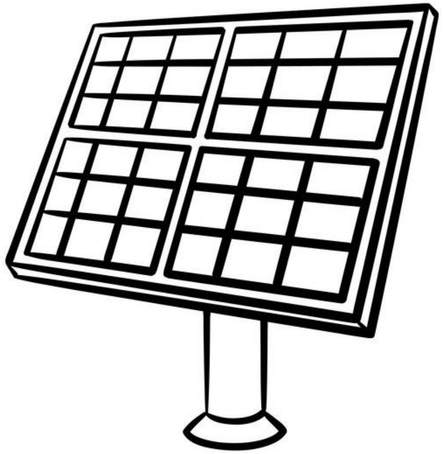
Grid-Interactive, Resilient Lighting and Plug Load Management System Using DC Power



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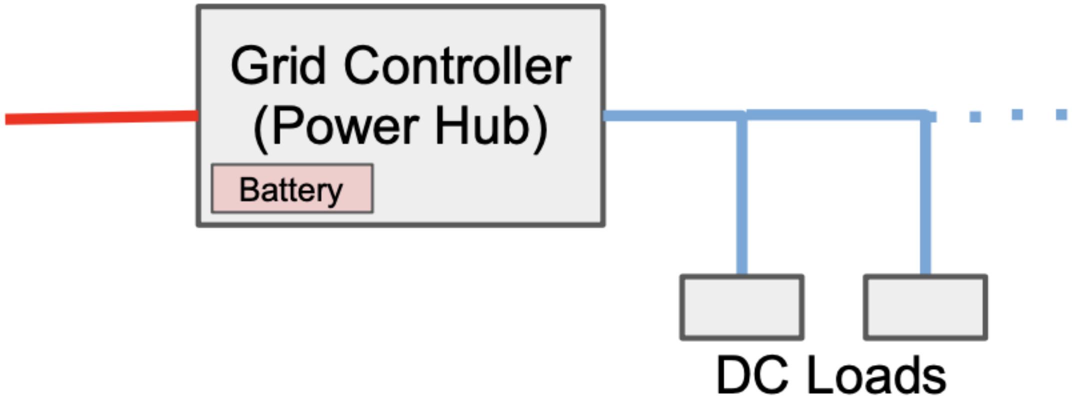
WBS # 3.2.6.84

Project Summary

Objective and outcome

- Develop **power distribution and control system based on updated DC power and communication standards**.
- New power distribution architecture allows significantly higher power levels at lower cost than current standards such as PoE.
- Satisfy building occupant and grid needs through predictive modeling and control to manage power flows.



Team and Partners

LBNL – *Standards, storage analysis, benchtop demonstration*

Legrand North and Central America – *Use cases, predictive control, market analysis* (**CRADA partner**)

Stats

Performance Period: 3/1/2022–3/30/2024 (**New Project**)

DOE budget: $500k, Cost Share: $500k

Milestone 1: Use Case Report

Milestone 2: Standards Review

Milestone 3: Benchtop Demonstration

CRADA Partner – Legrand (LNCA)

Global manufacturer of electrical wiring systems, lighting, building controls, and audio-visual, sold under brands such as Legrand, Pass & Seymour, Raritan, Finelite, Wattstopper, and On-Q.

Legrand’s interest in this CRADA partnership:

- DC Power Devices
  - Increasing presence in office and consumer equipment
  - Power and control standards increase customer choice
  - Smart interactive devices provide system efficiencies
- Power Distribution and Control Architecture Standards
  - Prepare for Future Energy Markets with Flexibility and Adaptability
  - Provide a common environment for new product development
  - Provide a means of interoperability from different manufacturers
- Predictive Control Algorithm Development
  - Adapting Known Solutions in New Environments
  - Expanding Capabilities of Control System
  - Moving from Device Efficiency to Systemic Efficiencies

Problem – Today's DC Power Systems Limit Progress

- Integrating "modern" loads, energy storage and solar into legacy AC grid has drawbacks
- Direct DC power distribution has many advantages – resilience, grid stability, improved payback through efficiency and reduced costs

BUT

- Existing standards for DC power with communications (e.g., Power-over-Ethernet or USB) are limited to niche applications
  - **Optimized for high-speed data**, not power distribution
  - Require **expensive** cabling, high energy losses
  - **Limited power capacity**
  - Limited network topologies (point-to-point power links from a single power hub)
  - No way to plug-and-play solar and storage

Solution: Digitally managed DC power, optimized for power distribution

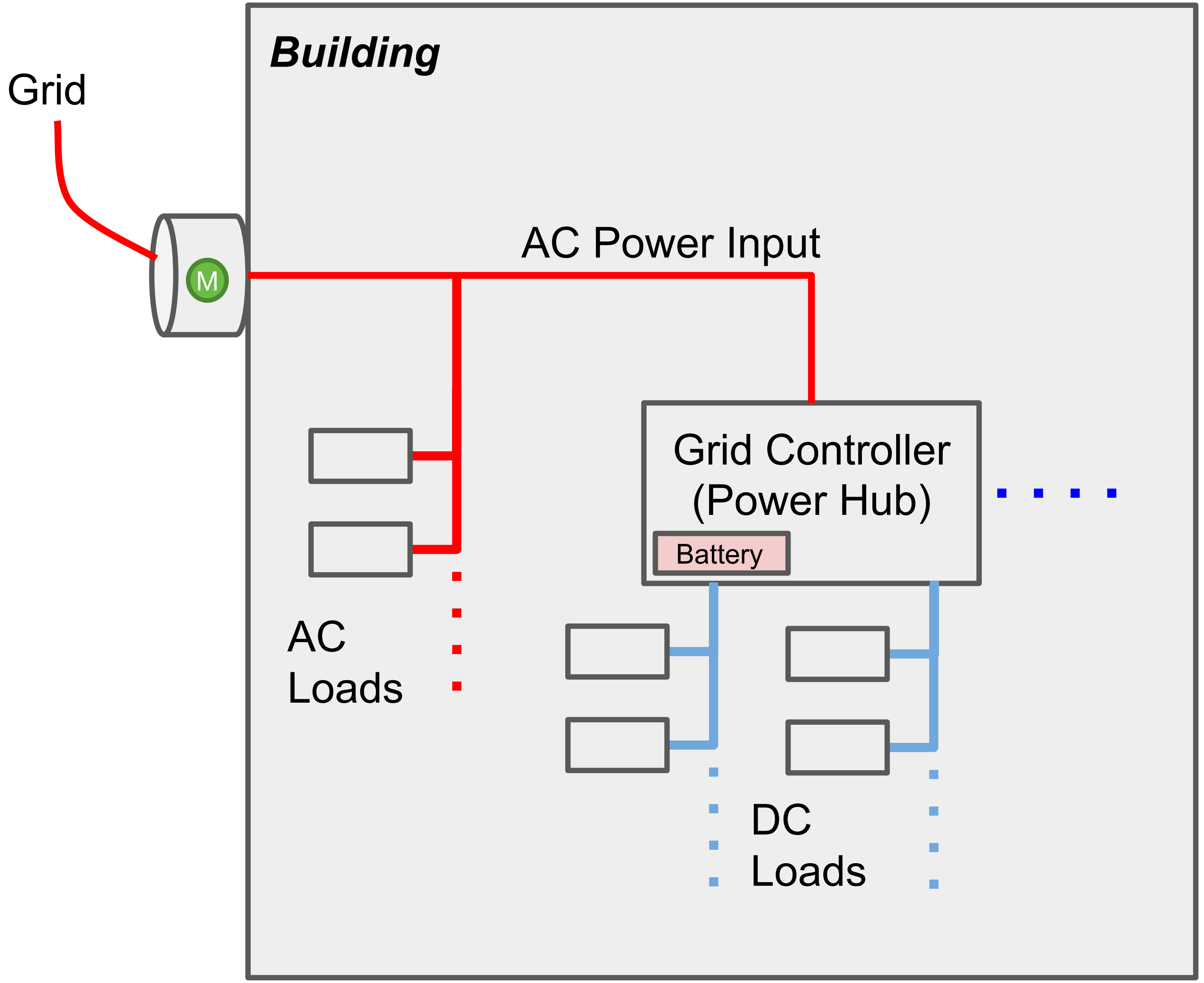
Alignment and Impact – Project & BTO Goals

BTO Goal	Project Goal
Energy Efficiency	**Reduce power conversion losses** by >10%
	Integrate predictive controls to manage loads
Electrification	Transmit up to **1kW of power** per circuit using low-voltage DC, to serve most loads in occupied spaces
	Avoid oversizing infrastructure by **managing capacity constraints**
Transform Grid Edge	Provide **grid-edge flexibility** through predictive controls
	Facilitate **plug and play operation** of generation, storage, and loads
Equity	**Reduce cost** of integrating PV and storage in buildings to **improve access** for low-income and disadvantaged communities

Approach – Learn From Existing DC Solutions

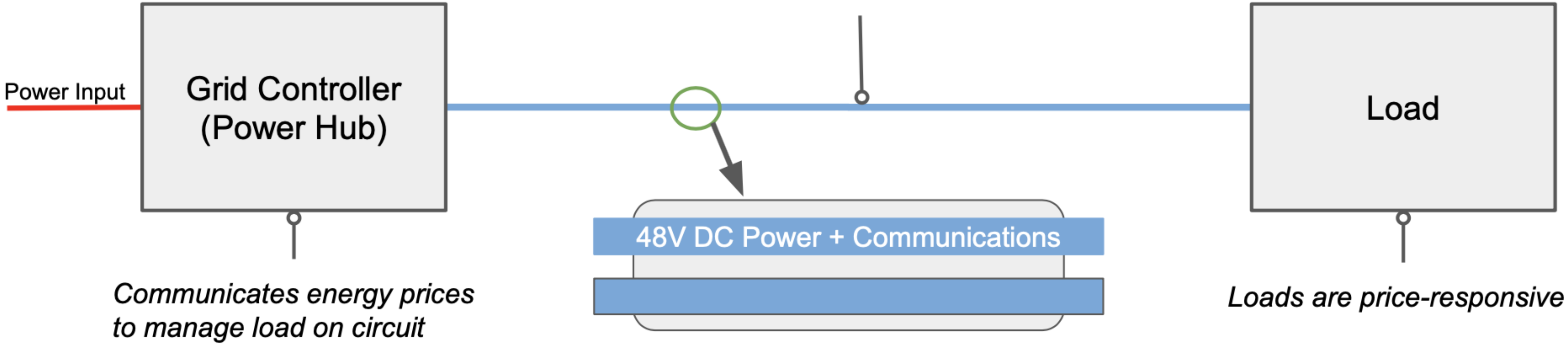
- Review existing power link standards for digitally managed DC power
  - Mainly USB (especially USB-C) and Power-over-Ethernet (PoE)
  - Limited review of other standards/technologies
  - Identify limitations, and areas to leverage for new standard
- Factors considered (particular focus)
  - Topologies supported
  - Connectors
  - Cabling
  - Voltages
  - Current
  - Grounding
  - Arcing
  - Capacity
  - Communication (Physical layers, power distribution management, Internet Protocol data)
  - Relevant organizations

Approach – Define a New Building Power Architecture

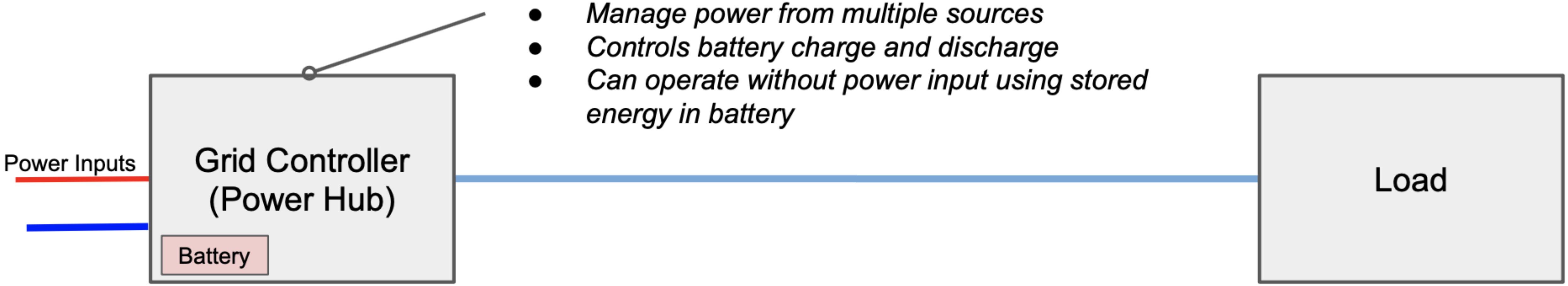


Approach – New DC Link Standard

- *Power digitally managed through capacity and price*
- *Optimized for efficient power distribution up to 1kW per circuit, at low cost*
- *Standard Internet Protocol communications for implementer-defined applications (e.g., device control)*



Approach – DC Network Power Management



- *Sets power prices based on availability from power inputs and battery*
- *Uses power prices to balance supply and loads*
- *Manage power from multiple sources*
- *Controls battery charge and discharge*
- *Can operate without power input using stored energy in battery*

Approach – Barriers and Mitigation Strategies

Barriers, technical challenges, project risks	Mitigation strategies
Achieving target power level at low-voltage with affordable/acceptable cabling infrastructure & grid controllers	Dynamic capacity management ensures safe operation
Auto-detection of cabling infrastructure for dynamic capacity management	Will develop prescriptive system specification if auto-detection is not feasible
Efficient usage of energy storage in the system	Distributed storage analysis will explore cost benefits of distributed storage
Developing prototype devices that implement new standard	Extend existing products (e.g., Domatic) to implement the new link standard

Approach – Commercialization

- Test benchtop-scale prototype system to show feasibility of core concepts
  - Implement key use cases such as emergency lighting
  - Demonstrate grid controller and several loads implementing electrical and communication aspects of standard
- Contribute proposed standard “outline” to standards organization

Progress – Defining Use Cases

Electrical Load Use Cases	System Application Use Cases
• Distributed Loads - Including Demand Response • Life-safety: Emergency Lighting • Other Life-safety Loads • Telecom Closets • Power Reliability and Redundancy	• Diverse Energy Sources • On-site Renewable Power • Open Space Distributed Power • Flexible space utilization • Residential Applications

Focus on building applications that have:

- High concentration of DC loads (e.g., LEDs, electronics, variable-speed motors)
- High reliability needs
- Primarily commercial buildings, but standard should apply to residential also

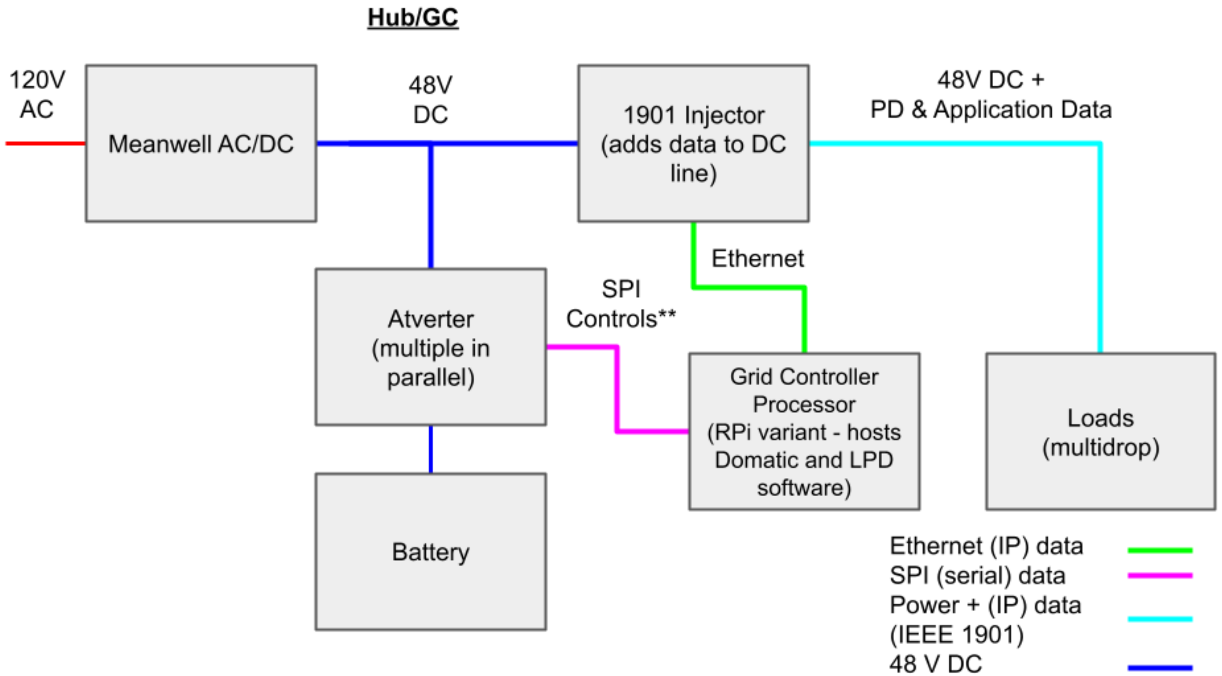
Progress – Benchtop Demonstration Plan

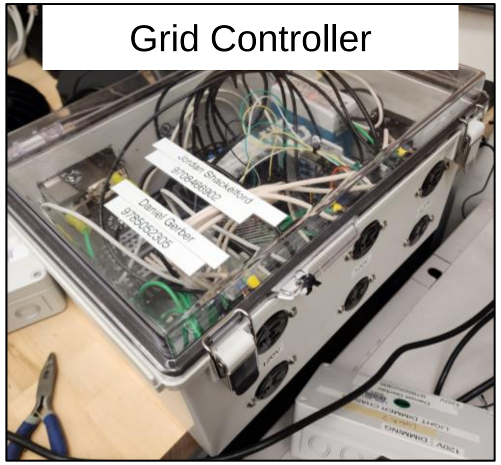
Test several use cases

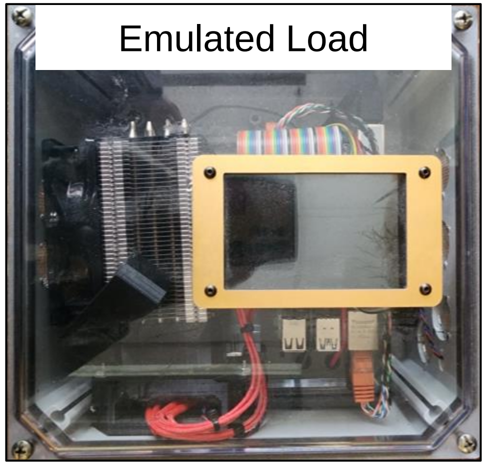
- Emergency lighting & other life-safety
- Telecom closet
- Open space distributed power and battery storage
- Residential

Develop prototypes of several devices that implement digitally managed DC power

- Grid controller with battery
- Several loads




Grid Controller


Emulated Load

Upcoming Work

Remainder of Project

- **Finish sketching out proposed standard**
- Demonstrate prototypes and evaluate results
- Present standard and demo results to standards organization (probably IEEE 802.3 and Emerge Alliance)
- Develop market adoption plan


IEEE 802.3 Ethernet

David Law
IEEE 802.3 Working Group Chair
David_Law@3Com.com

Version 1.0 (January 2010)

IEEE

Beyond the end of this project

- Standardization: Published standard
- **Promote through trade group (e.g., Ethernet Alliance)**
- **Develop test & certification protocols**
- **Work with device and component manufacturers to produce products**
- Demonstrate in real buildings (ideally involving high-profile purchasers like GSA, other portfolio managers)

Thank You

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REFERENCE SLIDES

Project Execution

	FY2022				FY2023				FY2024			
Planned budget	$125k				$250k				$125k			
Spent budget	$80k											
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Milestone 1.1: DC Power Use Case and Requirements Report												
Milestone 2.1: DC Power Standards Landscape Report												
Milestone 3.1: Energy Storage Analysis Report												
Current/Future Work												
Milestone 4.1: Predictive Controls Requirements and Design Memo												
Milestone 5.1: Prototypes for Testing												
Benchtop testing												

- Project start delayed 2 quarters to negotiate CRADA agreement

Team

LBNL (Standards, storage analysis, benchtop demonstration)

- Rich Brown, PI
- Bruce Nordman, Power architecture and standards
- Daniel Gerber, Storage analysis and demonstration lead

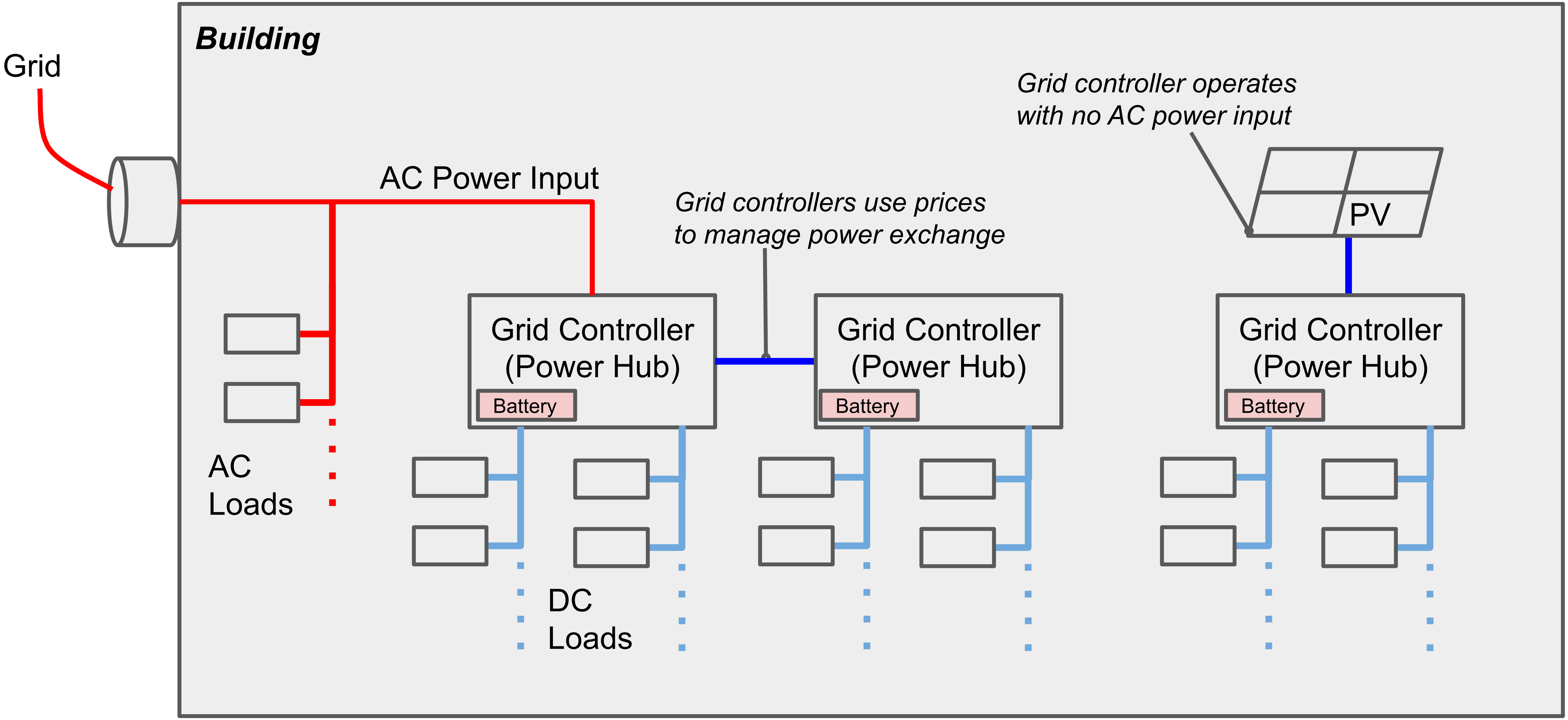
Legrand (Use cases, predictive control, market analysis)

- Pete Horton, Project lead
- David Clothier, Technical lead

Domatic (Demonstration partner)

- Jim Baldwin, Founder

Approach – Full System Architecture

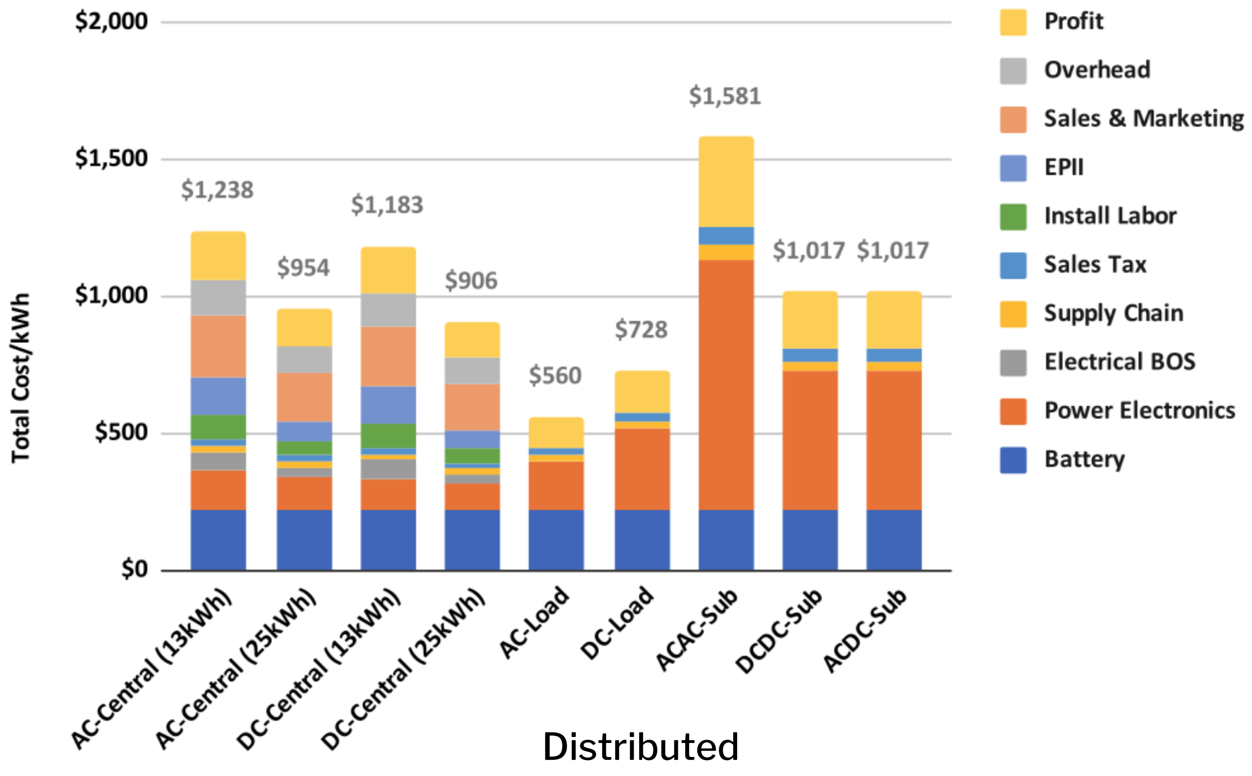


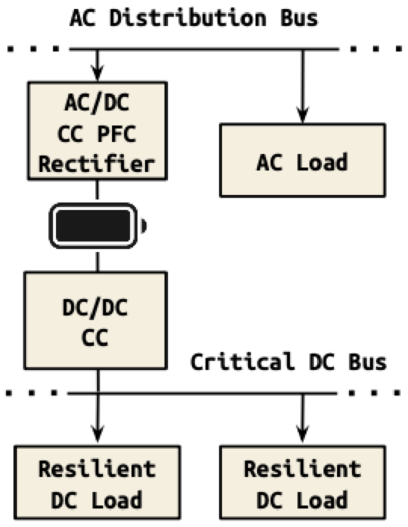
Progress – Defined Functional Requirements

Link	Load	Grid Controller
Link must be able to communicate: • Electricity prices • Information to manage capacity constraints • Identifying information from a load to a grid controller (e.g., unique identifier, voltage requirements, etc.) • “Energy Reporting information, including voltages observed from loads to GC (for power quality purposes) Link must support: • Hot plugging and unplugging of loads • Energy Reporting by loads • Carry a power level up to 1 kW • Define a standard connector for each end of the link	Loads must be able to: • Receive price signals and use prices for Demand Response • Receive and act on emergency load reduction commands • Send requests for power capacity and comply with grants of capacity and subsequent changes to that • On initial connection with a power link, send limited identifying information, including emergency load shed priority • Do Energy Reporting, including sending instantaneous measured voltage • Facilitate users setting DR priorities / policies / preferences	Grid controllers must be able to: • Compute and communicate the local electricity price • Manage capacity constraints of individual circuits and the whole controller by taking in requests from loads, granting capacity to loads, revising those grants, and changing the price • Take in identifying information from a load during link startup and any adjustments during link operation • Request Energy Reporting information from loads and track usage over time • Coordinate with BEMS for predictive control

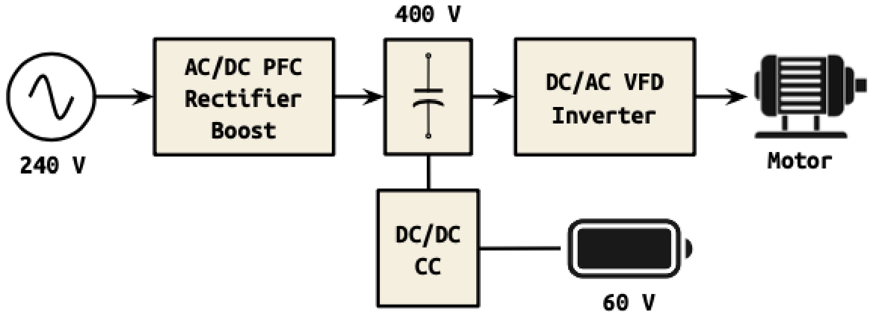
Progress - Distributed Storage Analysis

- Explore how distributed storage can avoid installation and soft costs of central storage
- Examined AC and DC versions of (a) load-packaged storage, (b) resilient subsystems
- Results show extensive installation and soft cost avoidance
- Also investigated battery sizing in load packaged storage for building electrical infrastructure reduction and resilience





(b)



(a)