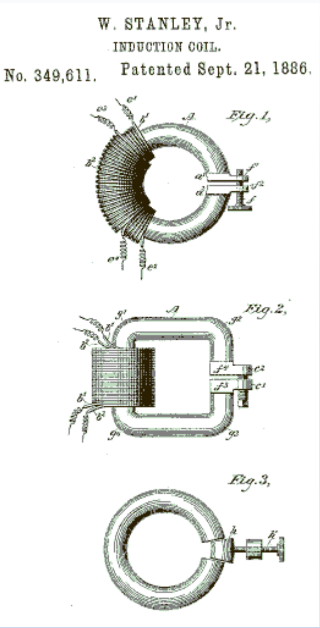
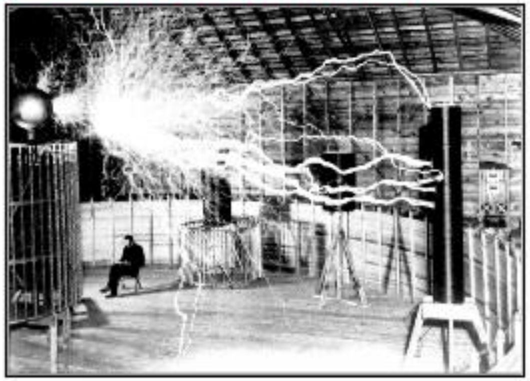


Nikola Tesla In The Lab He Set Up In Colorado Springs (1899) To Study Electric Energy By Generating Millions Of Volts (Note: The Photo Below Is a Double Exposure.)



Electric Power Systems: The Old, The Modern, The Future

IEEE Berkshire Section

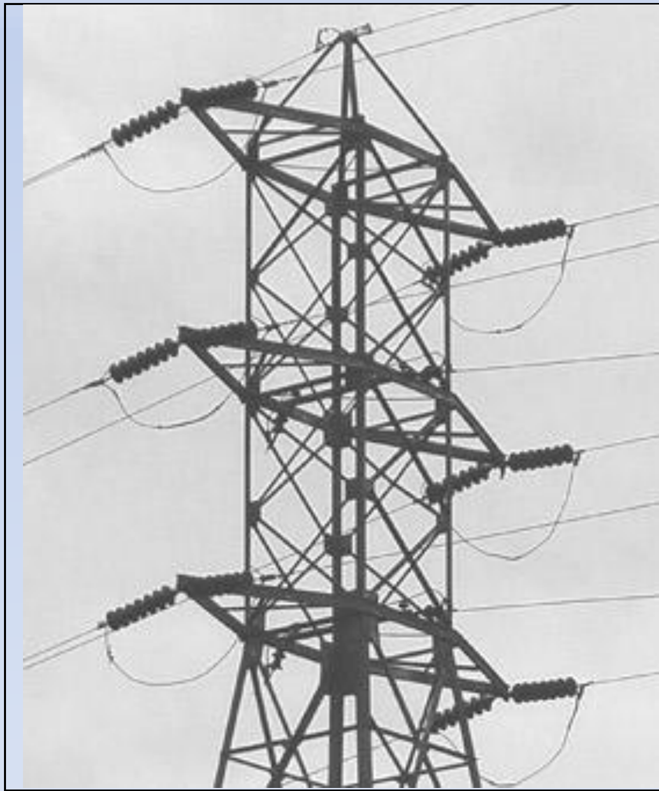
March 31, 2016

Dr. George Gela

BETC

Electric Power Systems:
The Old, The Modern, The Future

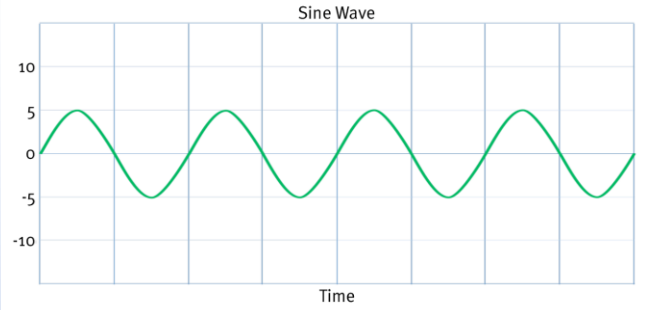
Electric Power Systems:
The Old, The Modern, The Future



Steinmetz's Experimental Power Line, 1908. Schaghticoke-Schenectady power line was a testing ground for new power grid technology

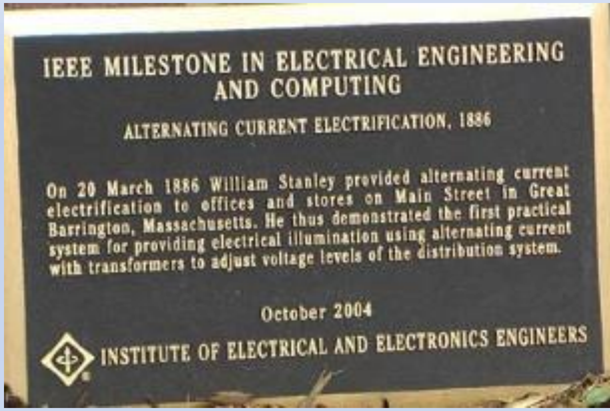
Great Barrington 1886 The first AC power distribution system using transformers (top) Stanley developed the prototype transformer (bottom) in 1885, it was robust, reliable and was a significant leap forward in technology.

It all started right HERE



- The Berkshire Eagle, Sunday, March 20, 2016:
  - '130 years ago, G. Barrington experiment lit path to future' (note: that was in 1886 – 130 year ago)
  - 'On this day 130 years ago, inventor and chief engineer for Westinghouse Electric Co., William Stanley, Jr., working for and with Inventor and industrialist George Westinghouse, demonstrated the first complete system for high voltage alternating current transmission.'

History of Electric Power Systems

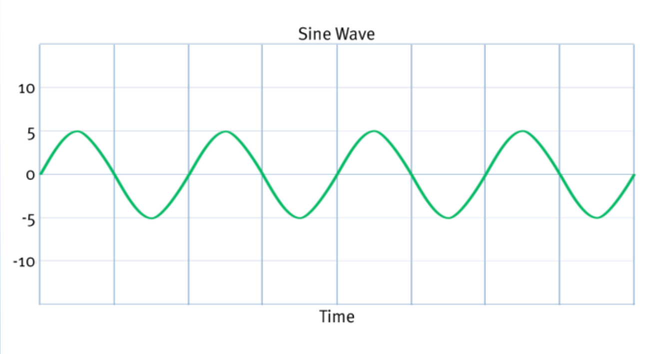


- It all started here, in Northeast
- Visit Great Barrington, Pittsfield
- Work continues

	
Mechanicville Power Station, Mechanicville, New York 1897	Redlands Mill Creek 1 powerhouse Redlands, CA 1893

Edison Tech Center

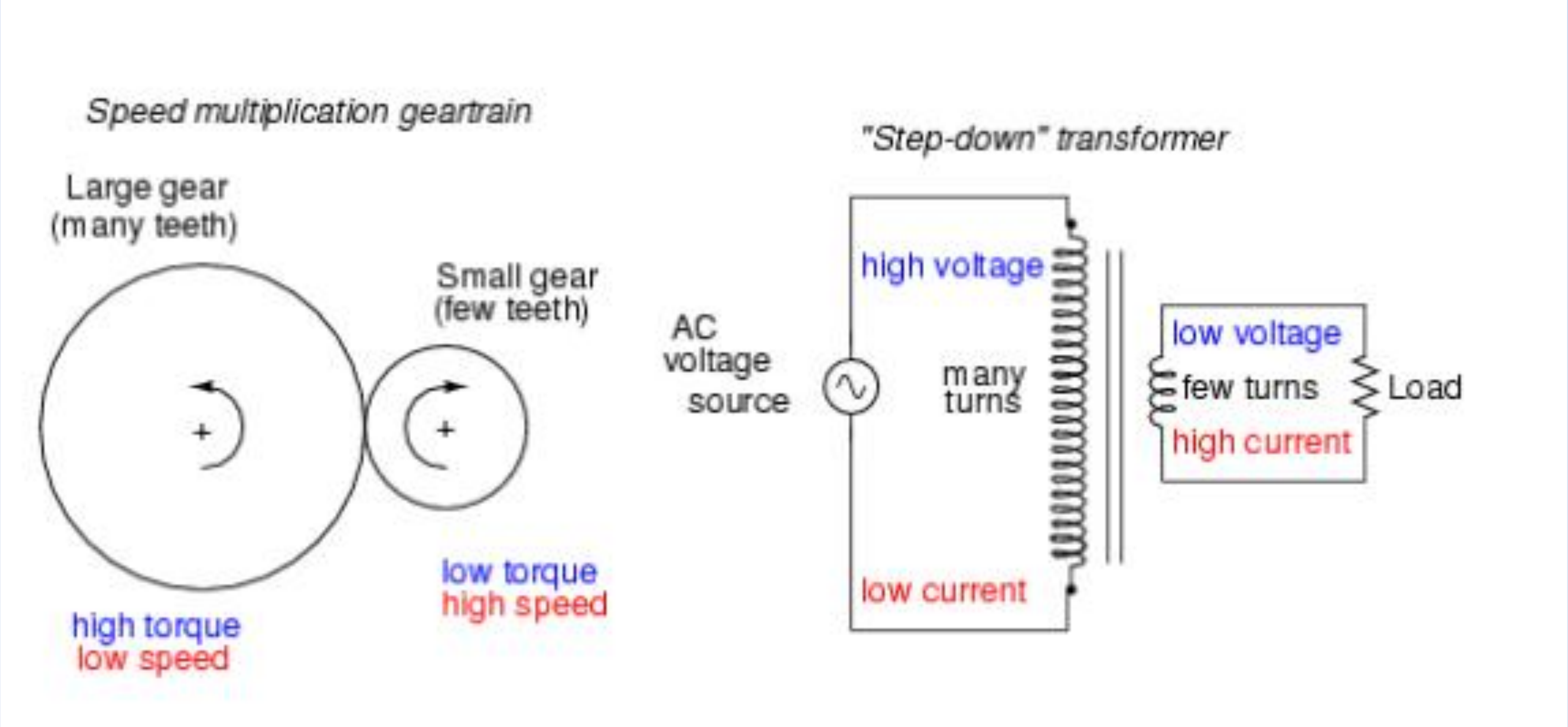
It all started right HERE

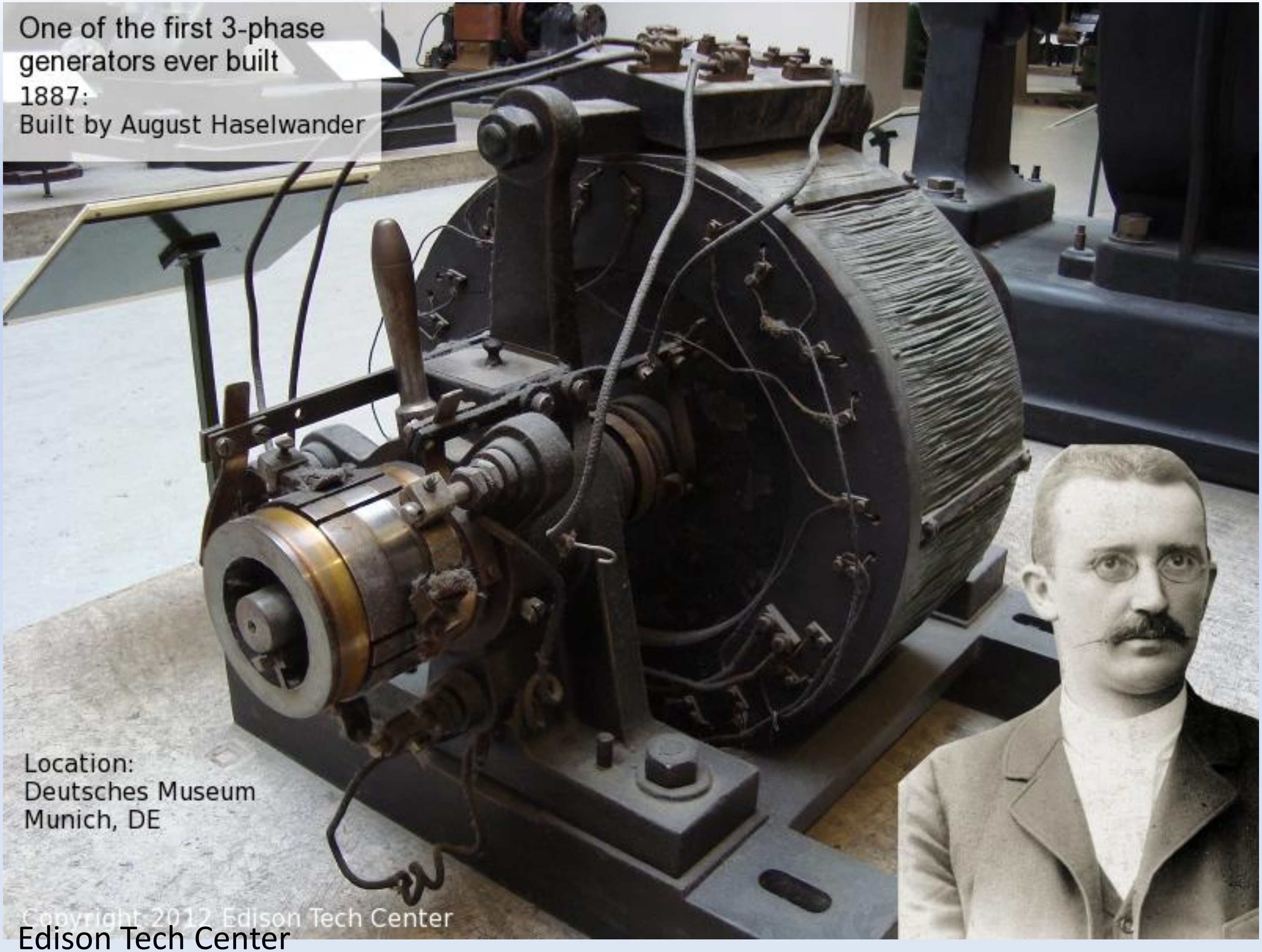


- The Berkshire Eagle, Sunday, March 20, 2016:
  - 'With his transformers, Stanley was able to allow 3,000 volts of electricity to travel from an AC generator installed near Cottage Street through wires strung on Main Street.
    There, in six basements in buildings along the main thoroughfare, his machines "transformed" the high voltage current by reducing it to 500 volts so that it could safely light 30 100-volt incandescent lamps connected to the system.'

What is a transformer?

- Transformer analogy





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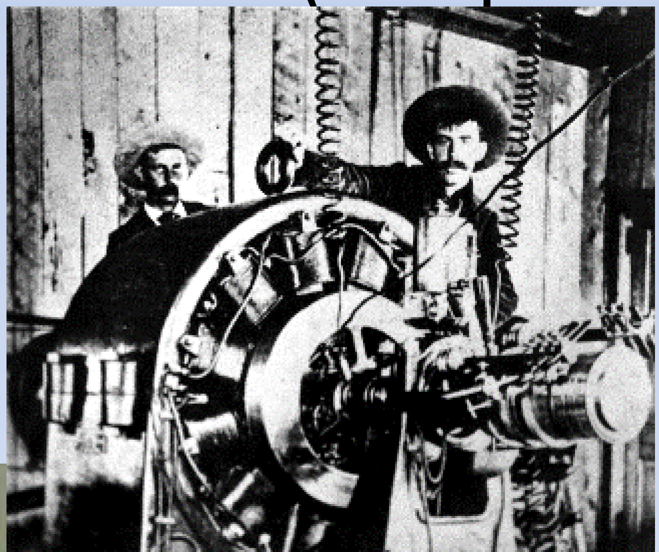
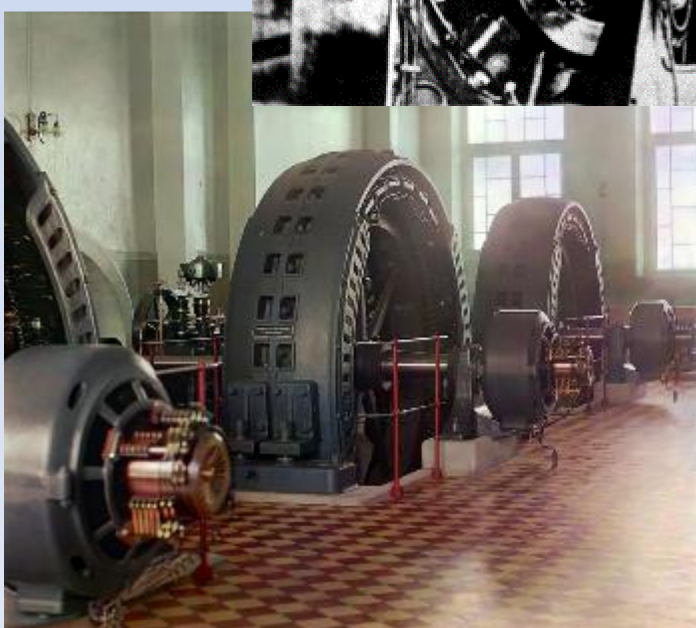
How do we produce AC?

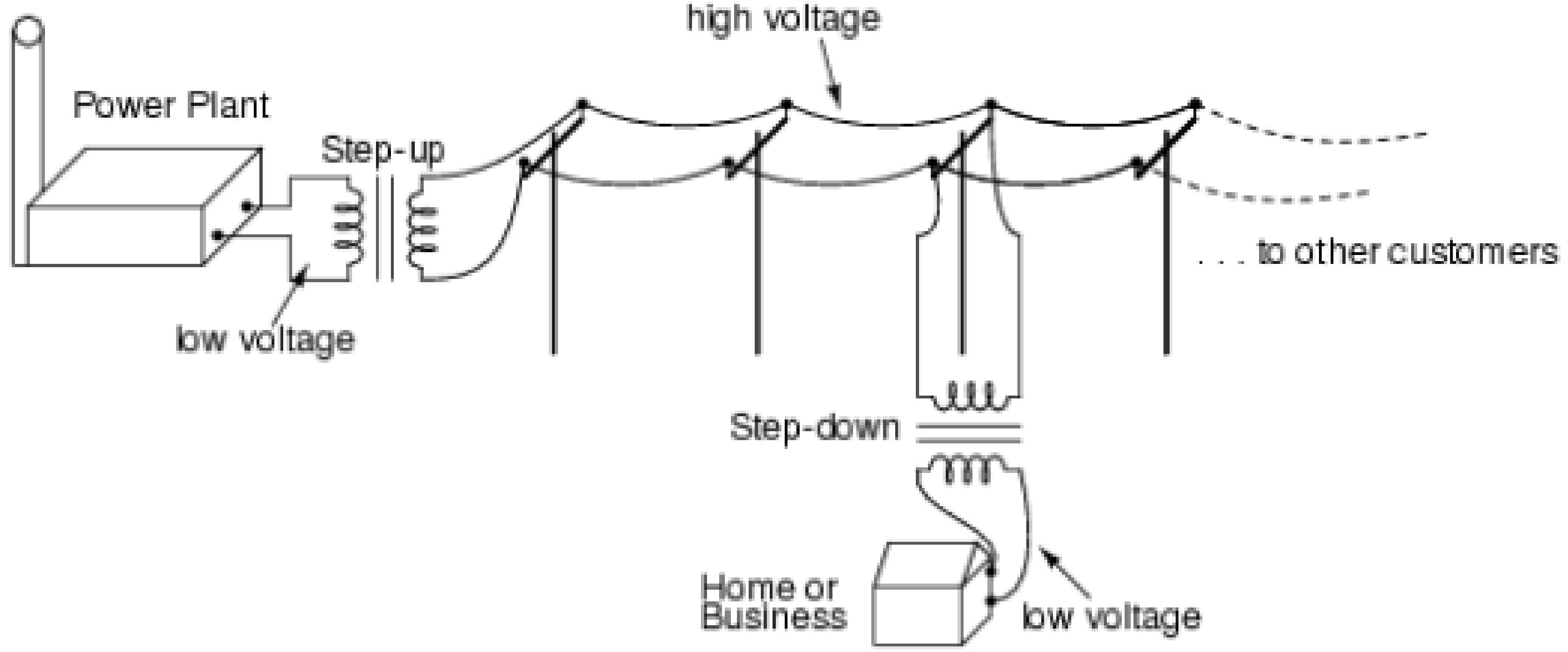
- Alternator (Wikipedia)





Workers pose in 1891 with 100-hp Westinghouse synchronous alternator at the Ames power plant located near Ophir, Colorado. At the time it was the largest alternator Westinghouse made. It was used as a generator, connected by belt drive to a six-foot Pelton water wheel driven by water from water from the San Miguel River. It produced 3000 volt, 133 Hertz, single phase alternating current to drive a similar alternator connected by copper power line s 2.6 miles (4.2 km) that acted as a motor to drive a stamp mill at the Gold King Mine. It replaced an existing steam mill that was difficult to run because of a lack of timber to use as fuel.

What is an AC power system?



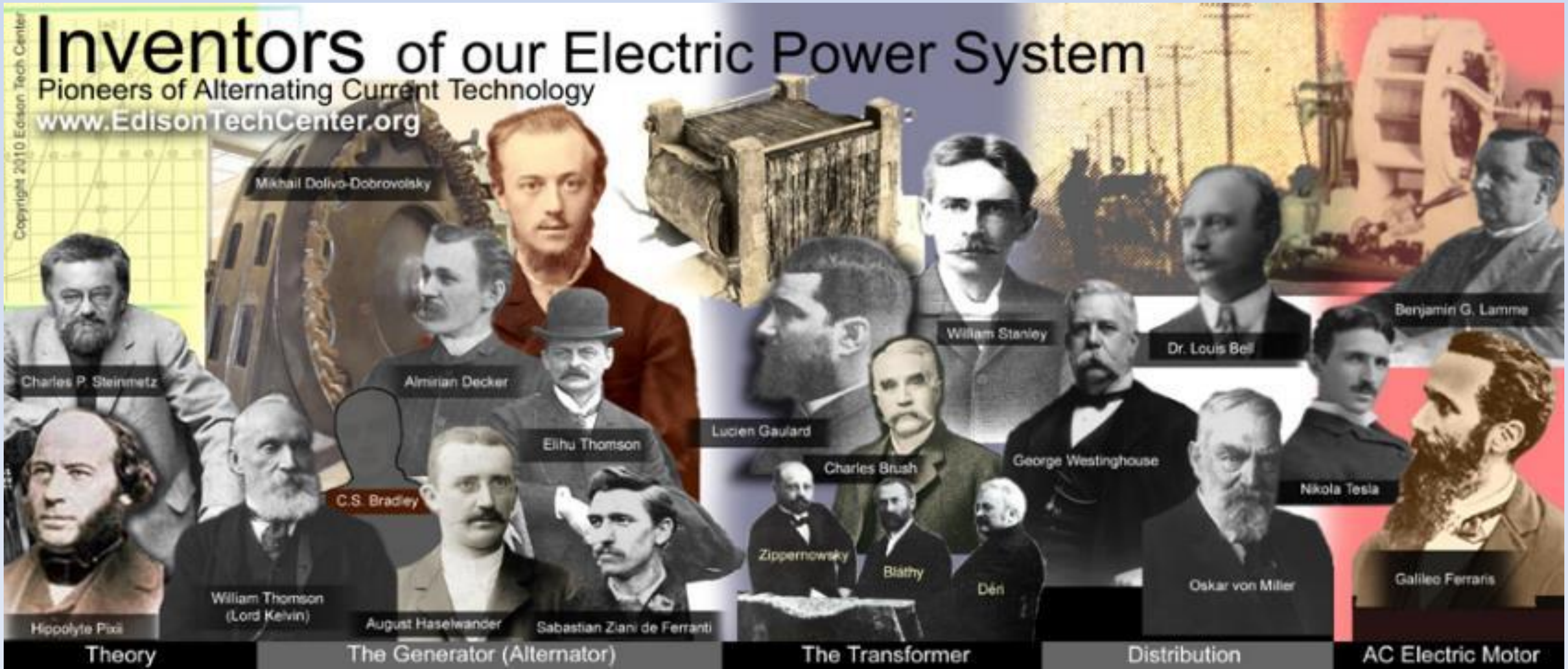
Simple AC Power System

- Every power system has three major parts
  - Generation: source of power, ideally with a **specified voltage and frequency**

  - Transmission/distribution system: **transmits power**; ideally as a perfect conductor
  - Load: consumes power; ideally with a **constant resistive value**

Alternating current power drives our world today. AC power was the next logical step after DC power was established.

- The founders, developers, and visionaries of AC power are depicted below.



What is AC voltage? (IEC definition)

Area	Circuit theory / General
IEV ref	**131-11-25**
en	**alternating voltage** **alternating tension**

voltage that is a periodic function of time with a zero direct component or, by extension, a negligible direct component

Note – For the qualifier AC, see IEC 60050-151.

BETC

What is AC current?

alternating current AC	

electric current that is a periodic function of time with a zero direct component or, by extension, a negligible direct component

Note 1 to entry: For the qualifier AC, see IEC 60050-151. Note 2 to entry: This note applies to the French language only. [SOURCE: IEC 60050-131:2002, 131-11-24]

AC Challenges

- AC electric energy must be consumed as it is produced – cannot be stored as electricity
- Voltage control
- Frequency control
- Generation often far from the load
- Overhead towers, wires
- Underground cables

What about DC?

- Is there a role for DC in the AC world?
- Last DC residential system
- Back-to-back DC
- Long-distance
- Low voltage

What is DC voltage? (IEC definition)

Area	Circuit theory / General
IEV ref	**131-11-23**
en	**direct voltage** **direct tension**

voltage that is time-independent or, by extension, periodic voltage the direct component of which is of primary importance

Note – For the qualifier DC, see IEC 60050-151.

What is DC current? (IEC definition)

Area	Circuit theory / General
IEV ref	**131-11-22**
en	**direct current**

electric current that is time-independent or, by extension, periodic current the direct component of which is of primary importance Note – For the qualifier DC, see IEC 60050-151.

DC Challenges

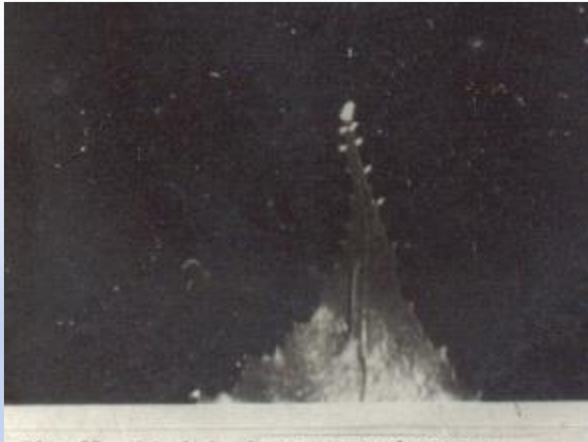
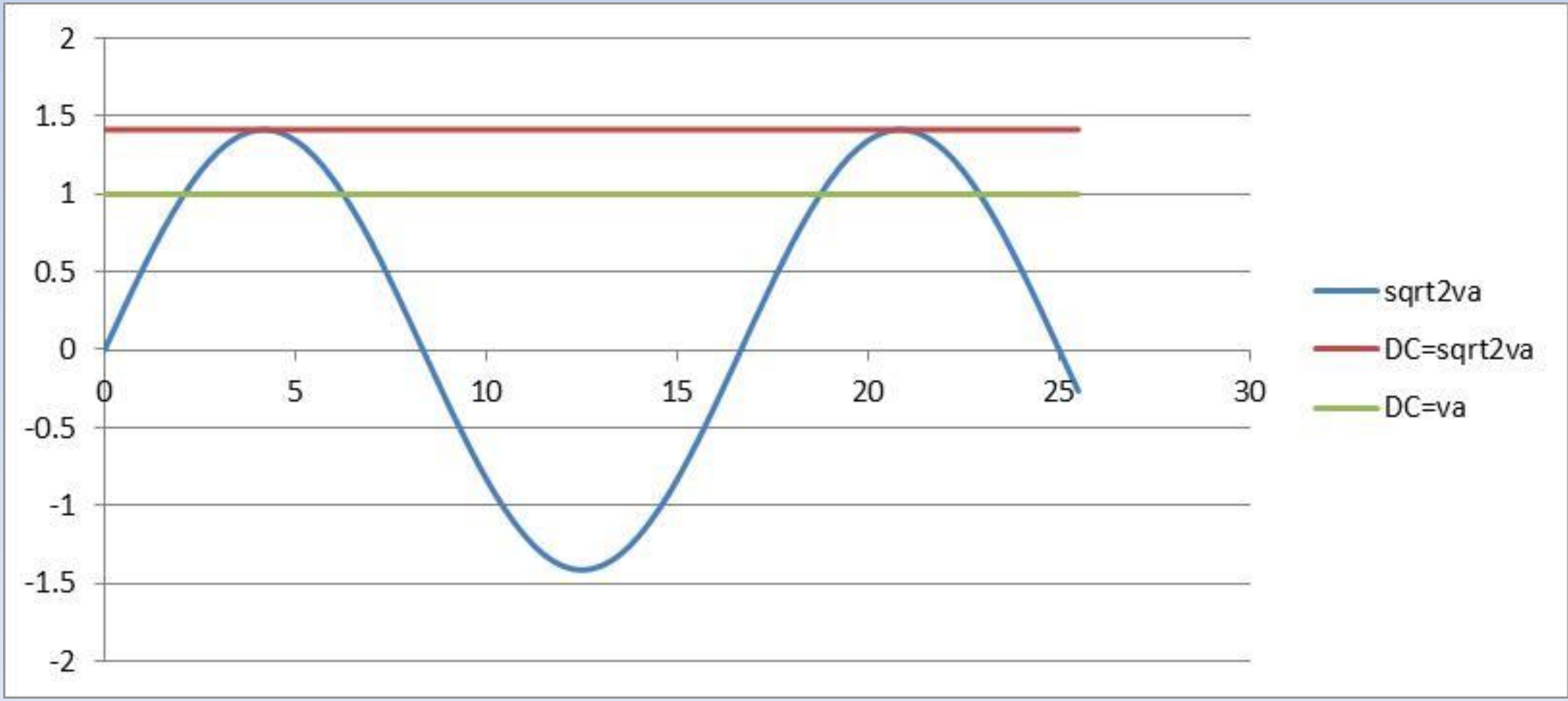


Fig. 25. Birch leaf appearance in corona.

- Voltage transformation
- Energization of lines and CABLES (initial current, line and CABLE capacitance)
- Current interruption (switches,
circuit breakers,
fault clearing, etc.)
- Corona
- Human sensation

Comparing AC and DC

- What should we use as basis of comparison?



Electric Power Systems:
The Old, The Modern, The Future

Decades and M$ of research worldwide

- A lot of research done here: Pittsfield, Lenox

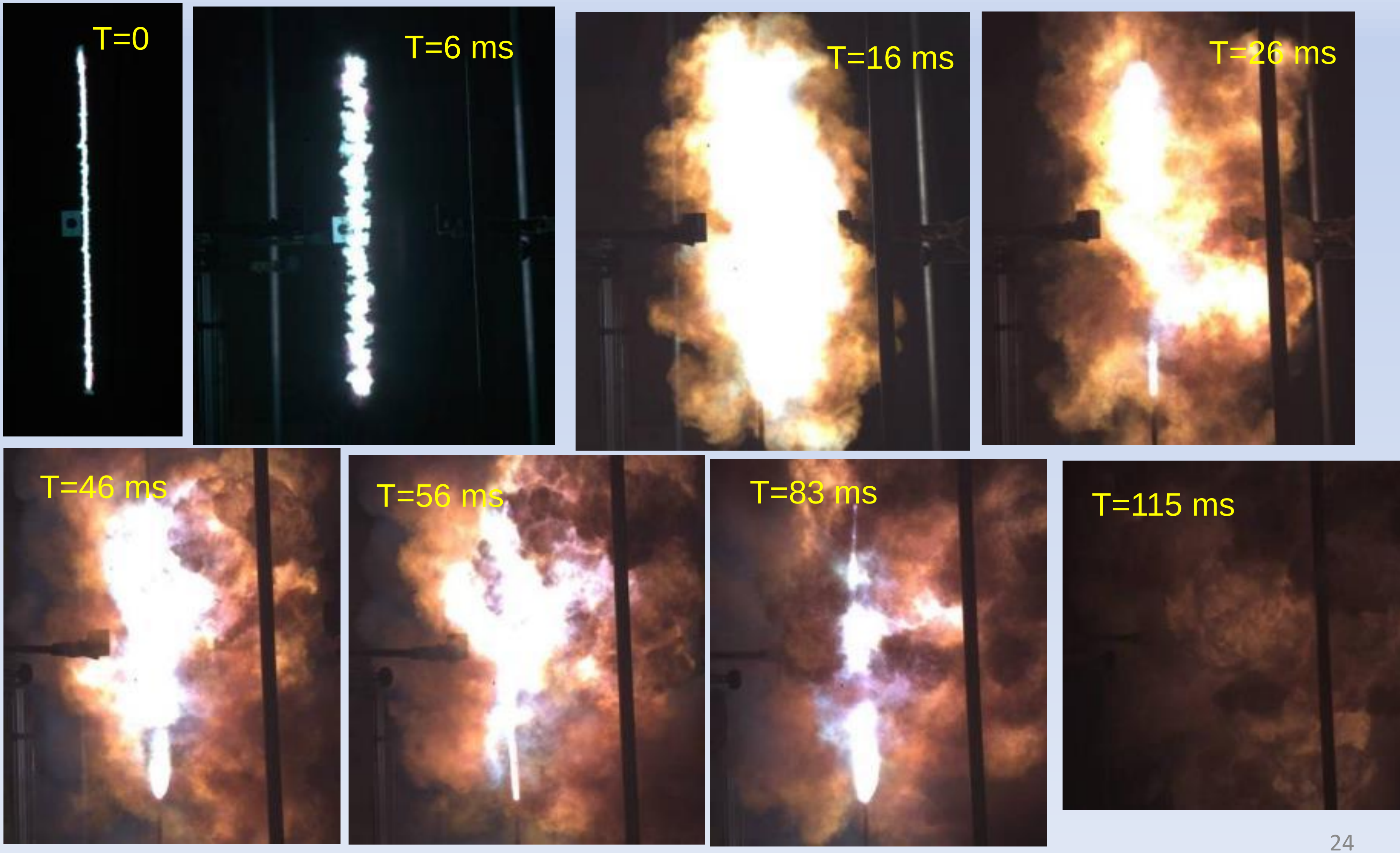
Decades and M$ of research worldwide

- A lot of research done here: Pittsfield, Lenox





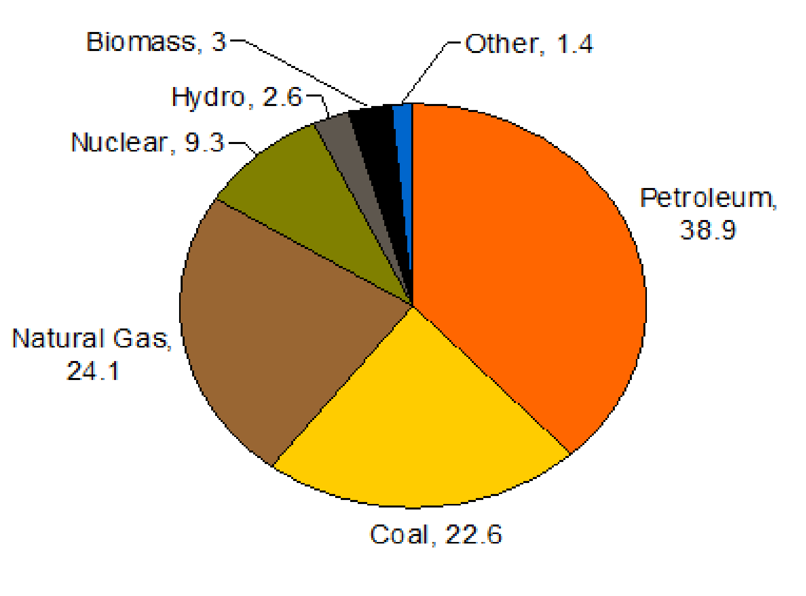
Examples: 40 kA, 6 cycles, 4 ft gap, Test 9-3773 (time step: 1 ms; 83 ms ~ 5 cycles)



Major components of a line

- Foundation
- Tower, pole
- Insulators, insulation
- Conductors
- Shield wires
- Grounding
- ROW
- Vegetation
- Add-ons, shared facilities, fences, encroachment

Sources of Energy - US



About 86% Fossil Fuels

In 2009 we got about 0.75% of our energy from wind and 0.04% from solar (PV and solar thermal)

CO_2 Emissions (millions of metric tons, and per quad)

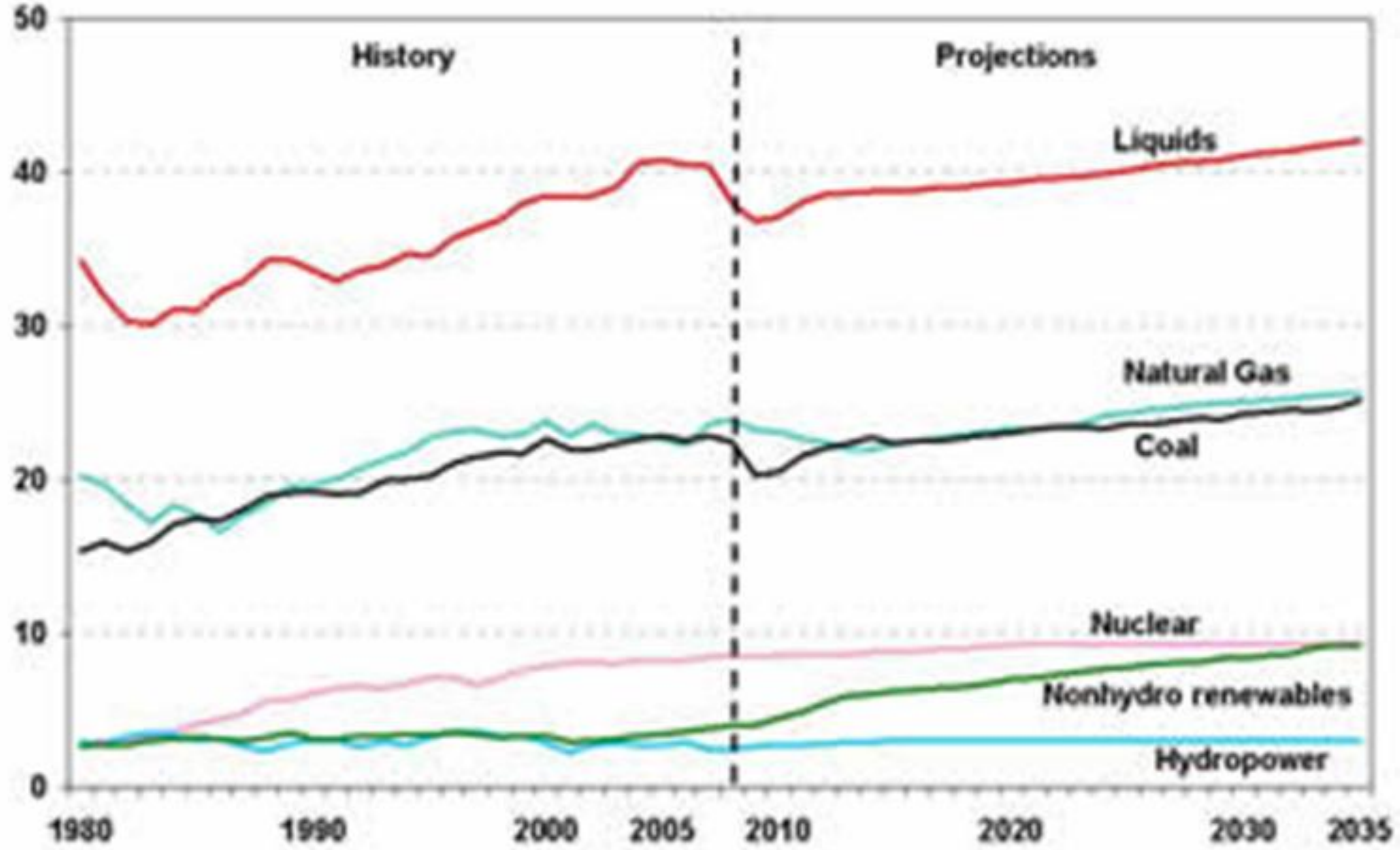
Petroleum:	2598,	64.0
Natural Gas:	1198,	53.0
Coal:	2115,	92.3

1 Quad = 293 billion kWh (actual)

1 Quad = 98 billion kWh (used, taking into account efficiency)

Source: EIA Energy Outlook 2011

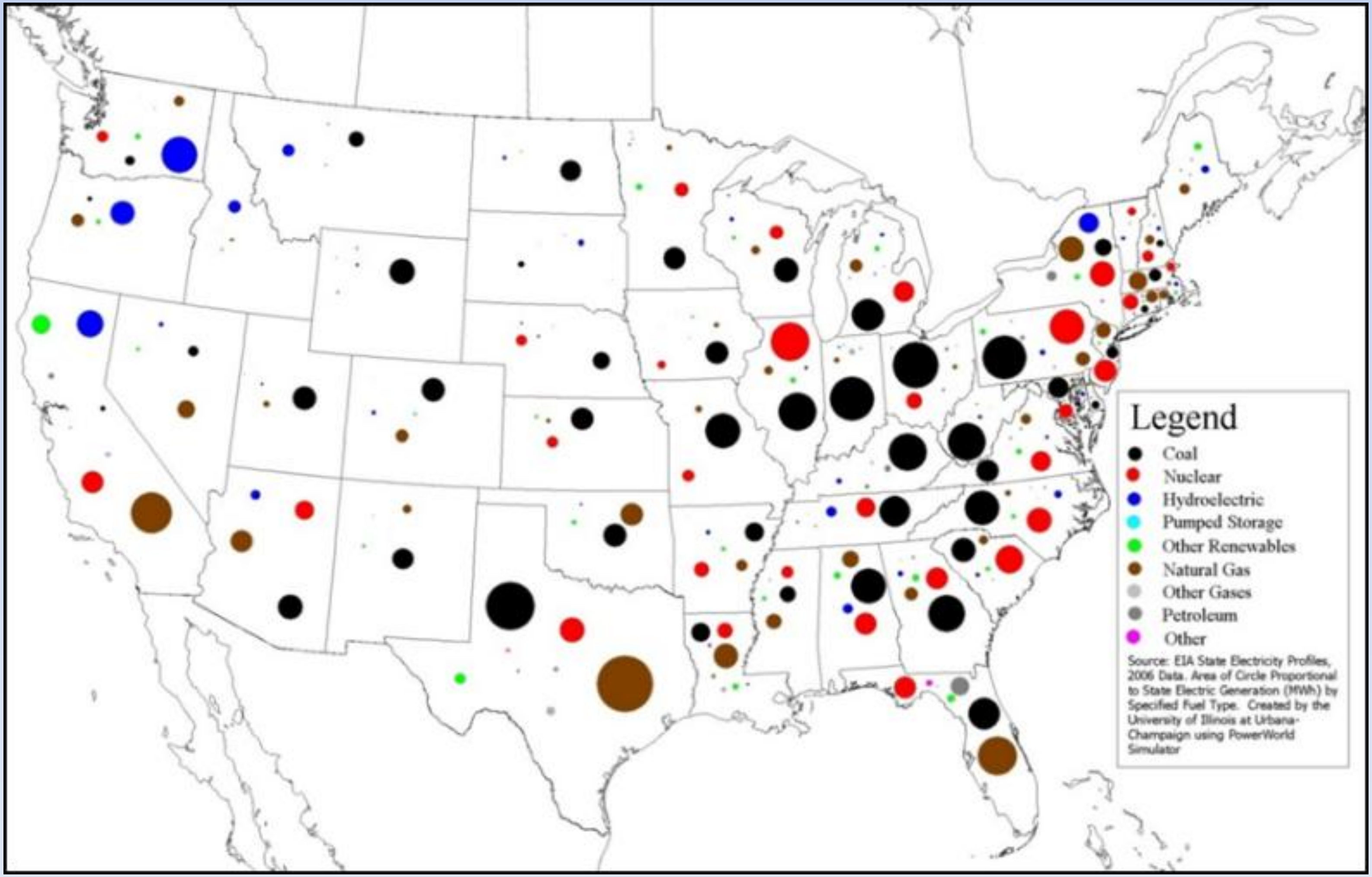
US Historical Energy Usage



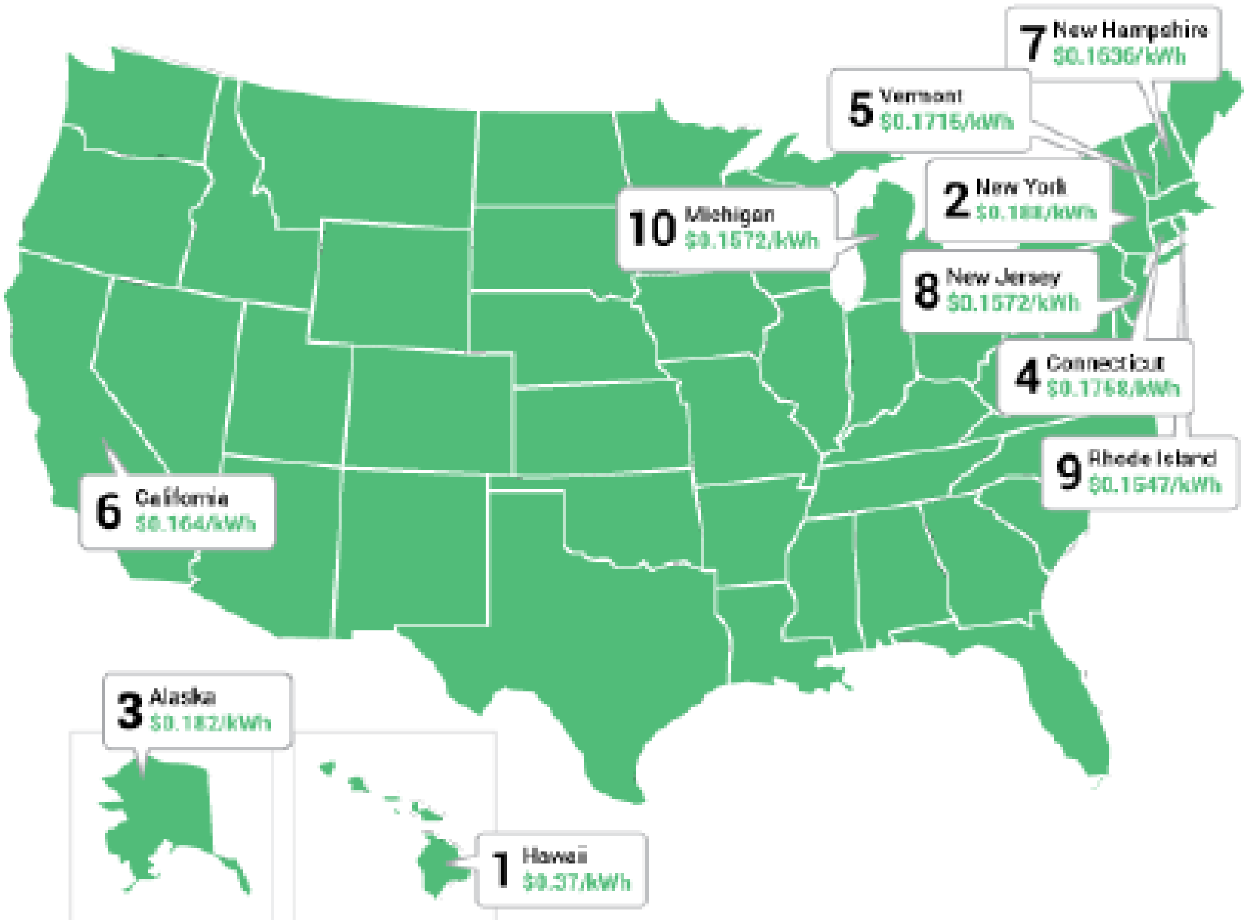
Data says we will be 81% Fossil in 2035!!

Source: EIA Annual Energy Outlook, 2010

Electric Energy Sources by State



Top 10 Most Expensive States For Electricity



Data source:
Energy Information Administration. "Electricity Data Browser."
http://www.eia.gov/electricity/data/browser.

Infographic © Industry Dive 2014

Control center

What are the highest line voltages?

- Hydro-Québec 735-kV lines in Canada
- AEP 765-kV lines in the U.S.
- 750kV and 1150kV lines (USSR-Russia) (the 1150 kV line now operates at 500 kV)
- EDELCA (Venezuela) 765-kV lines
- FURNAS (Brazil) 750-kV lines
- NYPA (U.S.A.) 765-kV lines (operates at 345 kV)
- Eskom 765-kV lines in South Africa
- POWERGRID (India) 765kV lines
- KEPCO 765-kV lines in South Korea
- TEPCO (Japan) 1000-kV lines
- 1000 kV lines in China
- 1200 kV line in India

Hydro Quebec 735 kV - Canada

Figure 15.4-3 Hydro-Québec/TransÉnergie tubular self supporting tower.

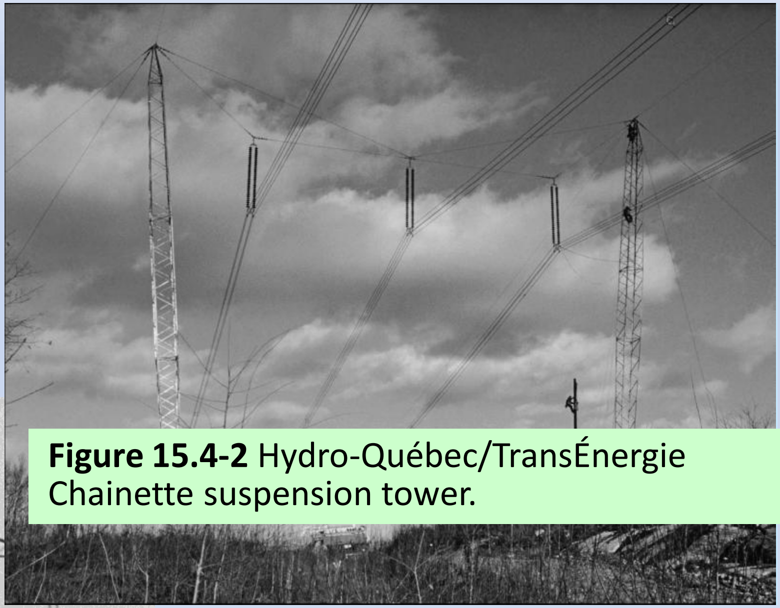


Figure 15.4-2 Hydro-Québec/TransÉnergie Chainette suspension tower.

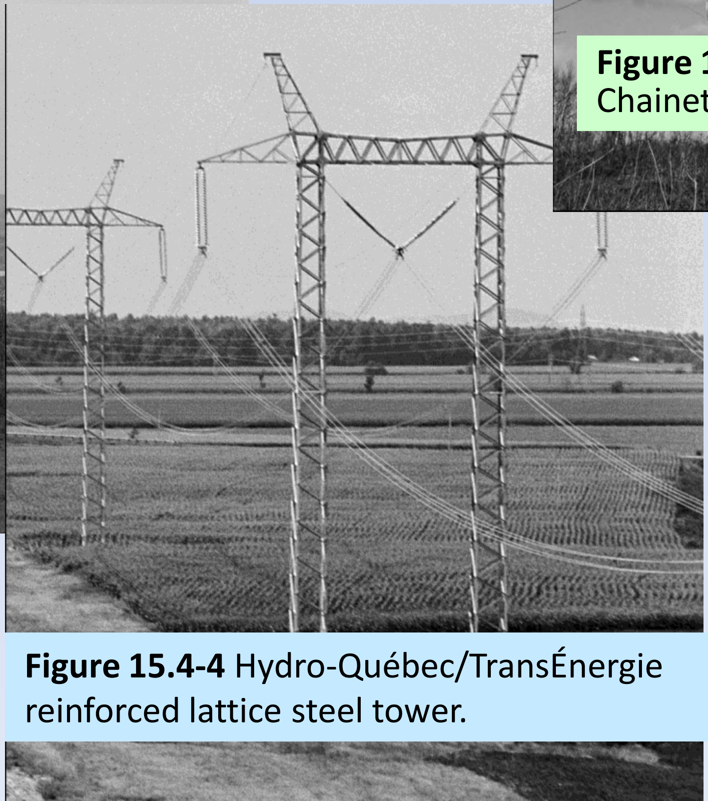


Figure 15.4-4 Hydro-Québec/TransÉnergie reinforced lattice steel tower.

AEP 765 kV

- Experienced many of the same socio-political forces as Hydro Quebec experienced in the deployment of Hydro Quebec's 735kV system
  - Energy needs not always in harmony with environmental goals
- Developed various tower designs

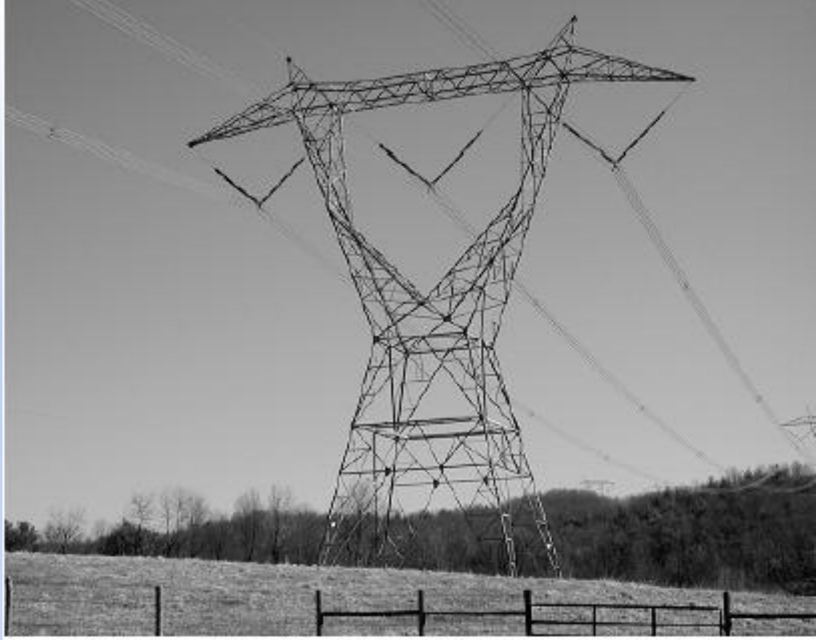


Figure 15.5-1 AEP 765-kV self-supporting suspension tower with four-conductor bundle.

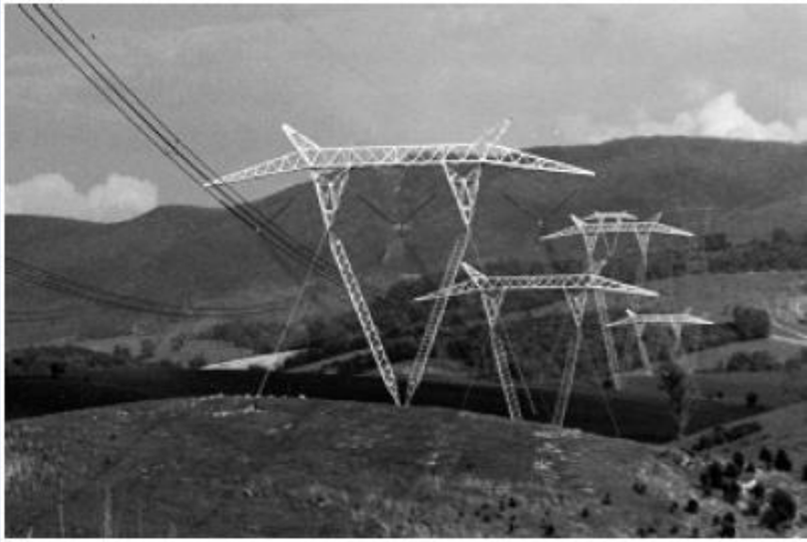


Figure 15.5-2 AEP 765-kV guyed-V suspension tower with four-conductor bundle.

USSR 700 kV and 1150 kV - Russia

- The USSR EHV system was developed to address the vast expanse of the original USSR system and generation located remotely from population centers
  - 4400 miles across the USSR grid
- Voltage selected by technica
  - Land cost minimal
  - Environment given limited attention (compared to the West)
- First 750 kV line
  - 1967, 55 miles long

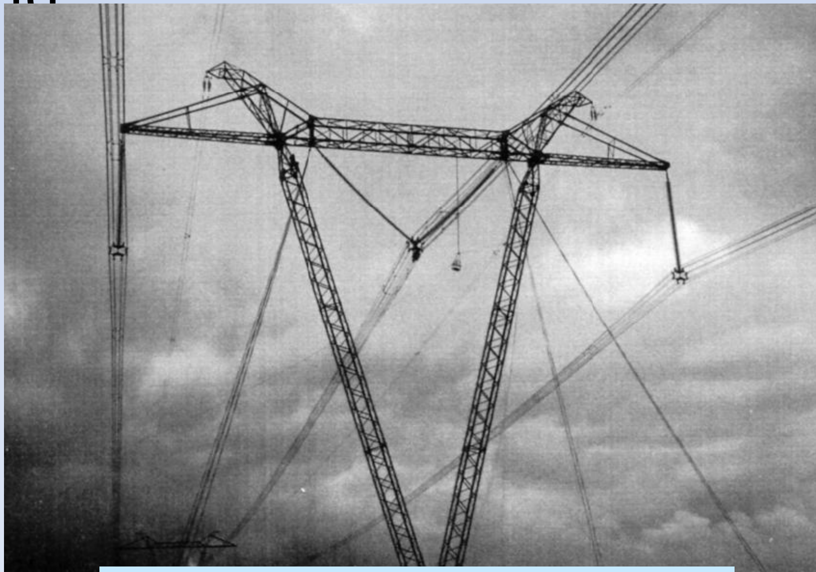
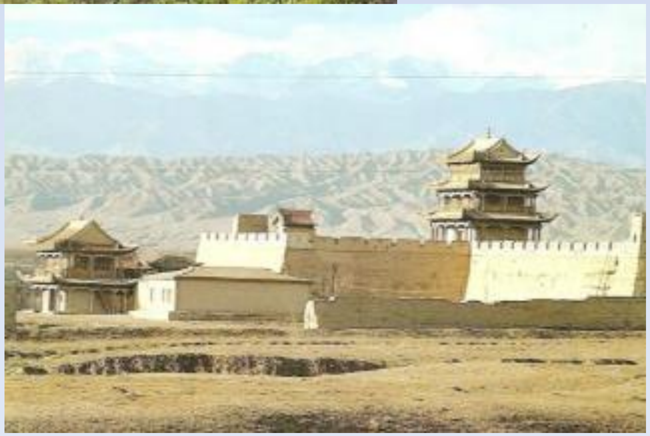
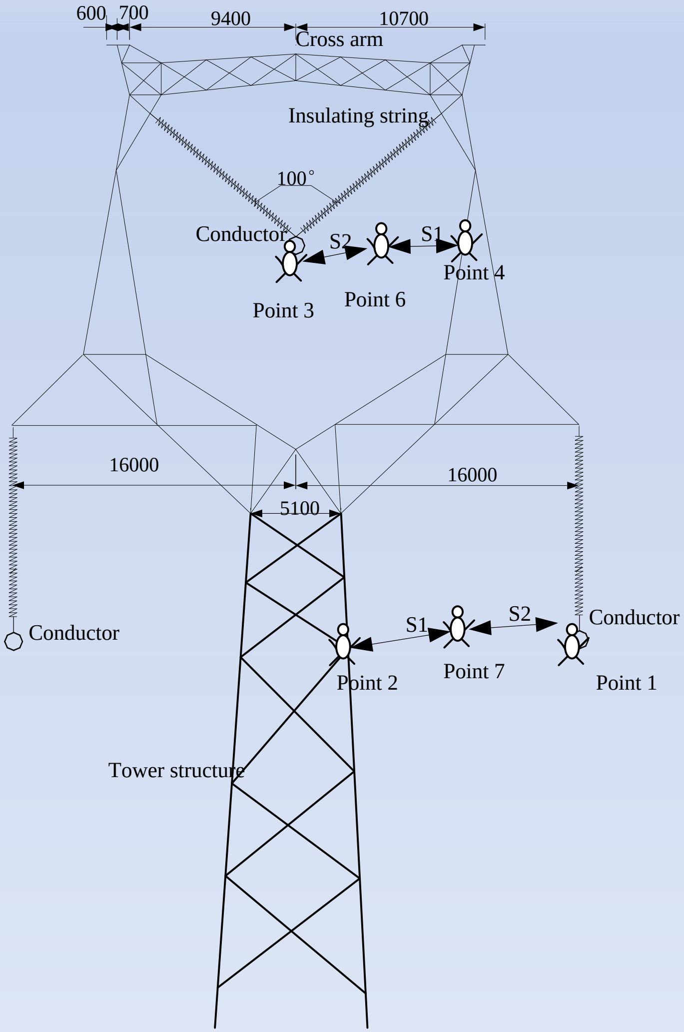


Figure 15.6-4 1150-kV tower.

1000 kV line, China, long, varied terrain

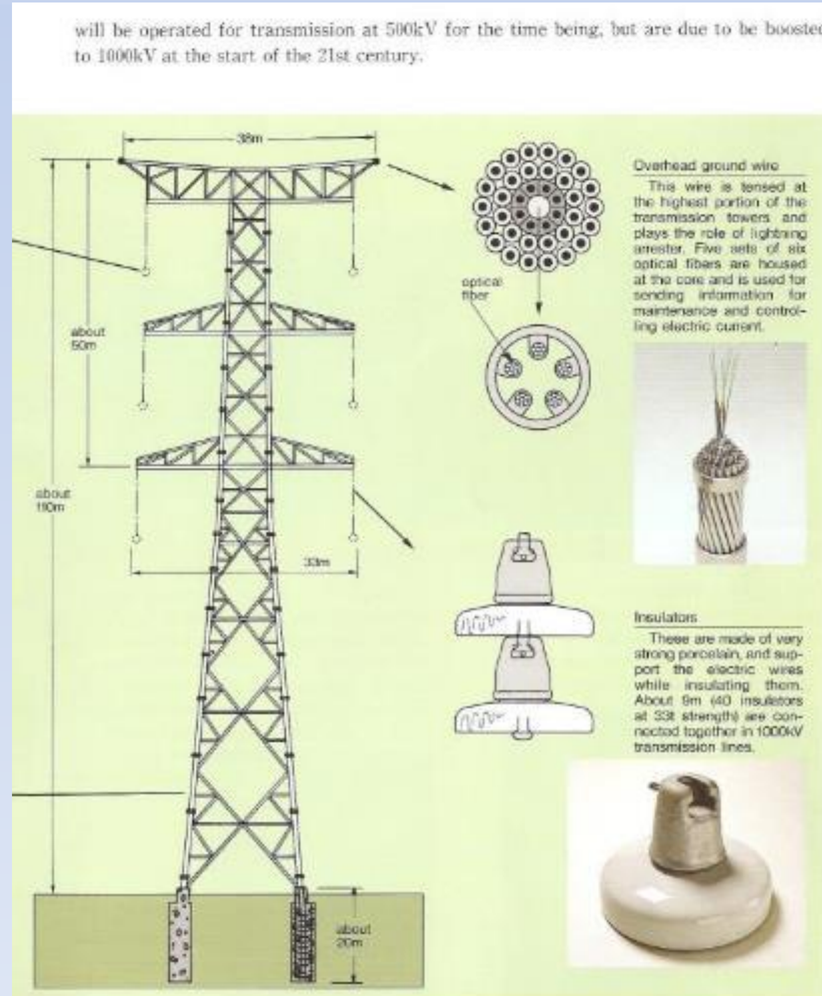
- Suspension and deadend towers





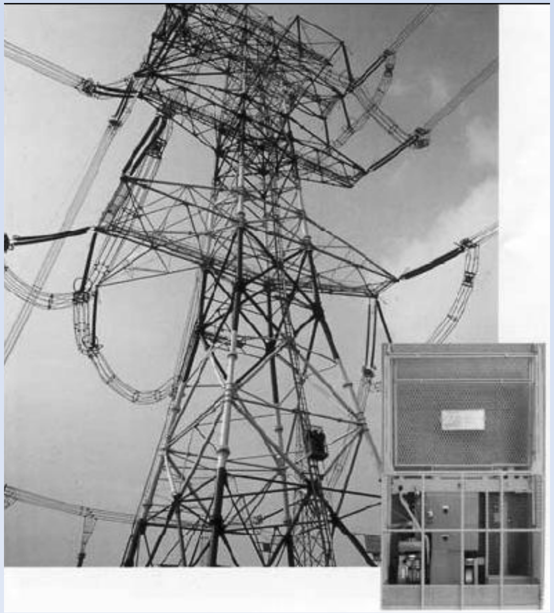
Tokyo Electric Power Company (TEPCO) 1000-kV Lines - Japan

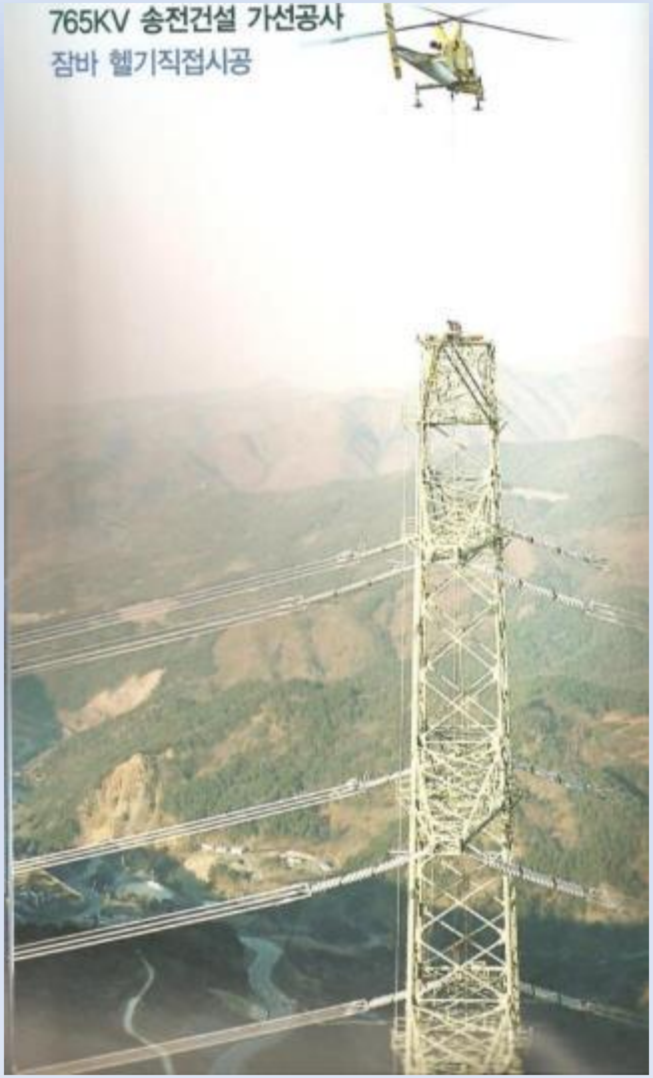
- Continuing growth exceeds the capacity of 500 kV system
- Difficult to obtain ROW
- Decided to construct 1000 kV lines
- One line was energized in 1992 at 500 kV, still operating at 500 kV
- Another line branch has been constructed
- Once the entire system is completed, it will be energized at 1000 kV



Korea Electric Power Corporation – South Korea

- Committed to expanding their grid with 765 kV in the early 1980's to support the country's economic growth
- First double circuit 765 kV line





Korea Electric Power Corporation – South Korea

- Tower main members are steel tubular pipes
  - Work staging platforms were installed at hillside tower locations to minimize environmental impact of construction
- Typical tangent tower is 300' tall
  - Each tower can accommodate a gas-powered car as an elevator

Figure 15.12-3 765-kV tower showing elevator and its rail.

1200 kV, India

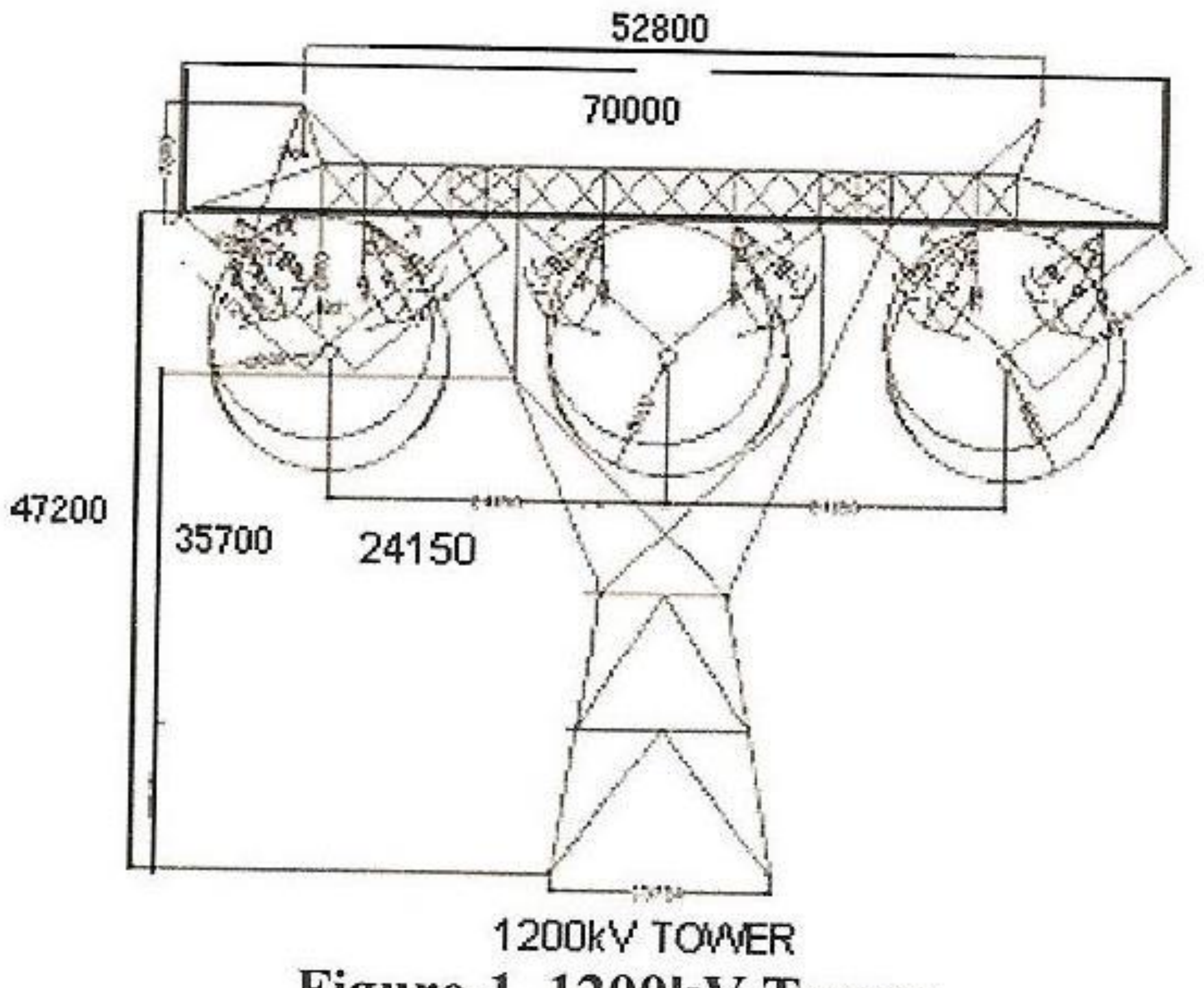


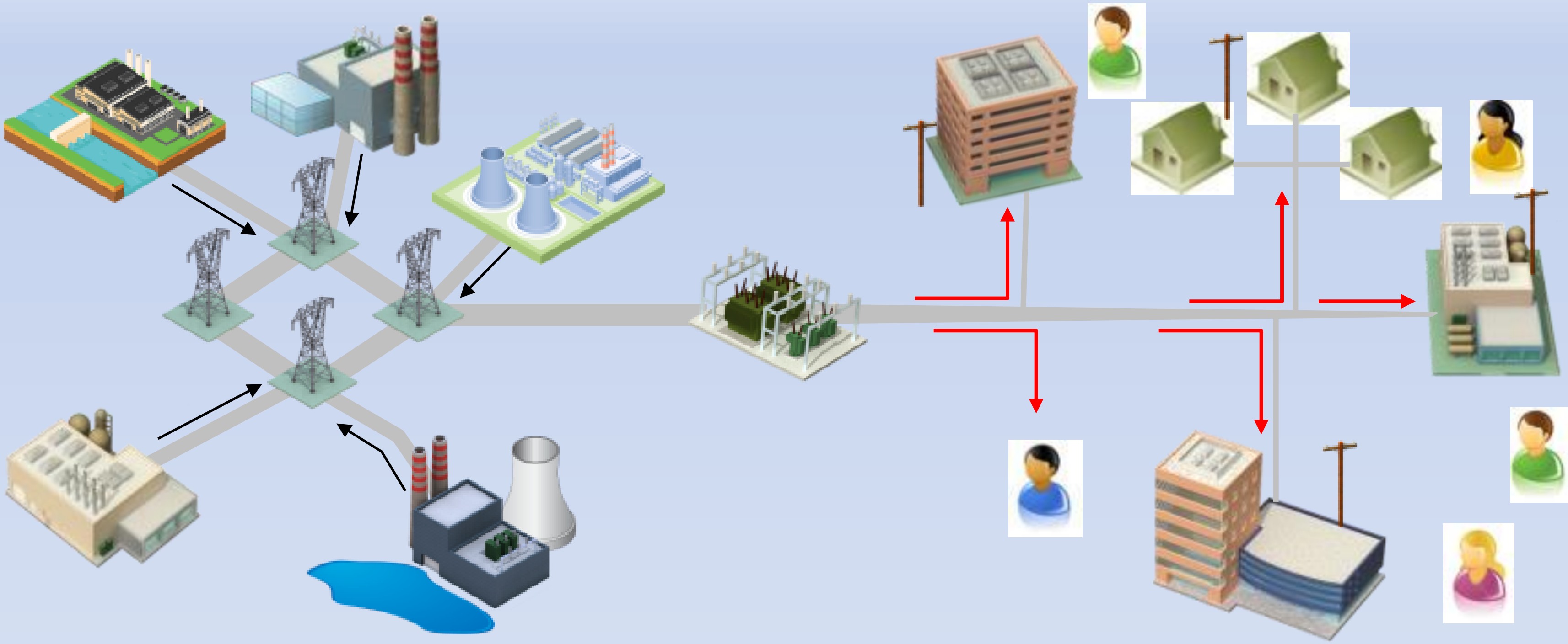
Figure-1, 1200kV Tower

Towers support conductors

- Some towers are small, some are very massive, some are very pretty
- Made of wood, steel, concrete

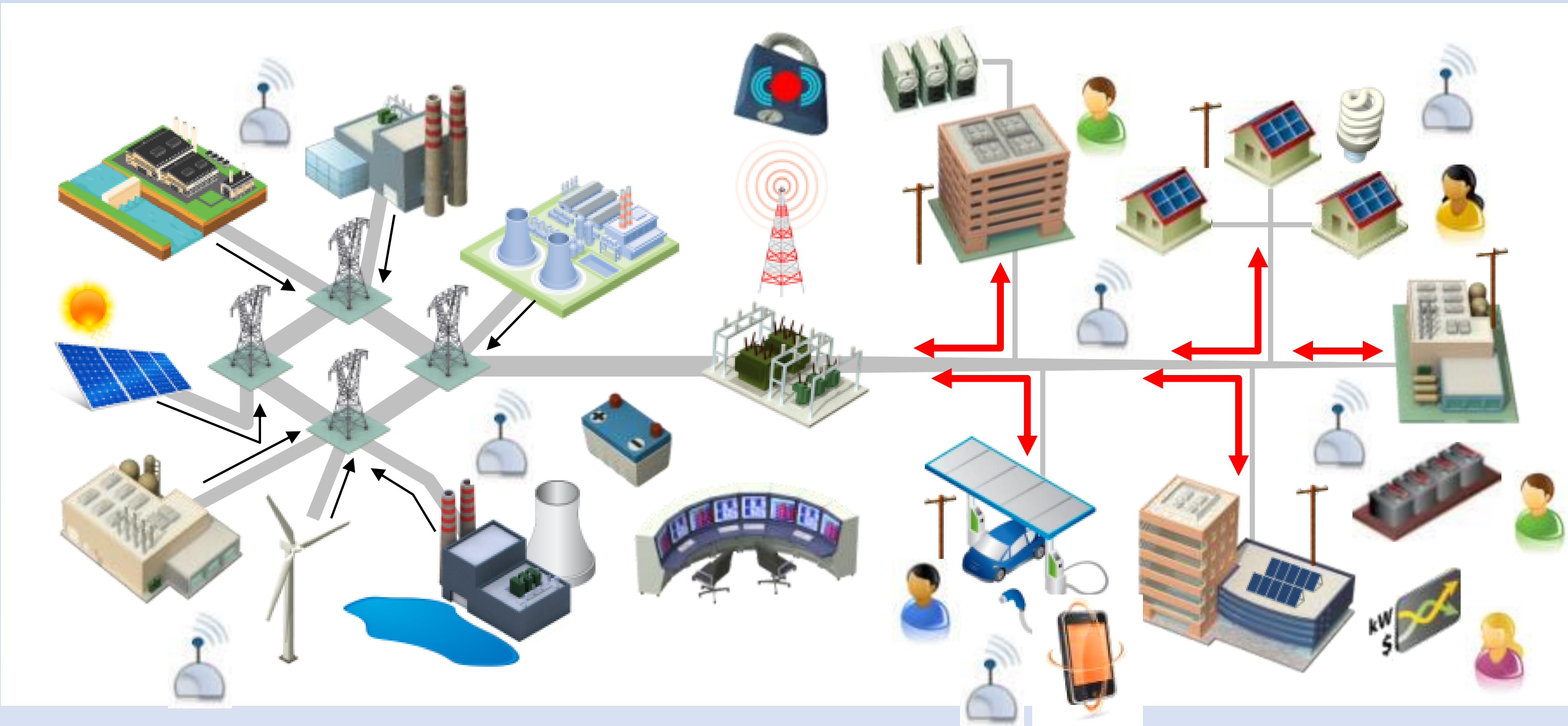
Electric Power Systems:
The Old, The Modern, The Future

Where are we today?
Historical challenge: Balance generation with load



Base Load Generation + **Load Following Generation** +/– **Bulk Energy Storage** = **Customer Demand** – **Interruptible Load DR**

Where are we today?
Future challenge: Flexibility, Resiliency, Connectivity



Power System that is Highly Flexible, Resilient and Connected and Optimizes Energy Resources

Ecological awareness

- “Ecological awareness is the one characteristic that will make the new generation of engineers – and particularly energy engineers – different from their predecessors. Too often in the past engineering projects were justified solely on economic criteria without regard for their impact upon the environment.
  As the professed custodians for this nation’s resources the engineer must take major responsibility for their optimum and balanced use.”
- Olle I. Elgerd, “Electric Energy Systems Theory: An Introduction”, McGraw-Hill, 1971

Your task

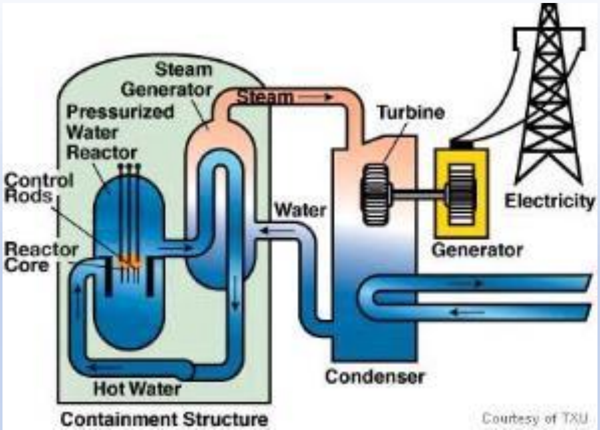
- "Your task is nothing less than the creation of a whole new civilized industrial technology to replace the brute machine that raised so much ecological hell."

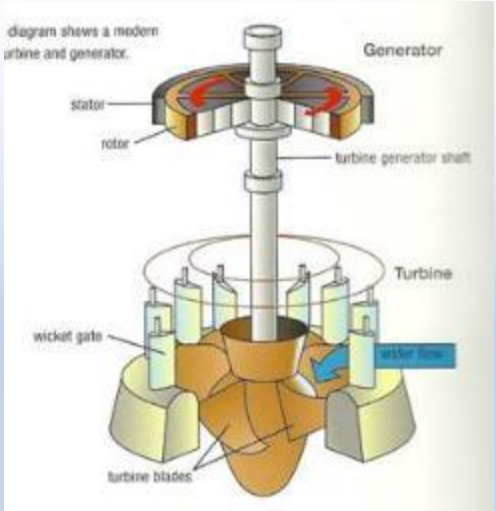
- Walter J. Hickel, Secretary of Interior, in a speech to the graduating class of Stevens Institute of Technology, May 1970.

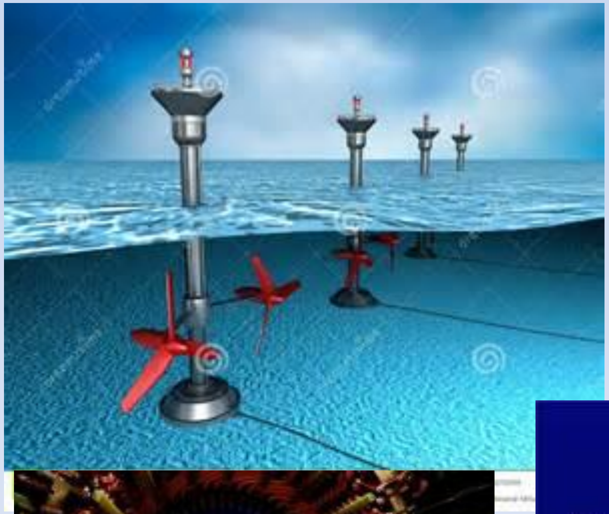
Electric generators

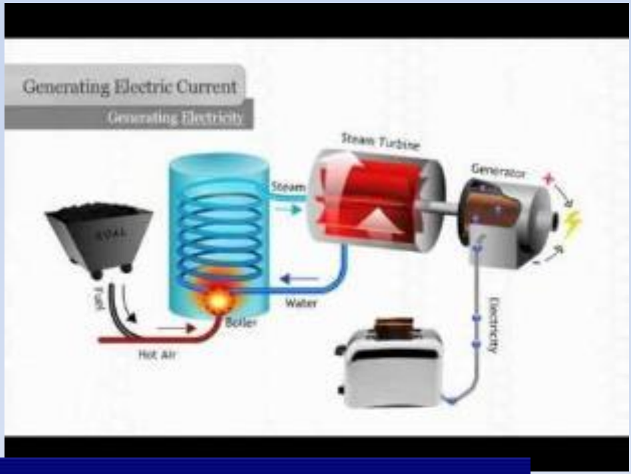
- Converts energy from PRIME-MOVER to electric power
- Prime–Mover (source of mechanical power):
  - Hydro turbine (example: Niagara Falls)
  - Steam turbine (coal-fired, gas fired, diesel, nuclear)
  - Wind turbine
  - Wave energy
- Other sources: solar, batteries (chemical): DC energy converted to AC (inverter)

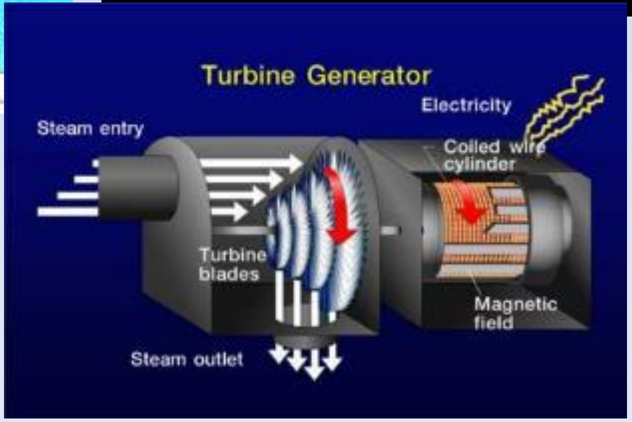
Prime-movers











Example 1

- In 1982, the US consumption of fuels, in quad, was as follows (see table): Calculate the total energy produced during one year in GWhr, assuming average overall power plant efficiency of 10% (efficiency = energy out/energy in)

Fuel type	Amount (quad)
Coal	16.1
Oil	32.1
Gas	20.2
hydro	2.9
nuclear	2.9

1 quad = 293297222222.22 kWh

1 kWh = $3.4095106405145 \cdot 10^{-12}$ quad

- *Solution:*
  - Total amount of fuel consumed = 74.2 quad or 21.75 PWh = $21.75 \cdot 10^{15}$ Whr
  - At 10% efficiency, energy produced is 2.175 PWh

What is Green Engineering?

At WNE

Green Engineering Concentration

- As the growth of the world's populations and economies puts an ever increasing strain on the social and physical environment, today's engineers are faced with developing solutions that use renewable energy sources, reduce waste energy, minimize the impact on the environment, reduce poverty in the world, and provide prosperity for all.
- In the junior year, a student may choose to remain in the general mechanical engineering course of study or specialize with a concentration in Green Engineering.

DC in an AC World

an EMerge Alliance Perspective

Paul Savage, Chairman – EMerge Alliance

CEO, Nextek Power Systems

IEEE PES
Super Session
July 29, 2015

70 Terawatt Hours of Losses in Homes in the US alone!

DC@Home

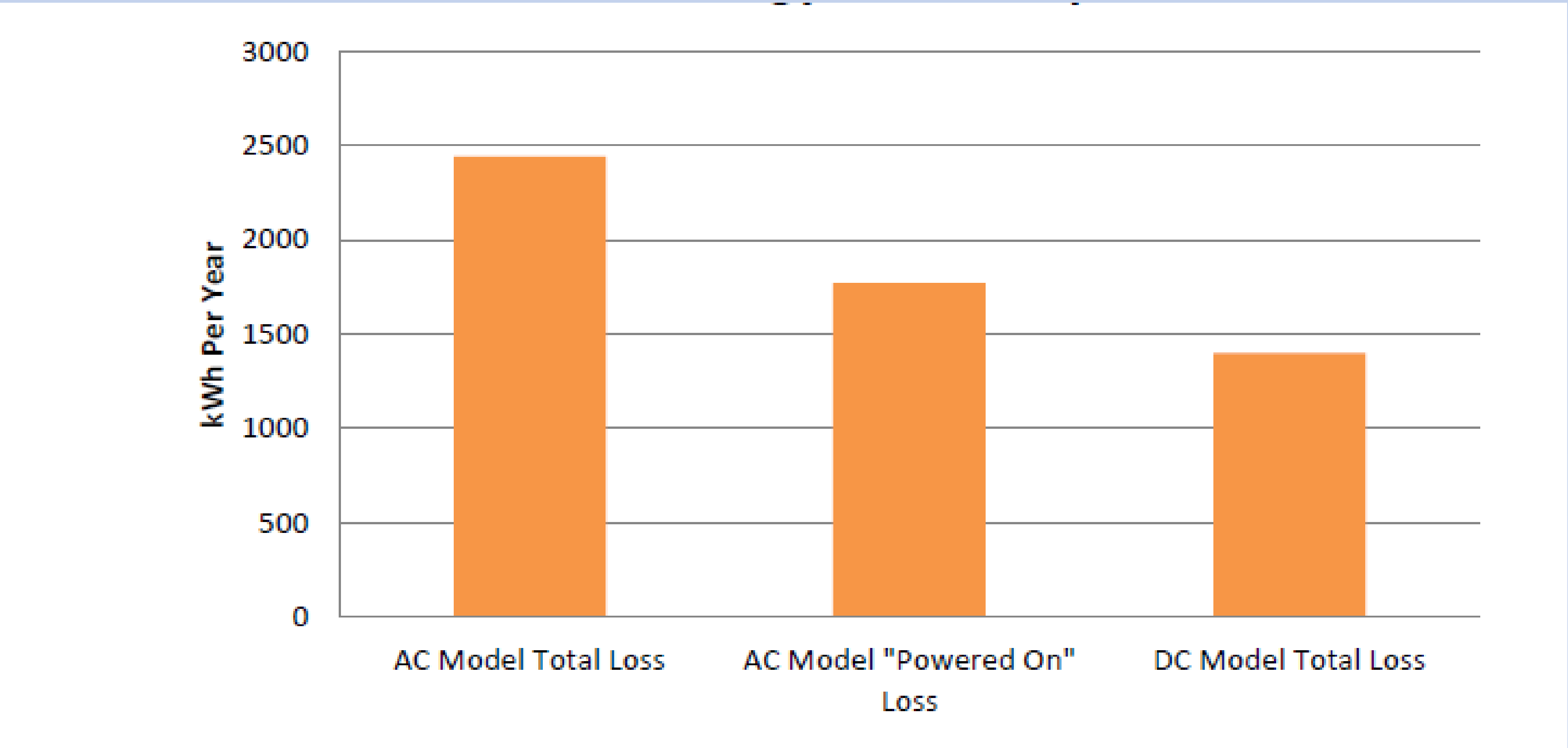
Issues with Mixing DC and AC

- Different physics
- Different switching and routing characteristics
- No zero crossing in DC for equipment to use to soft start and stop on

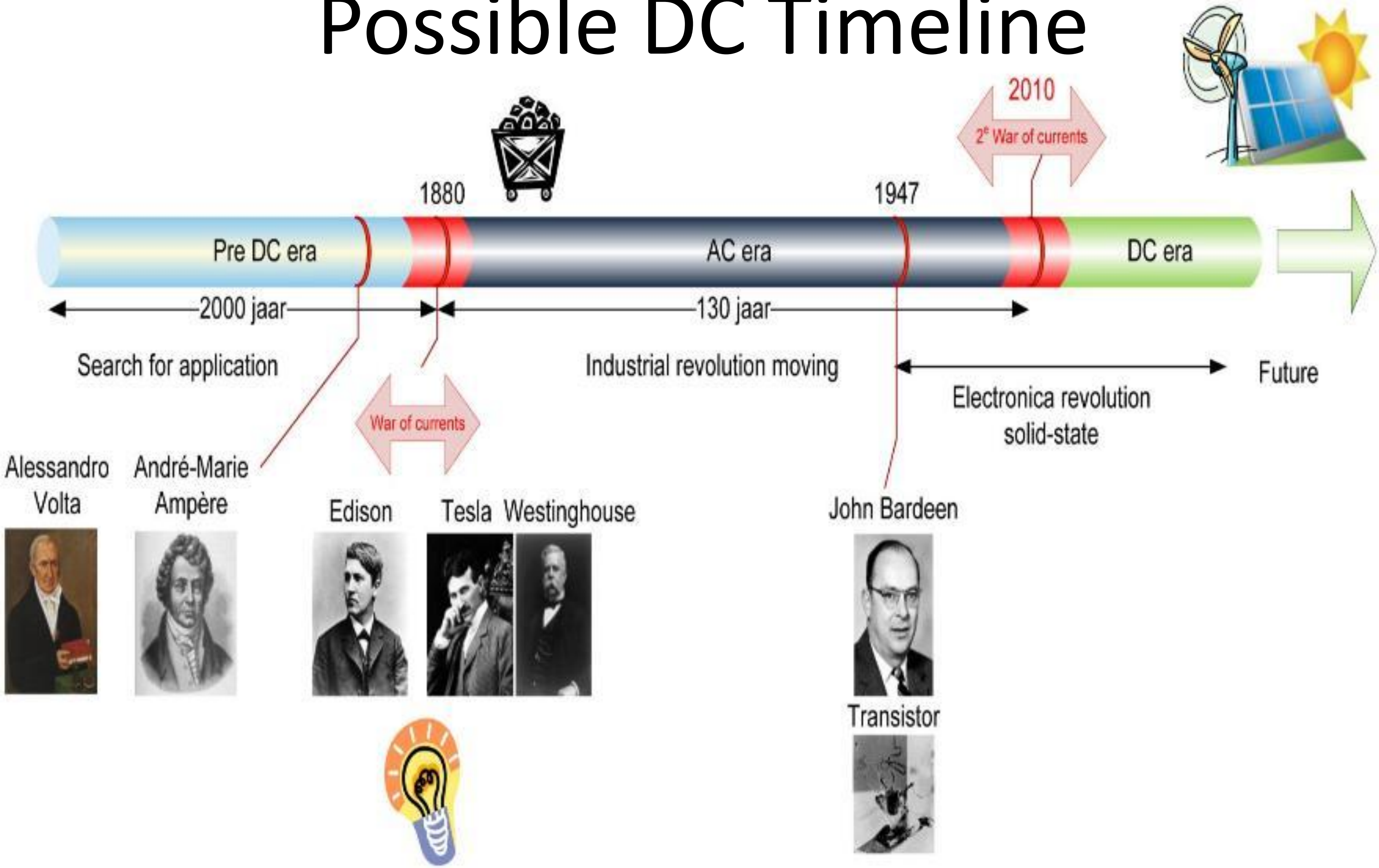
4 Choices

- Mix AC and DC on the same system
- Create new DC wiring for new homes only
- Create new DC wiring for renovations as well as new homes
- Move to DC only in the home

AC vs DC Energy Loss Comparison (43 % Less Loss)



Possible DC Timeline



Timeline thanks to Harry Stokman – Direct Current

Creating the Enernet

Direct Current: Reinventing Building Power

Vision → Standards → Eco-system → Transformation

THE ENERNET: Doing for power what the Internet did for information networking

TRANSFORMING THE 21ST CENTURY ENERGY ECONOMY

Zero Net Energy Buildings
Automated Demand Response
Smart Buildings - Buildings as Robots
Powering The Internet of Things

Resilient Non-synchronous Micro Grids
The Transactional Energy Network
Energy to the Developing World
Power to the People

"Electrons are the currency of the future World economy – not the barrel of oil."

Why DC current?

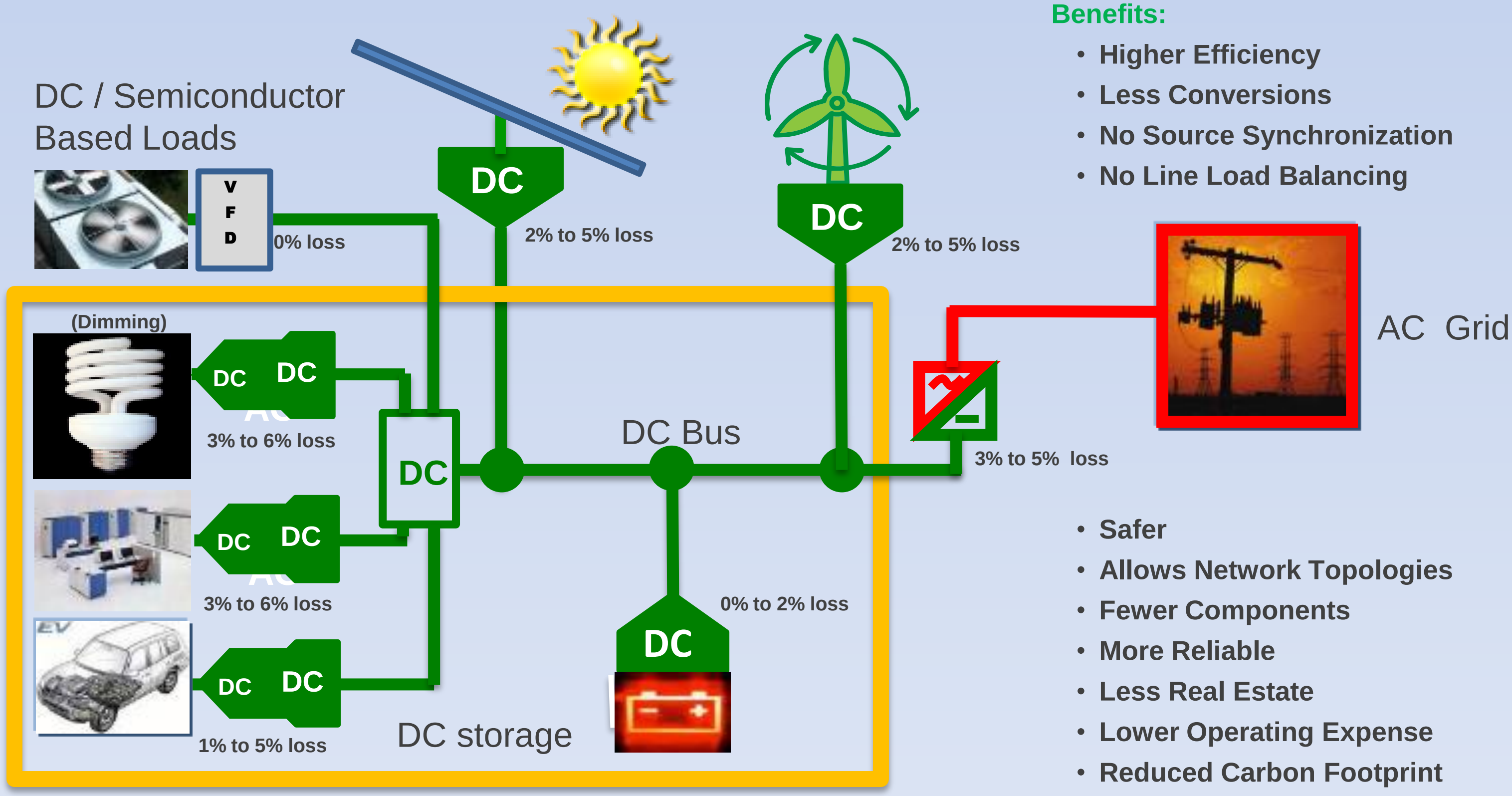
- Increased flexibility, modularity, resiliency
- Improved safety
- Better utilization of cables and wires
- Increased efficiency
- Reduced need of materials, lower costs

The EnerNet

Vision

About Hybrid AC/DC Microgrids

The Ideal End State…



Benefits:

- Higher Efficiency
- Less Conversions
- No Source Synchronization
- No Line Load Balancing

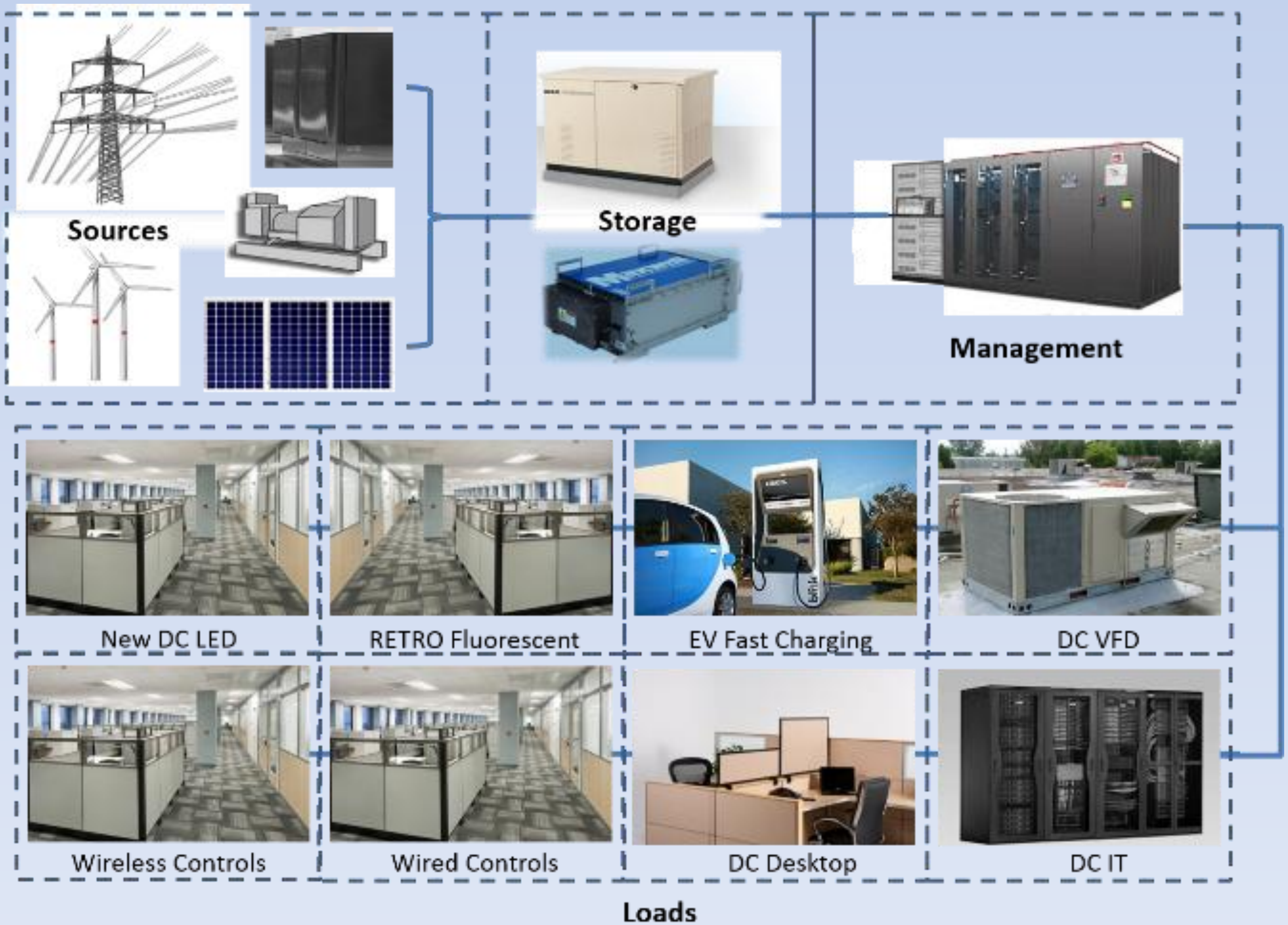
- Safer
- Allows Network Topologies
- Fewer Components
- More Reliable
- Less Real Estate
- Lower Operating Expense
- Reduced Carbon Footprint

Where are we now?

Eco-system

About the Deployment Process

Existing & New Building Stock Equally Considered

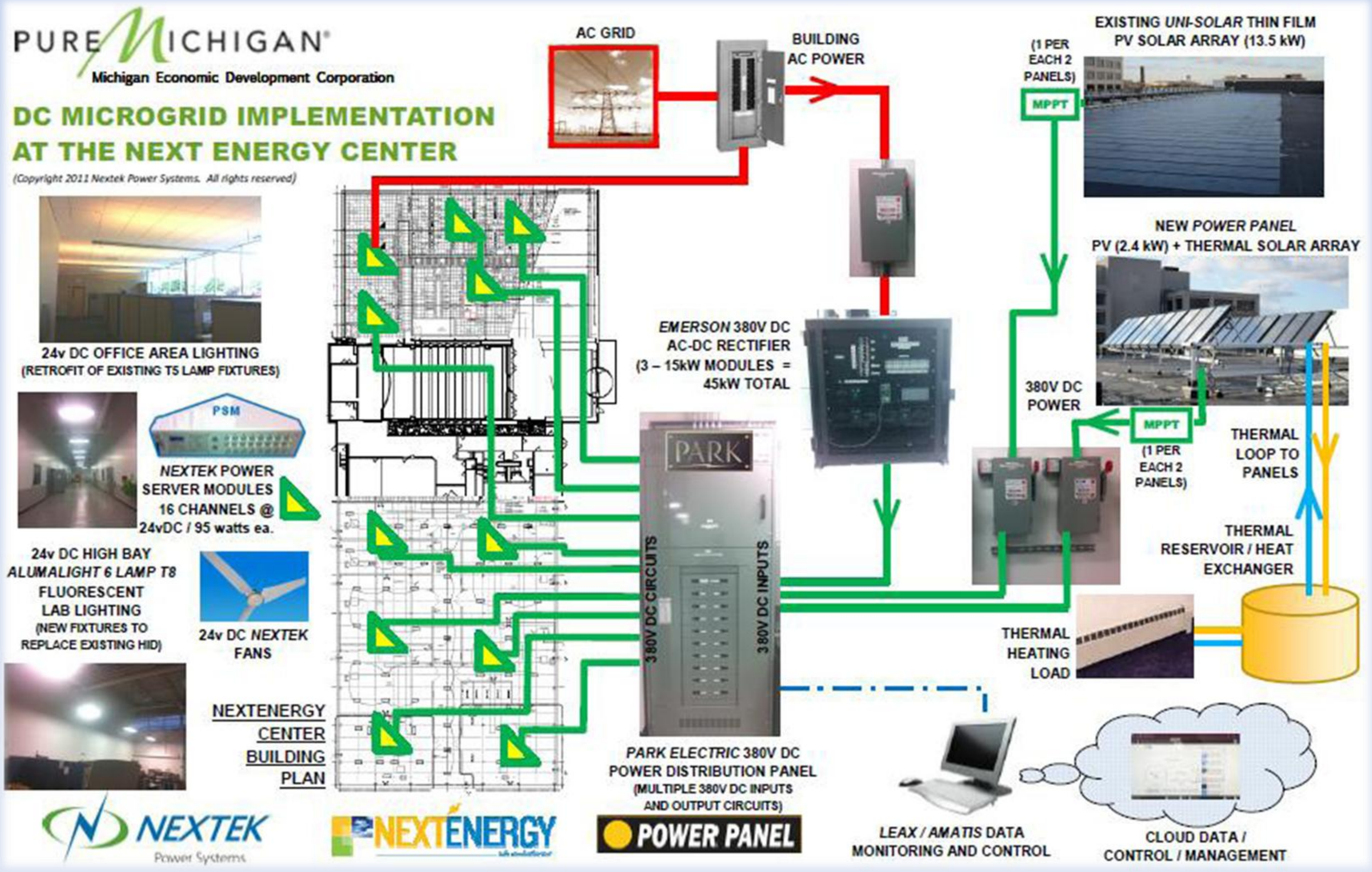


Hybrid AC/DC Buildings

Transformation

Building Campus DC Microgrids

Full Scale Applications Under Development



75+ Demonstration, Test, Beta Sites

The Applications are not Restricted

DC Powered Interior Spaces:

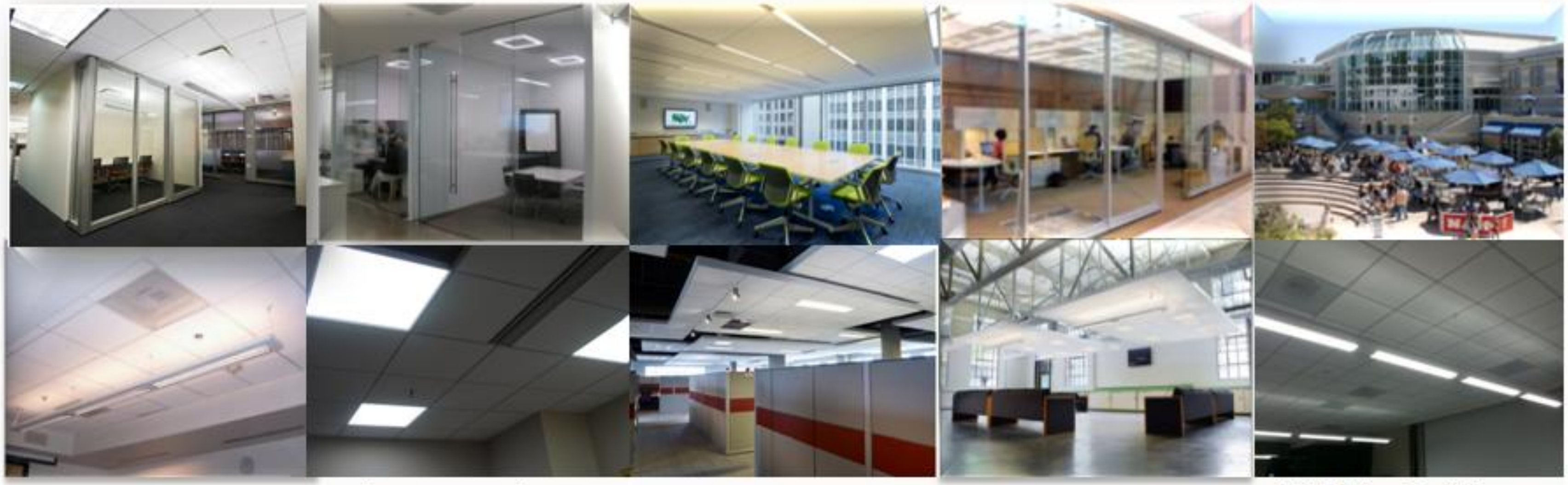
PNC Financial Services
Headquarters Office
Pittsburgh, PA

Lauckgroup
Architectural Office
Dallas, TX

US Green Bldg Council
Conference Rooms
Washington, DC

Nextek Power
NextEnergy Center
Detroit, MI

UC San Diego
Sustainability Center
San Diego, CA



Southern Cal Edison
Utility Services Office
Irwindale, CA

Johnson Controls
Headquarters Office
Milwaukee, WI

Optima Engineering
MEP Firm
Charlotte, NC

LA Community College
Trade Tech Campus
Los Angeles, CA

CA Lighting Tech Center
UC Davis Campus
Davis, CA

IEEE Smart Village

- “Empowering local entrepreneurs to transform lives in remote off-grid communities through renewable energy and technology”
- As of @ 2015, successful pilot projects serving more than 50,000 people in 34 villages in ten countries around the world.
- Portable solar panels

Appendix

Why Direct Current?

1. DC increases the flexibility, modularity and resiliency

- Allows meshed microgrid structures by eliminating frequency and phase angle of different connections.
- Power and voltage can be fully articulated in solid state power electronics.
- In pure dc networks the connection of any node is in general possible.
- Interconnected sub-microgrids are actively and freely controllable and in general can act independently of one another.
- Allows incremental addition of multiple distributed energy supplies connected in multiple positions throughout the topology.
- Can operate in connected or islanded modes, therefor can be operated remotely.
- Allows transactional management of source, storage and load assets in autonomous, semi-autonomous and hierarchical communication structures.

Why Direct Current?

2. Improved Safety

- Alternating current (AC) and Direct current (DC) have slightly different effects on the human body, but both are dangerous above a certain voltage and current. The effect depends upon the amount of current, duration of flow, pathway of current, voltage applied and impedance of the human body.
- AC is generally rated as more dangerous because to produce the same effect, the amount of DC flow must be two to four times greater than AC. The effect of current includes the induction of cardiac fibrillation which is the main cause of death by electric shock.
- The total impedance of the human body is highest for DC and decreases as AC frequency increases. And AC voltages are generally stated as an RMS value, thus the peak voltage of AC is 1.3 times as follows:

Vac	120	208	220	240	277	480	13,800
V_{peak}	156	294	311	339	392	679	19,519

Why Direct Current?

2. Improved Safety

- It's comparatively easier to let go of the gripped 'live' parts with DC than AC. This is in contrary to the popular belief the "AC allows time to pull away from the 'live' part because of the alternating cycles which pass through zero while DC current has continuous flow. This is simply not true as the frequency is too rapid to allow any useful relaxation of the muscles, a condition called tetanus. As revealed in IEC publication 60479 – "Effects of current on human beings and livestock, the let-go of parts gripped is less difficult in the case of DC." This is based on actual experimental evidence, not hearsay.
- But while contact with conductors is less dangerous with DC than AC, contact with high-voltage electrical conductors should be avoided regardless of the type of electrical current. So as such, so-called "touch-safe" extra-low voltage and controlled current dc is increasingly preferred when casual or incidental touch by humans is probable.

Why Direct Current?

3. Better utilization of cables and wires

- The deeper use of dc technology allows a higher utilization and redundancy in the cables and wires. In today's open ring buses the power may have to flow through the opposite arm of the ring any time after the occurrence of a fault. Therefore the utilization of cables is not very high.
- With increased dc meshing individual cables can be better utilized because different routes are possible for the power flow. As a result, the infrastructure of the distribution network system can be cheaper because a lower cable reserve requirement is necessary.
- As currents increase, more power per wire cross-section is possible with dc due to the lack of skin-effect. DC makes better use of the wire's core.
- Due to the lack oscillating magnet fields, dc wires can be more closely positioned without phase interference.

Why Direct Current?

4. Increased efficiency

- Power electronic converters for pure dc systems are highly efficient because they are soft switching and a higher operating frequency is possible compared to standard ac systems (50/60 Hz).
- Due to the increased frequency, particularly the losses in the transformer of the dc-dc converter are reduced.
- Reactance loss with AC power is not insignificant, so the losses in the lines and converters can be significantly reduced by the elimination of reactive power in the system.

5. Reduced need of materials, lower costs

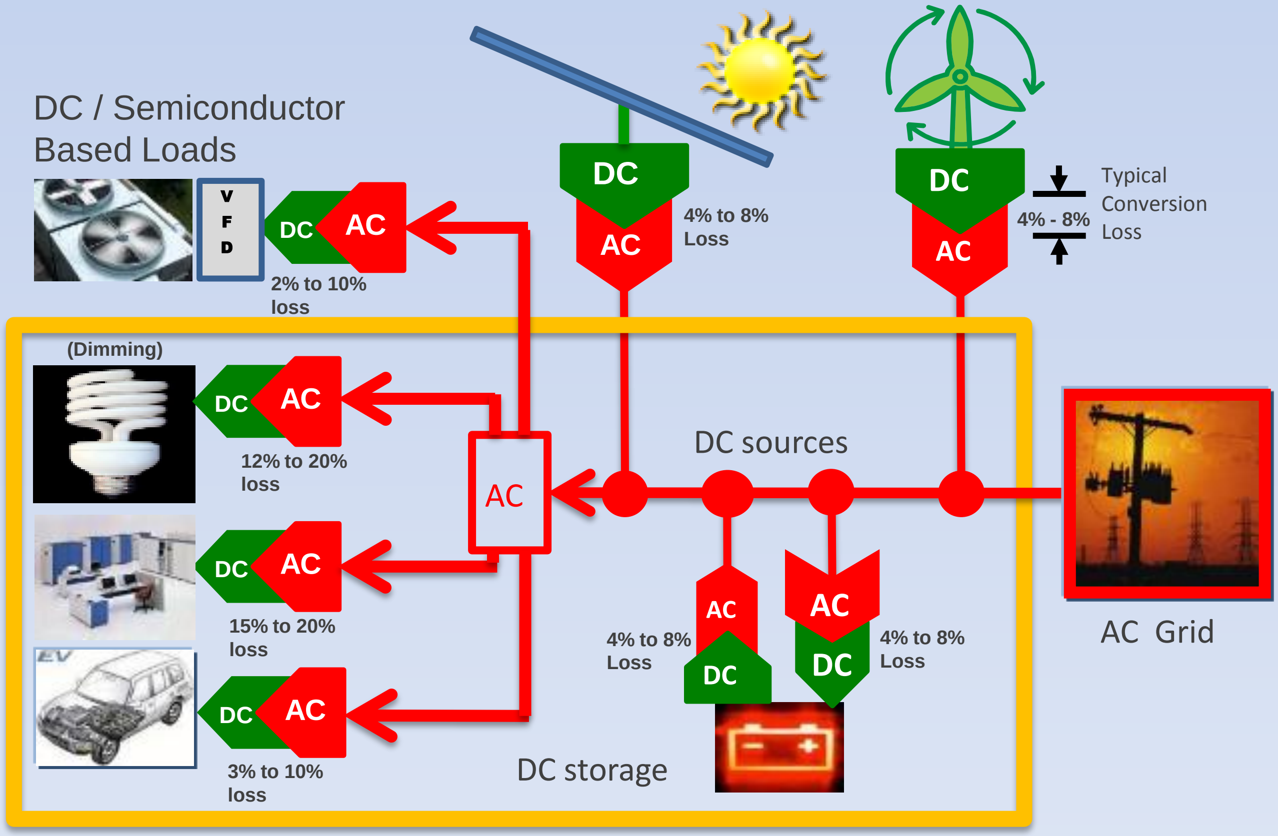
- Due to the increased operating frequency, smaller passive components in the dc-dc converters are possible which leads to a reduction in the usage of materials (especially copper and steel) and therefore to a cost reduction.

The EnerNet

Vision

About Hybrid AC/DC Microgrids

The Status Quo...

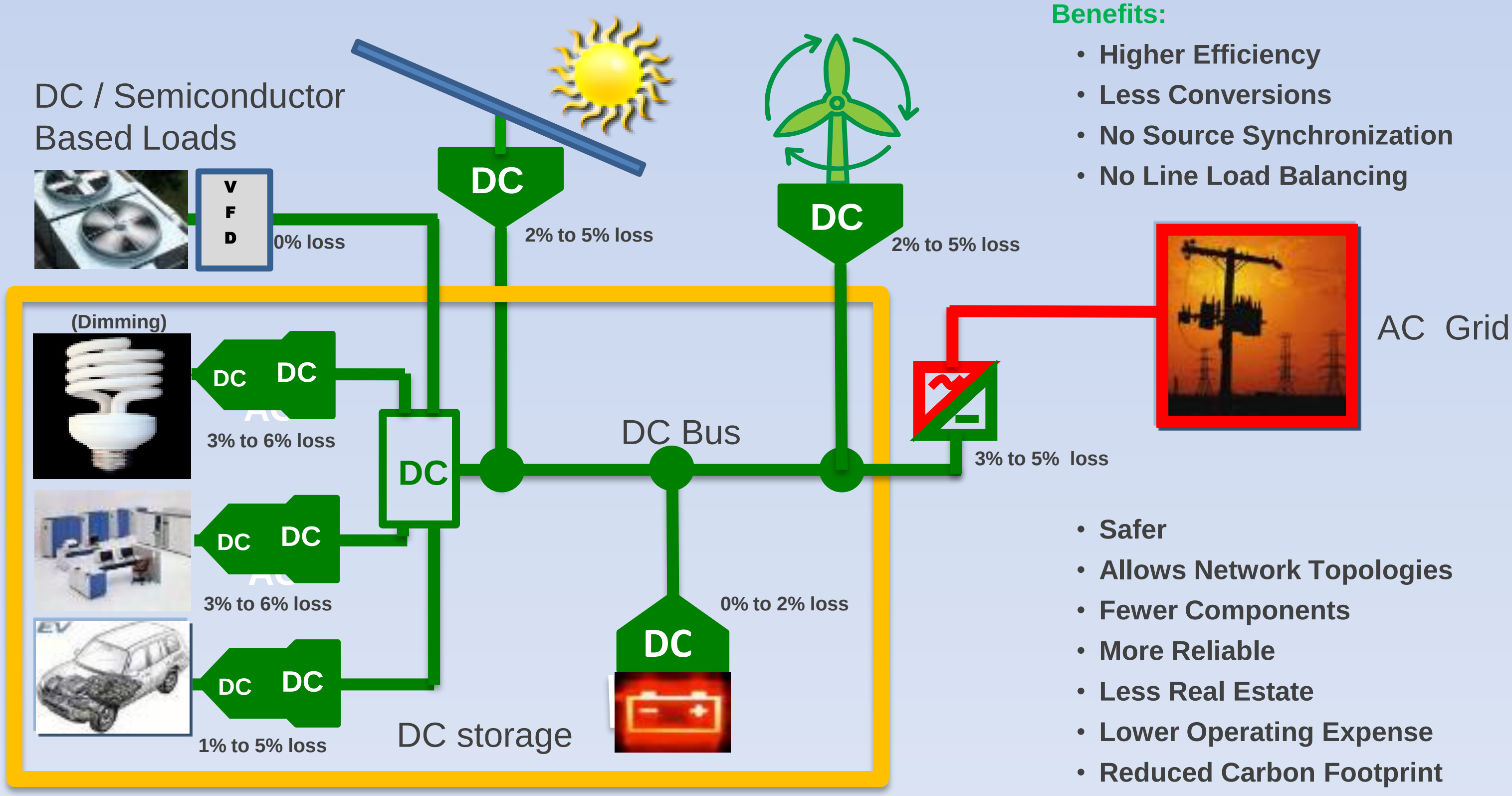


The EnerNet

Vision

About Hybrid AC/DC Microgrids

The Ideal End State...



Benefits:

- Higher Efficiency
- Less Conversions
- No Source Synchronization
- No Line Load Balancing

- Safer
- Allows Network Topologies
- Fewer Components
- More Reliable
- Less Real Estate
- Lower Operating Expense
- Reduced Carbon Footprint

DC in an AC World

an EMerge Alliance Perspective

Paul Savage, Chairman – EMerge Alliance

CEO, Nextek Power Systems

IEEE PES
Super Session
July 29, 2015

70 Terawatt Hours of Losses in Homes in the US alone!

DC@Home

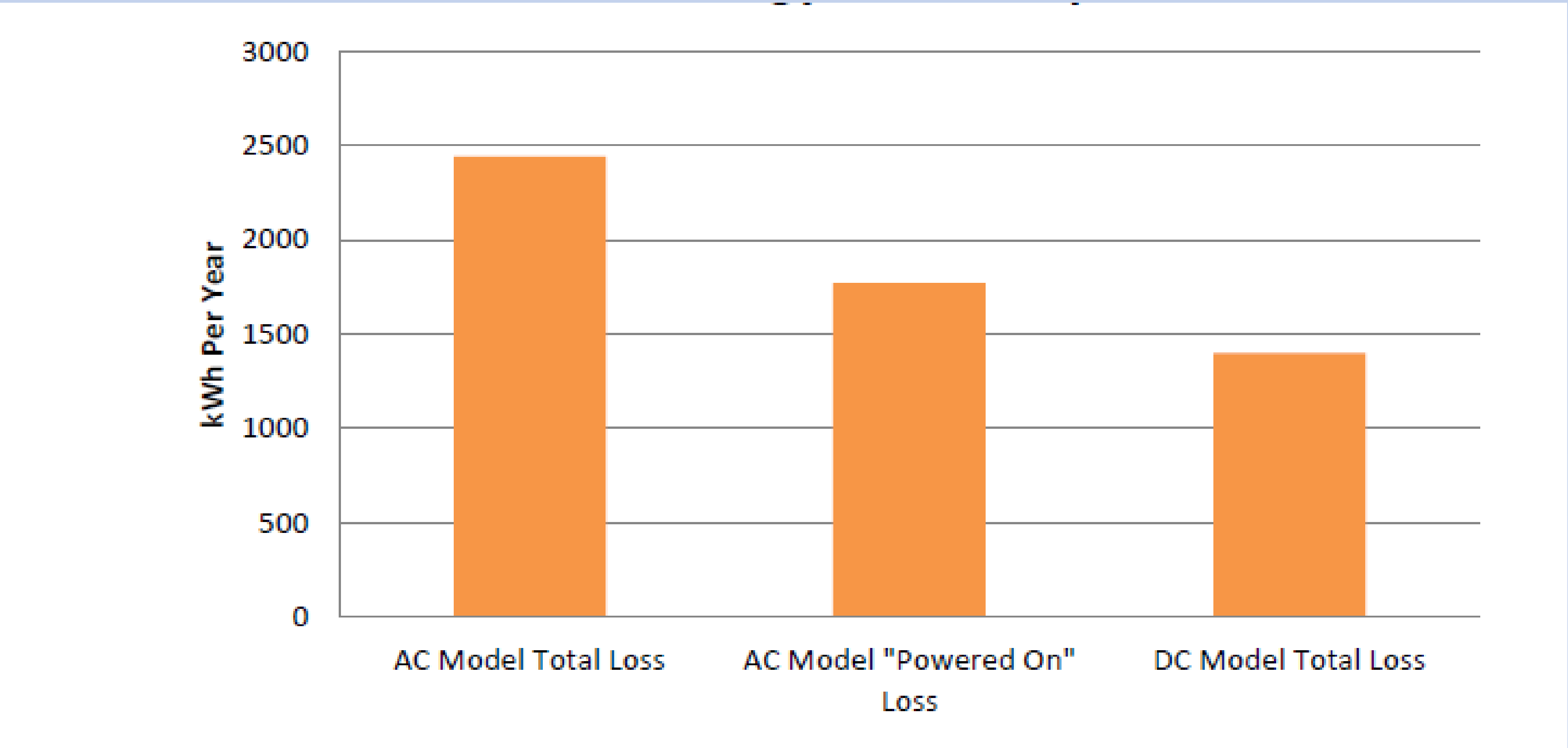
Issues with Mixing DC and AC

- Different physics
- Different switching and routing characteristics
- No zero crossing in DC for equipment to use to soft start and stop on

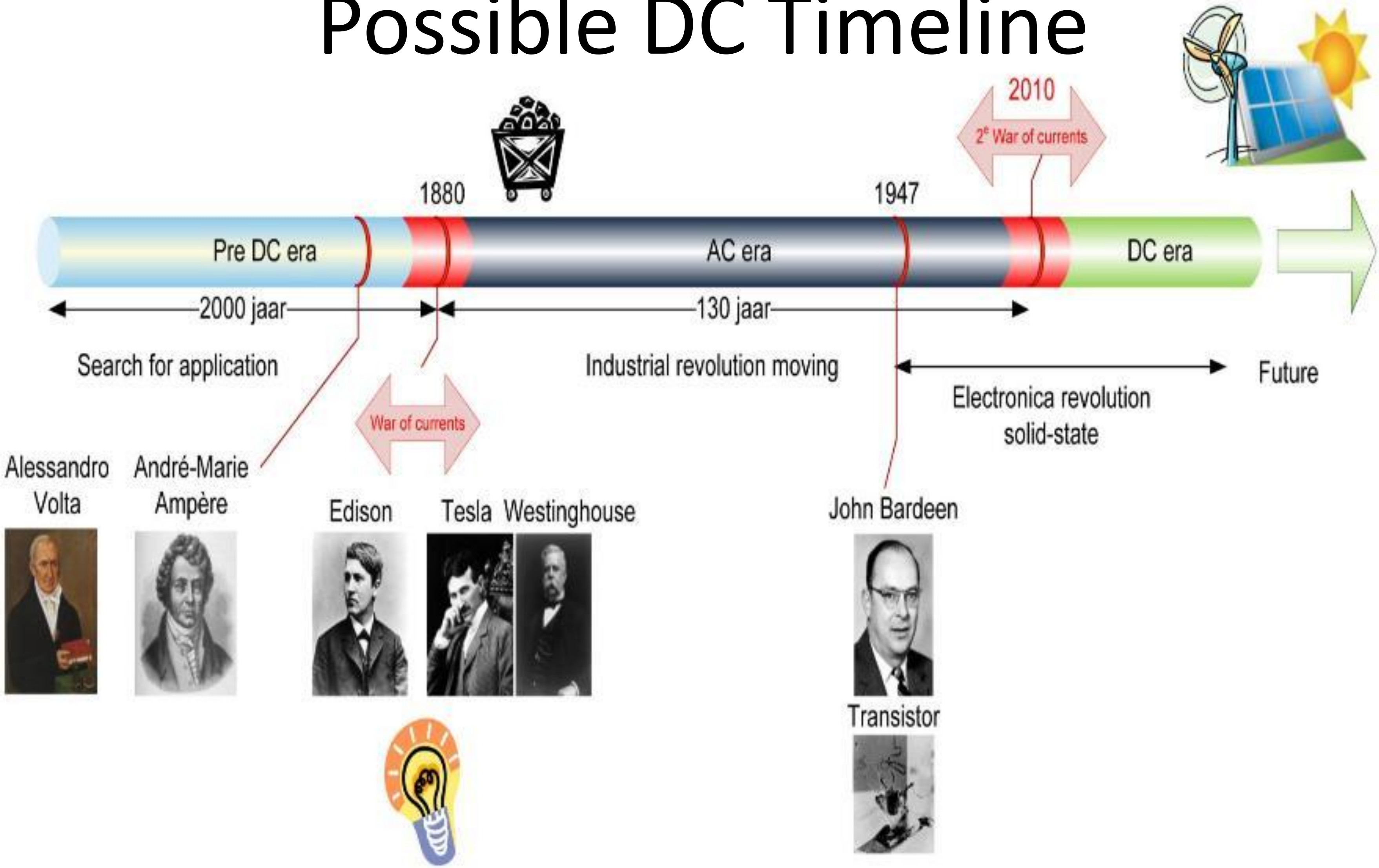
4 Choices

- Mix AC and DC on the same system
- Create new DC wiring for new homes only
- Create new DC wiring for renovations as well as new homes
- Move to DC only in the home

AC vs DC Energy Loss Comparison (43 % Less Loss)



Possible DC Timeline



Timeline thanks to Harry Stokman – Direct Current

Creating the Enernet

Direct Current: Reinventing Building Power

Vision → Standards → Eco-system → Transformation

THE ENERNET: Doing for power what the Internet did for information networking

TRANSFORMING THE 21ST CENTURY ENERGY ECONOMY

Zero Net Energy Buildings
Automated Demand Response
Smart Buildings - Buildings as Robots
Powering The Internet of Things

Resilient Non-synchronous Micro Grids
The Transactional Energy Network
Energy to the Developing World
Power to the People

"Electrons are the currency of the future World economy – not the barrel of oil."

Why DC current?

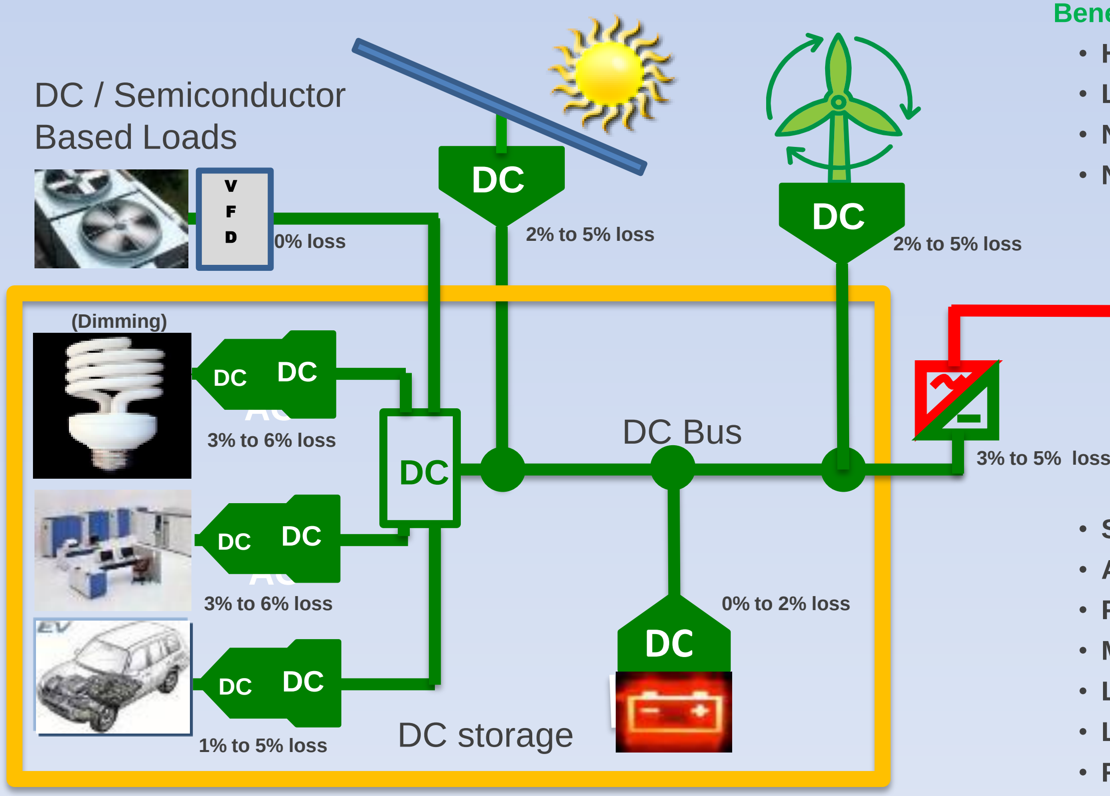
- Increased flexibility, modularity, resiliency
- Improved safety
- Better utilization of cables and wires
- Increased efficiency
- Reduced need of materials, lower costs

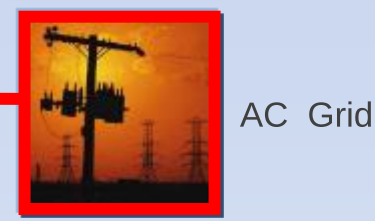
The EnerNet

Vision

About Hybrid AC/DC Microgrids

The Ideal End State…





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- Reduced Carbon Footprint

Challenge of Existing Buildings

85% of buildings that will exist in 2030 are here today!

"The Need for Standards that allows an Opportunistic Transformation Strategy"

Must Consider:

- **Retrofits**
- **Renovation**
- **Re-Use**
- **New Builds**

A Family of Open Power Application Standards for Hybrid DC Microgrids

THE HYBRID BUILDING

THE HYBRID HOUSE

Reinventing Commercial Building Power

Reinventing Residential Power

Standards Development

- Open membership, participation, and governance
- Any **individual** or **organization**
- Includes **academia**
- Incudes **government**
- Any **industry** or size of company

Entity (Corporate) Method

- Participants are "entities," i.e., companies, universities, government bodies, etc.
- Unlimited number of representative and alternates represent the entity
- All entities can make proposals and register comments
- **Each eligible entity has 1 vote**
- Requires minimum of 3 entities
- Entity sends representatives to virtual meetings

Rigorous Process Meets Globally-Accepted Standardization Principles

- EMerge's formal process produces results that reflect the collective, consensus view of participants and enables industry to achieve specific objectives and solutions

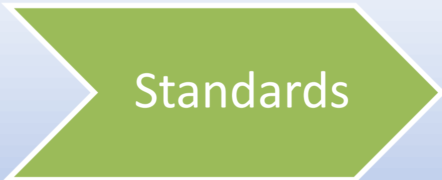
- EMerge's process is widely recognized and aligns with the WTO and OpenStand principles

World Trade Organization

open stand

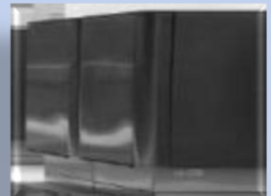
- **Transparency**
- **Openness**
- **Impartiality & Consensus**
- **Cooperation**
- **Due Process**
- **Accessibility for deployment**

What’s in the works?



Standards that are Modular

Providing an Opportunistic Path Forward



Standards Activities

Issued	*Occupied Space*
Issued	*Data Center & Central Office*
Active	*Task Level (desktop & plug loads)*
Active	*Whole Building Microgrids*
Pending	*Outdoor DC / Electric Vehicle Charging*
Pending	*Building Services (HVAC)*
New in 2014	*Residential & Light Commercial*
Plan for 2015	*Remote Residential & Small Village*
Plan for 2016	*Retail Commercial*

EMerge Alliance Connecting the Dots…

E.J. CURTIS ASSOCIATES, INC.

Nicholson & Sun LLC

Hybrid AC/DC Buildings

Transformation

Beginning with the Occupied Space

Developed for commercial interiors

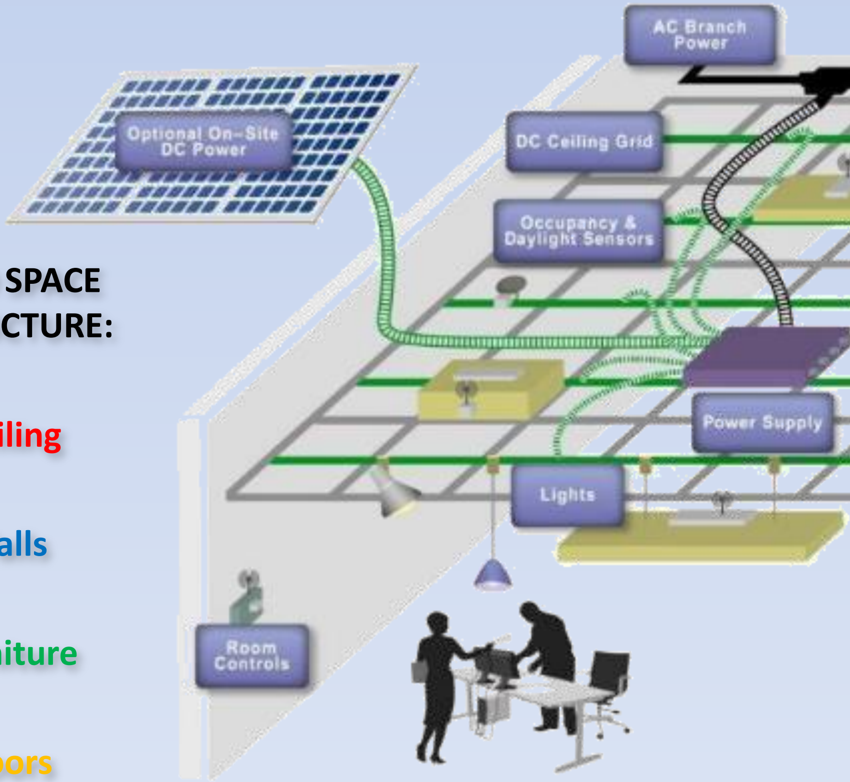
OCCUPIED SPACE INFRASTRUCTURE:

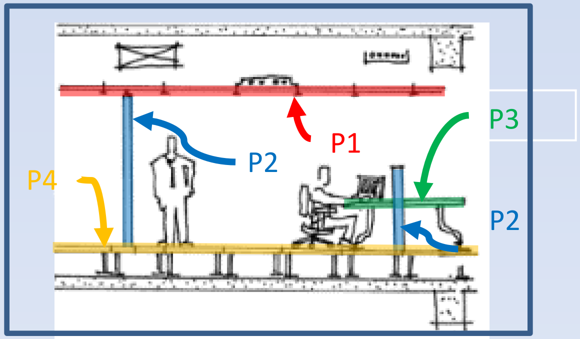
P1 = Ceiling

P2 = Walls

P3 = Furniture

P4 = Floors





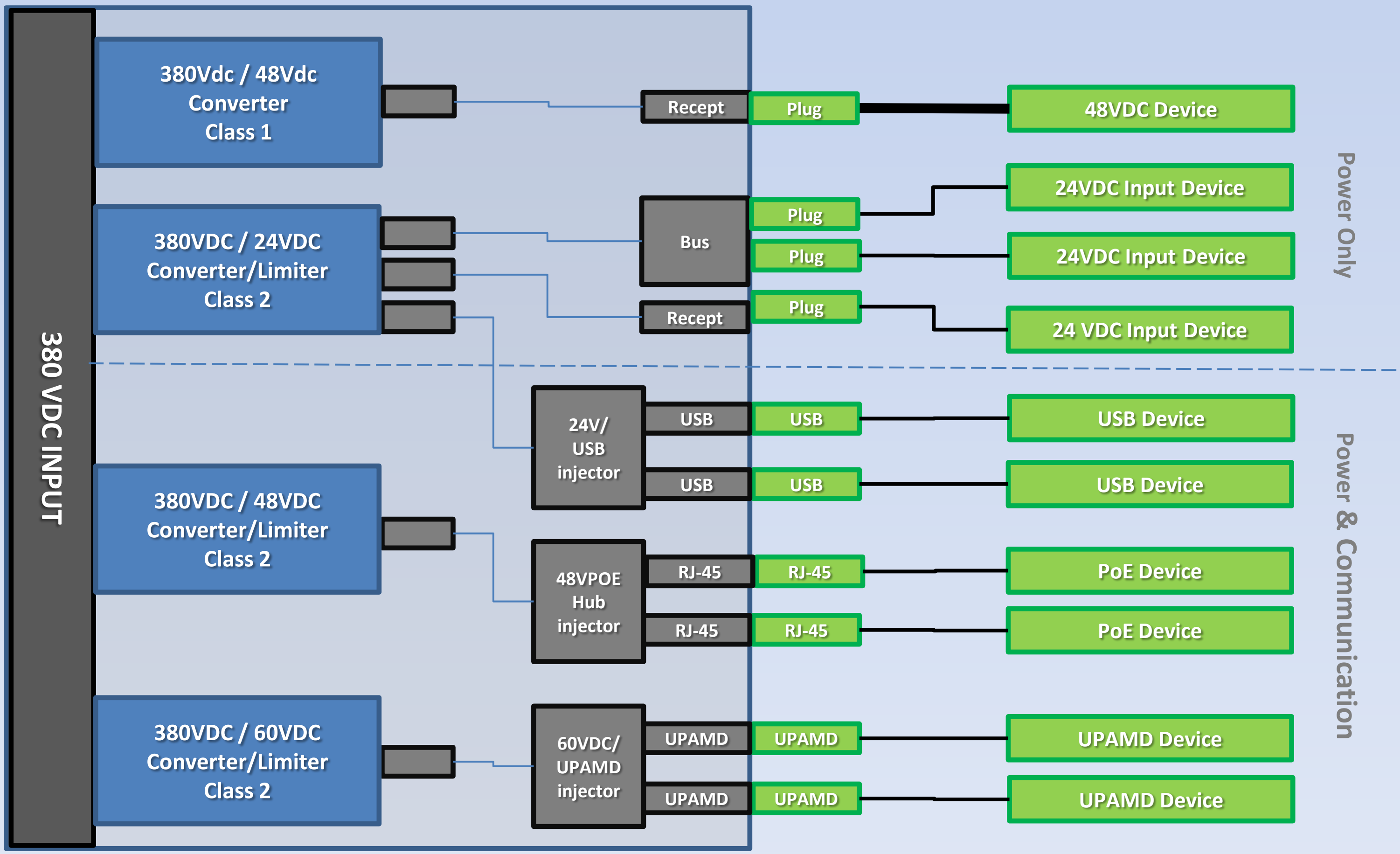
Hybrid AC/DC Buildings

Transformation

Plug & Play DC at the Desktop

The Challenge of the Desktop: Multiple Voltages & Interconnects

380Vdc to xVdc Circuits

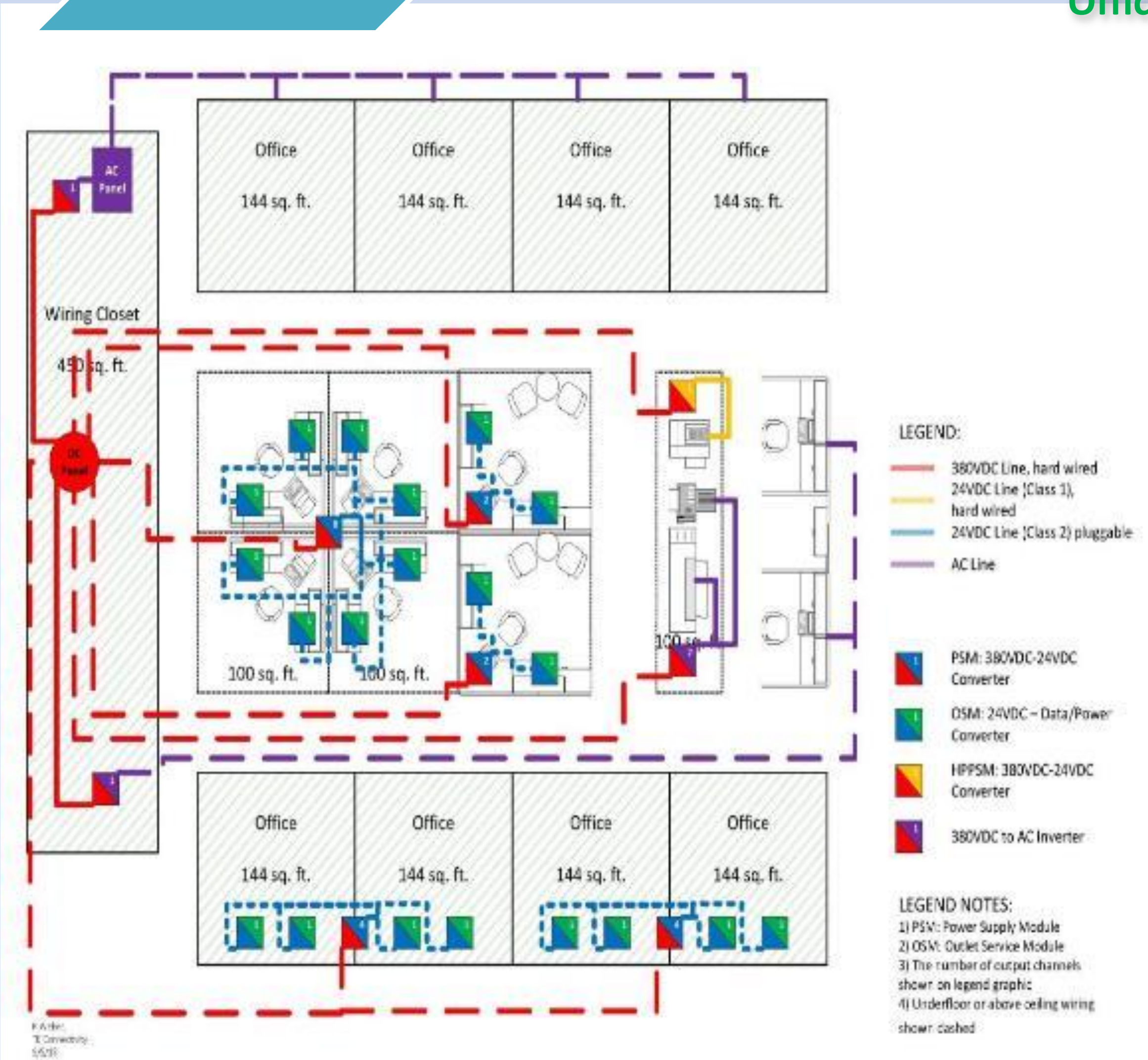


Hybrid AC/DC Buildings

Transformation

About Hybrid AC/DC Microgrids

Office Workstation DC Power Distribution



- Plug & Play 24Vdc Class 2
  - 380Vdc Feed
  - Alt. 120-220-277Vac Feeds
- According to EMerge Draft Standard TLF V0.01
- Desktop Connectivity:
  - USB-PD 5-20Vdc
  - PoE 48Vdc
  - IEEE UPAMD/P1823
  - 24 Vdc Native 5mm Plug
- Includes:
  - 100 or200 Watts/Desktops
  - Class 2 Touch Safe Outlets
  - Optional 120Vac Outlets
  - Power Use Monitoring

Hybrid AC/DC Buildings

Transformation

From Desktops to Data Centers

Focused on Energy Surety, Reliability, Space and Energy Efficiency

- Huge and growing energy user in buildings
- Not just Google or Facebook
- 99% are "small" (server rooms, closets, etc…2.5 million total)
  - Contain majority of all servers (57%)
  - From 2-32 servers per location
  - Less internal expertise in power/space/heat management
- 6 billion KW hours could be saved each year with a 10% improvement in data center energy efficiency

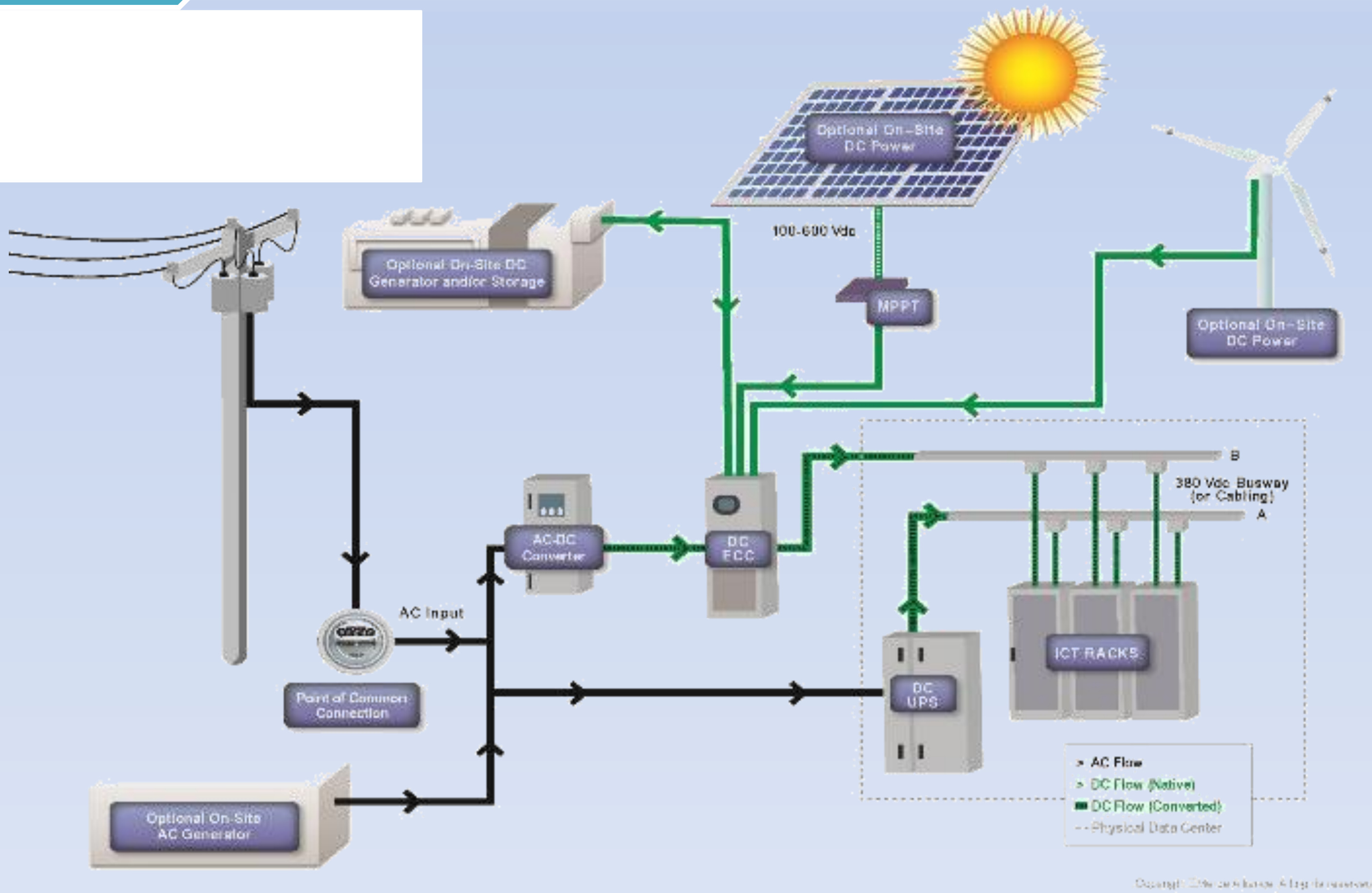
Sources: EPRI, EPA

Hybrid AC/DC Buildings

Transformation

Including Specialty Building Applications

380Vdc distribution Standard has been Issued Product Registry is Open



Hybrid AC/DC Buildings

Transformation

DC for Building Services

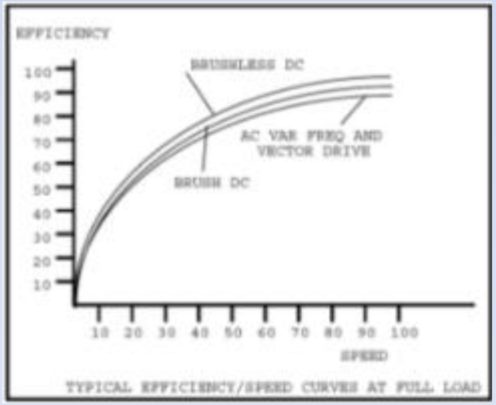
AC Motor applications are moving to DC Variable Speed Drives

Variable Speed = modulated, efficient energy use

DC DRIVES MAY BE BETTER BECAUSE. . .

- DC drives are less complex and more efficient with a 1X power conversion from AC to DC.
- DC drives are normally less expensive for most horsepower ratings.
- DC motors have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose:
  - ✓ Can provide a wide speed range at constant torque.
  - ✓ DC regenerative drives are available for continuous regeneration for overhauling loads. Similar AC drives are more complex and expensive.
  - ✓ DC can provide starting & accelerating torques in excess of 400% of rating.

Photos courtesy of Emerson



BLDC motor use: higher efficiency & torque, better articulation, increasing availability.

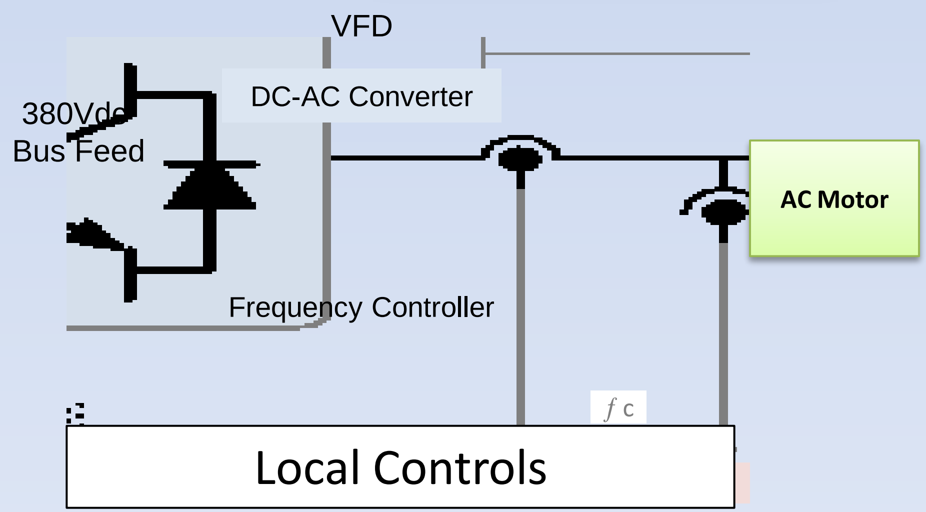
Hybrid AC/DC Buildings

Transformation

DC for Building Services

VFD Motor (HVAC) Power Distribution

- Grid Connected or Islandable
- Multiple Site Based Sourced
  - Solar
  - Wind
  - Fuel Cell
  - LP/NG Generator
- According to EMerge Draft Standard C/BM TS V0.01
- Connectivity:
  - 380 Vdc Non-synchronous Bus
  - Rack Mounted Power Management
  - N+1 Conversion Redundancy
- Includes:
  - Up to 150 KW Loads
  - Scalable in 15KW increments
  - Rack Metering Power Use
  - N+1 to distribution bus
  - Direct dc failsafe Back-up Power

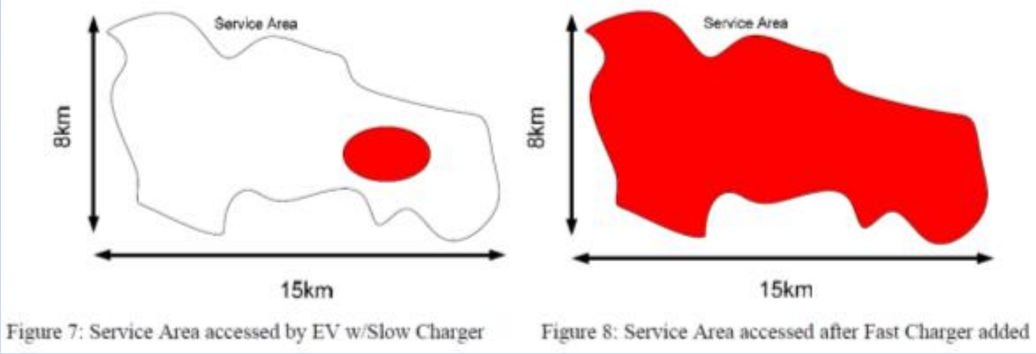


Hybrid AC/DC Buildings

Transformation

DC for Building Exterior Applications

DC Fast-charging should dominate Commercial & Office Sites



EVS24 Stavanger, Norway, May 13-16, 2009

Photos courtesy of ABB

DC charging is best for "away from home" charging because:

- Unlike conventional residential power outlets, which can take up to eight hours to charge an electric vehicle,
- Most DC fast chargers need only 15-30 minutes to do the job.
- A DC fast charge can add 60 to 80 miles of range to a light-duty PHEV or EV in 20 minutes.

Approx. 3000 DC Charging stations exist already, expected to double every year.

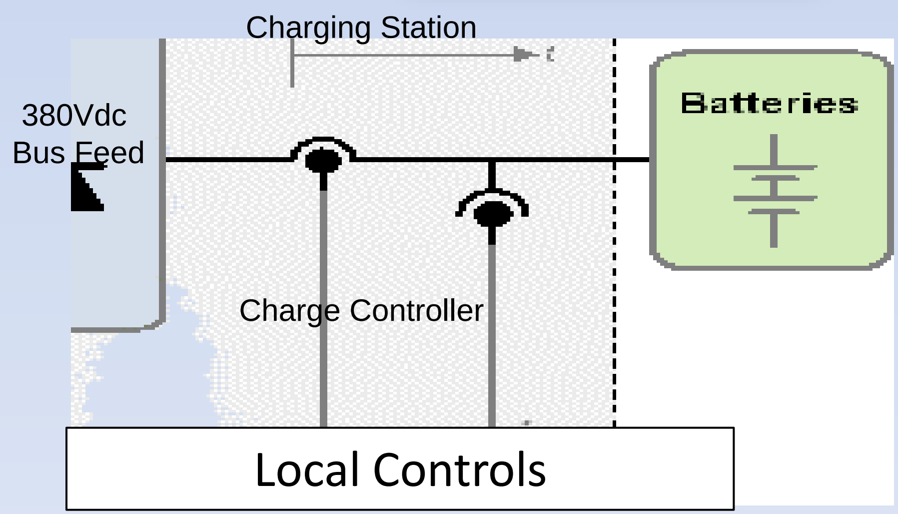
Hybrid AC/DC Buildings

Transformation

DC for Building Exterior Applications

EV DC Fast-Charging Distribution

- DC Level 3 (Fast) Electric Vehicle Charging
- Charging Station Protocols
  - CHAdeMO
  - SAE
- According to EMerge Draft Standard C/BM TS V0.01
- Connectivity:
  - 380 Vdc Non-synchronous Distribution Bus
  - Power Management via DC Microgrid Control
  - Local Multi-Vehicle Charge Management
- Includes:
  - Authorization system
  - Online management with data per user via OCPP
  - Smart Simultaneous multi car charging
  - AC wallbox - external charging connections



Hybrid AC/DC Buildings

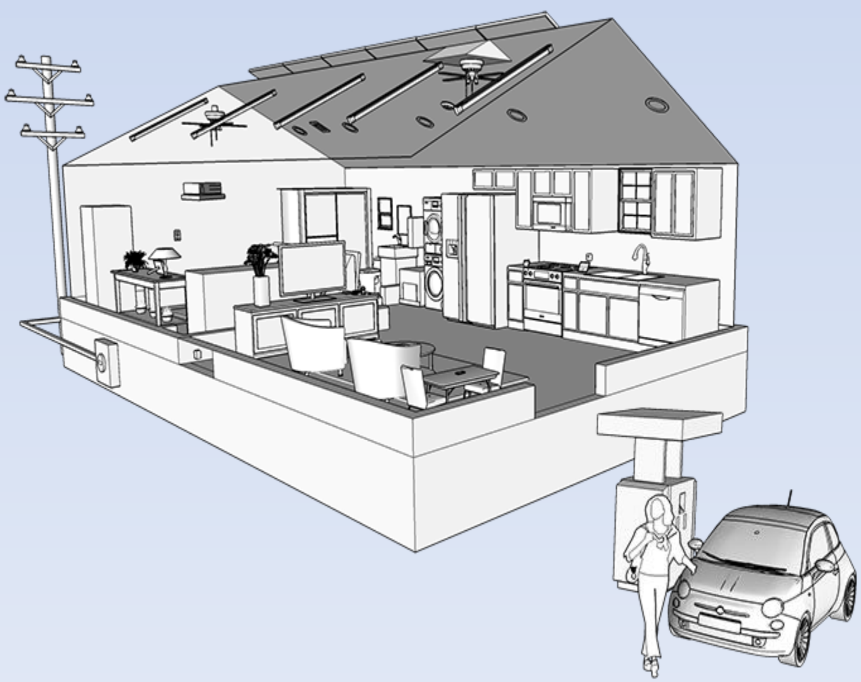
Transformation

Residential Standards Highlights

A Collaborative : NextEnergy, IEEE and EMerge

- A Living Lab Demonstration of DC electric power distribution for smart residential and small commercial buildings.
- Target hybrid AC/DC power by defining standardized interfaces with AC power systems.

NEXTHOME
a DC Connected House

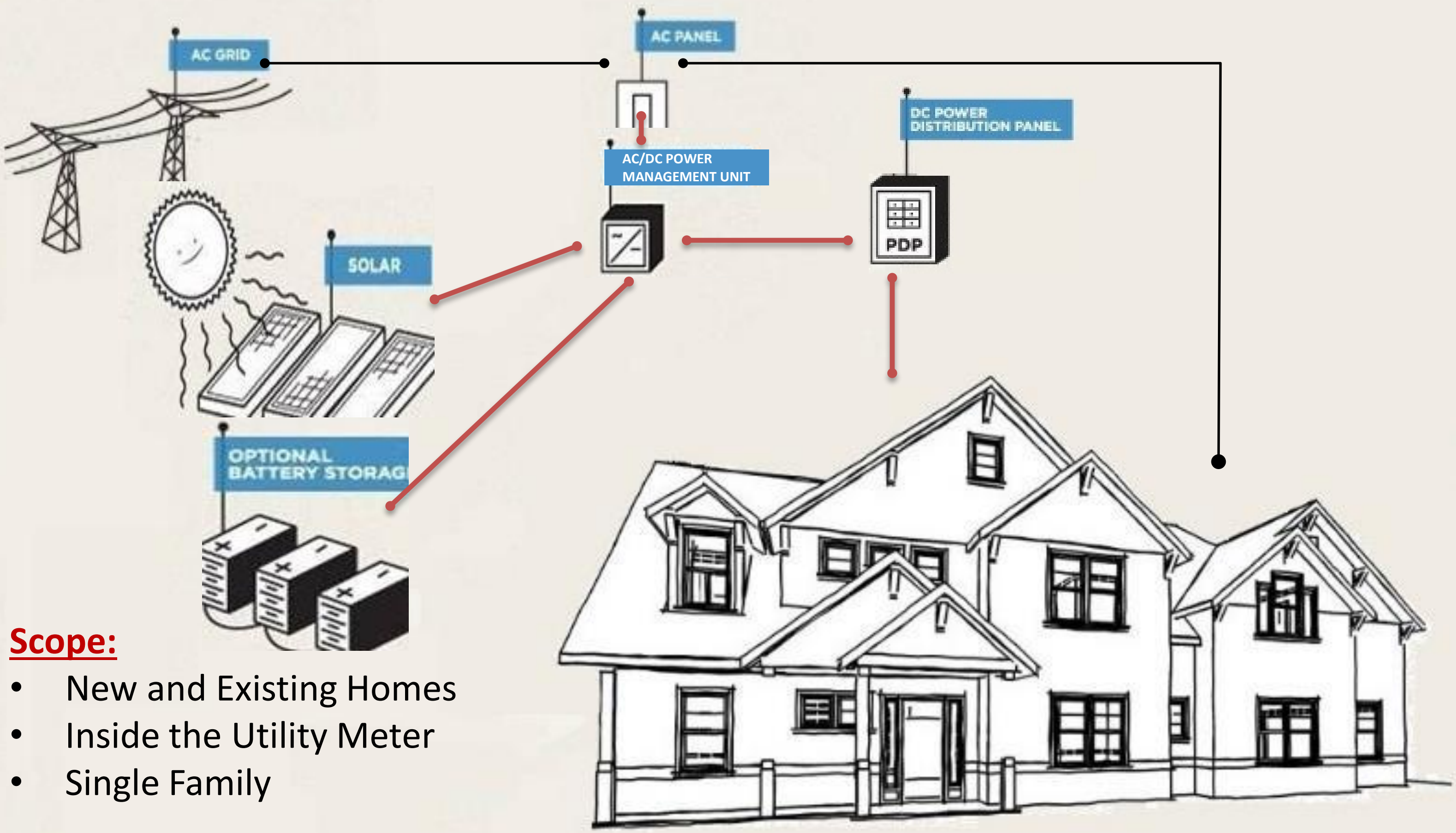


- Provide a transformational path from AC homes to include effective use of DC.
- It will apply to new and existing building design and construction/renovation.
- Include sub-system electric microgrids to form a complete power distribution system.
- Includes on-site distributed power generation, storage & electric vehicle connectivity.
- NextHome: a “living lab” within NextEnergy’s testing & validation platforms.

Hybrid AC/DC Buildings

Transformation

Initial Residential Standard Scope



Scope:

- New and Existing Homes
- Inside the Utility Meter
- Single Family

Hybrid AC/DC Buildings

Transformation

DC Powered Digital Store of the Future

Whole Building DC Power Distribution

Taking Net-Zero to the Next Level

Hybrid AC/DC Buildings

Transformation

DC Microgrid Click & Brick Integration

Facilitating the Digit Commerce Age









Where are we now?

Eco-system

About the Deployment Process

Existing & New Building Stock Equally Considered

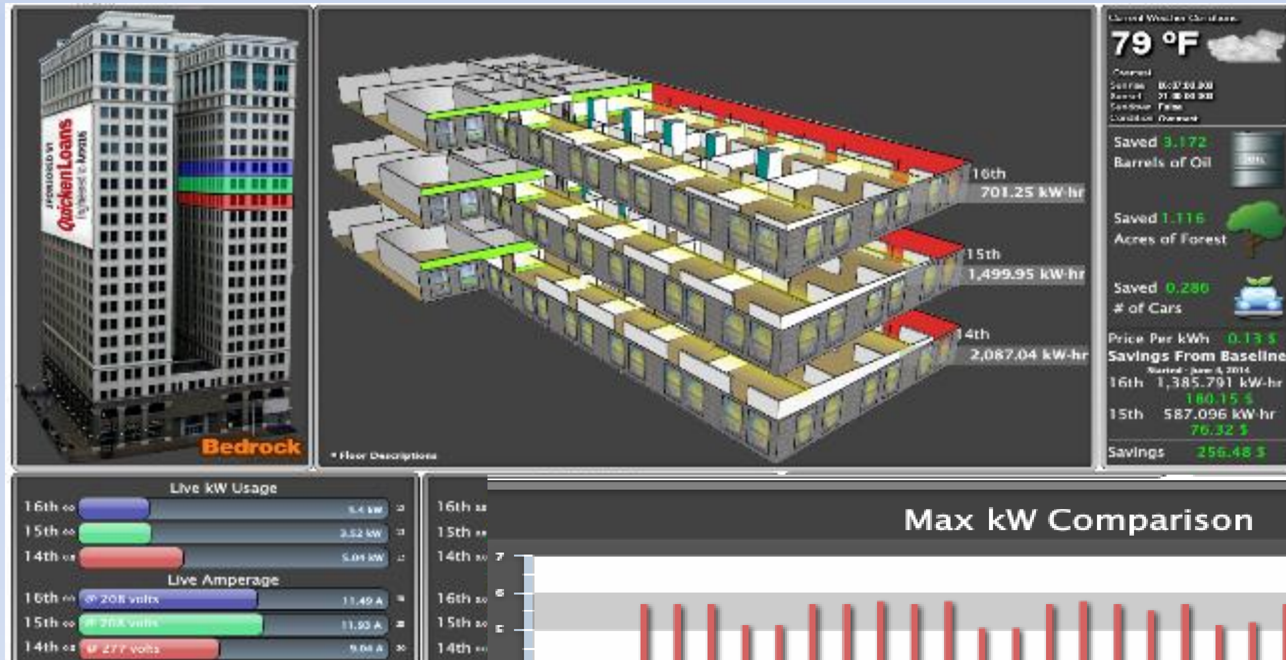
Quicken Loans

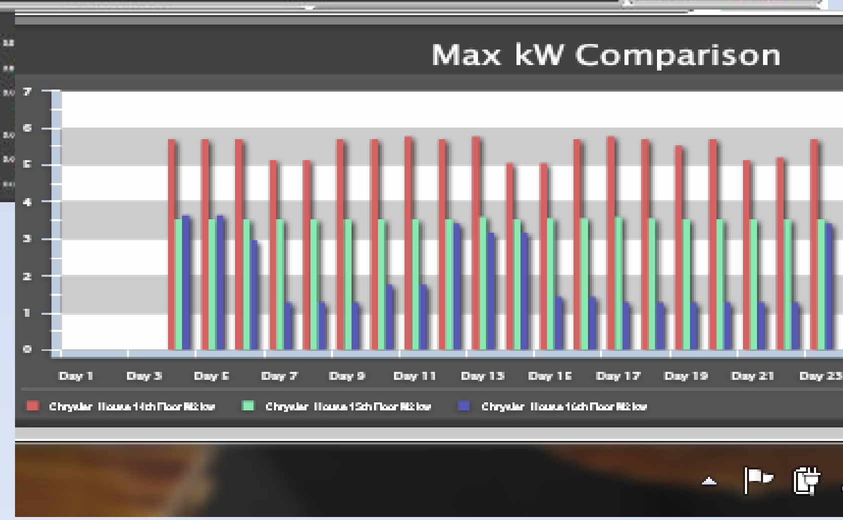
Detroit

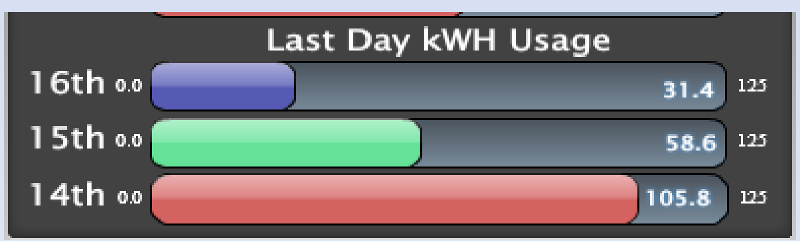
- Low voltage dc LED fixtures
- Wireless Internet Controls
- Re-configurable plug & play design
  - Design: Integrated Design Solutions
Build: Turner Construction
  - EMerge Registered Products
    - Lighting: Acuity/Lithonia LED fixtures
    - Armstrong® DC FlexZone™ Ceiling
    - TE Connectivity cables
    - Nextek power servers & SKY controls

Chrysler House – Detroit, MI

- **3 Floors of Class A Office Space**
- **14th Floor:**
  T8 Fluorescent – No Controls
- **15th Floor:**
  LED Retro Tube – No controls
- **16th Floor:**
  LED Retro Tube – W SKY controls
- **Dramatic Energy Savings 75%!**
- **Recognized by Americas Green Challenge**
  (White House Initiative)





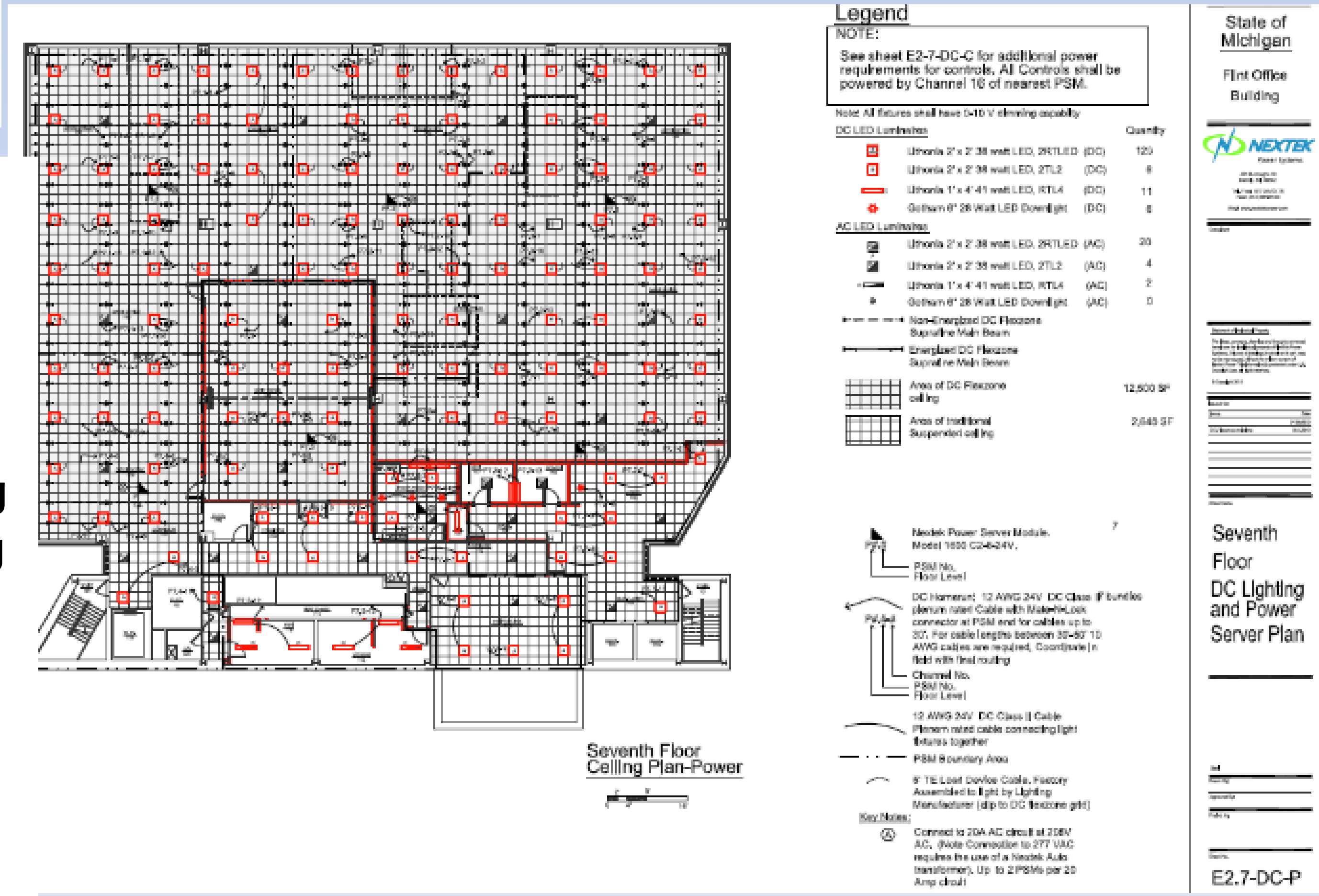


State of Michigan Treasury Building

- Low voltage dc LED fixtures
- Wireless Internet Controls
- Re-configurable plug & play design
  - Design: McMillan & Associates
  - Build: B&B Construction
  - EMerge Registered Products
    - Lighting: Acuity/Lithonia LED fixtures
    - Armstrong® DC FlexZone™ Ceiling
    - TE Connectivity cables
    - Nextek power servers & SKY controls

State of Michigan – Flint Office Bldg.

- **Deep Renovation of 7 Story Office Bldg.**
- **110,000sf of 24v DC LED Lighting**
- **70,000sf of DC Energized Ceiling**
- **Wireless Lighting Control**
- **Plans Underway for Direct Coupled® Solar**
- **Complete Late 2014**



green.ch
The Internet Company

West Data Center

- 10% less energy, PUE=1.18
- 15% less capex – 20% lower install
- 25% smaller footprint
  - Designed by: ABB/HP
  - Constructed by: Various
  - Registered EMerge Products:
    - ABB Rectifiers, power protection and switchgear*
    - Anderson Power Products/Ideal Connectors

Hybrid AC/DC Buildings

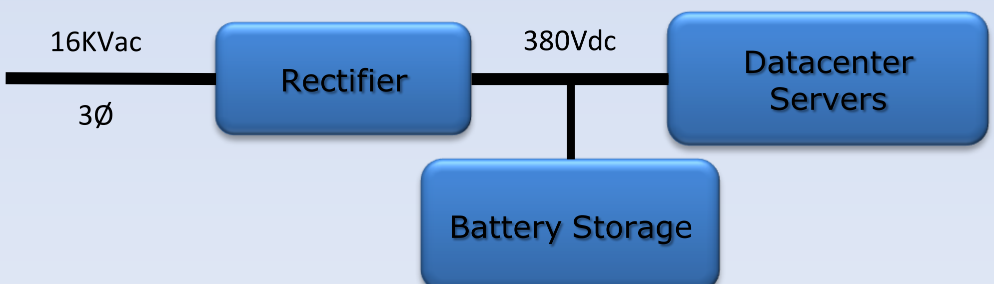
Transformation

Using the Data/Telecom Standard

Full Scale Field Applications Have Begun

Green.ch-ABB Zurich-West 380Vdc Data Center

- ABB/Validus Power Distribution
  - In: 16KV AC
  - Out: 1MW @ 380Vdc
  - Battery Backup: 10 mins
  - Backup Generation
- $1,100m^2$ of $3,300m^2$ Vdc
- HP 2U, Blades & Storage Servers
- Demonstrated Benefits
  - **10%+ Better Energy Efficiency**
  - **15% Lower Capital Cost**
  - **25% Smaller Footprint**
  - **20% Lower Installation Costs**



Photos courtesy of ABB* and HP*

Steel ORCA Data Center

- 380 Volt dc bus architecture
- Highest resiliency and reliability
- Scalable design saves 50% CapEx.
  - Design: Crabtree, Rohrbaugh & Assoc.
  - Constructed by: Gilbane Co.
  - EMerge Registered Products:
    - GVA & Goldeneye lighting
    - Armstrong® DC FlexZone™ Ceiling
    - UE Starline DC busway
    - TE Connectivity cables
    - Emerson Network Power rectifiers
    - Nextek Power servers & SKY controls
    - IBM Mainframe – HP/Cisco Servers

PNC Finance Branch Bank

- Net Zero Building
- Low Voltage dc LED Fixtures
- Power directly from on-site solar
  - Design: Gensler
  - Build: Turner
  - EMerge Registered Products:
    - Lighting: Acuity/Lithonia LED fixtures & Controls
    - Armstrong® DC FlexZone™ Ceiling
    - TE Connectivity LVDC cables
    - Nextek power servers

Hybrid AC/DC Buildings

Transformation

Whole Building DC Microgrids

Commercialization is on its way…

PNC Financial Services Group Inc. announced the debut of its new net-zero energy bank branch during first quarter 2013 in Fort Lauderdale, Fla.

PNC branch exceeds LEED Platinum certification and is PNC's most energy efficient building, using 50 percent less energy than a typical branch.

NEXTENERGY
ask us what's next

NextEnergy Center

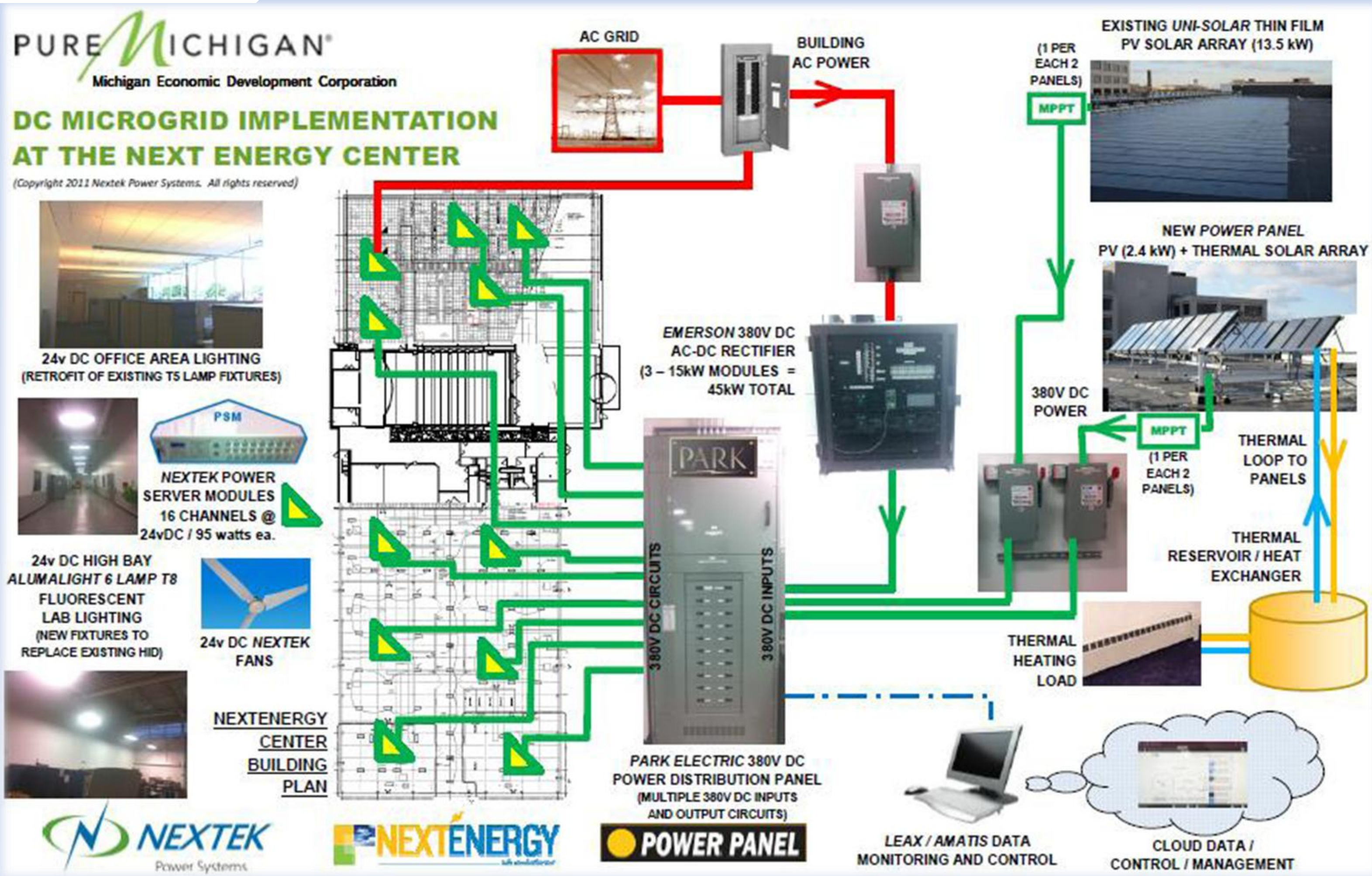
- Hybrid AC/DC Microgrids
- Plug & Play Architecture
- Multiple renewable energy sources.
  - Designed by: Various
  - Constructed by: Various
  - EMerge Registered Products
    - Acuity/Lithonia LED fixtures
    - Armstrong® DC FlexZone™ Ceiling
    - TE Connectivity cables
    - Anderson/Ideal Connectors & cables
    - Emerson Network Power Rectifiers
    - Nextek Power servers & SKY controls
    - Bosch home appliances*
    - Step Warm dc radiant floors*

Hybrid AC/DC Buildings

Transformation

Building Campus DC Microgrids

Full Scale Applications Under Development



TE Connectivity Engineering Center

DC Lighting + Energized Ceiling Grid

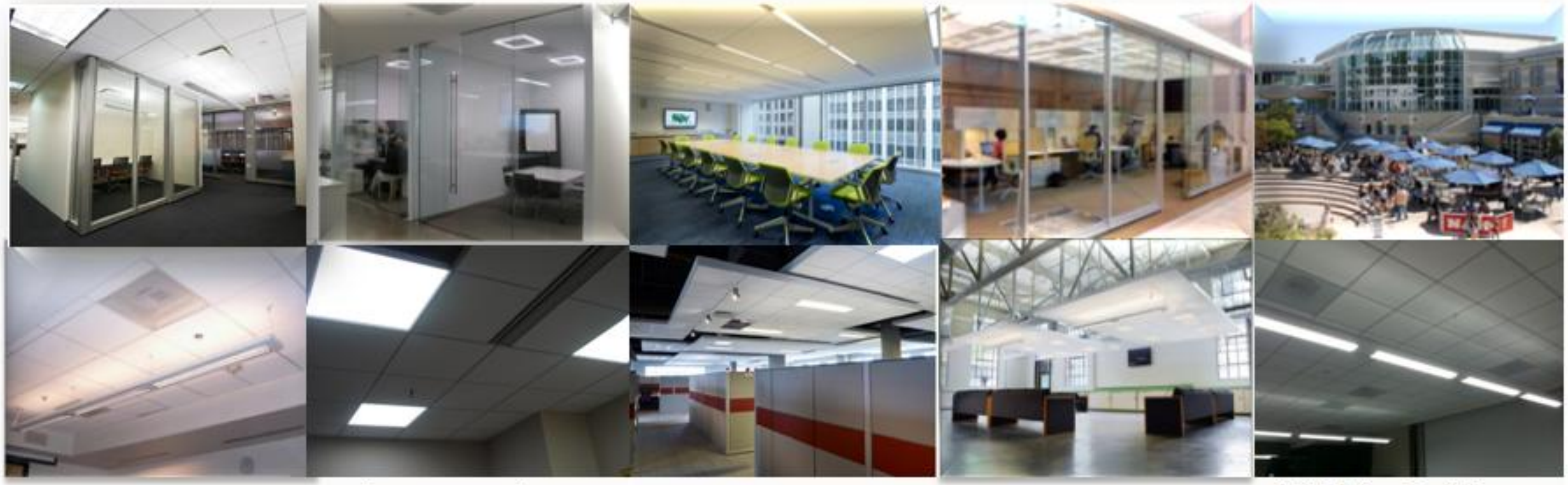
- Full energized top and bottom rails of suspended ceiling
- 10,000sf of DC Lighting
- Traditional design / bid / build process

75+ Demonstration, Test, Beta Sites

The Applications are not Restricted

DC Powered Interior Spaces:

PNC Financial Services Headquarters Office Pittsburgh, PA	Lauckgroup Architectural Office Dallas, TX	US Green Bldg Council Conference Rooms Washington, DC	Nextek Power NextEnergy Center Detroit, MI	UC San Diego Sustainability Center San Diego, CA



Southern Cal Edison Utility Services Office Irwindale, CA	Johnson Controls Headquarters Office Milwaukee, WI	Optima Engineering MEP Firm Charlotte, NC	LA Community College Trade Tech Campus Los Angeles, CA	CA Lighting Tech Center UC Davis Campus Davis, CA

GREENBUILD®

INTERNATIONAL CONFERENCE AND EXPO

NET ZERO ZONE & LIVE MICROGRID SHOWCASE

at

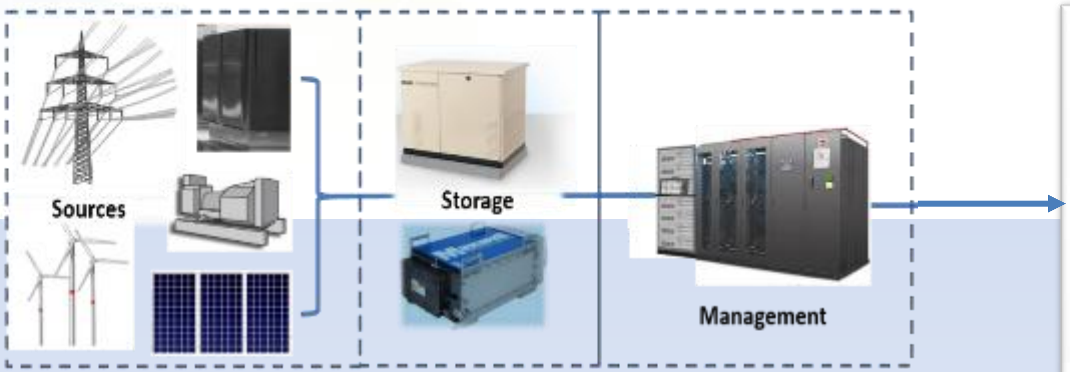
Greenbuild International Conference & Expo 2015
Expo: Nov. 18-19 | Conference: Nov. 18-20
Washington, D.C.

Facilitated by

EMerge® ALLIANCE

THE AC/DC HYBRID MICROGRID DEMONSTRATION

Greenbuild 2015 will use a live microgrid to provide both ac and dc power to exhibition space from on-site alternate energy generation, storage and distribution - Solar, Wind, Micro Turbine, Kinetic, and Fuel Cell Electricity Generators, with battery storage in a dc bussed Microgrid

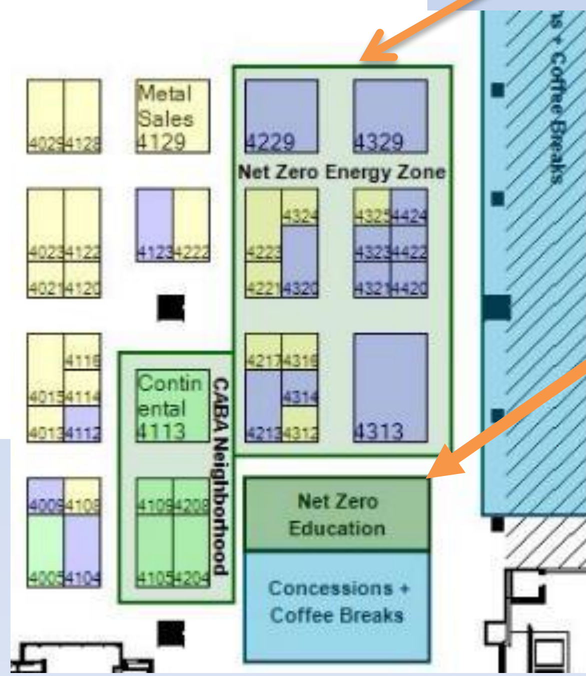


A UNIQUE DEMONSTRATION AND EXHIBITION OPPORTUNITY FOR THE BUILDING MICROGRID MARKET

HOW TO PARTICIPATE IN THE PREMIER NET ZERO ZONE & MICROGRID SHOWCASE

DISTRIBUTED POWER SOURCES

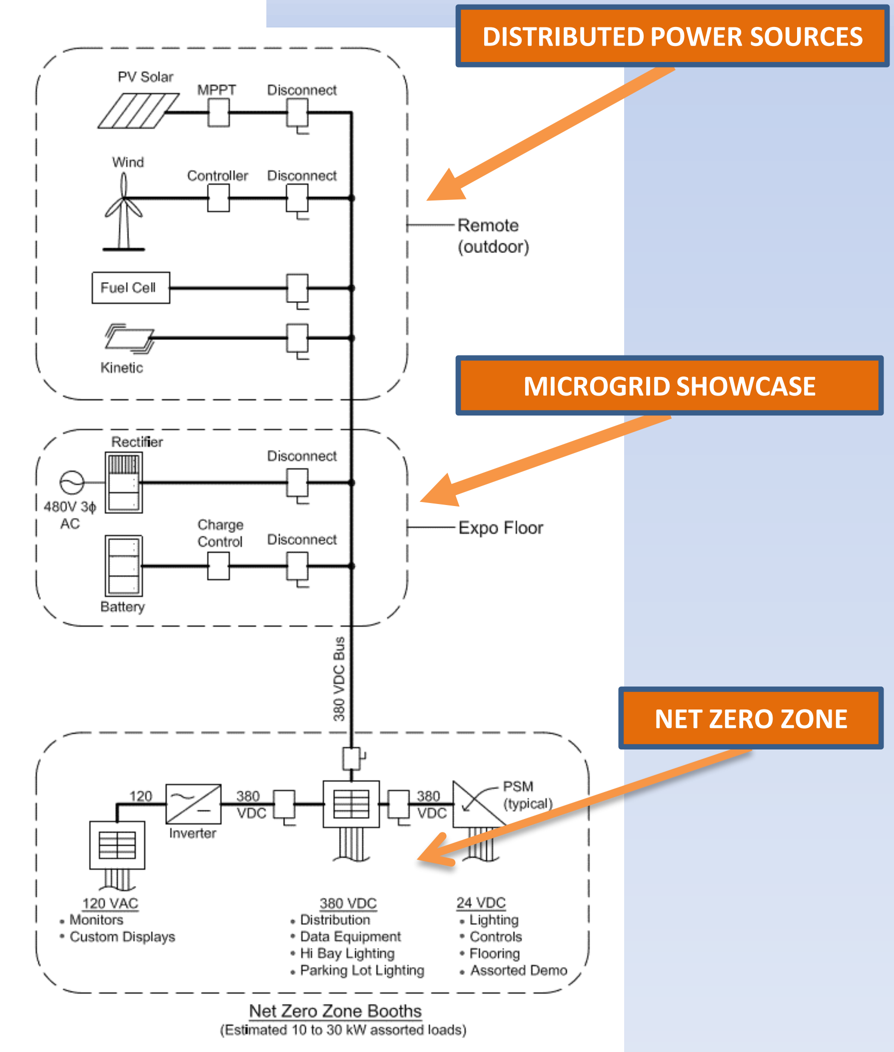
NET ZERO ZONE



MICROGRID SHOWCASE

Inside the Expo Hall at Greenbuild

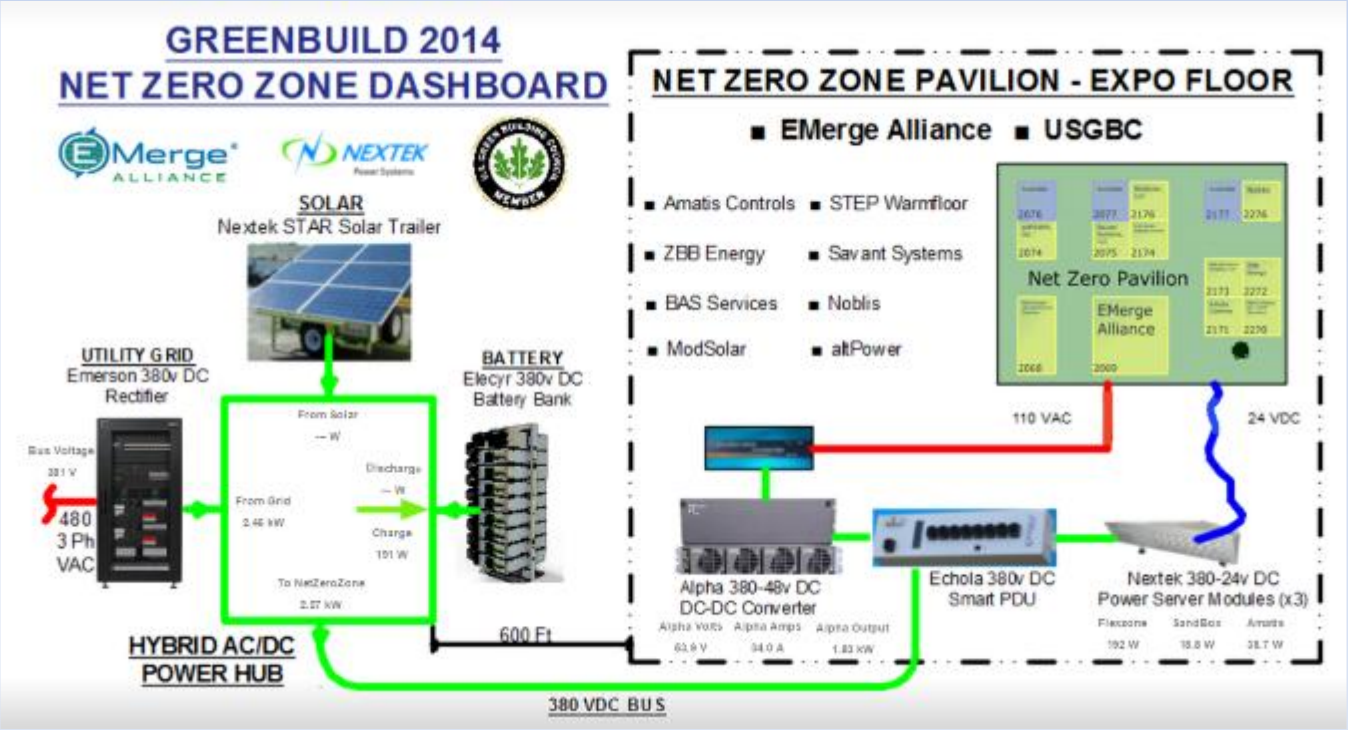
NET ZERO ZONE & MICROGRID SHOWCASE
HOW IT WORKS



Description:

- Exhibitors can choose:
  - 120 Vac
  - 24Vdc
  - 48Vdc
  - 380Vdc
- Power sources and batteries will sit on the bus behind a disconnect
- Power management will convert ac source and manage bus
- MEP team will coordinate interconnect design & specs.

Washington DC Convention Center Exhibit Floor Microgrid



Thank You!

www. EMergeAlliance.org

BETC

title

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