Lawrence Berkeley National Laboratory
Environmental Energy Technologies Division

Integrated building energy systems design considering storage technologies

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Outline

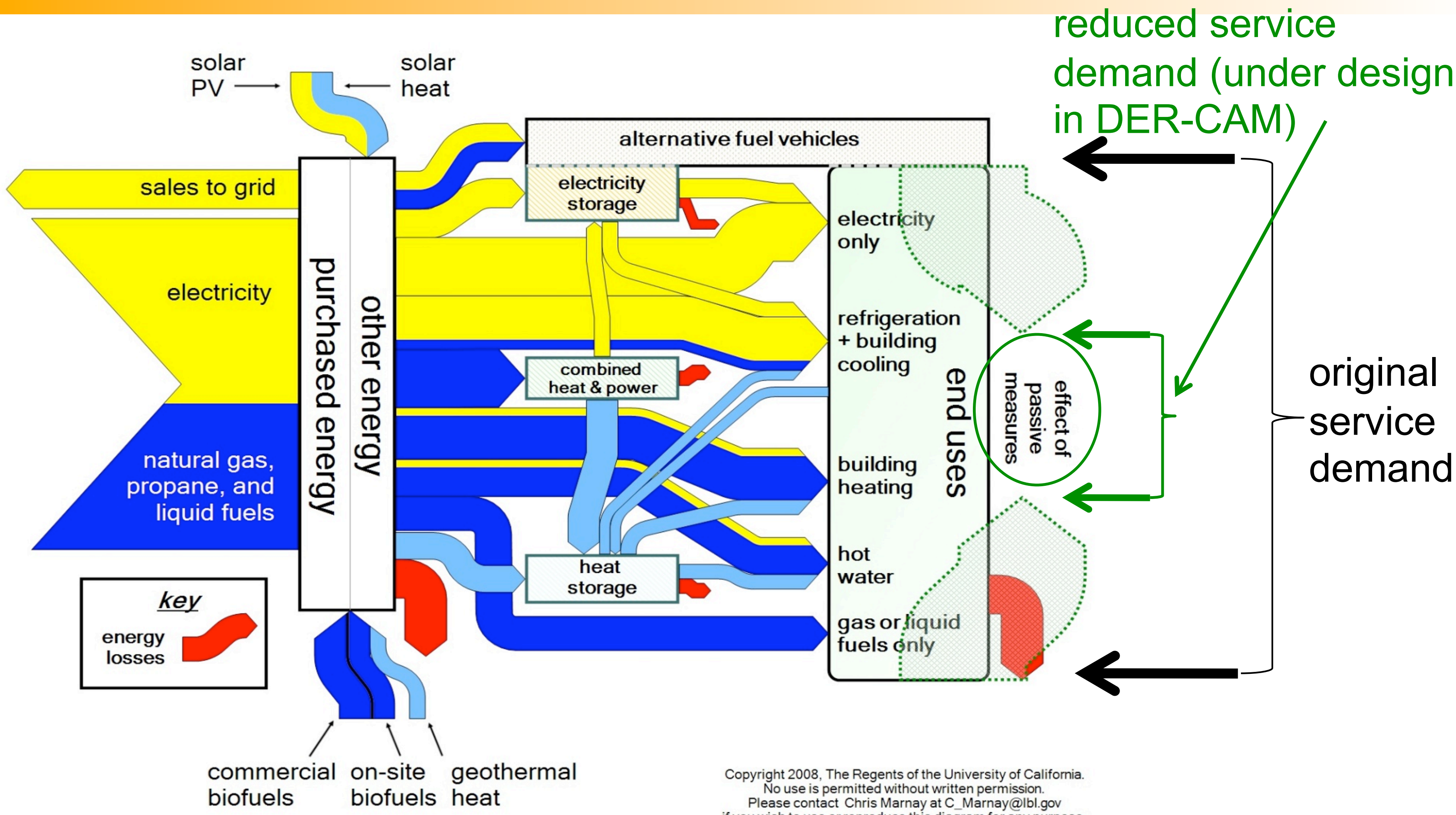
- Introduction
- The Distributed Energy Resources - Customer Adoption Model (DER-CAM) Concept
- DER equipment parameters used in this analysis
- CA nursing home example
- NY nursing home example
- Cost versus CO_2 minimization for CA case
- Conclusion

(Past focus on CHP and now microgrids)

Introduction

- Commercial sites such as hotels, data centers, hospitals, etc. are attractive distributed energy resources (DER) hosts, with or without combined heat and power (CHP).
- Very limited understanding of economic and environmental interactions between DER with CHP, absorption chillers, PV, solar thermal, and storage exists.
- How does the presence of storage technologies alter sites' energy costs and carbon emissions?
- How does the solution change with more focus on CO_2 than costs?
- How do storage and PV interact?

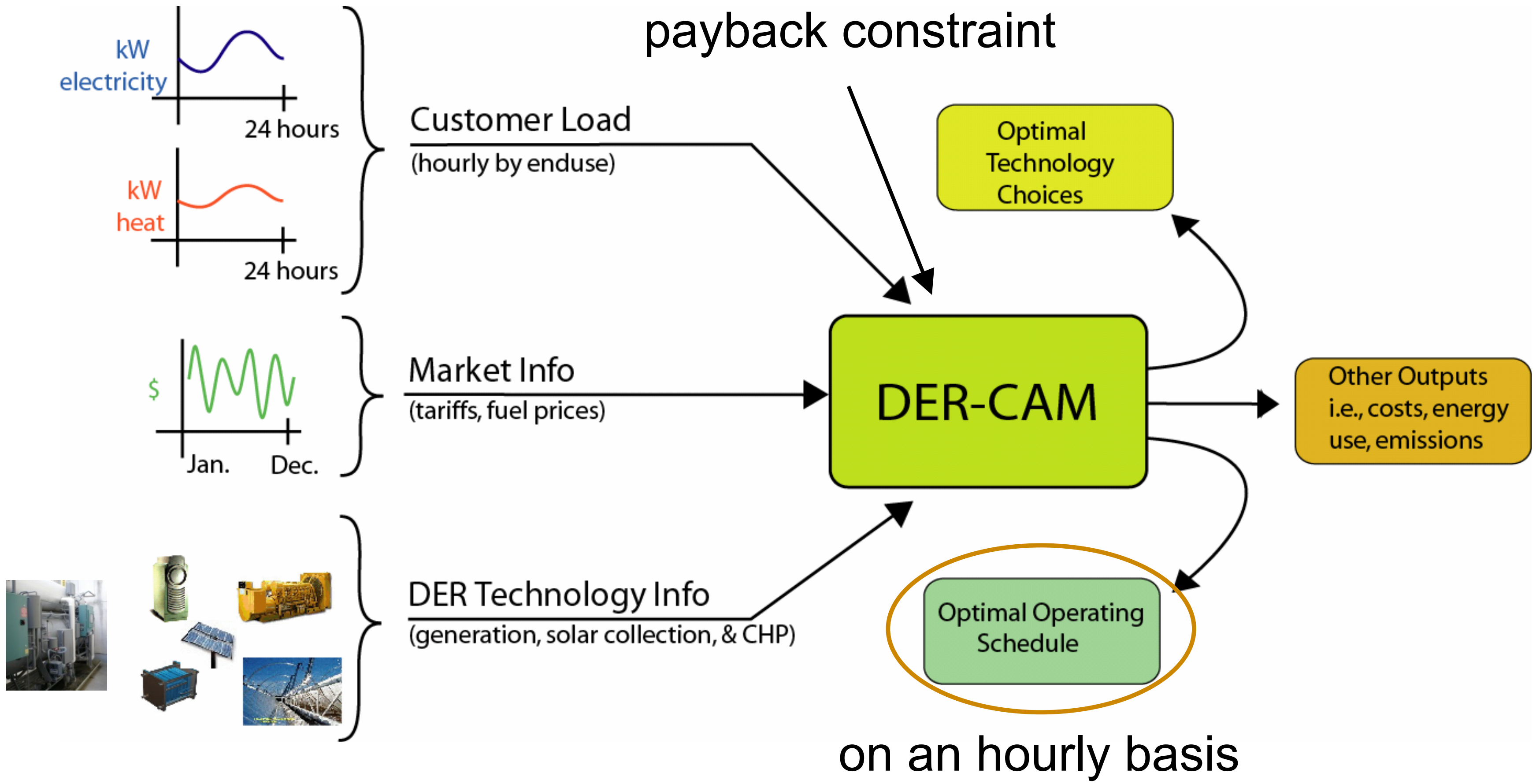
Global Concept



DER-CAM Concept

- Mixed Integer Linear Program (MILP), written in the General Algebraic Modeling System (GAMS®)
- Minimizes annual energy costs, carbon emissions, or multiple objectives of providing services on a microgrid level (typically buildings with approx. 200-2000 kW peak)
- Produces technology neutral pure optimal results with highly variable run times
- Has been designed for more than 7 years by Berkeley Lab and under license by researchers in the US, Germany, Spain, Belgium, Japan, and Australia
- Commercialization plans

DER-CAM Concept



DER Equipment Parameters used in this Study

discrete

	reciprocating engine	fuel cell
capacity (kW)	100	200
sprint capacity	125	
installed costs ($/kW)	2400	5005
installed costs with heat recovery ($/kW)	3000	5200
variable maintenance ($/kWh)	0.02	0.029
efficiency (%), (HHV)	26	35
lifetime (a)	20	10

only integer numbers available

continuous

fixed unavoidable costs →

	electrical storage (lead acid)	thermal storage	flow battery	absorption chiller	solar thermal	photovoltaics
intercept costs ($)	295	10000	0	20000	1000	1000
variable costs ($/kW or $/kWh)	193	100	220 / 2125	127	500	6675
lifetime (a)	5	17	10	15	15	20

Runs

- Most important runs that are shown in this presentation are
  - run 1: no investments in DER, all energy is from local utility
  - run 2: all DER technologies are allowed at current costs
  - run 3: storage costs reduced by 75% electricity, & 88% heat and PV incentive of 2.50 $/W provided
  - run 4: results from run 3 are forced as DER-CAM solution except storage itself (allows assessing the benefit of storage)
  - run 5: low storage costs and PV costs are reduced approx. 60%
- CA tariffs: demand charges (up to $15/kW) and TOU-tariffs that vary with the season and hour (TOU variation: 78%), also moderate NG prices of ca. 11 $/GJ (vs. 13 ¢/kWh)
- NY tariffs: almost flat electric tariffs, 23% higher NG prices than in CA

CA Nursing Home, Cost Minimization

at current technology costs

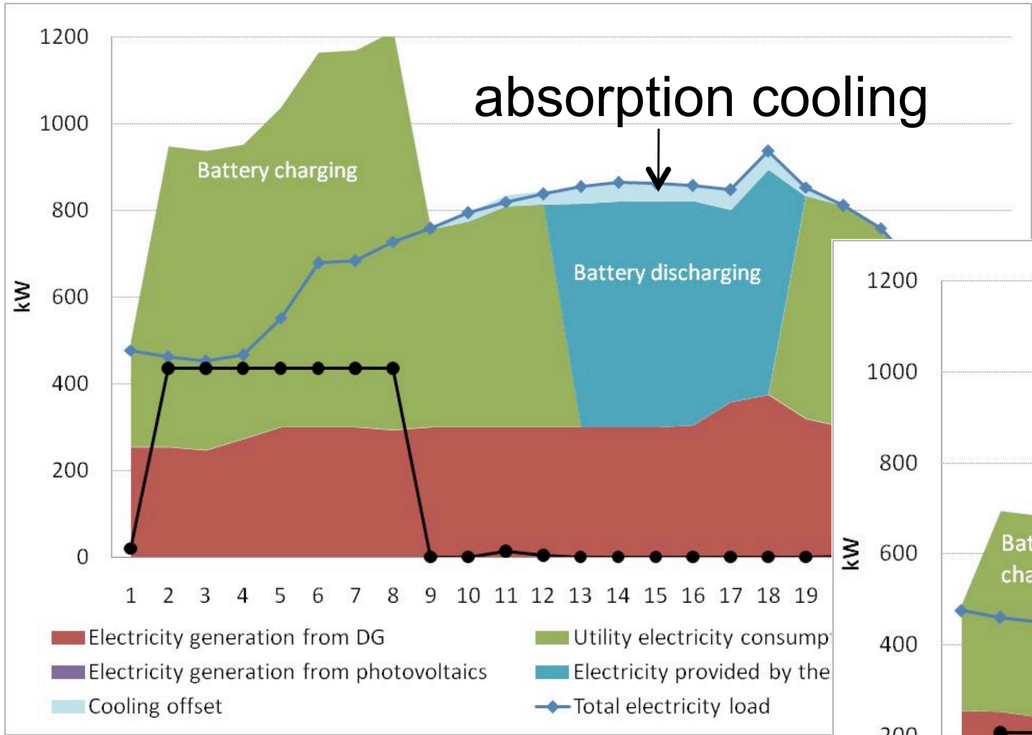
	run 1	run 2	run 3	run 4	run 5
	do-nothing	invest in all technologies	low storage costs and PV incentive of 2.5$/W	force low storage / PV results	low storage costs and 60% PV cost reduction
equipment					
reciprocating engine, Tecogen 100 kW with heat exchanger (kW)	n/a	300	300	300	300
abs. chiller (kW in terms of electricity)	n/a	48	46	46	40
solar thermal collector (kW)	n/a	134	109	109	43
PV (kW)	n/a	0	0	0	517
electric storage (kWh)	n/a	0	4359	n/a	2082
thermal storage (kWh)	n/a	0	123	n/a	47
annual total costs (k$)					
total	964	926	916	926	910
% savings compared to do nothing	n/a	3.94	4.98	3.94	5.60
annual energy consumption (GWh)					
electricity	5.76	3.23	3.33	3.22	2.40
NG	5.70	9.99	10.00	10.03	10.10
annual CO_2 emissions (t/a)					
emissions	3989	3465	3520	3469	3058
% savings compared to do nothing	n/a	13.14	11.76	13.05	23.35

marginal CO_2 emission rate utility: 513 g/kWh

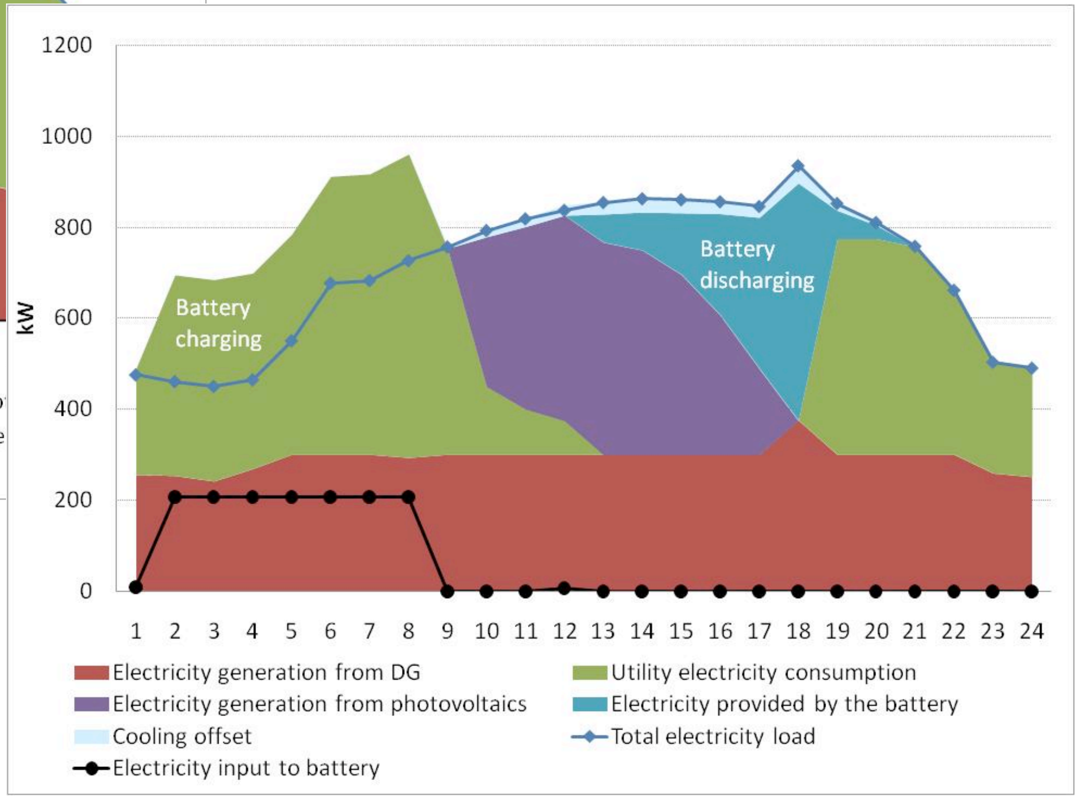
ICEs are a very stable solution

less carbon reduction potential with big electric storage

CA Nursing Home
Cost Minimization



run 5: diurnal electricity pattern for the CA nursing home on a July weekday



run 3: diurnal electricity pattern for the CA nursing home on a July weekday

CA Nursing Home Cost Minimization

- Storage technologies are not attractive at current price levels
- Cheaper storage technologies result In less carbon reduction potential compared to the case without storage
- Electric storage systems are charged by cheap off-peak electricity and not by PV
- Storage inefficiencies and the same marginal carbon emissions during on- and off-peak periods result in higher carbon emissions
- At current price levels and technology costs internal combustion engines with heat exchanger, abs. chillers as well as solar thermal is economically attractive for the nursing home.

NY Nursing Home
Cost Minimization

at current technology costs

	run 1	run 2	run 3	run 4	run 5
	do-nothing	invest in all technologies	low storage costs and PV incentive of 2.5$/W	force low storage / PV results	low storage costs and 60% PV cost reduction
equipment					
reciprocating engine, Tecogen 100 kW with heat exchanger (kW)	n/a	0	0	0	0
abs. Chiller (kW in terms of electricity)		100	112	112	112
solar thermal collector (kW)		1438	2350	2350	2350
PV (kW)		0	0	0	0
electric storage (kWh)		0	294	n/a	294
thermal storage (kWh)		0	4862	n/a	4862
annual total costs (k$)					
total	1196	1161	1149	1179	1149
% savings compared to do nothing	n/a	2.93	3.92	1.42	3.92
annual energy consumption (GWh)					
electricity	6.02	5.90	5.95	5.82	5.95
NG	7.14	5.24	3.50	4.82	3.50
annual CO_2 emissions (t/a)					
emissions	5702	5276	4990	5141	4990
% savings compared to do nothing	n/a	7.46	12.46	9.84	12.46

utility marginal CO_2 emission rate 733 g/kWh

ICE and PV are not chosen

11 times bigger than in CA!

storage adoption is inverse to the CA case

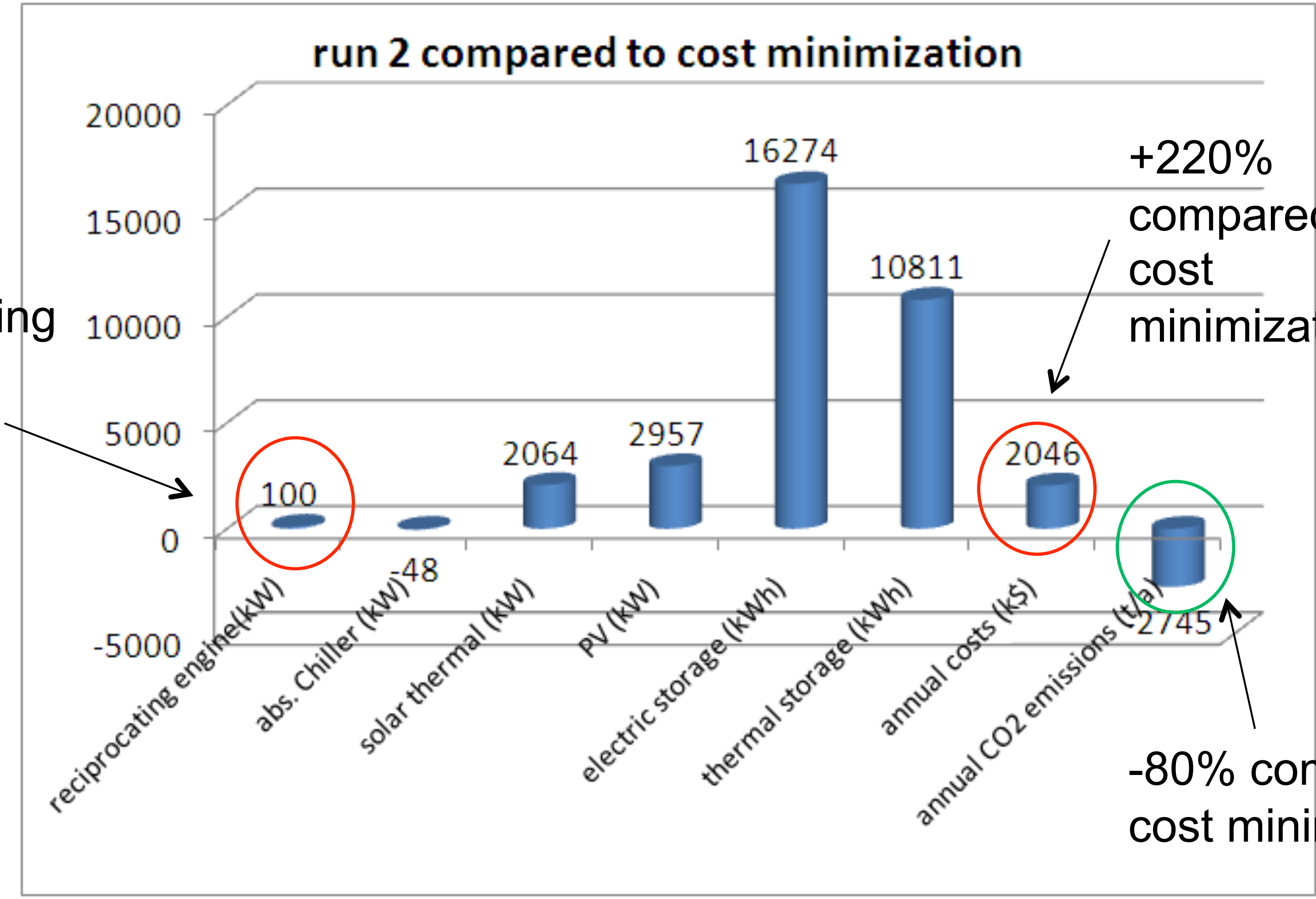
higher carbon reduction potential with heat storage

Comparison
Cost Minimization

- NY examples with almost flat electricity tariffs and higher natural gas prices show (14 $/GJ vs. 14 ¢/kWh)
  - less or no electric storage and ICE adoption
  - but more solar thermal adoption despite less solar radiation

  → higher heating demand combined with the absence of DG-CHP compensates for the lower solar radiation and increases the solar thermal adoption for the NY example
  - due to the flat NY electricity tariff batteries are also charged during the day
- The CA example shows that electric storage adoption is driven by economic decisions to avoid on-peak grid purchase, i.e. demand charge and expensive on-peak electricity.

CA Nursing Home CO_2 Min. vs. Cost Min.

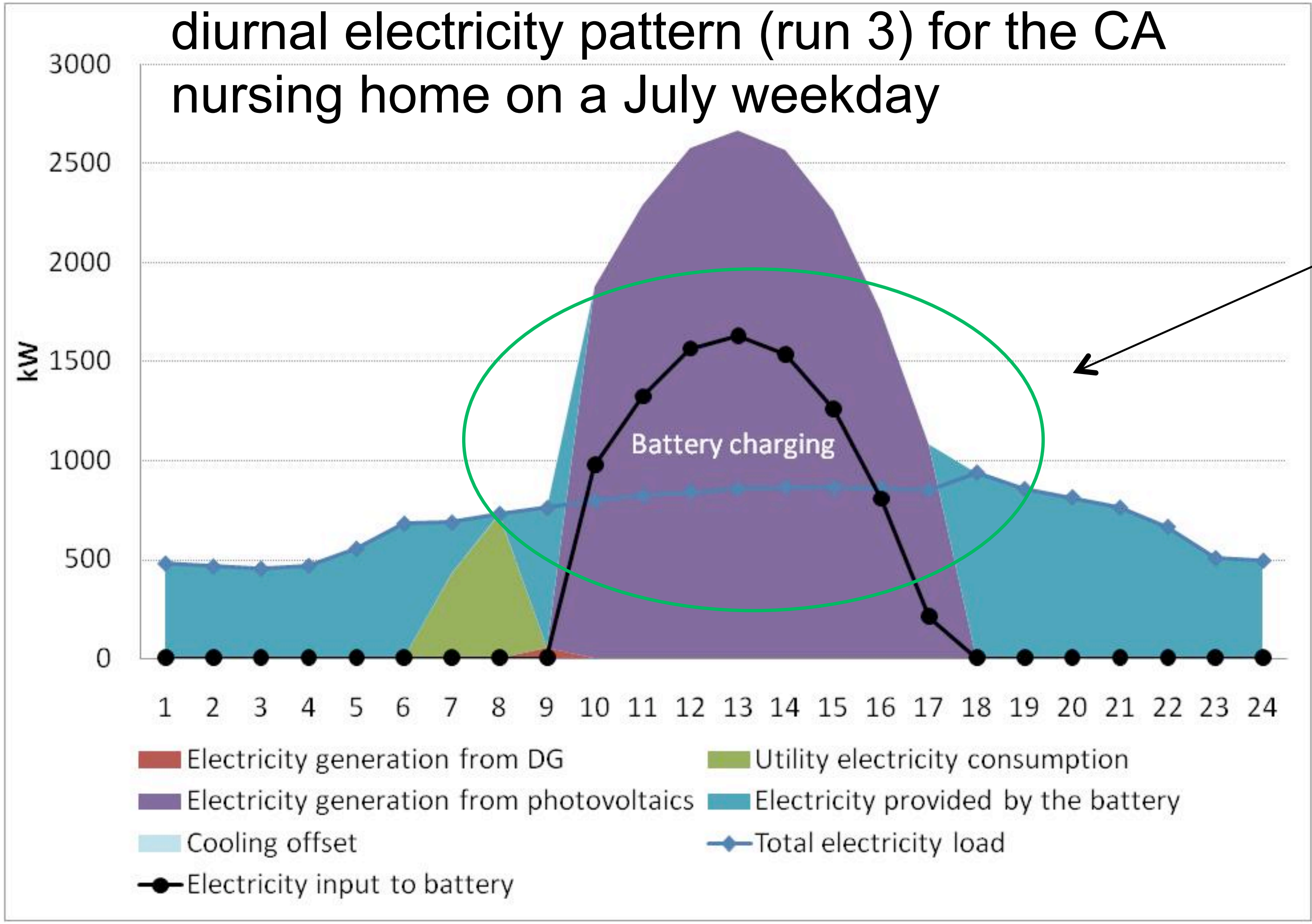


also reciprocating engines increase

+220% compared to cost minimization

-80% compared to cost minimization

CA Nursing Home CO_2 Minimization



energy costs are not important→ batteries are charged by PV

Conclusion

- PV is not an *economic* option to charge electric storage, even at price levels 60% lower than today's prices
- Under *cost minimization* PV is not used for battery charging and both are in competition
- Using grid electricity for battery charging results in higher CO_2 emissions than without batteries
- Under *CO_2 minimization* high energy costs for the site and unrealistic equipment adoption, *need consideration of efficiency*
- But results in 80% CO_2 reduction and solar energy is stored
- Storage inefficiencies are not important if costs are neglected
- Approach valuable for finding low carbon footprint building energy systems, but we lack understanding and representation of the technologies necessary