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Smart buildings with electric vehicle interconnection as buffer for local renewables?

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Environmental Energy Technologies Division

presented at Researching the Intelligent City: Key Challenges of Integrating Urban Energy and Mobility Systems Research Symposium, Berlin, May 30, 2011

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

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Researching the Intelligent City:
Key Challenges of Integrating Urban Energy and Mobility Systems
Research Symposium, Berlin, May 30, 2011

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Berkeley Lab 75 Years of World-Class Science 1931-2006

Outline

- Lawrence Berkeley National Laboratory
- are we considering both sides of the coin?
- Lawrence Berkeley National Laboratory's Distributed Energy Resources Customer Adoption Model (DER-CAM)
- Web-Optimization, software as service for a University building
- Example result for a University building and electric vehicle (EV) modeling

How does the number of EVs connected to the building change with different optimization goals (cost versus CO_2) ?

- conclusions
- additional Information

Lawrence Berkeley National Lab

- Located in the San Francisco Bay Area
- Berkeley Lab was founded in 1931 by Ernest Orlando Lawrence, a physicist who won the 1939 Nobel Prize in physics for his invention of the cyclotron
- Berkeley Lab is a member of the U.S. laboratory system supported by the U.S. Department of Energy and attached to the University of California (UC) Berkeley and is charged with conducting unclassified research across a wide range of scientific disciplines in 23 divisions as Accelerator & Fusion Research, Physics, Environmental Energy Technology, etc.
- 4 200 scientists, engineers, support staff and students
- budget of $811 million in 2010
- eleven Nobel Prizes

Are we considering both sides of the coin?

- mobile and local storage can absorb renewable energy in principle
- mobile storage can be linked in principle to commercial and residential buildings and integrated in smart buildings
- Is it that simple or does the research community simplify?
- How will a building optimize its energy usage without knowing its hourly consumption? Smart meters?
- Do we have the proper communication and data infrastructure to optimize buildings?
- What are the incentives for building owners to integrate renewables and electric vehicles?

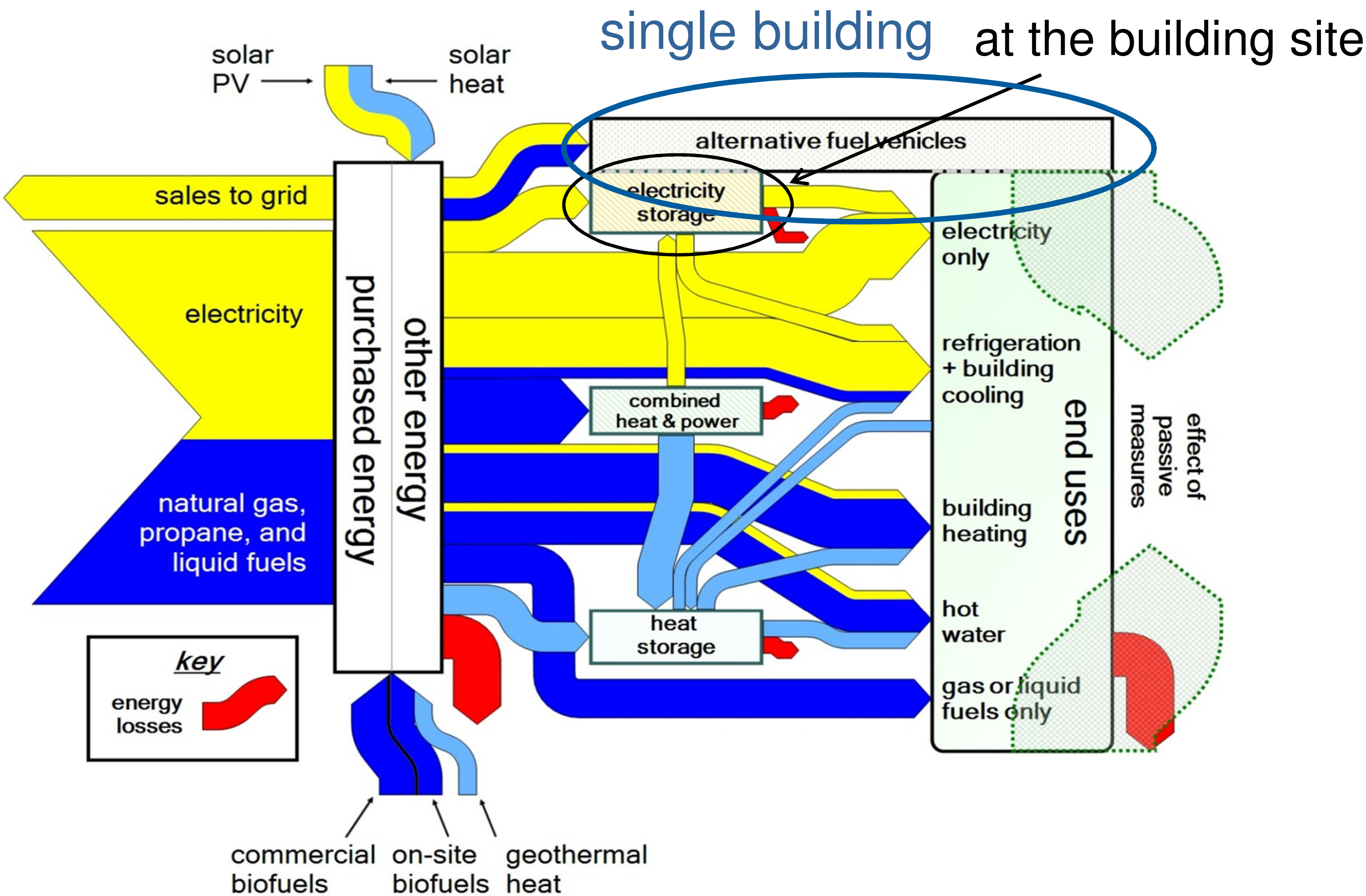
Complex research problems

Is it that simple or does the research community simplify?

Yes, too simple. Complex interactions between competing decentralized technologies are neglected mostly.

The Distributed Energy Resources Customer Adoption Model (DER-CAM)

Building optimization concept



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 to a building micro-/smartgrid
- produces technology neutral pure optimal results, delivers investment decision and operational schedule
- has been designed for more than 9 years by Berkeley Lab and collaborations in the US, Germany, Spain, Portugal, Belgium, Japan, and Australia
- first commercialization and real-time optimization steps, e.g. Storage & PV Viability Optimization Web-Service (SVOW), *http://der.lbl.gov/microgrids-lbnl/current-project-storage-viability-website*

Hourly demand

How will a building optimize its energy usage without knowing its hourly consumption?

It can hardly optimize its energy usage and models for estimating the hourly consumption are needed.

Data

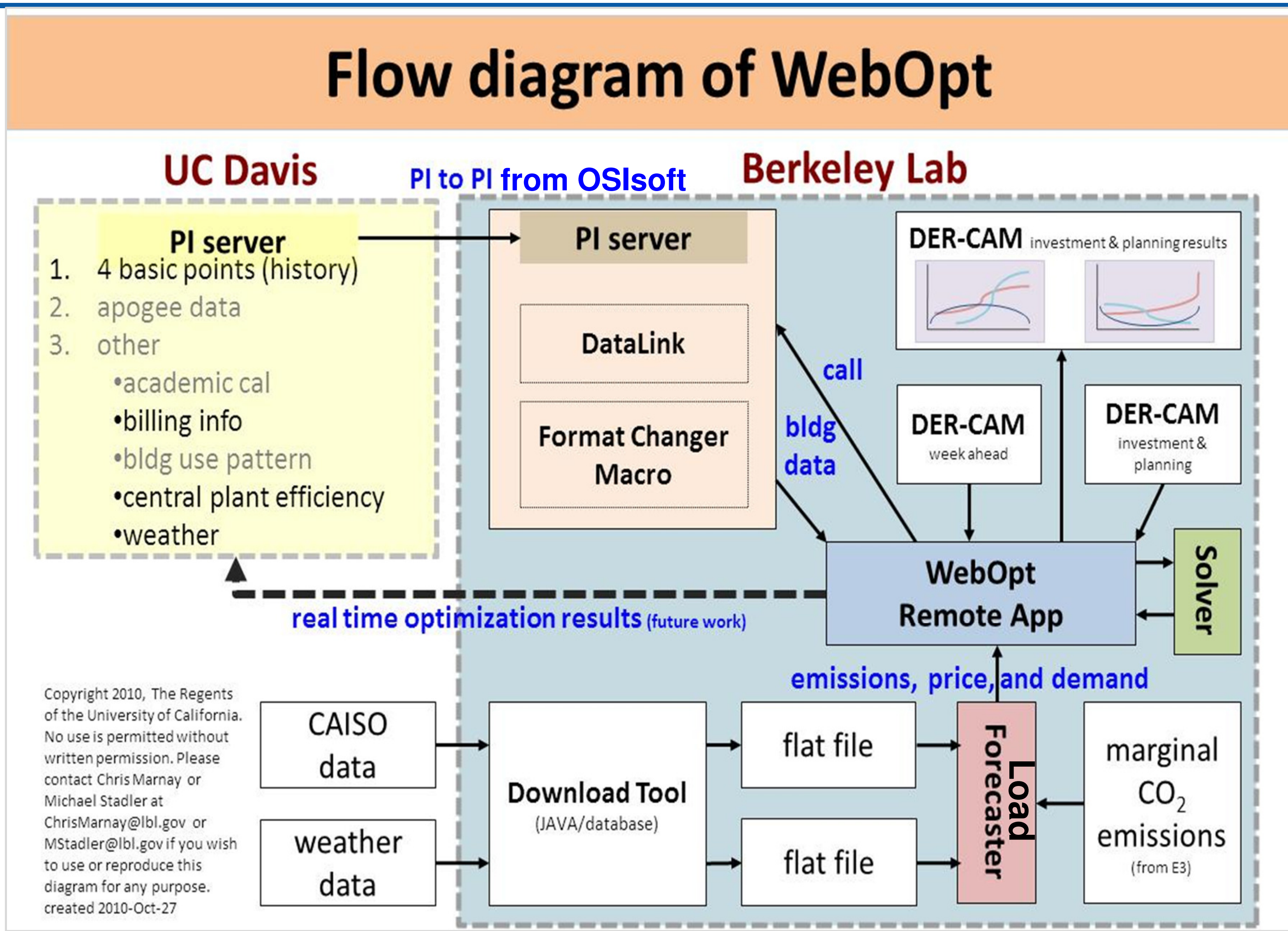
Do we have the proper communication and data infrastructure to optimize buildings?

Projects performed in the U.S. and ongoing research in Europe indicate that we do not have the proper infrastructure and data collection in place.

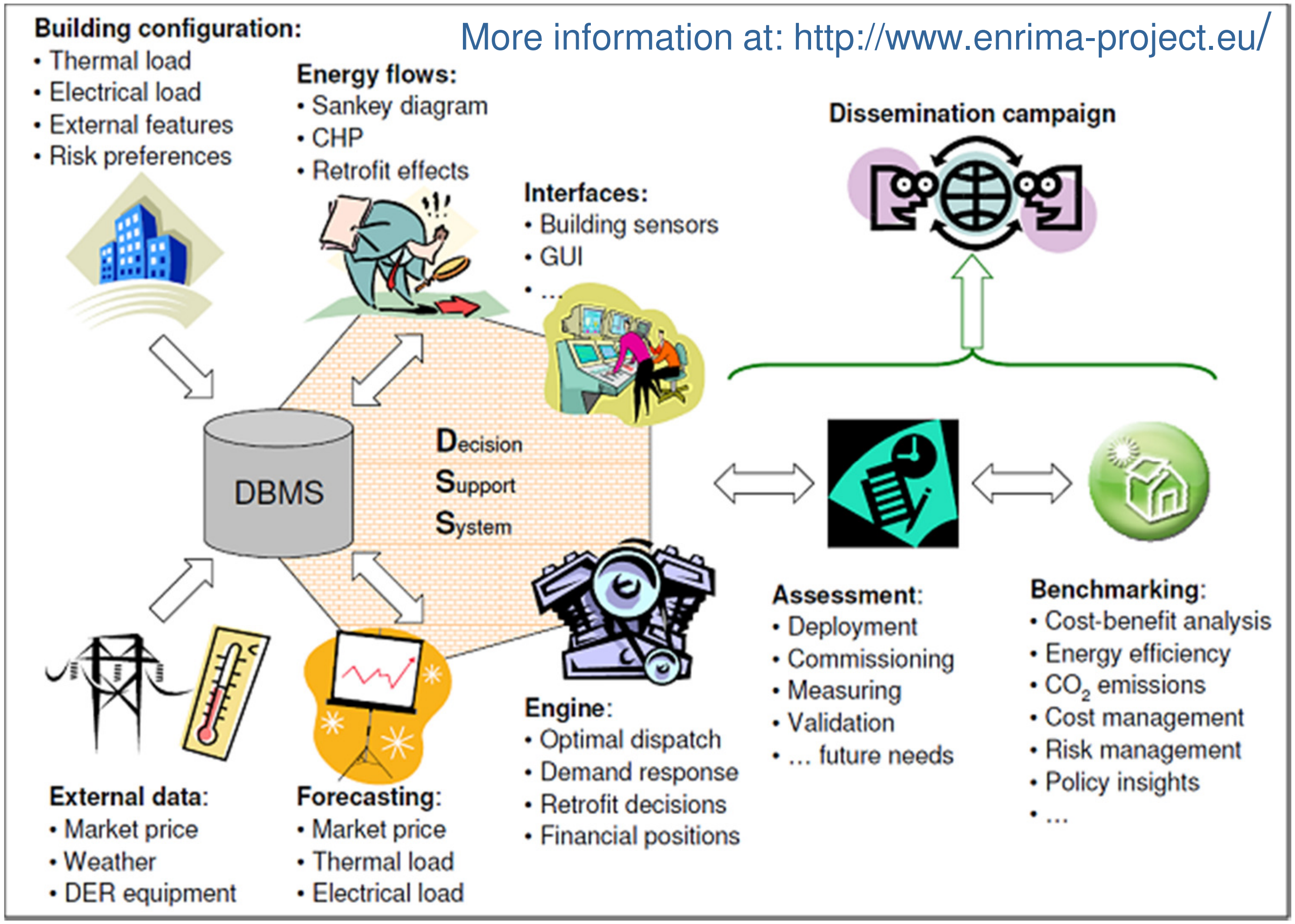
Optimization over the web

Web-Optimization to provide a simple optimization platform, which also forecasts loads for the building

Web-Optimization with DER-CAM for the University of Davis



European project EnRiMa*)



*) Energy Efficiency and Risk Management in Public Buildings

For example: test sites in Austria do not collect hourly loads and energy management system (EMS) data. Reason: no priority on energy saving or no idea how to use the data → web-optimization service

Costs versus CO_2

What are the incentives for building owners to integrate renewables and electric vehicles?

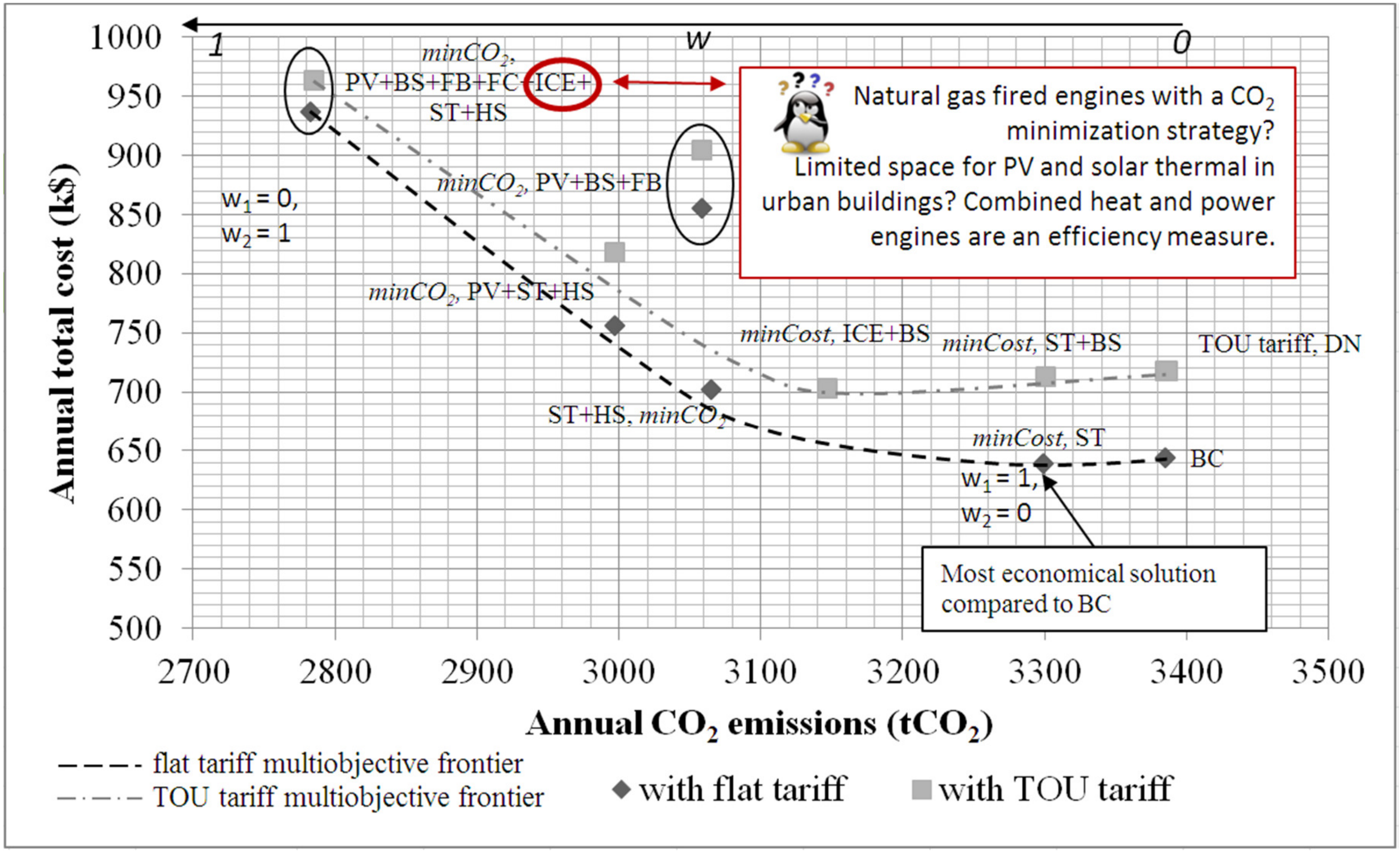
Example results for a University at Davis Building and Electric Vehicle Modeling for a Healthcare Facility in San Diego, California

Different optimization goals

Multi-objective frontier (minimize the combination of costs and CO_2 emissions for building)

$$\min\left((1-\omega)\cdot\frac{Cost}{ReferenceCost}+\omega\cdot\frac{CO_2emissons}{ReferenceCO_2emissons}\right)$$

Web-Optimization with DER-CAM for the University of Davis

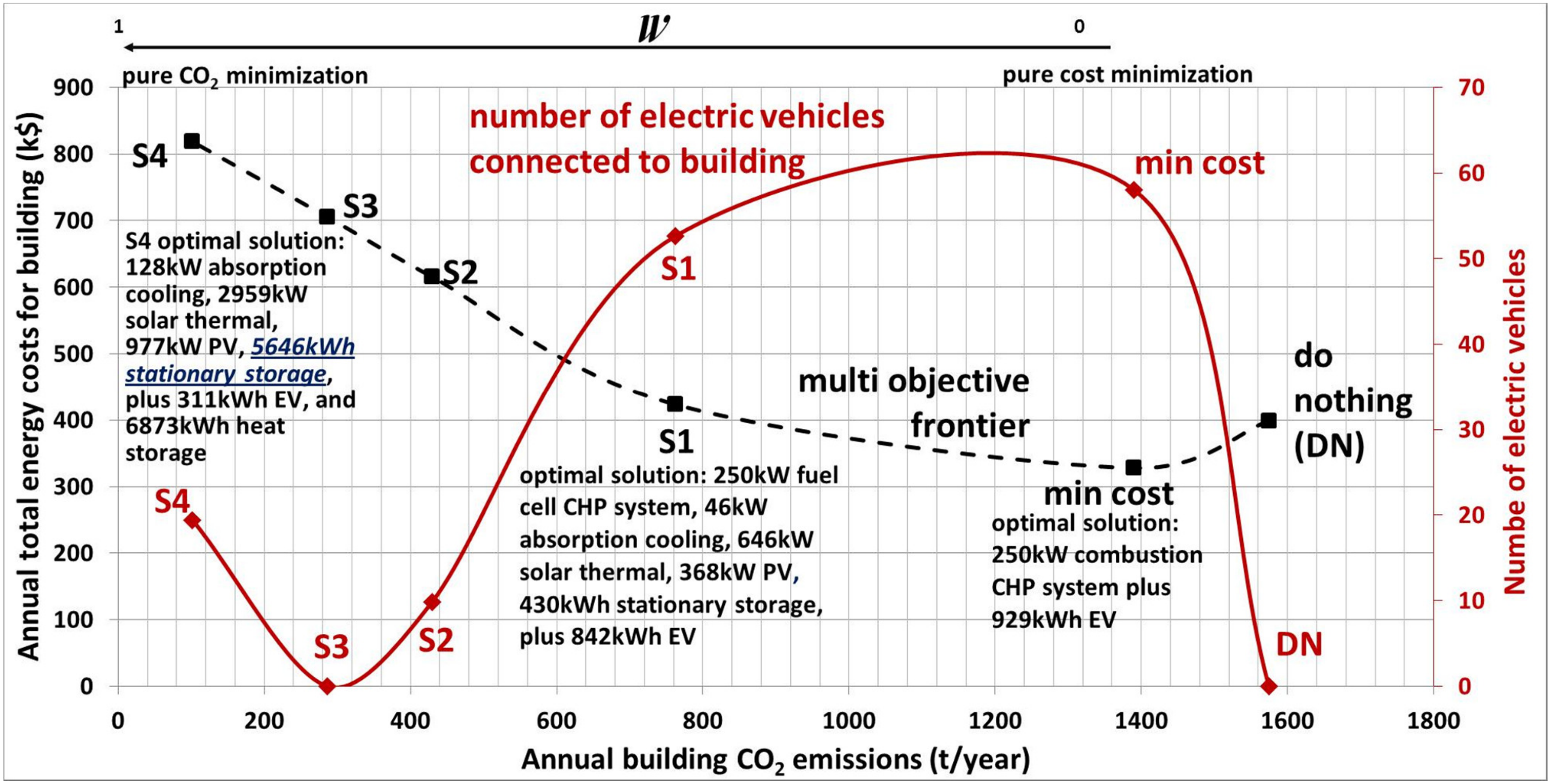


PV: photovoltaic, BS: conventional lead acid battery, FB: Zinc Bromine flow battery, FC: fuel cell with waste heat utilization, ICE: internal combustion engine with waste heat utilization, ST: solar thermal conventional collectors, HS: Heat storage, BC: Base case, and DN: "Do nothing" case

More information at: der.lbl.gov

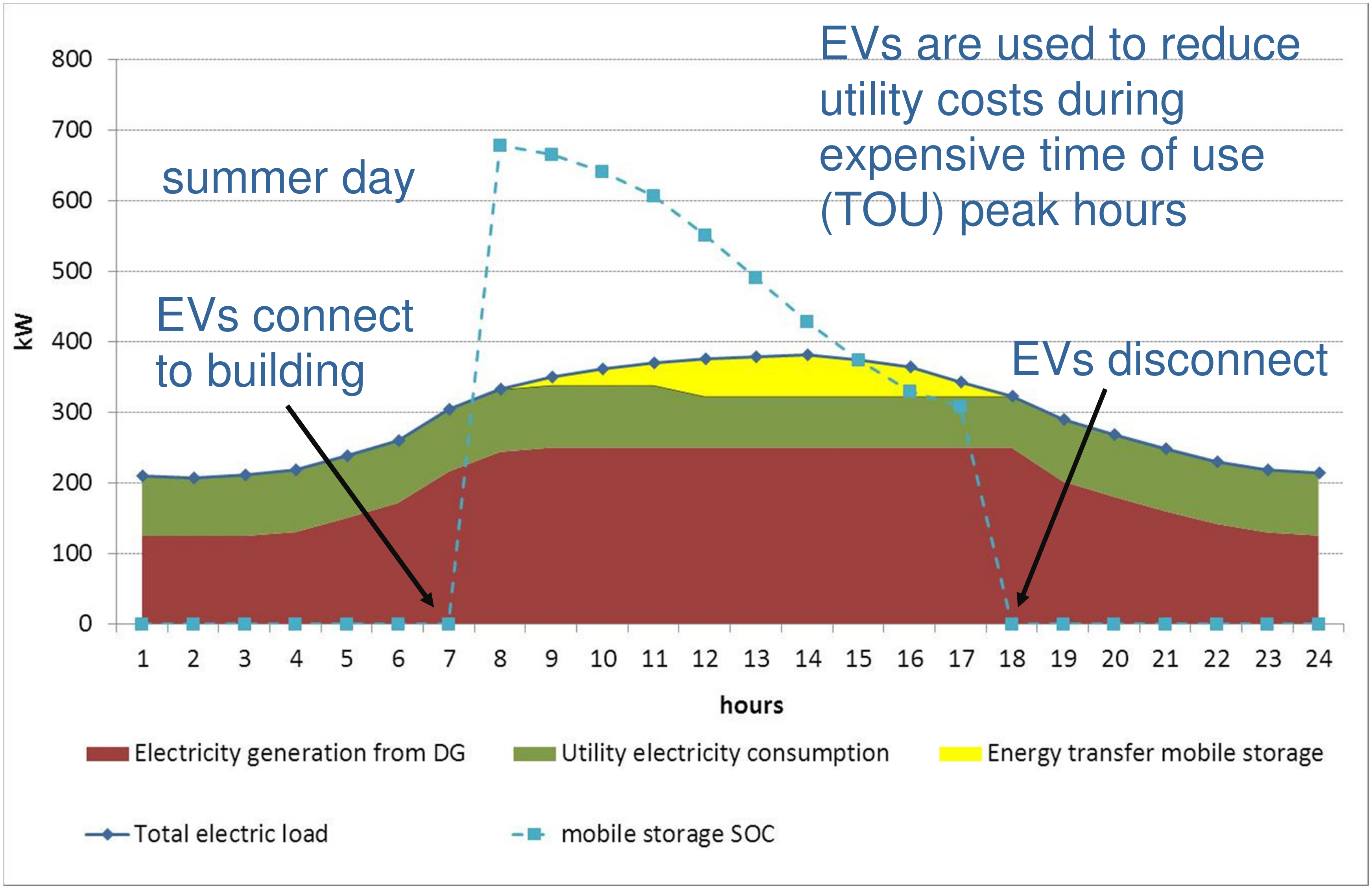
Environmental Energy Technologies Division

Multi-objective frontier / EVs connected @ healthcare facility

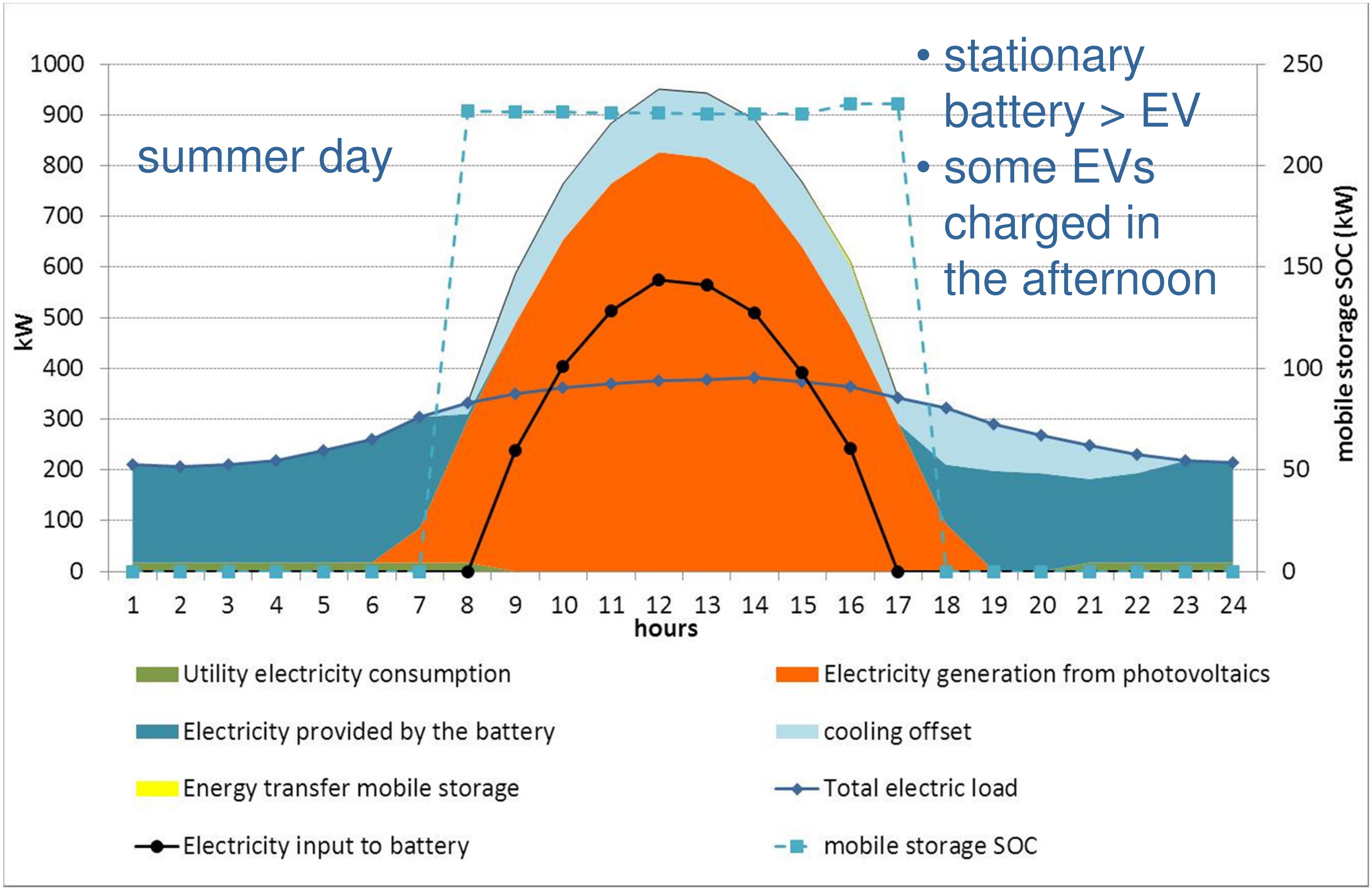


- ✓ connected EVs reach maximum around “min cost” solution (*w*=0)
- ✓ with increasing *w*: stationary batteries become more attractive to building than EVs → <u>second life of EV batteries</u>?

Diurnal electric pattern for min cost @ healthcare facility



Diurnal electric pattern for point S4 @ healthcare facility



Conclusions for a Healthcare Facility in San Diego

Conclusions

- EV Charging / discharging pattern mainly depends on the objective of the building (cost versus CO_2)
- performed optimization runs show that stationary batteries are more attractive than mobile storage when putting more focus on CO_2 emissions. Why? Stationary storage is available 24 hours a day for energy management→ more effective
- stationary storage will be charged by PV, mobile only marginally
- results will depend on the considered region and tariff

→ final research work will show the results for 138 different buildings in nine different climate zones and three major utility service territories

Literature

Stadler Michael, Ilan Momber, Olivier Mégel, Tomás Gómez, Chris Marnay, Sebastian Beer, Judy Lai, and Vincent Battaglia: *"The added economic and environmental value of plug-in electric vehicles connected to commercial building microgrids,"* 2nd European Conference on SmartGrids and E-Mobility, 20-21 October 2010, Bedford Hotel & Congress Centre, Brussels, Belgium, LBNL-3885E.

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Stadler Michael, Afzal Siddiqui, Chris Marnay, Hirohisa Aki, Judy LAI: *"Control of Greenhouse Gas Emissions by Optimal DER Technology Investment and Energy Management in Zero-Net-Energy Buildings,"* European Transactions on Electrical Power 2009, Special Issue on Microgrids and Energy Management, LBNL-2692E.

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End

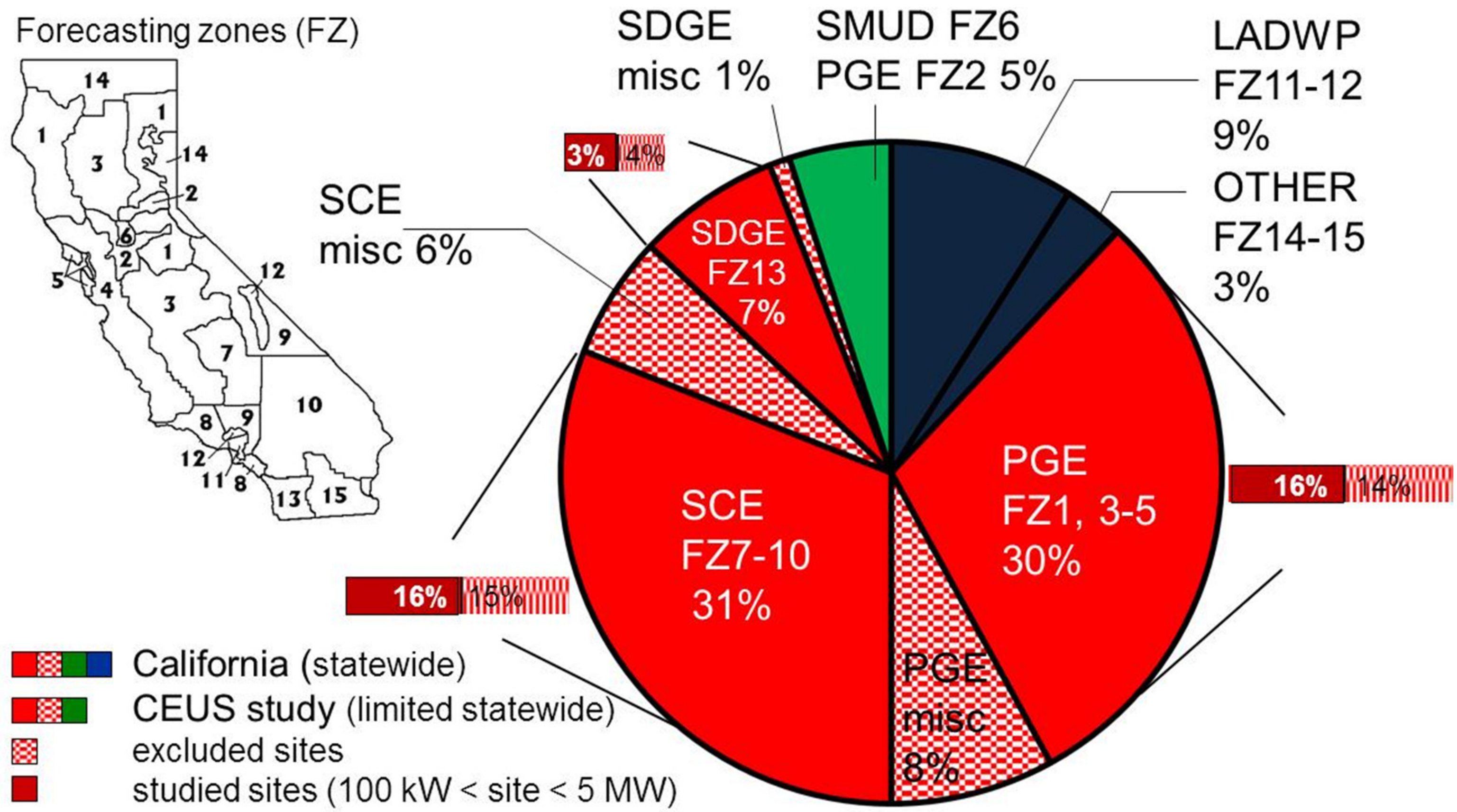
Thank you!

Questions and comments are very welcome.

Ongoing EV modeling for California

The California Commercial End-Use Survey (CEUS) Database

CEUS



<u>objective / final EV project goal</u> : EV modeling at 138 buildings[x)] in nine climate zones

[x)] hospitals, colleges, schools, restaurants, warehouses, retail stores, groceries, offices, and hotels

Details for healthcare facility

2020 Equipment Options, Tariffs, and Building Analyzed

Equipment

- EVs belong to employees/commuters
- EVs can transfer energy to the building and vice versa
- the building energy management system (EMS) can manage (charge/discharge) the EV batteries during connection hours
- EV owner receives exact compensation for battery degradation and energy delivered to the building

EV-building connection period	8am – 5pm
EV-home connection period	7pm – 7am
EV battery state-of-charge (SOC) when arriving at the healthcare facility	73%
EV battery SOC when leaving the healthcare facility	≥32%
EV battery charging efficiency	95.4%
EV battery discharging efficiency	95.4%
EV battery capacity	16 kWh
Maximum EV battery charging rate	0.45 [1/h]

Equipment

- also combined heat and power (CHP), PV, solar thermal, stationary battery, etc. is considered in the analysis

- technology costs in 2020 are based on "Assumptions to the Annual U.S. Energy Outlook", e.g.
  - fuel cell with heat exchanger: $2220 - $2770/kW, lifetime: 10 years
  - internal combustion engine with heat exchanger: $2180 - $3580/kW, lifetime: 20 years
  - PV: $3237/kW, lifetime: 20 years
  - stationary battery: $193/kWh
  - etc.

Details can be found at "The CO_2 Abatement Potential of California's Mid-Sized Commercial Buildings." Michael Stadler, Chris Marnay, Gonçalo Cardoso, Tim Lipman, Olivier Mégel, Srirupa Ganguly, Afzal Siddiqui, and Judy Lai, California Energy Commission, Public Interest Energy Research Program, CEC-500-07-043, 500-99-013, LBNL-3024E, December 2009.

Building / tariffs

- electricity and gas loads for a San Diego healthcare facility are based on CEUS
  - peak electric demand: 399 kW
  - annual electricity demand: 2.33 GWh
  - annual natural gas consumption: 2.13 GWh (72700 therm)
- TOU rates and demand charges:
  - on-peak electricity up to 0.13 $/kWh
  - off-peak rates around 0.09 $/kWh
  - demand charges up to 12.8 $/kW-month
- electric rate at residences (homes) for EV charging: $0.138/kWh

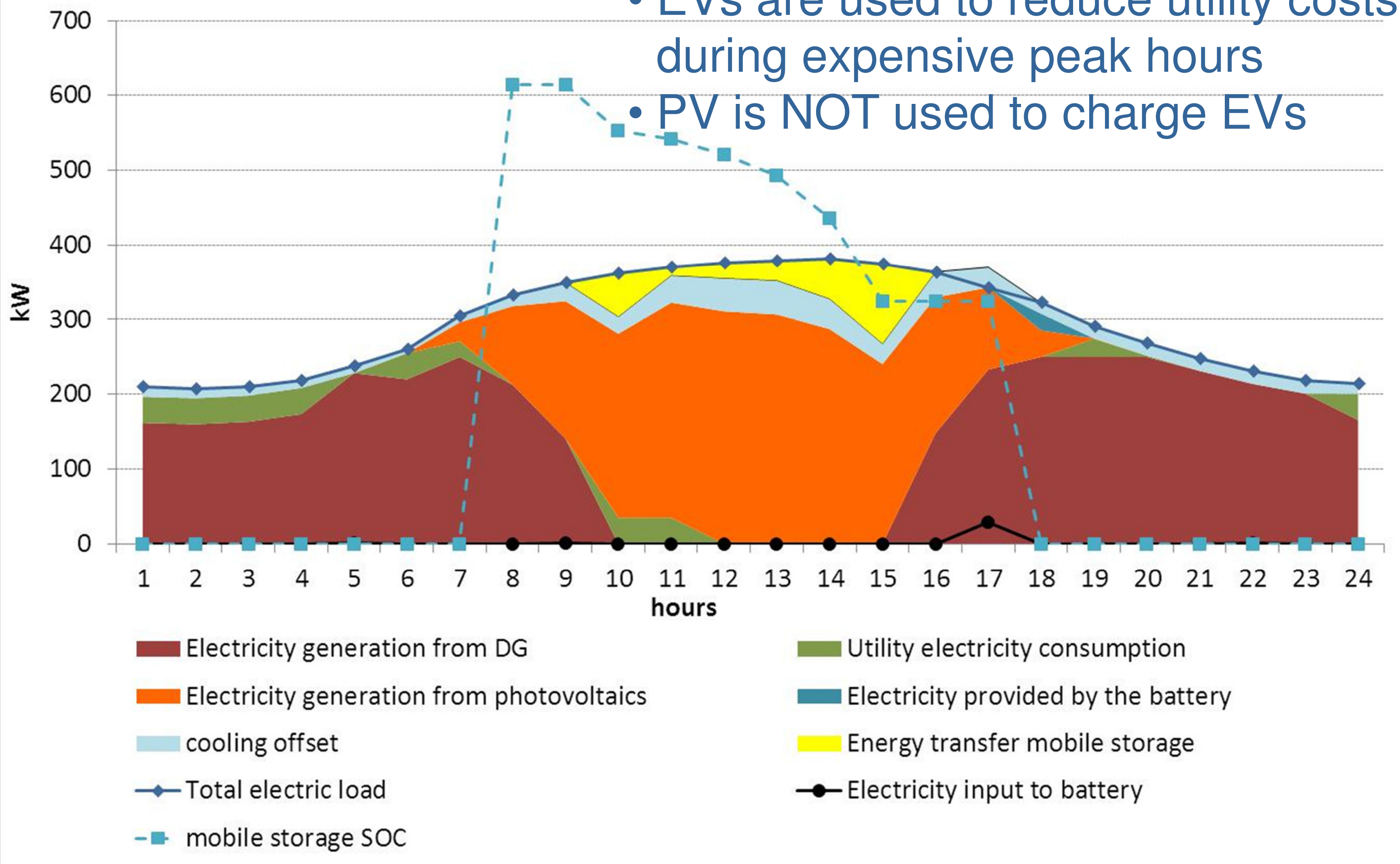
Details for healthcare facility

Optimization Results for Summer Days

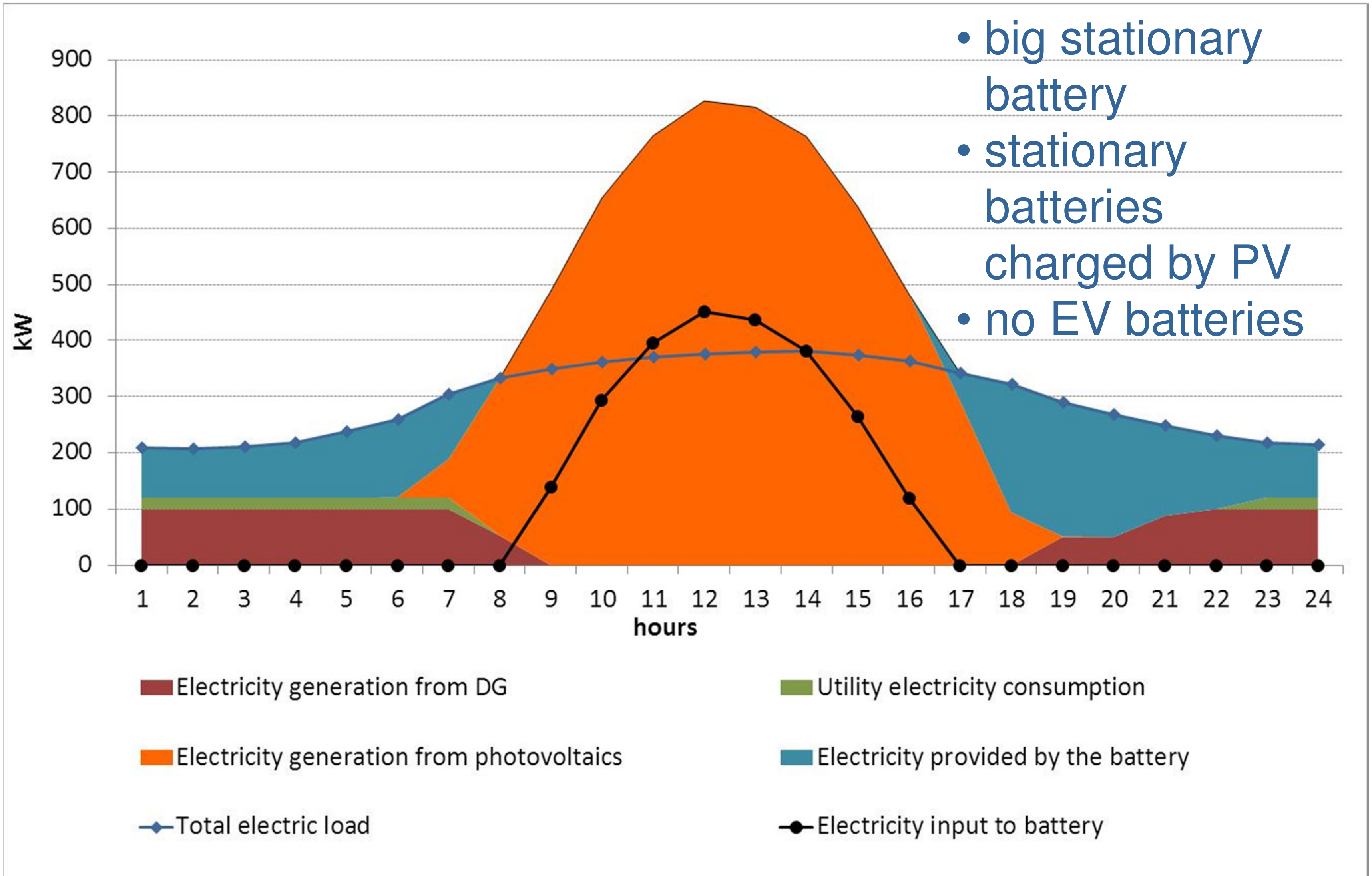
Optimal Investments in DER Technologies and Operation, Optimal EV Discharging / Charging subject to different building strategies

Diurnal electric pattern for point S1 @ healthcare faciltity

- EVs are used to reduce utility costs during expensive peak hours
- PV is NOT used to charge EVs

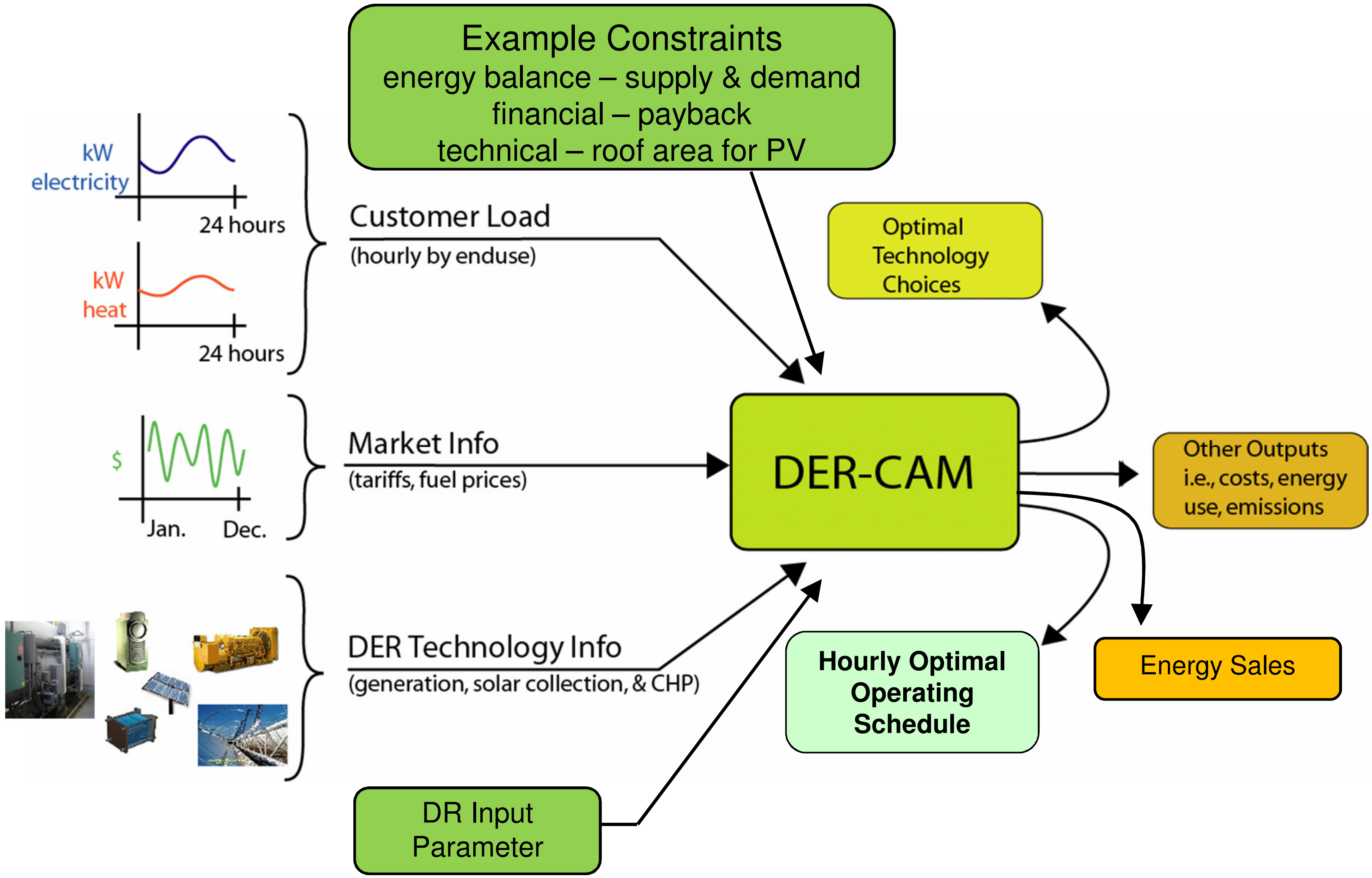


Diurnal electric pattern for point S3 @ healthcare facility



- big stationary battery
- stationary batteries charged by PV
- no EV batteries

High-level schematic of DER-CAM



Representative MILP

Simplified* DER-CAM model

Energy balance
+energy purchase
+energy generated onsite
= onsite demand + energy sales

Operational constraints
-generators, chillers, etc. must operate within performance limits
-heat recovered is limited by generated waste heat
-solar radiation / footprint constraint

Objective function, e.g. min. annual energy bill for a test year:
+energy purchase costs
+*amortized* DER technology capital costs
+annual O&M costs
+ CO_2 costs
- energy sales

Financial constraints
-max. allowed payback period, e.g. 12 years

Regulatory constraints
-minimum efficiency requirement
-emission limits
-CO_2 tax
-CA min. eff. requirement for subsidy and (in future) feed-in tariff
-ZNEB

Storage and DR constraints
-electricity stored is limited by battery size
-heat storage is limited by reservoir size
-max. efficiency potential for heating and electricity

***does not show all constraints**

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