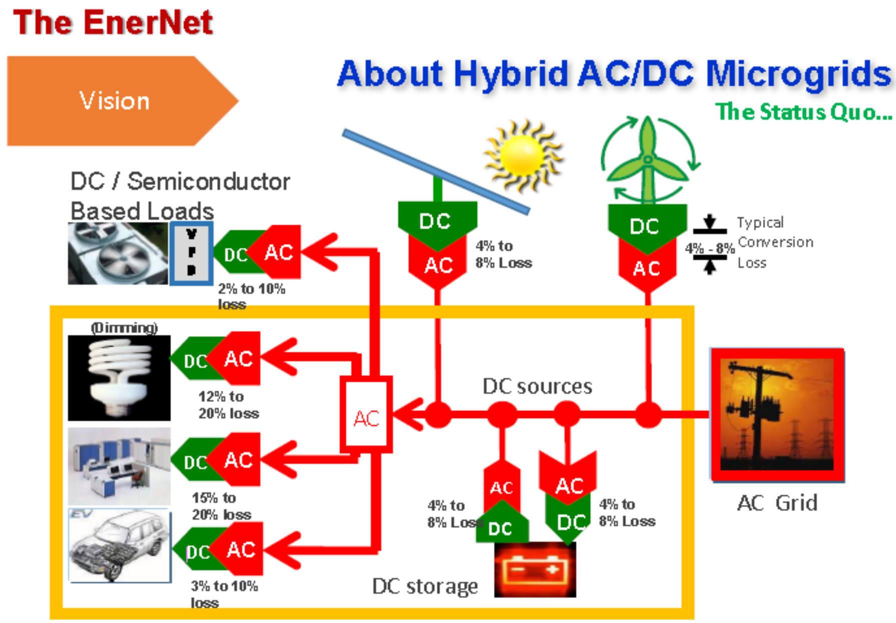

Figure 4: Status Quo AC/DC Hybrid Microgrid Distribution Network
Source: EMerge Alliance

Studies conducted by IEEE and Los Alamos National Laboratory hold conservative perspectives. IEEE estimates that DC distribution may improve efficiency of 3.4% for buildings without access to AC (e.g., islanded building with PV and storage installed), and only improve efficiency of 1.3% for buildings that have access to AC. Los Alamos National Laboratory estimates that DC distribution improves efficiency by 2-3% for buildings where the load and generation are well matched.

This paper is not meant to provide a detailed comparison of efficiencies for AC and DC; it is simply to show that estimates vary. Stakeholders will need to conduct due diligence to determine efficiency gains for their specific application. At the publication date of this paper, Colorado State University, along with the National Renewable Energy Laboratory and other partners are working on a study to characterize energy efficiency of AC and DC products. The data will enable an enhanced toolset for the building industry to directly compare alternative AC and DC systems.

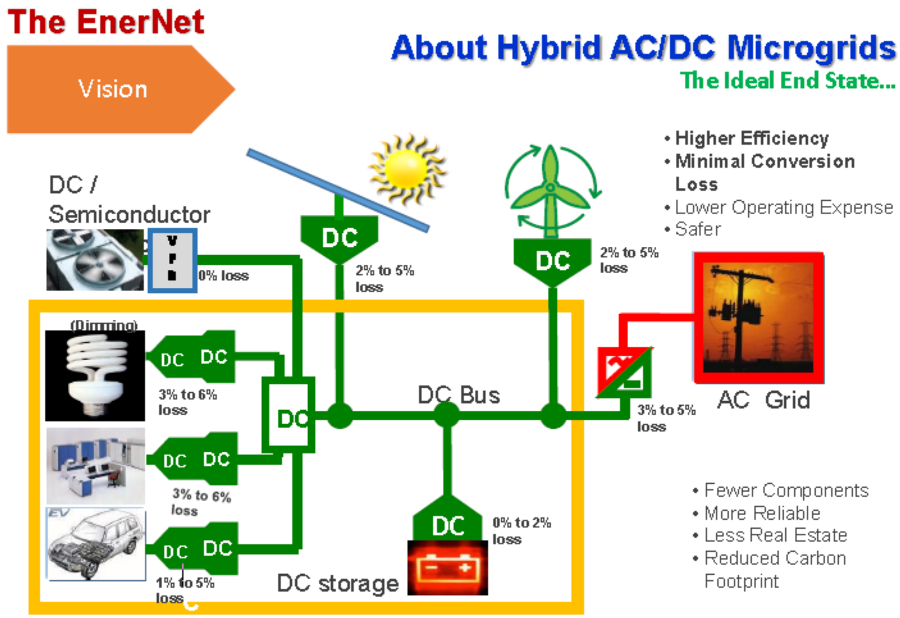

Figure 5: New AC/DC Hybrid Microgrid Path to Net Zero Energy Buildings
Source: EMerge Alliance

There have been some efforts to accelerate market adoption of DC technology since the early 2000s. The EMerge Alliance, a consortium that includes product manufacturers, has developed a standard for 24V DC power distribution in occupied spaces as well as a standard for 380V DC power distribution in data/telecom centers and is on the way to develop DC standards for residential and commercial buildings and campus microgrids. Some companies are providing diverse DC hardware appliances and software controls for building-level microgrids (Navigant Research, 2015). Examples of several DC building pilot projects are in Appendix A.

The majority of DC deployment has occurred with high-voltage electricity transmission, telecommunication facilities and towers and low voltage electricity service such as Power over Ethernet (PoE). However, medium-voltage DC distribution, which is usually deployed in residential, commercial and industrial buildings, has potential for growth. In particular, DC data centers are one application in the medium-voltage range that could experience significant growth. In 2015 there was relatively modest capacity of 16. 9 MW, and by 2024 annual capacity it could reach 886 MW—mostly from the Asia Pacific region (Navigant 2015).

Figure 6 illustrates how the amount of DC in buildings could change over time. The status quo is where buildings are fed by the traditional AC distribution network and converters enable use of DC-based devices. The percentage on the Y axis of Figure 6 is only illustrative—the AC infrastructure will continue to be a significant backbone to support buildings in the future. Buildings could become more hybrid AC/DC systems. These systems are fed by AC, which is converted to DC in one central location and then DC is distributed to all end use devices. Another possibility is that more buildings could be fed by DC from devices like solar photovoltaics and energy storage systems which are natively DC. All DC systems could be more prevalent in remote area applications where there isn't an existing AC grid infrastructure.

The time horizon and adoption rate of DC infrastructure is dependent on a number of factors. These factors include return on investment for DC equipment, building types, availability of DC products, codes and standards development and stakeholder engagement.

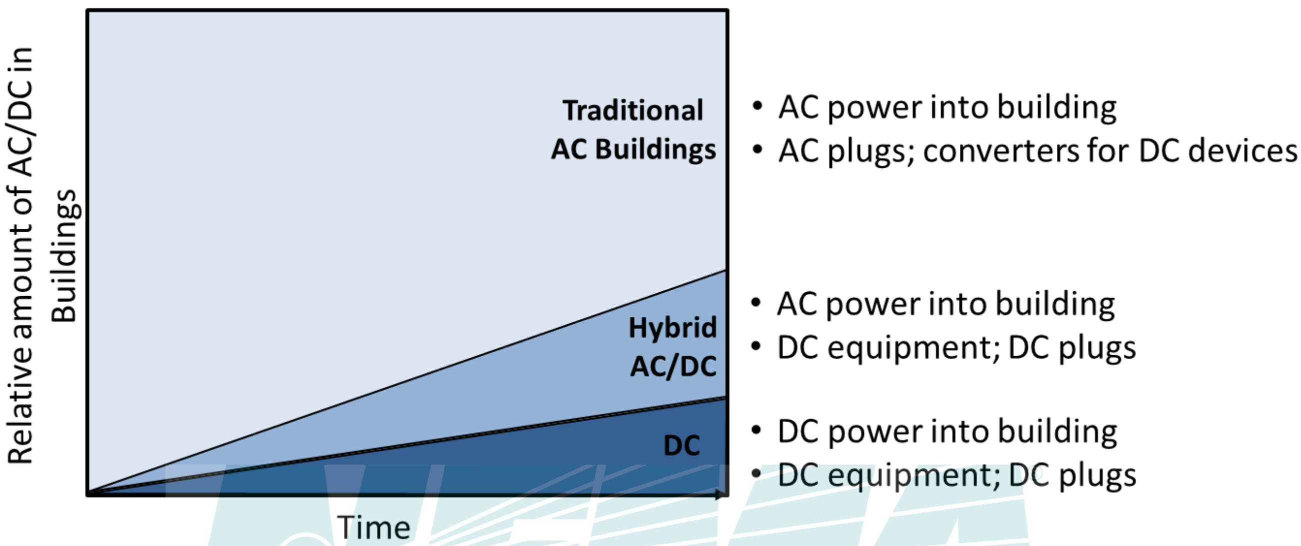

Figure 6: There are Several Scenarios for DC in buildings

SCOPE

This paper focuses on deployment of medium and low voltage DC technology in residential, commercial and industrial buildings. While an application for DC based systems, telecommunication facilities, and towers are not included in the discussion. The white paper also focuses on North American deployment of DC based systems but also covers some international efforts.

The survey was conducted with vendors, technical experts, research laboratories, standards development organizations, and other stakeholders to explore the existing landscape and future scenarios for DC in buildings. This paper summarizes the results from the survey and provides background on the primary drivers for DC systems. It also highlights potential benefits of using DC in buildings and opportunity areas in next five to ten years. The data should be interpreted as the best available from a snapshot in time from a set of stakeholders.

DRIVERS

Several industry drivers have the potential to increase the penetration of DC systems in buildings. Examples of drivers include the growth of distributed energy resources such as solar and energy storage integration in the grid, increasingly native DC loads, and government initiatives.

GROWTH OF DER INTEGRATION

Distributed energy resources (DER) can be a key contributor for enabling microgrids and DC systems in buildings. With dramatic cost reduction in PV panels, the solar industry has experienced an average annual growth rate of 68% in the last decade (SEIA, 2017). Furthermore, the lower cost of battery storage makes DER even more cost competitive as it can solve the intermittency problem associated with renewable energy by smoothing supply and demand. Electricity generated by natively DC devices can save 5% to 8% conversion loss as estimated in an all-DC building scenario (Denkenberger et al., 2012). Combined with battery storage, which is also natively DC, there is the potential for additional electricity savings (Vossos et al., 2014).

SOLAR PHOTOVOLTAICS

The International Energy Agency's Photovoltaic Power System Programme's report found that 75 gigawatts of solar were installed globally in 2016—bringing the installed global photovoltaic capacity to at least 303 gigawatts (IEA, 2016). That equates to producing 375 billion kilowatt-hours of solar power each year, which represents 1.8 percent of the electricity demand of the planet.

Figure 7 shows that in 2016, United States solar installations almost doubled compared to 2015, while the solar prices dropped 19% (SEIA, 2017). The cost of solar panels has dropped by more than 70% since 2010, leading to a PV installation boom in the U.S.

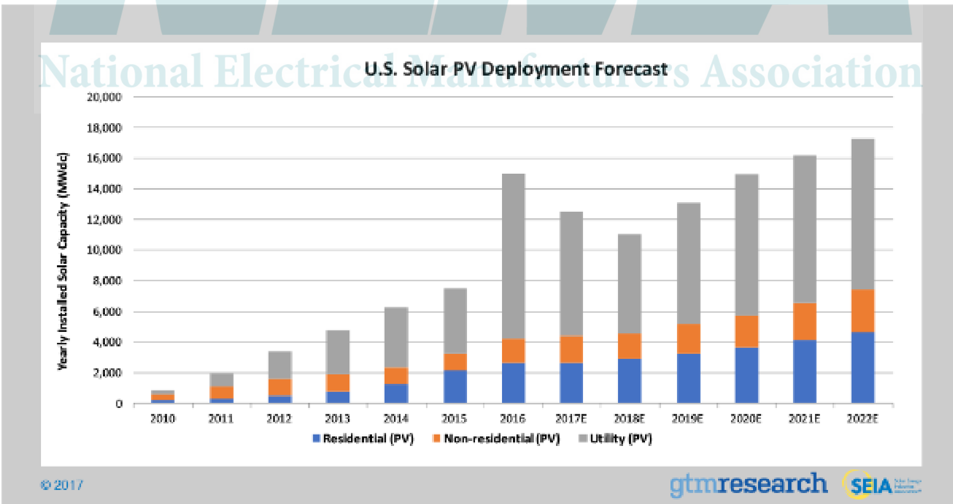

Figure 7: U.S. Solar PV Deployment Forecast, SEIA, 2017
Source: GTM Research

ENERGY STORAGE

Energy storage systems have experienced a significant technology and economic evolution in recent years. The improvement of smaller capacity batteries was a key factor for the development of mobile devices. This technology is now applied to larger storage devices that are used for electric vehicles, and more recently as a power source in houses. Energy storage deployment in the U.S. has rapidly increased since 2014 as the cost per kWh of capacity of batteries has dropped nearly threefold between 2009 and 2013 (CLASP, 2016). Figure 8 shows that residential and commercial grid connected solar-plus-battery systems are already cost-competitive in high-rate market such as Honolulu, HI, and will reach grid parity in Los Angeles, CA and Westchester, NY in the near future (Rocky Mountain Institute, 2015).

DC power generated by solar PV can be directly stored in a battery. Energy storage can also be also be used to power DC devices, which reduces energy conversion losses.

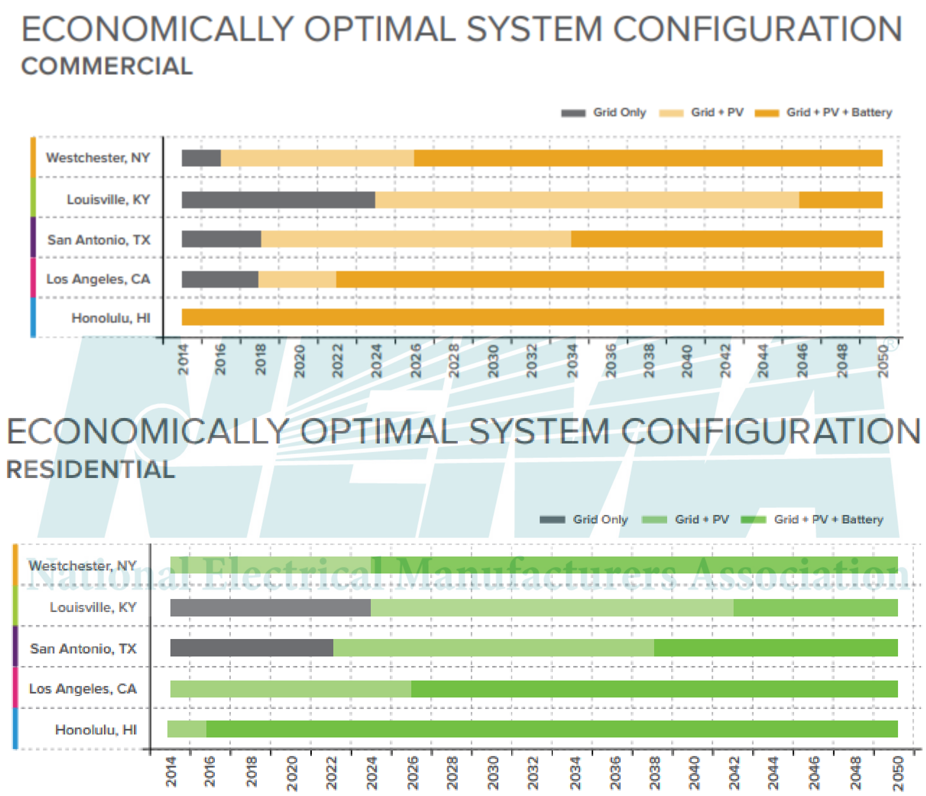

Figure 8: Economically Optimal System Configurations for Commercial and Residential Sectors

Source: Rocky Mountain Institute 2015

INCREASINGLY NATIVE DC LOADS

The loads being served by today's AC grid are becoming more natively DC due to the proliferation of electronics, LED, and DC plug loads. Figure 9 shows that native DC loads share about 32% of U.S. residential electricity use. Combined with electric vehicles, appliances and heating, ventilation and air conditioning (HVA/C) products that use DC motors, the native DC loads share could be as much as 63 to 74% (CLASP, 2016). The share has the potential to rise in the foreseeable future with a growing digital economy, more advanced motor driven appliances, and the rise of electric vehicles.

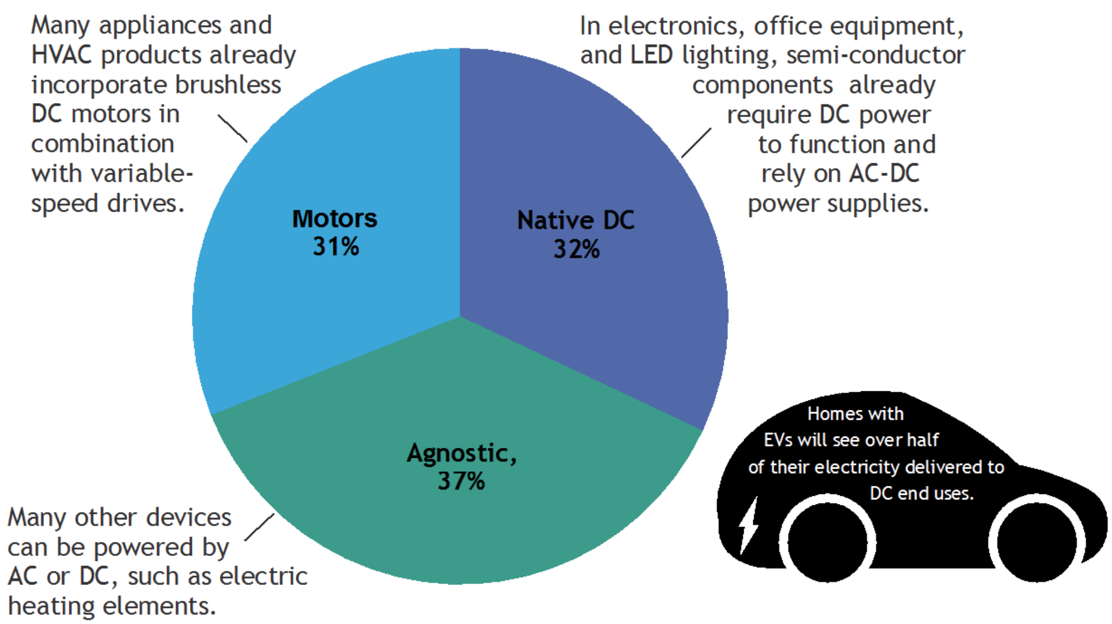

Figure 9: Percentage of U.S. Residential Electricity Consumption that is DC, AC-DC Agnostic, and Motorized

Source: CLASP DemandDC White Paper 2016

GOVERNMENT STANDARDS AND INITIATIVES

Today, energy used in buildings accounts for about 40% of total U.S. energy consumption, however, nearly one third of energy is wasted in buildings and industry (DOE, 2015). This presents opportunities for energy efficiency technologies and solutions that are cost-effective today. Federal and state governments have published energy efficiency standards, as well as several building efficiency initiatives such as zero energy buildings to improve energy efficiency performance, providing an opportunity for DC in buildings.

ENERGY EFFICIENCY STANDARDS

The Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE)'s Strategic Plan and Implementing Framework for 2016-2020 outlines a plan to reduce the energy consumption per square foot in all U.S. building by 30% by 2030, compared to a 2010 baseline. In order to achieve the goal, various energy efficiency standards, including minimum efficiency standards for appliances and equipment, building energy efficiency standards, and energy efficiency resources standards (EERS) should continue to be established and implemented. Thirty states and the District of Columbia have already adopted energy efficiency policies as of July 2017, in which 24 states have adopted an EERS, four states have set voluntary goals, and two states have established energy efficiency pilot programs (EIA, 2017). Current building energy codes have covered about 70% of U.S. building energy use to improve the efficiency performance, and EERE, as of the publication date of their Strategic Plan, was going to continue to promote energy savings by testing new technologies to incorporate into the existing codes (2016-2020 EERE Strategic Plan, 2015). DC in buildings has the potential to contribute to these energy efficiency goals.

ZERO ENERGY BUILDINGS

Zero energy buildings, also known as zero net energy (ZNE) buildings are buildings where the total energy consumption is equal to the total energy generated on-site through renewable resources. A zero energy building target is becoming more practical with the penetration of DER. The European Commission is working towards the goal that all new buildings to be nearly zero energy by the end of 2020, and all new public buildings must be nearly zero energy by 2018 (The Energy Performance of Buildings Directive, 2010). Progress has also been made in the U.S. with the Department of Energy's Zero Energy Ready Home Program and many states now have multiple buildings. California has set the goal to achieve ZNE buildings by 2020 for residential buildings and 2030 for nonresidential buildings. According to New Buildings Institute, there has been a 74% increase in ZNE buildings in the last three years in the U.S. as 53 buildings verified and 279 buildings on their way to be verified as ZNE buildings (see Figure 10).

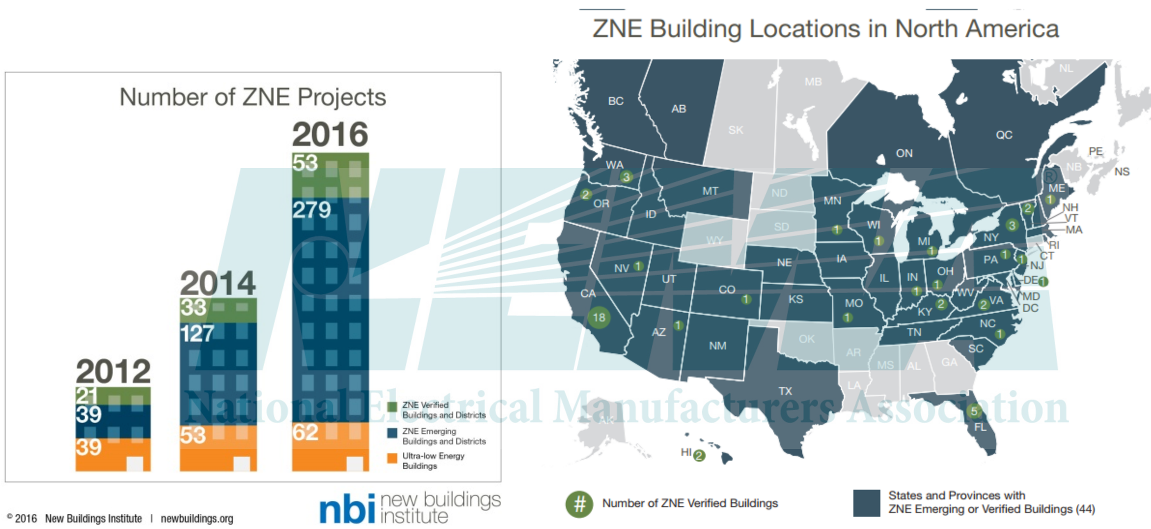

Figure 10: Number and Locations of ZNE Buildings in the U.S.
Source: New Building Institute

BENEFITS

After analyzing the results of NEMA's survey of manufacturers, industry experts, and other stakeholders, there were several main benefits identified for DC in buildings. Figure 11 highlights survey respondents' results related to the benefits from DC in buildings. Respondents were asked what they thought were benefits from a pre-populated list. They could choose as many of the suggested benefits as they felt appropriate. The main benefits of DC in buildings are energy efficiency improvement (68.42%), more flexible and simple design for electricity system (65.79%), lower installation costs (36.84%) and reliability improvement (36.84%). Additional benefits included safety improvement and lower capital costs. Examples of the benefits captured in the other category include power over Ethernet and integration of renewable energy and energy storage. While 90% of the respondents thought that there were some kinds of benefits, 10% felt that DC in buildings provided no benefits.

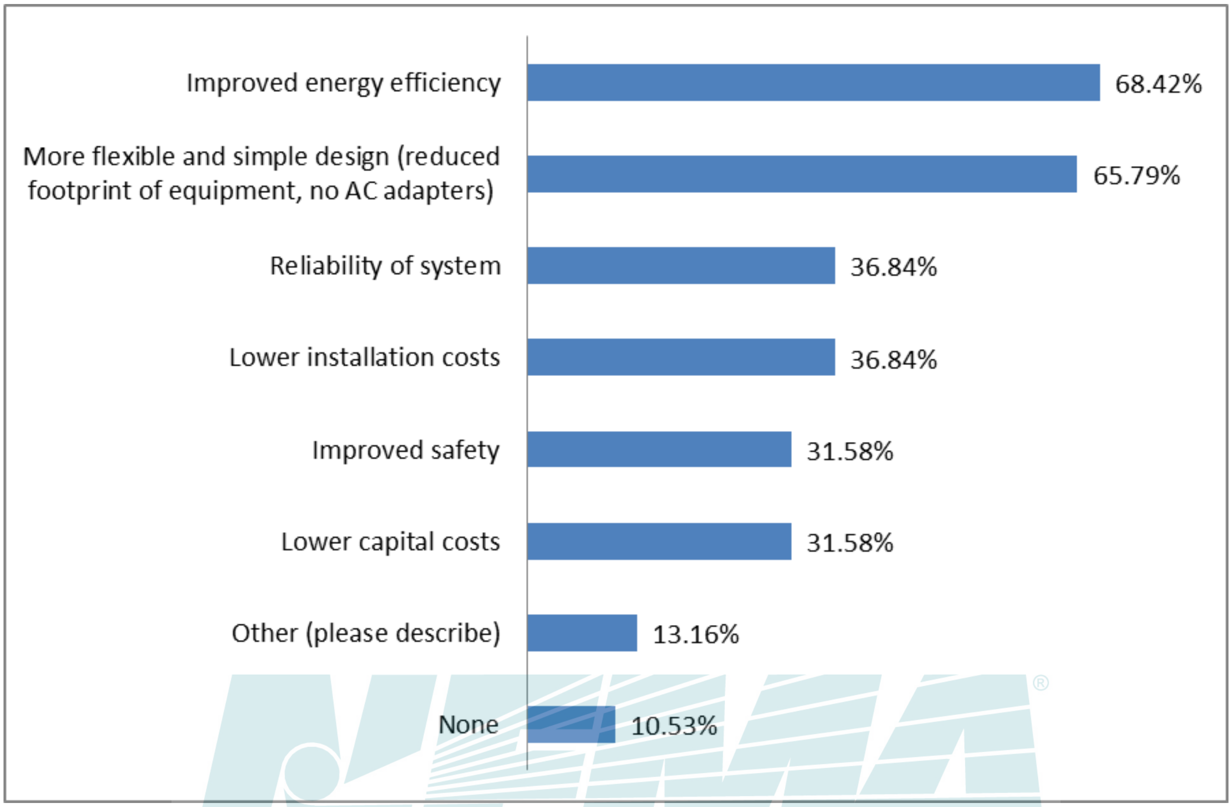

Figure 11: Benefits of DC in Buildings

"Other" responses include:

a. Power Over Ethernet enables networking
b. Renewable energy and energy storage integration

MARKET OPPORTUNITIES

Respondents were also asked to indicate where the market opportunities were today, in five years and in ten years. The biggest opportunity for DC in buildings today primarily exists in the area of off-grid microgrids, data centers, fast-chargers for electric vehicles (EVs), and grid-tied microgrids. As shown in Table 1, in the next five to ten years there is expected growth in the opportunities for DC industrial, residential, and commercial buildings.

Survey respondents were asked the following question:

> *Using a scale from 0 to 5 in which 0 is no opportunity at all and 5 is an extremely significant opportunity; rate the following items according to how significant of an opportunity each category is for DC today, in 5 years, and in 10 years?*

Table 1: Opportunities for DC in buildings today, in 5 years, and in 10 years

	Mean		
	Today	In 5 Years	In 10 Years
Residential	1.9	3.0	3.6
Commercial	2.5	3.4	3.9
Industrial	1.5	3.1	3.5
Data centers	3.4	3.6	3.8
Microgrids (with AC grid connection)	3.0	3.4	3.8
Microgrids (remote applications)	3.6	4.0	4.1
Fast chargers for electric vehicles	3.2	3.7	4.0

BARRIERS

Similar to early adoption of any other kind of new technology, DC in buildings faces a variety of barriers to more widespread deployment. Table 2 shows that existing AC infrastructure and insufficient DC products are ranked as the primary challenges for DC penetration in buildings today. Lack of explicit standardization and building codes are also considered as major barriers as manufacturers have no guidance to design DC products. Respondents mentioned that lack of industry awareness as well as trade practices also hinder DC deployment in buildings. Safety issues were not identified as a significant barrier as new circuit breakers and protection relays have been developed to avoid DC arc faults (Navigant Research, 2015).

The survey results revealed that the effect of insufficient DC products would be weakening notably as companies such as ABB and Bosch have begun commercializing DC appliances. The gap of standardization and building codes would be narrowed in next ten year as efforts have been contributing to accelerating the early market adoption. However, the ubiquity of AC systems will remain as the major barrier, as well as lack of industry awareness and trade practices.

Survey respondents were asked the following question:

> *Using a scale from 0 to 5 in which 0 is not a challenge at all and 5 is an extremely significant challenge, rate the following items according to how significant of a challenge each presents for DC systems in buildings.*

Table 2: Challenges for DC in Buildings Today, in 5 years, and in 10 years

	Mean		
	Today	In 5 Years	In 10 Years
Existing AC infrastructure	3.8	2.9	2.2
Safety	2.6	2.0	1.6
Standards development	3.2	2.4	1.8
Building codes	3.1	2.4	1.6
Lack of DC products	3.8	2.9	1.7
Other (please describe)	5.0	3.7	2.7

"Other" responses:

a. Industry awareness and experience
b. Lack of knowledge/training in trades
c. Trade practice

The survey also asked the same question about challenges, but for DC in buildings in the developing world (e.g., remote applications without a grid connection. Table 3 shows the respondents' results.

Table 3: Challenges for DC in Buildings in the Developing World Today, in 5 Years, and in 10 Years

	Mean		
	Today	In 5 Years	In 10 Years
Safety	3.4	2.7	2.1
Standards development	3.4	2.6	1.8
Building codes	3.1	2.6	2.1
Lack of DC products	3.7	2.7	1.8

An International Electrotechnical Commission (IEC) survey, covering global low voltage direct current (LVDC) stakeholders, collected the following information about the current state of the markets and overall future market prospects in the respondents' organizations. The results are summarized in Figure 12.

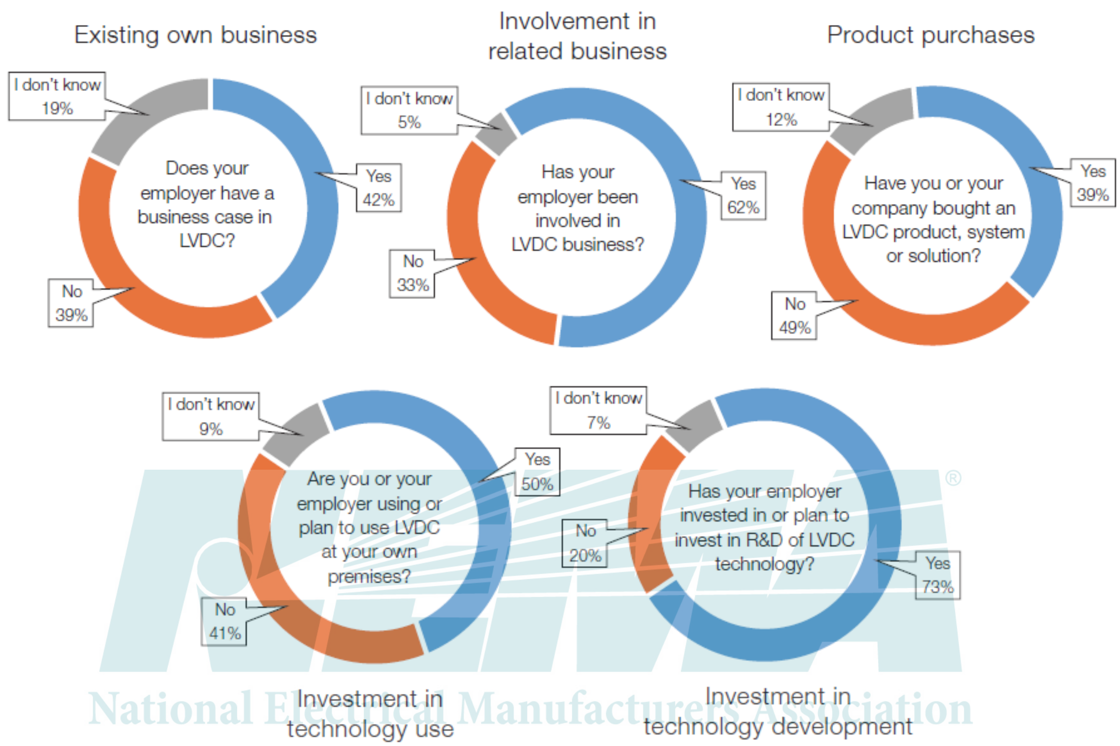

Figure 12: International Electrotechnical Commission Respondents' Involvement and Background Knowledge of LVDC-Related Markets

Source: IEC Report on LVDC Electricity for the 21st Century, 2017

STANDARDIZATION AND BUILDING CODES GAPS

There are only a few building codes and standards available today that address DC systems. Table 4 has several examples.

Table 4: Examples of DC Power Delivery Standards

Source: National Rural Electric Cooperative Association, Tech Surveillance, DC Power in Buildings; Separating the Hype from Reality, 2017

Standard	Application	Status
Emerge Commercial Buildings v1.0	First commercial building and campus requirements.	Pending
EMerge Occupied Space v2.0	Power distribution requirements for commercial interior (tenant spaces)	Available
EMerge Residential v1.0	First residential building requirements.	Pending
NFPA 70, U.S. National Electrical Code	Various low voltage DC (<1000V) requirements, including batteries, PV, grounding and bonding, and safety in the workplace.	Available
Power over Ethernet	Power delivery over Cat 5 Ethernet cabling at up to 25.5W (updates may allow up to 100W)	Available with updates pending for early 2018
USB Power Delivery	Low voltage DC through USB cabling for small electronics at up to 20V and 100W	Available

Survey participants were asked about standardization and building code gaps. Codes and standards gaps can be explored, and advocacy activities can be developed ultimately to help to deploy DC infrastructure in buildings.

STANDARDIZATION GAPS

Figure 13 shows that 64% of the respondents thought that standardization gaps exist, 30% said that the market is not mature enough for standards development, and only 6% deemed that no standardization gaps exist.

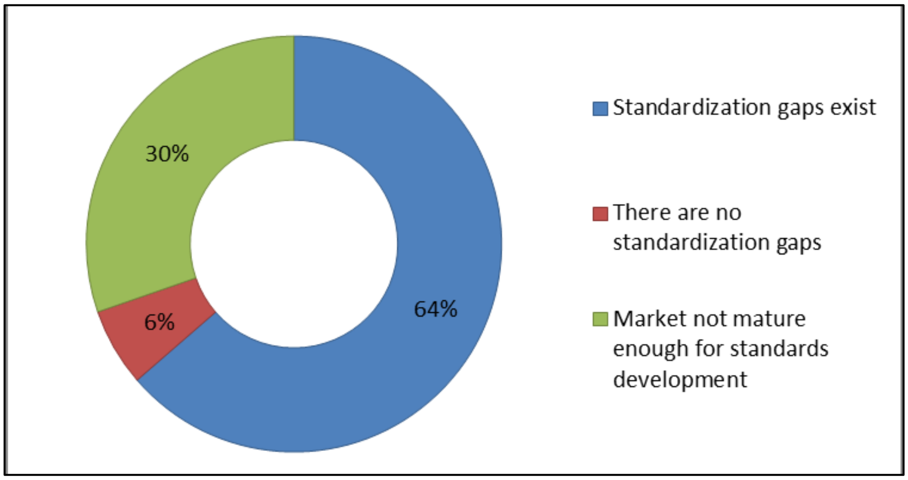

Figure 13: Survey Results on Standards Gaps

The existing standardization gaps include:

a. Connectors, wiring, interfaces, bidirectional vehicle charging / discharging systems
b. Electronic circuit protection
c. DC data center at 380 VDC
d. DC HVA/C standards at 24/380 VDC
e. DC lighting standards at 48/380 VDC
f. Safety testing and test methodologies
g. Energy efficiency standards such as EnergyStar for DC equipment
h. National Electrical Code (NEC) should update and equipment rating standards to require both AC and DC ratings
i. Integration of appliances and equipment for DC into existing AC infrastructure
j. Role of USB
k. Interconnection

CODE GAPS

Figure 14 shows that 52% responded by saying that the building code gaps exist, 30% think this market is not mature enough for standards development, and 18% believe that no building code gaps exist.

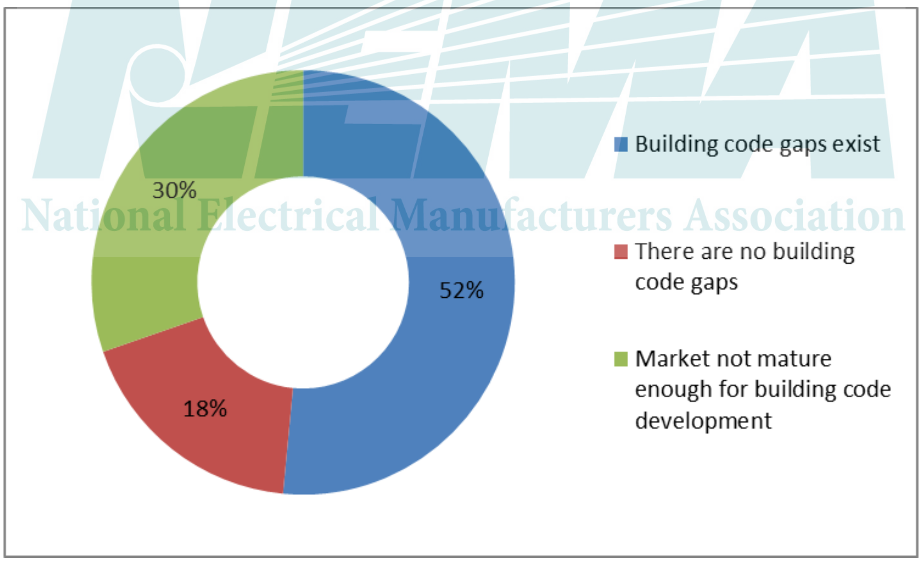

Figure 14: Survey Results on Code Gaps

The existing building code gaps include:

a. Installation rules
b. Wiring methods and receptacles, cord connected appliances
c. Safety system
d. Interconnection
e. Specification of what portions of an LVDC system that need professional installation/maintenance operator or home owner activities

NEXT STEPS

While some stakeholders are not convinced that DC in buildings is worth the investment, others are interested in being proactive to develop these systems. Listed below are actions that could be taken to accelerate market adoption of DC power systems in buildings:

a. **Analyze gaps in codes and standards.** There are few codes and standards today that give specific treatment of DC. They are mostly in the area of data centers and Power over Ethernet. Without standards and codes, electrical manufacturers have no explicit criteria to design DC products or ensure product compatibility. After gaps have been identified, then key stakeholders should submit revisions to the standards committees to fill them, such as standards for gaps mentioned in the previous section. Changes in codes and standards should fulfill the requirements in terms of safety and reliability.
b. **Encourage DC products and control systems.** Insufficient DC products are one of the primary barriers to promote DC distribution. These products range from generation and storage to end-use appliances, as well as control system and fundamental hardware such as connectors, wiring and circuit breakers. Manufacturers should develop DC products and control systems that have at least the same capabilities as equivalent AC products. Energy efficiency programs such as ENERGY STAR or tax credits can reduce the cost burden to stimulate the development and commercialization of DC appliances. Stakeholders should also advise the U.S. Department of Energy to revise individual test procedures to allow DC power source in addition to AC power. (Alliance to Save Energy, 2017)
c. **Encourage adoption of distributed energy resources and native DC loads.** On-site renewable generation coupled with energy storage and native DC loads are the key elements enable DC distribution in buildings. Industry alliances and energy efficiency groups should continue to promote building efficiency programs such as Leadership in Energy and Environmental Design and Zero Net Energy that accelerate DERs and native DC loads proliferation. Companies are starting to provide solar installation as well as battery solutions to residential, business and government customers. Partnerships with vendors can better introduce DC power generation infrastructure and end-use devices to homes by utilizing their channel to customers (CLASP, 2016).
d. **Demonstrate pilot installations that combine DC power sources and DC loads for both new construction and retrofit.** Relatively few pilot projects have been conducted to examine the technical feasibility of DC distribution in buildings (see Appendix A). However, more field data about energy efficiency performance, safety and resilience performance, and customer experience are required to compare with AC systems. With more field data, it will help to provide valuable decision making information for stakeholders.
e. **Educate stakeholders on DC distribution in buildings.** To stakeholders, communications and outreach activities are critical for seeing further deployment of DC infrastructure. Best practices and lessons learned can be passed along to help new adopters integrate DC infrastructure more quickly and economically. Communications and outreach can also be targeted to the policy and regulatory community to help inform them. Appendix C has examples of the stakeholder network that could be engaged to help promote the integration of DC in buildings.
f. **Train the workforce with essential skills to deploy DC in buildings.** Electricians are familiar with today's dominant AC electrical infrastructure. Training on DC systems could be designed to educate electricians and related jobs with new systems codes and fundamental DC hardware. Standards organizations and industry groups should work collaboratively to develop training

materials for electricians to design, install and operate DC appliances in buildings safely and reliably.

g. **Monitor international activities.** The biggest growth of DC distribution in buildings is projected to occur in Asia Pacific and Europe (Navigant Research, 2015). The European Commission is working towards the goal that all new buildings to be nearly zero energy by the end of 2020, and China is working with the U.S. on joint research projects demonstrating DC technology in buildings. International practices should be monitored and collaborate, where appropriate, with international counterparts.

NEMA ACTIONS

NEMA will work to provide a fair and balanced understanding of the advantages and disadvantages of DC in buildings. Based on NEMA's efforts and others, stakeholders will need to make business decisions to invest in these systems based on their circumstances.

The survey results outline at a high level what some of the codes and standards gaps are for DC in buildings. A more in-depth analysis of standard and code gaps will be conducted by NEMA. This analysis will cover the following:

a. **Deep dive into today's United States codes and standards.** NEMA will continue to identify existing DC codes and standards gaps, as well as where these codes and standards have been adopted.

b. **Analysis of future needs.** NEMA will leverage the survey results to conduct additional research to identify applications where DC could be used in the next ten years based on trends and drivers in the building area. NEMA will also conduct a gap analysis of where existing codes and standards and technology may fall short of future needs, as well as recommend changes to existing codes and standards and identify new codes and standards that should be developed.

c. **Partnership strategy**. NEMA will identify organizations that are active in the development of DC codes and standards and recommend partnership strategies to help explore the adoption of DC in buildings.

NEMA will coordinate with other DC stakeholders (see Appendix C) to identify and bridge the standards and codes gaps, if any. Where appropriate, NEMA's government relations department can also help to advocate for federal and state policies that are favorable for the development of DC in buildings. NEMA can leverage existing advocacy work in the area of energy efficiency to ensure that DC in buildings is covered in these activities.

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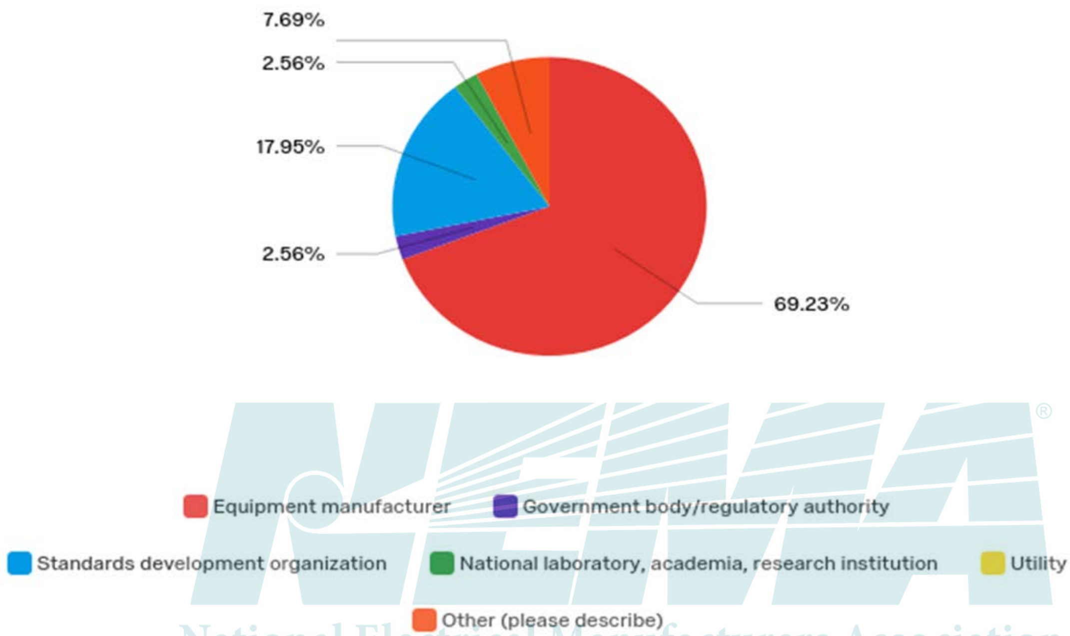
APPENDIX A: EXAMPLES OF PILOT PROJECTS IN THE U.S.

Project	Location	Operator	Description
NextHome	Detroit, Michigan	NextEnergy & Emerson Network Power	- The project demonstrate the benefit of AC/DC hybrid residential buildings coupled with DER and energy storage - Home Energy Management System can be used to manage real-time electricity balance - A 24V and 380V DC wiring system exists to eliminate conversion loss from AC to DC
Colorado Sustainability Alliance DC Project	Denver, Colorado	The Alliance for Sustainable Colorado	- The project is retrofitting existing commercial buildings to utilize DC to feed as much native DC equipment as possible - On-site renewable energy is installed to generate DC with energy storage system - Connected to the AC grid to import AC for non-DC compatible equipment and insufficient energy storage
Bosch Direct Current Building-Scale Microgrid Platform (DCBMP) Project	Southern California	Bosch & Honda & California Lighting Technology Center (CLTC)	- The project is transforming warehouse building to a commercial-scale DC building microgrid that expects to save up to 30% cost - CLTC will design the lighting system used in DCBMP and collect performance data to document the cost savings, energy efficiency and the system functionality

APPENDIX B: DEMOGRAPHICS

Survey respondents were asked which of the following best describes their organization. The results are shown below:



Category	%	Count
Equipment manufacturer	69.23%	27
Government body/regulatory authority	2.56%	1
Standards development organization	17.95%	7
National laboratory, academia, research institution	2.56%	1
Utility	0.00%	0
Other (please describe)	7.69%	3
Total	100%	39

"Other" responses

a. Electrical Trade Association
b. Trade association for electrical manufacturers
c. Consulting engineer

APPENDIX C: STAKEHOLDER ENGAGEMENT

Other stakeholders that should be engaged in the process include:

a. Industrial-Scale Users
    - Distribution network operators and electrical utilities
    - Electrical contractors
    - Residential and commercial builders
    - Telecom and data center operators, builders and related service providers

b. Manufacturers and Vendors of Equipment and Products
    - Consumer appliances and lighting products
    - Power converters
    - Power cables and power line components
    - Switching and protection devices, installation accessories
    - Photovoltaic power plant equipment
    - Battery and other electrical energy storage systems

c. Standards Organizations
    - National Electrical Manufacturers Association
    - EMerge Alliance
    - Institute of Electrical and Electronics Engineers (IEEE)
    - International Electrotechnical Commission
    - American National Standards Institute

d. Other Supporting Stakeholders
    - Governmental bodies and regulatory authorities
    - Universities and technical colleges (academia and education)
    - National Fire Protection Association
    - Research institutes (such as the Electric Power Research Institute)
    - Testing and certification institutes
    - National Laboratories
    - Industry and consumer associations including trade and policy interest groups (similar to the International Energy Agency)
    - Development banks and multilateral financial and aid institutions, such as World Bank, African Development Bank, USAID, etc.

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