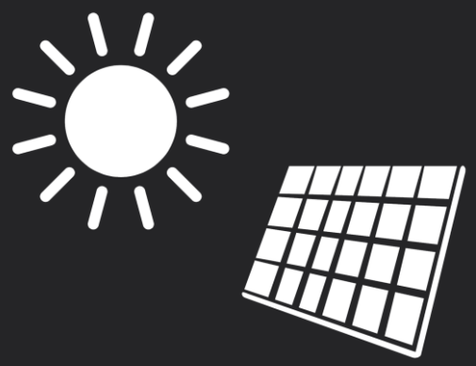
RENEWABLES

Benefits of Using Direct Current Based Power Distribution Architectures for Commercial Buildings for Improved Utilization of On-Site Renewable Energy

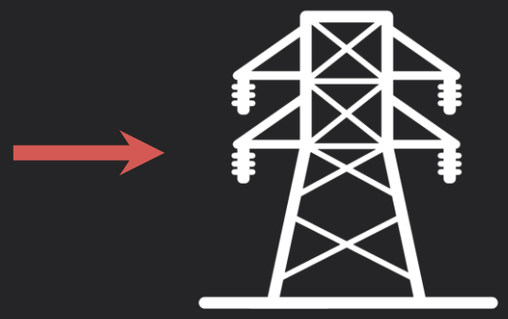
Sharmila Ravula
Director – Business Development

Solar Array



Inverter

2% - 8%

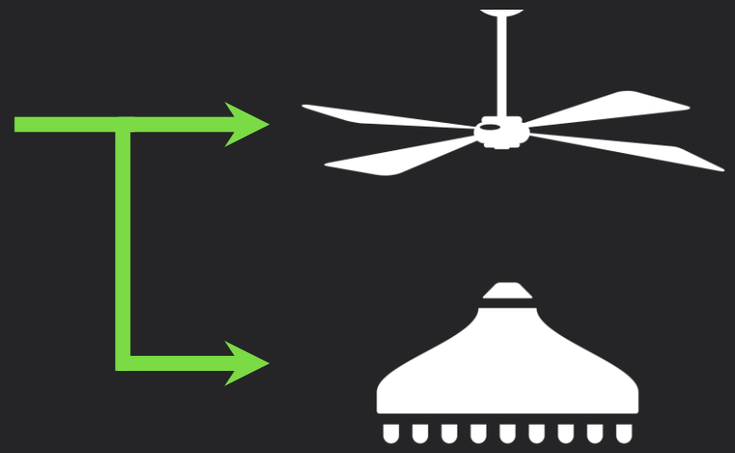


Grid

Conversion Losses

4%

AC Building Loads



Solar Array

Grid

DC Fans

DC Lights

Storage
(optional)

Power
Server

Energy
Management
System

Less Investment

Inherent Islanding

Lower Energy Losses

Prioritization of Loads

Ride Through Blackouts

Fault Tolerance

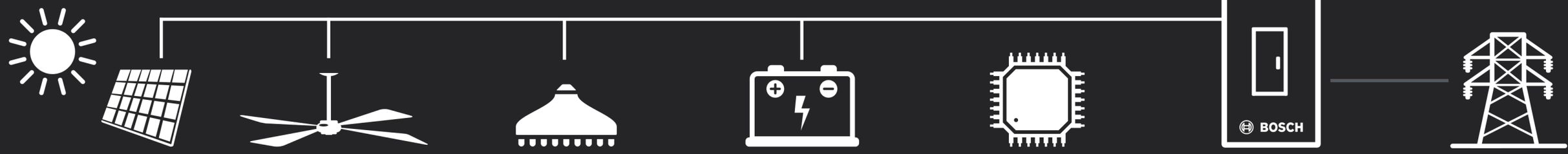
Higher Reliability

Self Healing

Lower Lifetime Costs

Emergency Lighting

Utility Friendly



1) Pilot (Bosch Dev Lab 1.0) Plymouth, MI | 2013 FINISHED
DC Load Size: 3.3 kW

2) Building Scale Demo Charlotte, NC | 2014 FINISHED
DC Load Size: 15 kW

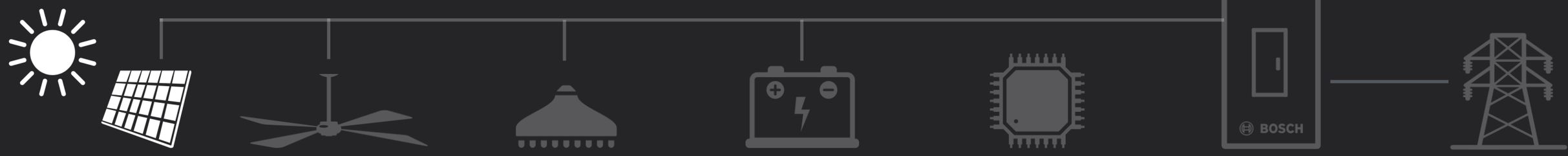
3) DOD Awarded Demo Ft.Bragg, NC | 2015 FINISHED
DC Load Size: 15 kW

4) Bosch Building Installation Plymouth, MI | 2015 UNDERWAY
DC Load Size: 30 kW

5) Bosch Dev Lab 2.0 Mooresville, NC | 2015 UNDERWAY
DC Load Size: 30 kW

6) CEC Awarded Demo (Honda) California | 2016 IN DESIGN
DC Load Size: 150 kW
350,000 sqft

- 15kW DCMG Array
- 15kW AC Reference Array

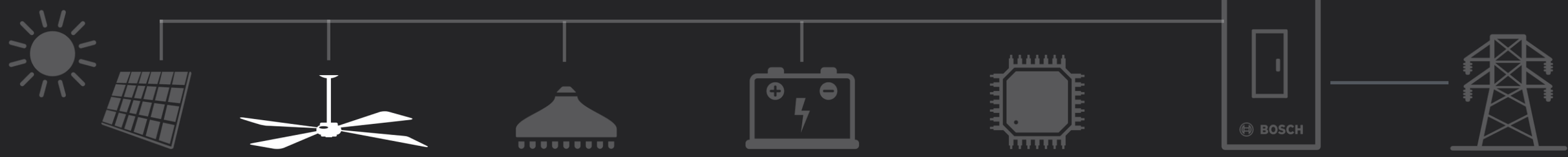


DOD Bosch DC Fan Installation

Nov 16th, 2015

- 4 Bosch Drive DC Fans
- 18’ Diameter
- Solar Powered

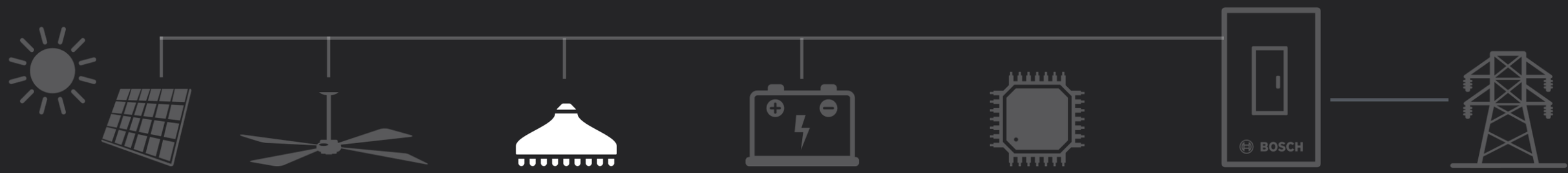
  (operates over wide voltage range)



DOD Bosch DC Light Installation Nov 16th, 2015

- 44 Bosch DC Induction Lights
- 260W Constant Power Output
- Solar Powered

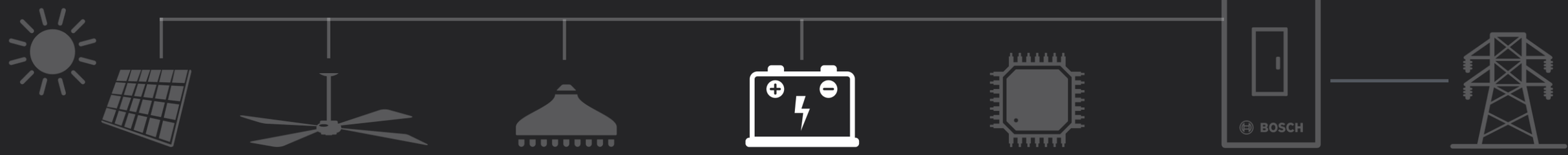
  (operates over wide voltage range)



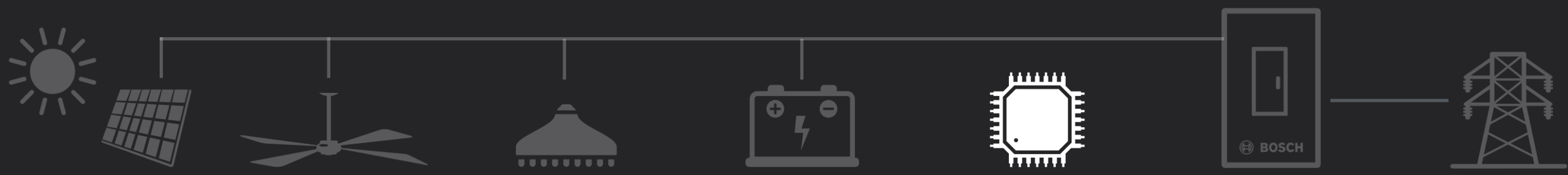
DOD Bosch Energy Storage Installation

Nov 16th, 2015

- 100 kWh Storage
- Power Backup
- Demand Response
- Peak Load Shaving
- Load Shifting



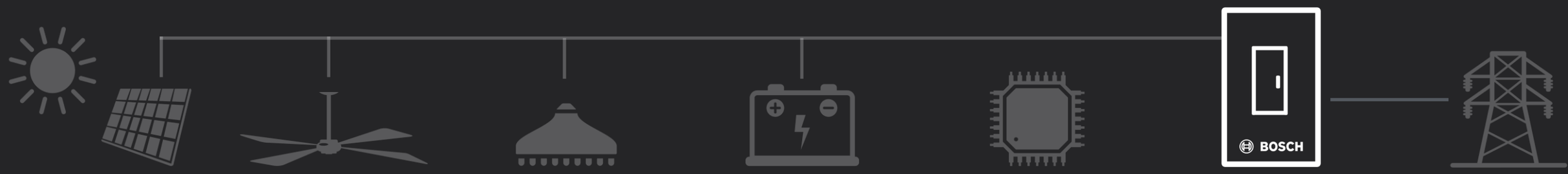
- Local & Remote Control
- Mobile Access
- Cloud Based Monitoring & Control
- Alerting (off normal / critical)
- Load Prioritization



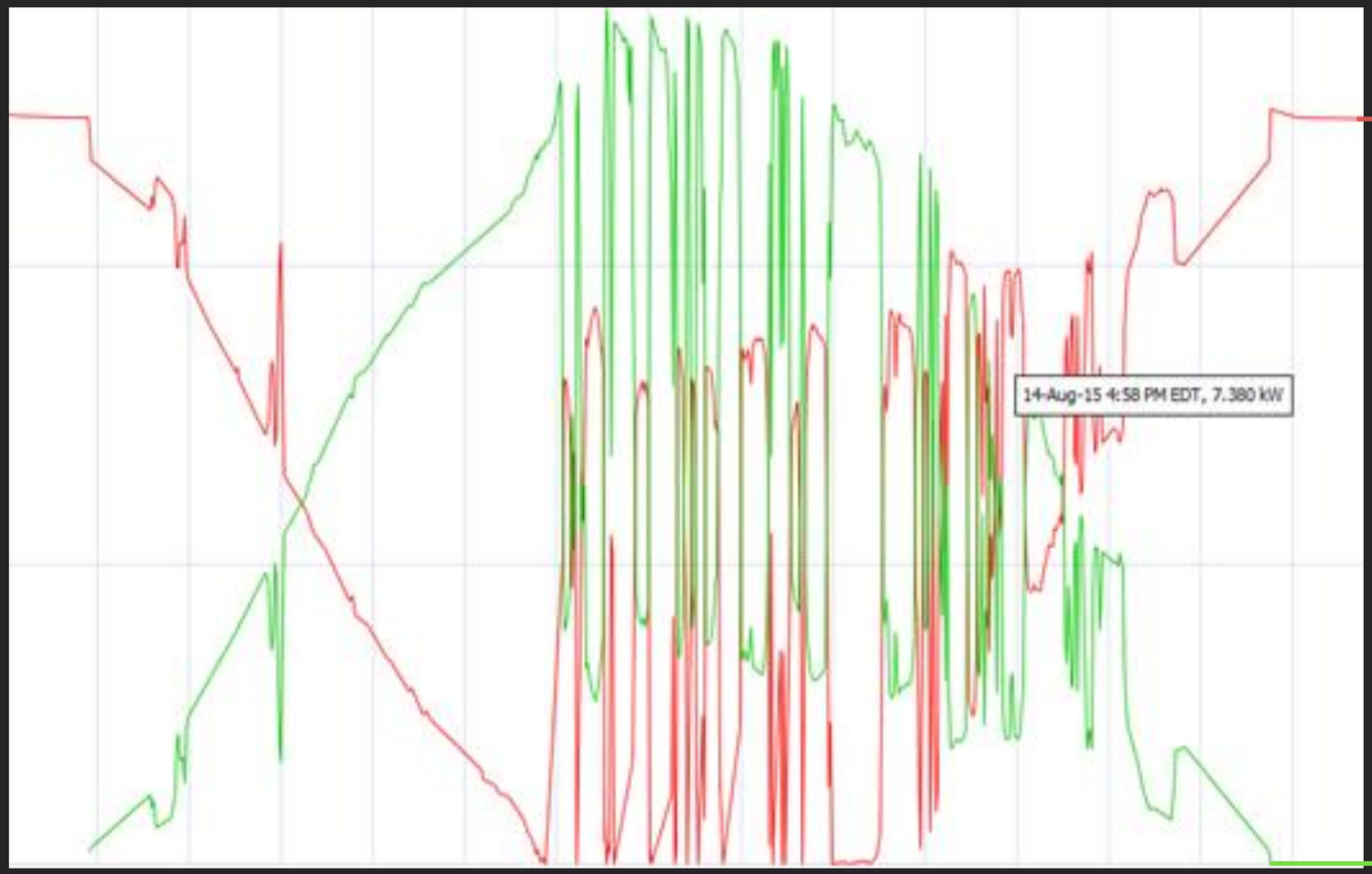
Bosch Power Server

October 2, 2015

- 30kW Power Output
- N+1 Configuration
- Networked
- Solar Input
- MPPT
- Wall Mountable

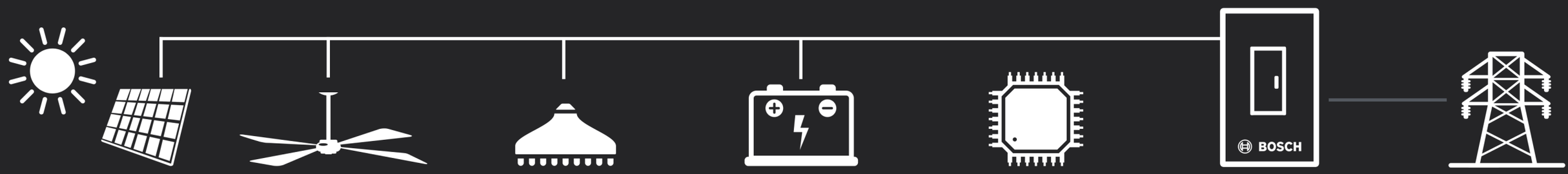


7am noon 7pm

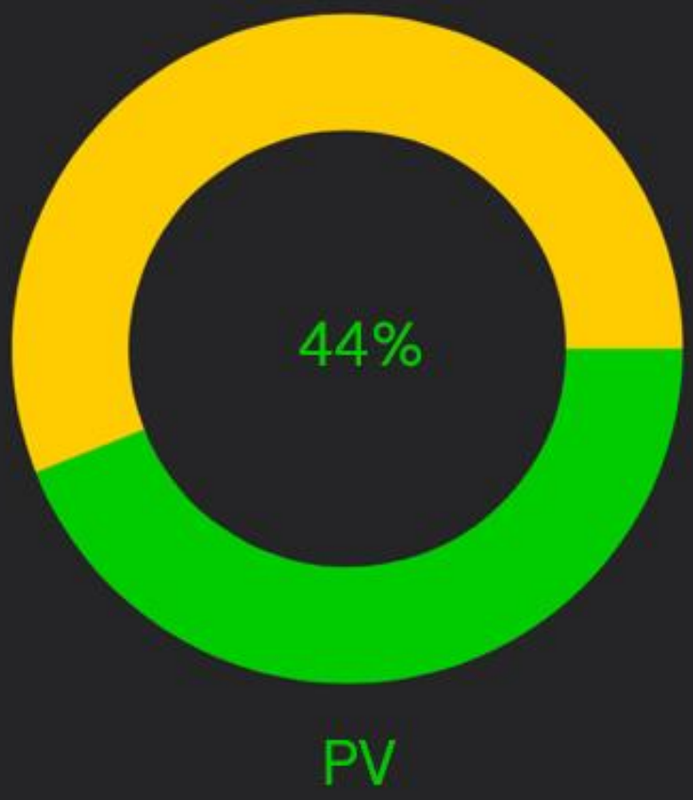


Grid Power

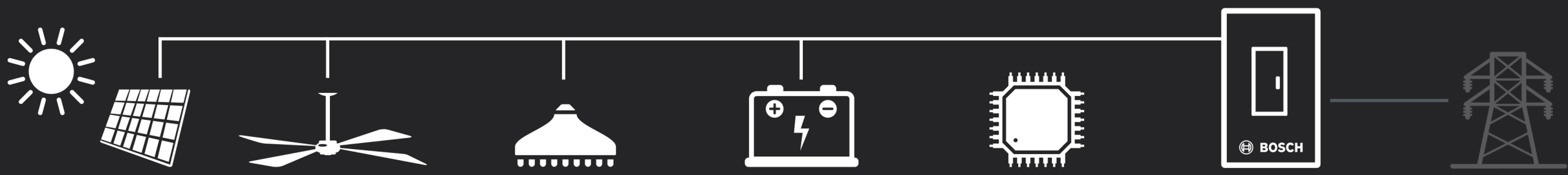
Solar Power



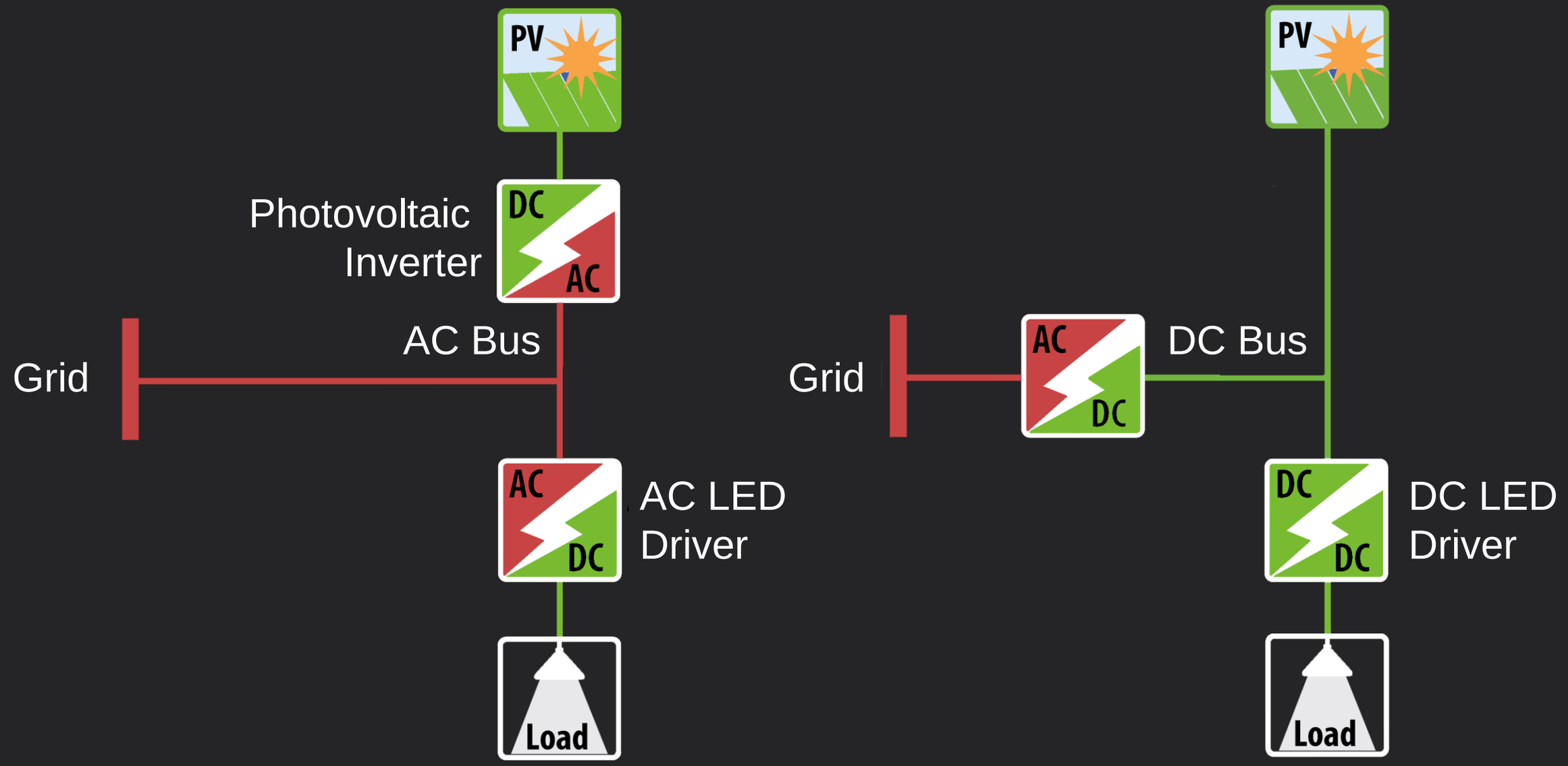
DC Load Power Sources



	Long-Term AC Losses	Long-Term DC Losses	Long-Term AC vs. DC
	Total 12.5%	Total 3.0%	Total 9.5%
Real-Time AC Losses	Lights 7.0%	Lights 3.0%	
	Inverter 4.3%	Inverter 5.5%	



Analyze Energy Performance
Bosch DC Microgrid vs. Equivalent AC Microgrid



Conventional AC Technology

DC Microgird

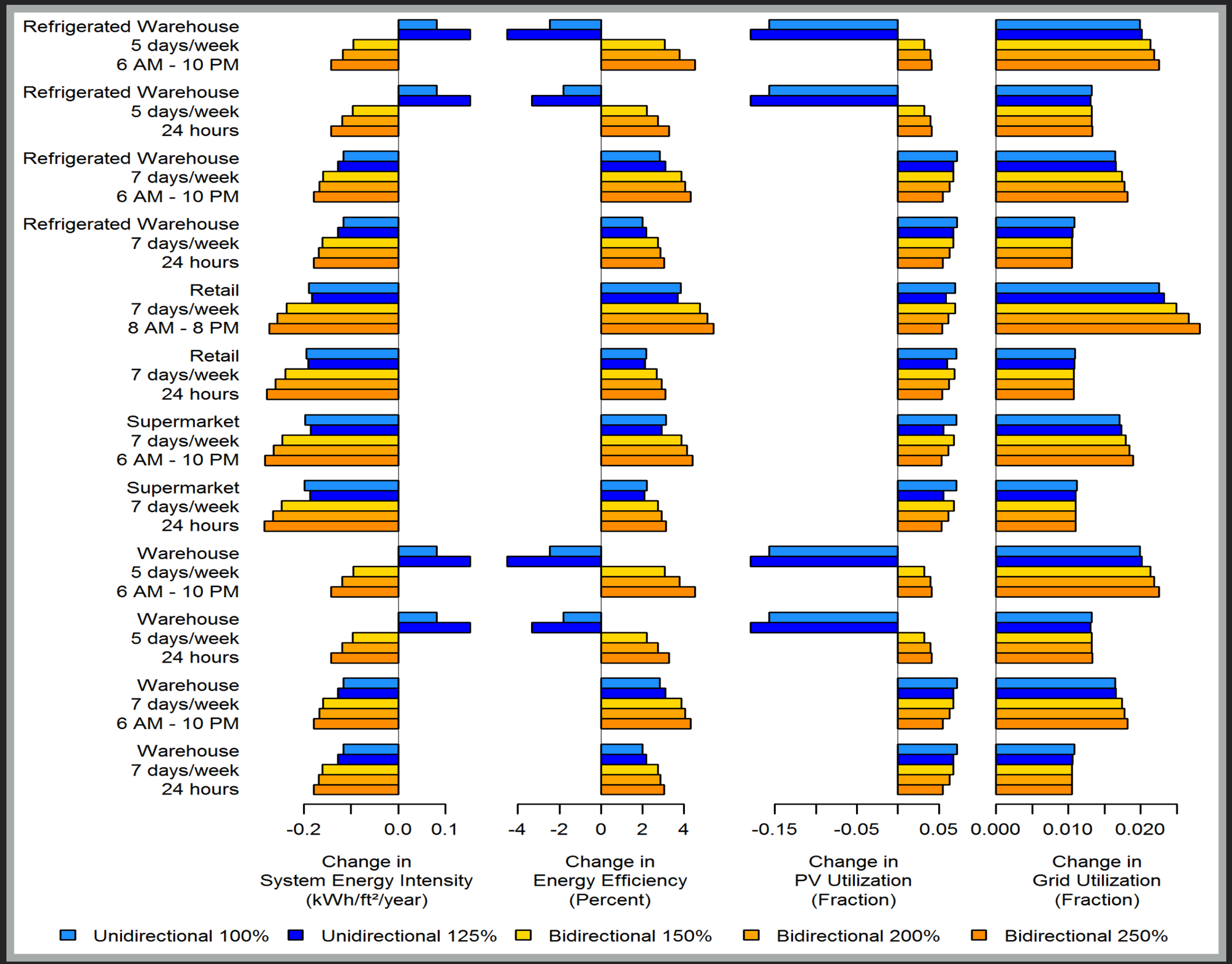
DCMG Type \ Array Size[a]	100%	125%	150%	200%	250%
Unidirectional DCMG	✓	✓			
Bidirectional DCMG			✓	✓	✓

Schedule \ Building	Retail	Supermarket	Refrigerated Warehouse	Non-Refrigerated Warehouse
6 a.m.–10 p.m. 5 days/week			✓	✓
6 a.m.–10 p.m. 7 days/week		✓	✓	✓
8 p.m.–8 p.m. 7 days/week	✓			
24 hours/day 5 days/week			✓	✓
24 hours/day 7 days/week	✓	✓	✓	✓

Building Type	PV Size
Retail	99kW
Supermarket	45kW
Warehouse	27kW

Solar World SW 270 Monocrystaline

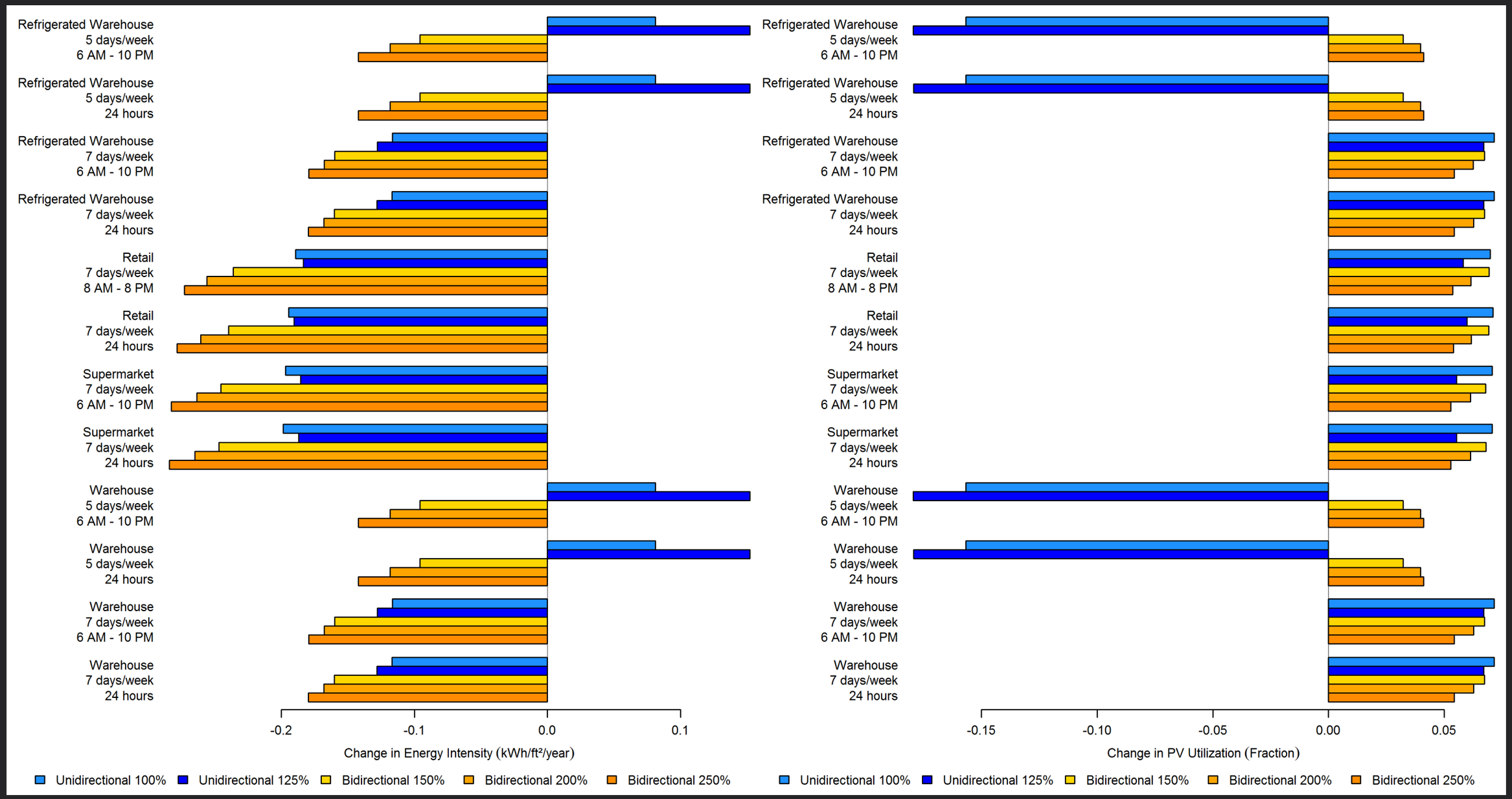
DCMG Compared to AC Baseline



Lighting System Energy

Change in Energy Intensity (kWh/ft²/year)

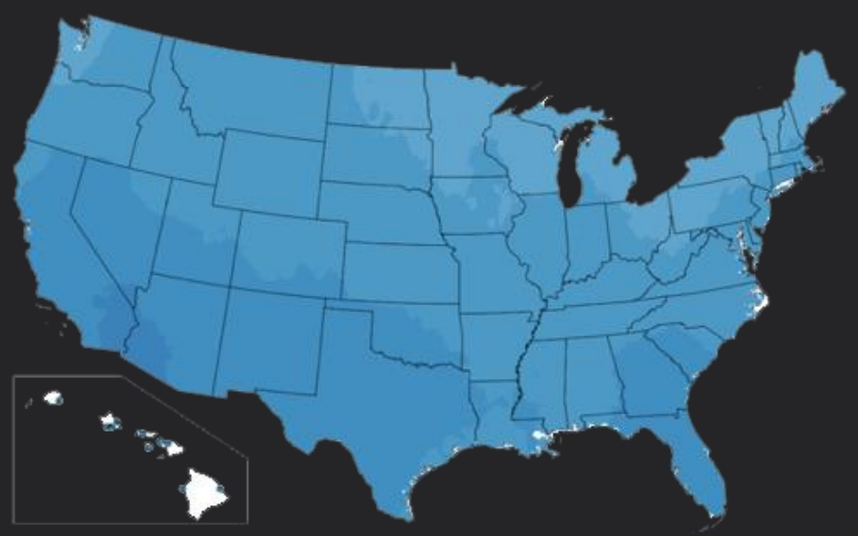
Change in PV Utilization (Fraction)



Performance Map: Lighting System

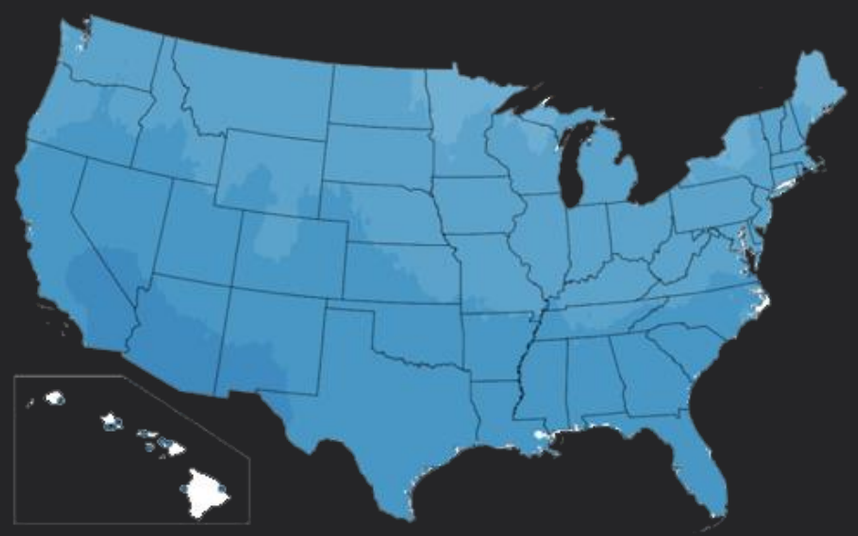
Nov 16th, 2015

Change in Annually Energy Intensity



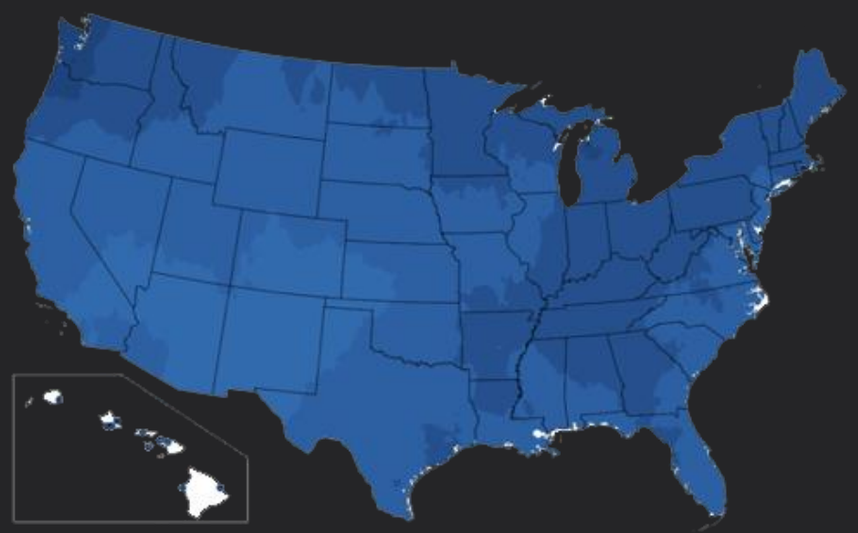
-0.20 Change in Energy Intensity (kWh/ft²/year) 0.20

Change in System Energy Efficiency



-4.75% Change in Energy Efficiency (%) 4.75%

Change in PV Utilization



-0.085 Change in PV Utilization (Fraction) 0.085

Change in Grid Utilization

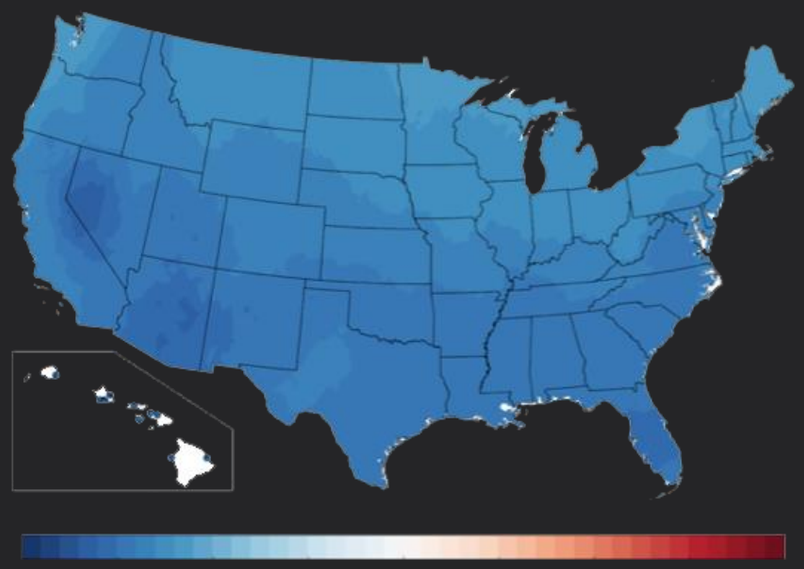
-0.0220 Change in Grid Utilization (Fraction) 0.0220

Warehouse, 6AM-10PM Operation, 7 days/week, Unidirectional DCMG, 100% Nominal Array Scaling Factor

Performance Map: Site Total Energy

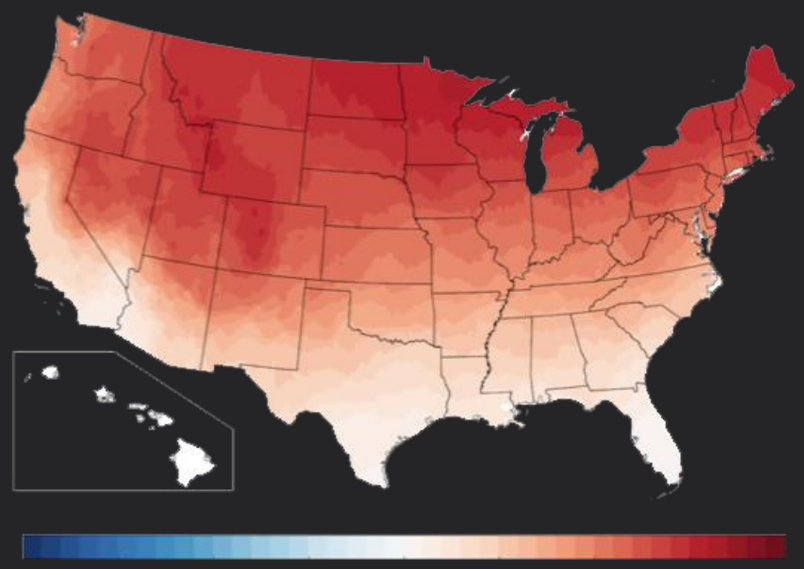
Nov 16th, 2015

Change in Site Electricity Intensity



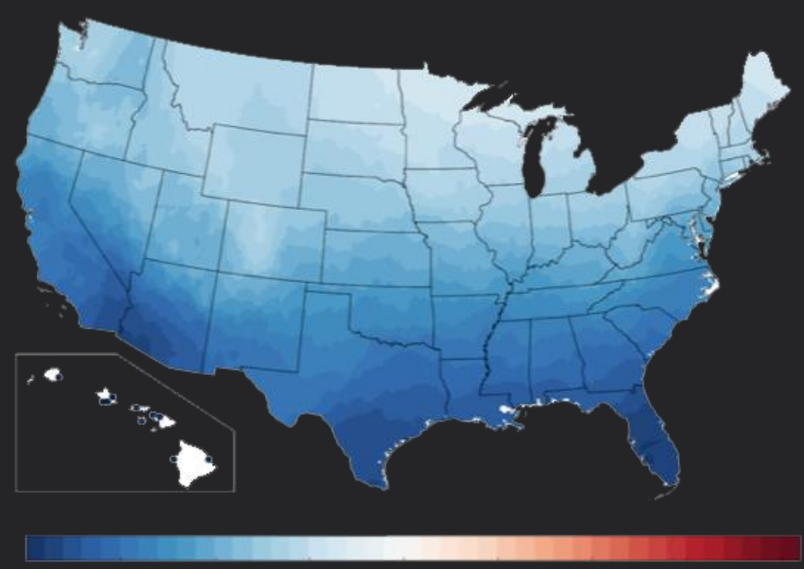
-0.26 Change in Site Electricity Intensity (kWh/ft²/year) 0.26

Change in Site Natural Gas Intensity



-0.51 Change in Site Total Energy Intensity (kBtu/ft²/year) 0.51

Change in Site Total Energy Intensity



-0.7 Change in Site Total Energy Intensity (kBtu/ft²/year) 0.7

DCMG Saves Energy in All Climate Zones

*Greatest impact in heavily air-conditioned regions due to reduced losses
(losses that introduce additional heat into the building)

Warehouse, 6AM-10PM Operation, 7 days/week, Unidirectional DCMG, 100% Nominal Array Scaling Factor

Sharmila Ravula
Robert Bosch LLC
Director – Business Development

Address
4009 Miranda Avenue
Palo Alto, CA 94022

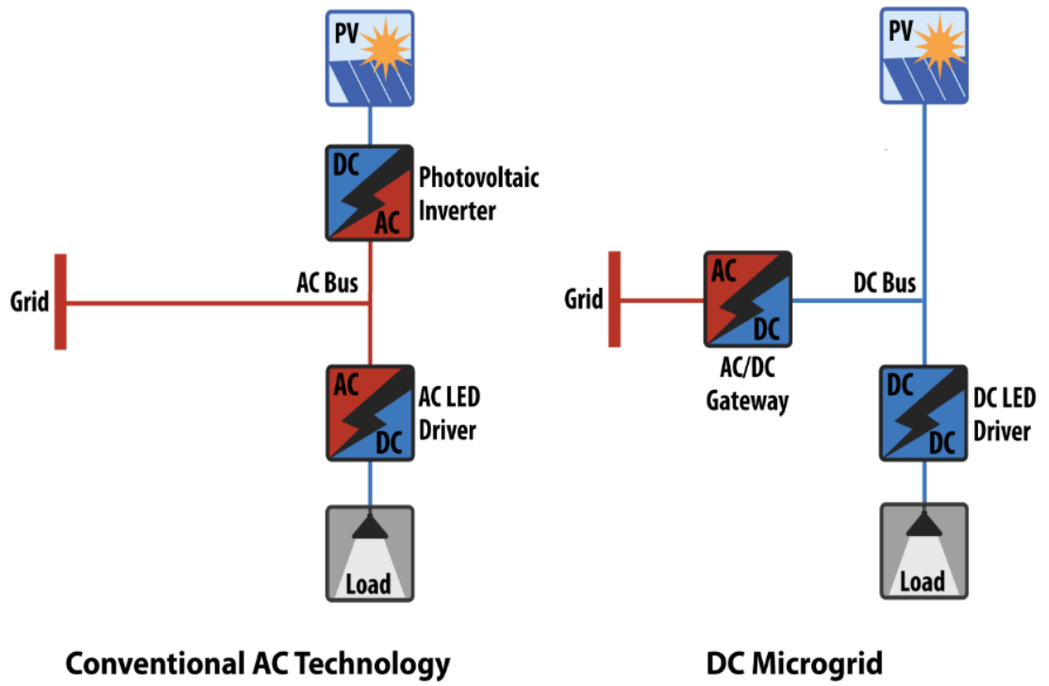
E-Mail
Sharmila.ravula@us.bosch.com

Phone
(650)852-2251

BACKUP

Performance Metrics

- NREL computed seven key performance metrics for each simulated case:
- *High bay lighting system:*
  - ***grid energy intensity:*** *kWh/ft^2/year*
  - ***energy efficiency:*** total output (load) energy/total input (source) energy
  - ***PV utilization fraction:*** the fraction of PV energy that is either delivered to the load or exported to the electric grid
  - ***Grid utilization fraction:*** the Fraction of grid energy that is delivered to the load

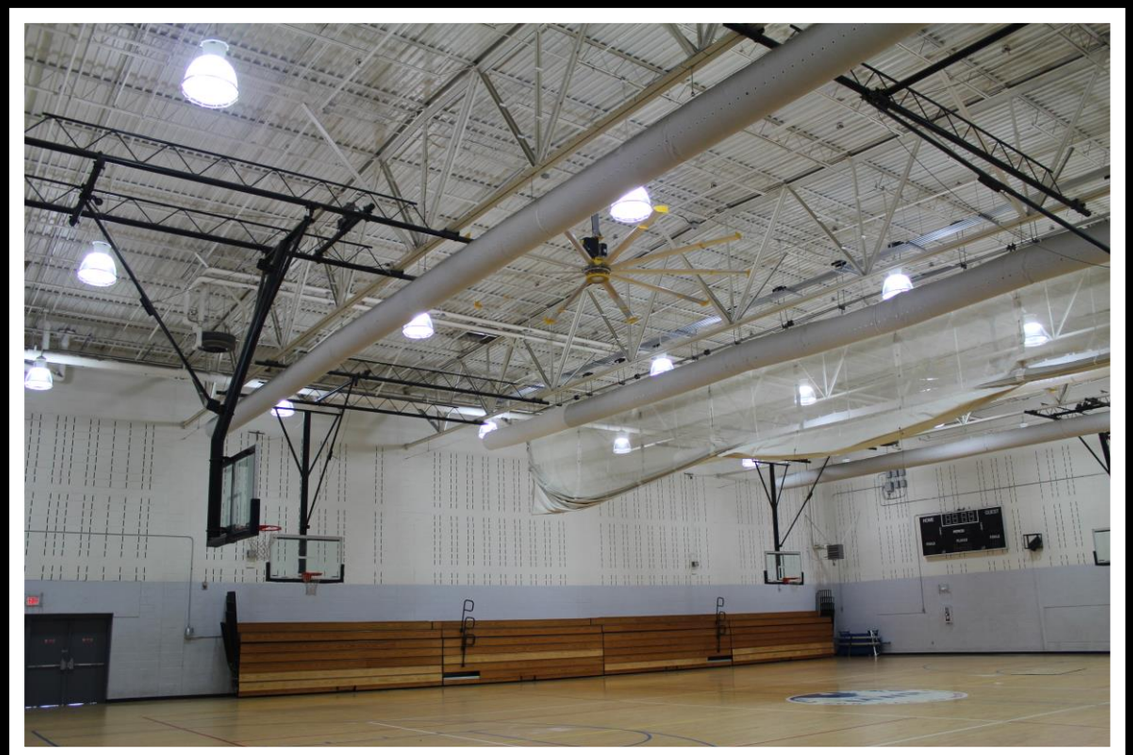


Performance Metrics

- *Site*
  - ***change in electricity intensity:*** change in net annual site electricity consumption (includes electric cooling)
  - ***change in natural gas intensity:*** change in annual site natural gas consumption (for additional heating)
  - ***change in total energy intensity:*** change in total net annual site energy consumption for the DCMG compared to the AC baseline (kBtu/ft^2/year)

DOD DCMG Up & Running

October 2, 2015



Gymnasium

Weight Room