Fort Hunter Liggett Microgrid Conversion

Gregory Vallery and Michael Stadler
gregory.l.vallery.civ@mail.mil
MStadler@lbl.gov
http://building-microgrid.lbl.gov/
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DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
ANALYTICS | PLANNING | OPERATIONS

Berkeley Lab-Team: G. Cardoso, N. DeForest, D. Baldassari, T. Brandt, N. DeForest, T. Forget, L. Le Gall, G. Gehbauer, M. Hartner, S. Mashayekh, C. Milan, M. Stadler, D. Steen, J. Tjaeder

Berkeley Lab Partners: Massachusetts Institute of Technology (MIT), EPRI, Metropolitan Washington Council of Governments, Brookhaven National Laboratory, Fort Hunter Liggett, TriTechnic, MIT Lincoln Laboratory, University of New Mexico, Public Service New Mexico, Universidad Pontificia Comillas – IIT, Xcogen Energy LLC, CSIRO, NEC

U.S. DEPARTMENT OF ENERGY

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Introduction on Fort Hunter Liggett and Lessons Learned from USAG Vicenza Italy

Caserma Ederle/Del Din Microgrid with Central Energy Plant and Distributed Generation

- Technical issues:
  - Communication: isolated network
  - Network certification: DIACAP now RMF
  - Central power generation vs. distributed generation
  - Reference signal
  - Precise Phase Matching
  - Harmonics
  - Reacting faster than the grid

- Saving money:
  - Microgrid, if implemented correctly can reduce implementation of future distributed energy generation and storage systems
  - Distributed systems can reduce equipment number and sizes, increase reliability and reduce maintenance costs (see following slides on FHL)
  - DER-CAM logic can reduce energy costs with potential to make money (see second part of the presentation)

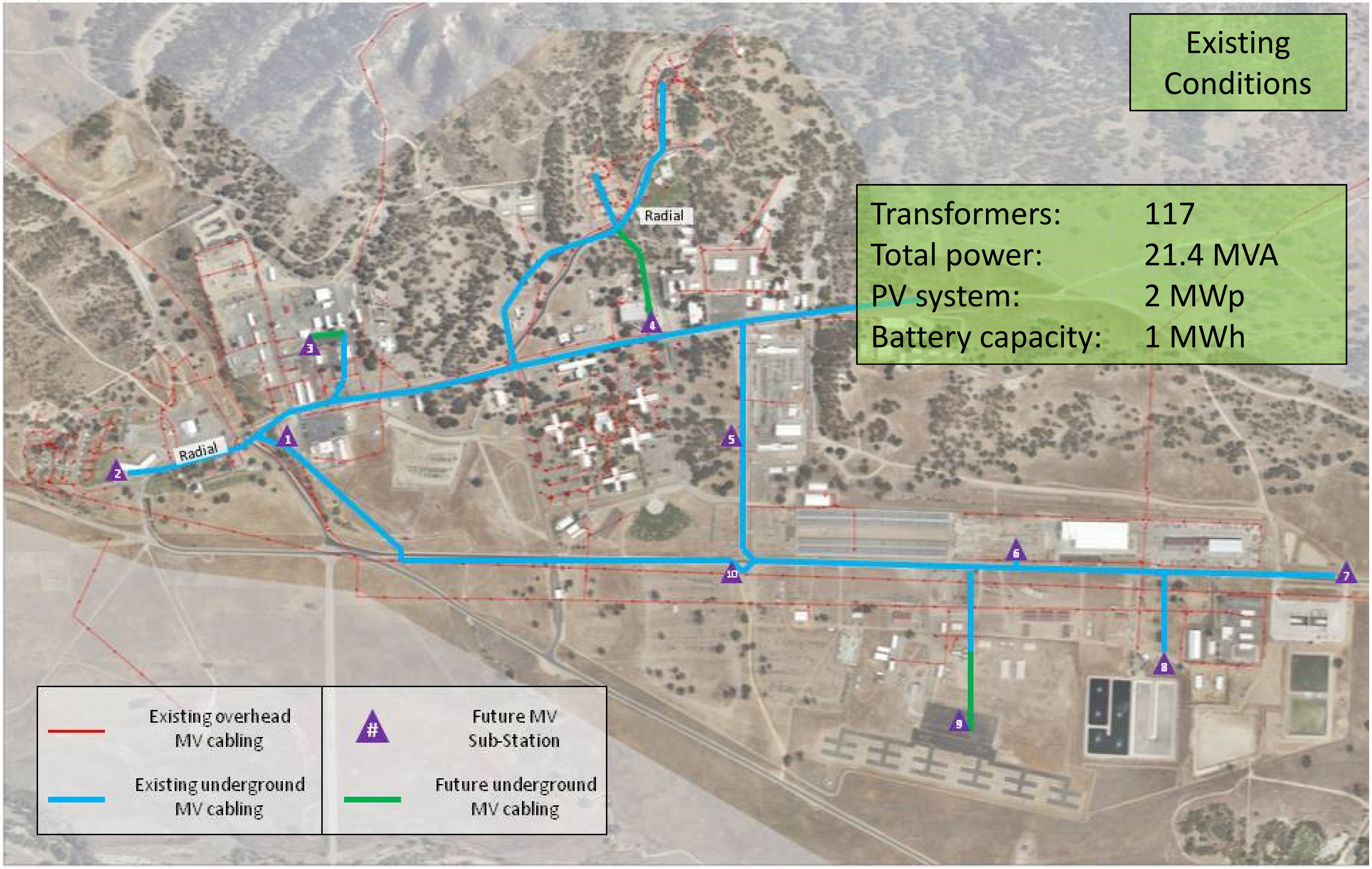
- Fort Hunter Liggett (FHL) currently has a centralized 2 (+1 under construction) MW PV and 1 MWh battery

- Planning for Net-Zero: requires 8 to 9 MW PV

- Planning for energy security: will require 16 MWh of battery for continues operation

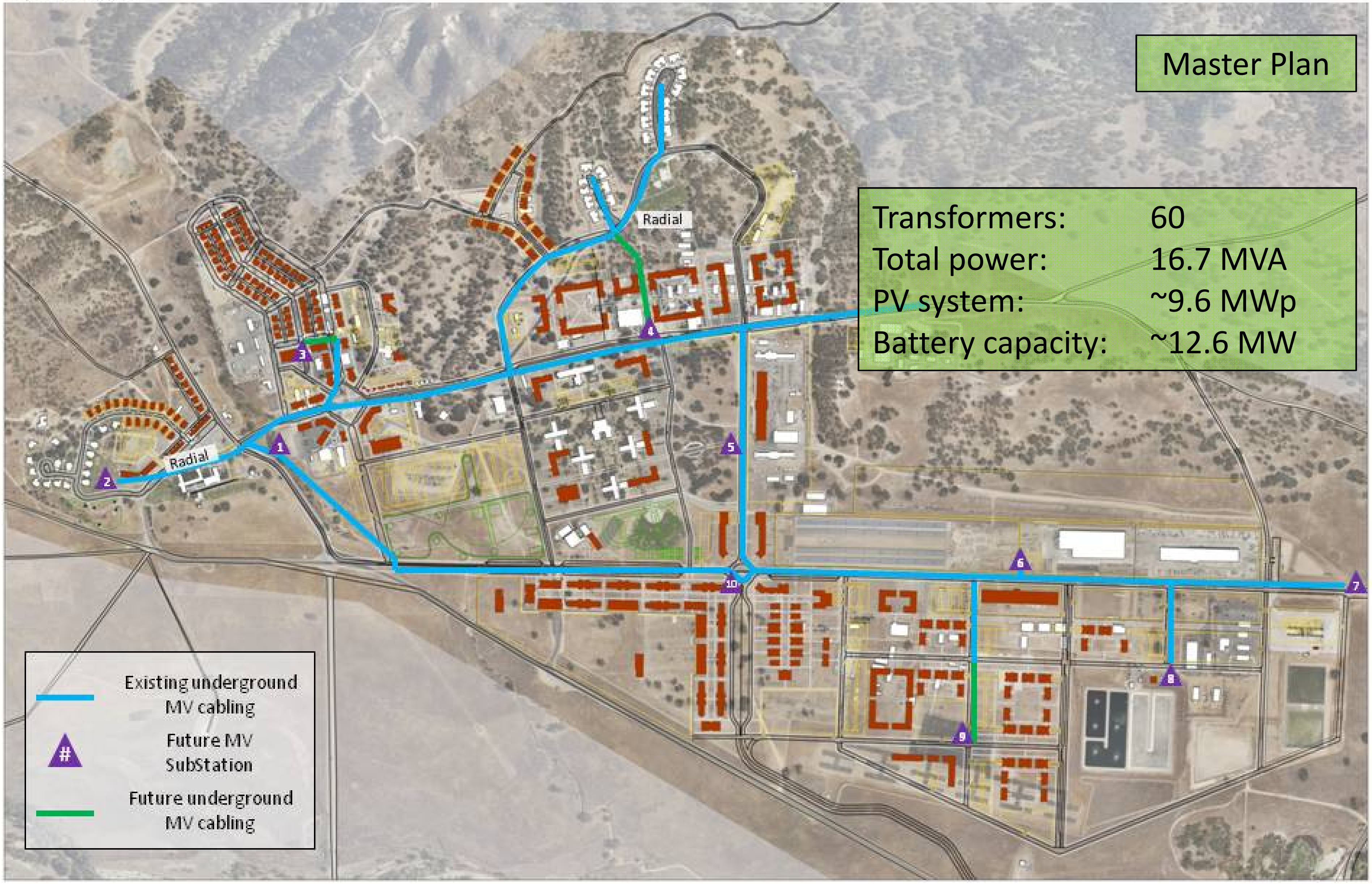
US Army Garrison - Fort Hunter Liggett

Micro Grid Concept Design



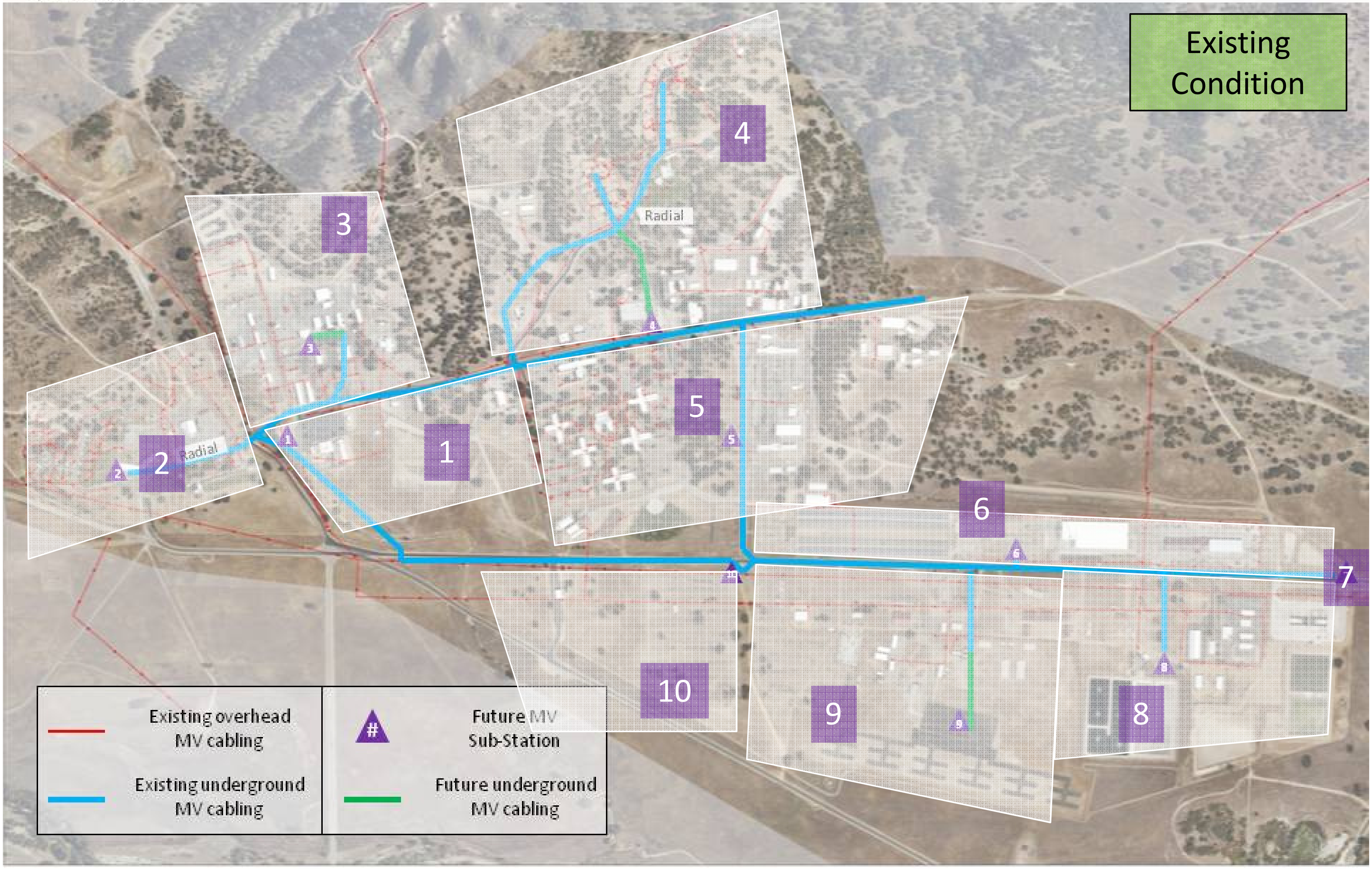
US Army Garrison - Fort Hunter Liggett

Micro Grid Concept Design



US Army Garrison - Fort Hunter Liggett

Micro Grid Concept Design

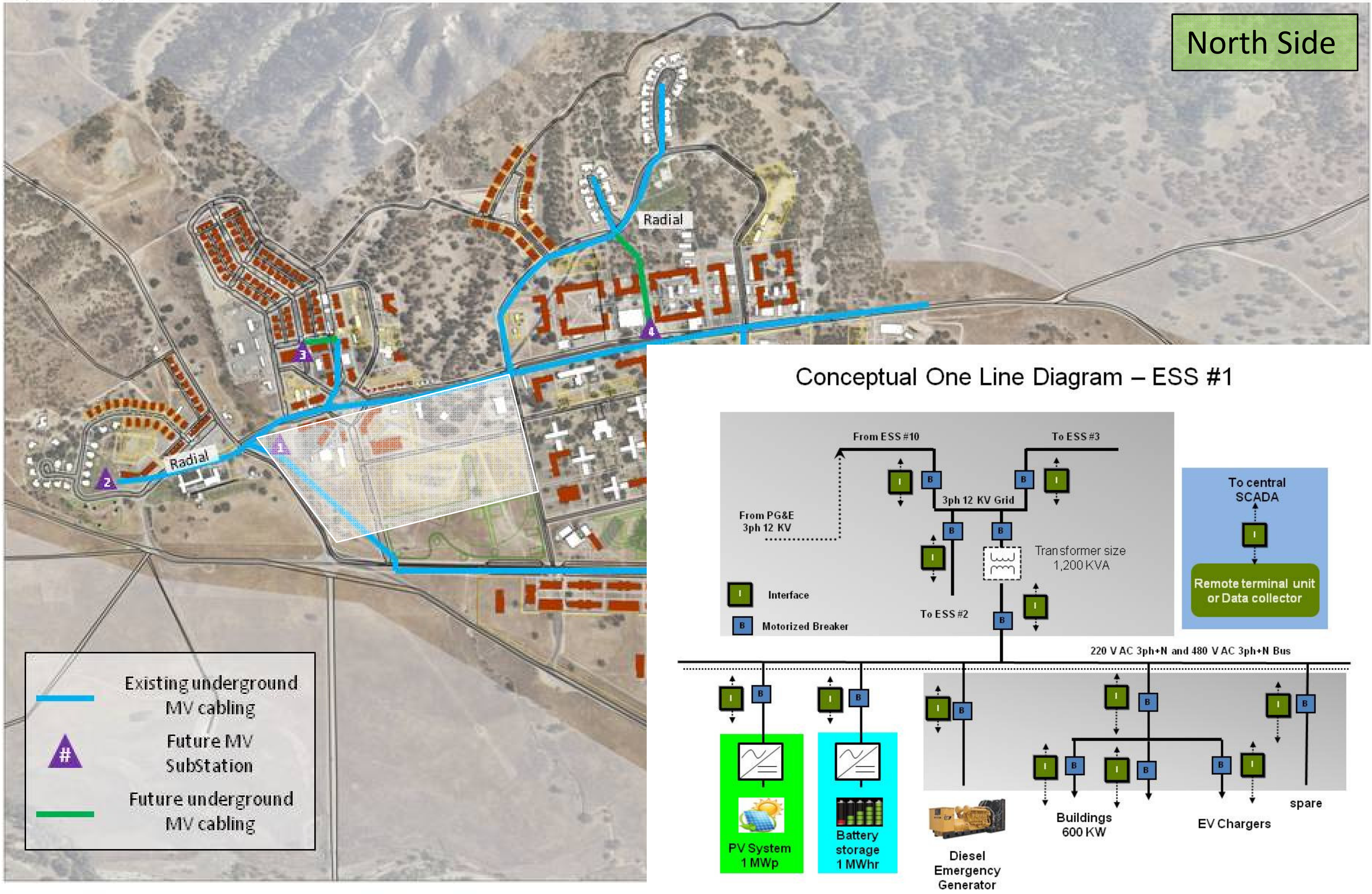


US Army Garrison - Fort Hunter Liggett

Micro Grid Concept Design

US Army Garrison - Fort Hunter Liggett

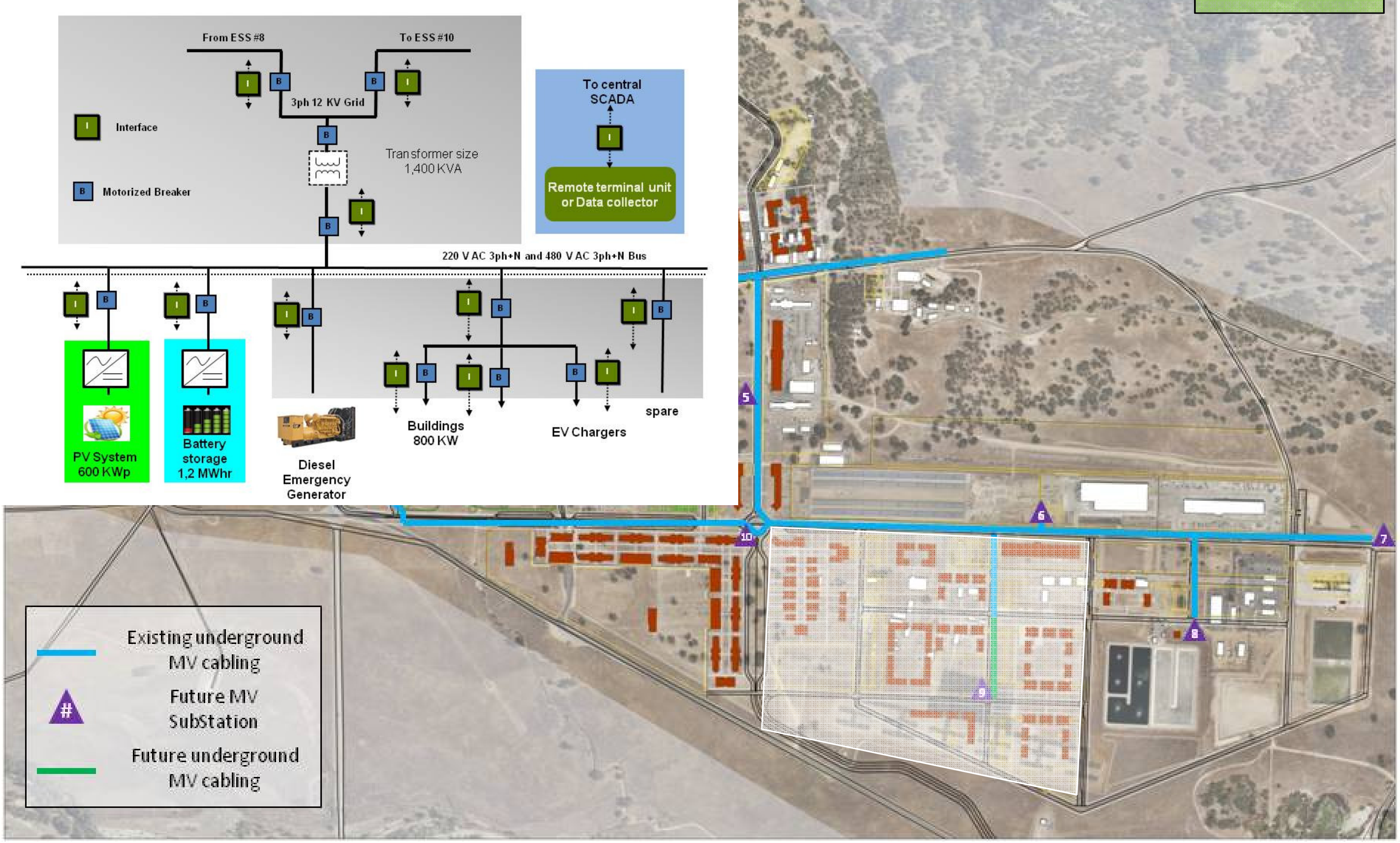
Micro Grid Concept Design



US Army Garrison - Fort Hunter Liggett

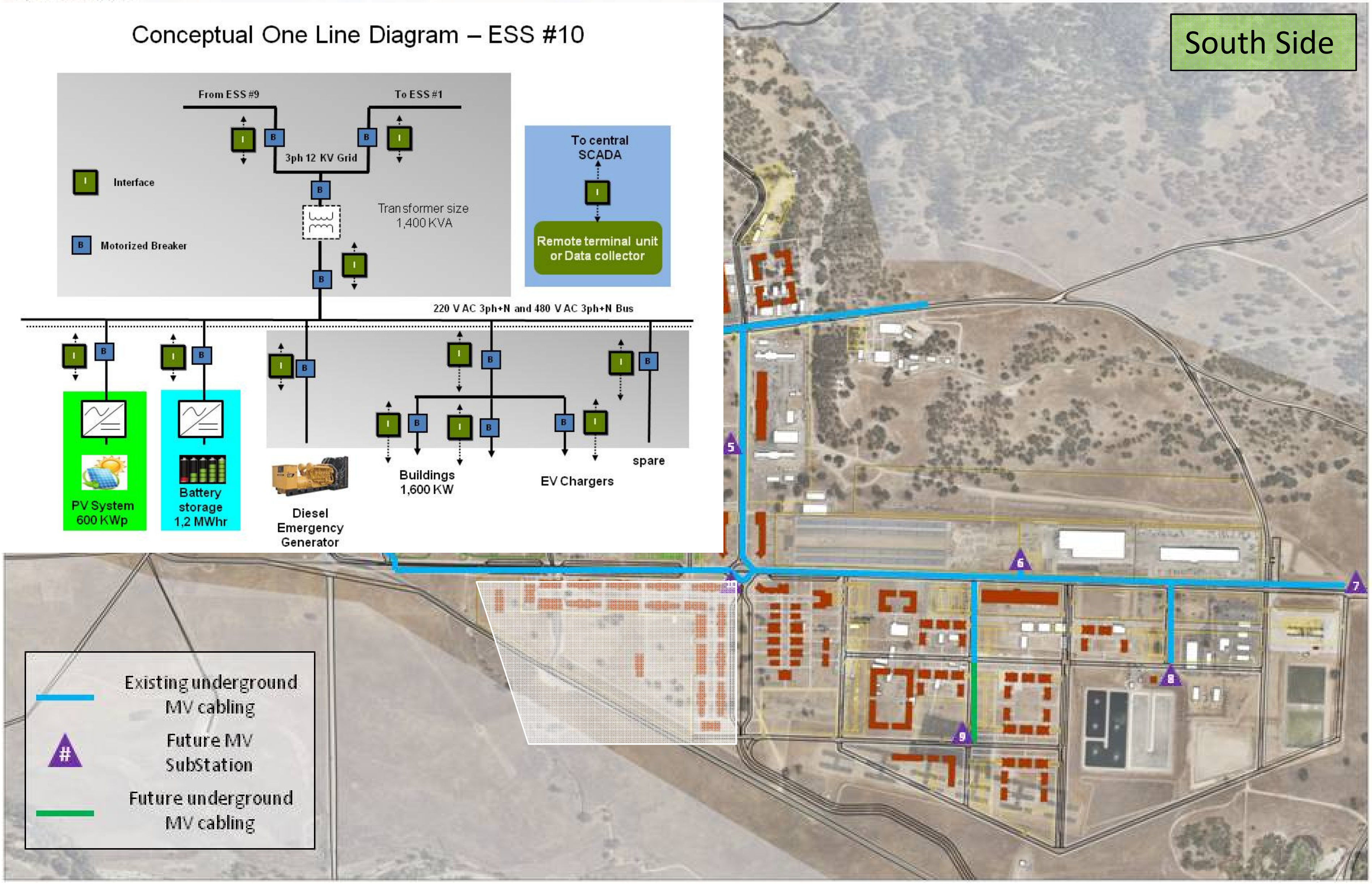
Micro Grid Concept Design

Conceptual One Line Diagram – ESS #9



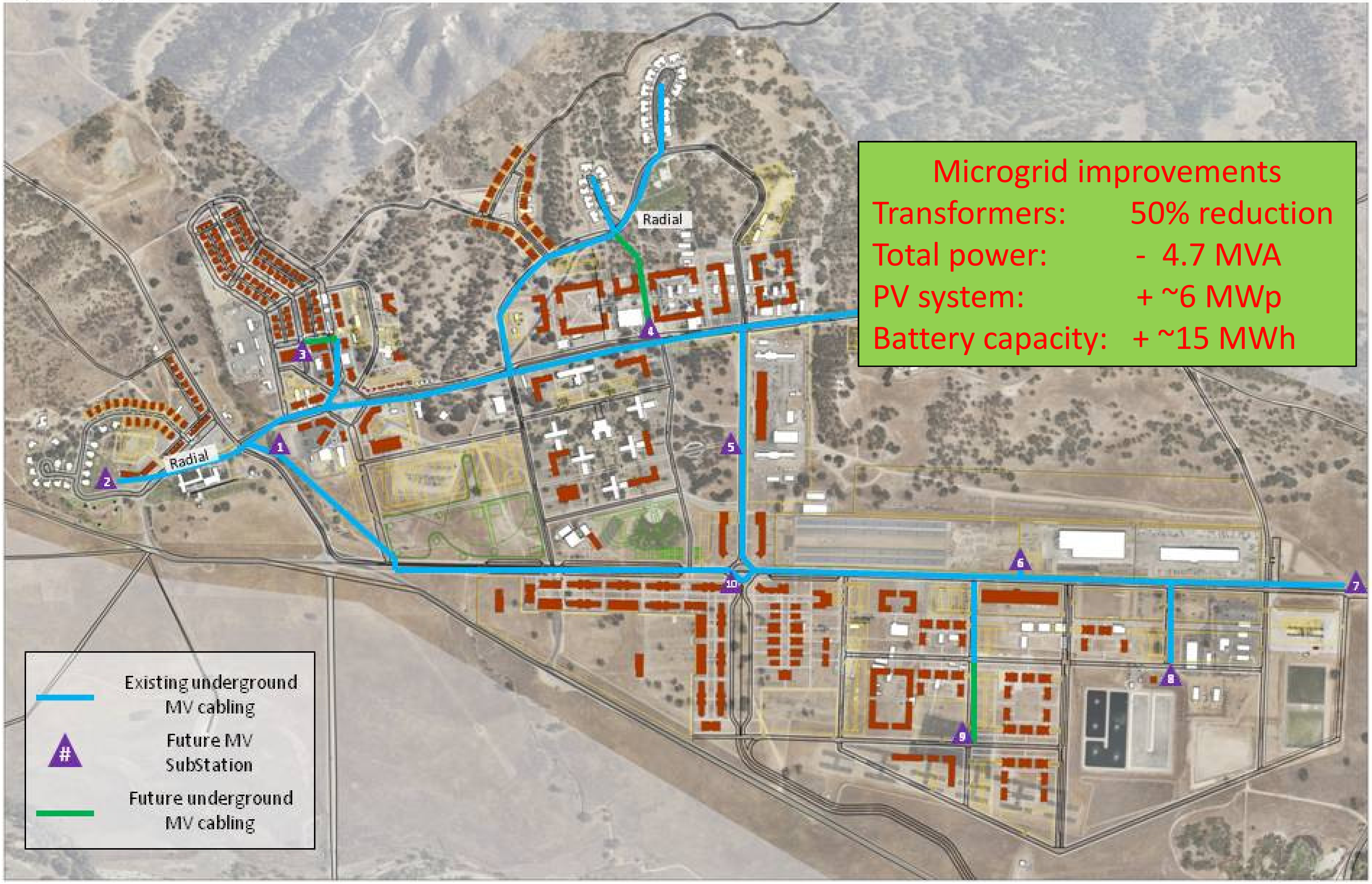
US Army Garrison - Fort Hunter Liggett

Micro Grid Concept Design



US Army Garrison - Fort Hunter Liggett

Micro Grid Concept Design

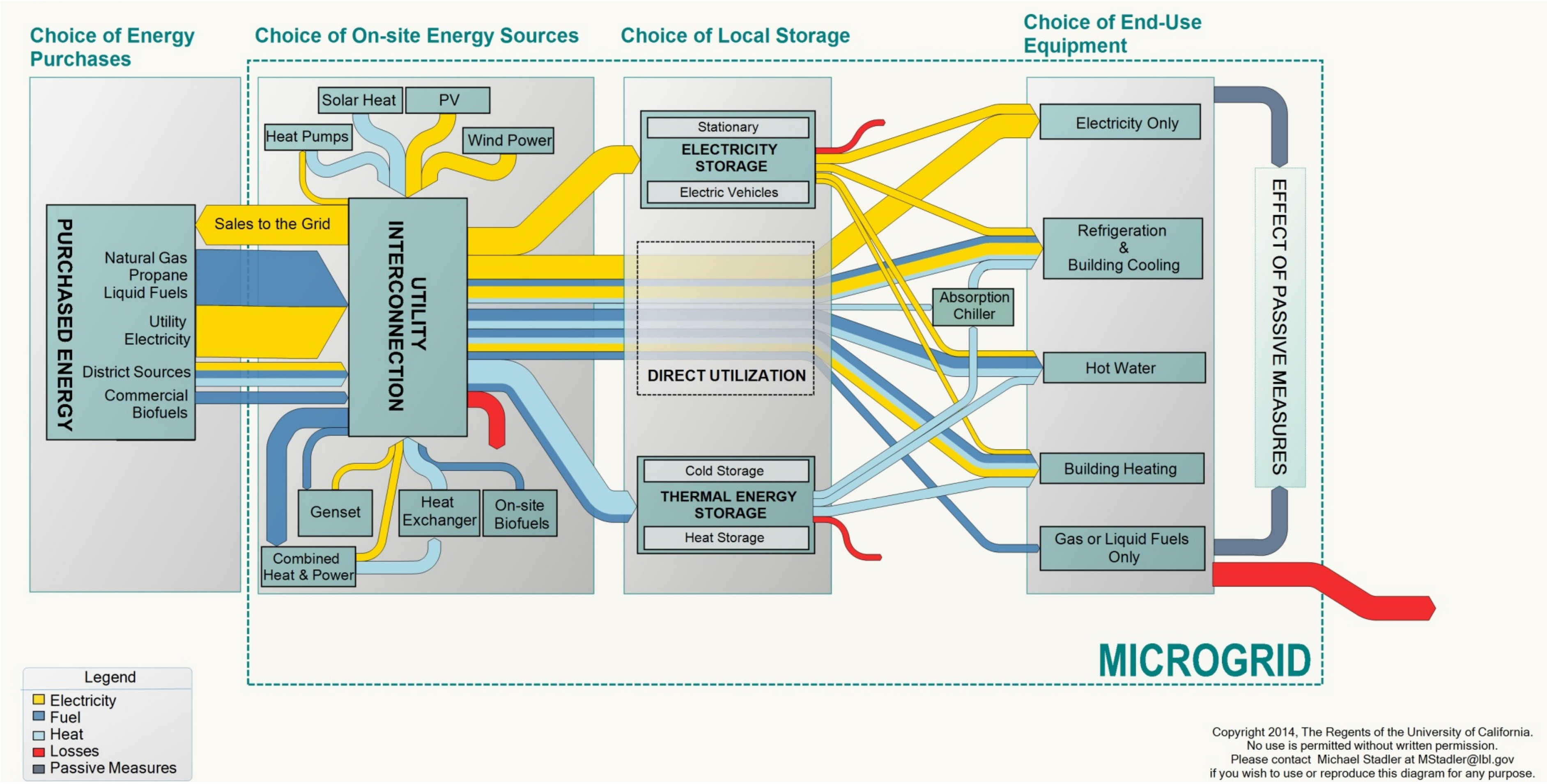


Microgrid improvements

Transformers:	50% reduction
Total power:	- 4.7 MVA
PV system:	+ ~6 MWp
Battery capacity:	+ ~15 MWh

Global Model for Microgrids

Microgrid Architecture and Decision Making with DER-CAM



DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

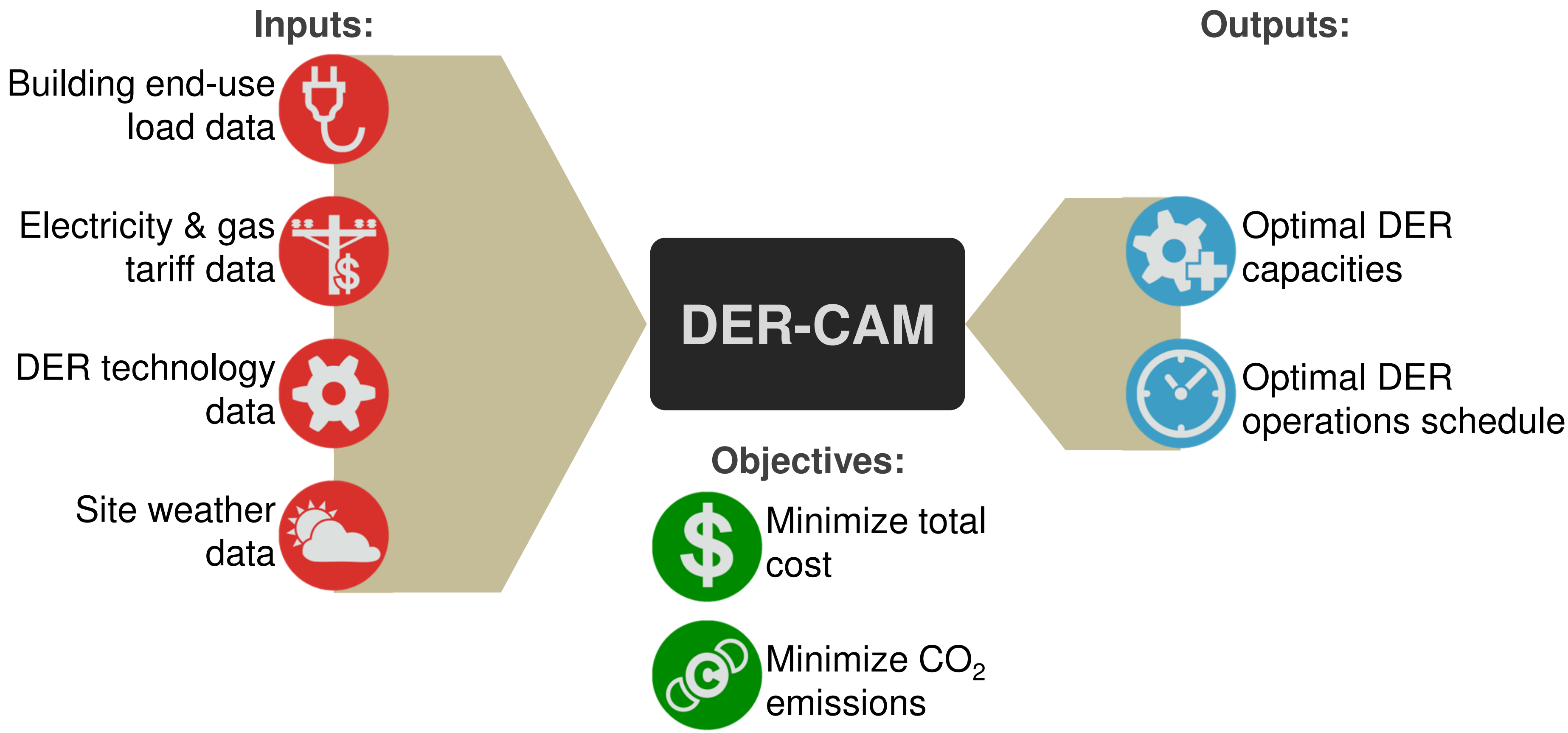
Distributed Energy Resources Customer Adoption Model (DER-CAM)

- is a deterministic and stochastic Mixed Integer Linear Program (MILP), written in the General Algebraic Modeling System (GAMS®)
- started as a building CHP optimization tool 13 years ago
- supported by the U.S. DOE, OE, DoD, CEC, private industry
- two main objective functions:
  - cost minimization
  - CO_2 minimization
- other objectives are possible, as well as multi-objective

  subject to microgrid/building constraints and energy balance
- produces optimal investment and dispatch results for biogas/diesel/natural gas CHP, fuel cells, ICE, micro-turbines, gas-turbines; PV, solar thermal, hot and cold water storage, batteries, heat pumps, absorption chiller, EV, passive measures (insulation, window changes, etc..)

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS



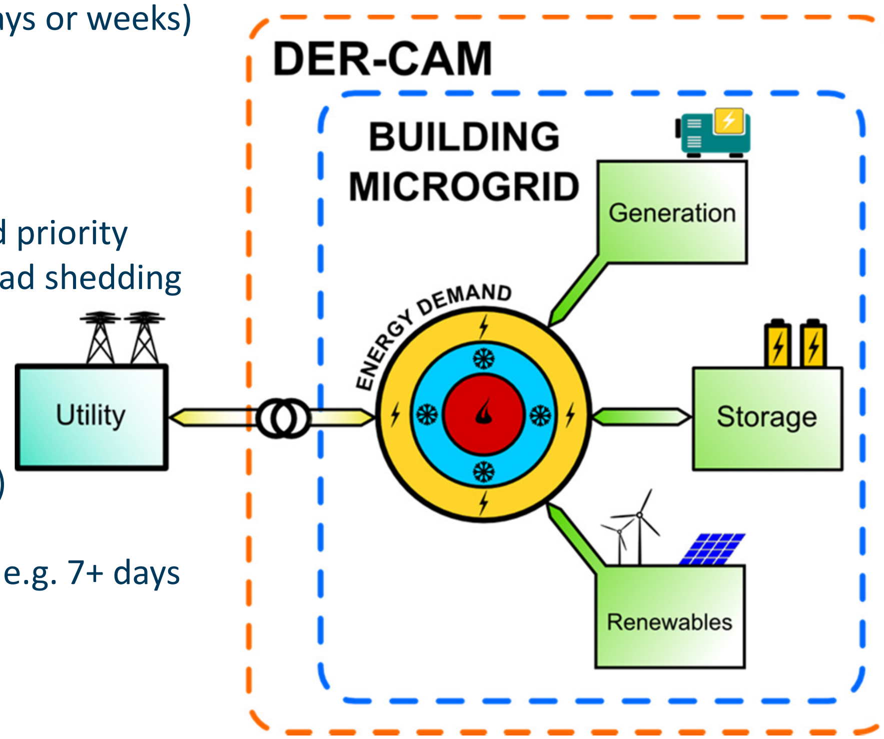
- **Investment & Planning:** determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs
- **Operations:** determines optimal week-ahead scheduling for installed equipment and *forecasted* loads, weather and tariffs

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

New features:
Microgrid capabilities, designed for resiliency

- *Voluntary & forced islanding*
  - grid availability from reliability model: MTTF / MTTR
  - reliability measured by un-served load
  - variable outage length (from a few minutes to several days or weeks)
  - voluntary islanding determined by microgrid economics
- *Load Prioritization / Critical loads*
  - user defined load priorities (up to 3 priority levels)
  - max. acceptable shedding amount and duration per load priority
  - economic trade-off for each priority level determines load shedding vs. backup DER
  - direct load control modelling
- *Optimize offline dispatch (islanded)*
  - energy management strategies (load shifting / shedding)
  - energy storage
  - resource availability – for extended times after outages, e.g. 7+ days
- *Plan backup generation*
  - trade-off: additional capacity vs. backup-only
  - offline fuel needs



DER-CAM

DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Our Partners and DER-CAM Licensees

Our Partners

Microgrid Capabilities and Resiliency at Fort Hunter Liggett

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Objective: Use DER-CAM to perform an assessment on optimal DER at FHL to enable microgrid capabilities. Focus on resilience against natural disasters.

- Blackout cases: none, 3 h, 24 h, 7 days

- Standard DER-CAM assessment (no blackouts):
  - Existing DER
  - Existing DER + additional PV and storage
  - Existing DER + additional DER (full DER-CAM technology range)

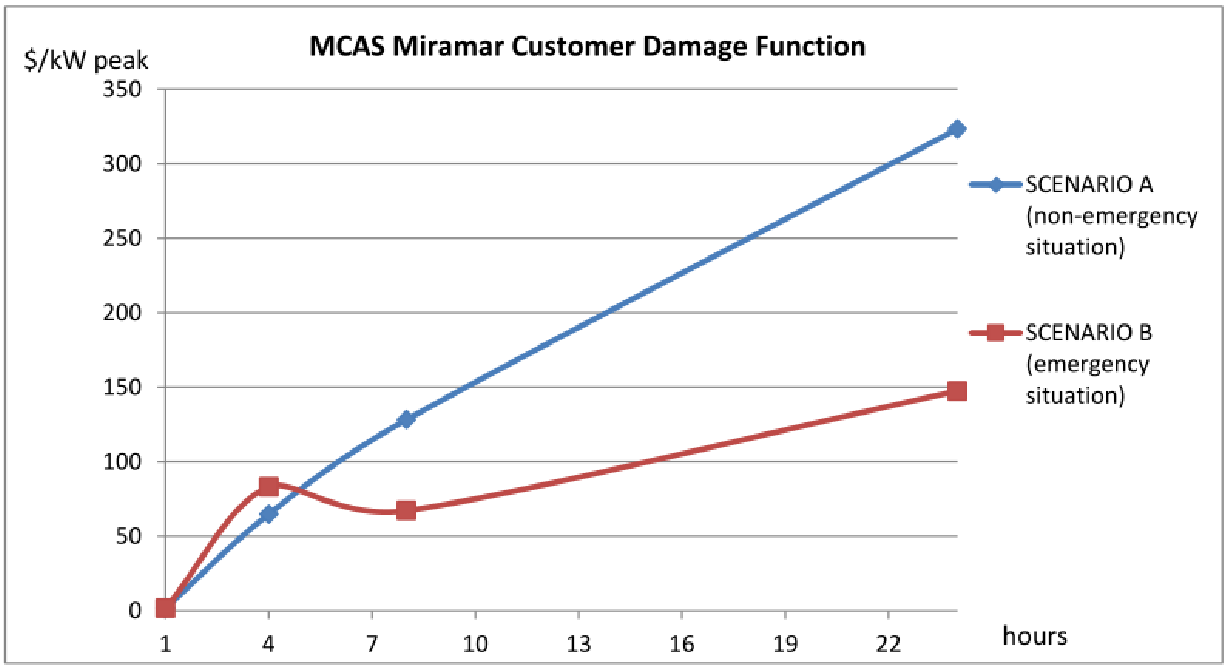
- DER-CAM assessment considering blackouts:
  - Existing DER
  - Existing DER + additional PV and storage
  - Existing DER + Diesel backup generators
  - Existing DER + additional PV, batteries and diesel backup generators
  - Existing DER + additional DER (full DER-CAM technology range)

Load prioritizations: 10% Critical loads; 20% Low Priority; 70% Medium priority

Customer Damage Function (CDF)

Customer Damage Function is used to estimate outage costs as a function of the outage duration.

*Value of Electrical Energy Security (VEES) ~ Outage Duration * $/kW peak * Peak Demand*



Source: Valuing Energy Security: Customer Damage Function Methodology and Case Studies at DoD Installations, NREL

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Fort Hunter Liggett – DER-CAM assessment - 24h blackout

Key Results*)

(Costs in million USD)	Existing PV and Storage	Existing PV, Storage + Diesel Backup	Additional PV and Storage	Additional PV, Storage and Diesel Backup	All DER
TOTAL COSTS	5.363	3.068	3.655	2.976	2.702
Electricity Costs	2.216	2.216	0.785	1.661	1.145
Fuel Costs	0.320	0.326	0.320	0.324	0.477
Annualized Capital Costs	0.491	0.510	2.475	0.971	0.976
O&M Costs	0.001	0.001	0.001	0.001	0.036
CDF Costs	2.330	0.009	0.059	0.010	0.000
Annual CO_2, ton	4955	4973	2132	4119	4444
Installed Capacity					
Photovoltaic, kW	2000	2000	4936	3106	2077
Electric Storage, kWh	1000	1000	20709	4374	1250
Diesel Backup, kW	-	1400	-	1000	-
ICE, kW	-	-	-	-	2000
ICE HX, kW	-	-	-	-	500
Absorption Chiller, kW	-	-	-	-	2807
Solar Thermal, kW	-	-	-	-	801

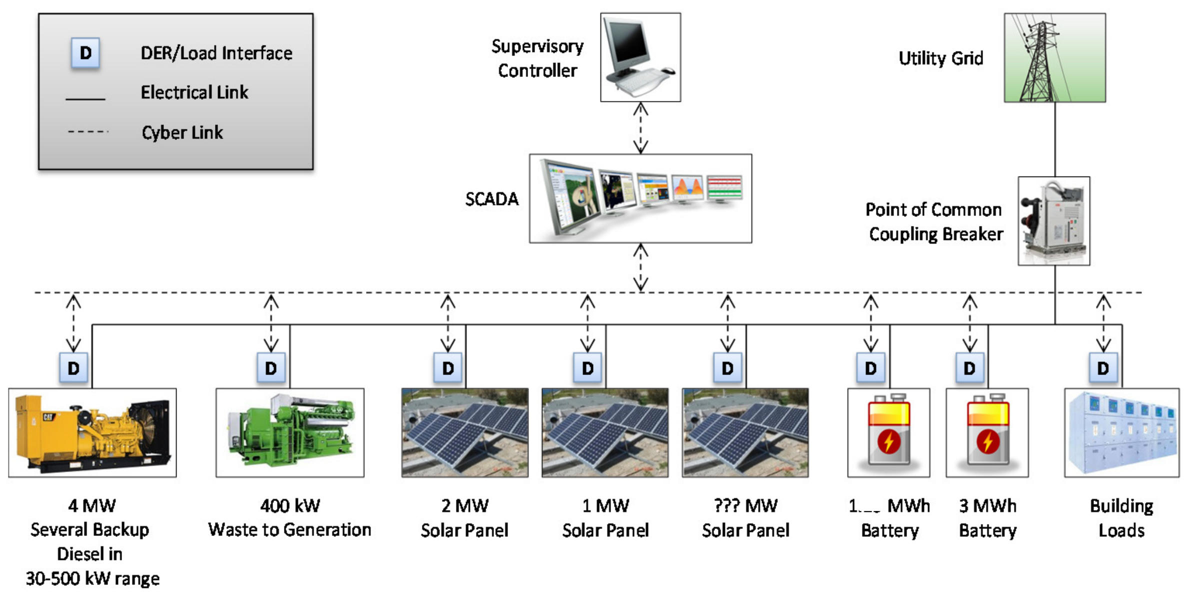
- Results show that additional PV and storage, in addition to backup generation, will allow FHL to survive 24h outages without any major service disruption at low costs – diesel consumption roughly 1250 gallons for 24h
- When considering all DER options, the optimal investment solution allows enough flexibility to maintain operation during 24h outages and lowest costs

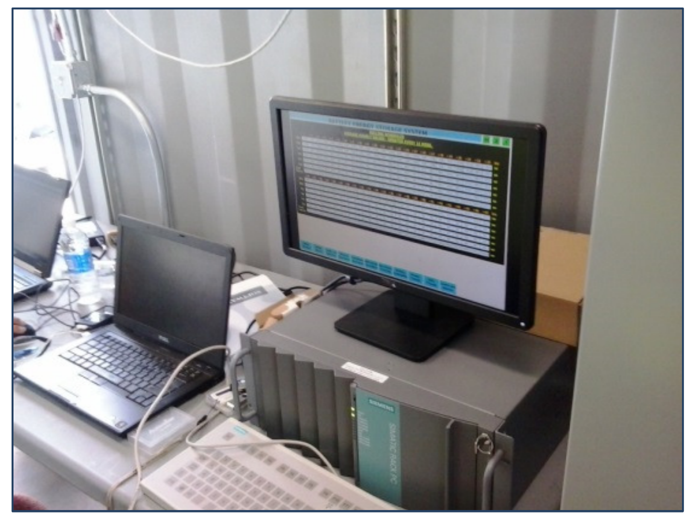
*) Sales are not part of this analysis

Microgrid Controller Work at Fort Hunter Liggett

Fort Hunter Liggett – Technology Portfolio

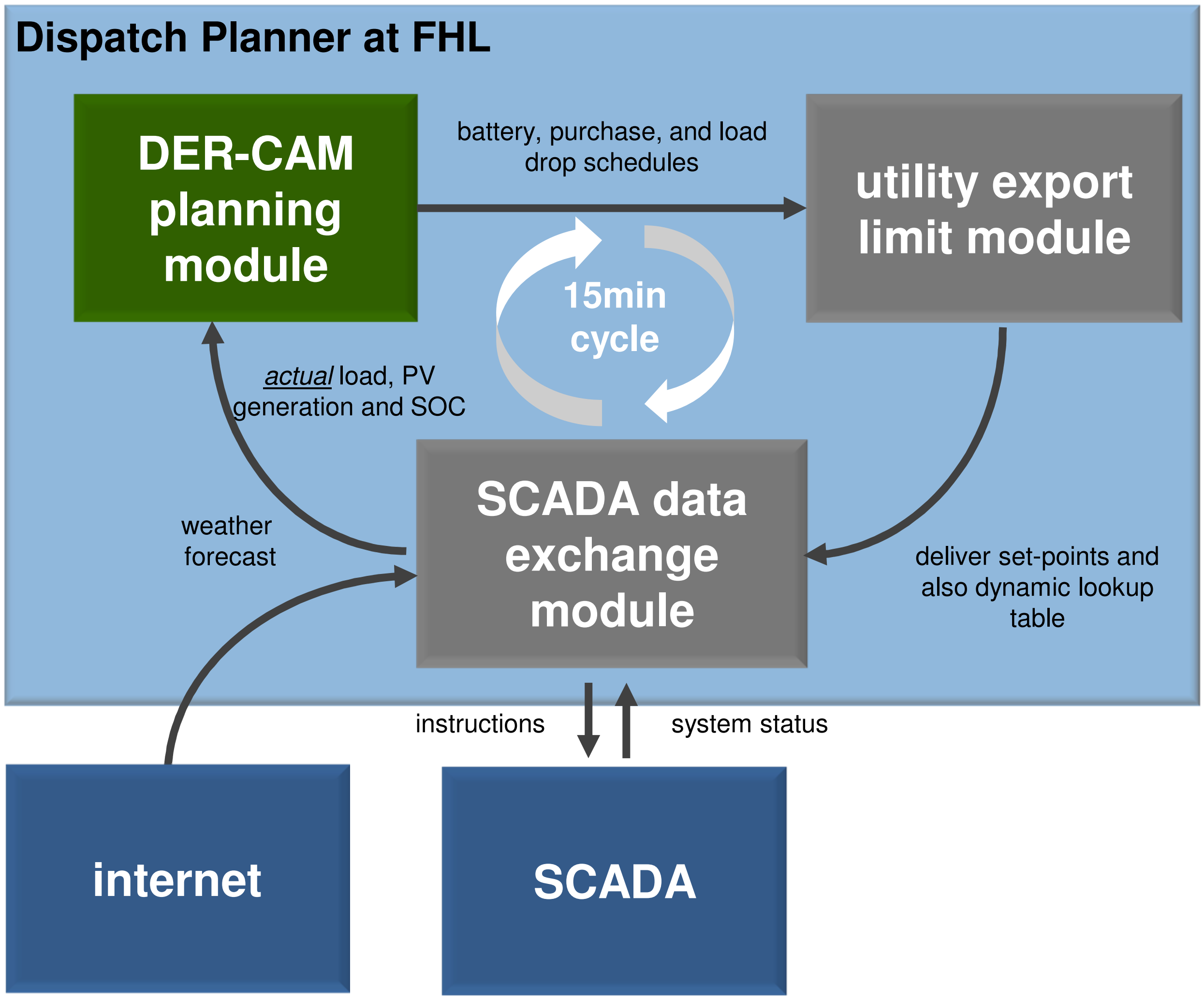
- goal: use Operations DER-CAM based supervisory microgrid controller to optimize operation schedules and limit grid export
- current technologies: 2 MW of PV, 1 MWh battery, and 4 MW backup diesel,
- planned 2016: several MW of PV, 3 MWh battery, and 400 kW waste to generation





DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

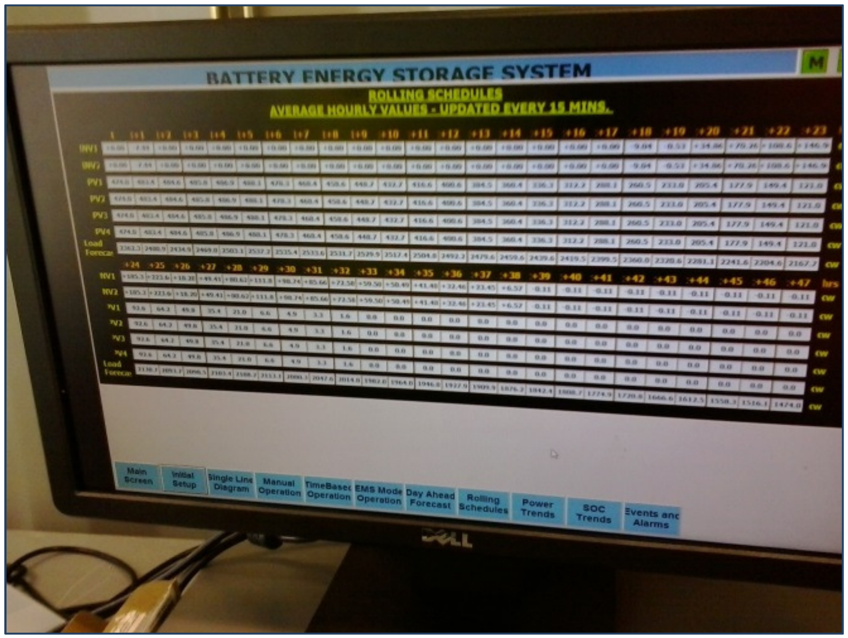
ANALYTICS | PLANNING | OPERATIONS

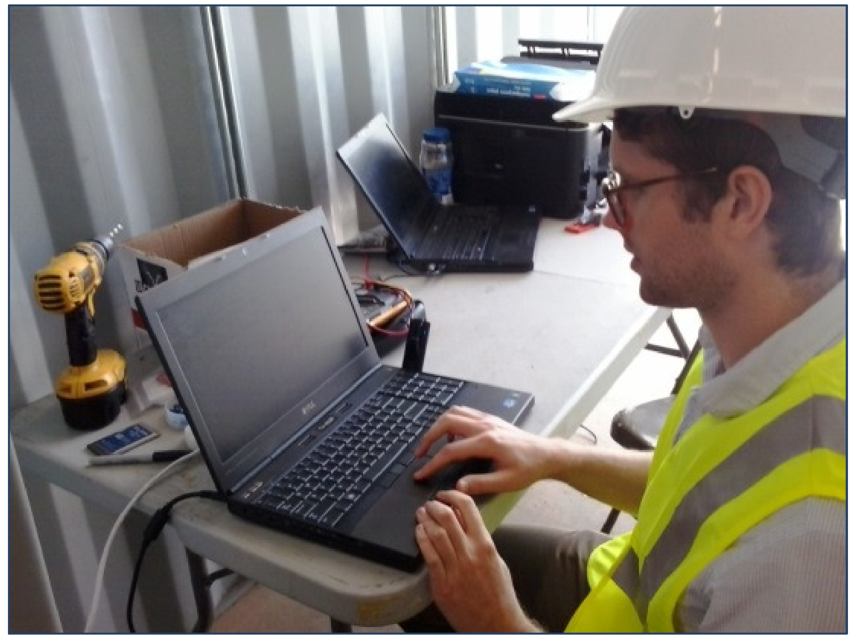


DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Successful Feeding of Operations DER-CAM Dispatches into the SCADA System

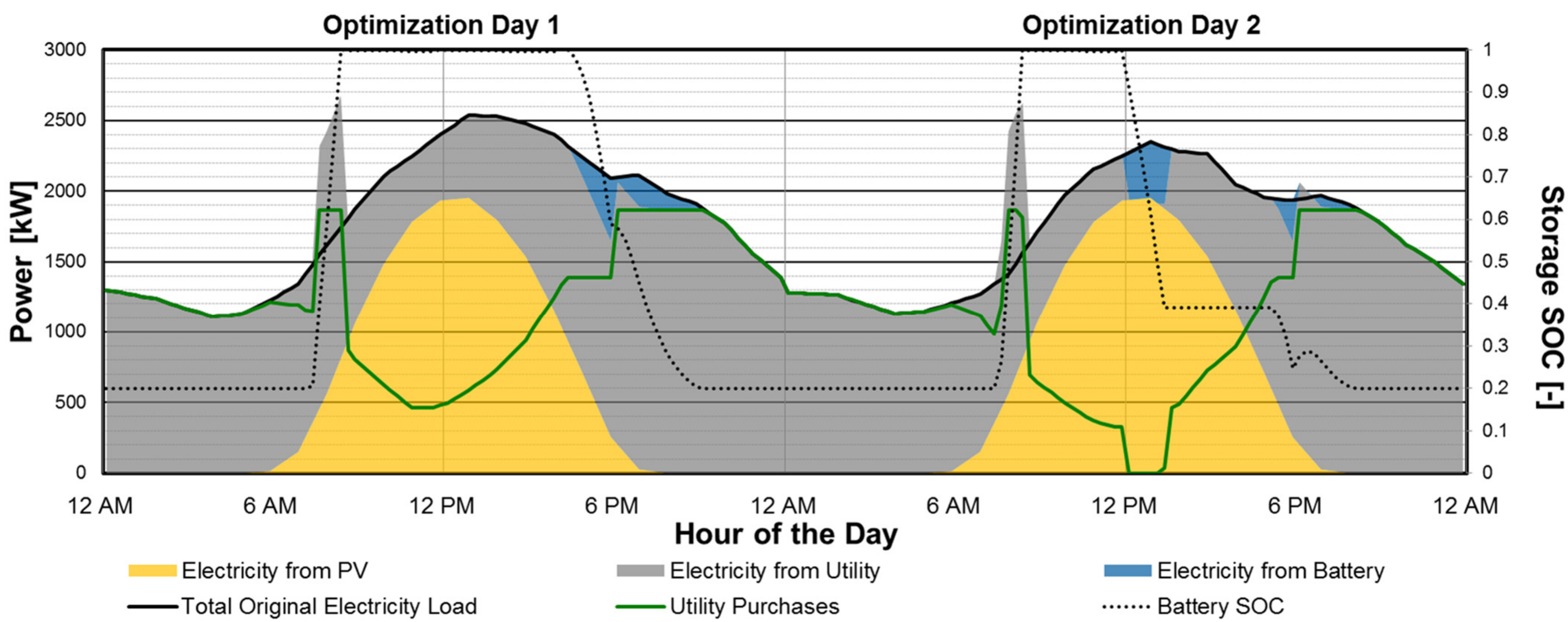




DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

- two-days ahead predictive optimization
- PV and load forecasts are inputs to Operations DER-CAM



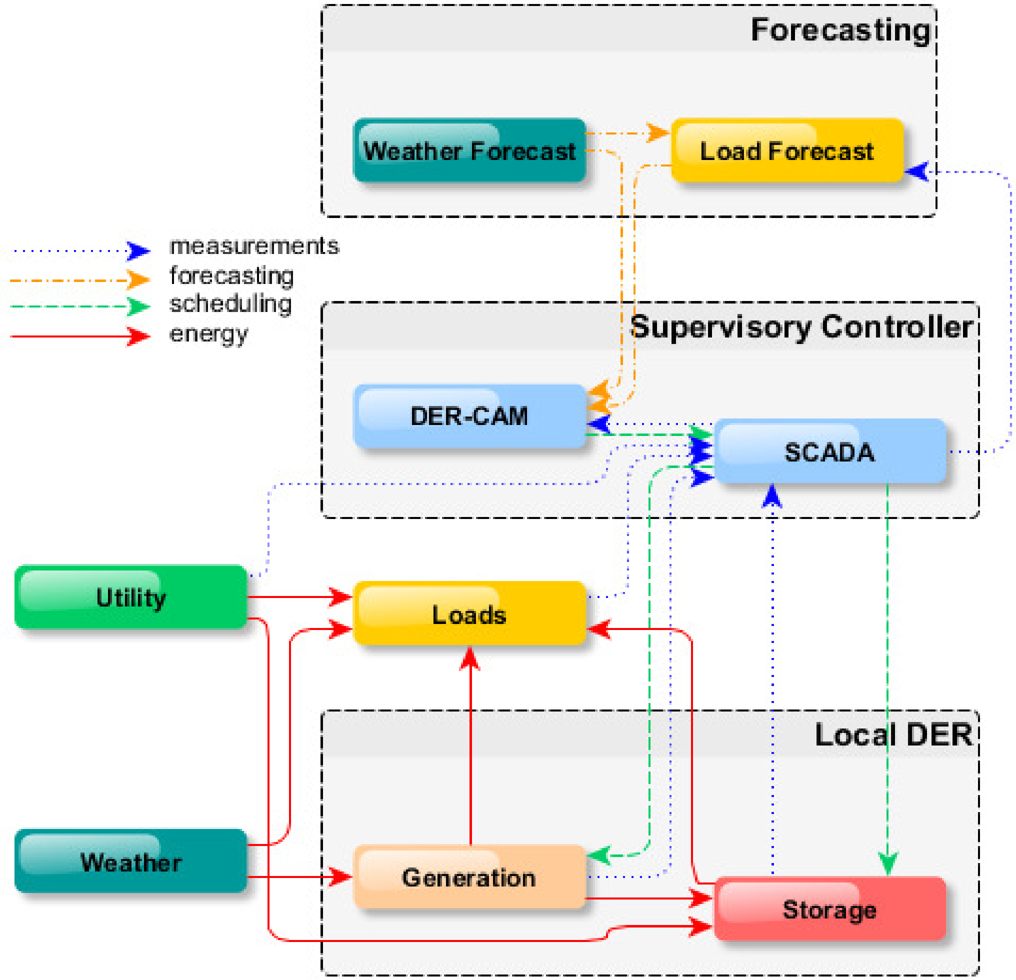
Multi-Layered Microgrid Controller with Utility Connectivity

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

Utility and Microgrid Interactions

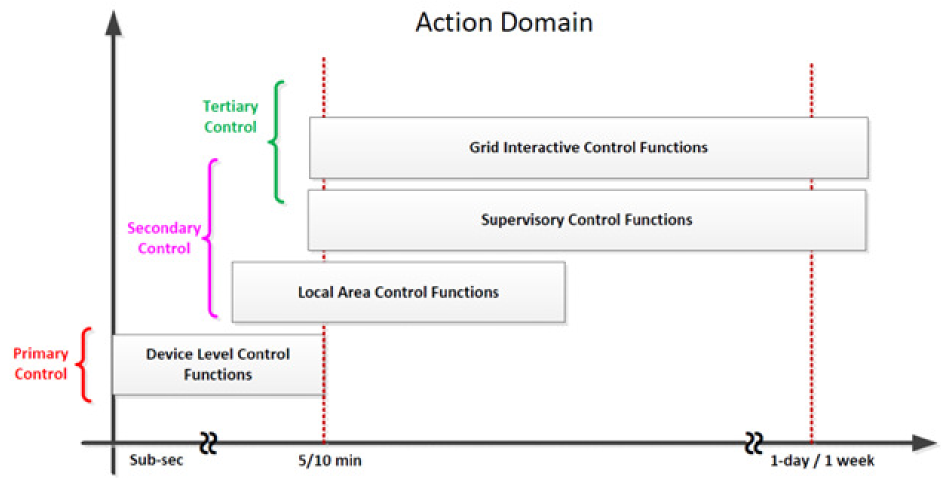
schematic of physical and cyber interactions between utility, microgrid site, local resources, microgrid controller, and optimization problem



Layered Architecture for Utility-Interactive Microgrid

Function Assignment

Block 4	**Grid Interactive Control Functions** (Area EPS control, Spot Market, DMS, TSCADA, Connection to adj. Microgrid)
Block 3	**Supervisory Control Functions** (Forecasting, Data management and Visualization, Optimization [e.g. Volt/ VAR, Economic dispatch], Dispatch, State Estimation, Emergency Handling, Generation Smoothing, Spinning Reserve, Topology Change Management, Black Start, Protection Coordination)
Block 2	**Local Area Control Functions** (Sequence Logic/Status control, Load Management, Building Energy Management, Plant Controller, AGC, Fast Load Shedding, Resynchronization, Disturbance Recording)
Block 1	**Device Level Control Functions** (Voltage/Frequency Control, Reactive power Control, Electric Vehicle Control, Energy Storage Control, Load Control, Generation Control, Islanding Detection, Fault Protection)



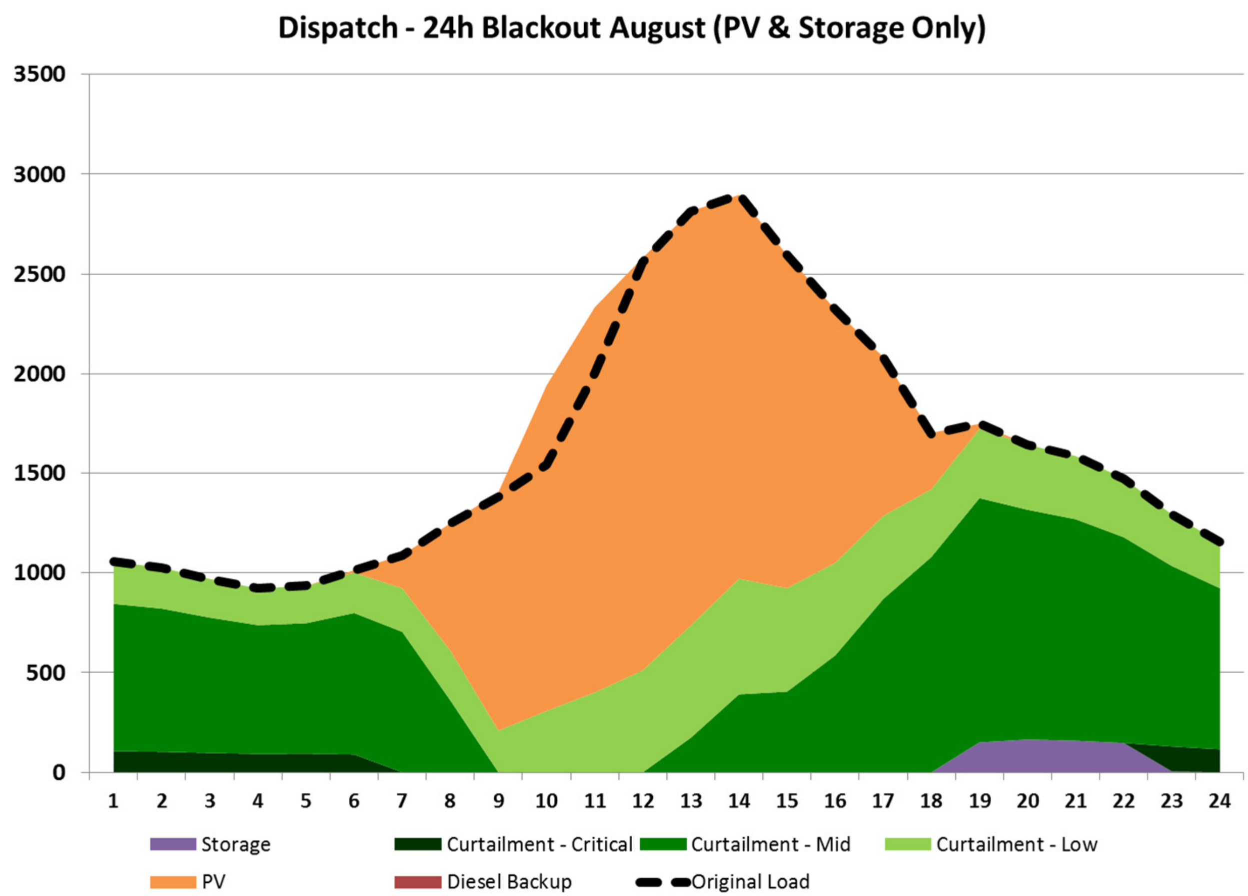
Questions and comments are very welcome!

Backup Slides on FHL

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

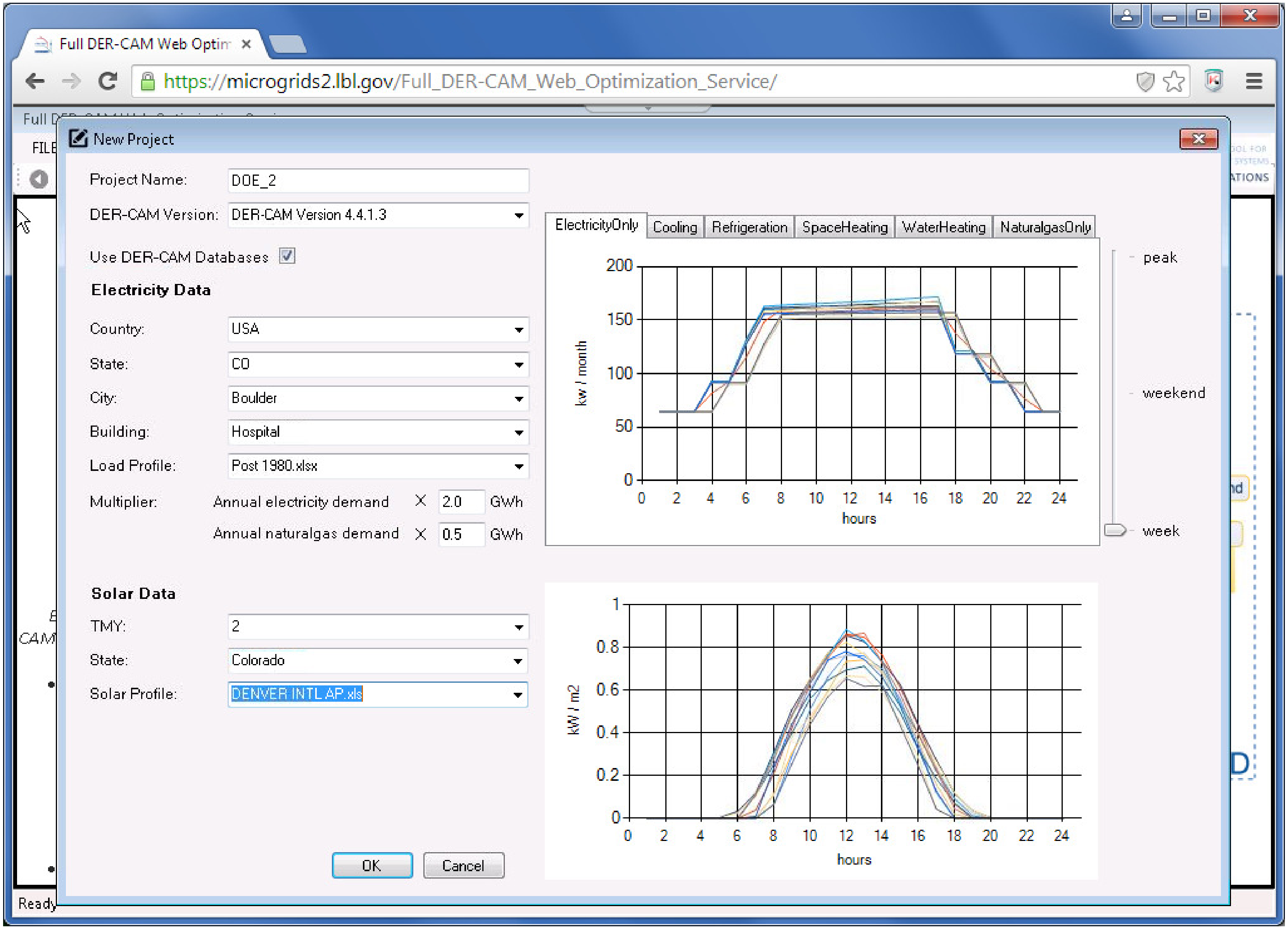
24h blackouts, only PV and storage



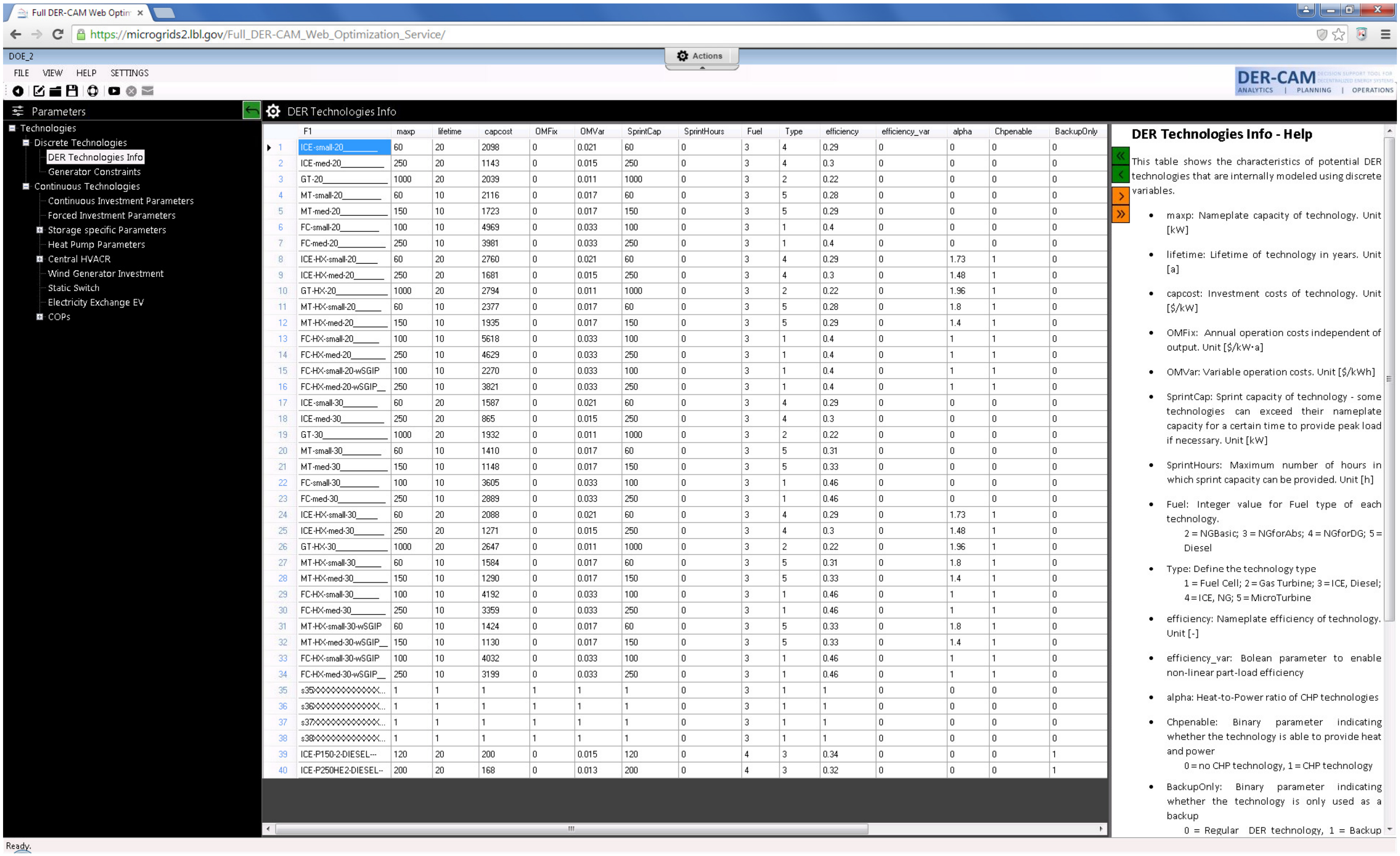
With the current PV and storage capacity alone, FHL would have severe curtailments in the event of a 24h outage, and would not be able to supply all loads

Backup Slides on DER-CAM Interface

Databases


Full DER-CAM Web Optim
https://microgrids2.lbl.gov/Full_DER-CAM_Web_Optimization_Service/
New Project
Project Name: DOE_2
DER-CAM Version: DER-CAM Version 4.4.1.3
Use DER-CAM Databases
Electricity Data
Country: USA
State: CO
City: Boulder
Building: Hospital
Load Profile: Post 1980.xlsx
Multiplier: Annual electricity demand X 2.0 GWh
Annual naturalgas demand X 0.5 GWh
Solar Data
TMY: 2
State: Colorado
Solar Profile: DENVER INTL AP.xls
OK
Cancel
ElectricityOnly
Cooling
Refrigeration
SpaceHeating
WaterHeating
NaturalgasOnly
kw / month
hours
peak
weekend
week
kW / m2
hours
Ready

Example Input Screen for Technologies



	F1	maxp	lifetime	capcost	OMFix	OMVar	SprintCap	SprintHours	Fuel	Type	efficiency	efficiency_var	alpha	Chpenable	BackupOnly
1	ICE-small-20________	60	20	2098	0	0.021	60	0	3	4	0.29	0	0	0	0
2	ICE-med-20_________	250	20	1143	0	0.015	250	0	3	4	0.3	0	0	0	0
3	GT-20_____________	1000	20	2039	0	0.011	1000	0	3	2	0.22	0	0	0	0
4	MT-small-20________	60	10	2116	0	0.017	60	0	3	5	0.28	0	0	0	0
5	MT-med-20_________	150	10	1723	0	0.017	150	0	3	5	0.29	0	0	0	0
6	FC-small-20________	100	10	4969	0	0.033	100	0	3	1	0.4	0	0	0	0
7	FC-med-20_________	250	10	3981	0	0.033	250	0	3	1	0.4	0	0	0	0
8	ICE-HX-small-20_____	60	20	2760	0	0.021	60	0	3	4	0.29	0	1.73	1	0
9	ICE-HX-med-20______	250	20	1681	0	0.015	250	0	3	4	0.3	0	1.48	1	0
10	GT-HX-20__________	1000	20	2794	0	0.011	1000	0	3	2	0.22	0	1.96	1	0
11	MT-HX-small-20_____	60	10	2377	0	0.017	60	0	3	5	0.28	0	1.8	1	0
12	MT-HX-med-20_______	150	10	1935	0	0.017	150	0	3	5	0.29	0	1.4	1	0
13	FC-HX-small-20_____	100	10	5618	0	0.033	100	0	3	1	0.4	0	1	1	0
14	FC-HX-med-20_______	250	10	4629	0	0.033	250	0	3	1	0.4	0	1	1	0
15	FC-HX-small-20-wSGIP	100	10	2270	0	0.033	100	0	3	1	0.4	0	1	1	0
16	FC-HX-med-20-wSGIP__	250	10	3821	0	0.033	250	0	3	1	0.4	0	1	1	0
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18	ICE-med-30_________	250	20	865	0	0.015	250	0	3	4	0.3	0	0	0	0
19	GT-30_____________	1000	20	1932	0	0.011	1000	0	3	2	0.22	0	0	0	0
20	MT-small-30________	60	10	1410	0	0.017	60	0	3	5	0.31	0	0	0	0
21	MT-med-30_________	150	10	1148	0	0.017	150	0	3	5	0.33	0	0	0	0
22	FC-small-30________	100	10	3605	0	0.033	100	0	3	1	0.46	0	0	0	0
23	FC-med-30_________	250	10	2889	0	0.033	250	0	3	1	0.46	0	0	0	0
24	ICE-HX-small-30_____	60	20	2088	0	0.021	60	0	3	4	0.29	0	1.73	1	0
25	ICE-HX-med-30______	250	20	1271	0	0.015	250	0	3	4	0.3	0	1.48	1	0
26	GT-HX-30__________	1000	20	2647	0	0.011	1000	0	3	2	0.22	0	1.96	1	0
27	MT-HX-small-30_____	60	10	1584	0	0.017	60	0	3	5	0.31	0	1.8	1	0
28	MT-HX-med-30_______	150	10	1290	0	0.017	150	0	3	5	0.33	0	1.4	1	0
29	FC-HX-small-30_____	100	10	4192	0	0.033	100	0	3	1	0.46	0	1	1	0
30	FC-HX-med-30_______	250	10	3359	0	0.033	250	0	3	1	0.46	0	1	1	0
31	MT-HX-small-30-wSGIP	60	10	1424	0	0.017	60	0	3	5	0.33	0	1.8	1	0
32	MT-HX-med-30-wSGIP__	150	10	1130	0	0.017	150	0	3	5	0.33	0	1.4	1	0
33	FC-HX-small-30-wSGIP	100	10	4032	0	0.033	100	0	3	1	0.46	0	1	1	0
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36	s36XXXXXXXXXXXX...	1	1	1	1	1	1	0	3	1	1	0	0	0	0
37	s37XXXXXXXXXXXX...	1	1	1	1	1	1	0	3	1	1	0	0	0	0
38	s38XXXXXXXXXXXX...	1	1	1	1	1	1	0	3	1	1	0	0	0	0
39	ICE-P150-2-DIESEL---	120	20	200	0	0.015	120	0	4	3	0.34	0	0	0	1
40	ICE-P250HE2-DIESEL--	200	20	168	0	0.013	200	0	4	3	0.32	0	0	0	1

Example Results

DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

BERKELEY LAB

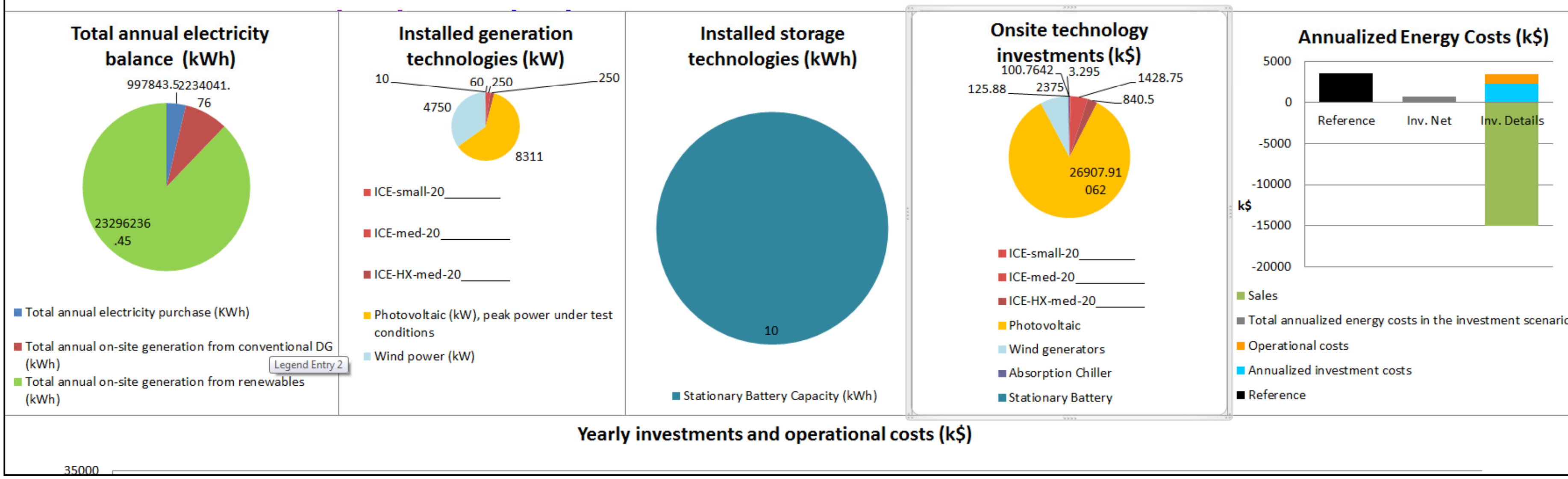
3/9/2015

NOTE: Please enable MACROS in this workbook in order to process the DER-CAM result file

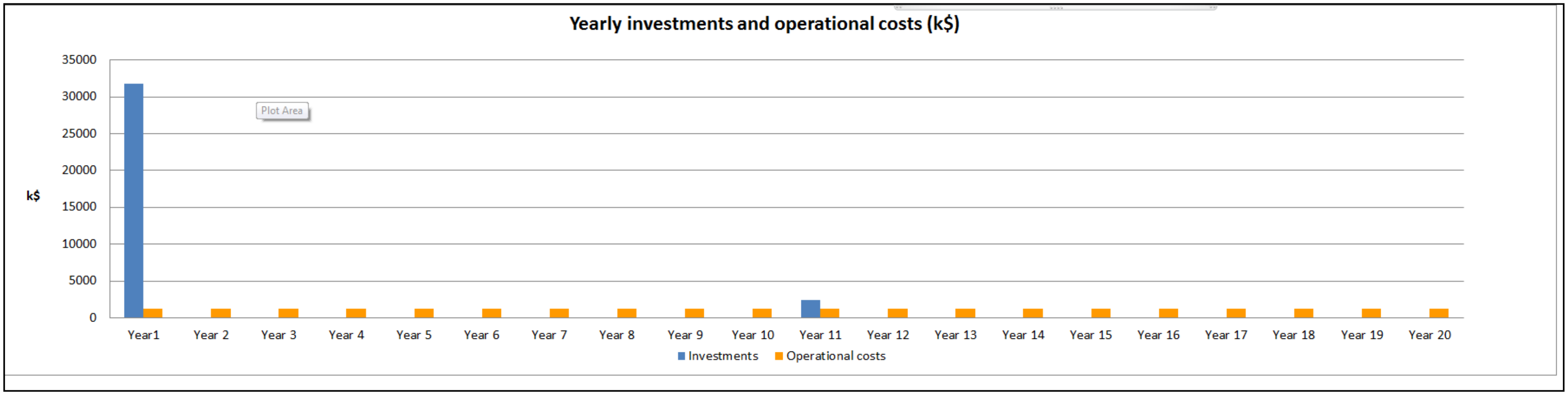
	Total Annual Energy Costs (k$)
Reference	3600
Investment scenario (incl. annu	725.201
Savings (%)	142.6%

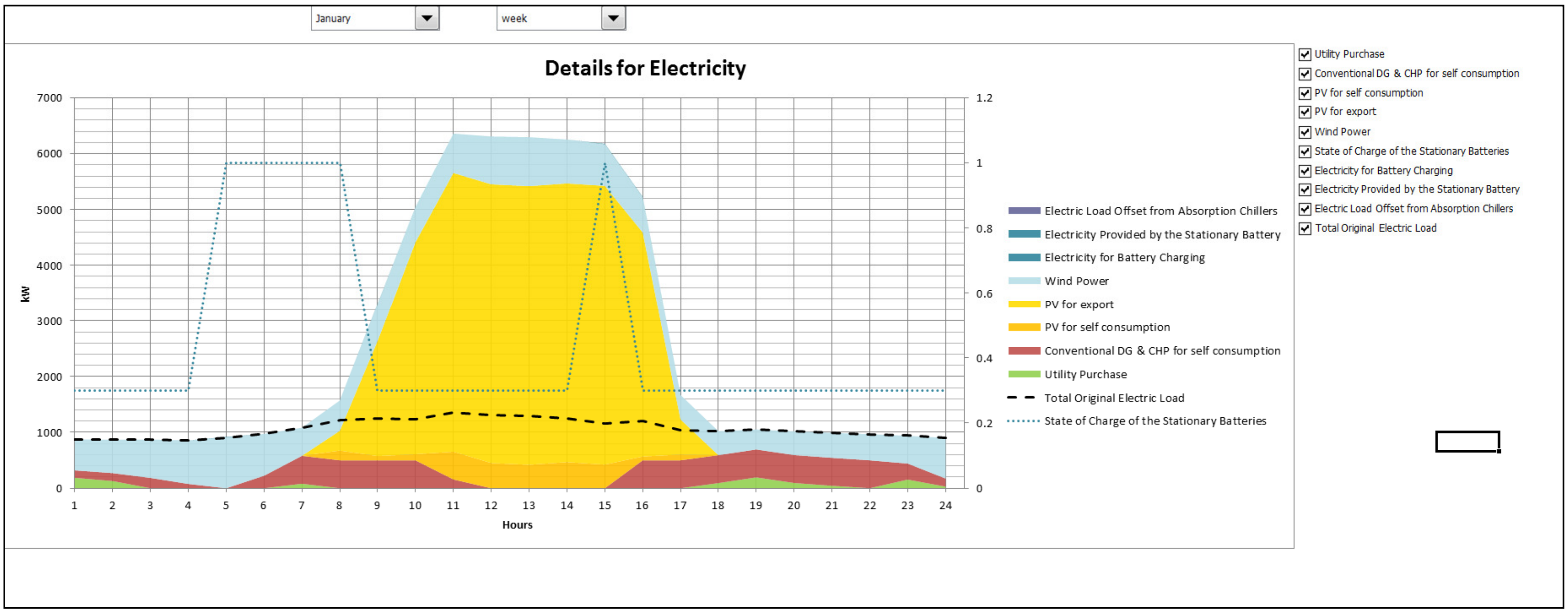
	Total Annual CO2 emissions (metric tons)
Reference	2846.276
Investment scenario (incl. annu	2770.656
Savings (%)	2.7%

1metric ton=1.10 tons (US)



Example Results





DER Controller at University of New Mexico's Mechanical Engineering Building (UNM ME) in Albuquerque, New Mexico

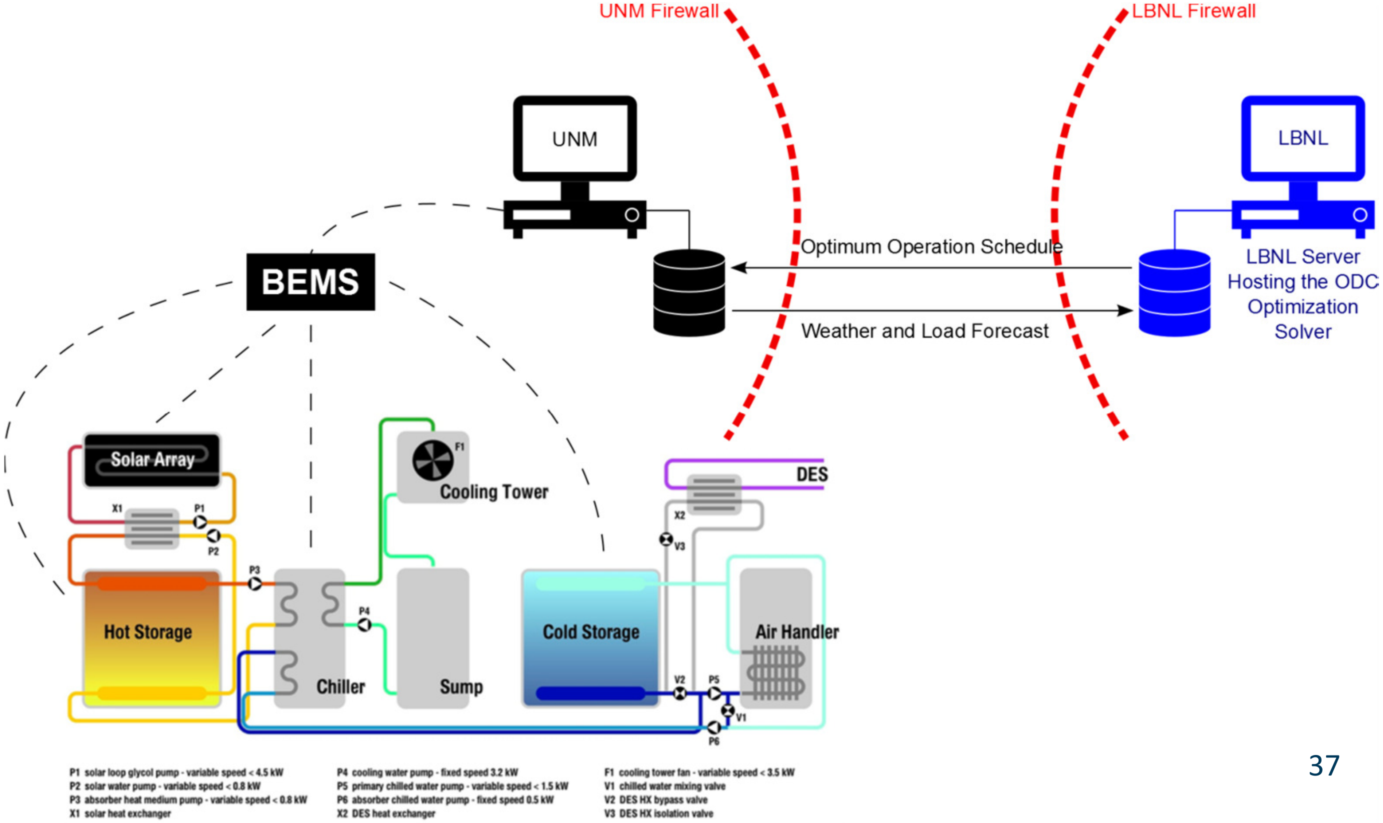
DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

THE UNIVERSITY of NEW MEXICO

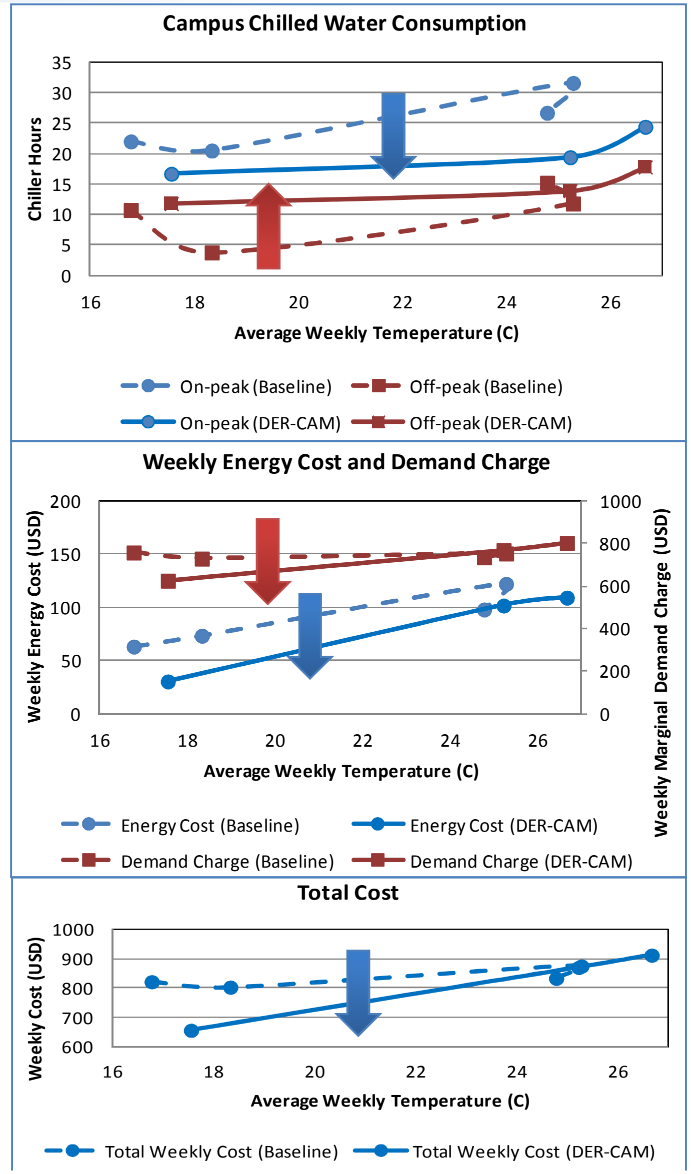
UNM ME – DER Controller

- goal: use the Operations DER-CAM in a Software-as-a-Service model for closed loop optimum cooling operation in the UNM ME
- technologies: heat storage (30 m^3, 510 kWh_{th}), cold storage (350 m^3, 2620 kWh_{th}), absorption chiller (70 kW_{th}), and solar thermal (232 m^2, 170 kW_{th})



Savings with the DER-CAM Controller

- comparison of 3 DER-CAM operated and 4 baseline weeks in summer 2014:
  - week of 05 May 2014 - Baseline – 16.8 ℃
  - week of 12 May 2014 - DER-CAM – 17.6 ℃
  - week of 20 May 2014 - Baseline – 18.3 ℃
  - week of 01 July 2014 - Baseline – 25.3 ℃
  - week of 08 July 2014 - DER-CAM – 25.2 ℃
  - week of 15 July 2014 - Baseline – 24.8 ℃
  - week of 22 July 2014 - DER-CAM – 26.7 ℃
- observations:
  - 55% saving in weekly energy cost
  - 16% saving in weekly marginal demand charge
  - 19% saving in total weekly cost



DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS

ANALYTICS | PLANNING | OPERATIONS

THE UNIVERSITY of NEW MEXICO

DER-CAM Online Interface at UNM ME

- online interface for the UNM ME operation (http://iseslab.unm.edu/dercam.html)
- measurements shown in real-time
- DER-CAM schedules depicted
- deviations from the optimum schedules visualized