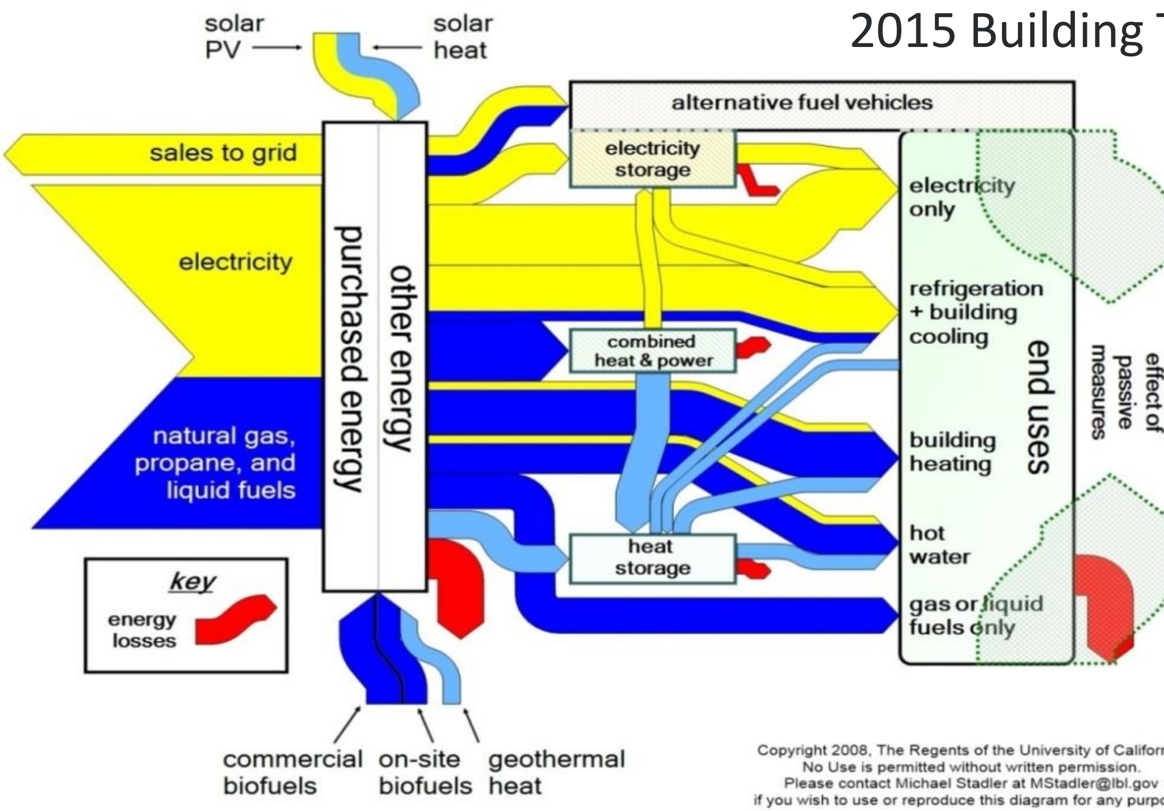
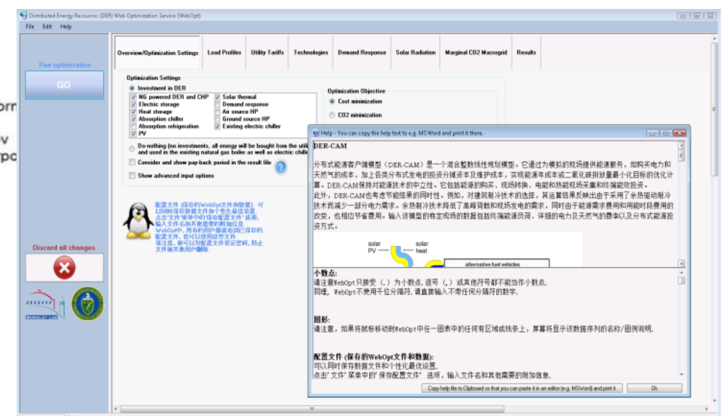
Microgrid Equipment Selection and Control in Buildings

2015 Building Technologies Office Peer Review



CERC-BEE is a five year, $50M program created by the U.S. Department of Energy and Chinese Ministry of Science and Technology. This work is being done under the buildings part of the program, http://cercbee.lbl.gov/

In this project LBNL is working with Tianjin University, and C3 Energy on the U.S. side, and XIngYe Solar in China.



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Project Summary

Timeline:

Start date: June 2011

Planned end date: Dec 2015

Key Milestones

1. UNM Mech Eng Blg. model development; summer 2012
2. Chinese WebOpt; Dec 2012
3. U.S.-China regional comparison study on DER technology potential in buildings; mid 2013

Reference Buildings Analysis Set; Fall 2013

4, UNM performance analysis: Dec. 2014

5, B71T electrochromic window control: Dec. 2014

6. B26 forecast based control: Dec. 2014

Budget:

Total DOE $ to Jun 11~Dec 14: $670K

Total DOE $ in FY15 : $220K

Key Partners:

Univ. of New Mexico	Tianjin University
C3 Energy	Tongji University
PNM (electricity utility)	XingYe Solar
Santa Fe Com. Col.	Beijing U. of Const. & Architecture

Project Goal:

Using a Software as a Service model provide optimal equipment choice and operating guidance for low energy buildings employing multiple supply and demand-side technologies .

Target Market/Audience:

Developers of complex commercial buildings and microgrids involving integration of on-site generation, storage, load control, grid services, etc. in the U.S. and China.

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Purpose and Objectives

Problem Statement: Ultra efficient buildings and microgrids offering low carbon resilient energy services require complex optimization for equipment choice, operations.

Target Market and Audience:

1. Investment & Planning: building designers & owners, visualization developers
2. Operations: DER equipment & control system vendors, microgrid operators
3. Analysis: policymakers, vendors

Impact of Project: Provide methods and software to operate building microgrids.

1. Output: software tools to optimize DER technology selection and operation.
2. CA 2050 study shows commercial buildings have large DER technology potential. Our regional study shows DER technologies may reduce CO2 intensity in Chinese commercial buildings by 40%.
   a. near-term: 4 NM buildings, XingYe building, JCI Shanghai demonstrations
   b. intermediate-term: extend NM buildings and add controls capabilities
   c. long term: demonstrate DER technologies optimal operation and controls
      add power quality and grid interaction for district scale solution

Approach

Approach: Deploy software tools base on the Distributed Energy Resources Customer Adoption Model (DER-CAM) developed over a decade at LBNL.

1, a web-based DER-CAM version, WebOpt, finds optimal on-site generation, storage, control, etc., equipment combinations that minimize cost, carbon footprint, or a combination, using either English or Chinese.

2, a seven-day-ahead optimal control strategy generator, Operations DER-CAM. This is being used at UNM Mech Eng. Blg. & U. of Tianjin Blg. 26, and B71T electrochromic window control in LBNL, with others in process.

3, an automated WebOpt analysis of multiple buildings to build bottom up estimates of market trends.

Key Issues: Need to extend WebOpt to other technologies, developing interfaces to various control systems difficult. Linearize some technologies with non-linear characteristics

Distinctive Characteristics: DER-CAM is an analytic model that delivers ultra-fast guaranteed optimal solutions to complex building investment and operations problems.

Progress and Accomplishments

Lessons Learned: Interest in microgrids is exploding but changing objectives, challenge of implementing schedules in building control systems is significant (simplified approach needed)

Accomplishments: Chinese language interface for WebOpt developed and extensive training conducted in China, ~150 WebOpt users in U.S., ~80 in China, and ~500 worldwide, DER potential study completed and published-2012, Reference Building capability developed -2013 (all these suggest rapid deployment possible), **energy use of UNM Mech. Eng. Blg. lowered by ~20% in 2014 (gains are most significant for complex energy systems). And LBNL B71T Electrochromic window control to trade-off cooling and lighting energy**

Market Impact: software use in both U.S. and China.

1. Conducted trainings in the U.S. and China to use DER-CAM
2. Beijing Workshop of DER technologies to engage U.S. manufacturers and Chinese stakeholders in using this tool
3. Currently, a few buildings use Webopt for DER technologies selection in the U.S. and China. Implemented NM buildings on real-time control.
4. Provide DER technologies selections optimization in projects in China (hospital project in China) and US
5. Application on demonstration buildings and successful story
6. Start to work on district level work.

Awards/Recognition: Additional funding from PNM

WebOpt User Statistics

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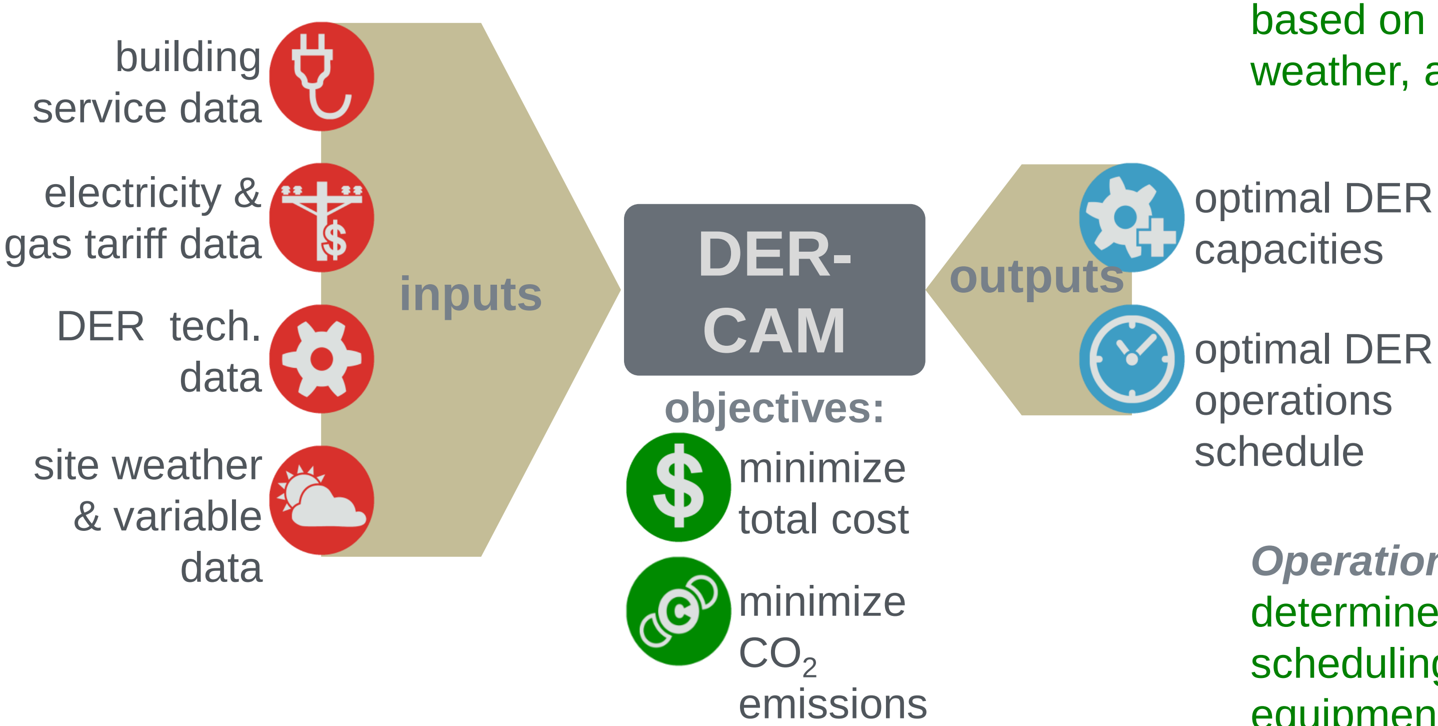
DER-CAM Inputs & Outputs

Investment & Planning:
determines optimal equipment combination and operation based on *historic* load data, weather, and tariffs

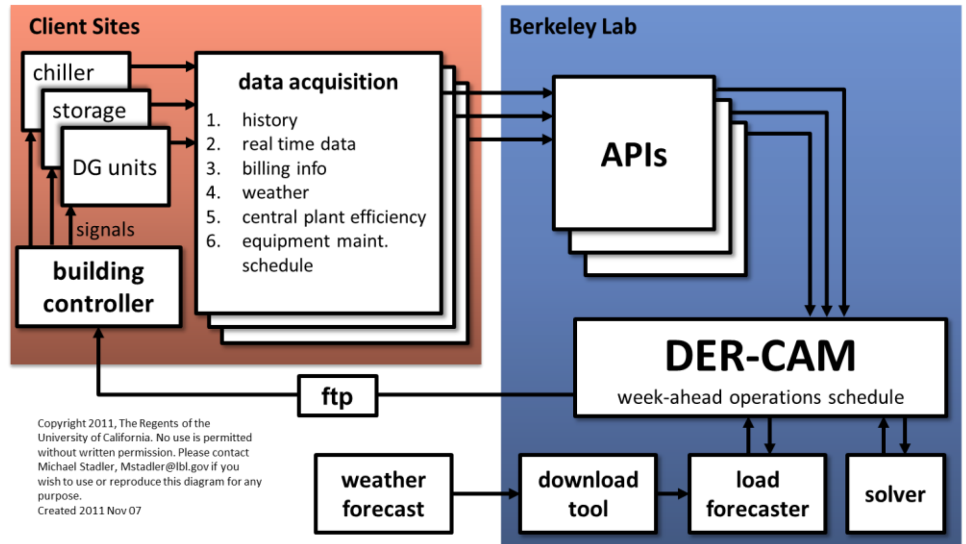


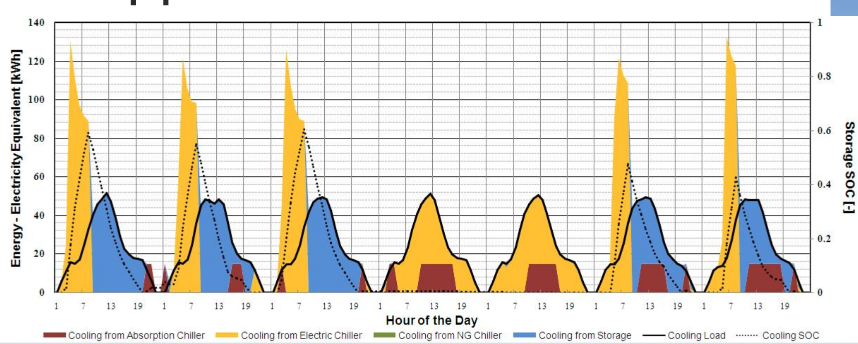
Operations:
determines optimal week-ahead scheduling for installed equipment and *forecasted* loads, weather and tariffs

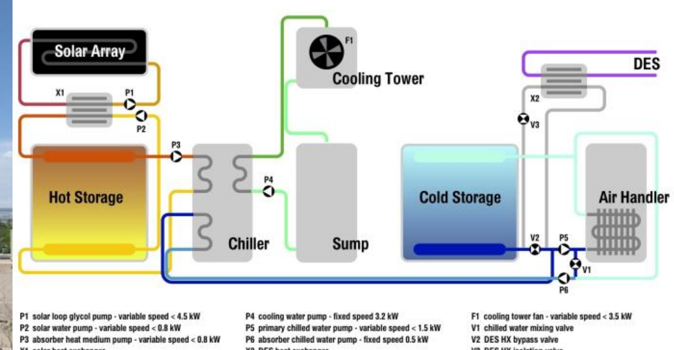
UNM Mech. Eng. Blg. Intro

objectives:

- generate optimized scheduling of cooling equipment with *Operations DER-CAM*
  - solar thermal collection
  - hot water storage
  - chilled water storage
  - absorption chiller
- deliver daily automated control instructions
- establish SaaS approach applicable to LEB







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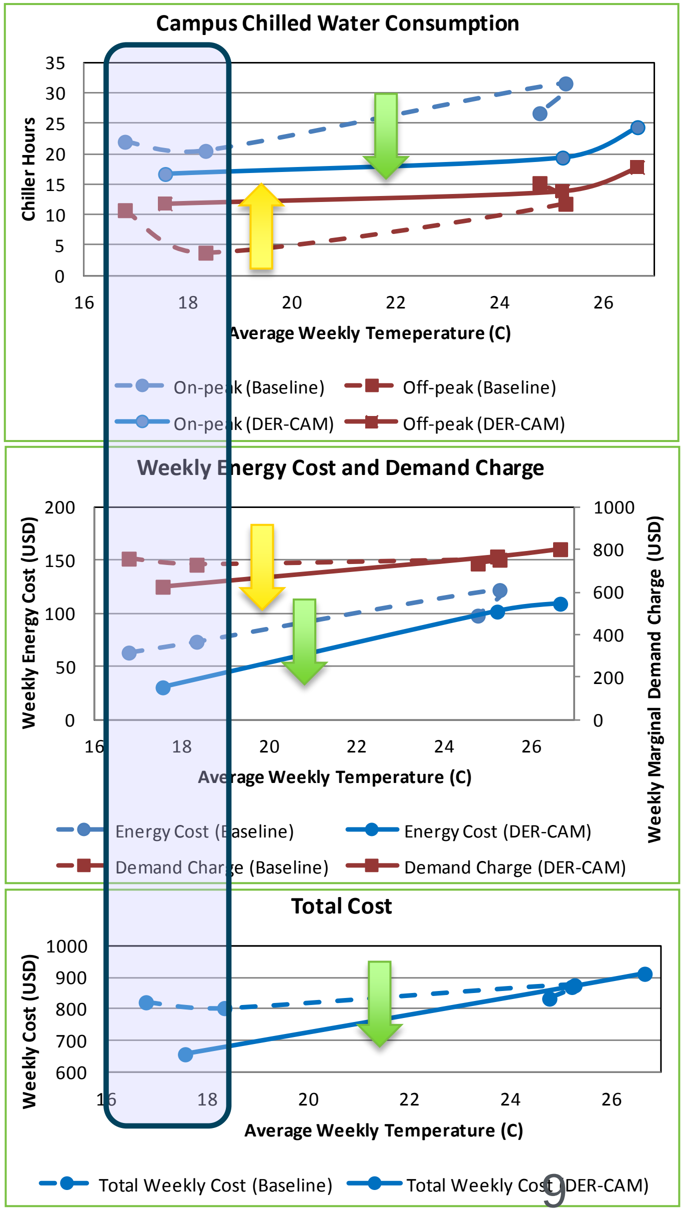
NM Demonstration Bldg. – UNM ME (2014 Accomplishment)

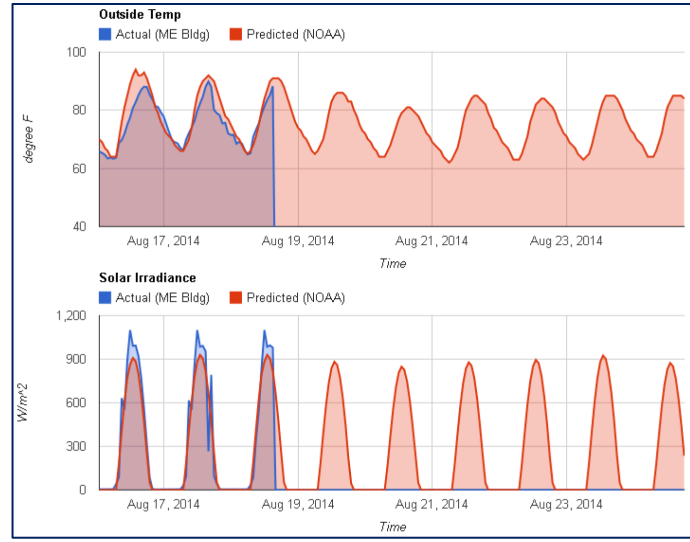
- Comparison of three DER-CAM operated and four baseline weeks in summer 2014:
  - Week of 05 May 2014 - Baseline – 16.8 °C
  - Week of 12 May 2014 - DER-CAM – 17.6 °C
  - Week of 20 May 2014 - Baseline – 18.3 °C
  - Week of 01 July 2014 - Baseline – 25.3 °C
  - Week of 08 July 2014 - DER-CAM – 25.2 °C
  - Week of 15 July 2014 - Baseline – 24.8 °C
  - Week of 22 July 2014 - DER-CAM – 26.7 °C

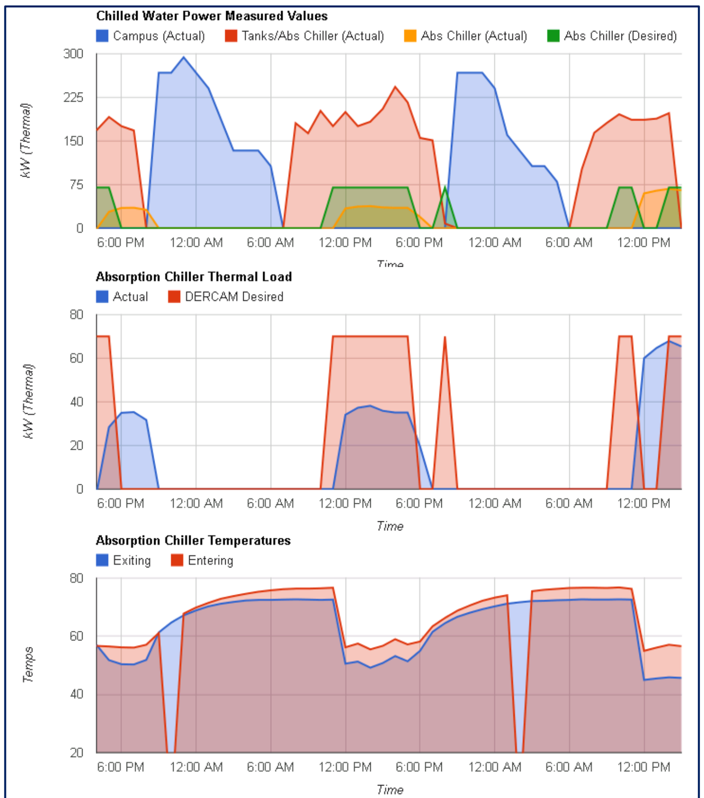
- Observations:
  - Better DER-CAM performance in cooler weeks
  - Comparison of the three weeks in May:
    - max 55% saving in weekly energy cost
    - 16% saving in weekly marginal demand charge
    - Average ~19% saving in total weekly cost

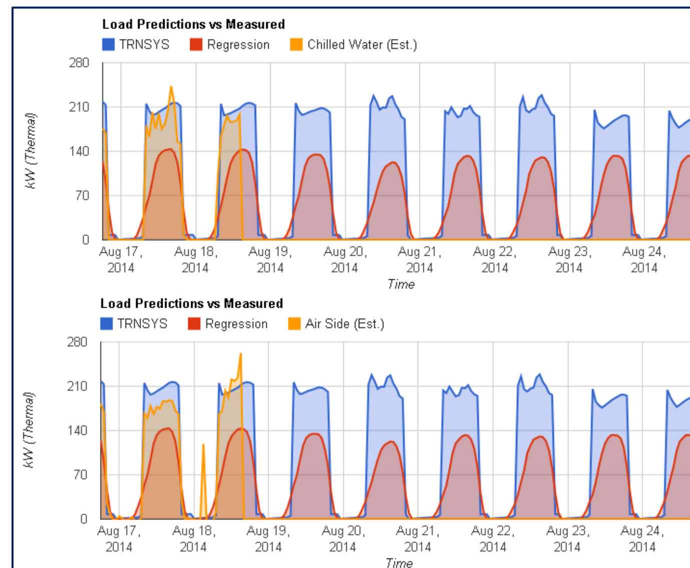


NM Demo Bldg. – UNM ME (2014 Accomplishment)

- Online interface for the UNM ME building operation
- http://iseslab.unm.edu/dercam.html
- Measurements are shown in real-time
- Regression vs model based forecast comparison
- DER-CAM schedules are depicted
- Deviations from the optimum schedules are visualized







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Integrating Dynamic Shading Models into ODC

- ElectroChromic windows (EC) are a type of shading system. EC provide different levels of shading with a small electricity consumption required only for the switching process ($0.5 Wh/m^2$, 5V)
- Trade-off: Increasing the shading level decreases the cooling loads, but increases the lighting load → An optimization is required
- An approach for variable shading support (EC windows, shutters, etc) in ODC was developed
- Integration of dynamic shading is interesting, since:
  - It affects other loads (end-uses)
  - Hence, makes the problem very complicated
    → DER-CAM can help
  - It is representative of demand-side technologies
    → Improvement in demand-side technologies in ODC

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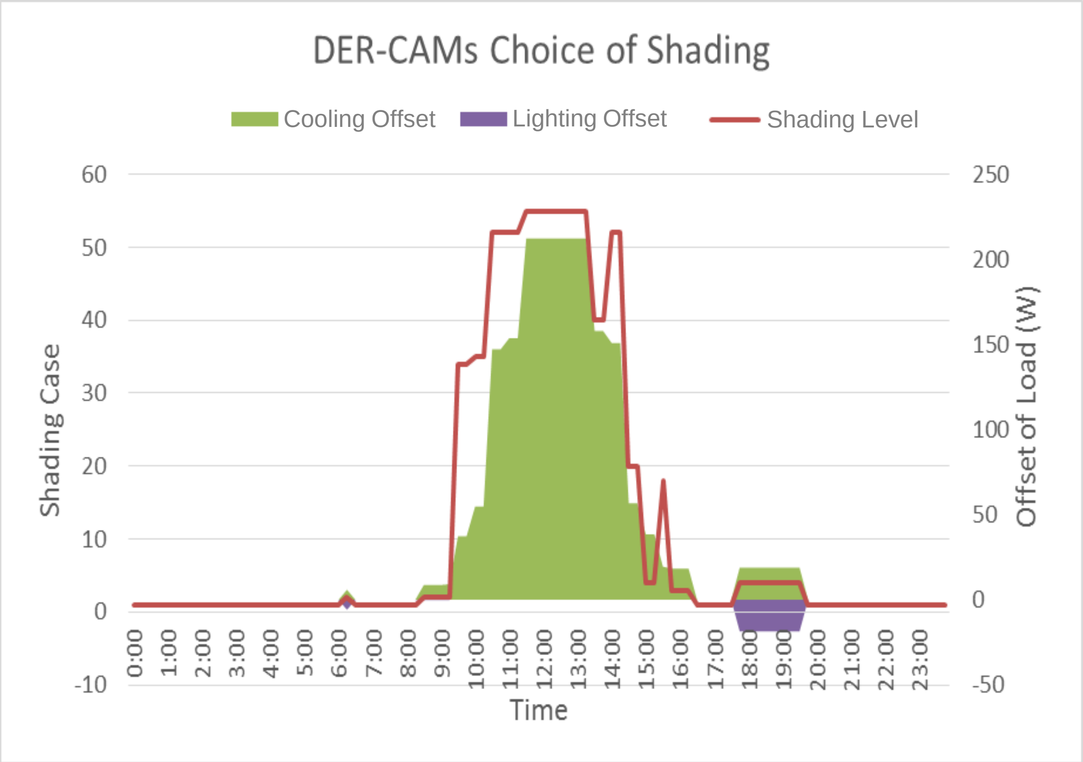
Integrating Dynamic Shading Models into ODC

- An office building with PV and electrical storage[1]:
  - This figure shows one day (24 hours)
  - DER-CAM can choose between 64 different shading levels
  - Significant cooling load reduction and slight increase in lighting energy



Overall ~41% electricity cost savings compared to clear pane window.[1]

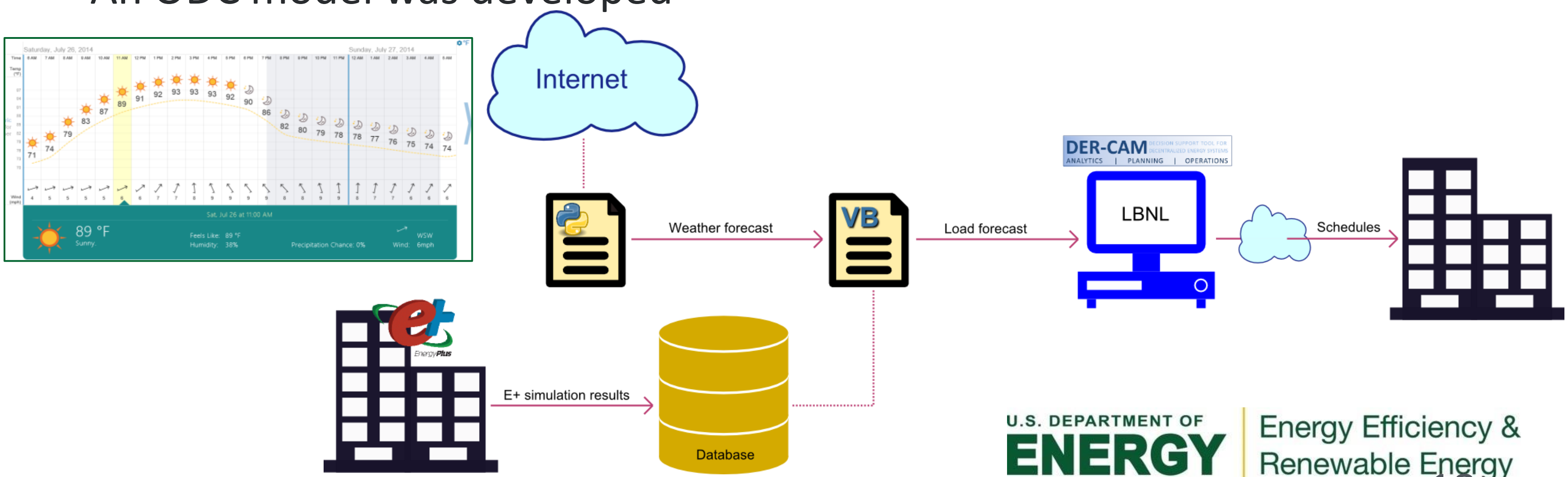
1. Christoph Gehbauer, "Implementation of shading technologies into linear optimization models," MSc Thesis, University of Applied Sciences Technikum Wien, Vienna, Austria, 2014.

Demonstration Bldg. - Tianjin Univ. Bldg. 26

- A proof-of-concept for optimized building operation scheduling using Software as a Service (SaaS) in China
- Progress made so far:
  - An E+ model for the building was developed
  - Developed a pre-simulated database, composed of temperature and load data
  - Forecast building load script developed to:

    a) obtain 7-day weather forecast, and

    b) find the closest match in the Database
  - An ODC model was developed



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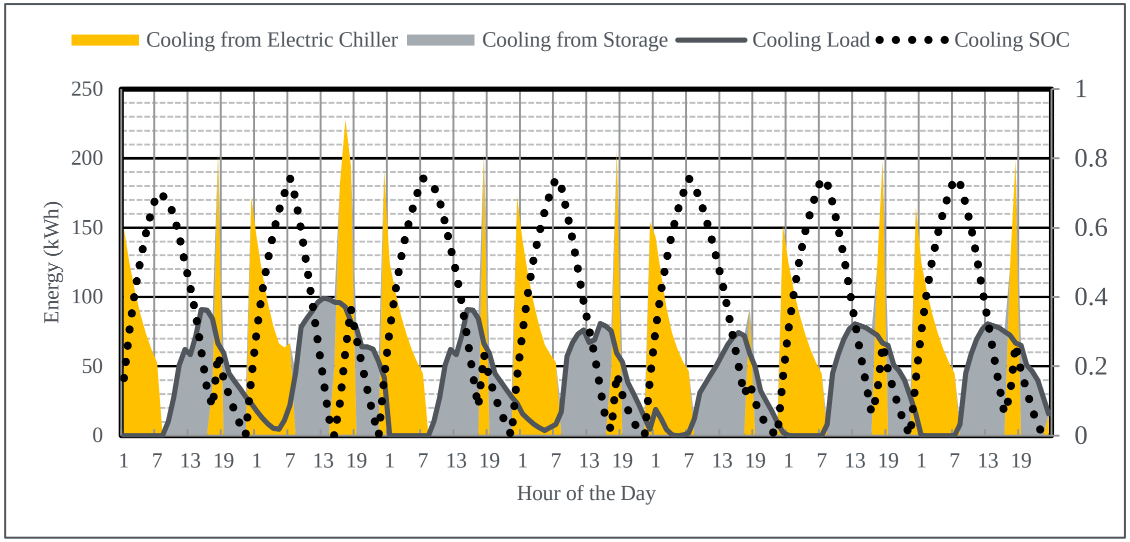
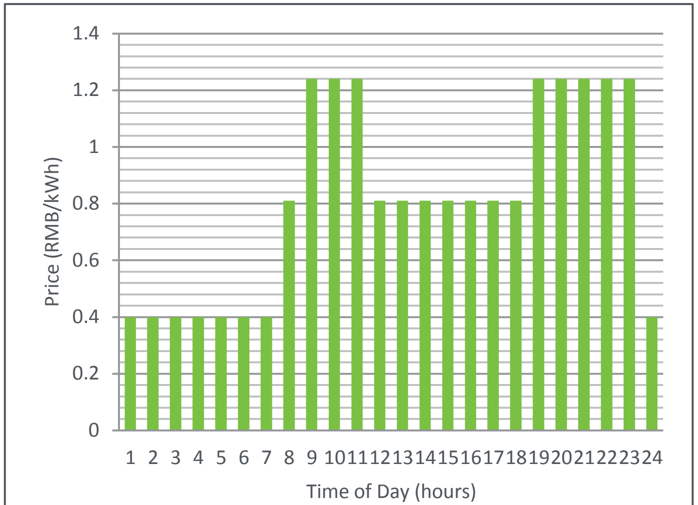
Demonstration Bldg. - Tianjin Univ. Bldg. 26

- Optimum cooling loop operation for building 26 for 17 July 14 – 23 July 14, assuming an arbitrary 7,500 kWh_{th} cold storage, with the following tariff





1 USD = 6.1 RMB

- Next steps:
  - Implementing the schedules using available controllable loads in the building
  - ~40% savings on cooling energy cost

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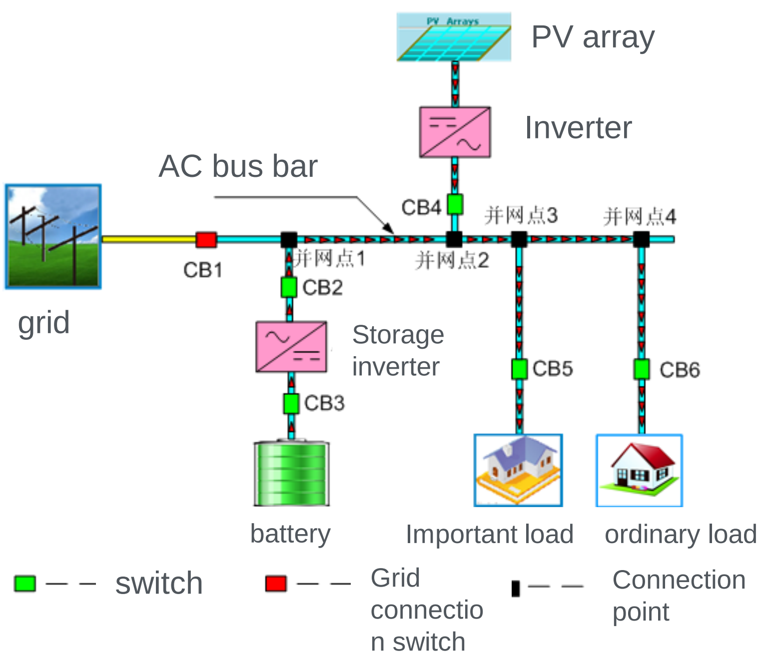
Zhuhai Xingye Building Design

- Assist microgrid design in Zhuhai Xingye building
  - Solar analysis,
  - Sizing of the energy storage system
  - DC vs AC microgrid comparison
  - Building microgrid island mode vs grid-connection mode
  - Microgrid control system



Project Integration and Collaboration

Project Integration: Reference Building capability developed for C3 Energy, and collaboration with XingYe on development of its demonstration building in Zhuhai.

Partners, Subcontractors, and Collaborators:
University of New Mexico, working together under PNM project
Tianjin University, Blg. 26 demonstration, Wuhan development, and JCI Shanghai building in 2015.

Communications: CERC reviews, Energy & Buildings article, ACEEE, ECEEE conference paper, graduate student thesis, Shenzhen IBR

Next Steps and Future Plans

Next Steps and Future Plans:

1. Refine UNM model for charging and discharging of the storage
2. JCI Shanghai building DER system optimization
3. District scale planning and optimization tool development
4. Review of other open source tools

Team members

- U.S.: Wei Feng, Chris Marnay, Nan Zhou, Michael Stadler, Gonzalo Mendes, Gonzalo Cardoso, Salman Mashayekh, Nicholas DeForest, Shi Wang, He Gang, Ping Liu

- China: Neng Zhu (Tianjin), Hongwei Tan (Tongji), Duo Luo (Xingye), Jia Wang (BUCEA)

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REFERENCE SLIDES

Project Budget

Project Budget: Overall full project cycle budget should be ~800k$.
Variances: Early budget erratic, but consistent now.
Cost to Date: $600k with 670k granted.
Additional Funding: $85K from PSN, in-kind from industrial partner, funded visitors from China & Europe, shared travel with other China projects.

Budget History					
FY11– FY2013		FY2014		FY2015 – Dec 2015	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
400	100	237.5	200	210	250

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Project Plan and Schedule

2015 schedule

Milestone	Time
Develop energy models for load analysis of Twin Bridges area	06/2015
Load aggregation method to take district energy system transport loss into account.	08/2015
Single building vs district energy system optimization iterations	12/2015
District Energy-cost vs CO^2 performance analysis	12/2015
Volttron existing capacity and communication interface review	05/2015
DER-CAM operation optimization model for the demo buildings	09/2015
Measure building energy performance with and without optimal controls to analyze the savings	12/2015

A Project of CERC-BEE (US-China Clean Energy Research Center Building Energy Efficiency Consortium)

Pioneering U.S. – China Innovation for Widespread Adoption of Very Low Energy Buildings Through Partnerships and Real World Impact

BERKELEY LAB · Oak Ridge National Laboratory · MIT · ICF International · NRDC · UC Davis University of California

U.S. Research Leads

Dow · Energy Foundation · Saint-Gobain · Bentley · ClimateMaster · C3 Energy · 3M · Lutron

U.S. Industrial Partners *(Funding +40% Annual Average Growth Rate)*

Research Strategy → Huge Impact:
- U.S./China construction market ~ 2B m2
- CO_2 savings ~ 100Mt/year by 2025

Technologies, Software → **New Patent Applications**

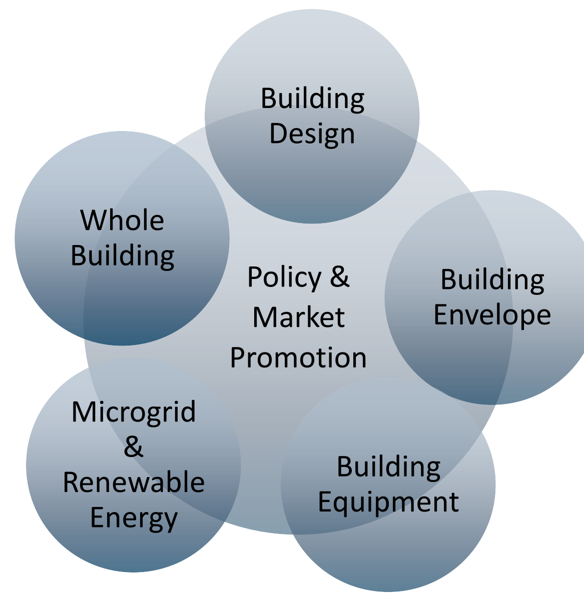
Demonstration Buildings, Commercial Impact, Tools and Guidebooks → **Market**

Wide Adoption Very Low Energy Buildings → **Policy**

ABOUT: CERC-BEE is a five year, $50M program created by the U.S. Department of Energy and Chinese Ministry of Science and Technology.

R&D TEAMS: U.S. national laboratories, and U.S. and Chinese universities, and research institutes team up with industry partners to accelerate innovation and deployment.

SELECTED RESEARCH OUTCOMES:
- Launched eight new products and developed two software tools (e.g. Cloud tool for microgrids, 40 new users from China)
- Won R&D Top 100 Award for GSHP by Climate Master
- Exceeded IP goals: ~ 25 patents filed, 4 approved; inventions disclosed and more in process (e.g. sprayable liquid flashing, cool roof materials)
- Developed 20 standards (e.g. LBNL involved in new Chinese commercial building code revision)
- Published 135 Chinese and 54+ US academic research papers



Website: cercbee.lbl.gov

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