DC Applications for Energy Efficiency

2017 National Symposium on Market Transformation

April 3, 2017
Arlington, VA

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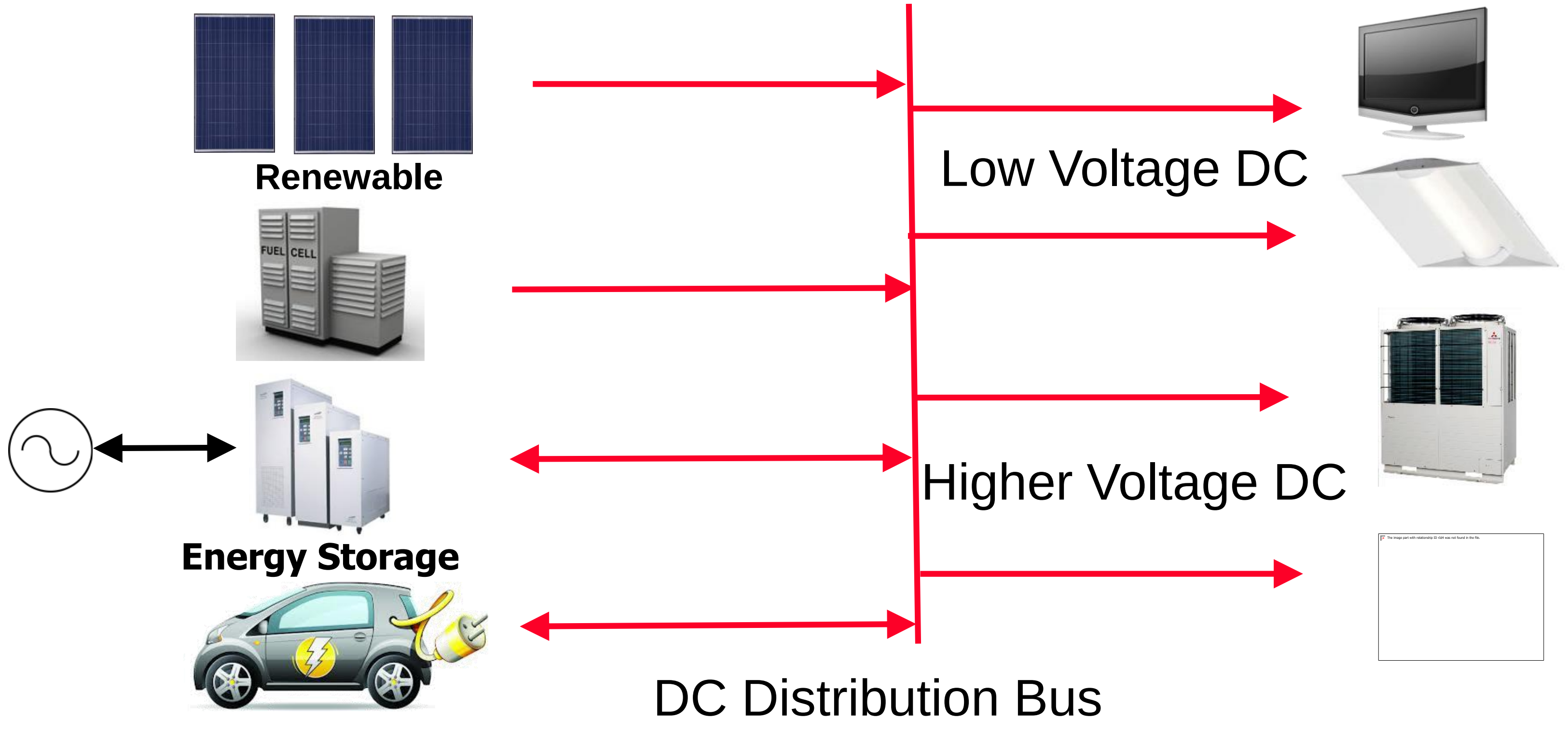
Imagine the limitations if data only flowed in one direction…

- Now, consider the potential of using bi-directional energy in building and homes.
  - DC Power with on-site storage gives us the power to push and pull energy for cost optimization and to distribute energy storage for resilient operation.
- When we combine bi-directional power with IoT and analytics we will be able to reduce the cost of energy, improve grid stability, and reduce carbon.
- To optimize DC power use – we need systems thinking.

DC Power - Integration of DC Supply & Loads



DC Energy - Business Case

Market Drivers:

- Cost effective energy conservation
- Sustainability
  - Meet climate change goals
  - Zero-net energy (ZNE) buildings
  - Dematerialization
- Improved system performance
  - Lighting / HVAC
- Resiliency

DC Energy - Use Cases

LVDC / PoE Lighting

Zero-net energy (ZNE) buildings

- On-site generation / storage

Data / Telecommunications Centers

- On-site generation / storage
- DC Loads – servers

Appliances / HVAC

- Up to 40% labor savings with LV DC cabling.
- 6-8% energy savings
- Ultra low dimming

ACEEE American Council for an Energy-Efficient Economy

CEE Consortium for Energy Efficiency

DC Appliances and HVAC Systems

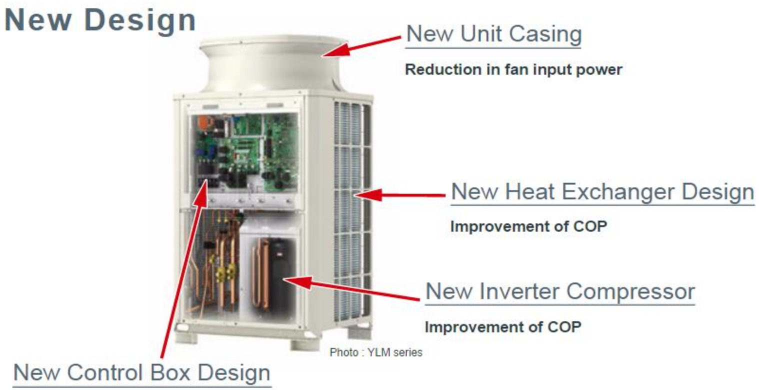
Inverter driven VRF

- Significantly higher partial load efficiency

Appliances

- Direct drive (DC) motors partially contribute up to $900 in annual savings* with washing machines.

Opportunity to Dematerialize for saving capital funds



Modeled Energy Savings:

Energy savings estimates vary depending on presence of battery storage, converter efficiencies, and study type (modeled vs. experimental):

Study Type	Scenario	Electricity Savings
Modeling	Building with Battery Storage	2% – 3% [1]
	All-DC building (res. and com.) No battery storage	5% residential 8% commercial [2]
	All-DC Residential Building	5% w/o battery 14% w/ battery [3]
	All-DC Residential Building	5.0% conventional building 7.5% smart bldg. (PV-load match) [4]

1:Backhaus et al (2015); 2:Denkenberger et al (2012); 3:Vossos et al (2014); 4:Willems & Aerts (2014)

Energy Savings:

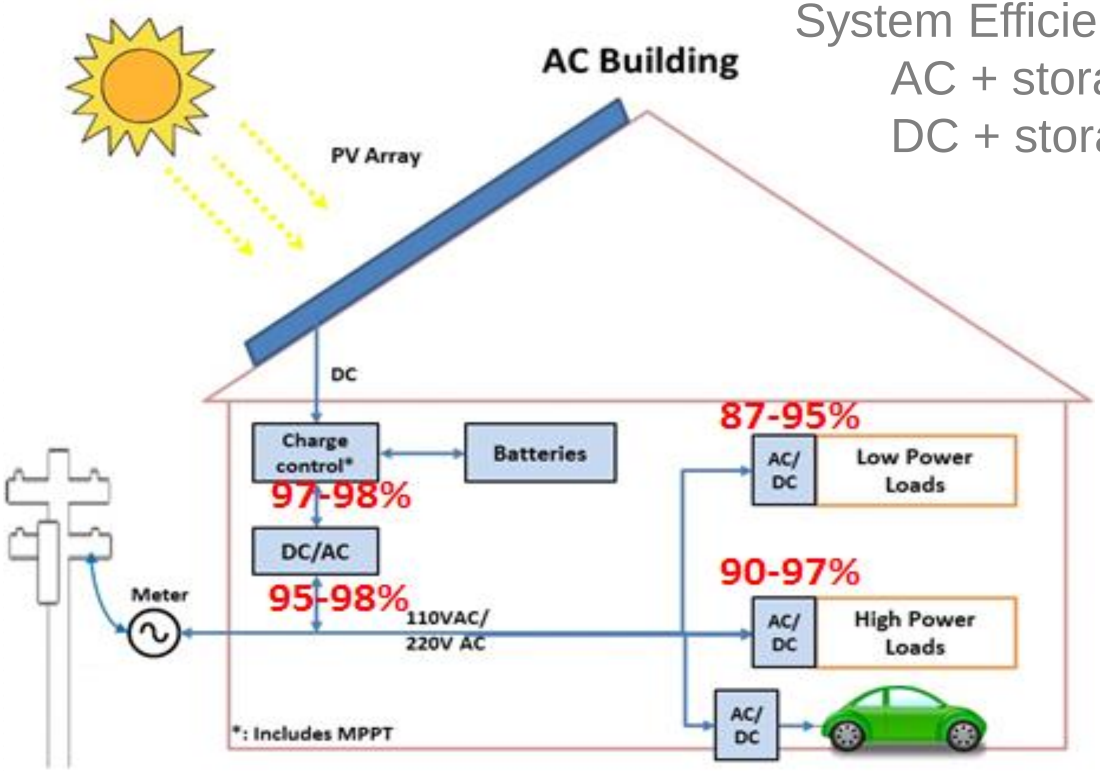
Energy savings estimates vary depending on presence of battery storage, converter efficiencies, and study type (modeled vs. experimental):

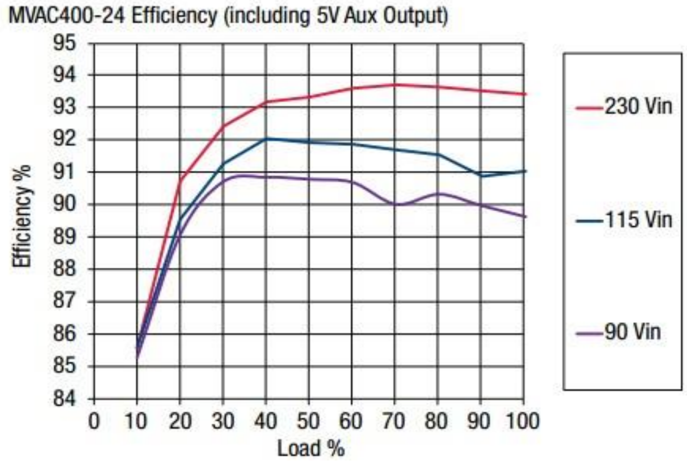
Study Type	Scenario	Electricity Savings
Experimental	LED DC system (no battery)	6% – 8% (modeled) [5]
	All-DC office building (battery, EV)	4.2% [6]
	All-DC Building (battery, EV)	2.7%–5.5% daily energy savings [7]

1:Backhaus et al (2015); 2:Denkenberger et al (2012); 3:Vossos et al (2014); 4:Willems & Aerts (2014); 5:Fregosi et al (2015); 6:Noritake et al (20114); 7:Weiss et al (2014)

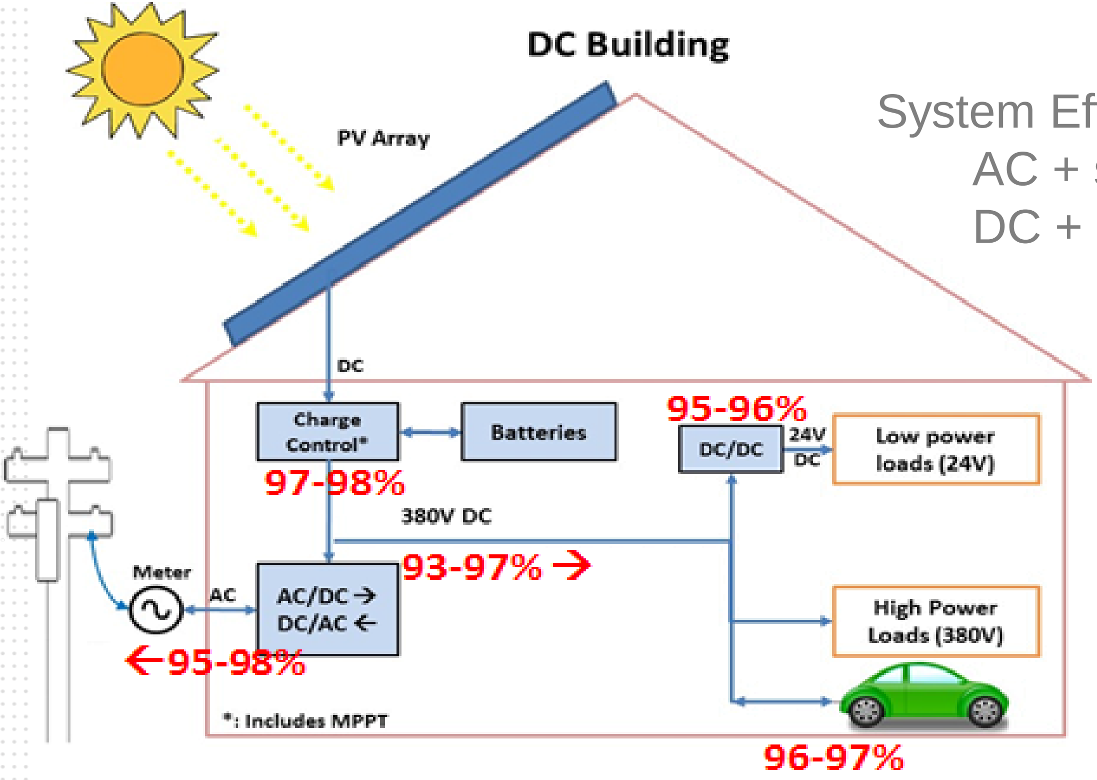
Simulating Power System Losses AC Loads

System Efficiency using AC Loads
AC + storage 74-89%
DC + storage 87-93%

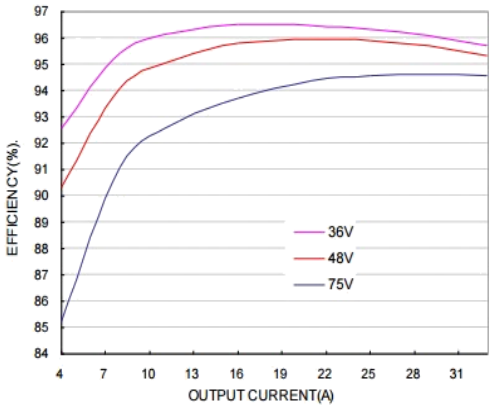




Simulating Power System Losses DC Loads



System Efficiency using DC Loads
AC + storage 81-89%
DC + storage 89-93%



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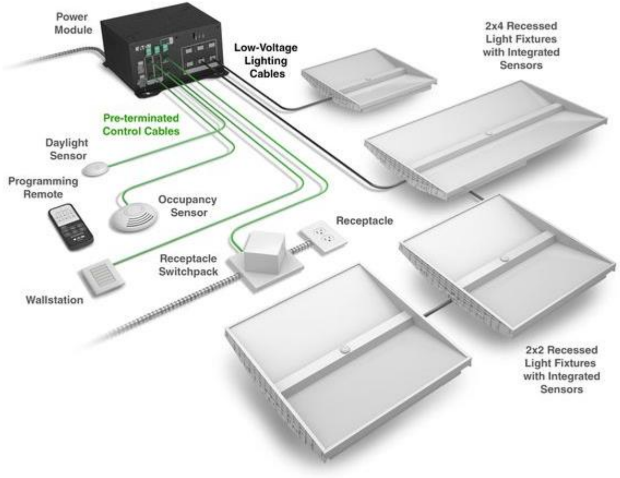
CEE Consortium for Energy Efficiency

DC Solutions in the Market

Through market driven silo's.

- We still need the "killer app" that justifies the secondary power supply.
- LED Lighting and emergency lighting / requirements could be the App.
- Resiliency and connectivity will accelerate adoption.

Lighting



AV Equipment

Until then ASE SEI recommends:

- Controlled tests of DC vs. AC to verify energy & cost savings
- Field demonstrations in new construction and retrofit to identify practical barriers and savings in actual use
- Market development activity to overcome lack of DC-ready appliances (e.g., CLASP initiative) and other equipment (e.g., breakers, converters, small DC storage hub)
- Demonstrate DC microgrids for community-scale solar and multifamily buildings

Additional Recommendations:

- DOE / BTO leadership to assess energy savings and other benefits of DC-powered appliances.
- Investigate new models for system integration with power and data combined, such as PoE and USB-C
- IEEE and other standard organizations to support designers and users on the safe and efficient application of DC power.
- DoE to encourage and avoid creating market barriers to emerging DC products (Energy Star ratings for DC appliances)

For a more comprehensive list, reference ASE Systems Efficiency Initiative report in May 2017

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Top DC Predictions – Frost and Sullivan

1. DC powered buildings have the potential to increase the energy independence, efficiency, safety and security in a building ecosystem.
2. DC distribution will not supersede the existing alternating current (AC) infrastructure that is built around legacy AC systems within the next 10 years.
3. Renewable energy integration with energy storage systems will be the first step towards driving direct current (DC) powered buildings.
4. Higher adoption of electric vehicles (EVs) will be an enabler for energy storage systems (ESS) as it will bring the battery cost down over a period of time.