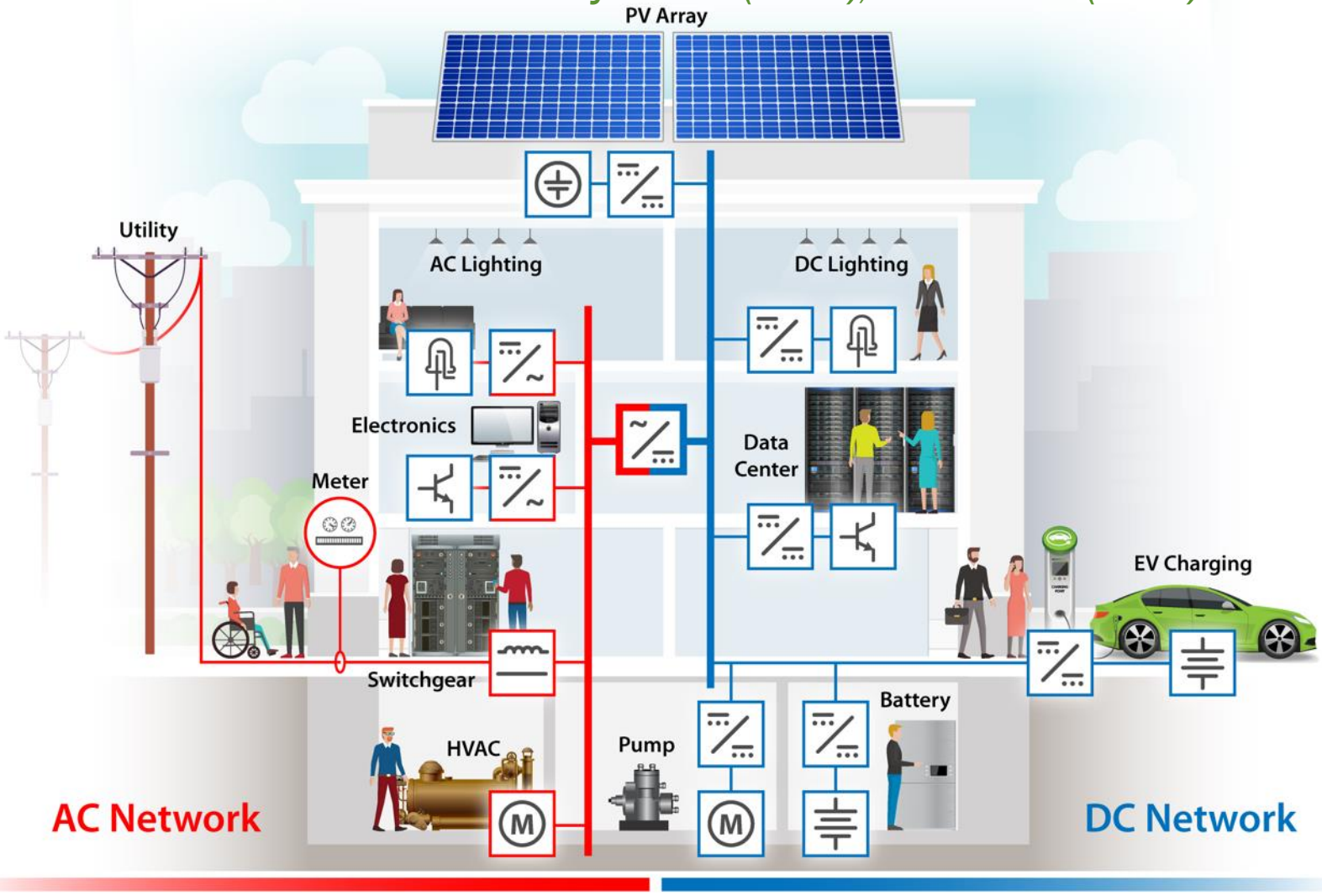
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Building-Level DC Distribution Systems

NREL (WBS# 2.2.2.40) and LBNL: (WBS# 2.2.2.46)

Willy Bernal (NREL), Rich Brown (LBNL)



Project Summary: NREL (WBS# 2.2.2.40) and LBNL: (WBS# 2.2.2.46)

Timeline:

Start date: October 1, 2018

Planned end date: September 30, 2021

Key Milestones:

1. Project Work Plan; 12/15/2018
2. Establish performance metrics and measurement methods; 9/30/2019

Key Partners:

⇒ eMerge Alliance

⇒ GSA

⇒ American Geophysical Union

Budget:

Total Project $ to Date: $45,244

- DOE: $33,244
- Cost Share: $12,000

Total Project $: 2,395,000

- DOE: $2,200,000
- Cost Share: $195,000

Project Outcome:

Quantify the performance of DC distribution systems in buildings and further validate energy models for electrical distribution systems in buildings. Accelerate the development and adoption of DC distribution technology by identifying technical barriers for installing, operating, and maintaining DC distribution systems and documenting targeted future research and development needs to overcome these challenges.

Team

Michael Deru
Mechanical engineer with expertise in integration and validation of high efficiency building systems

Willy Bernal
Electrical engineer with expertise on benchmarking emerging green technologies and microgrids configuration and operation

Stephen Frank
Electrical engineer focused on controls and optimized electricity distribution systems for buildings

Omkar Ghatpande
Electrical engineer with expertise in design and manufacturing of renewable power distribution systems

Richard Brown
Systems engineer with expertise in integration and validation of networked controls and power systems in buildings

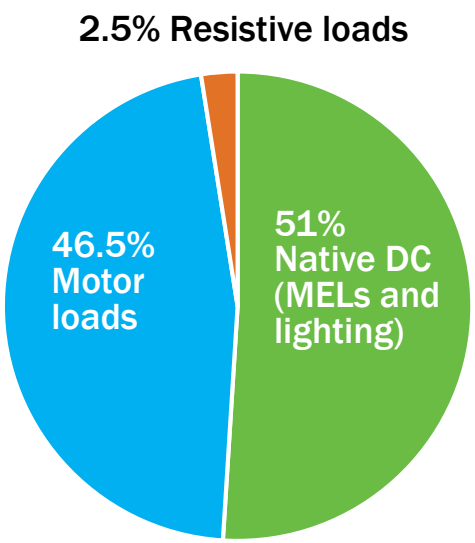
Bruce Nordman
Architect focused on networked controls and local power distribution in buildings

Vagelis Vossos
Physicist focusing on efficiency versus cost-effectiveness in building systems and equipment, with several publications on DC systems.

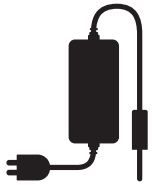
Daniel Gerber
Electrical engineer with expertise modeling and prototyping efficient power electronics for DC power

Challenge

- Buildings use alternating-current (AC) power distribution systems
- Most equipment uses direct-current (DC) electricity internally
- AC-to-DC converters are required at each device
- Expanding use of DC loads and sources in buildings
- Conversion stages and equipment incur in energy losses and maintenance cost
- 5.6 million commercial buildings in the US in 2012



Commercial Building Electrical Loads

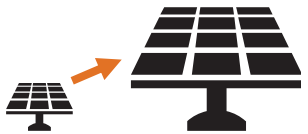


80%

Electricity will flow through **power electronics converters** by 2030

14%

Average **AC-DC conversion loss**



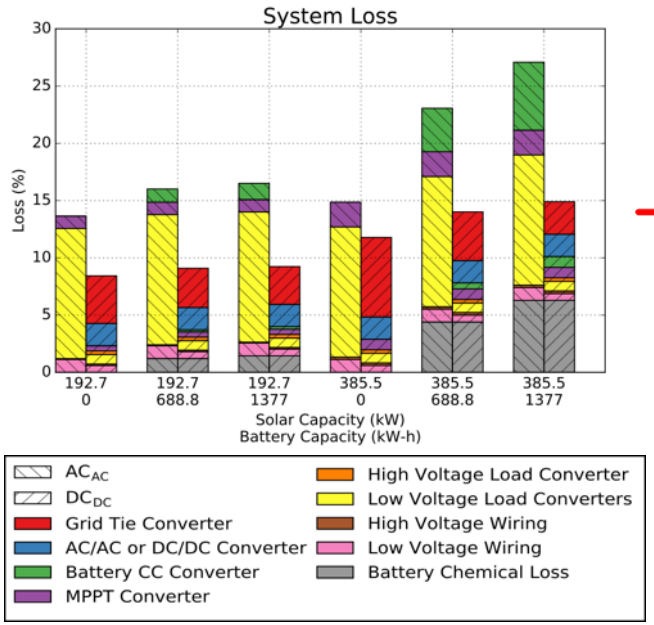
2.5x

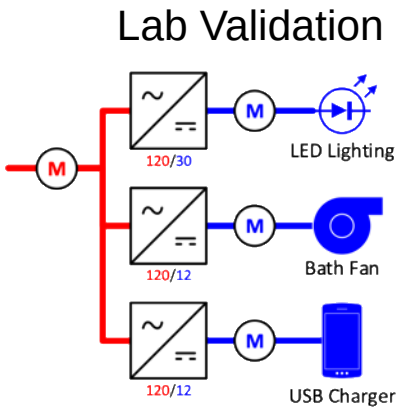
Growth in PV installations from 2012 to 2017

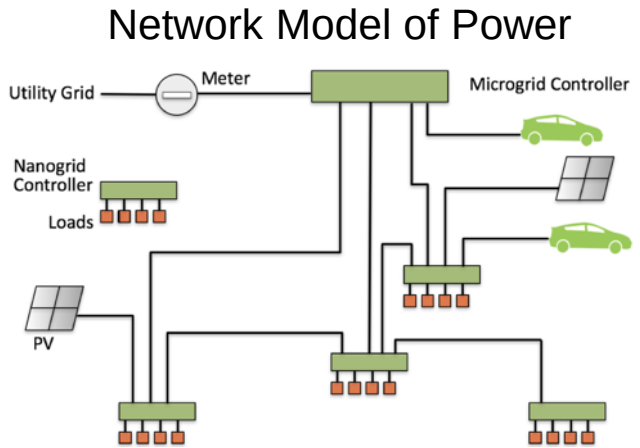
Sources: EIA (2012); DOE Power America website (2018); Garbesi, Vossos, and Shen (2011); Perea et al. (2018)

Related BTO-Funded Projects on DC Power

- **US-China Clean Energy Research Center (CERC) Smart Grid & DC Power (FY16-FY20)**
  - Model energy savings from DC power and validate with lab measurements
  - Conduct techno-economic analysis of DC systems and their life-cycle performance
  - Analyze savings and benefits from communications and control in networked DC systems
  - Transfer results to global technology standards







- **DC Design Tool (NREL-led, FY18-FY20)**
  - Develop simulation-based design tool for comparing AC and DC building distribution
  - Validate models with lab measurements, including indirect effects on internal gains

Approach

Define challenges and opportunities to overcome the technical and market barriers.

Lead: LBNL

Develop metrics and methods to accurately and comprehensively quantify the performance of electrical distribution systems

Lead: NREL

Field validation of DC distribution systems to reduce the uncertainty for DC systems and make recommendations for improved performance

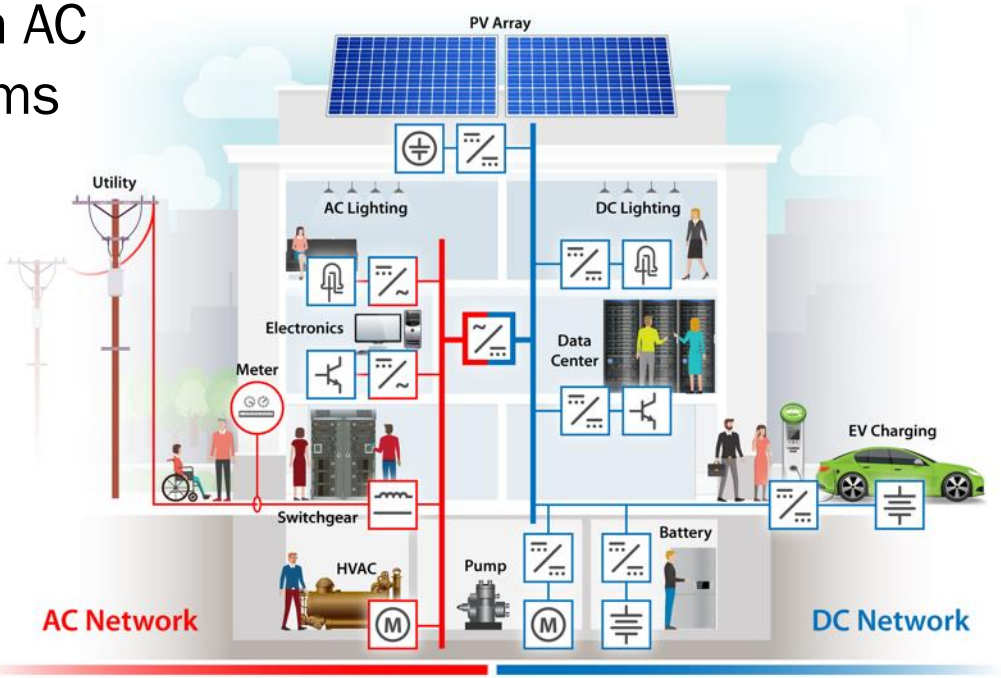
Lead: NREL

Approach: Task 1 – Define challenges and opportunities

a. Challenge:

Uncertainties in changing from AC to DC power distribution systems

⇒ Design and implementation
⇒ Energy and cost performance
⇒ Availability and performance of DC products
⇒ Lack of DC standards
⇒ Lack of proven performance



b. Mitigation:

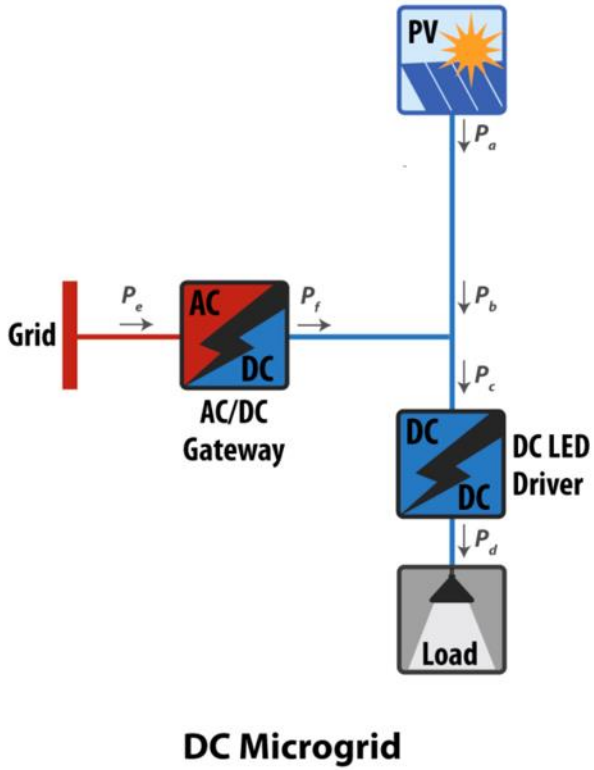
We will work with our partners and the industry to clearly define the state of the industry and the challenges and opportunities

Approach: Task 2 – Develop metrics and methods

a. Performance predictions for DC systems vary widely and are based on
   - ⇒ Inconsistent assumptions
   - ⇒ Poor measurement and analysis approaches
   - ⇒ Questionable claims
   - ⇒ Conflicting results

b. We will define clear and consistent
   - ⇒ Performance metrics for energy and non-energy benefits
   - ⇒ Measurement methods
   - ⇒ Analysis methods

c. We will build on previous research of DC system



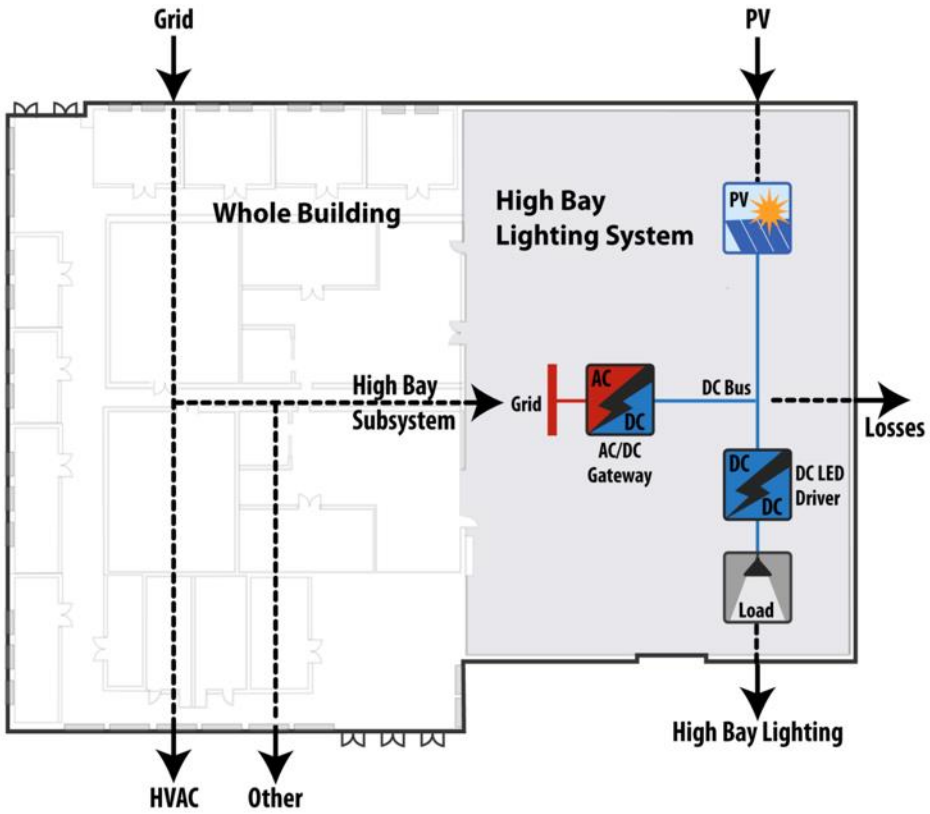
DC Microgrid

Source: Illustration by Marjorie Schott, NREL

Approach: Task 3 – Field validation of DC systems

Validating performance in real buildings will reduce the uncertainty and risks for building owners, utilities, policy makers, and manufacturers

⇒ 2 to 4 Field Evaluation Sites
⇒ New or existing DC distribution power-system installations



Source: Illustration by Marjorie Schott, NREL

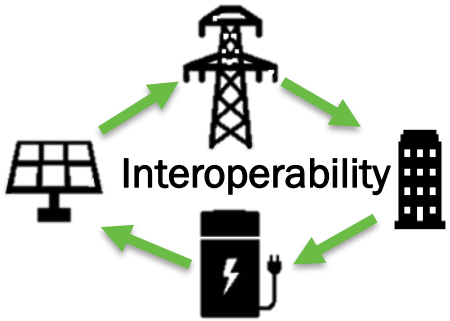
Impact

This project will help define the benefits of DC power distribution systems in buildings and accelerate its adoption.

Energy Savings

3%-5% building electricity savings for buildings with no on-site renewables or storage

11%-18% buildings with onsite renewables or storage



DC electrical system more adept to connect with renewables and batteries

Installation/Maintenance

Increase reliability due to reduced number of conversion stages and thus equipment

Operator Safety

Low voltage circuits for lighting and plug loads are safer for operators and maintenance staff

Progress

We have completed six months of a three year project and are on track with our milestones and deliverables.

Task 1

- ☑ Completed some background research
- ☑ Developed outline and started preparing the draft report due to DOE 6/30/2019

Task 2

- ☑ Completed some background research: reviewed 20+ articles and reports.
- ☑ Developed outline and started preparing the draft report due to DOE 6/21/2019

Task 3

- ☑ Developed a site selection criteria for working with GSA and have a list of potential field validation sites
- ☑ Working with American Geophysical Union to prepare for monitoring and validation of their building:

Stakeholder Engagement

Industry association leading the adoption of DC power distribution in commercial buildings

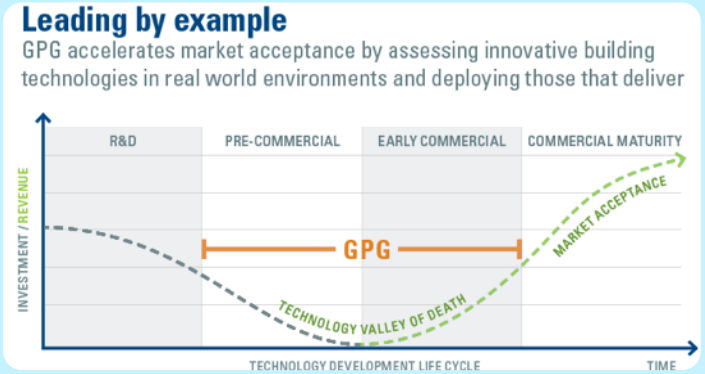
- ⇒ More than 100 member organization
- ⇒ Develops technical application standards

Federal building manager and field validation partner

- ⇒ Assess innovative tech in real world environment
- ⇒ Accelerates market acceptance

Field validation partner in their net zero building retrofit

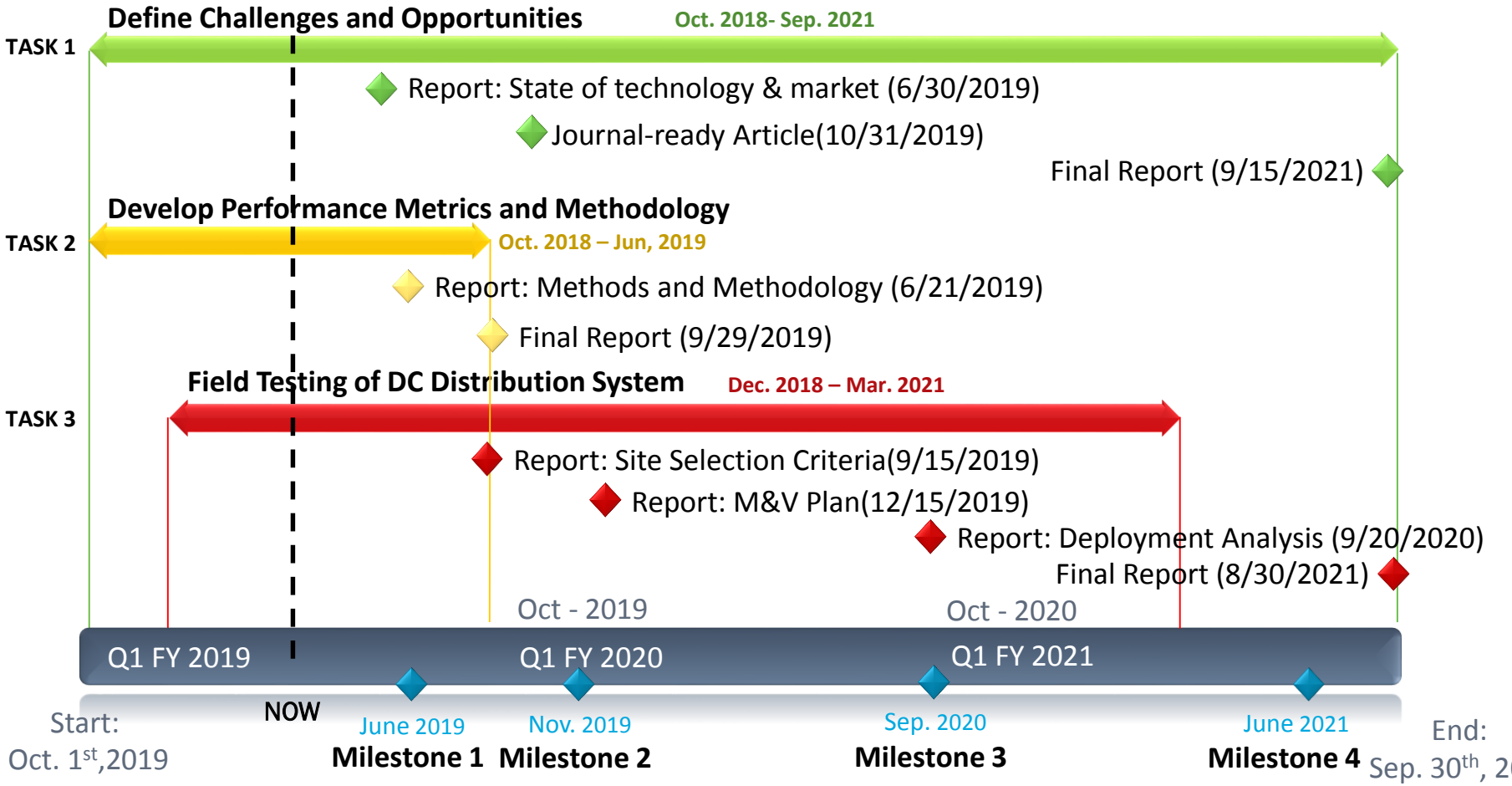
(Source: Emerge Alliance)



(Source: GSA/GPG)


(Source: AGU100)

Remaining Project Work



Major Milestones:

M1. Complete development of performance metrics and measurement methods for electrical distribution systems

M2: Identify at least two field test sites and develop project M&V plans

M3: Preliminary report on performance for technologies and test sites

M4: Report on opportunities for improved performance and energy savings for DC distribution systems

Thank You

NREL Transforming ENERGY

Willy Bernal

720-326-0841

willy.bernalheredia@nrel.gov

BERKELEY LAB

Richard Brown

510-486-5896

rebrown@lbl.gov

REFERENCE SLIDES

Project Budget

⇒ **Project Budget: Table below**
⇒ **Variances: Project on track**
⇒ **Cost to Date: $49,000**
⇒ **Additional Funding: None.**

Budget History					
Oct. 1st 2018– FY 2019 (current)		FY 2020 (planned)		FY 2021 – Sept. 30th 2021 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$725,000	$65,000	$750,000	$65,000	$725,000	$65,000

Project Plan and Schedule