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U.S. DEPARTMENT OF ENERGY

Application of the Software as a Service Model to the Control of Complex Building Systems

Michael Stadler

Jonathan Donadee, Chris Marnay, Gonçalo Mendes, Jan von Appen, Olivier Mégel, Prajesh Bhattacharya, Nicholas DeForest, Judy Lai

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MStadler@lbl.gov http://der.lbl.gov/

Outline

- Building optimization, Lawrence Berkeley National Laboratory's Distributed Energy Resources Customer Adoption Model (DER-CAM)

- Web-Optimization, software as service (SaaS) for a University building

- Example results for the University of California at Davis, Dining building

Natural gas fired combined heat and power (CHP) units with CO_2 minimization strategy?

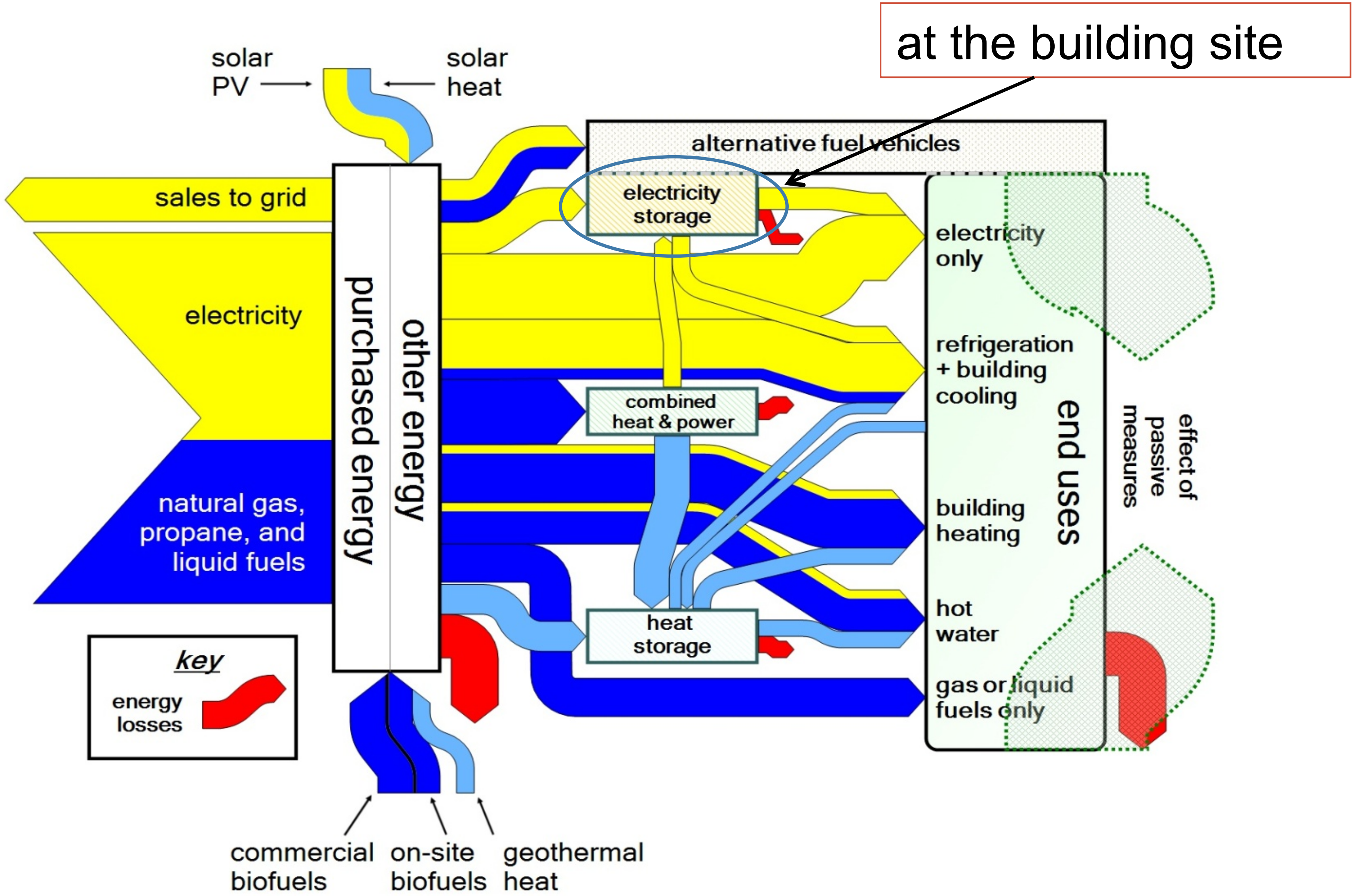
- conclusions

- additional Information

Complex optimization problem

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

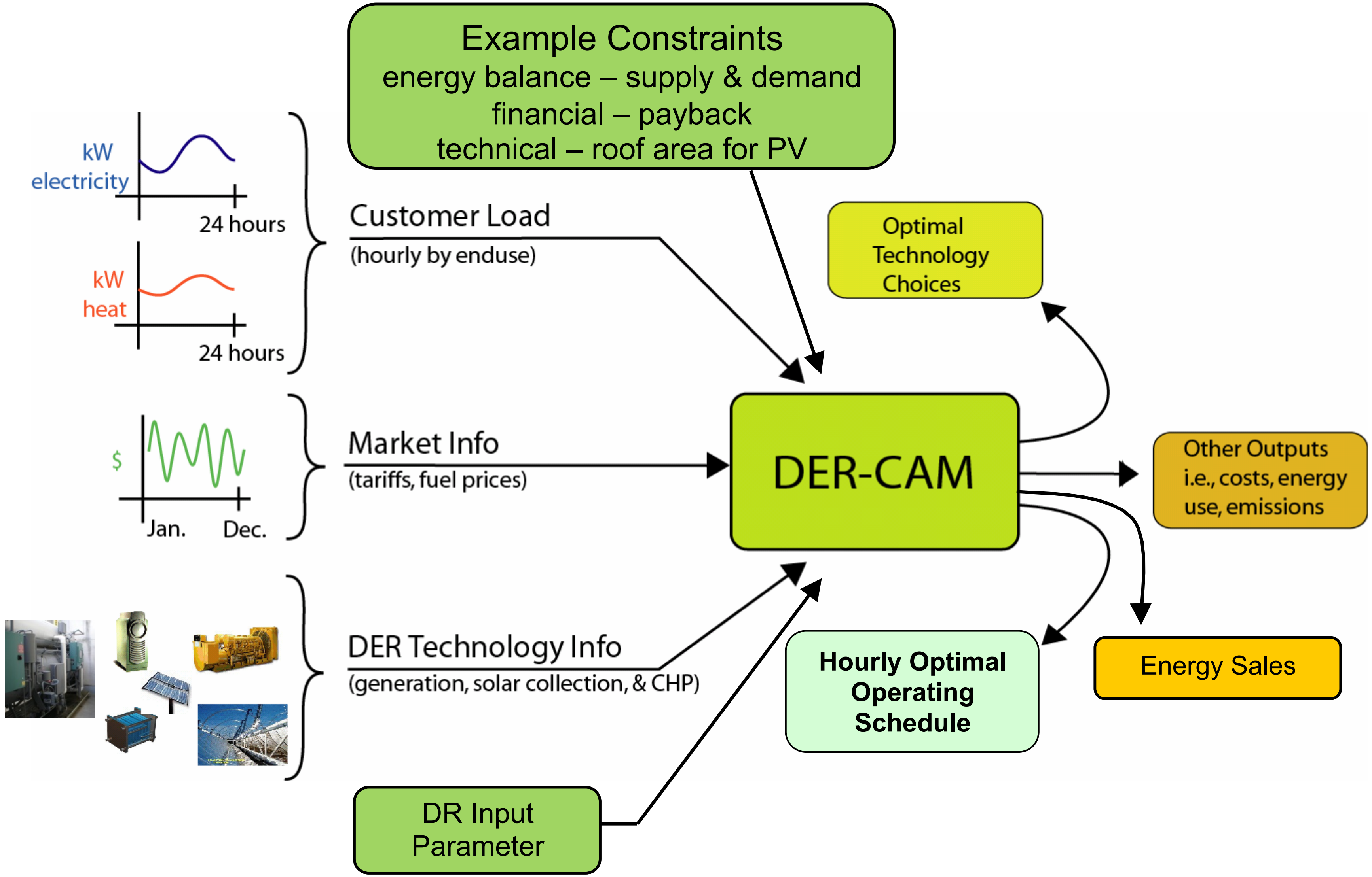
Building optimization concept for single building



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*

High level schematic for DER-CAM



Different optimization goals

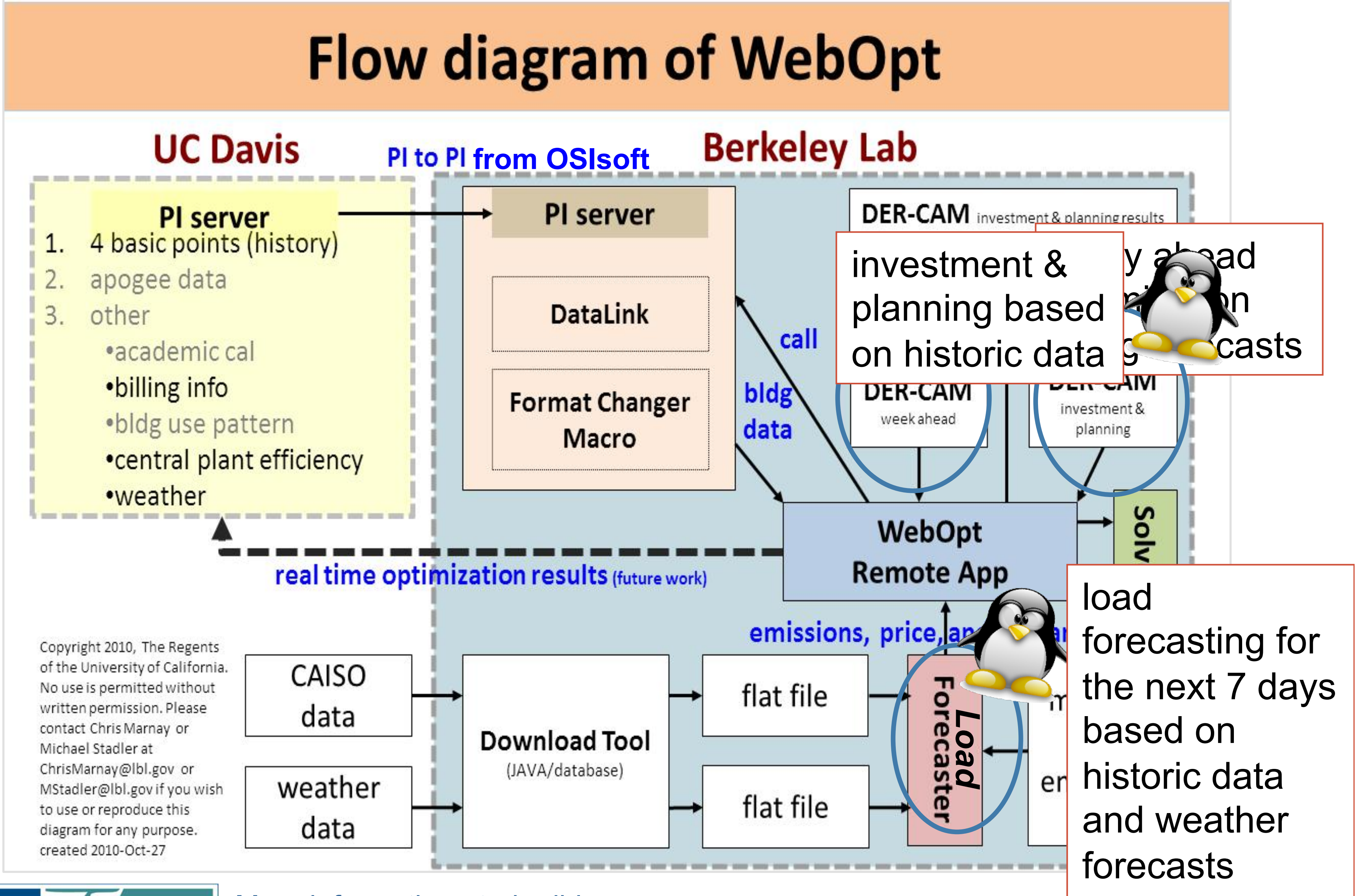
Multi-objective frontier (minimize the combination of costs and CO_2 emissions for building)

$$\min\left(\omega_1 \cdot \frac{Cost}{MaxCost} + \omega_2 \cdot \frac{CO_2emissons}{MaxCO_2emissons}\right)$$

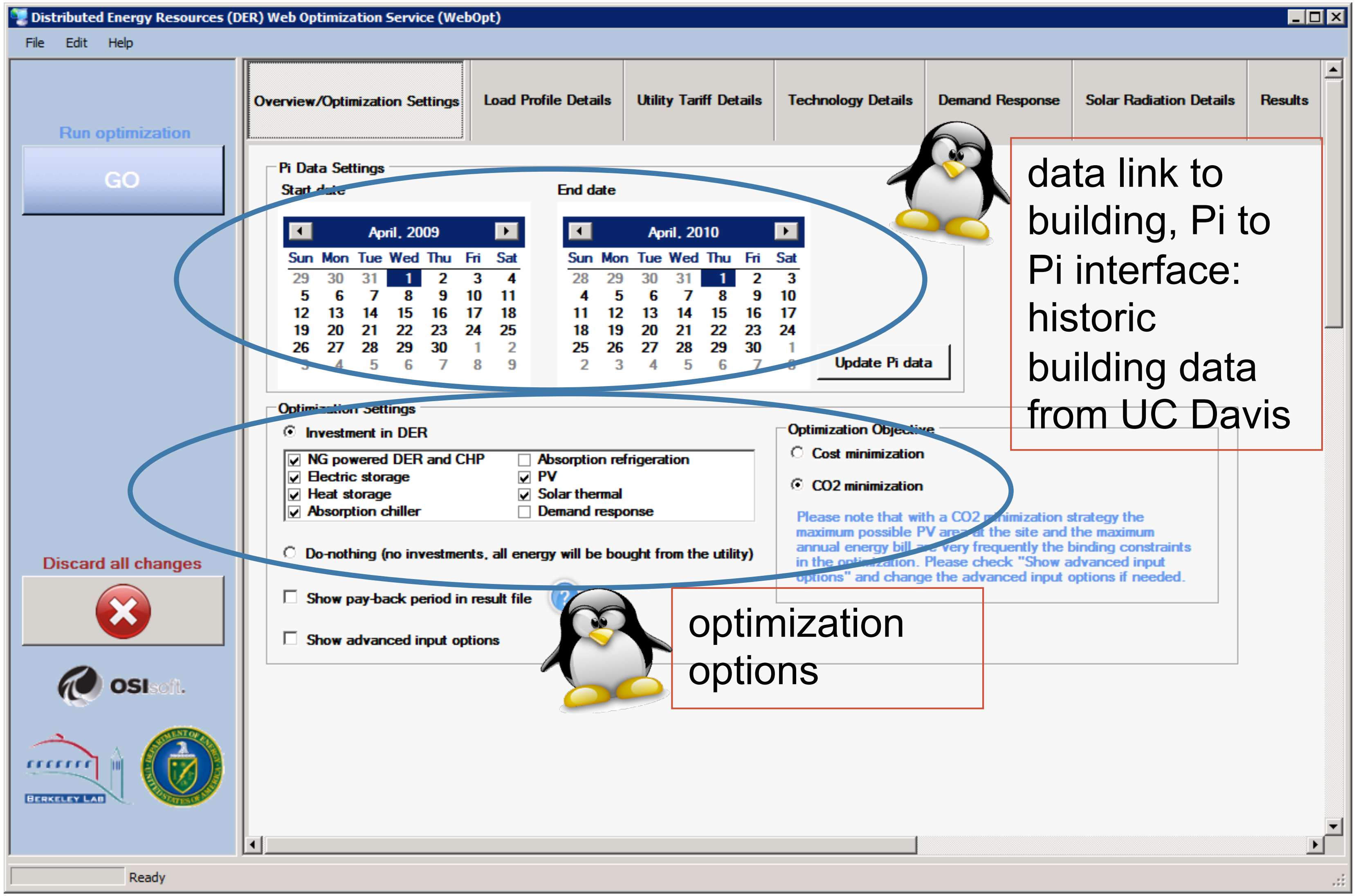
Optimization over the web

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

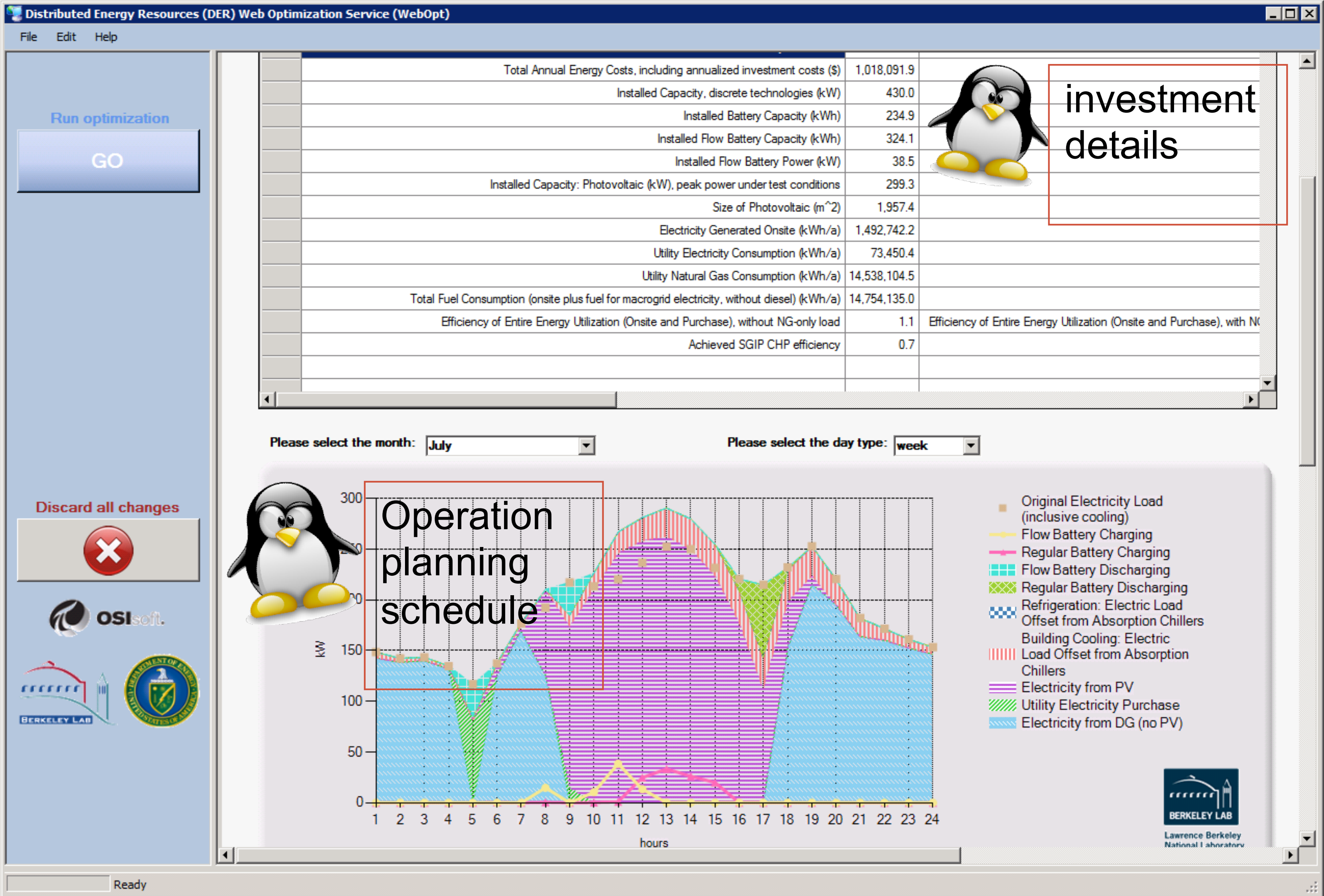
Web-Optimization with DER-CAM for the University of California, Davis



WebOpt interface (investment & planning)



WebOpt results (CO_2 min., w_2=1)



Total Annual Energy Costs, including annualized investment costs ($)	1,018,091.9
Installed Capacity, discrete technologies (kW)	430.0
Installed Battery Capacity (kWh)	234.9
Installed Flow Battery Capacity (kWh)	324.1
Installed Flow Battery Power (kW)	38.5
Installed Capacity: Photovoltaic (kW), peak power under test conditions	299.3
Size of Photovoltaic (m^2)	1,957.4
Electricity Generated Onsite (kWh/a)	1,492,742.2
Utility Electricity Consumption (kWh/a)	73,450.4
Utility Natural Gas Consumption (kWh/a)	14,538,104.5
Total Fuel Consumption (onsite plus fuel for macrogrid electricity, without diesel) (kWh/a)	14,754,135.0
Efficiency of Entire Energy Utilization (Onsite and Purchase), without NG-only load	1.1
Achieved SGIP CHP efficiency	0.7

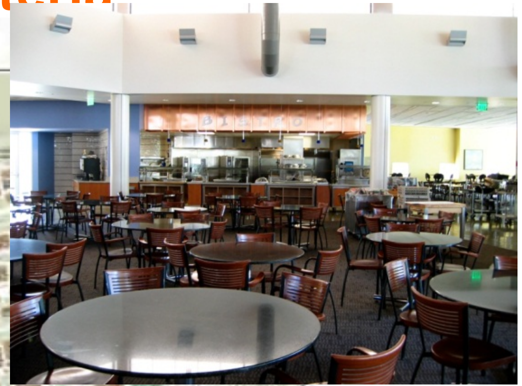
Case study

University of California at Davis

First WebOpt client UC Davis: Dining building

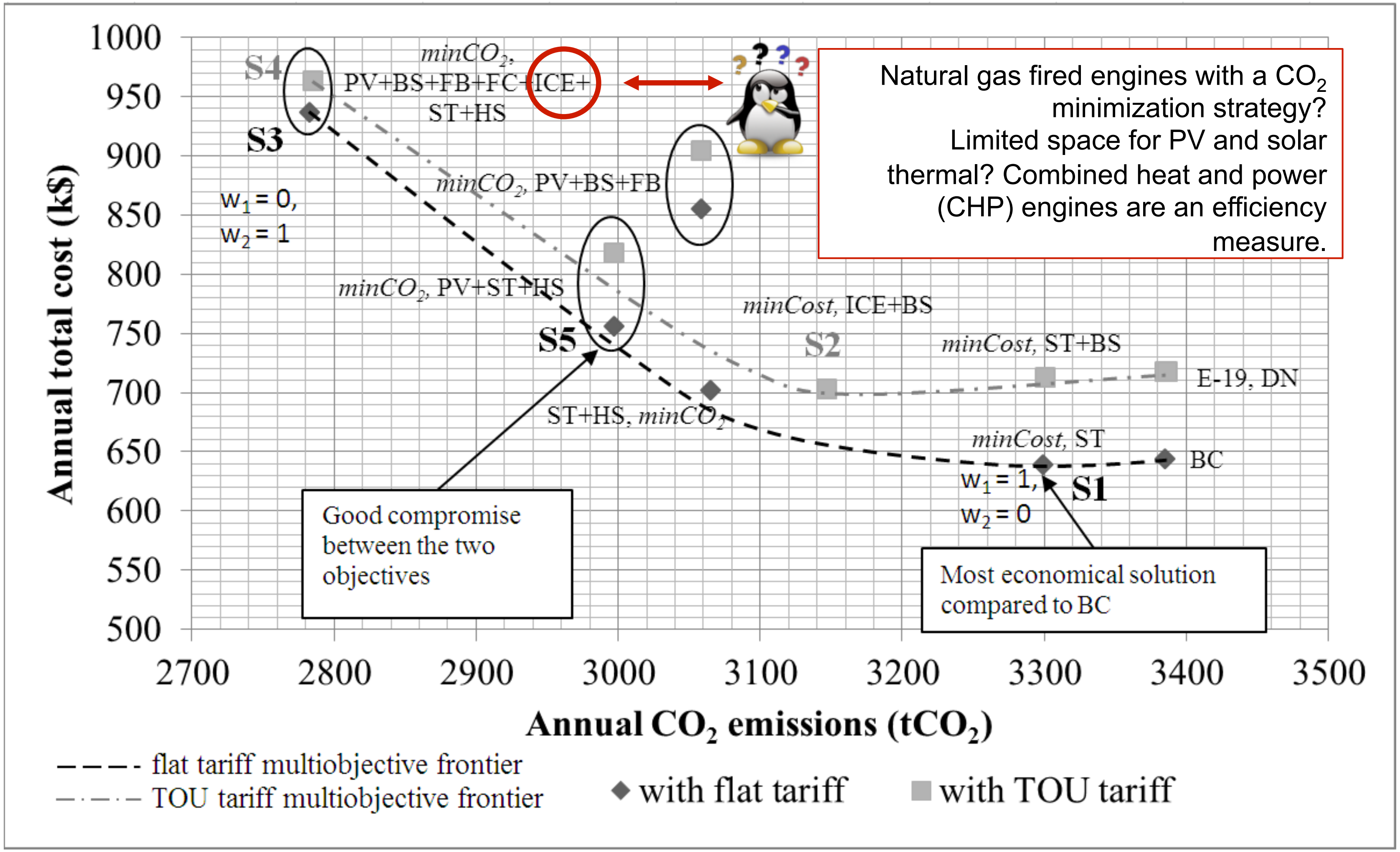
- one level building (4650m^2)
- electricity, natural gas & steam
- serves 3 meals a day to students
- ~2 yrs of sub-metered data
- no detailed data on electric appliances

pilot site:
student cafeteria



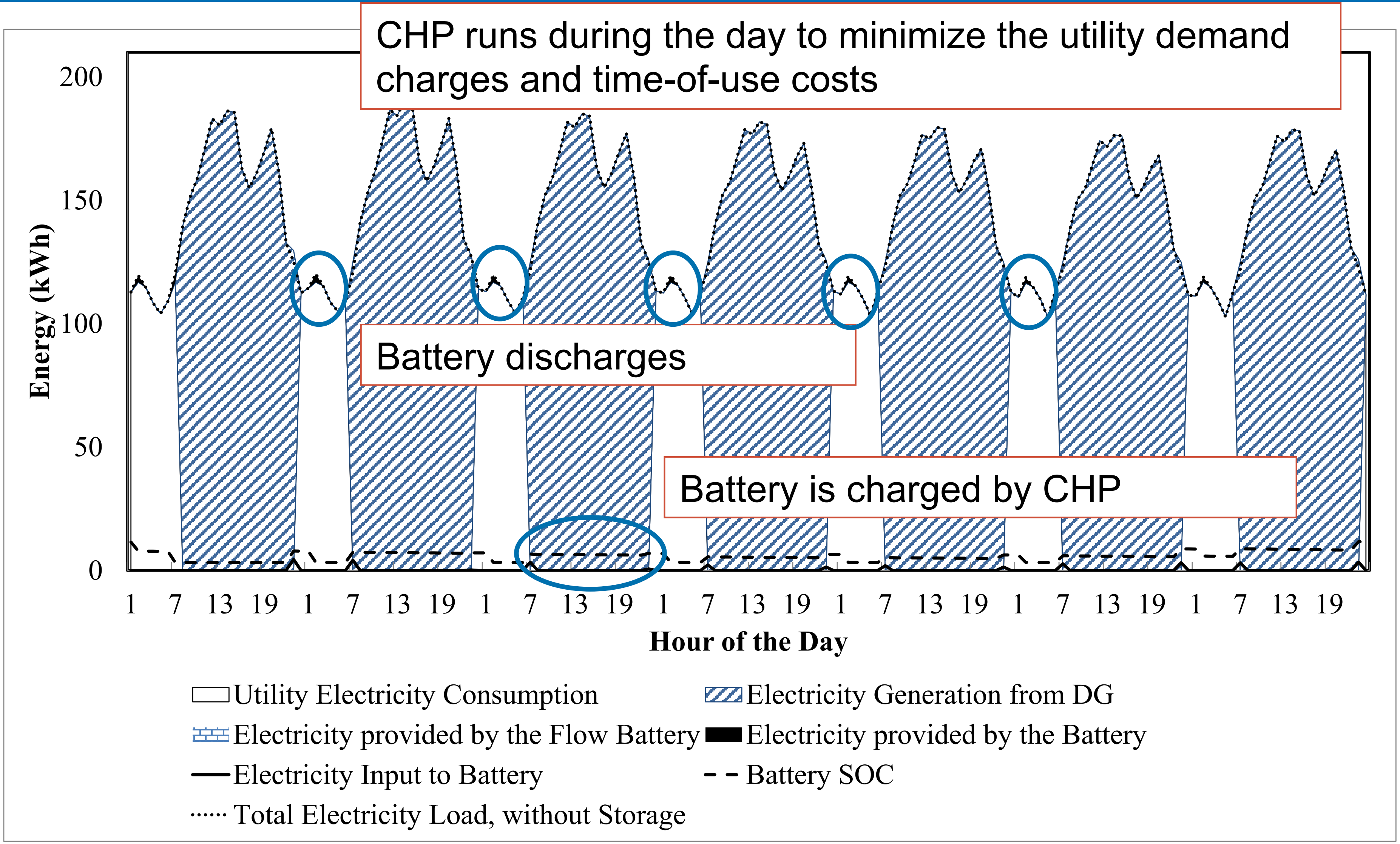
University of California, Davis

Web-Optimization with DER-CAM for UC 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

Diurnal electric pattern for point S2 from 09-Jan-11 to 16-Jan-11 (cost minimization)



Conclusions

Conclusions

- Web-Opt provides access to building optimization by
  - forecasting the sites' load (our experience shows that building operators do not have a good way to collect and forecast building loads)
  - providing a simple graphical interface
  - by removing the burden for expensive specialized software
- The UC Davis case study shows that
  - efficient CHP plays a role at CO_2 minimization strategies
  - CHP can be used to minimize utility costs
  - more detailed data points are needed to model sophisticated load shifting in buildings
  - consideration of conventional efficiency measures is necessary to complete analysis.

End

Thank you!

Questions and comments are very welcome.

Literature

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Equipment

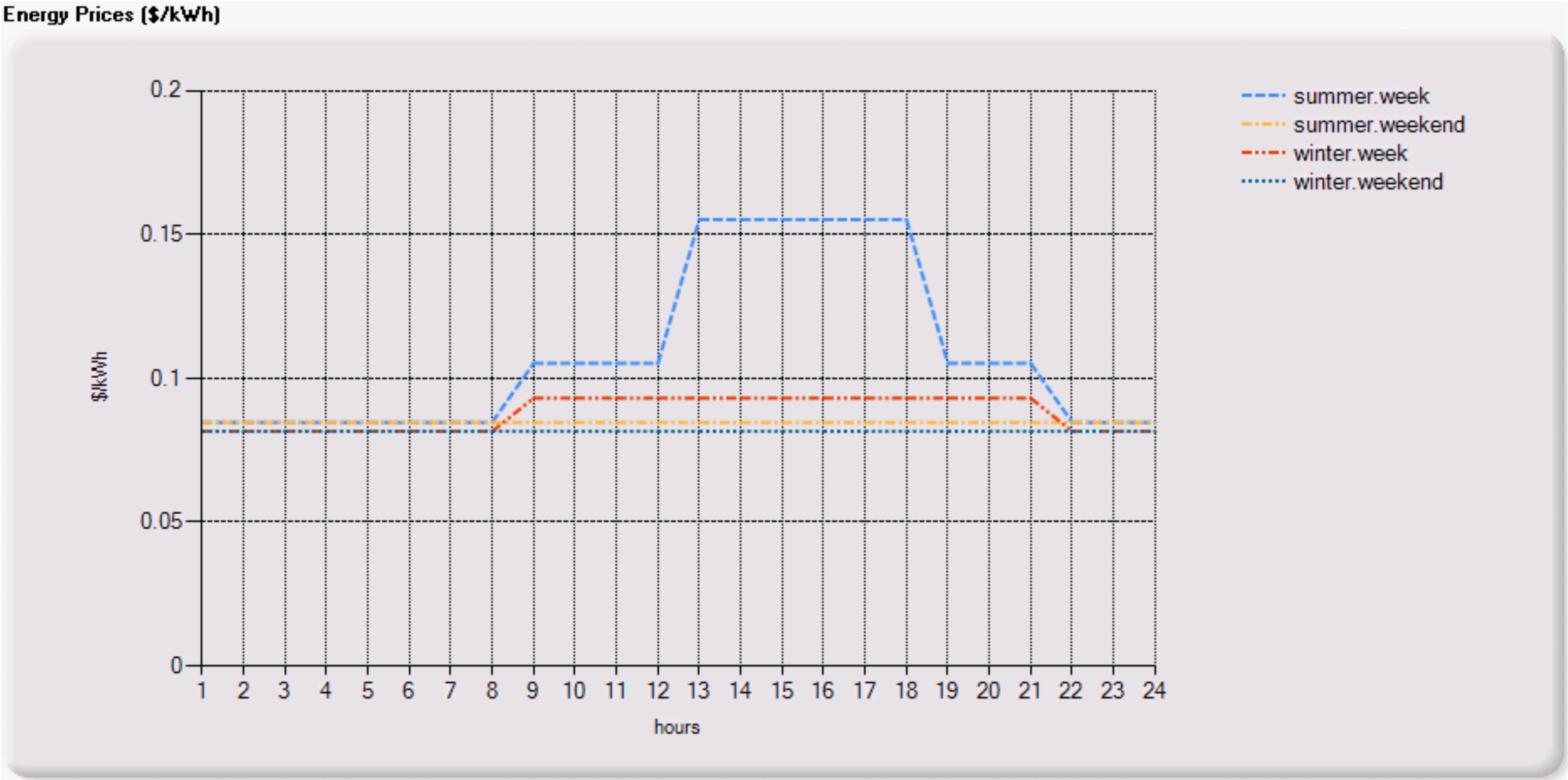
Technology	Fixed cost ($)	Maintenance variable cost ($/kWh)	Maintenance fixed cost ($/kWh)	Lifetime (years)
Lead-acid battery	0	200	0.0	6
Generic heat storage	10 000	100	0.0	17
Zinc-bromine flow battery energy	0	220	0.1	10
Zinc-bromine flow battery power	0	2 125 ($/kW)	0.0 ($/kW)	10
Photovoltaics	0	8 300 ($/kW)	0.3 ($/kW)	20
Solar thermal	1 000	400	0.1	15

Parameter	Lead-acid battery (%)	Zinc-bromine flow battery (%)	Heat storage (%)
Charging efficiency	87	84	90
Discharging efficiency	87	84	90
Decay rate	0.4	0.0	1
Maximum charging rate	20	N.A.	25
Maximum discharging rate	40	N.A.	25
Minimum state of charge	30	25	0

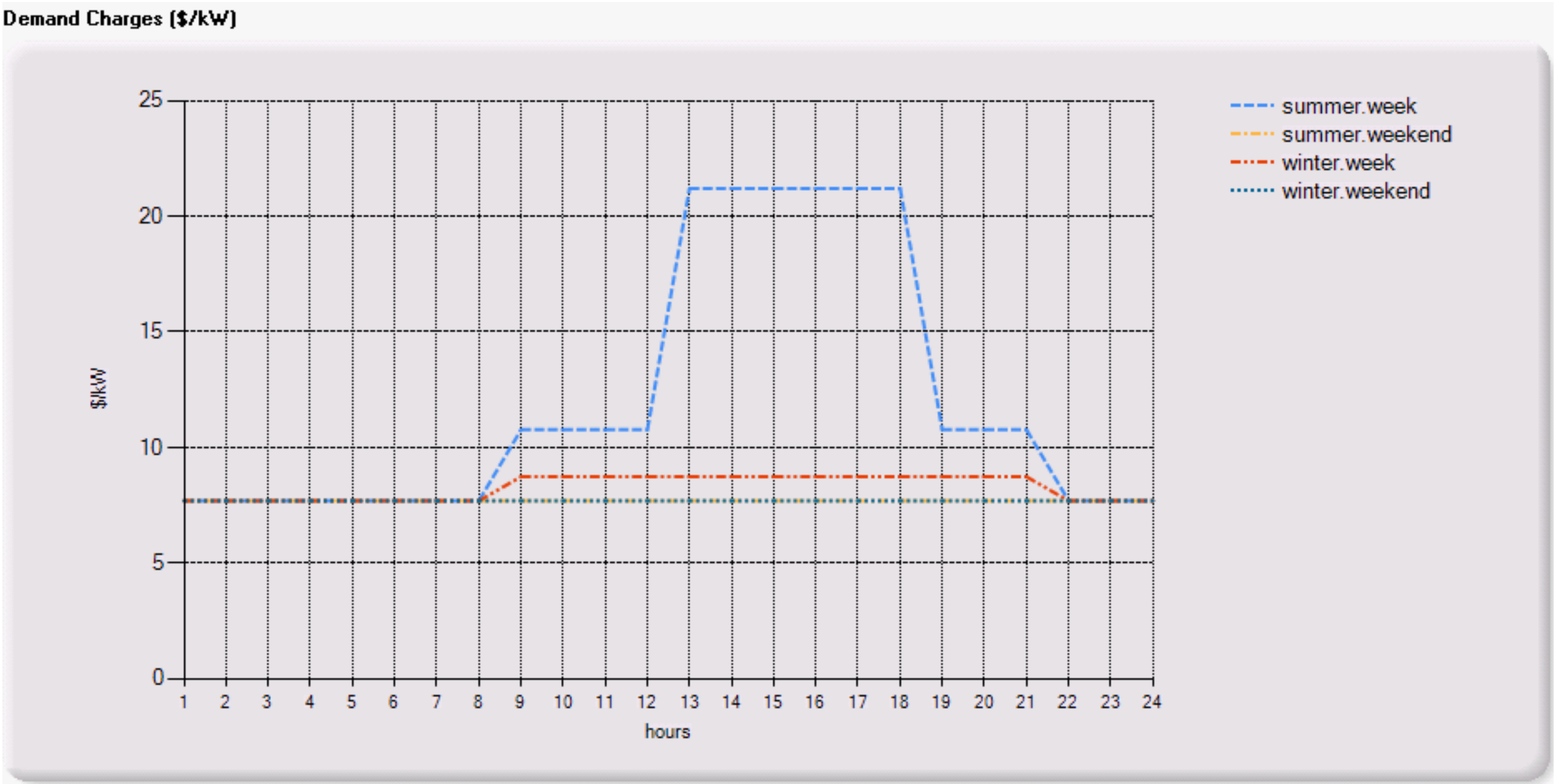
Equipment

Technology	Rated power (kW)	Capital cost ($/kW)	Maintenance variable costs ($/kWh)	Electric efficiency (%)	Heat-to-power ratio	Lifetime (years)
Small ICE with heat exchanger	60	3580	0.018	29	1.73	20
Medium ICE with heat exchanger	250	2180	0.013	30	1.48	20
FC with heat exchanger	250	2700	0.029	36	1.00	10

E-19 time of use tariff



E-19 time of use tariff



Representative MILP

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

Simplified* DER-CAM model

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**