



DC Power Systems

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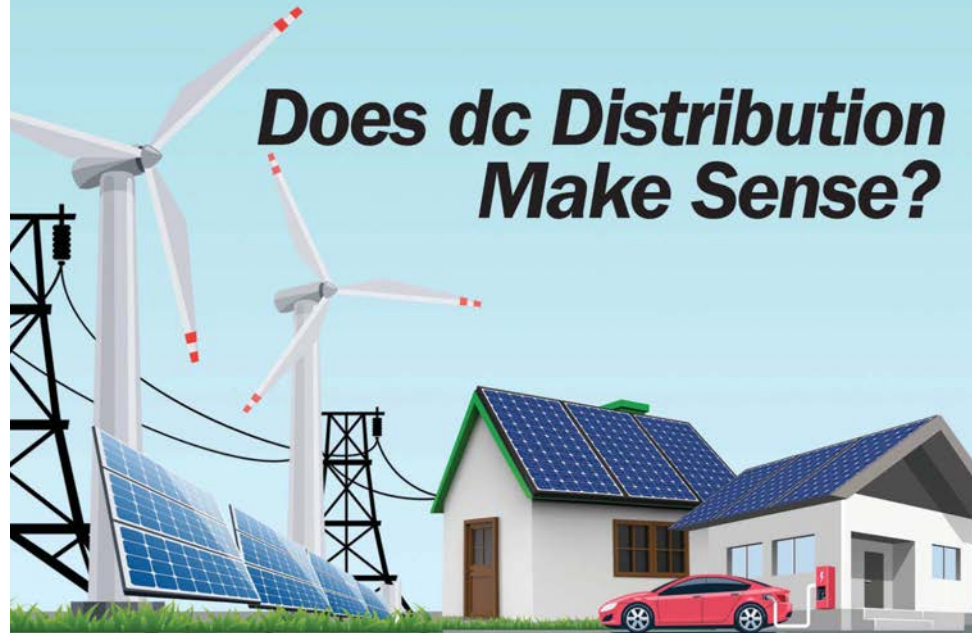
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MAGAZINE



Does dc Distribution Make Sense?



SOLAR-DC MICROGRID FOR INDIAN HOMES
DC LOCAL POWER DISTRIBUTION
ARE MICROGRIDS THE FUTURE OF ENERGY?
DC MICROGRID PROTECTION



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Brief History of the U.S. Electricity Industry

Electrification of our modern world was called "the greatest engineering achievement of the 20th Century" by the National Academy of Engineering



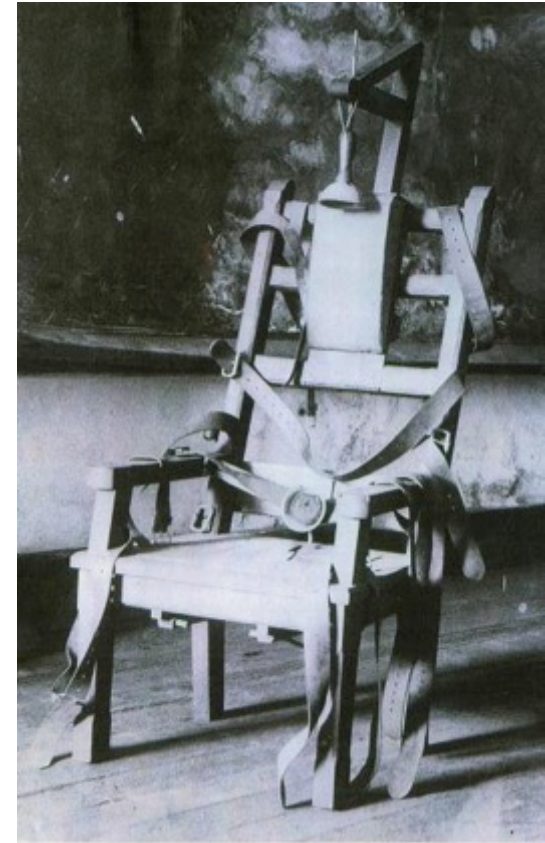
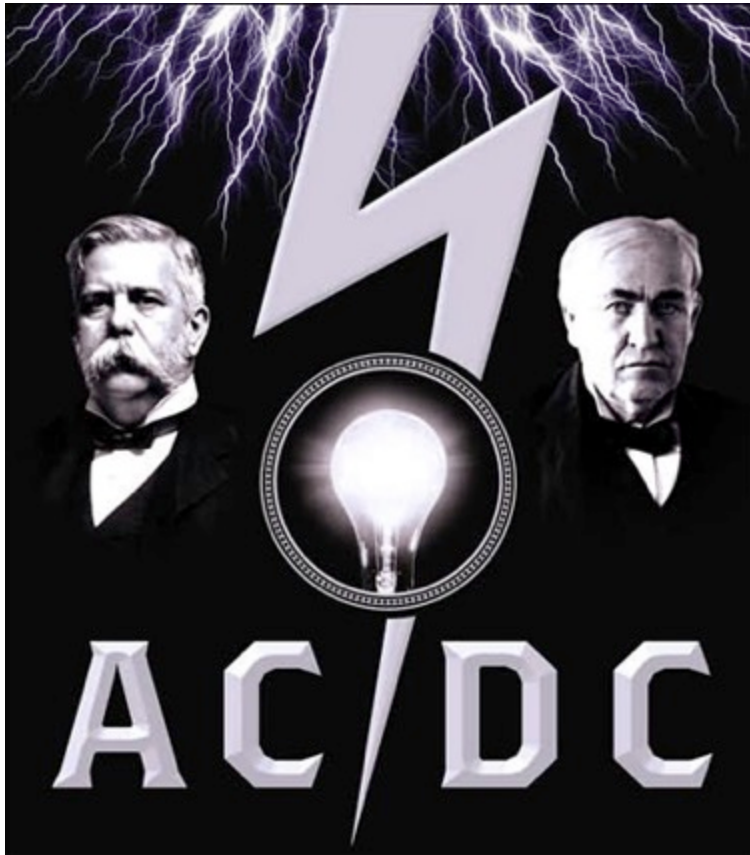
Pearl Street Station



Niagara Power Station

Source: Wikipedia

AC/DC War (1885-1895)



Reference: *AC/DC: The Savage Tale of the First Standards War*

“The electric chair developed not out of the desire for a method of execution more humane than hanging but through an effort of one nineteenth-century electric company to discredit the other.”

Reference: *Executioner's Current* by Richard Moran

Nikola Tesla and Westinghouse



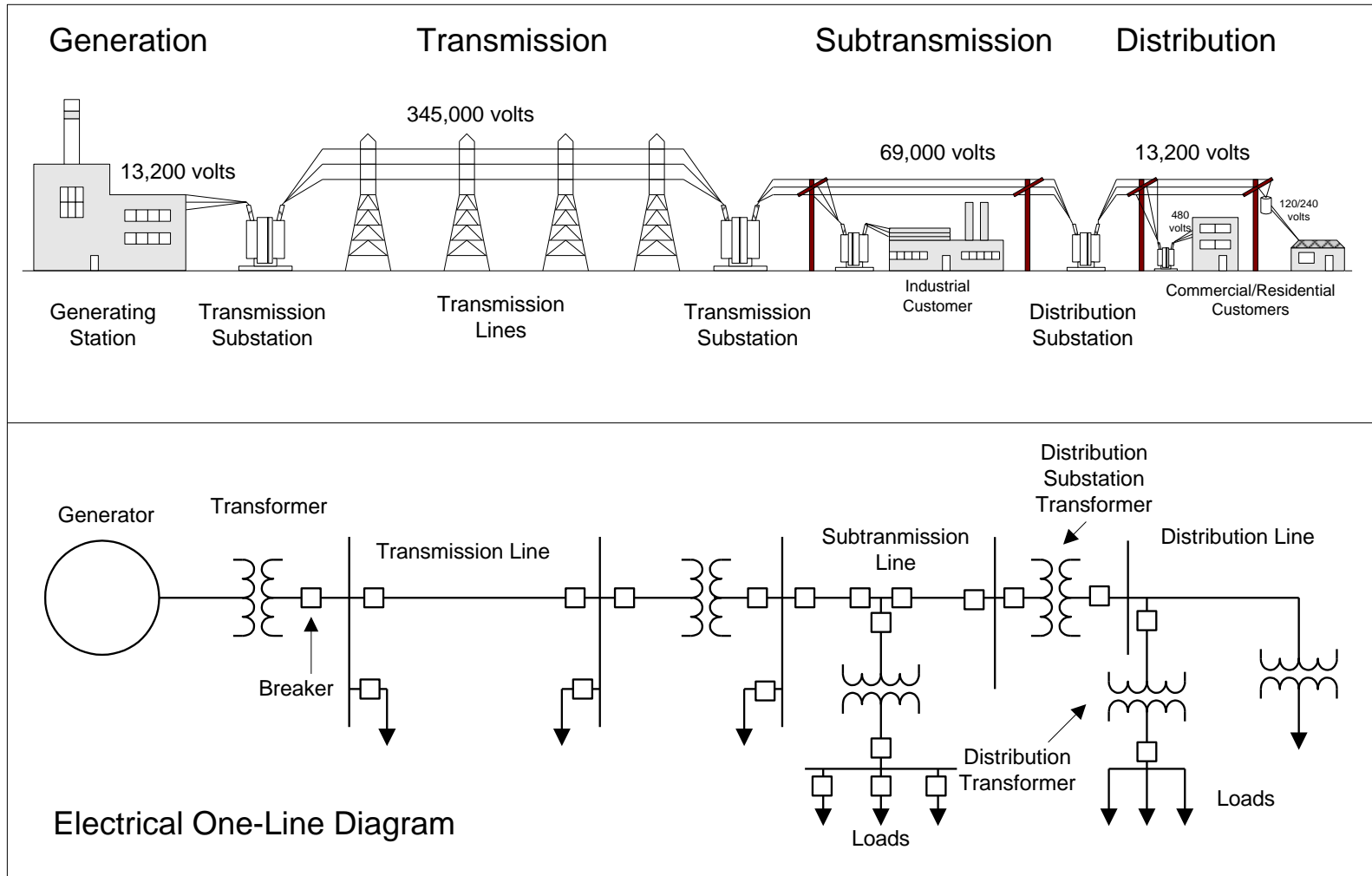
Courtesy: Tesla Memorial Society of New York



"CITY OF LIGHT" at the Columbian Exposition at the 1893 Chicago World's Fair.

- **1893 World's Fair in Chicago, Illinois was to be lighted electrically**
- **Bids**
 - DC (Edison)
 - AC (Westinghouse/Tesla)
- **AC was the most cost effective approach at the time**

The Electricity Grid



Motivation for DC Power Systems

- Many of the more common loads have become intrinsically DC - Lighting, TVs, Computers, Telecommunication, Data centers, **Appliances**
- Key renewable and distributed resources (Solar, battery storage, fuel cells) are DC
- Most classical ac generation devices can actually operate more efficiently if connected through variable frequency AC drives¹
- Opportunities for increased efficiency, reliability, security, independence, and cost

1. L. Zubieta, "Are Microgrids the Future of Energy?," *IEEE Electrification Magazine*, June 2016.

Driving the Shift to DC

- **HVDC**
- **Transportation**
- **The developing world – energy independence and greater affordability**
 - Mobile 12 V battery loads
 - Simple DC loads and sources offer energy independence
- **Military operations – forward operating bases, electric ships**
- **Telecommunications**
- **Datacenters – increased reliability, higher efficiency (28% more), lower cost (up to 15% reduction)²**



Source: FREEDM Systems Center, NC State



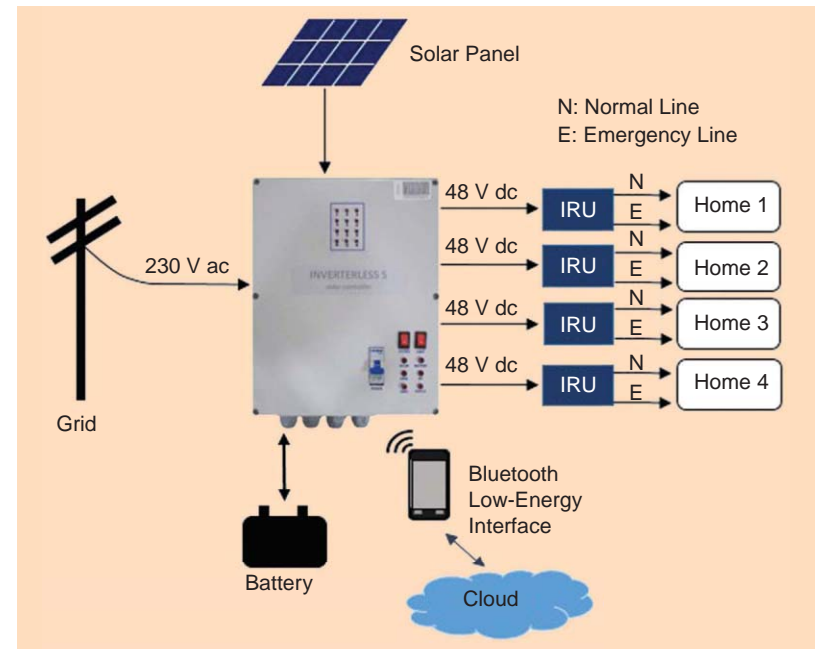
Directly from [3]

2. "Edison Redux: 380 Vdc Brings Reliability and Efficiency to Sustainable Data Centers," *IEEE PES Magazine*, November 2012.

3. A. Jhunjhunwala, A. Lolla, P. Kaur, "Solar-dc Microgrids for Indian Homes: A transforming power scenario," *IEEE Electrification Magazine*, June 2016.

DC Microgrids in India – Key Results

- **Limited access to electricity**
 - 267 million people in India without access to electricity
 - In example of 6 states studied, over 90% of customers experience daily power outages for >4h
 - Many homes without wires despite village being considered electrified
- **Key issue not necessarily supply-demand gap or transmission constraints but affordability**
- **Solar-DC Microgrids offer a solution:**
 - Solar-dc home microgrid enables 24/7 power vs. on-grid ac home
 - Delivery of energy at higher efficiency in DC (91%) vs. AC (65%) at 1/4 the cost for same sources (local PV)
 - “for an efficient off- grid solar-dc home the power costs are lower than even the current grid-connected ac homes”

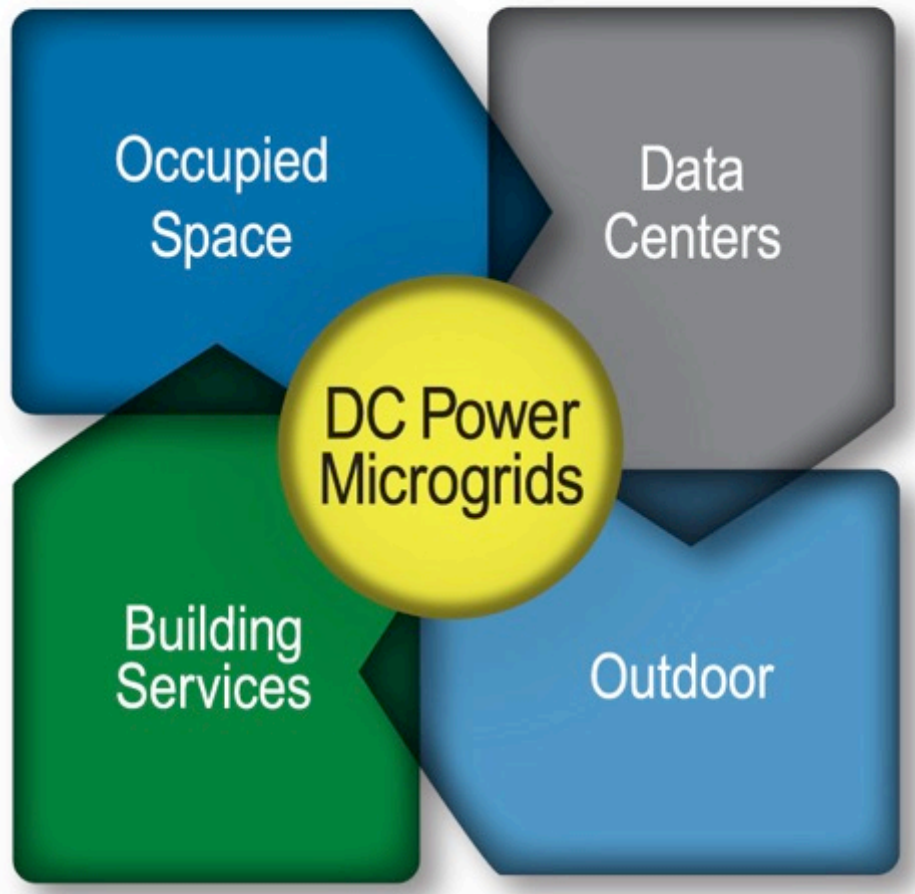


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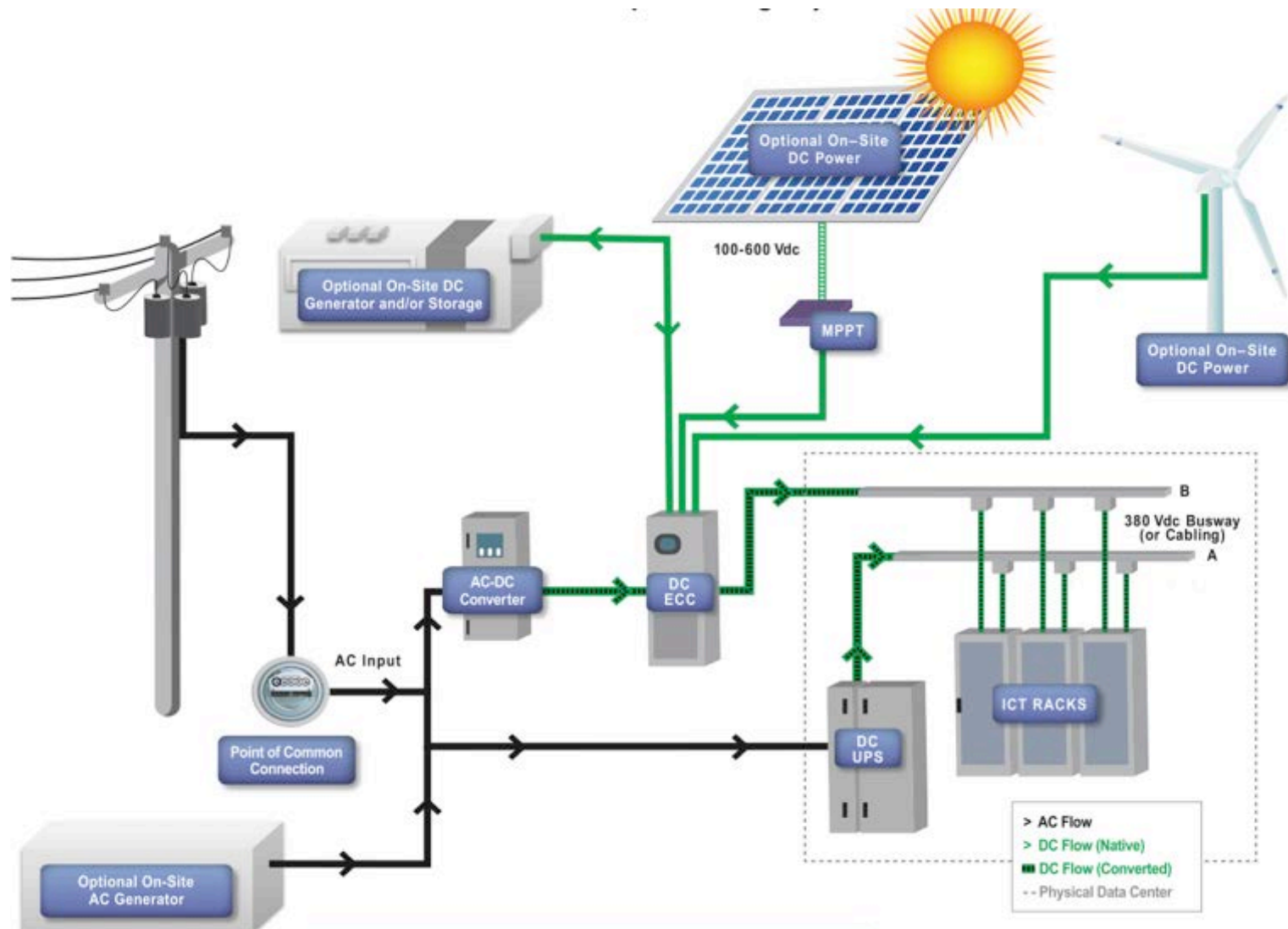
DC Power Systems: Vision for Buildings

Vision: DC Microgrids in Buildings



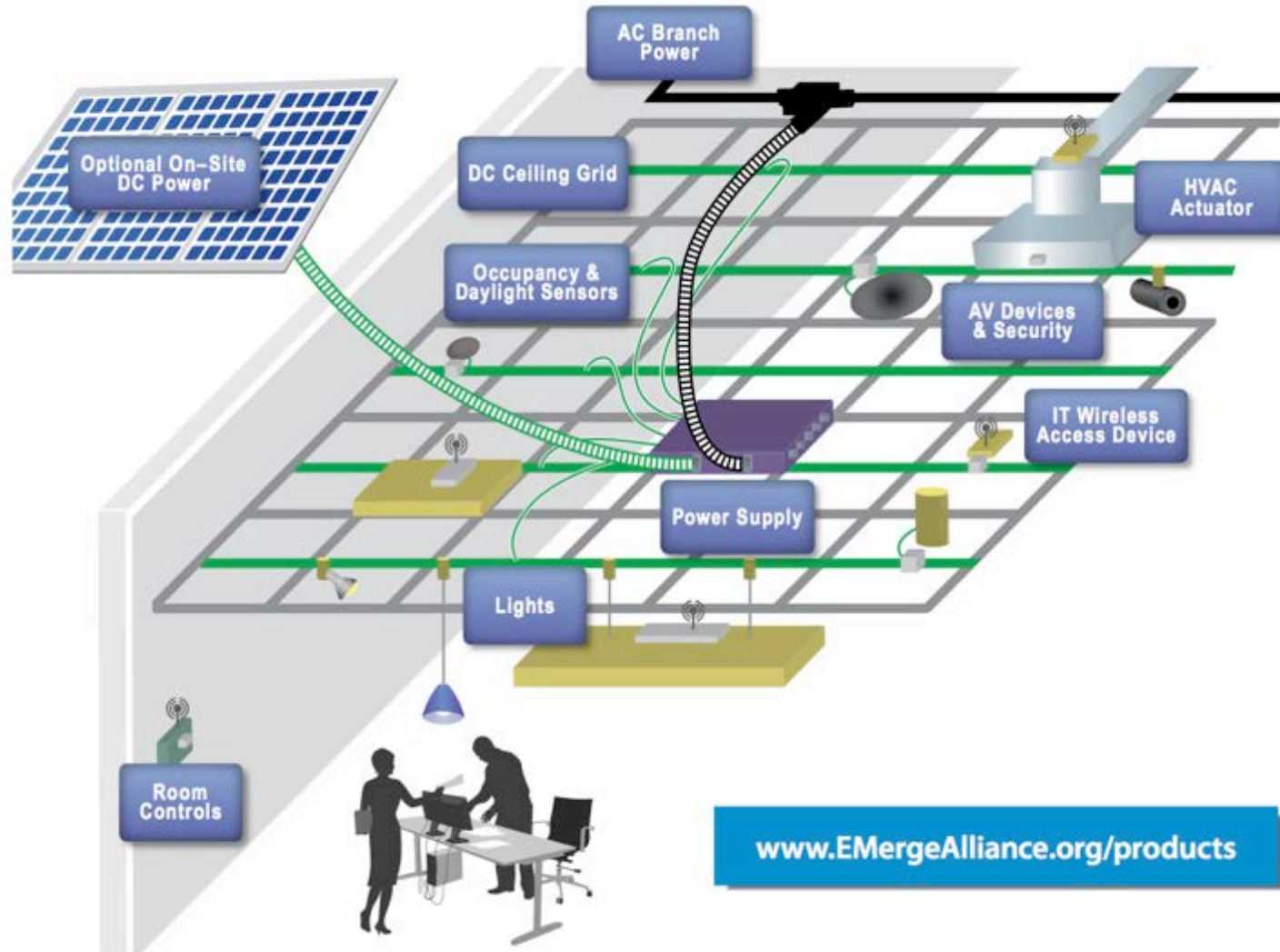
Directly From: "DC Microgrids: Advanced Power Distribution Platforms for Flexibility, Savings & Sustainability in Buildings," *Emerge Alliance*, emergealliance.org.

DC in Data Centers



Directly From: "DC Microgrids: Advanced Power Distribution Platforms for Flexibility, Savings & Sustainability in Buildings," *Emerge Alliance*, emergealliance.org.

DC in the Occupied Space



Directly From: "DC Microgrids: Advanced Power Distribution Platforms for Flexibility, Savings & Sustainability in Buildings," *EMerge Alliance*, emergealliance.org.

Obstacles to Adoption of DC Power Systems

- **Misconceptions** – safety, efficiency, capabilities
- **Lack of Standards and Codes** – few references for engineers, manufacturers, and installers
- **Lack of Products**
 - Majority of products in the home are DC (each with their own converter), but not many can plug into a 380 Vdc or 48 Vdc outlet
 - Many appliances are dc at their core, but not available as dc-power dc appliances
 - Protection devices

Opportunities

- **An opportunity to create a global DC standard**
- **Universal power connectivity: democratization of electricity**
- **Parts commonality – stationary and mobile power systems**
- **Decrease electronic waste – mobile phone chargers in EU**
 - In US: 379 million external power supplies in landfill each year
- **Potential to improve energy independence and access for billions**