

Lawrence Berkeley National Laboratory

Lawrence Berkeley National Laboratory

Title

Integrated Modeling of Building Energy Requirements Incorporating Solar Assisted Cooling

Permalink

<https://escholarship.org/uc/item/80q3x41v>

Authors

Firestone, Ryan
Marnay, Chris
Wang, Juan

Publication Date

2005-08-10

Integrated Modeling of Building Energy Requirements Incorporating Solar Assisted Cooling

Ryan Firestone, Chris Marnay, and Juan Wang*

*1 Cyclotron Road MS-90-R4000, Berkeley, CA 94720-8136, USA, tel: +1.510.486.7028, fax: +1.510.486.7976, e-mail [C. Marnay@lbl.gov](mailto:C.Marnay@lbl.gov), URL: der.lbl.gov

1. Introduction

This paper expands on prior Berkeley Lab work on integrated simulation of building energy systems by the addition of active solar thermal collecting devices, technology options not previously considered (Siddiqui et al 2005). Collectors can be used as an alternative or additional source of hot water to heat recovery from reciprocating engines or microturbines. An example study is presented that evaluates the operation of solar assisted cooling at a large mail sorting facility in southern California with negligible heat loads and year-round cooling loads. Under current conditions solar thermal energy collection proves an unattractive option, but is a viable carbon emission control strategy.

2. Distributed Energy Resources Customer Adoption Model

The Distributed Energy Resources Customer Adoption Model (DER-CAM) finds the cost minimizing optimal combination of equipment and operating schedule to meet the useful energy flows required at a site, given end-use energy loads, electricity and natural gas prices, and DER equipment options. Slide 2 shows the flows of energy in a building from the inflows of purchased or solar energy on the left towards the useful energy flows on the right. DER-CAM solves this entire system simultaneously.

3. San Bernardino Mail Sorting Facility

The mail sorting facility is a huge (25 000 m²) building in the desert east of Los Angeles. Daytime maximum temperatures average 40 C in summer but fall to 23 C at midnight, while winter highs are only about 15 C, and it never freezes. Each evening and night, machinery processes 2 million pieces of mail, resulting in year-round cooling loads and a 1.6 MW summer peak electrical load near midnight. Electricity consumption totals about 2 GWh/a for cooling and 8 GWh/a for all other uses, leading to a total annual energy bill of US\$930,000 (US\$0.09/kWh). Heating loads are negligible. High electricity prices, abundant solar radiation and a large rooftop area, and year-round cooling loads make this building an apparent prime candidate for solar cooling.

4. Data Inputs

Current California subsidies for distributed generation are applied as follows: US\$600/kW for reciprocating engines and large turbines, US\$800/kW for microturbines, and US\$3500/kW for photovoltaics, but are excluded from the carbon cases. Other input data was collected as shown in the bibliography.

5. Modeling Approach

Two types of solar collectors are considered 1) low temperature flat plate collectors used as pre-heating to single effect absorption chillers (COP = 0.7) with supplemental heat being provided by waste heat or natural gas and 2) high temperature, pressurized, concentrating collectors used to fire double-effect chillers (COP = 1.2) with waste heat and/or natural gas preheating. For both types of collector, two sensitivities were performed: 1) decreasing the cost (\$/kW) of collectors to reflect either technological progress or further subsidies; and 2) imposing annual carbon emission constraints while removing the DER subsidies and minimum payback constraints. The average carbon intensity for the local utility is 0.131 kg/KWh (Price et. al. 2002).

6. Results

Natural gas reciprocating engines (mostly 1 MW systems) with heat recovery and absorption cooling are selected in all instances. At current collector costs (US\$150/kW for low temperature and US\$1400 for high temperature), DER-CAM chooses a 1 MW reciprocating engine system, 1.1 MW single effect absorption chiller, and a 1.5 MW low temperature collector. This lowers the annual bill by 14% to US\$802,000. Only 30% of electricity use is self-generated and absorption cooling displaces a further 8.8%. Low temperature collectors are economic up to US\$450/kW; however, cost savings relative to DER systems without collectors are small: only 5% even if free, and just 1% at current costs. High temperature collectors provide significant cost savings (16%) if free but are not economic above US\$950/kW.

Slide 5 shows how heat and electricity loads are met in two cases: above are January low temperature results at current collector costs; below are July high temperature results if collectors cost US\$500/kW, less than half of current costs. However, DER systems including high temperature collectors and double effect chillers could reduce the site carbon emissions by up to 500 t/a

(40%) at a control cost of US\$500/t. Systems including low temperature collectors and single effect chillers would require a public cost of US\$1500/t to reduce emissions 500 t/a, due to a heavier reliance on expensive photovoltaics. Slide 7 shows the installed capacity of DER equipment for the carbon constraint sensitivity. Figure 8 shows the annual energy costs for the site in this sensitivity. These are the Pareto curves of the cost/carbon dual optimization.

7. Conclusion

At current costs, low temperature collectors are a cost effective addition to DER systems at the example site, but offer only minimal energy cost savings. High temperature collectors are not cost effective but offer greater opportunity for carbon savings and at a lower control cost.

8. Bibliography

- Bailey, O., et al. *Distributed Energy Resources in Practice: A Case Study Analysis and Validation of LBNL's Customer Adoption Model*. Berkeley Lab report LBNL-52753. February 2003. **Site information and characteristics**
- EIA (U.S. Energy Information Administration) "Chapter 10: Renewable Energy." *Annual Energy Review 2003*, DOE/EIA-0384(2003), September 2004. **Solar collector cost and performance**
- Firestone, R. *Distributed Energy Resources Customer Adoption Model Technology Data*, Berkeley Lab. January, 2004. Available online at <http://der.lbl.gov/data/DERCAMTechDataOnline.pdf> (last accessed August, 2005). **Absorption chiller and PV cost and performance**
- Goldstein, L., et. al. *Gas-Fired Distributed Energy Resource Technology Characterizations*. National Renewable Energy Laboratory report NREL/TP-620-34783. November 2003. **Reciprocating engine, microturbine, turbine, and heat exchanger cost and performance**
- Price, L., et al. 2002. "The California Climate Action Registry: Development of methodologies for calculating greenhouse gas emissions from electricity generation." Proc., ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, D.C. **Average carbon emissions for the local utility**
- SCE (Southern California Edison), "Schedule TOU-8." *Southern California Edison Tariff Books*, Sheets 38928E - 38930E and 38461E – 38473E. Revised July 2005. **Electricity prices**
- Siddiqui, A., et al. "Effects of a Carbon Tax on Microgrid Combined Heat and Power Adoption." *Journal of Energy Engineering* special issue on quantitative models for energy policy, planning and management, Apr 2005, vol. 131(1).
- SoCalGas (Southern California Gas Company), "Schedule GT-10." *Southern California Gas Company Rate Schedules*. August 2005. **Natural gas prices**

Integrated Modeling of Building Energy Requirements Incorporating Solar Assisted Cooling

1

presentation at

International Conference on Solar AC

6-7 Oct 2005

Kloster Banz, Bad Staffelstein, Germany

by

Chris Marnay*, Ryan Firestone, & Juan Wang

Berkeley Lab, Berkeley CA, U.S.A.

*Contact: C_Marnay@lbl.gov tel: +1.510.486.7028

der.lbl.gov

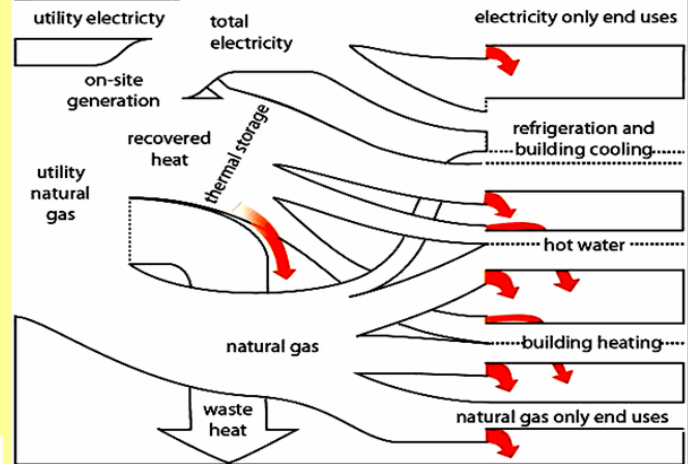
research supported by the U.S. Dept of Energy and the California Energy Commission

Environmental Energy Technologies Division



DER Customer Adoption Model (DER-CAM)

2



Environmental Energy Technologies Division

San Bernardino USPS, Redlands CA (near Los Angeles)

Redlands, California



Environmental Energy Technologies Division



Collector Cost Results

4

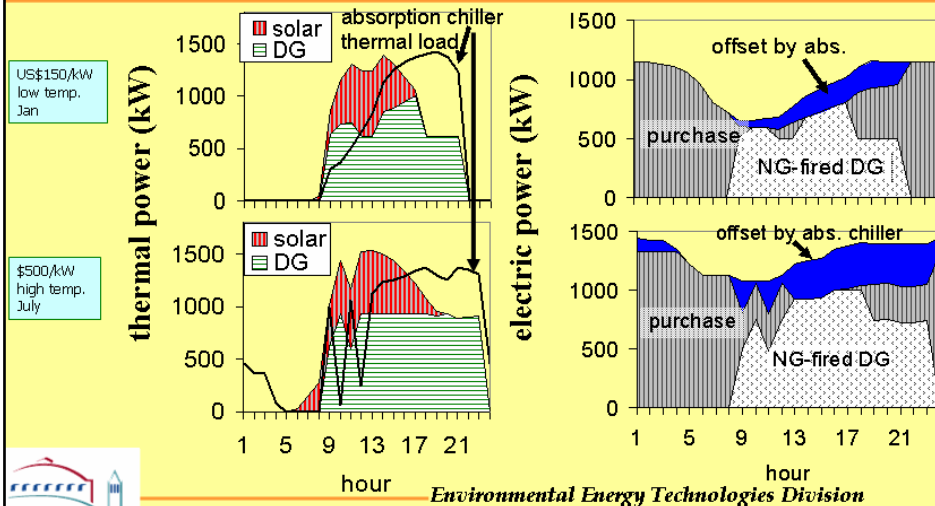
- low temp. collectors are economic
- chosen system:
 - 1 MW (electric capacity) of reciprocating engines
 - 1.1 MW (thermal cooling capacity) single-effect absorption chiller
 - 1.5 MW (thermal heat provided) low temperature collector
- but only provide 45% of heat
- and only lower the annual bill by 1%
- high temp. collectors and PV are not chosen



Environmental Energy Technologies Division

Meeting Absorption Chiller and Electric Loads

5



Carbon Constraint Results

6

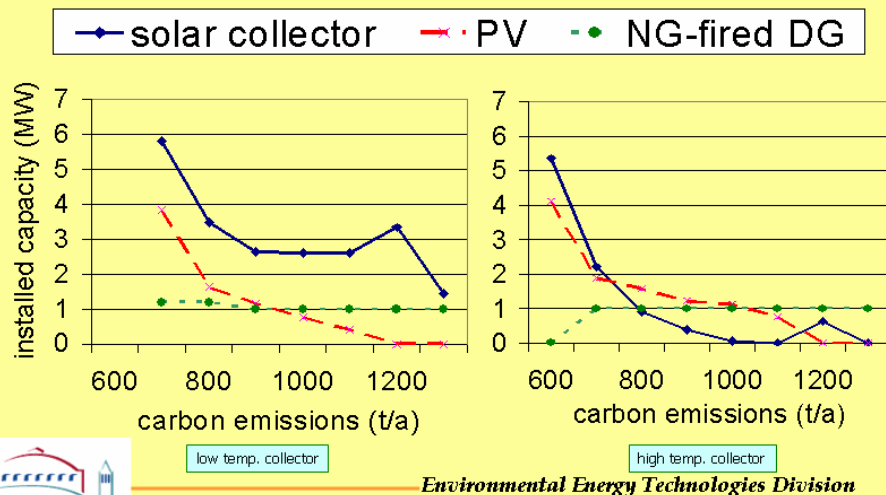
- high temp. collectors provide carbon savings at lower control cost than low temp. collectors
- for low carbon reductions PV is...
 - more economic than high temp. collectors
 - competitive with low temp. collectors
- solar thermal is still valuable because of storage which offsets evening cooling loads



Environmental Energy Technologies Division

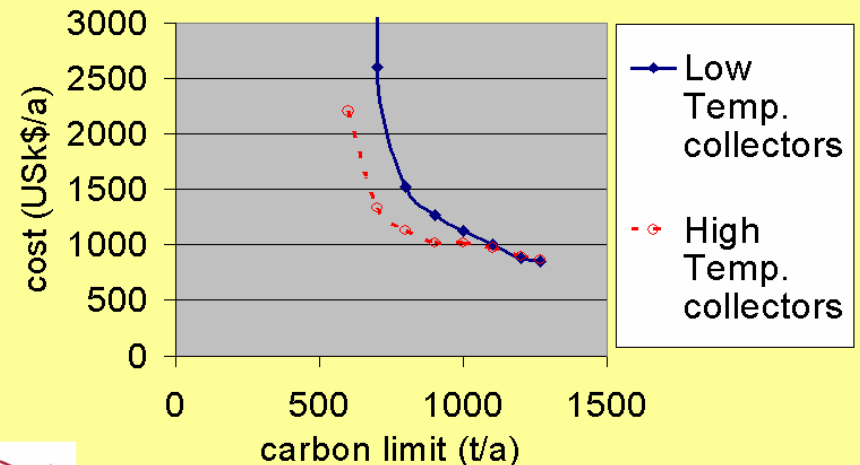
DER Equipment Installation Under Carbon Constraint

7



Pareto Minimization of Cost and Carbon Emissions

8



Environmental Energy Technologies Division