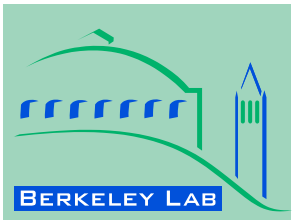
LBNL-6354E



ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Web-Based Economic and Environmental Optimization of Microgrids

Michael Stadler, Chris Marnay, Nicholas DeForest, Joe Eto, Gonçalo Cardoso, Andrea Mammoli, Hans Barsun, Richard Burnett, Dave Klapp, and Judy Lai

Environmental Energy Technologies Division

January 20, 2012

presented at the 2012 IEEE PES Innovative Smart Grid Technologies Conference, January 16-20 2012, Washington Marriott Wardman Park, Washington D.C., USA.

http://eetd.lbl.gov/EA/EMP/emp-pubs.html

The work described in this presentation was funded by the Office of Electricity Delivery and Energy Reliability, Smart Grids Program, and also by the Energy Efficiency and Renewable Energy's Technology Commercialization Fund, both of the U.S.DOE under Contract No. DE-AC02-05CH11231. The authors are also very grateful to Merrill Smith for her continued support of the DER-CAM development.

Disclaimer

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof, or The Regents of the University of California.

Ernest Orlando Lawrence Berkeley National Laboratory is an equal opportunity employer.

Web-Based Economic and Environmental Optimization of Microgrids

M. Stadler, C. Marnay, N. DeForest, J. Eto,
G. Cardoso, A. Mammoli, H. Barsun, R. Burnett, D. Klapp, J. Lai

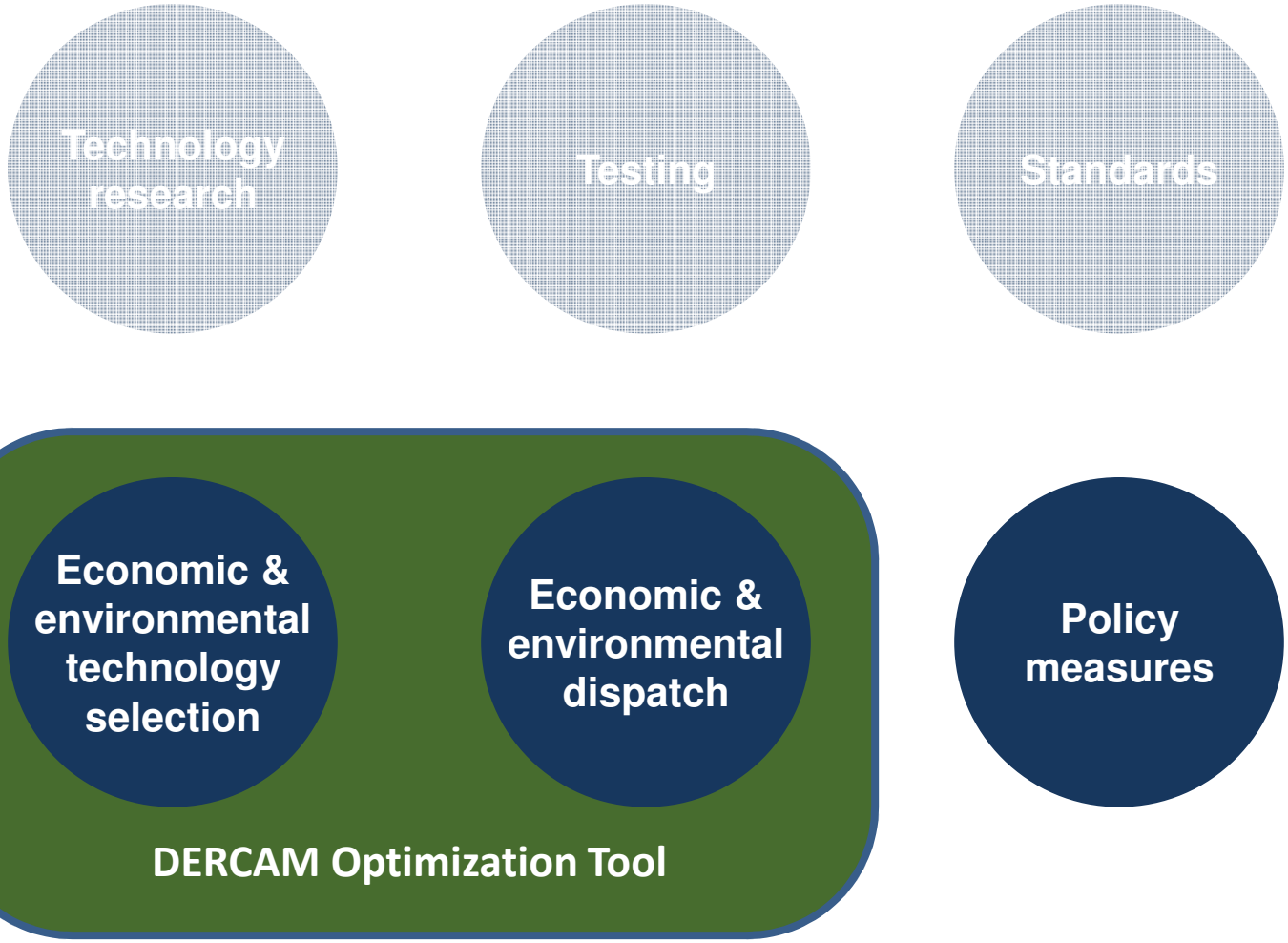
mstadler@lbl.gov
der.lbl.gov

IEEE PES Power & Energy Society®
IEEE

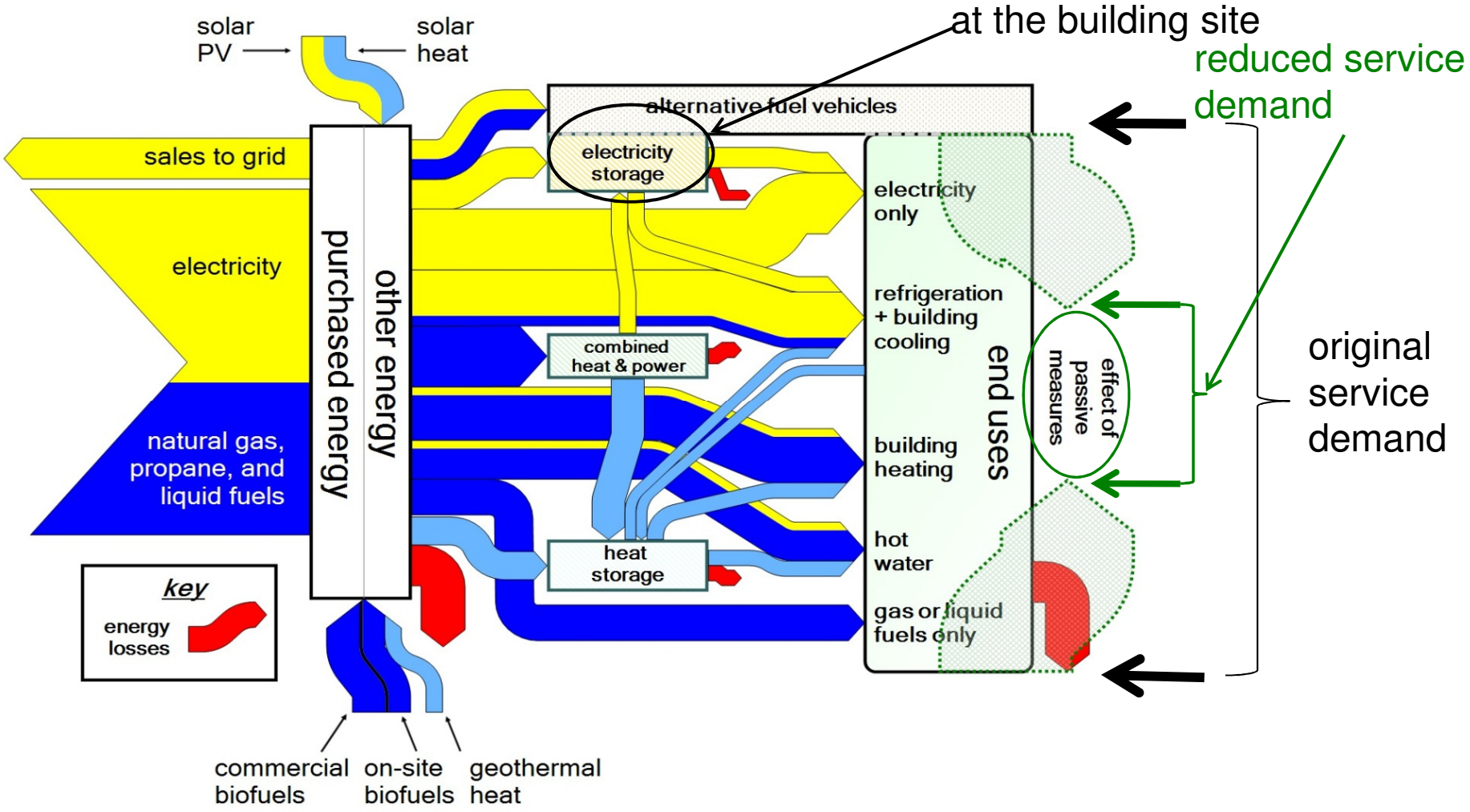
Outline

- Our contribution to microgrids / global concept
- What is DER-CAM?
- Web-Opt: connecting clients to DER-CAM
- Example applications
  - AEP test-bed: Columbus, OH
  - Santa Rita Jail: Dublin, CA
  - University of New Mexico: Albuquerque, NM
- Further/Future Work

Our Contribution to Microgrids



Global Model Concept for Microgrids



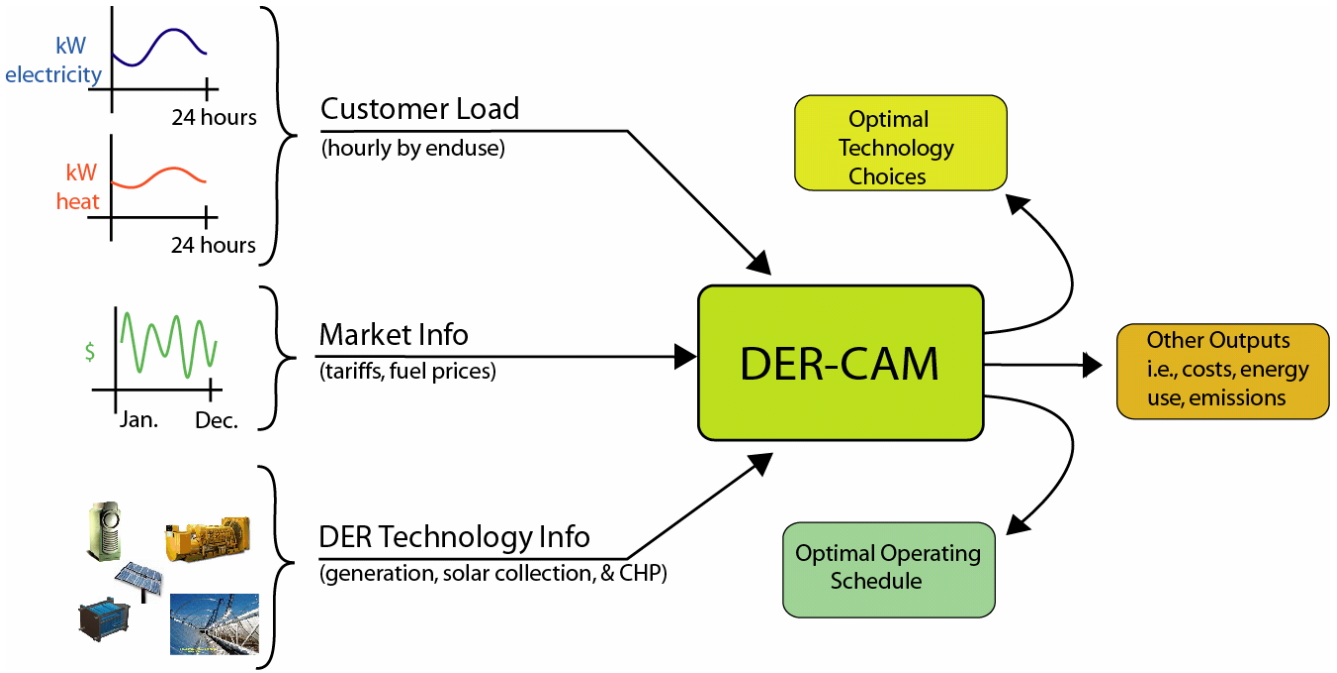
What is DER-CAM

Distributed Energy Resources Customer Adoption Model (DER-CAM)

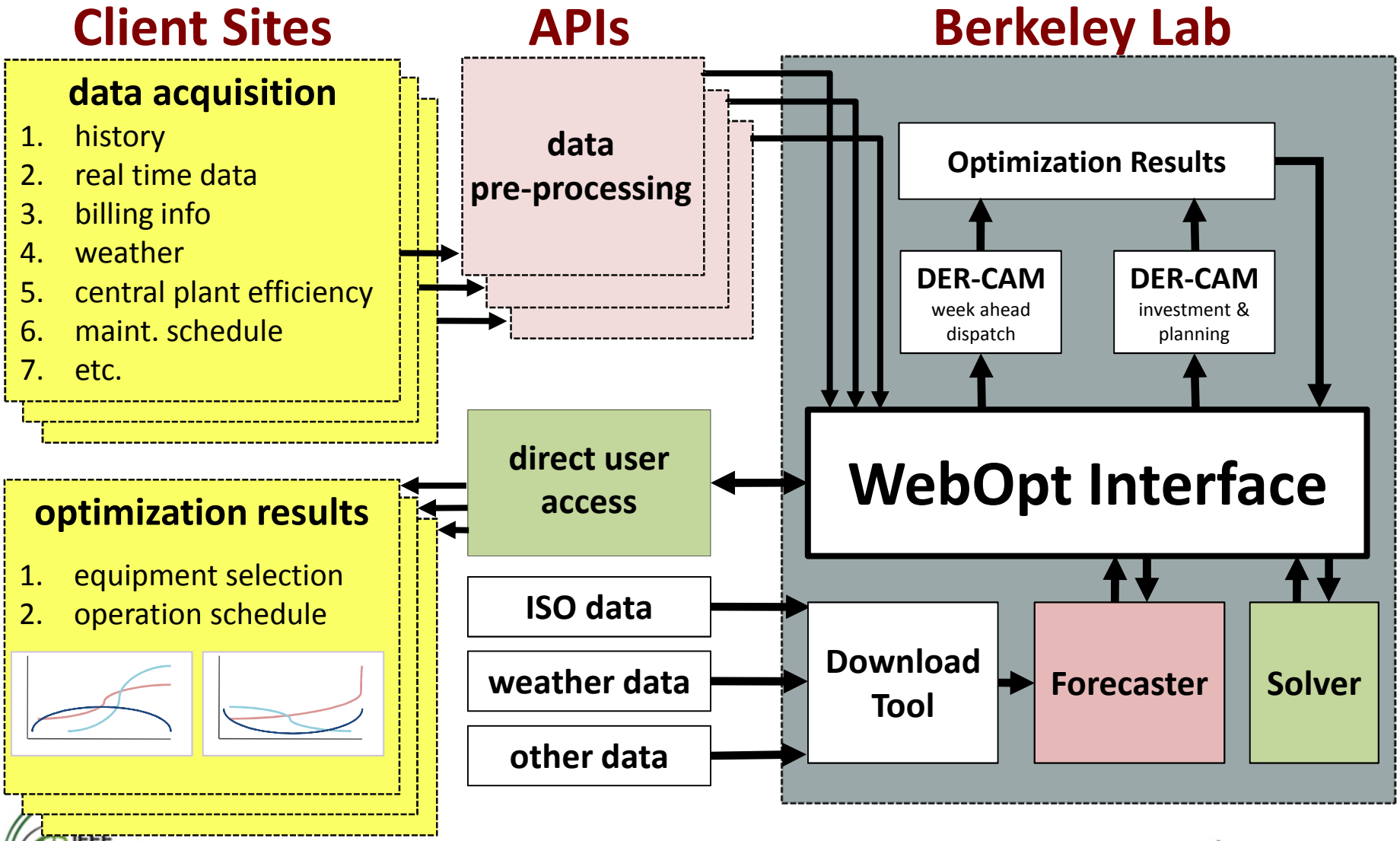
- is a deterministic Mixed Integer Linear Program (MILP), written in the General Algebraic Modeling System (GAMS®)
- minimizes annual energy costs, CO_2 emissions, or multiple objectives of providing services on the building level (typically buildings with 250-2000 kW peak)
- produces technology neutral pure optimal results with highly variable runtime
- has been designed for more than 10 years by Berkeley Lab and collaborations in the US, Germany, Spain, Belgium, Japan, and Australia → exchange visitors
- first commercialization (*web clients*) and real-time optimization steps
- 270 DER-CAM *web clients* to date

DER-CAM Versions

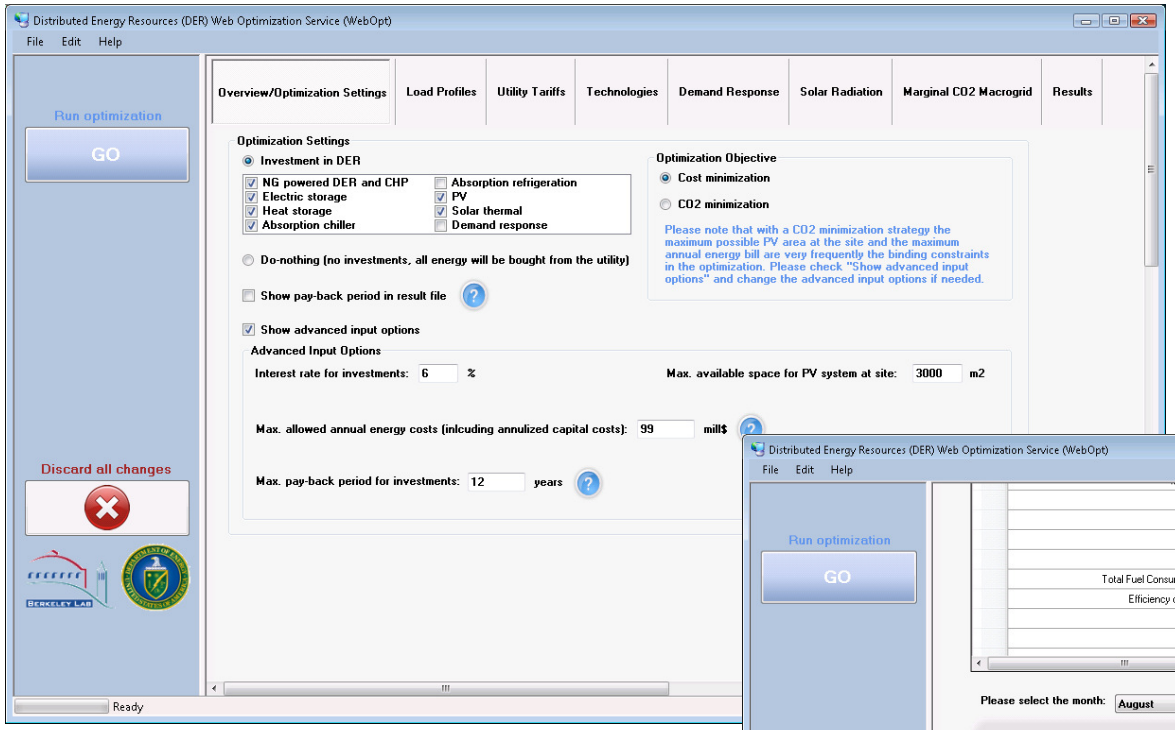
- **Investment & Planning:** determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs
- **Operations:** determines optimal week-ahead scheduling for installed equipment and *forecasted* loads and weather, tariffs

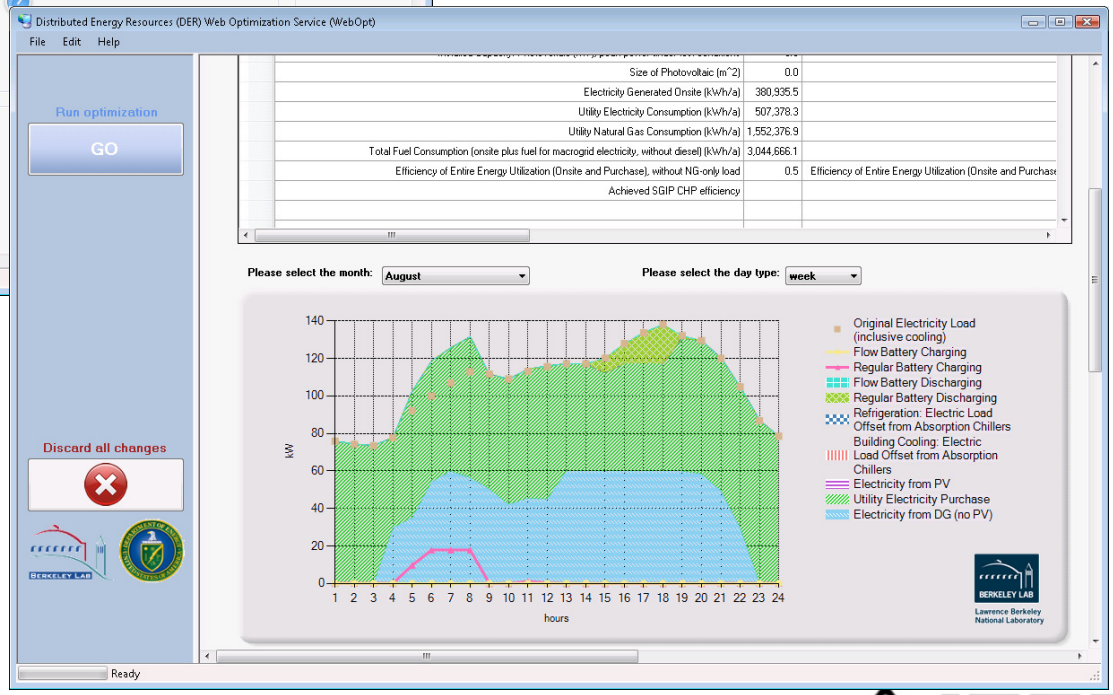


Access to DER-CAM via WebOpt



Investment & Planning WebOpt: Web-Interface





DER-CAM Web-Service for natural gas fired CHP, PV, solar thermal, electric storage, and absorption chillers

- no direct EMS coupling / feedback

http://der.lbl.gov/der-cam/how-access-der-cam

IEEE PES Power & Energy Society®

IEEE

Application 1: AEP

CERTS Microgrid *Concept*

- seamless islanding and reconnection via single PCC
- peer-to-peer, autonomous coordination among micro-sources (w/o high bandwidth communications)
- plug-and-play - no custom engineering
- energy manager on arbitrary platform

CERTS Microgrid *Test Bed Demonstration at AEP*

our objectives:

- generate load profiles and optimal scheduling for testing of 3 CHP systems
  - TECOGEN PROTOTYPE 60kW CHP
  - OLYMPIAN 100kW CHP
  - TECOGEN INV 100KW CHP
- develop automated interface for schedule delivery to AEP

Application 2: Santa Rita Jail (SRJ)

objectives:

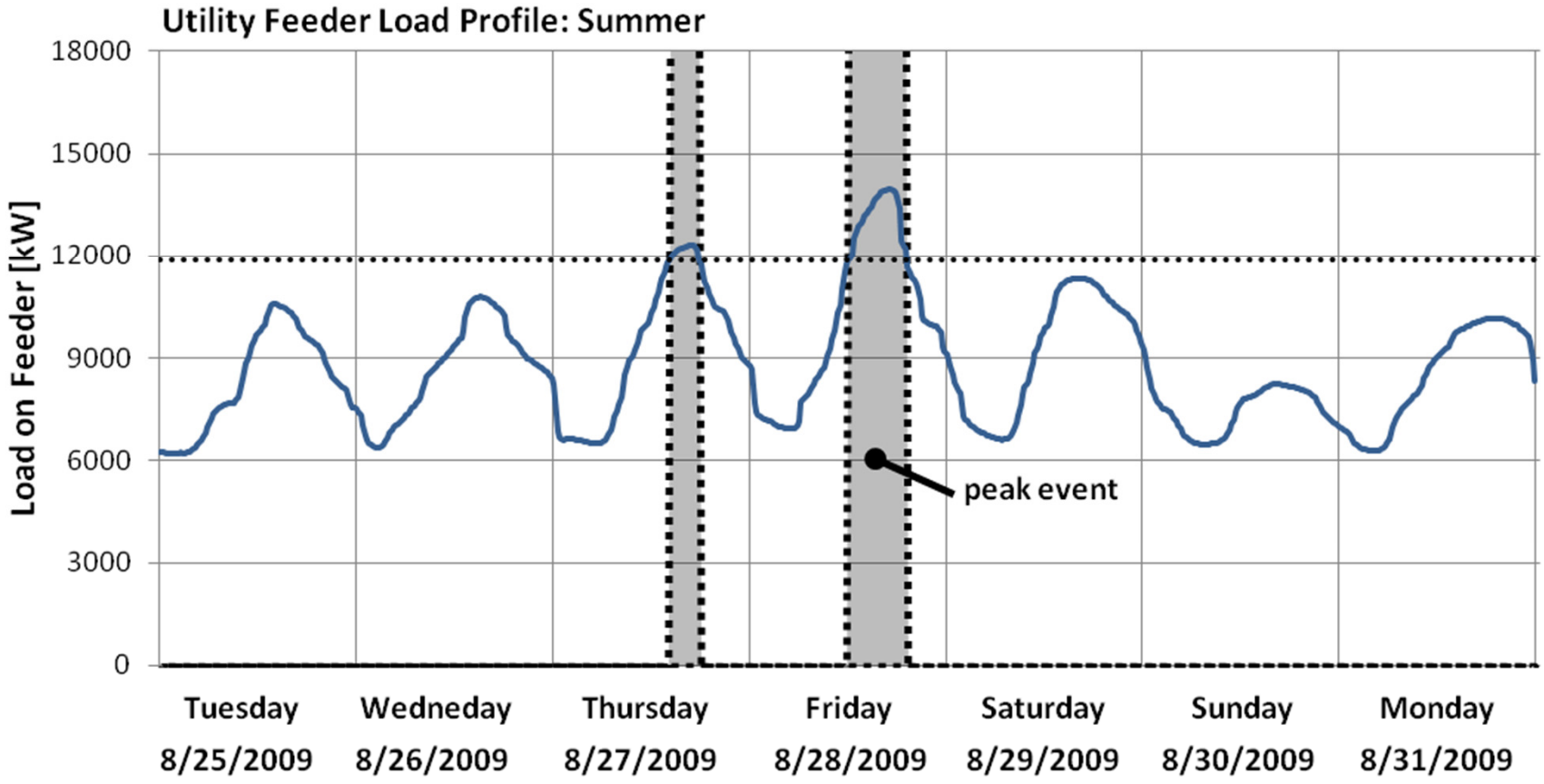
- deliver optimized week-ahead scheduling of onsite electric storage with Operations DER-CAM
- determine potential reduction in utility feeder peak demand through strategic battery dispatch

3 MW peak load facility
CERTS microgrid functionality

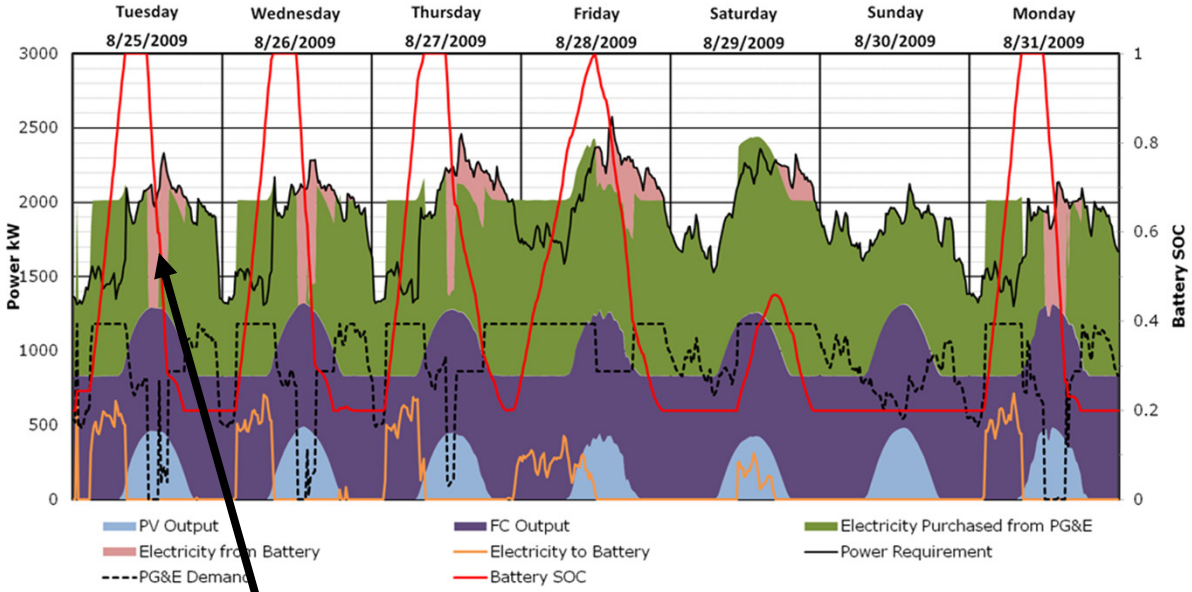
DER On-site:

- photovoltaic: 1.2 MW peak
- fuel cell: 1 MW molten carbonate
- electric storage: 2 MW 2MWh Li-ion

SRJ: Utility Feeder Demand



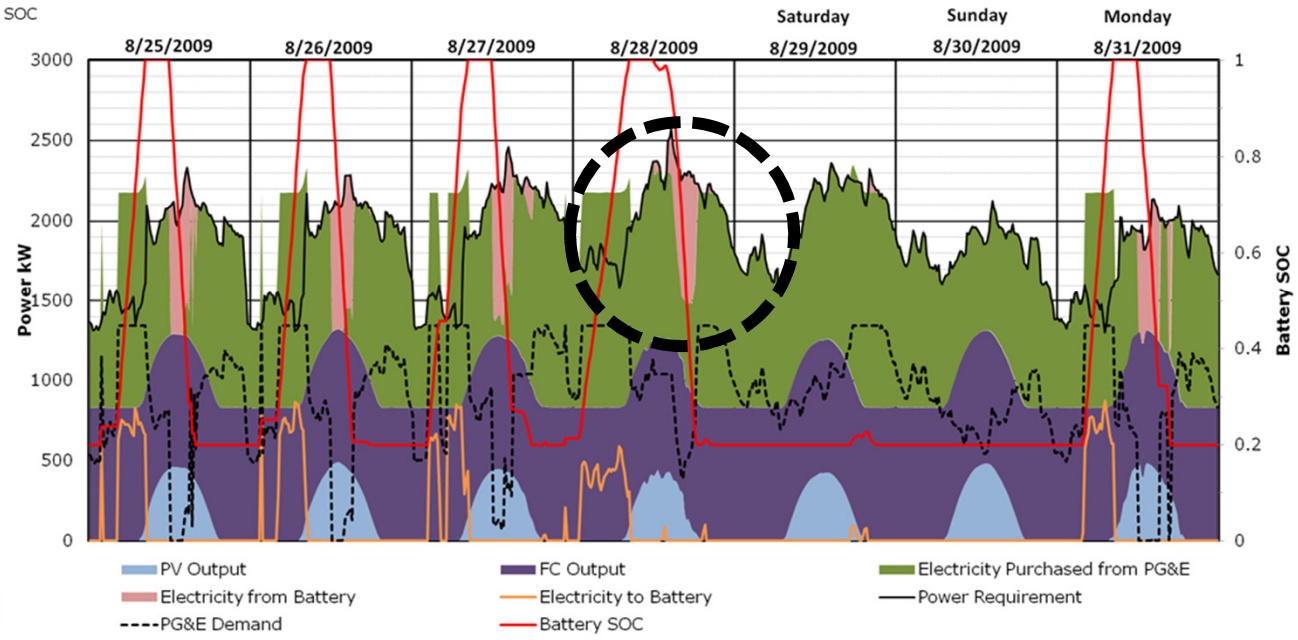
SRJ: Optimal Schedules*



Solution 1:
utility bill
minimization

Solution 2:
feeder peak
minimization
+$3.8k demand charge
3.5% reduction

DER-CAM minimizes on-peak purchases due to high demand charge



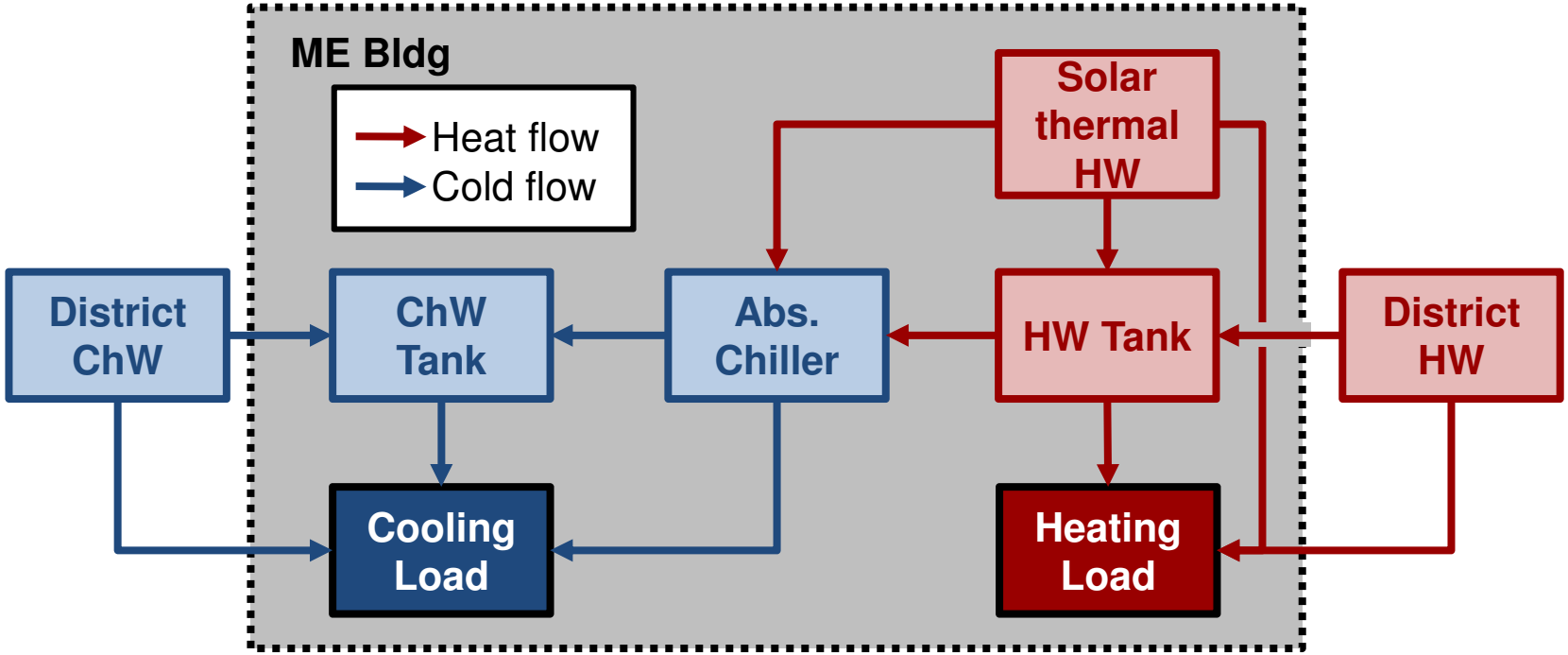
***Jail-Only Results**
(note scale)

Application 3: UNM

objectives:

- generate optimized scheduling of cooling equipment
  - solar thermal collection
  - hot water storage
  - chilled water storage
  - absorption chiller
- deliver results daily via automated interface to UNM building control system (delta controller)

UNM Test Equipment/Configuration

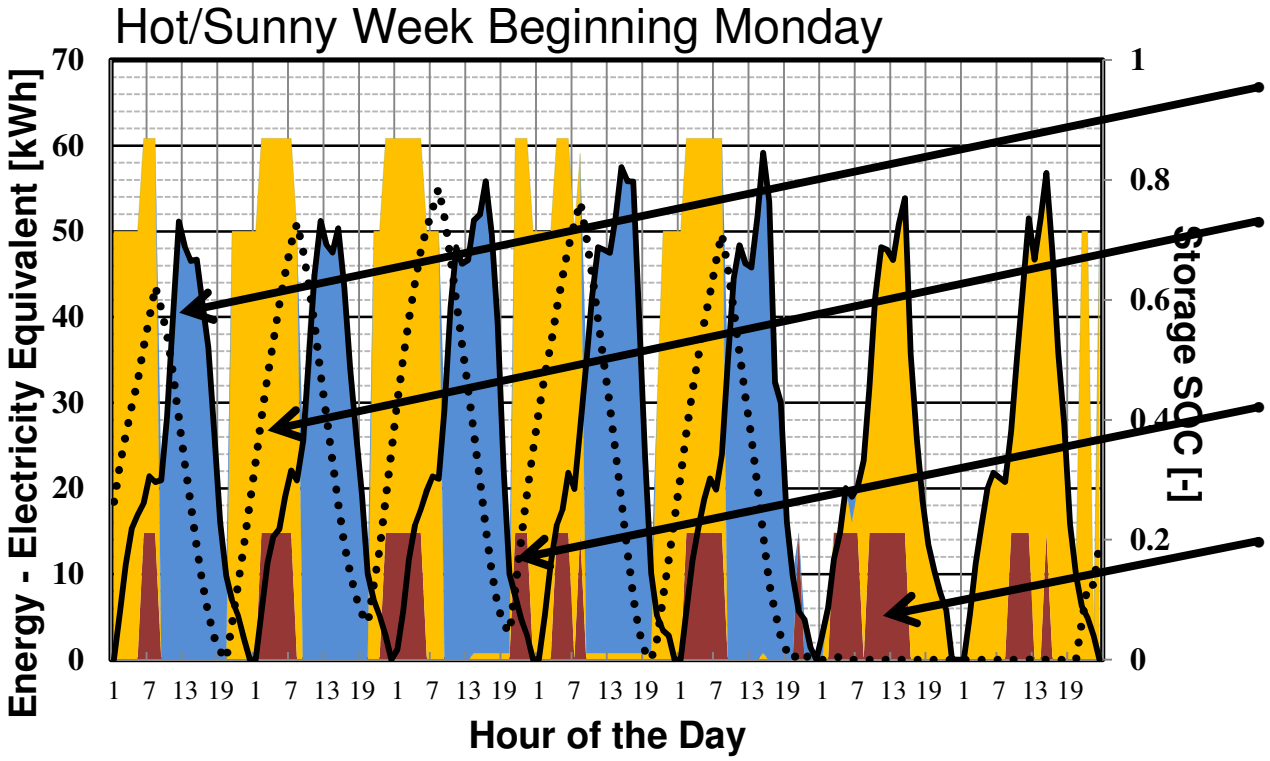


equipment capacities:

- solar thermal: 170 kW peak rating
- absorption chiller: 70 kW
- chilled water storage: 3800 kWh
- hot water storage: 300 kWh (9000 gallons)

(all values thermal)

UNM: Cooling Results



cold storage sufficient for most on-peak demand

cold storage recharged during cheap off-peak hours

abs. chiller runs off-peak to avoid chiller pumping costs

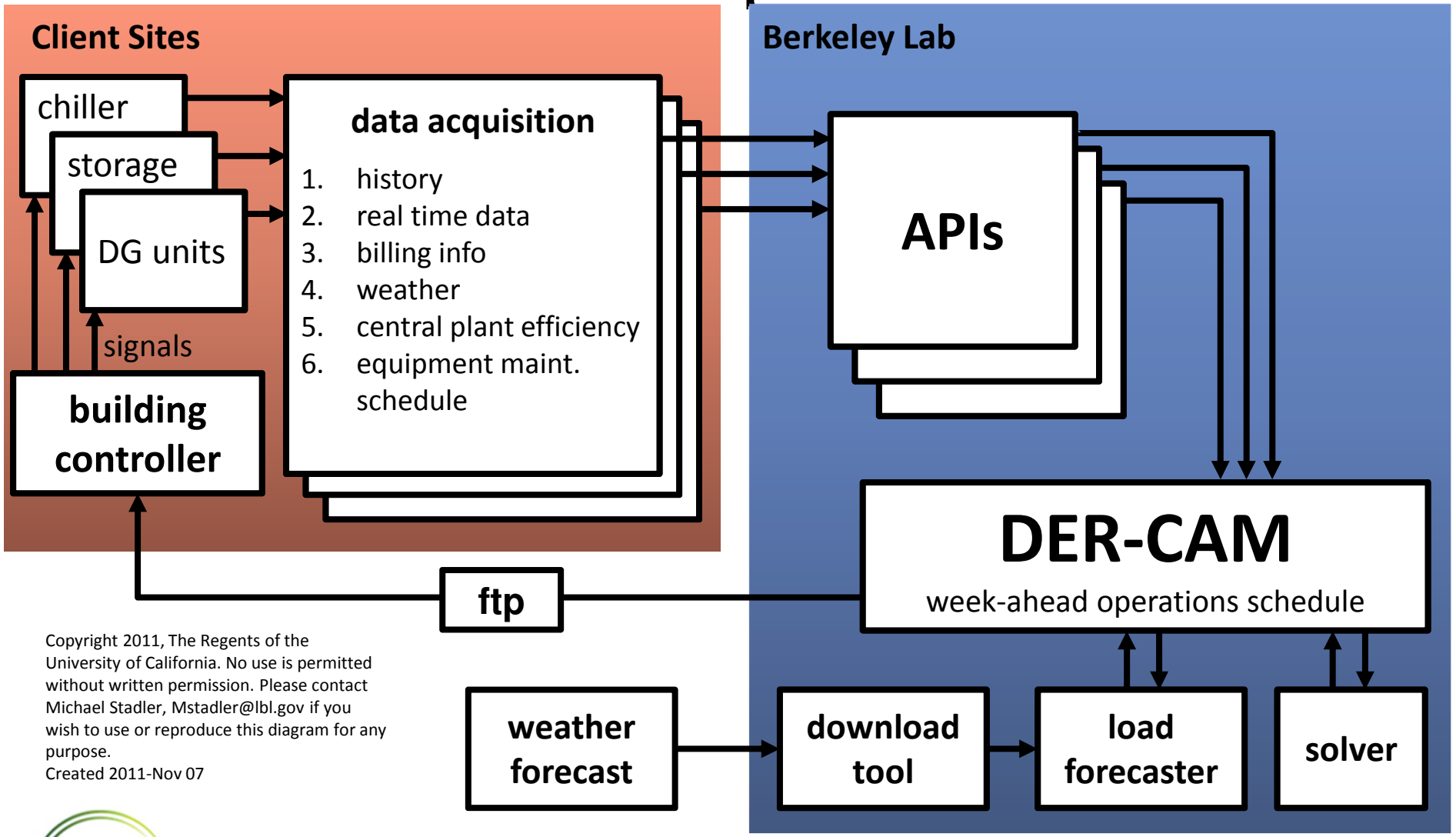
abs. chiller constrained to 2 cycles per day

automated delivery of results through the duration of cooling season (mid October)

IEEE PES Power & Energy Society®

IEEE

UNM WebOpt Structure



Copyright 2011, The Regents of the University of California. No use is permitted without written permission. Please contact Michael Stadler, Mstadler@lbl.gov if you wish to use or reproduce this diagram for any purpose.
Created 2011-Nov 07

Further/Future Work

- sporadic fuel-cell outages complicate forecast of utility electricity demand → stochastic optimization
- microgrid multi-objective optimization framework
- plug-in electric vehicle demonstration at Los Angeles AFB
  role: extend demonstration to a true microgrid, provide OpenADR instructions from CAISO AS & SCE DR markets, optimize all bidding and scheduling (esp. PEV charging & discharging), control loads while grid connected, balance generation and prioritize loads while islanded
- finish Web-Interface for operations DER-CAM
- add new technologies, e.g. wind, heat pumps
- convert linear DER-CAM to a non-linear optimization to be able to capture technical constraints more realistically, e.g. efficiency curves
- integration of building energy simulation, flexible temperature set points, demand-side control
- power flow constraints, voltage support

End

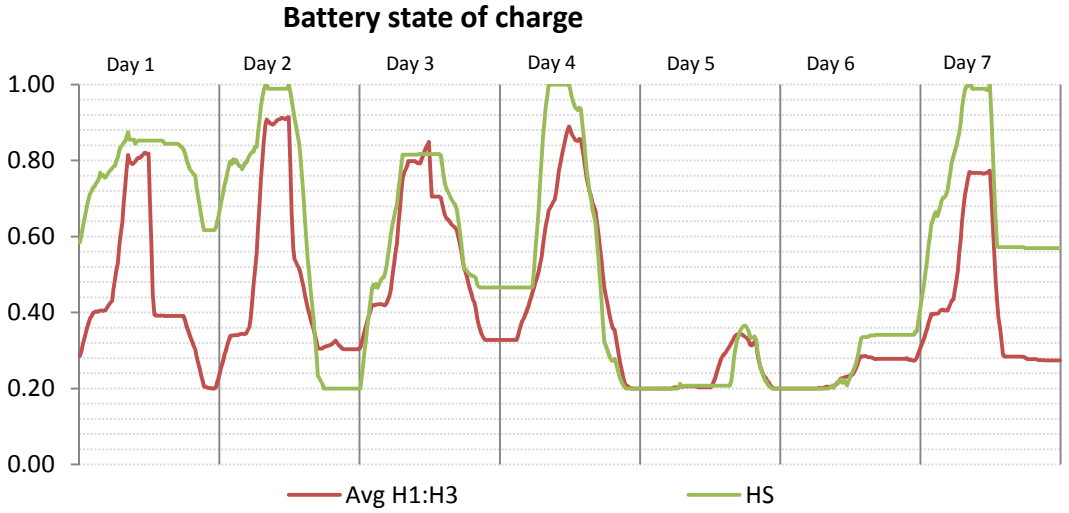
Thank you!

Questions and comments are very welcome.

Further Work/Uncertainty

- implementation of stochastic linear programming in Operations DER-CAM to model uncertainty
- possibility to explicitly account for uncertainty through user defined scenarios
- generic approach allows introducing uncertainty in multiple parameters, such as generation outages, fuel prices or weather conditions
- first application under design is the optimal battery scheduling at the SRJ under the uncertainty in fuel cell availability
- using the stochastic approach allows minimizing energy costs under any possible scenario realization

Further Work/Uncertainty, Draft Results



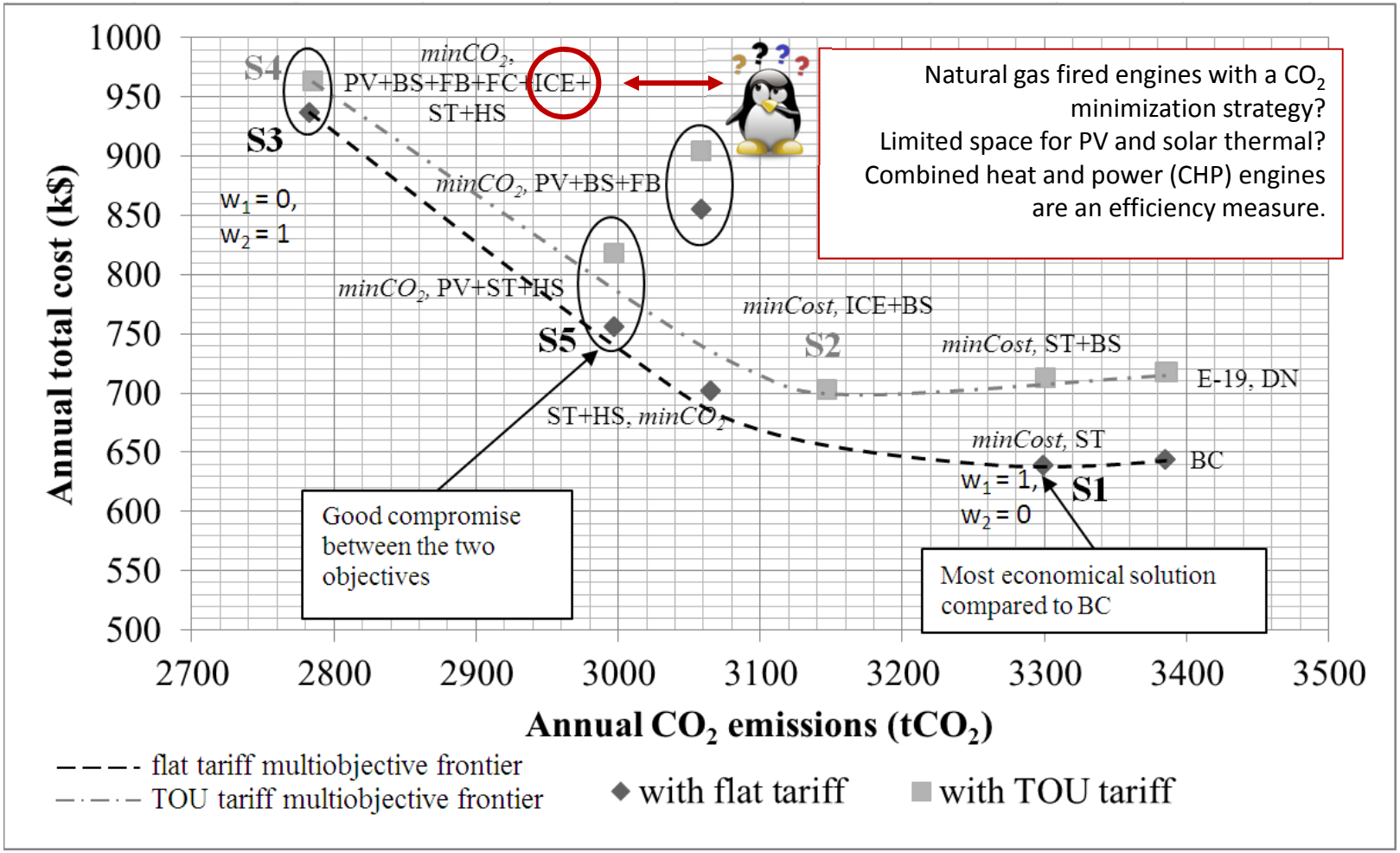
Avg. H1:H3 – Average of optimal battery schedules H1 to H3, obtained from fuel cell availability scenarios 1 to 3.

HS – Optimal battery schedule obtained by the stochastic model, where all scenarios are considered simultaneously.

Observed fuel cell scenario	1		2		3	
Battery schedule	Avg. H1:H3	HS	Avg. H1:H3	HS	Avg. H1:H3	HS
Total energy costs	$ 70 296	$ 69 126	$ 59 017	$ 57 560	$ 64 213	$ 60 431
TOU charges	$ 26 807	$ 26 837	$ 21 245	$ 21 351	$ 23 232	$ 21 821
Demand charges	$ 42 705	$ 41 567	$ 29 596	$ 28 160	$ 35 661	$ 30 968

- optimal battery schedules can be obtained assuming availability scenarios separately (deterministic approach) or simultaneously (stochastic approach)
- the stochastic approach yields lower energy costs in the realization of unexcepted events and a more conservative scheduling

Microgrid multi-objective optimization framework



PV: photovoltaic, BS: conventional lead acid battery, FB: Zinc Bromine flow battery, FC: fuel cell with waste heat utilization, ICE: internal combustion engine with waste heat utilization, ST: solar thermal conventional collectors, HS: Heat storage, BC: Base case, and DN: "Do nothing" case

More information at: der.lbl.gov