DC Power Distribution in Buildings

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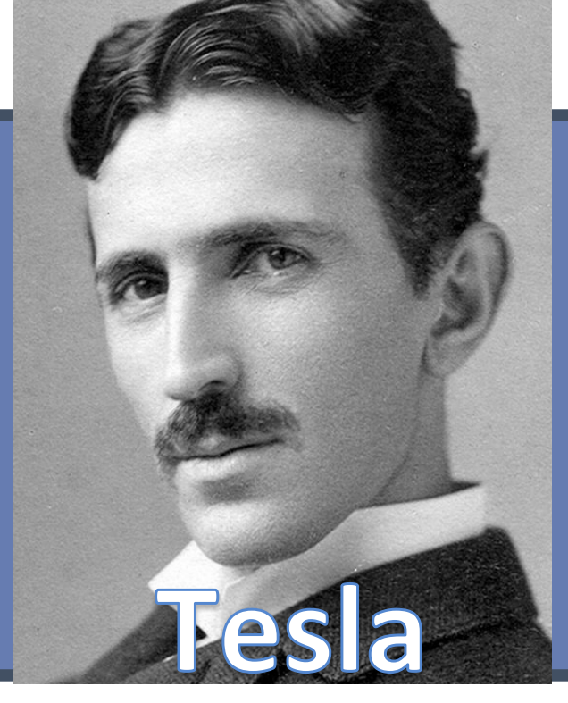
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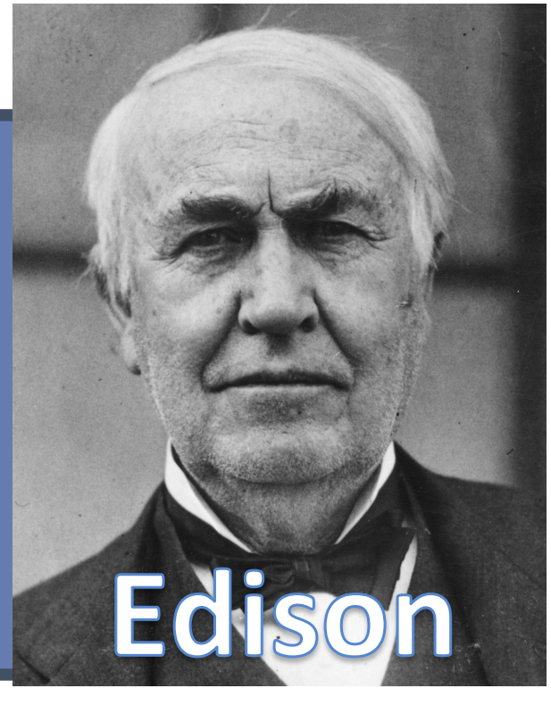
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Why DC?

DC Power most effective with Local Generation and Storage

- Energy Efficiency: Lower conversion loss with natively DC loads (LEDs, electronics, variable speed motors)
- Cost: Lower equipment capital cost (once market size increases)
- Non-energy benefits: easy local reliability, better power quality, flexibility
- Communication: New capabilities - plug-and-play for generation & storage

Overall Project Objectives

- Research and demonstrate technical viability of DC building distribution
- Simulate and measure its potential energy efficiency savings and other benefits (renewable integration, reliability, resilience, power quality, etc.)
- Enhance benefits through communication, using low voltage (<600 V) DC directly integrated with renewable energy technologies and storage in buildings

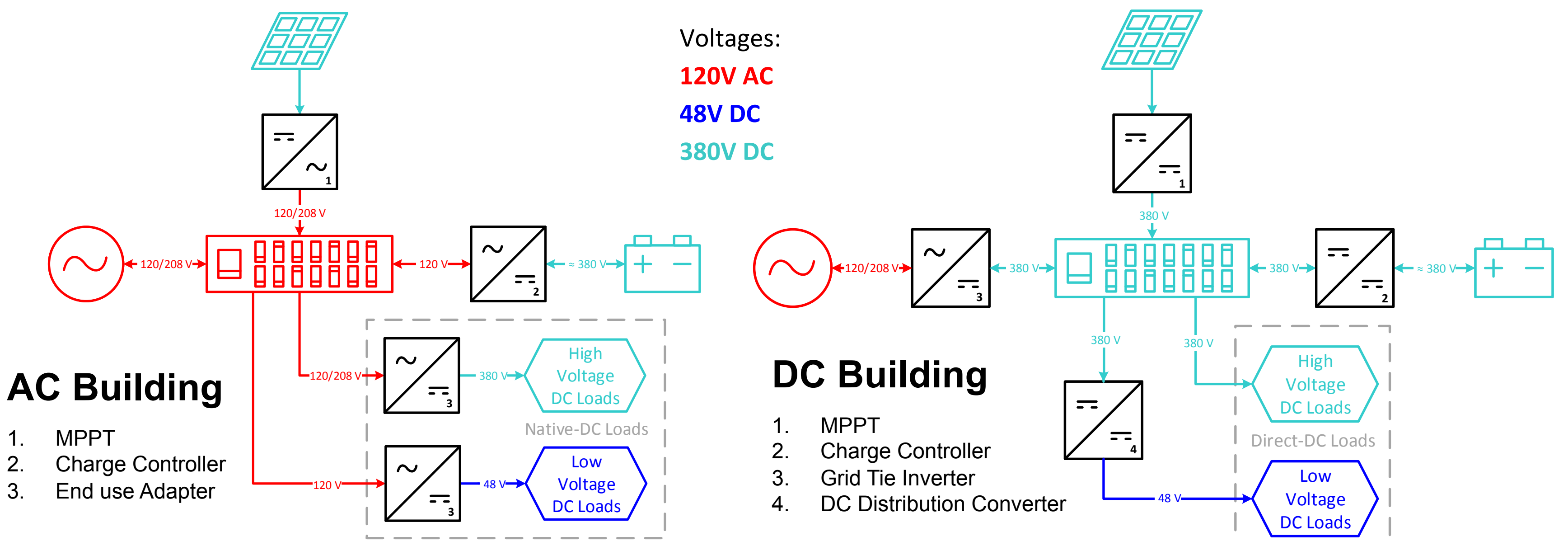
Task 1: Energy savings modeling and measurement of DC buildings

- Review and analyze different results in previous literature
- Model and validate with lab measurements DC power
- Conduct Tech-economic analysis of DC system and their life-cycle performance in buildings

Task 2: Communications and Control in networked DC systems

- Develop a sophisticated simulation model for networked DC grids
- Use this model to demonstrate quantitative savings / benefits

Task 1: Efficiency and Economic Savings Model

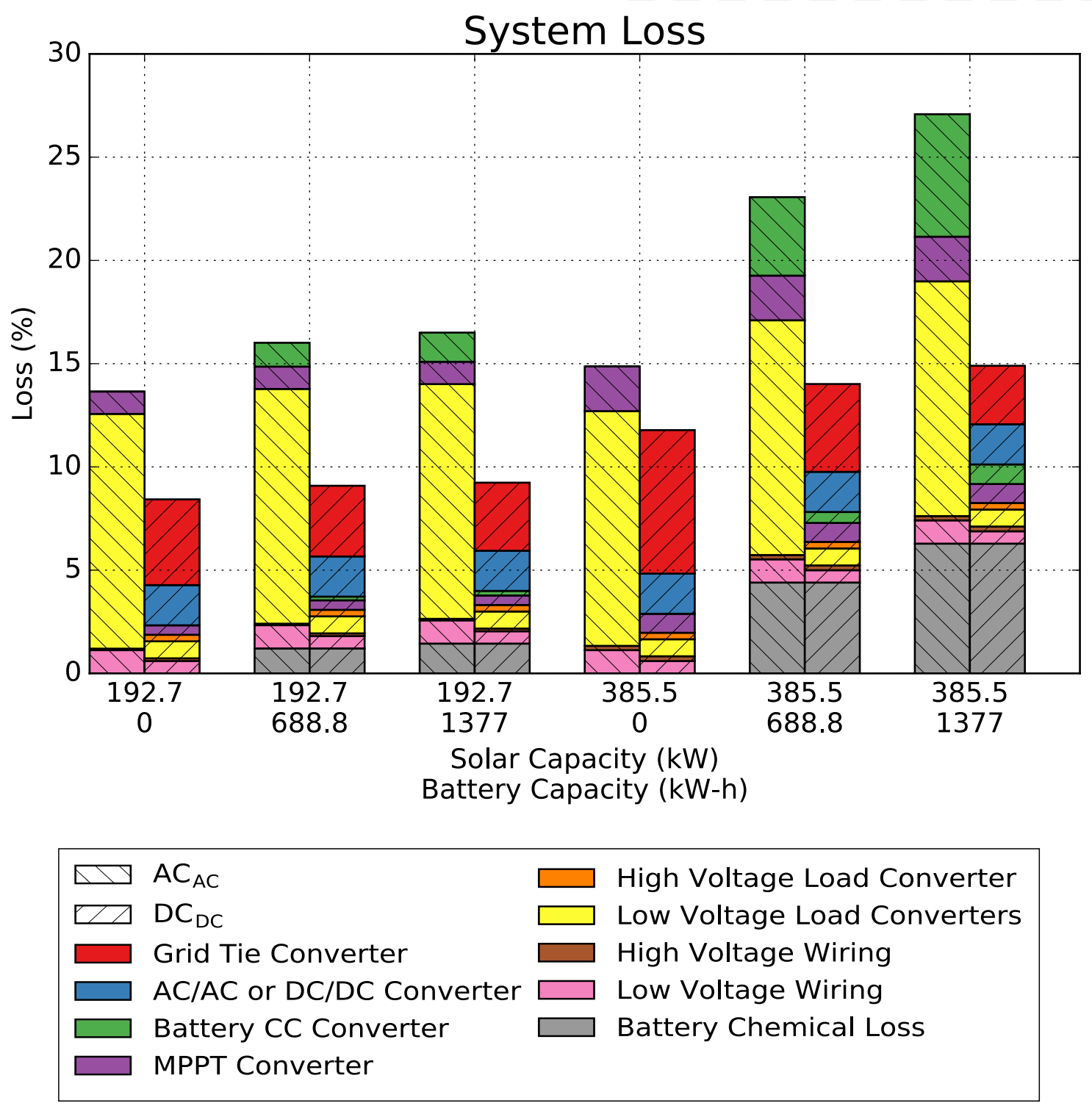


AC Building

1. MPPT
2. Charge Controller
3. End use Adapter

DC Building

1. MPPT
2. Charge Controller
3. Grid Tie Inverter
4. DC Distribution Converter



$$\text{LCC} = \text{First Cost} + \sum_{y=1}^{\text{Lifetime}} \frac{\text{Operating Cost}(y)}{(1 + \text{Discount Rate})^{y}}$$

$$\text{Payback} = \frac{\text{First Cost}_{\text{DC System}} - \text{First Cost}_{\text{AC System}}}{\text{Operating Cost}_{\text{AC System}} - \text{Operating Cost}_{\text{DC System}}}$$

Description	Network	Average LCC Savings (US$)
Total First Cost ($)	AC	252,000
	DC	301,000
Net Annual Electricity Consumption (kWh/yr)	AC	177,000
	DC	101,000
Average LCC Savings ($)	AC vs. DC	61,000
% Cases with Net Benefit	AC vs. DC	>90%
Average Payback Period (yr)	AC vs. DC	~1

Research Goals

- Use simulations to determine efficiency savings
- Estimate economic benefits of DC distribution
- Model medium size Los Angeles office & other bldgs.
- Include realistic profiles for solar output and load
- Use converter efficiency curves, and detailed battery and wiring models

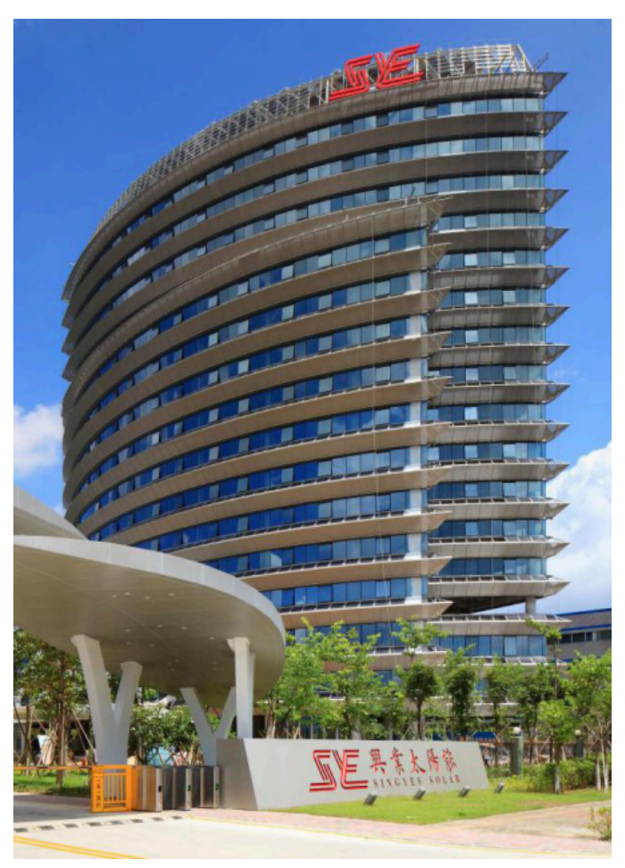
Efficiency Results

- 12% baseline efficiency savings with DC
- DC is more efficient with high solar and battery cap.
- AC building loss is dominated by the poor efficiency of **load packaged rectifiers** (wall adapters)
- AC buildings with lots of storage see loss in the **battery inverter**
- DC building loss dominated by the **grid tie inverter**, particularly bad with high solar and no storage
- Both buildings suffer significant **battery chemical loss**

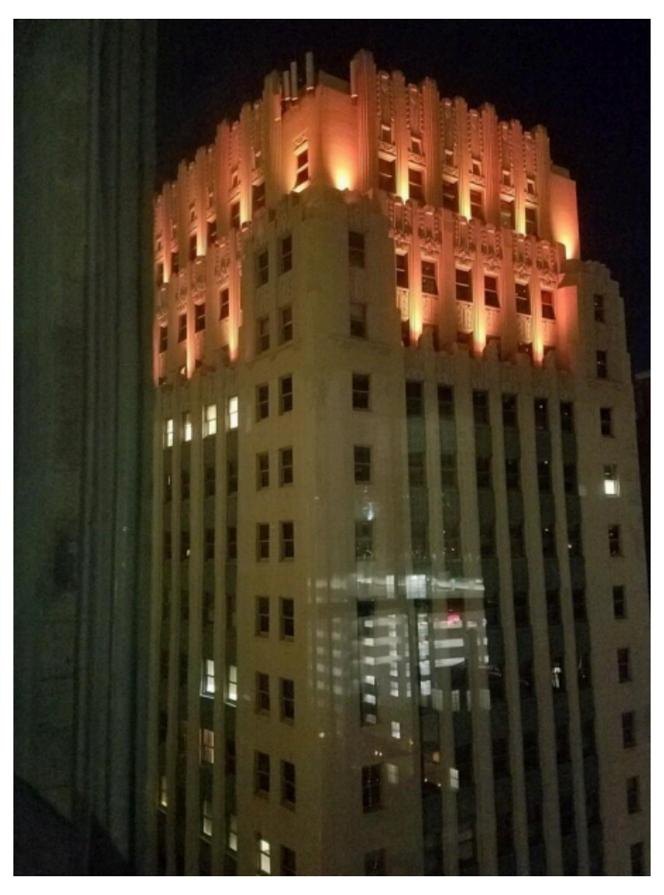
Techno-Economic Analysis

- Results determined from market cost data, grid tariffs, and Monte-Carlo analysis
- First cost is higher for DC
- With significant reliability efficiency savings, the payback period is less than a year

Proposed Demo Sites


Xingye Solar
Shenzhen

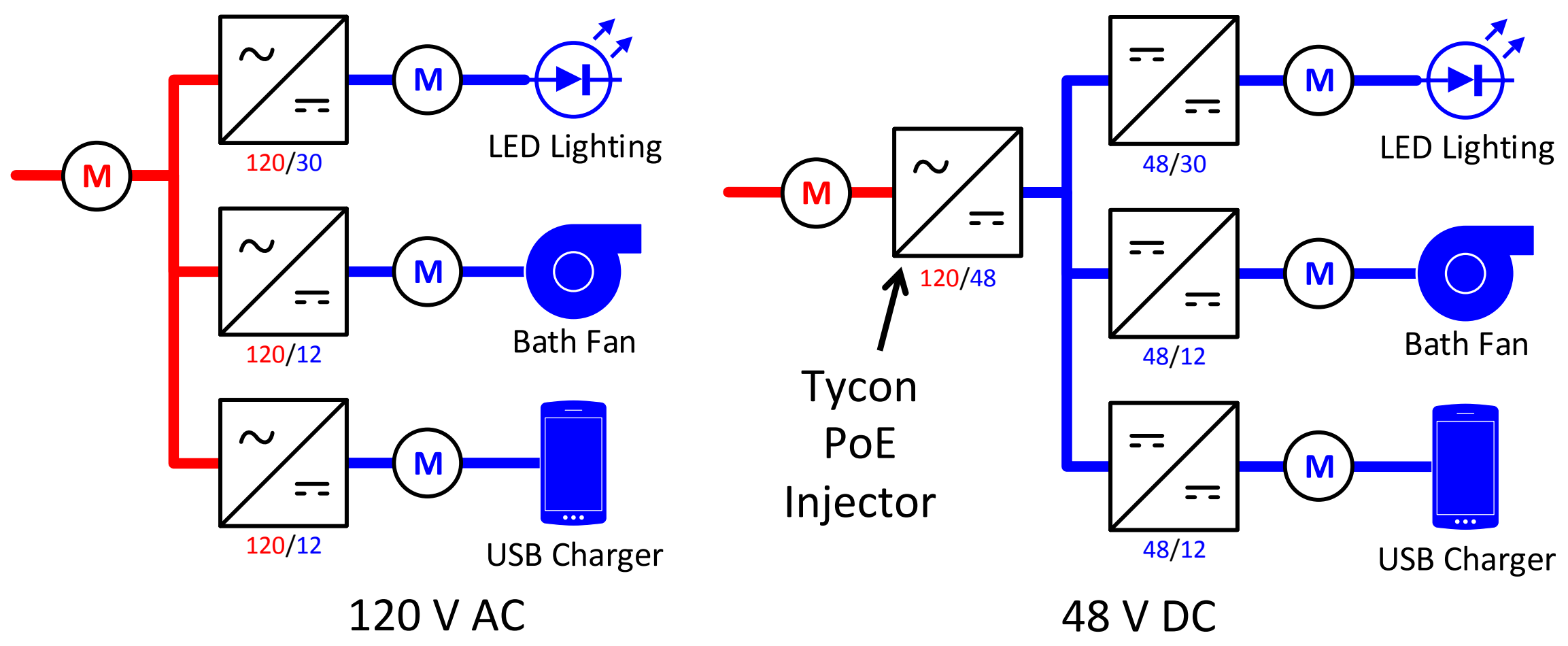

IBEW Building
San Leandro

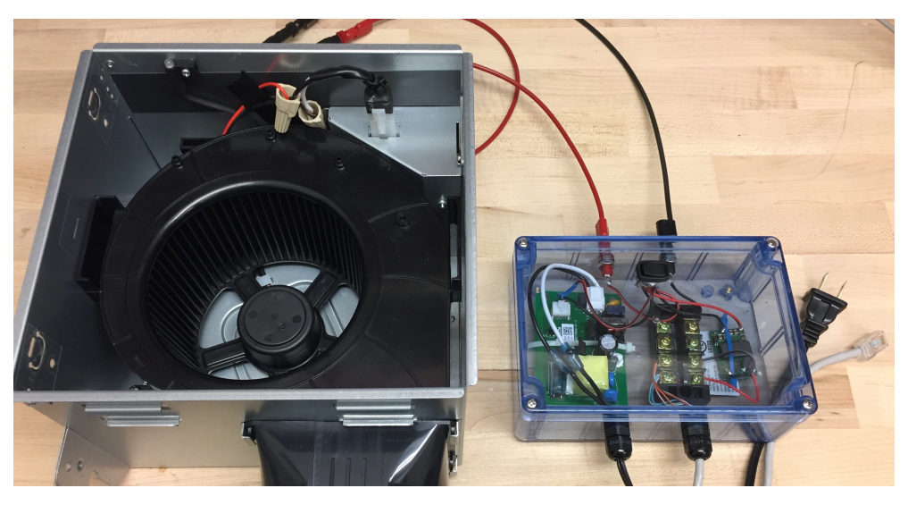

Marriott Sinclair
Fort Worth

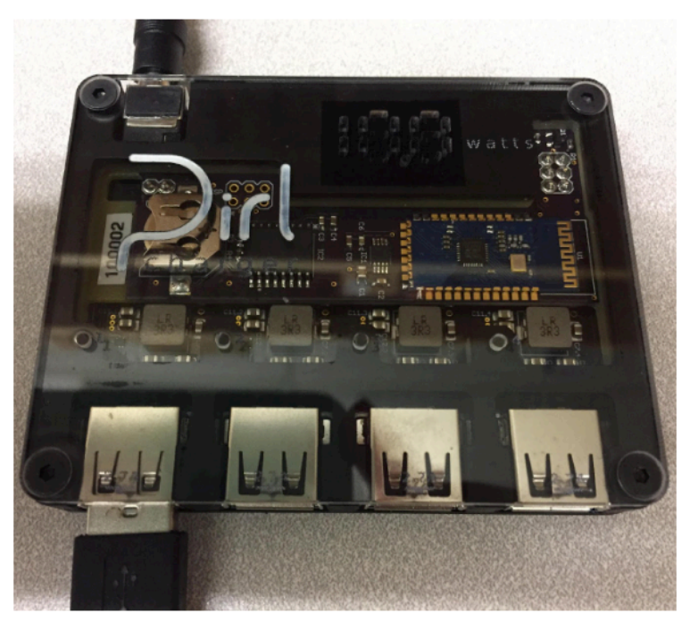

IBR Building
Shenzhen

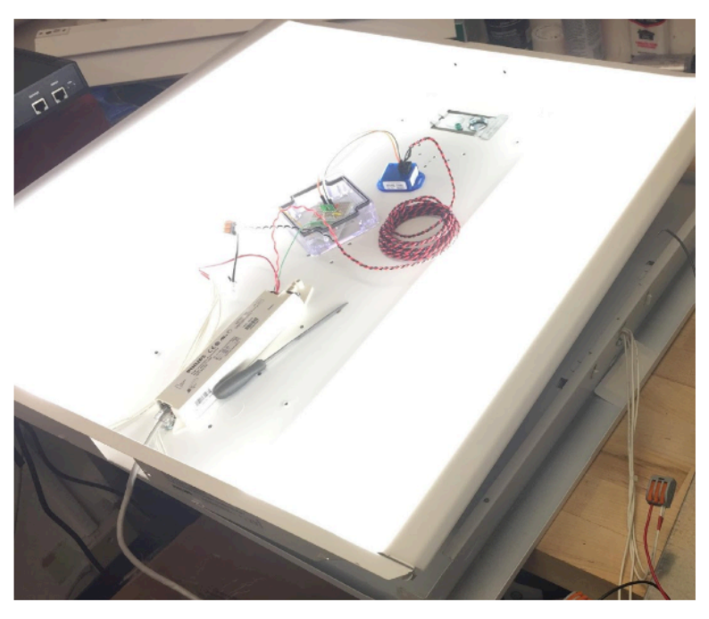
Task 1: Hardware Testing and Verification

- Experimental devices selected to represent major end-uses: lighting, HVAC motor loads, electronics
- Modified power electronics in sample devices to accept 120 V AC or 48 V DC




Bath Fan

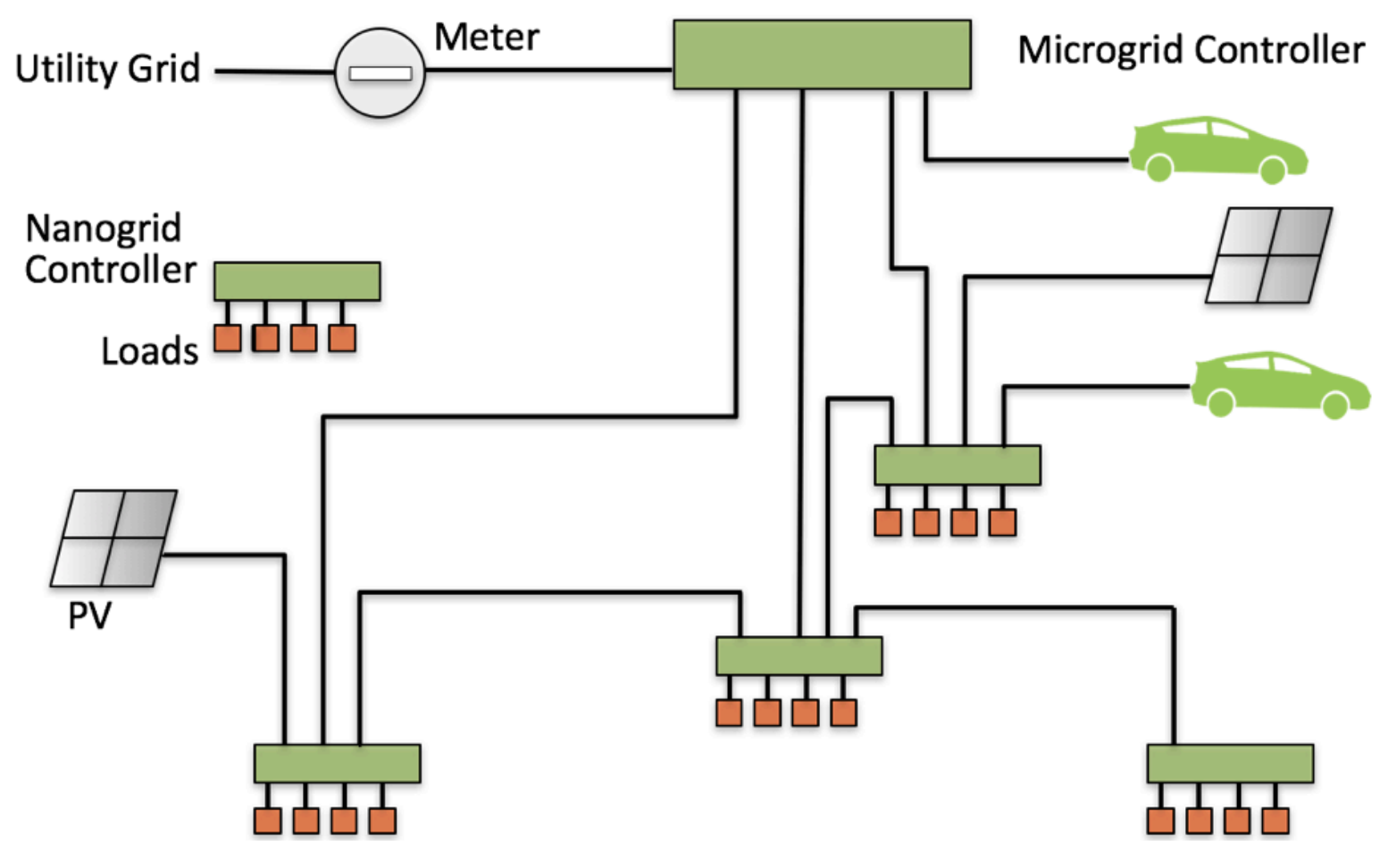

USB Charger


LED Fixture

- Selected devices tested in AC and DC systems with different load configurations
- All results than 3% error - simulation vs. experiment
- Main DC system loss due to the inefficient PoE injector

Experiment	Connected loads	Median measured input power (AC, DC)	Median modeled input power (AC, DC)	Median percent error
Test 1	LED fixture, bath fan	31.4 W 35.2 W	31.2 W 36.1 W	-0.48% 2.45%
Test 2	LED fixture, wall adapter	33.0 W 38.3 W	33.1 W 38.9 W	0.16% 1.61%
Test 3	Bath fan, wall adapter	16.0 W 22.7 W	16.1 W 22.3 W	0.81% -1.92%

Task 2: Local Power Distribution



What

- "Network model of power" – brings principles of Internet system architecture to electricity
  - Only within buildings – does not extend past utility meter
- Organized bottom-up, into "nanogrids", each with local price of electricity
- All power exchange peer-to-peer, digitally managed

Why

- Enables local storage and generation to be truly plug-and-play
- Inherently safe; simple, flexible; inter-building power links
- Creates better value proposition for Direct DC – efficiency gains
- Enables inexpensive microgrids - inexpensive local reliability

Overall Plan

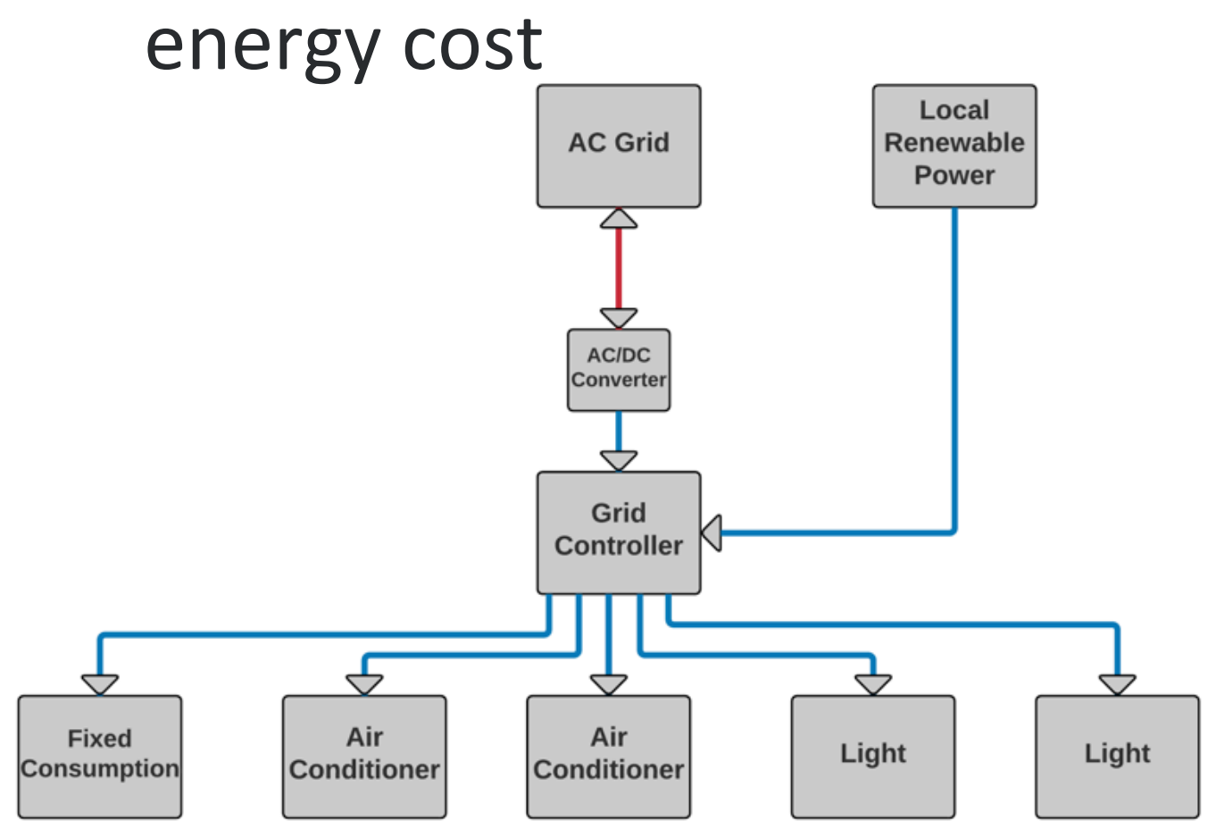
- System architecture → Communication model
- Simulation model → Quantitative benefits
- Hardware → It really works
- Communication model → Technology standards

Market Impact

- Technology standards → **Products**
- Simulation code → **Sample algorithms for industry**

Initial results

- Modeled single, simple nanogrid with 3 tariffs
- Tariffs drive local price, causing different:
  - Use of battery
  - End–use device operation
- Dynamic **local prices** reduce total energy cost



Commercialization

- Local Price Indicator in newest version of Ethernet – IEEE 802.3bt

IEEE

ethernet alliance

Potential Impact

DC Power Distribution

- Reduces electricity use by 5-13%
- Significantly decreases life cycle cost
- Improves safety, power quality, and resilience
- Price-based control creates scalable network organization

Websites

- dc.lbl.gov
- nordman.lbl.gov

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