2017 INDUSTRY RESEARCH REPORT

ELECTRO·FEDERATION CANADA

POWER SHIFTS

Emerging Low-voltage Trends, Impacts & Opportunities for the Canadian Electrical Channel

In collaboration with: INCEPT strategies

ELECTRO·FEDERATION
CANADA

About Electro-Federation Canada

Electro-Federation Canada (EFC) is a national, not-for-profit industry association. EFC represents over 250 member companies that manufacture, distribute, market and sell a wide range of electrical products, contributing over $10B to the Canadian economy and employing approximately 40,000 workers in more than 1,200 facilities across the country.

EFC members manufacture and distribute various electrical products, including distribution equipment, industrial controls, lighting, motors and generators, transformers, wire and cable, wiring supplies and electric heating. These categories form the basis of EFC's Product Sections, offering a strong nucleus for members to discuss issues and opportunities pertaining to their company's product focus. In addition, EFC maintains a strong focus on electrical safety, sustainability, advocacy, codes and standards, and serves as a hub of networking, education, and industry research. Learn more at www.electrofed.com.

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About INCEPT Strategies

INCEPT Strategies is a privately-held consulting firm in Ontario's Toronto area, established in 2013 to deliver tailored business development strategies and services to commercial and industrial clients. Strong mechanical and electrical technical understanding and diverse market expertise allow INCEPT Strategies to identify effective business strategies and innovative tactics to improve market position, meet challenges, and seize opportunities.
For more information visit: www.inceptstrategies.com.

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Note: the results in this report should be interpreted as trends; not as absolute statistics.

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1. EXECUTIVE SUMMARY

The shift from electrical to digital systems, and the emerging low-voltage power options to supply them, may be the biggest change the electrical industry has seen in the last 100 years. This transition is having significant impact on every aspect of the traditional electrical channel – from product conception, production, sales, delivery and installation. Equipping the channel to embrace emerging technologies, specifically those related to low-voltage direct current (LVDC) power developments[1], and opportunities derived from LVDC systems, is the purpose of this research study by Electro-Federation Canada. The segments identified as growth areas in the LVDC market are: LED Lighting, Sensors & Controls, Data Connectivity & Security, and Renewables & Battery Storage.

But when do these opportunities become gainful? At which point will this new technology pass the 'threshold of no return' in the electrical industry? Remember how quickly LEDs reached the tipping point and gained wide market adoption? LVDC-powered systems and applications are increasingly being produced, sold and installed today based on growing end-user demands—the heightened benefits and opportunities of this technology point to the widespread integration and use of electrical products in LVDC environments.

Five Key Report Findings:

1. **Market Demand:** Research findings confirm that market demand is underway. The rapid growth of DC-run digital equipment such as computers, media equipment, variable-speed drives and electronic lighting, has led to a situation where we generate power in DC, convert it to AC for delivery, and then convert it back to DC at points of use, losing up to 30% of the supplied energy. DC-fed digital devices are taking the market lead ahead of AC-motors. This has opened the market for LVDC power supply systems which operate at voltages under 60Vdc and are classified as touch-safe. Moreover, as renewables and battery storage (both DC) join the grid as economical sources of power supply, direct current is increasingly a logical choice for in-building supply.

2. **Partnerships & New Players:** Market trailblazers are developing strategic partnerships to promote LV adoption. One example is EMerge Alliance, a group of more than 80 industry players, formed for just this purpose. Others are leaders such as Cisco and Armstrong, each partnering with lighting and controls manufacturers. Many electrical manufacturers are already offering low-voltage solutions—and require help to bring their products and solutions to market. New players are quickly entering what was formerly the sales scope of the electrical channel. These new players are marking their territory in this low-voltage space to fill a void that the electrical industry has not yet met, and in doing so, are bringing about channel disruption.

   Over time, fewer but larger players will emerge, either from within the electrical channel or from outside the channel, who will offer end-to-end solutions for full systems integration. Those existing players who recognize these changes as a natural evolution and address it, will rise, while those who do not, run the risk of becoming marginalized.

3. **Market Adoption:** The industrial sector was the first to pursue energy-saving opportunities presented by the Internet of Things (IoT). The Commercial sector is also very active, given goals for net-zero buildings and LEED-certified smart buildings – property managers and building owners are looking for integrated systems to reduce energy costs, optimize space utilization and enhance the overall in-building experience of occupants. In-building distribution options are rapidly developing, which combine power and communications over the same connected cable, and two types of systems lead the way:

   - PoE (Power over Ethernet) systems
   - DLVP (Distributed Low Voltage Power) systems

   The residential DC industry is in a much earlier stage of development, but it will present the largest market sector for DC building power – home buyers today are more interested in Smart Home features and technology than they were two to five years ago.

4. **Codes and Standards:** The need and demand for standards that address application design and the installation of LVDC systems, is high. Regulators all over the globe are collaborating with industry to refresh existing electrical codes, and in particular, to clarify and establish codes and standards for combining power and communications over the same cable. New changes in the works for the 2018 Canadian Electrical Code include:

   - New Subsection 16-300: Class 2 Power and Data Communications
   - Revised Table 19: Wire and cable conditions of use

5. **New Trades:** Electricians have long been the chosen installer for most electrical work, but these new LVDC systems are pulling in a new set of installers: Instrumentation & Electrical (I&E) Technicians, Electrical & Control (E&C) Technicians, Lighting Technicians and IT Technicians. These trades offer electrical skills, matched with IT knowledge of electronics and software—a pairing especially important when we consider the safety, cybersecurity and privacy concerns associated with integrated electrical and data communication systems. Electrical contractors, the market mainstay for electrical project design and installation, also now have new players to compete with: System Integrators and I&E Contractors. These players offer network and software skills to design, procure, install, program and commission multi-element sensing and control systems.

Where are we now? Manufacturers are in competition and have proprietary protocols that prevent other manufacturers' devices or systems from integrating with their own. Manufacturers need to consider providing APIs (Application Program Interfaces), or adopt a common communications platform (e.g. BacNet) if systems such as lighting, HVAC and Security are to communicate with one another.

How close is LVDC to the Tipping Point? Let's not underestimate it! Consider how fast LEDs reached the tipping point in adoption. Take action now!

[1] In this report, 'LVDC' refers to voltages <60Vdc, which is a common interpretation among end users, wholesale distributors, manufacturers and other channel members who design, supply and install electrical products. In the electrical market, this voltage level is occasionally referred to as Extra-Low-Voltage, and sometimes by the safe-to-touch classification of SELV - Safety (Separated) Extra-Low-Voltage (see Glossary).

2. BACKGROUND AND METHODOLOGY

Electro-Federation Canada (EFC) has undertaken an exploratory study, in collaboration with INCEPT Strategies (www.inceptstrategies.com), a strategic marketing and business development firm, to examine the status of emerging low-voltage (LV) power developments, and to explore the implications and opportunities that the evolving developments bring to the electrical industry.

The purpose of the study is three-fold:

1. **Educate** – to bring EFC members up to a current and common level of understanding, with a working knowledge of the language and terms in use;
2. **Explore** – the benefits of low voltage, current market activity, trends and barriers; and
3. **Look to the Future** – describe the outlook for LV adoption going forward, and the implications for the electrical channel as we know it.

The method used for this study was also three-fold:

1. **Review** existing literature, research and resources;
2. **Study** key LV topics, by sector, exploring their status, trends, barriers and opportunities; and
3. **Host an Industry Summit** on LV market activities, with a representative mix of channel players.

The EFC Market Research Committee (see bottom of page) helped determine the overall scope, focus and methodology for this study. Via teams, they conducted in-depth secondary research investigations to gain qualitative insights from published sources (Appendix B) on five key topic areas:

- LED Lighting
- Power over Ethernet (PoE)
- Sensors & Controls
- Data Connectivity and Security
- Renewables and Battery Storage

As a part of this research exploration, EFC hosted a one-day industry summit in March 2017 in Toronto, which brought together a select group of industry representatives with experience and interest in the LV market. This summit allowed participants to engage in a structured and facilitated collaborative discussion on the trends, opportunities for, and potential impacts of low-voltage power developments (i.e. <60Vdc and PoE) on the electrical market. Close to 50 attendees participated at the summit, representing a cross-section of electrical manufacturers and distributors, contractors and installers, consulting engineers and designers, property managers, system integrators, service providers, safety regulators and others.

EFC extends a special thanks to the following companies that participated in this Summit:	
3M Canada	National Cable Specialists
CommScope	Paul Wolf Lighting & Electric Supply
Cree Canada	QuadReal Property Group
Eaton	Relamping Services
Electrical Safety Authority (ESA)	Reptech Enterprises Limited
General Cable	Rogers Centre
Guild Electric Ltd.	Sonepar Canada
HH Angus & Associates	STANDARD Products
IDEAL INDUSTRIES (CANADA), CORP.	Stanpro Lighting Systems
Illumna Drive Solutions	Superior Essex International
Intermatic Canada	Sustainable Environmental Solutions
Kerrwil Publications	The State Group Inc.
Legrand Canada	WESCO Distribution
Missing Link Technologies	

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3. 'SHIFT' HAPPENS

'Shift' Happens. The electrical industry is undergoing massive transformation as it enters a new era of technological change. The ways in which electrical products and systems operate are vastly changing as new advancements in technology arise. Concepts such as Smart Cities and Net Zero homes and buildings are driving new social responsibility behaviours among end users in the market. In turn, these behaviours are creating opportunities for new integrated power and control systems, and applications that are readily available, flexible, efficient and more cost-effective than before.

Who is Driving the Shift?

This technology shift has led to an altered state of supply and demand in the electrical channel: end users are demanding smart, connected solutions—and new Low-voltage Direct Current (LVDC) technologies and solutions are rising to meet these new demands. In a recent *Markets & Market* report[2], Canada's position on this trend is growing faster than the U.S. or Europe, in part due to legislation on carbon-footprint reduction.

This LVDC uptake requires engineers, integrators and architects to design and specify new solutions, drives manufacturers to produce new products and systems, and ultimately, requires distributors and contractors to sell, install and service them.

Market trailblazers are taking notice of this new trend and are beginning to pursue LVDC opportunities. You don't have to go too far to hear about partnerships developing and businesses emerging that are offering new products and services. Those once considered 'outside entities' to the electrical market are now establishing a solid footprint in our industry as they become complementary—or competitive—players.

Consider these developments:

- Cisco partners with electrical manufacturers to offer connected Power over Ethernet (PoE) solutions;
- Armstrong Ceiling Solutions teams up with electrical manufacturers to install LVDC-powered ceiling-based integrated systems for lighting, sensors and controls and other digital devices;
- Telcos expand their traditional utility role – e.g. Verizon acquires a lighting controls company and also Yahoo;
- HVAC contractors acquire electrical contractors;
- System integrators make inroads into our industry by offering end-to-end solutions that connect a variety of disparate systems, such as power, communications, HVAC, security and fire, lighting and others;
- Niche distributors specializing in electronics, renewable energy and low-voltage solutions are both emerging and evolving; and
- 80+ companies join to form EMerge Alliance, to help establish standards, address barriers and drive adoption of LV technologies.

IMPORTANT NOTE:

LVDC Reference in this Report

Power supply utilities consider low-voltage DC to refer to any DC voltage below 1500V, and large industry (e.g. automotive) might consider LVDC to refer to DC voltages of 600V or less. For the purposes of this study, we are referring to voltages <60Vdc, which is a common interpretation among end users, wholesale distributors, manufacturers and other channel members who design, supply and install electrical products. In the electrical market, this voltage level is occasionally referred to as Extra-Low-Voltage, and sometimes by the safe-to-touch classification of SELV - Safety (Separated) Extra-Low-Voltage (see Glossary).

These channel expansions have one thing in common: they are all giving rise to new business models and aim to offer connected solutions elements that were once outside their scope—and notably, are well within the electrical domain. For example, the IT channel is now active with LVDC integration—for IT specialists, datacomm is a known platform, but new power supply demands are not.

Why Low-voltage DC (LVDC)?

Today, we generate electricity as direct current (DC) and then convert it to alternating current (AC), before supplying it to end users. This is sensible when you consider that the bulk of the loads that consume this power have historically been AC motors. However, in recent years, the rapid growth of DC-run digital equipment has led to a situation where we generate power in DC, convert it to AC for delivery, and then convert it back to DC at discrete points of use such as computers, media equipment, variable-speed drives and electronic lighting. This double conversion consumes up to 30% in energy losses[3]. Such inefficiencies are enough to hold back the adoption of renewable energy elements like photovoltaics, power storage solutions like lithium ion batteries, and similarly affect controls, sensors and LED lighting by slowing payback. To address this conversion barrier, interest in DC power supply has increased, as has interest in LVDC, specifically.

The primary focus of this report is on the key trends that are leading the adoption of LVDC systems.

Later in this report, other methods of low-voltage power supply, including Power over Ethernet (PoE) and Distributed Low Voltage Power (DLVP) are also covered. This report will also examine the implications and opportunities that these low-voltage trends are expected to have on the electrical channel…as we know it today.

[2] "North America Low Voltage Industrial Controls Market worth 6.30 Billion USD by 2020", Market and Markets report overview. Accessed April 2017: http://www.marketsandmarkets.com/PressReleases/north-america-low-voltage-industrial-controls.asp

[3] "Slow Electricity: The Return of DC Power?", Low-Tech Magazine, April 2016. Accessed March 2017: http://www.lowtechmagazine.com/2016/04/slow-electricity-the-return-of-low-voltage-dc-power.html

4. OUTLOOK & OPPORTUNITIES FOR THE CANADIAN ELECTRICAL CHANNEL

The Race is on. As end users continue driving the demand for connected, plug-and-play solutions that offer comfort, convenience and personalization—both at home and at work—the electrical industry will need to step up its game to meet market demands, or lose out on emerging opportunities to other solution providers, system integrators, electronics, IT and other niche distributors, datacomm specialists and others. These external players are gaining insight on the significant potential of integrated systems using low-voltage power, such as LVDC, Distributed Low Voltage Power (DLVP) and PoE. Given the low-voltage, low-risk nature of these systems, many non-electrical parties are entering this space and offering services and solutions to end users at a growing rate.

The outlook for low-voltage DC powered systems is promising—especially when you consider all of the activities already at play today:

- Manufacturers are steadily introducing new lines of products and devices that configure with low-voltage DC power
- Renewable energy and battery storage are lining up to supply new in-house DC microgrids to fuel the DC-powered devices
- Installations of LED fixtures, sensors, and controls that run over PoE and DLVP systems are gaining strong traction
- Regulators and standards organizations are updating current codes to account for new technical capabilities and emerging power and datacomm requirements for new applications.

With these emerging developments in motion, the future of LVDC is clearly upon us. At a recent International Electrotechnical Commission (IEC) General Meeting in Germany, the focus was on *Low-voltage DC – future or already present?*. Vimal Mahendru, President of Legrand-India and Convenor for IEC's System Evaluation Group (SEG), stated that given the recent adoptions in IoT, PoE and Smart homes:

> **"I can safely conclude that we are already living in a DC world, we only need to visualize it accordingly!"**
> **– Vimal Mahendru, President of Legrand-India and Convenor for IEC's System Evaluation Group (SEG)**

EFC asked participants at its LVDC Industry Summit to share insights on when their company expects to offer LVDC technology and services to customers. Of those surveyed, close to half indicated they already offer this to customers. Another 22% have plans in development and will offer this within a year.

This is another indication that the outlook for emerging LVDC-powered systems is optimistic and the opportunities that arise from this technology trend should be something that the electrical channel players consider as they build out their strategies.

Opportunities

The topic of LVDC systems is very broad. EFC collaborated with Market Research Committee members and Summit participants to gauge the scope of this topic and to determine key areas of importance. During the Summit, participants were split into three groups and were tasked with identifying top opportunities that will result in the biggest changes in the electrical industry. Each of the groups started with the same list of nine areas of potential opportunity, and were given the chance to add more topics. Each team narrowed the list down to three key areas they believed will have the most impact on the electrical channel. Their selections are listed here, in ranked order:

1. Sensors and Controls (integrated systems, communications protocols)
2. Power over Ethernet (PoE)
3. Renewables & Battery Storage
4. Energy Management, Personalization of Space
5. Smart Cities, Net-Zero Buildings, Social Responsibility

These opportunities are explored in the forthcoming pages of this report, with a focus on how each of these relate to emerging low-voltage DC-powered systems.

> **"There isn't a day that passes by where I don't see a job without some form of low-voltage or PoE requirements attached to it."**
> **– Kim Osborne, HH Angus & Associates**

5. AN END-TO-END OVERVIEW OF LOW VOLTAGE

This section of the report provides an overview of the entire low-voltage landscape—from the different streams of DC power and low-voltage power systems available today (direct current, Power over Ethernet and distributed low-voltage power) – to DC microgrids.

DC Power

The power supply grid has been providing AC power as the most efficient means to support the dominant motor-loads market for many decades. Now, end user loads are becoming more dominated by electrical devices that use DC power, thanks to the advent of the semiconductor 50 years ago. DC power for building applications is not new, it's been used with variable frequency drives on motors for years. More recently, there has been a rapid adoption of DC-consuming LED lighting, new media technologies, data centres, and the entry of electric vehicles.

In addition to considerations for hybrid DC/AC systems in our market today, DC grids are also being rapidly adopted in countries with unstable AC systems (e.g. India). Implementation revenue in the global DC distribution network market is expected to grow from $2.8 billion ($US) in 2015 to $5.1 billion in 2024.[4]

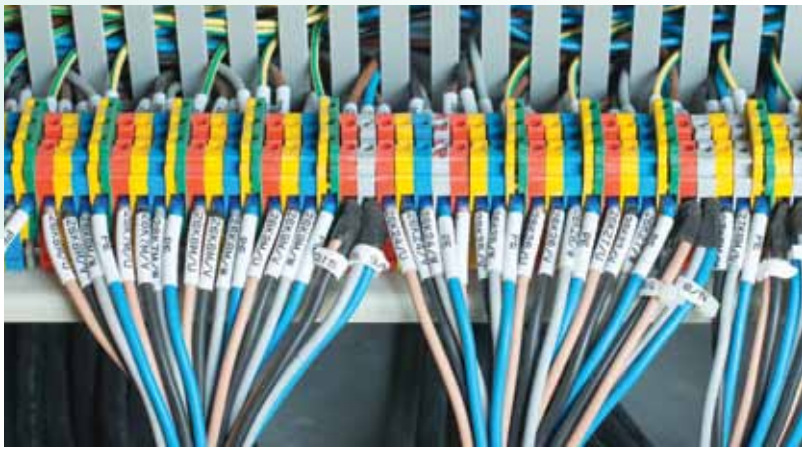
Low Voltage DC

There are strong economic reasons to look at low-voltage DC systems, whether they just supply power, or are designed to also offer data communication (e.g. PoE and DLVP). "If we could move to a low-voltage infrastructure, where simple low-voltage wire [can be used] without the requirement of mechanical protection [rigid conduit], that's a 50%, or greater, reduction in the installation cost of infrastructure," offers Chris Andrews, Product Manager, Low Voltage Lighting & Control Systems, Eaton, speaking at EFC's LVDC Industry Summit about feedback from market players. In addition, light fixtures that are low voltage and running off low-voltage infrastructures, can have 10% or 12% more efficiency than regular line-voltage systems.

"If we could move to a low-voltage infrastructure...that's a 50% or greater, reduction in the installation cost of infrastructure."
- Chris Andrews, Eaton

Also at the Summit, two styles of touch-safe LVDC power delivery systems were presented: one was a program involving Armstrong's suspended ceilings that incorporates their Flexzone product. Flexzone is a suspended ceiling grid that looks like a standard commercial tiled ceiling installation but is energized, and via clip-on whips, powers lighting fixtures and digital sensing and control devices for lighting, ventilation, shading and security.

The second product presented was a recently-introduced public charging system for digital devices such as mobile phones, tablets and computers. Public spaces and commercial offices are the target market. This system uses 24 Volts power supplied over rail, and again, the conversion to DC is done only once. Rail segments support up to 24 devices at a time with the system being smart enough to understand



when each rail is fully loaded. A simple touch-safe rail of any preferred length goes across a wall or other accessible surface where ever there are people to use it. It uses a proprietary USB connector that centres itself onto the rail and allows you to plug your USB into it, and it can slide on the rail and be moved.

Power over Ethernet

Power over Ethernet (PoE) is not a new technology. What originally served as the backbone for voice-over IP (VoIP) systems, this technology has grown to power other office systems such as corporate Wi-Fi. The range of PoE's application continues to grow steadily due to its growing power-carrying capacity—from its original 7 Watts in 2000 to its incremental increase to 60 Watts today…and soon much more.

PoE has been on quite a journey. In 2009, a new standard by the Institute of Electrical and Electronics Engineers (IEEE): IEEE 802.3at, increased the transmitted power limit to 30W to meet the demands of other new network-capable devices, such as wireless access points and security cameras. This was designated as PoE+.

More recently, a new industry standard is being drafted (IEEE 802.3bt), which will significantly increase the amount of power delivered to end devices—this time to 100 Watts, allowing PoE to broadly power lighting fixtures and a wide range of digital devices, sensors and controls.

The transition of PoE—from powering communication systems to becoming a primary electrical load carrier—has created the need for the electrical industry to re-examine their role in PoE and Ethernet codes and standards, devices, applications, project designs and installations.

Eaton describes PoE as a natural fit in applications where data network integration is expected, making it an excellent choice for high-technology campuses, such as data centres, as well as some office, education and healthcare applications: "the PoE user understands and appreciates a data network infrastructure designed to process analytics, optimize space utilization and control all aspects of an entire facility over one system."

[4] "Direct Current Distribution Networks", Navigant Research, 2015.
Accessed: April 2016: https://www.navigantresearch.com/research/direct-current-distribution-networks

Note: The proposed change to the Canadian Electrical Code does not include the term "Power over Ethernet" because this reference might exclude other technologies that could evolve in the future that involve communications, power and data. Some of the new terminology proposed will be "Powered Device" and "Equipment Supplied with Power from Power Sourcing Equipment and which may be capable of communicating data". *See page 10 for discussion of standards and LVDC.*

However, a word of caution from Kim Osborne, a consultant at HH Angus, who also participated in EFC's LVDC Industry Summit. Kim warns: "PoE systems are designed to be optimized as information systems and not as power systems," and recommends more effort be paid to educating designers to better consider the electrical aspects so that this too can be optimized.

PoE Partnerships

This technology is so formidable that there have been a number of partnerships developed between leading equipment manufacturers and solution providers, such as Cisco Systems (Cisco's Digital Ceiling Partner Community). The possibilities through such partnerships extend the capabilities of PoE technology.

At a session hosted by the Illuminating Engineering Society (IES) in Toronto, guest presenter Shirley Coyle, President of Cree, Inc., emphasized that "a PoE-run fixture is not just a lighting control system; it is a sensor network and operating system that enables applications far beyond light." Shirley shared her perspective on trends driving lighting over PoE:

- Energy and Building Codes continue to demand more advanced controls and their use to improve energy efficiency (occupancy sensing, dimming, daylight harvesting);
- Sensors – technical advancements have brought about an abundance of options, and costs have dropped dramatically;
- Improvements in LED technology allow for integration of sensors directly into fixtures;
- Software systems are increasing in sophistication and application, as is the availability of big data and its analysis – thanks to inexpensive increased data storage capacity and increased computing power;
- Building systems and IP networks are expanding; and
- The evolution of PoE technology – from 7 Watts in 2000 to 90+ Watts in 2017

At EFC's LVDC Industry Summit, attendees identified the likely impacts of PoE adoption on electrical channel players:

CHANNEL PLAYERS	LEVEL OF IMPACT	OBSERVATIONS
Manufacturers – Electrical	High	- must respond to demand (reactive)
Distributors – Electrical	Medium	- can stock/sell anything - have to encompass both electrical & data - need knowledge upgrade
Contractors – Electrical	High	- bundling opportunity but declining role for lighting installs - required to continue to work in accordance with Codes - risk from emerging new integrators - knowledge upgrade
Contractors – LV, Data	Low-Medium	- already in this space; their role is expanding and growing as power and data systems converge Issues: - responsibility - knowledge upgrade
Designers	High	- open to new ideas - effective at translating demands

Regardless of the impact level your channel segment may experience, one thing is certain: the opportunities for PoE in the electrical industry are tremendous.

DC Microgrids

The topic of DC microgrids was also a point of discussion at EFC's LVDC Industry Summit. Many participants raised concern about barriers preventing DC microgrids from gaining mass appeal. Current Feed-in-Tariff (FIT) programs in Canada are a barrier to microgrid systems. The tipping point for this technology will be the adoption of net-metering and storage, allowing local generation and the use of DC power.

The Continental Automated Buildings Association (CABA) released a whitepaper, entitled *The Role of Hybrid AC/DC Building Microgrids in Creating a 21st Century Enernet*.[5] This paper examines the alternative of maintaining power in its native DC form from distributed generation and storage sources in a simplified, more flexible, efficient and resilient configuration in the building. The article describes how DC power could be aggregated with AC power from the public grid and distributed in a building via a hybrid AC/DC microgrid. The paper also explores the eventual interconnection of building-level microgrids within and between buildings and the public grid to create an energy network. They refer to this energy network as the "Enernet," analogous to the network of computers that constitute the Internet. Also discussed are the motivation, need and status of new standards to support the implementation of such buildings with wide-scale use of private microgrids that would typically run at 1500 Volts or less.

Distributed Low-voltage Power (DLVP)

Finally, low-voltage power can also be supplied via Distributed Low Voltage Power (DLVP) Systems. "Distributed Low Voltage Power (DLVP) blends the benefits of both AC and DC power distribution".[6]

Like PoE, DLVP provides power and communications over the same connected cable. In addition, it can be reconfigured at any time without a system rewiring. While both PoE and DLVP meet the same standards and electrical codes for Class 2 low voltage and share many components and functions, they are very different systems. According to Eaton, "DLVP's value is in its simplicity and flexibility. DLVP is so simple to configure that it can be plug-and-play commissioned at the time of installation by the same contractor. It was consciously developed to be simple, and it's great for applications with repeated spaces, like schools that have 40 classrooms with matching configurations." DLVP systems reduce the total installed cost of an LED lighting and controls project by up to 20%, in Eaton's experience.

[5] "The Role of Hybrid AC/DC Building Microgrids in Creating a 21st Century Enernet", Continental Automated Buildings Association (CABA), June 2016. Accessed April 2017: http://www.caba.org/CABA/DocumentLibrary/Public/AC-DC-Microgrids-Part-1.aspx

[6] "Distributed Low Voltage Power Combines Efficient Lighting with Intelligent Controls", Tom Lombardo, July 10, 2016. Accessed March 2017: http://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/12610/Distributed-Low-Voltage-Power-Combines-Efficient-Lighting-with-Intelligent-Controls.aspx

6. CODES, STANDARDS & REGULATIONS

As renewables and battery storage (both DC) take their place and join the grid as economical sources of power supply, it is extremely important that standards be established for the supply of DC power for markets in Canada, across North America, and globally. The following are some of the identified gaps in the Canadian Electrical Code, that have come about with the emergence of LVDC power developments. Regulators are collaborating with industry to provide guidance on standards for low-voltage installations.

Global Involvement

The European Telecommunications Standards Institute (ETSI) has been working with other international groups to harmonize DC power standards. One such group is EMerge Alliance, a California-based, non-profit industry organization that has formed a group of 80+ organizations to lead the adoption of safe DC power distribution in commercial buildings through the development of DC power standards. In 2009, EMerge Alliance released an open standard (Standard 1.0) for Low Voltage 24Volts DC, falling under Class 2 power restrictions, and below the fire hazard and shock hazard for workers and users. Cable options for this include 12-gauge wire and Cat 5 and 6 Ethernet cable. ETSI also released Standard EN 300132-3-1 v2.1.13 (1) of 2011 for 380VDC, as a more efficient offering than 208VAC and 415VAC, particularly for data centres, which was integrated into the 2013 US National Electrical Code (NEC). ETSI standards for whole building/campus applications are expected in 2017, to be followed soon thereafter by residential standards.

The International Electrotechnical Committee (IEC) has also been very active in the development of LVDC standards. This committee has established several System Evaluation Groups (SEGs), including: SEG4 that is tasked to examine *Low-voltage Direct Current Applications, Distribution and Safety for use in Developed and Developing Economies*, and SEG6 which will look at *Non-conventional Distribution Networks/Microgrids*.

Canada has been a part of this activity through the Canadian National Committee of the IEC (CANC.IEC). Electro-Federation Canada (EFC) and the National Electrical Manufacturers Association (NEMA) have also been very involved in the SEG4 group.

New Communications Plus Power Cabling

Recently, there has been increased interest in cables that can supply power to devices and handle sensing and control communications, such as Ethernet cable (subsequently termed, Power over Ethernet (PoE)). This interest in PoE has brought into play a gap in the Canadian Electrical Code (CEC) between data systems and communication systems, and powered devices. The CEC Part 1, Section 60: "Electrical Communication Systems" outlines the requirements for communication systems, however, adoption of this Section varies from province to province. For instance, in Ontario, the term "Communications" is defined in the Ontario Electrical Safety Code, but Section 60 ("Communication Systems") is not included—which means Ontario's Electrical Safety Authority (ESA) is not currently required to inspect communication systems.

Now, it is important to note that communication systems had traditionally been telephone wires only—and now include data. With data now morphing to become data and power together in the same cable assemblies, the Electrical Code will require some redefinition, especially considering these growing uncertainties:

- Does the Code now apply?
- Are permits required?
- Are inspections required?
- Who's allowed to do the work?
- Does it have to be a licensed electrician?
- Does it have to be a licensed electrical contractor?

The addition of power and data over an Ethernet cable has also raised some safety concerns. Traditionally, data cable bundling has not had to carry power continuously; it has run power intermittently at low voltages over data lines, whereas lighting in an office building would run all day at higher loads. The impact of powering devices, versus just carrying data on cabling systems, was never considered in its design, and data designs and installations have not evolved to address this. So, we must now consider what the effects of bundling and running power continuously might be.

The defined term "Ethernet" under the IEEE Standard (see Glossary of Terms in Appendix A) does fall within the limits of a Class 2 Circuit in Section 16 of the Canadian Electrical Code. So to some degree, the Code does address PoE, however, it does not deal with certain aspects like running conductors in parallel in the same cable assembly. The rating on conductors for these demands had never been considered, but now must be, with advancements in PoE. The main gaps in the Canadian Electrical Code are the heating effects of bundled cables that are subject to sustained loading, and also, the need to recognize the designations of Ethernet cable as an acceptable wiring means for Class 2 Circuits in Table 19 of the Electrical Code: "Conditions of use and maximum allowable conductor temperature of wires and cables other than flexible cords, portable power cables, and equipment wires".

To address the Code gaps identified above, a new Subsection to Section 16 has been proposed to the Canadian Electrical Code Part 1 Committee. The new Subsection 16-300 (*Class 2 Power and Data Communications*) will address power and data carried in the same cable assembly and powering devices that may or may not be delivering data.

While this redefinition is key, many people are still left wondering if products need to be approved if they are connected to the output of an approved Class 2 Power Supply. This is not required to be approved in Ontario, but PoE exceeds the limits of an approved Class 2 Power Supply even though it fits within the limits of a Class 2 Circuit. Subsection Section 16 is being updated, but the changes will also include updates to Table 19: "Conditions of use and maximum allowable conductor temperature of wires and cables other than flexible cords, portable power cables, and equipment wires" for cable designations.

John Calabrese with ESA explains: "the biggest thing is just recognizing that yes; this is an electrical installation even though it looks like a data system—maybe we shouldn't have been ignoring this all these years." He continues, "the desktop phone has been PoE for quite a long time but nobody realized it. You just think of it as a communications device, but it's powered. Security cameras are also powered and have data over the same cable. We have long thought of these examples as data systems so they were exempt from the Code. We need to shift our minds to recognize they are actually an electrical installation; it's a change of paradigm".

Where is LVDC Found Today?

Market Adoption

The adoption of new technology has gained rapid momentum, fuelled by consumers' demand for the latest trends (e.g. Tesla, iPhone), and their need for plug-and-play solutions that reduce time-to-install and increase cost savings. These factors are all driving the uptake of solutions like LVDC-enabled systems which offer fast, reliable and secure system-integration options for networks. But how do these trends carry over into residential, commercial and industrial spaces? These three sectors are quite different in their approaches and core needs.

According to a Darnell Group Report,[7] the DC building power market is set to exceed $2 Billion (US). An analyst with the Darnell Group said, "in the near term, data centres and commercial/Industrial facilities are expected to offer the bulk of the sales opportunities." These sectors are projected to reach their adoption stages by 2019. "A little further out, telecommunications installations will begin to offer significant possibilities for sales. The residential DC industry is in a much earlier stage of development…in the long run, residential construction will present the largest market segment for DC building power."

Residential

Homeowners are increasingly interested in Smart Home options, with new systems that can do more with less; they are opting for systems that are less complex, which offer quick installation, low labour and maintenance costs, and that reduce energy consumption. Low-voltage DC systems and applications allow homeowners to achieve these advantages by offering solutions that control lighting, security, entertainment, and heating systems—all from sensors running on low-voltage cables, connected to one central point of access such as a tablet or mobile phone. Wireless systems are also rising in popularity thanks to a different mix of opportunities, and have a different set of technical barriers and design consideration such as coverage, bandwidth and attenuation, however adoption will continue to grow as these improve.

Contractors have a clear opportunity to help design and develop homes that deliver integrated systems. Real estate agents are also now showing an interest in understanding what consumers are looking for in a Smart Home. At EFC's LVDC Industry Summit, Gerald Prolas from Legrand Canada shared insight from a study by Coldwell Banker Real Estate, which reported that 64% of real estate agents surveyed said that buyers today are more interested in homes with Smart Home features and technology than they were two to five years ago[8]. According to the survey, home buyers are most interested in Smart Home technology for the following categories:

- Security (65%)
- Temperature control (57%)
- Safety (48%)
- Lighting (46%)
- Entertainment (42%)
- Appliances (23%)

Gerald Prolas states that home technology adoption and the emergence of the Internet of Things (IoT) continue to fuel the requirements for automation in homes today. "There's more technology in the automobile that's parked on your driveway than there is inside your home!" Consumers will continue to expect enhanced technology features in their home, and are looking to security companies and system integrators to provide and install solutions. In fact, a 2016 McKinsey Connected Homes study found that three-quarters of connected home devices are purchased through such service providers today[9].

Bill Stephens from IDEAL shares: "from the end user's point of view, this technology is incredibly complicated. The options and choices they have are so immense, quite often they will not always make the best choice for themselves. But there's just so much out there. I don't know if standards will ever help that, but I know that when you talk to end users they are all over the map in what they want and what they need."

Builders, real estate agents and electrical contractors have no choice but to improve their technology and residential network knowledge—and this presents an opportunity for electrical equipment suppliers to lead in offering sales support and training.

[7] "DC Building Power: Emerging Trends, Application Drivers, Market Opportunities, Adoption Rates and Forecasts", published by Darnell Group. Accessed from NEMA Workspaces, March 2017: http://workspaces.nema.org/public/LVDC/Lists/Team%20Discussion/Attachments/14/darnell_market_product_info.pdf

[8] "Coldwell Banker Real Estate Survey Finds the Technology of Tomorrow Helps Many Smart Homes Sell Faster Today", March 11, 2015: https://www.coldwellbanker.ca/press-release/smarthomes

[9] "There's No Place Like a Connected Home," McKinsey & Company, 2016. Accessed February 2017: http://www.mckinsey.com/spContent/connected_homes/index.html

While interest in low-voltage technology among consumers is gaining momentum, the residential DC industry is still in a much earlier stage of development than the commercial and industrial sectors. Despite the trend towards Zero Net energy, this sector does not have an established set of standards or any large bodies or organizations actively promoting technology or products.[10] This slow progression of standards poses a risk for LVDC opportunities in the residential space (as it does in the other market sectors as well).

During the EFC LVDC Industry Summit, Karen Pugliese from CommScope stressed the importance of standards for LVDC systems, "without standards, there is a variance in what end users are going to get, as we've seen in the security industry. End users can end up with a system that doesn't talk to various other elements; they end up with a very slim semblance of what they thought they were going to get. As we go through this transition, standardization and education components will be critical."

Commercial

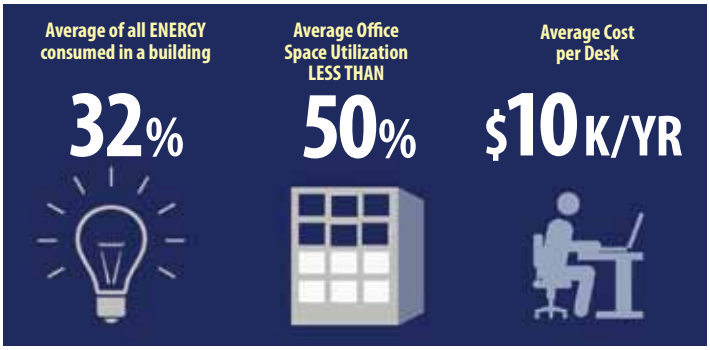
The state of California, a leader in energy management, has mandated Net-zero building designs for new construction by 2030: "we believe that DC-to-DC will play a role in reaching net-zero electricity in residential and commercial buildings."[11] With goals such as these set in other jurisdictions for LEED-certified "smart" buildings, property managers and business owners are moving towards establishing integrated systems that allow them to reduce energy costs, optimize space utilization, improve productivity and enhance the overall in-building experience of occupants.

Karen Pugliese from CommScope, shared her perspective on Smart Building adoption in the commercial space, "I do believe that organizations will look for means to provide employees with a better experience, and part of that experience is to allow employees to manage their space and manage how they work within the space. The only way for them to do that, the only way that I see them doing that long term, is through using an APP that the Internet of Things (IoT) runs on and a low-voltage cabling solution."

CEOs, CIOs and COOs are looking for ways they can reduce costs to fund new integrated retrofits and one of the first areas many are looking at is energy consumption. Energy is the largest percentage of costs within a building and lighting is the key driver in that; "32% of it comes down to lighting costs, followed by HVAC and other drivers," said Karen Pugliese. "LED lighting, whether run over low-voltage cable or not, offers significant cost savings."

But a more significant saving can be gained by examining space utilization. According to Karen, less than 50% of space in a typical building is utilized. With the cost per desk amounting to $10,000 per year, potential savings from better space utilization and increased employee productivity are far greater than energy savings (see Figure 1).

Figure 1: Energy vs. Space Costs



Source: CommScope

This same principle can be illustrated using the "3-30-300" Rule, which refers to the estimated amount a company pays per square foot annually for energy costs vs real estate costs vs the cost of its workforce respectively. This rule of thumb provides organizations with better visibility into their operating costs: "With energy representing approximately $3 per square foot, energy savings merely scratch the surface of the overall value proposition for smart buildings. Using sensor technologies to understand how occupants actually use space has the potential to reduce the $30/sq. ft. real estate costs by a factor of 10x the energy costs. And because a company's largest expense is often its payroll – at $300 per square foot – if you use smart building technology to offer customizable and controllable environments to increase employee productivity and tenant satisfaction, this value can be 100x the energy costs – or more."[12]

These building management trends are leading to commercial retrofits that include sensors and controls that provide real-time data on space utilization, so that lighting, temperature, etc. can be adjusted in each area based on changing occupancy needs. A low-voltage DC power infrastructure can provide power to such devices (often with the ease of plug-and-play functionality), as well as support the building systems that they serve, leading to higher electrical efficiencies, operating flexibilities, and competitive total project costs.

Figure 2: Contractor Experiences

"Took approximately three hours to install a 2,000 square foot space of lighting; from running the wire to the power module and connecting all the fixtures to working order versus traditional wiring which would have taken two electricians over a day to wire the same amount of fixtures."

– Contractor, Cincinnati, OH

"We have estimated before installation a **25% savings** in material dollars and **50% savings** in labor hours using DLVP."

– Contractor, Atlanta, GA

Courtesy: Eaton

In a presentation delivered at the EFC LVDC Summit, Chris Andrews from Eaton suggested that simple low-voltage wire DLVP systems offer a substantial reduction in installation time and costs over standard line voltage AC supply. As summarized in Figure 2, above, Chris shares experiences from two contractors who have installed LVDC systems:

In Case A, a contractor had budgeted two men for a day and a half (or 24 man-hours) to install an LED lighting control system. The contractor ended up installing the system by himself; one man in less than a day!

[10] "DC Building Power: Emerging Trends, Application Drivers, Market Opportunities, Adoption Rates and Forecasts", published by Darnell Group. Accessed from NEMA Workspaces, March 2017: http://workspaces.nema.org/public/LVDC/Lists/Team%20Discussion/Attachments/14/darnell_market_product_info.pdf

[11] "Direct Current to Direct Current – A Bridge to Zero Net Energy", Karl Johnson, California Institute for Energy and Environment, University of California at Berkeley & Elaine Hebert, Energy Efficiency Specialist, State of California, 2012. Accessed March 2017: https://ases.conference-services.net/resources/252/2859/pdf/SOLAR2012_0306_full%20paper.pdf

[12] "The 3-30-300 Principle: Smart Buildings Unlock Exponential Value", Environmental Protection, August 8, 2016. Accessed March 2017: https://eponline.com/blogs/environmental-protection-blog/2016/08/smart-buildings-unlock-exponential-value.aspx

Another contractor (Case B) has seen a 25% reduction in overall system costs and approximately a 55% reduction in labour man-hours on projects.

The opportunities are boundless. With the relatively low-risk of installing LVDC power systems, the commercial market is taking notice of this trend. LVDC power systems can be considered an extension of current building automation practices, something commercial markets are already well attuned to.

Industrial

The industrial sector has long been an adopter of DC PoE-powered integrated control systems. Many factories are already equipped with sensors and actuators that enable efficient process controls and effective operation of motors, pumps, fans, lighting, compressors, power supplies, computers, data networks, personal safety, and security. This sector has been the first to pursue the Internet of Things (IoT), for which it has its own subset name: "Industrial Internet of Things (IIoT)". This quest for smarter systems has also progressed to support the information exchange between pieces of production equipment, and this aspect of IoT/IIoT is referred to "Machine-to-machine (M2M)".

The longevity and wide-ranging benefits of integrated systems in the industrial sector show the strong promise of opportunities and results homeowners and businesses can expect as they adopt the next cycle of system interoperability. LVDC power is an ideal infrastructure by which to support these systems.

Note: Data centres are also a prime application for DC-powered infrastructures. A new standard has been developed by the EMerge Alliance partnership, and pilot installations using 308Vdc are operating successfully and are under study.

This next section offers a deep dive into some of the key elements that are driving LVDC power adoption and their impact on each of the three market sectors.

LVDC Developments Leading Adoption in the Electrical Market

The emergence of several new areas of technology development, namely LED lighting, digital sensors and controls, data connectivity and security components and networks, and renewable and power storage systems, are leading the drive to adopt LVDC-powered systems. This report takes a detailed look at these four key areas to determine current trends, outlook, barriers to change, and what benefits end users can expect to derive across the residential, commercial and industrial market sectors. While there is some cross-pollination of factors across sectors, each sector is evolving differently.

LED Lighting

LED lighting adoption is perhaps the leading catalyst for change in the widespread adoption of LVDC development in the market. Low-load LEDs have reached an important tipping point: costs for LEDs are more affordable, performance is improving steadily, both in light quality and efficiency, and regulations are keeping pace with this technology and facilitating its deployment.

Lighting design and quality must remain at the forefront – it must not become a 'footnote' for data and other uses.

The pairing of LEDs with low-voltage systems is an ideal match; LEDs make it possible to power lighting over low-voltage DC power systems such as Power over Ethernet (PoE) and LVDC. This combination offers low-risk, broad-coverage and has become a widely-used framework upon which to integrate controls, sensors and data connectivity solutions (either inside the fixtures or outside) to provide increased real-time intelligence for security and operating options. LED lighting enables more flexible control systems because on/off power-cycling doesn't reduce the lifetime of the LEDs the way that it did fluorescent technology.

The opportunities for LVDC-powered LED system applications are abundant. Currently, manufacturers are offering only select functionality in their commercial lighting control systems:

- Lighting and media control integrated with wired LV-power and communications systems
- Independent wired lighting control systems
- Hybrid wired and wireless control components

The scope of these and other offerings will expand as new end user expectations come into play. Still, with all the varied functionality and uses of lighting today, it's important to not lose sight of its core benefits and functionality. Nonetheless, the continued success of LVDC-powered LED lighting technology will drive wide adoption in other areas. We're already seeing development in low-voltage control systems and in data connectivity and security infrastructure enhancements.

Sensors and Controls

Lighting is tightly interwoven with another important trend that is driving the adoption of LVDC-powered environments: smarter and less expensive Sensors and Controls. Today's high-efficiency LED lighting pairs nicely with low-voltage sensor and control systems, whether powered or wireless. With the price of advanced sensing technologies having dropped dramatically, lighting fixtures are providing strategic ceiling placement, and this is creating an upsurge of low-voltage devices in the ceiling (coined "the digital ceiling").

New and emerging capabilities in lighting control systems range from simple dimmers to complex systems with occupancy response, daylight harvesting and receptacle or "Plug Load" controls. Their scope is now extending to include sensor technology that enables time scheduling, energy monitoring, and interaction with other infrastructures like security and HVAC. This transition toward a single, common system that controls all building functions, offers the vision of top-to-bottom building automation.

This trend to deploy sensors with lighting and control systems will continue, thanks to the high demand for operations data, sensor and

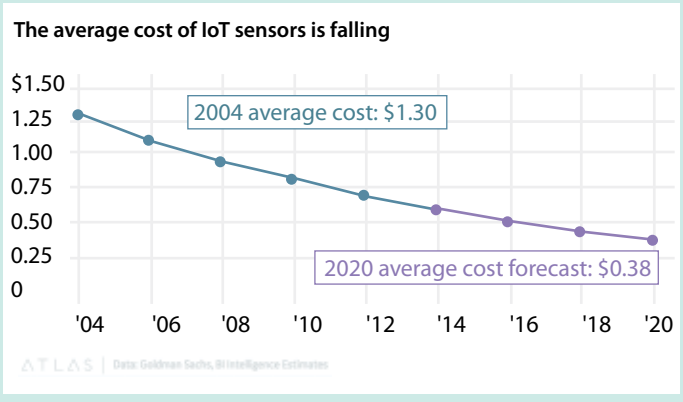
Sensors and Controls in Action

Source: Cisco

switch control APPs that mobile devices can offer, and the dropping cost of sensors (see cost curve in Figure 3).

How far are low-voltage sensor and control systems from reaching the tipping point? Let's examine the variables to determine current uses, trends, what might be a tipping point barrier, and what end users can expect from their low-voltage sensor and control system. See Table 1.

Figure 3: Cost curve for sensors



Data Connectivity and Security

A third element in the developing LVDC spectrum, relates to data that is gathered through low-voltage connected systems. As these systems become more sophisticated, they have the ability to gather, sort and exchange data in ways never experienced before. This end-to-end data access can provide countless benefits to users, including a single,

Source: Cisco

converged IP and media network to join together all of a building's separate systems networks to provide simplified management of facility operations.

These advancements in data access have raised some security concerns around how data is handled, and a growing number of companies are dedicating IT staff to source and procure products, oversee the interoperability of systems, manage and analyse data acquired from the systems, and manage cyber security. Suppliers, engineers and installers are tasked with providing validated designs and installations that mitigate data security threats. Many channel players are also adding dedicated data experts to their mix of operations personnel.

Data communications is not new to the electrical industry, but there is still much to learn about this space, especially as new broader standards are released to address changing technologies. It is in the best interests of the electrical industry to get involved and expedite development of regulations for new technologies in directions that create opportunities for the channel and not barriers.

Data connectivity and security solutions within an LVDC-powered environment are on the rise, as outlined in Table 2.

Renewables and Battery Storage

Power generation from renewables and storage of DC Power is increasing, and this power can be stored and then drawn from directly, without AC transformation and the power losses that come with that.

The movement towards renewable energy has gained traction in recent years, and the rate of adoption is growing with the electric vehicles, solar panels, and home batteries trending in the market. End users are searching for ways in which they can integrate appliances, lighting, HVAC, security and entertainment systems with renewable energy supply sources. A wider adoption of LVDC will perhaps occur once renewable energy and battery storage reach their adoption tipping point, perhaps fuelled by ongoing government and utility incentives. This pairing eliminates conversion power losses.

However, there are some barriers that may impede progress. During the LVDC Industry Summit, several participants raised concern over limitations in power storage. Group members expressed that product development into power storage and system-cost reduction must occur along with more supportive regulatory positions before they and renewables can be used to their full potential.

Despite these barriers, they are viable means for energy supply and are deployed for use in these areas shown in Table 3.

Table 1: LVDC and Controls and Sensors

LVDC – CONTROLS AND SENSORS	RESIDENTIAL	COMMERCIAL/INSTITUTIONAL	INDUSTRIAL
Where can it be found today?	Lighting, landscape lighting, power supplies Home alarm and video surveillance systems Heating systems (Nest), HVAC controls & fans Entertainment systems Appliances using power converters (fridges, freezers, dishwashers, washing machines, air conditioners, heaters, kitchen appliances) Hand-held electronics, computers	Simple dimmers to complex systems with occupancy, daylight and receptacle control Lighting systems, USB power, power supplies, fire alarm & security, HVAC controls, fans, pumps, AV systems IT data servers, hand-held electronics, computers	Most mature of the markets IT groups have always been involved in purchasing and installation decisions Fire alarm & security, HVAC controls, fans, pumps, data networks Process controls, sensors and actuators, motors (VFD), compressors, IT data servers, hand-held electronics and field devices, computers
Trends	Commercialization of LVDC distribution systems Predictive technologies (HVAC, weather) DC-powered computers/digital equipment Power storage and renewables are mostly DC New voice activation technologies (Google, Amazon) USB power electronics, reduce large loads (appliances), automation, solar, IoT, PoE, lifestyle devices LV sensors and switches have always been available, but are now being integrated into broader systems/applications New cables - higher wattage combine power & connectivity: CAT 6 cable in development to offer 100 watts, but no certification standards	Lighting, distributed power, hand-held devices, office equipment, security, POE Occupancy sensors, HVAC Driving force for new facility requirements is to do more with less space Predictive technologies developing and commercially available (e.g. to control timing of solar charging based on weather inputs) PoE being purchased by enterprise/IT channels due to their existing activity in security and process monitoring	Lighting, distributed power, micro controls, power savings (IT, Lighting), PoE, IoT Modular machine building is a current trend in the machinery market that is providing growth opportunities for LV AC & DC contactors Motor efficiency legislations which have been enacted all over the world, are likely to drive the global low-voltage motor market Growing consumption of low-voltage motors by other industries (mining, food & beverages, oil & gas, automotive, packaging), driven by growth in industrialization and steadily rising demand for energy across the globe. These are motors that run at voltages less than 1000 V.
Barriers to change	Retrofit limitations, USB 3.1 100W 5A limitation, voltage level standardization 12 to 50Vdc, power storage limitations, proprietary connectivity (no standard) Will electricians be able to handle LV; who else? Who will offer services to operate and maintain? Data installers and others can do installations instead of electricians; implications for CMEQ/IBEW Effects of combining power supply and communications on same cable – codes and standards needed; PoE concerns with overheating cables, no standards or guidelines currently in place; problem with POE because lights can't be daisy-chained so tons of cable needed		
	New human interface issues - untrained, unexpected technologies, new ignorance/ safety issues Devices have different voltages (different required DC voltages for normal devices in a home)	Several systems already in market but they're not interoperable Problems retrofitting old lighting and control systems with 0-10V dimming (requires major system reconfiguration) Canada currently uses Feed in Tariff, which is a less direct commercial incentive (this may be changing soon)	Heavy equipment requires AC, not DC Motor market is highly fragmented and very mature, so change often occurs slowly Lack of government incentives/ sanctions
Benefits to end customers	Limited hazards, more connectivity, low cost to install, energy savings, lifestyle enhancements (lighting, devices, simplify)	LED lighting enables more efficient control systems, because power cycling doesn't reduce the lifetime of LEDs Reduced hazards, more connectivity, low cost to install, energy savings, configurable, latest design trends	Safer to install, greater control, able to incorporate local power generation, lower cost to install

Table 2: LVDC and Data Connectivity and Security

LVDC – DATA CONNECTIVITY & SECURITY	RESIDENTIAL	COMMERCIAL/INSTITUTIONAL	INDUSTRIAL
Where can it be found today?	Lights, smart plugs, demand-responsive appliances, thermostats, home alarm & video surveillance, entertainment, music systems Voice control commands for home automation accessible via software/mobile devices	DC-powered digital ceilings, Li-Fi (office, retail experience) Plug-and-play connectivity for the 24Vdc standard Smart infrastructure (cities/ lamp posts/highways/cars) Lighting control (motion/ occupancy sensors for lighting, HVAC	Connectivity of sensors, actuators, robots, manufacturing devices such as 3D printers, and assembly line components, chemical mixing tanks, engines In applications where radio-frequency is not allowed Advanced process control devices
Trends	Increased integration with demand-responsive appliances, which requires "smart" communication with heat pumps, water heaters, thermostats, electric vehicle service equipment	Connected lighting Workspace environment (within and beyond an office building)	Increased integration of process control devices 3D printers (access to the market, flexible production and availability of products)
Barriers to change	No standard protocol for information sharing across devices (i.e ZigBee, Z-Wave, Nest all have disparate protocols and can't exchange information easily) No central point for home-owner to "connect" and control multiple devices without good understanding of different technologies and communications protocols	Similar to Industrial issues but with broader impact from exposure of consumers to risk Managing sheer volume of data; proprietary legacy systems; the need for enhanced security	Industrial communications protocols not necessarily IT network-compatible and vice versa Cybersecurity: privacy of proprietary information; plant-floor safety and product safety from security breaches into networks Data integration and system Interoperability of systems Development of a universal "machine data language" that promotes plug-and-play
Benefits to end customers	Self sufficiency, lifestyle enhancements - automation of household devices Cost, energy, time savings Security monitoring, reporting	Office automation - work/ time efficiencies & productivity (intelligent buildings will become more flexible work environments, quickly adaptable to new systems and users) Could easily be combined with data network, so one set of cables providing data and power where needed Rapid access to systems data monitoring/diagnostics Energy savings Reduced operational and maintenance costs Company and consumer data availability Employee accessibility	Plant floor enhancements Process and quality control info Labour savings, improved efficiencies through advanced robotics Energy savings Revenue stream through new product innovation (flexibility in product design and production) System monitoring/diagnostics

Table 3: LVDC and Renewables and Battery Storage

LVDC – RENEWABLES & BATTERY STORAGE	RESIDENTIAL	COMMERCIAL/INSTITUTIONAL	INDUSTRIAL
Where can it be found today?	Solar panels are used with battery storage units (like Tesla's Powerwall) to enable LVDC-controlled lighting Use inverters to convert to AC to feed the house Battery storage unit for time-of-day shifting or off-grid locations, e.g. at cottages	Crowded downtown cores limited by power – quick added capacity. Mostly solar play. e.g. Flynn building in TO can't tie power back to grid due to city regulations. Grid too complex to take on more power. Buildings need to be more independent	Power Gen: For variation and increased predictability – for grid management / reliability Supercapacitors or battery – can provide LVDC e.g. Plant tie-over between power kicking off & generator, with inverter to bring back to AC Wind Farms – LVAC --> N/A Solar Farms – LVDC, grouped and then stepped up to AC
Trends	The "consumerization of everything" - shift toward new technologies that optimize customer choice, like rooftop solar, portable power and electric vehicles Net-zero homes		Mechanical storage systems: including compressed air, pumped hydro and flywheel
Barriers to change	Lack of government programs/sanctions Slow process and ROI to sign MicroFIT contracts Own roof area not ideal for solar panels Wind energy not accepted in residential EV has been costly Lack of DC lighting standards, connectors DC appliances unavailable in the market	Canada currently uses Feed in Tariff, which is a less direct commercial incentive Lack of government programs/ sanctions Slow process and ROI to sign MicroFIT contracts Solar and wind require large space	Lack of government incentives/ sanctions Change is expected to start outside Industrial Batteries still pose safety hazard, toxic, etc.
Benefits to end customers	Reduces shock hazards and burdensome code restrictions Eliminates one stage of power conversion thereby resulting in greater reliability and savings. Produces little or no waste products such as carbon dioxide or other chemical pollutants, therefore has minimal impact on the environment		
		Battery-based systems offer advantages in transportability and size Distributed battery storage is extremely versatile, functions as generation, distribution infrastructure, load and demand response, all at once A DC-powered data centre requires 25-40% less square footage than AC counterparts, largely because computer equipment can connect directly to backup batteries. Rooms full of uninterruptable power supplies (UPS) and other equipment aren't needed, therefore gaining valuable real estate	Advances in battery design and construction have helped manufacturers improve efficiency and lifespan, as well as enhance safety of these systems

8. BARRIERS & POSSIBLE RISKS: LVDC POWER DEVELOPMENTS

The previous section alluded to specific barriers affecting LVDC adoption. This next section offers a high-level review of barriers that threaten the overall adoption of LVDC in the Canadian electrical market. As with anything new, there are always challenges that must be addressed before widespread adoption happens. The electrical channel must overcome the following obstacles so that low-voltage DC-run systems stay at the forefront and remain a viable and sustainable option for our market to explore.

Key Barriers

Early Adoption

Despite the headway made in low-voltage system adoption, this power trend is still relatively new. During early adoption of this technology (typically more of a migration than a leap), the electrical channel will need to gain familiarity with LVDC and keep a finger on the end-user pulse so that others don't secure an over-abundant share of this market.

LVDC is set to gain wide traction. Channel players must be committed to producing, marketing, selling, training, installing and servicing end-to-end solutions that are run by low-voltage DC power.

Shifts often come in waves as technology evolves. Consider the dynamics of electric vehicles and solar panels adoption as they have made their ways into the market. Time will tell how widely adopted DC-power and LVDC systems become, but with advancements in controls, sensors, data connectivity, battery storage and renewables, the pickup of DC-enabled technology may be gradual, but it is likely to have a significant impact on how applications run in future.

The electrical industry will need to rise to the challenge of meeting current and future end-user demands. If LVDC technology is to gain wide traction, channel players must be committed to producing, marketing, selling, training, installing and servicing end-to-end solutions that are run by low-voltage DC power.

System Interoperability

Where are we right now? If all these lights and sensing and control devices are installed into buildings, will they talk to one another? Are they compatible? Manufacturers are in competition to bring their versions of control-application systems to market, LVDC-powered and otherwise. The successful integration of these independent and varied types of systems will depend on their ability to communicate and share data.

Where We Are Today – An Example: If you buy three light fixtures from three different manufacturers and put all of them on the same control system, more than likely, the three light fixtures are not going to do the same thing at the same time because they were created independently using different communications protocols.

Even though the different products are PoE-compatible and they use RJ45 connectors and the same Ethernet cable (and they are physically the same thing, which is the point of the physical standard), unless you're using an API (Application Program Interface) to make all three systems be subservient to a third-party system (or designate one of the three systems to have control), they are not going to work together today.

The following conversation from the expert panel at EFC's LVDC Industry Summit gives sound perspective on this:

"I don't think that manufacturers are going to get together and all agree on the same protocol standard," shared Chris Andrews from Eaton. "I think the reality is going to be enabling systems that surrender control to another system, whether it be a higher order system, like a Building Automation System, or another proprietary system."

Karen Pugliese from CommScope added, "I think the biggest challenge is that if I want you to buy my lighting solution, regardless of whether it's PoE or not, the last thing I want is to make it easy for you to buy part of my lighting solution and two thirds of another lighting solution. I want you to be 100% committed to my lighting solution. I think the key is an API—and we saw this with our intelligent lighting system. We had a sensor network and a software solution. Our biggest challenge was getting the light fixture manufacturers to want to participate as part of that solution. And they didn't because they wanted to sell their entire solution. I do think that the consumer of those solutions over the course of time will probably drive that behaviour more than anything else."

Kim Osborne from HH Angus agreed: "I think it's also important that the end user have a say in this, because without pressure from the end users, nobody is going to standardize."

But what are the opportunities for a common communications protocol?

Bill Stephens from IDEAL INDUSTRIES pointed out: "if you look at where Building Automation Systems are, probably 90% of the world has now converged on BacNet-based systems protocols, an ASHRAE standard. It's fairly universal and more and more devices are being worked that way. More control systems that are auxiliary to the Building Automation System (heating, cooling) are also being designed to work with BacNet. This places a point of entry to standardization between what buildings are going to be using."

Bill suggested new cabling standards as another point of entry for standardization "which will allow a standard platform to design devices on. If you're going to go to high Power over Ethernet, which is going to be 90+ Watts per channel, as opposed to 60, that provides the ability to have a more general class of devices that will fit into that."

Karen Pugliese said, "I think the intent is to have the systems integrate with each other. You need the components. I think that's the easiest starting point. But eventually, the goal is to get to the lighting solution, and HVAC solution, and everything else communicating with each other—the way to get there is through an API. That will create an open source across all the platforms regardless of what infrastructure it sits on; regardless of whether that's low voltage or not."

Something to Consider:

During the Dotcom era, new Internet-based companies were rapidly entering the market; however, most start-ups failed in their attempt to succeed—they could only take their idea so far. Behind this wave, were large companies who quickly expanded the initial ideas, catapulting them to become some of the most successful companies around today (e.g. Google, Facebook, Amazon). The LVDC market is expected to follow a similar trend; the vast range of players in this space today (electrical, datacomm, system integrators, IT and other specialized distributors, security system experts, etc.) will decrease as the dominant players come out on top.

Codes, Standards & Regulations

A refresh of various sections within existing electrical codes and standards is required if we are to fully engage in low-voltage developments. Many gaps in the Canadian Electrical Code have surfaced because of advancements in low-voltage developments, particularly around direct current and Power over Ethernet applications. Current electrical industry practices have seen new codes being stalled by competitors and home builders who are blocking changes in favour of the status quo. This slow progression has led to a lot of uncertainty in the market. Manufacturers are unsure about product certification standards, installers are unclear about what they do and do not require inspection for. See page 10 for a detailed overview of some of the changes being considered within the realm of codes and standards.

Possible Risks of LVDC Infrastructures

Fire Risks: How big is the risk of pushing power over data? How much of a fire risk is this than the traditional powered data system? According to ESA's John Calabrese, running power and communications over the same cable, such as with PoE, hasn't been much of a risk so far. "Installation failure on conductors is the biggest risk from circuits being under continuous load. If that failure takes place, will that actually result in a fire? It's far less likely than in a Class 1 Power Circuit, but it doesn't mean it's impossible. I think it will affect performance of the system more than being a fire or shock hazard. It's uncertain how much greater a risk will it be when we start pushing those cables and connectors to carry power continuously."

Operational Risks: Chris Andrews from Eaton expressed, "the concern I have is what happens when you want to troubleshoot the system and someone says, 'Oh, it's a RJ45 – let me just de-mate it'… now it's 60 Watts of power, it's 50 Volts, and 1.1 Amps, and there's a load voltage arc. But it's low voltage. What's the big deal? The concern is that when a system undergoes a performance failure, many of the RJ45s, which are constructed from either gold or older palladium contacts, are very susceptible to damage from arcing. Just look at an RJ45 after you do a low-voltage high-power de-mate." Chris refers to the metal-melt and carbonizing effects that will occur, and while these may or may not present a direct safety hazard, it could be a performance hazard in terms of the long-term use effects, benefits and features of a low-voltage system.

Voltage Losses Over Distance: This is a big consideration for low-voltage applications, as it can cause issues with cable bundling, such as overheating and failure of insulation. The IEEE is particularly concerned about cable bundling issues of low voltage, as is the CEC, evidenced by the addition of new Subsection 16-300.

Old rules of thumb cannot be applied and it is important to remember that losses are a function of both power and voltage. For example, a contractor who attended the EFC LVDC Industry Summit pointed out that a cable bundle can represent a "mish-mash" of multi-tier elements: "While all you're talking about is Class 2, you're starting to look at whatever your sensors and devices are on, in case they turn out to be in the wrong bundles. The cables are all running a distance from the source and you can overheat on the cable, just like that. To optimize that, you'll have low-voltage distribution with higher-voltage levels [to address voltage losses on the line] and you'll have to offset that. You'll have to keep your final runs under 98 meters instead of 100 [for those specific cables in the bundle]."

Chris Andrews from Eaton explained, "devices can become extremely efficient when they're matched with low-voltage infrastructures, but transmission is definitely something to be aware of. Shorter runs over low voltage add great benefit. While many low voltage systems are good for up to 100 meters or 328 feet, does that necessarily mean you want to do that?"

Additional Considerations

New technologies and applications all bring additional elements of risk. Here are some other considerations that will warrant consideration with the adoption of low-voltage systems, including PoE, LVDC and DLVP:

- Who will engineer and specify the system?
- Who will purchase the system – Engineering, Facilities Management, Automation, or IT?
- Maintenance and operational needs are not yet known: potential conflicts and compatibilities
- There may be human interface issues – untrained personnel using unexpected technologies
- Who will be in control of the system?
- Who will be responsible for the system: for its oversight, and for any problems or failures?

The Future is Promising!

While these outlined barriers and risks may seem overwhelming, it is promising to know that the wheels are in motion to address these concerns. Regulators and standards organizations are working closely with industry leaders to challenge the norms and to update existing standards so they ensure the safety, security and reliability of low-voltage systems.

There is an opportunity for the electrical community to get ahead of this wave and significantly change their business structure so that, as an industry, we are providing relevant products and services to users, and not outdated offerings for which there is no longer a market.

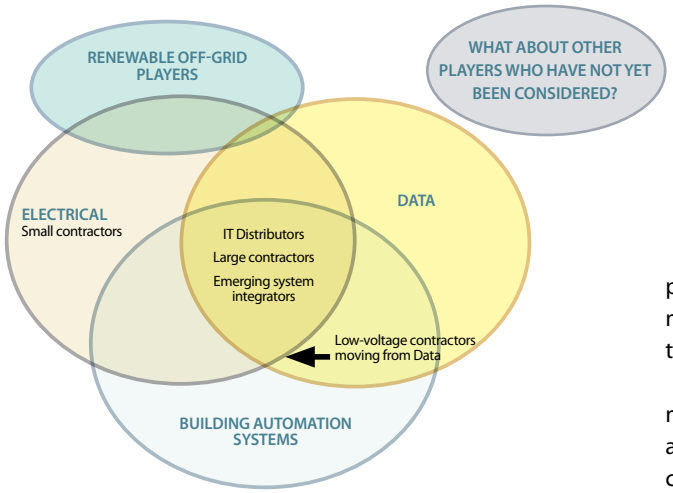
New Market Players

We are beginning to see datacomm specialists, system integrators, security-solution providers, electronic distributors and low-voltage distributors crossing over into the channel, competing with the electrical distribution and contracting markets. Some of these new players have electrical skills matched with IT knowledge of electronics and software, a pairing especially important when we consider the safety, cybersecurity and privacy concerns associated with integrated electrical and data communication systems. These changes in effect include:

- Large contractors have added data wings to their divisions
- Instrumentation & Electrical (I&E) Technicians, Electrical & Control (E&C) Technicians, Lighting Technicians and IT Technicians are trying their hand at low-voltage installations
- e-Commerce channel is on the rise
- Utilities are expanding their traditional role to include demand control
- Telcos are also further developing their role to include other services (Verizon adding a lighting controls company and Yahoo to their portfolio)
- HVAC contractors are buying electrical contracting firms

This 'collision of cultures' is illustrated in the Venn diagram below. This depiction of possible market shifts, assembled by participants at EFC's LVDC Industry Summit, shows the different forces in play.

Figure 4: Collision of Cultures within (and beyond) the Electrical Market



Note the prominent position that large contractors, IT distributors and Emerging System Integrators have across the three segments: electrical, data and building automation.

IT Distributors

IT distributors supply servers, data racks, UPS, cooling systems, software, network hardware such as routers and switches. The IT channel has typically provided the computing, storage, routing and switching of devices, while the Electrical channel often provides structured cabling, interconnection, patch panels, etc. With the introduction of PoE within the IT space, active switching components continue to be offered by IT, while the electrical player's role is primarily in structured cabling. Interestingly, within the Security segments, the onset of PoE and digital signalling have moved security into the IT space—and many (if not all) IT distributors are involved in the Security market. Likewise, in the Lighting and Industrial segments, there is more convergence between IT, controls and devices, which is leading to greater involvement of the IT channel into the traditional electrical domains of controls and lighting. This evolution could follow the same trend that the Security market has undergone.

System Integrators

System integrators are becoming more prominent in the marketplace, as they are increasingly relied upon by end users to connect disparate products and systems. *PC Magazine* defines this market segment as "an individual or organization that builds systems from a variety of diverse components. With increasing complexity of technology, more customers want complete solutions to information problems, requiring hardware, software and networking expertise in a multi-vendor environment."

There is a core need for a system integrator in today's multi-faceted technological era, given the wide-ranging applications and systems available that allow automation. Paul Oswald, President of Environmental Systems, Inc. (ESI) explains this core need that system integrators help fulfil: "at a very fundamental level, this consists of getting devices to talk to one another; LON to BACnet, to Modbus, to legacy, etc. At another level, it is getting software applications to work together such that data or information flows between the applications as part of a solution. These are two examples of what a system integrator does."[13]

The role of system integrators has expanded over time to include other key functions:

- Process re-engineering
- Network services
- System architectural design
- System integration and testing
- Product testing and evaluation
- Cybersecurity
- Integrator program services
- Server device profile development
- Custom application development

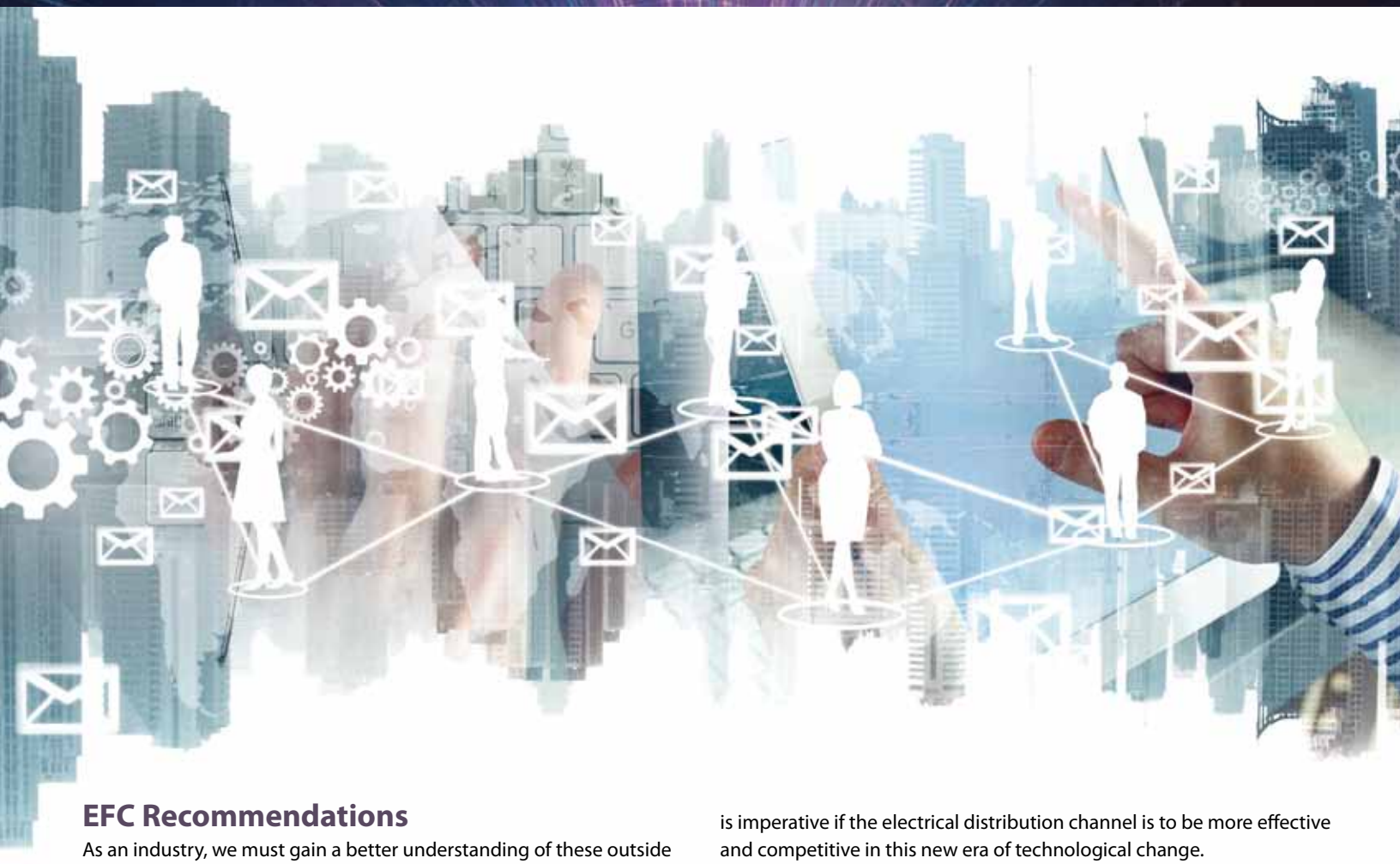
It is important to note that some of these functions are currently performed by the electrical channel today, but there is an opportunity for manufacturers, distributors, engineers, designers and installers to grow their core offerings to include new services required by end users today.

As a counterpoint, there is also benefit for our industry to collaborate more closely with system integrators so they become aware of standards and best practices. This is particularly important as systems become more complex and require integrators to have a deeper understanding of electrical regulations.

With the numerous end user benefits and market opportunities that low-voltage DC-powered systems provide, there is significant attention being drawn to this technology. Where the channel had once been the sole path for customers to go to for the design, sourcing, installation and servicing of electrical projects, the advent of low-voltage opportunities has further extended the channel's reach—and the emergence of new players who are joining/competing with the electrical channel is having an impact on the mix in this market.

[13] "What Does it Mean to be a System Integrator?", AutomatedBuildings.com, April 2015. Accessed: April 2017: https://www.thinkesi.com/System-Integrator-Paul-Oswald

10. INDUSTRY RECOMMENDATIONS



EFC Recommendations

As an industry, we must gain a better understanding of these outside forces that are moving into the inner folds of our channel and examine those that will have a lasting impact on our channel going forward. Consideration must be given on how we can build relationships with new emerging players—before they become competitors working in isolation from our channel. Just as codes and standards are undergoing a much-needed review of their guidelines, there is also an opportunity for the electrical industry—as a whole, to refresh our overall framework to include new opportunities and channel players.

Product Section Expansion

It is also an opportune time to consider the establishment of a new EFC Product Section Committee for low voltage-related technologies, including renewable solutions. As stated in a Darnell Group Report, "the development of products and power supplies designed to work in a DC power environment, is critical to the further expansion of DC power."[14]

Electrical Distribution Recommendations

As we have learned so far, the evolution of technology brings about new opportunities for all channel players. Numerous manufacturers have already introduced lines of low-voltage products and solutions. New specialty distributors offering low-voltage products and services have entered the market, as have other installers (system integrators, datacomm, security and IT solution providers).

Manufacturers need a channel through which they can quickly and cost-effectively get their products to market to meet end-user demand. So, there is a reliance on electrical distributors to adapt their core product and service offerings to meet this requirement. This evolution is imperative if the electrical distribution channel is to be more effective and competitive in this new era of technological change.

There are several other new realities and potential threats occurring in the market today that electrical distributors are encouraged to keep a close eye on:

- Tech-savvy DIY-ers who purchase products from big box retailers and install themselves;
- Residential dealers, security solution providers and system integrators who are called upon to install LVDC and provide value-added custom integrations and service; and
- e-Commerce purchasing that enables end users to find LVDC products quickly and economically

While these should be considered opportunities for growth for the electrical channel, they can quickly become challenges, or threats, if not pursued in a timely manner.

Manufacturer Recommendations

As manufacturers continue to expand their offerings, they must consider how their products and solutions will safely and securely operate with disparate products, as end user demands for systems integration heighten. Manufacturers will need to deploy standard protocols that allow other products to be configured with their own, to allow end-to-end system interoperability.

[14] "DC Building Power: Emerging Trends, Application Drivers, Market Opportunities, Adoption Rates and Forecasts", published by Darnell Group. Accessed from NEMA Workspaces, March 2017: http://workspaces.nema.org/public/LVDC/Lists/Team%20Discussion/Attachments/14/darnell_market_product_info.pdf

How Close is LVDC to the Tipping Point?

Let's not underestimate it!

The shift to LVDC-powered systems and corresponding applications and devices will have a tremendous impact on the electrical channel—and other leading technologies in the electrical space, including LEDs, electric vehicles, home batteries and renewable energy solutions.

This report has showcased several opportunities that can be achieved with advancements in low-voltage DC-powered systems. A number of challenges have also been explored. LVDC technology will reach wide adoption, and the challenges will need to be overcome if the electrical industry is to reap the benefits of the many opportunities it will introduce.

Consider how quickly LEDs reached the tipping point, a phenomenon that very few people expected to happen so fast. Let's not underestimate the opportunities and benefits that LVDC-powered systems will have on the electrical industry...and *far beyond* this channel.

12. APPENDIX A: LOW-VOLTAGE REPORT - GLOSSARY

The following glossary features commonly-used terms in this report, providing readers with context:

AC	Alternating Current
API	Applications Programming Interface: a set of subroutine definitions, protocols and tools for building application software
ANSI	American National Standards Institute
BacNet	A data communication protocol for building automation and control networks
CEC	Canadian Electrical Code
Connected Lighting	Luminaires are uniquely identified and integrated into the IT network in a building or city, and share information about their status and operations
Connected Spaces	Each luminaire has integrated sensors making it a point of intelligence that can share information on occupancy, activity patterns, changes in temperature or humidity and daylight levels
Class 1 Circuit	The portion of the wiring system between the load side of the overcurrent protection device and the connected load. Class 1 remote-control and signaling circuits typically operate at 120V, but the NEC permits them to operate at up to 600V [725.21(B)]
Class 2 Circuit	Typically includes wiring for low-energy (100VA or less), low-voltage (under 30V) loads such as low-voltage lighting, thermostats, PLCs, security systems, and limited-energy voice, intercom, sound, and public address systems
Connectivity	The specific protocols, services and signalling systems which allow analogue and digital traffic to move across physical capacity in such a way as to allow applications such as voice telephony or the Web to take place. (CRTC)
DC	Direct Current
DLVP	Distributed Low Voltage Power: combines intelligent lighting controls with efficient DC power distribution
DC Microgrid	Defined by the U.S. Department of Energy as a group of interconnected loads and distributed energy resources within clearly-defined electrical boundaries that act as a single controllable entity with respect to the Grid.
ES1	From IEC 62368-1; 5.2.1 Electrical energy source classifications; 5.2.1.1 ES1 (Electrical Safety Class 1): ES1 is a class 1 electrical energy source with touch current or prospective touch voltage levels - not exceeding ES1 limits (60 V dc and 2 mA) under normal operating conditions, abnormal operating conditions, and single fault conditions.
Enernet	Convergence of Energy (Smart Grid) and Ethernet (Communications Networks). Originally used by Bob Metcalf, co-inventor of Ethernet technology.
IoE	Internet of Everything
IoT	Internet of Things
IIoT	Industrial Internet of Things (see also M2M)
LiFi	A wireless optical networking technology that uses light-emitting diodes (LEDs) for data transmission
LCC	Limited Current Circuits where the maximum available current cannot exceed 2.0 mA dc, 0.7 mA peak ac, or 0.5 mA rms under both normal and single-fault conditions. There are also limits on allowable capacitance.
LPS	Product standards for electrical circuits under 60 Vdc and 100 W (100VA power) when combined with current: a Limited Power Source (LPS) is a secondary circuit with an open circuit output voltage, UOC, not exceeding the SELV circuit limits of 42.4 VPEAK or 60 Vdc. The maximum apparent power, S, available on the output under any load condition, and the maximum fault current, ISC, available on the output under any load condition, (including a short-circuit), are limited to magnitudes not likely to cause ignition under fault condition in components mounted on, or circuits constructed from, suitably rated materials. e.g. Very often the DC output of external AC/DC adapters comply with the LPS requirements, and the markings on the adapter may include an "LPS" marking on the nameplate. Internal AC/DC supplies with output rated < 100W meet the LPS limits.
LVDC	Low Voltage Direct Current (<60 Volts) – also see "SELV" in this glossary
Net-zero Buildings	Defined by the U.S. Department of Energy as a building unit that produces enough renewable energy to meet its own annual energy consumption requirements, thereby reducing the use of non-renewable energy in the building sector (also see ZNE - Zero Net Energy)
NEC	National Electrical Code (US)
M2M	Machine to Machine (see also IIoT)
PoE	Power over Ethernet: A software-based system that passes power and data over the same cable in a standardized way (<60 Volts), harmonizing control systems. For those PoE circuits that also carry signals, you have a combination of a small AC signal riding on top of the DC voltage.
PV	Photo Voltaic (e.g. PV cables are used in solar systems)
SELV	SELV - Safety (Separated) Extra-Low-Voltage - SELV specifications: the voltage between any two accessible parts/conductors or between a single accessible part/conductor and earth must not exceed a safe value, which is defined as 42.4 VAC peak or 60Vdc for no longer than 200 ms during normal operation. UL 60950-1 states that a SELV circuit is a "secondary circuit which is so designed and protected that under normal and single fault conditions, its voltages do not exceed a safe value." A "secondary circuit" has no direct connection to the primary power (AC mains) and derives its power via a transformer, converter or equivalent isolation device.
Smart Cities	An urban development vision to integrate information and communication technology and Internet of things (IoT) technology in a secure fashion to manage a city's assets.
Smart Grid	An electricity supply network that uses digital communications technology to detect and react to local changes in usage
System Integrator	An individual or organization that builds systems from a variety of diverse components. With increasing complexity of technology, more customers want complete solutions to information problems, requiring hardware, software and networking expertise in a multivendor environment.
ZNE	Zero Net Energy (also see Net-zero Buildings)

13. APPENDIX B: RESOURCES

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EMerge Alliance

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For a full listing of LVDC-related resources, go to
http://www.electrofed.com/resources-low-voltage-dc-power