ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

Poster: Thermal Energy Storage for Electricity Peak-demand Mitigation: A Solution in Developing and Developed World Alike

Nicholas DeForest[1], Gonçalo Mendes[1,2], Michael Stadler[1,3], Wei Feng[1], Judy Lai[1], and Chris Marnay[1]

1 Lawrence Berkeley National Laboratory, University of California, Berkeley, One Cyclotron Road, Berkeley, CA 94720, USA

2. Instituto Superior Técnico - MIT Portugal

Av. Prof. Cavaco Silva, Campus IST TagusPark, Porto Salvo, CP 2744-016, Portugal

3. Center for Energy and innovative Technologies, Austria

Environmental Energy Technologies Division

Poster presented at ECEEE 2013 Summer Study 3–8 June 2013, Belambra Les Criques, France

http://microgrid.lbl.gov

The Distributed Energy Resources Customer Adoption Model (DER-CAM) has been funded partly by the Office of Electricity Delivery and Energy Reliability, Distributed Energy Program of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. DER-CAM has been designed at Lawrence Berkeley National Laboratory (LBNL) and is owned by the U.S. Department of Energy. Gonçalo Mendes acknowledges the funding by Fundação para a Ciência e Tecnologia (FCT) PTDC/SENENR/108440/2008 and MIT Portugal Program.

Disclaimer

Thermal Energy Storage for Electricity Peak-demand Mitigation:

A Solution in the Developing and Developed World Alike

BERKELEY LAB

Nicholas DeForest[1], Gonçalo Mendes[1,2], Michael Stadler[1,3], Wei Feng[1], Judy Lai[1], Chris Marnay[1]

1. Lawrence Berkeley National Laboratory, 2. Instituto Superior Técnico - MIT Portugal, 3. Center for Energy and Innovative Technologies, Austria

Introduction

In much of the developed world, air-conditioning in buildings is the dominant driver of summer peak electricity demand. In the developing world a steadily increasing utilization of air-conditioning places additional strain on already-congested grids. This common thread represents a large and growing threat to the reliable delivery of electricity around the world, requiring capital-intensive expansion of capacity and draining available investment resources. Thermal energy storage (TES), in the form of ice or chilled water, may be one of the few technologies currently capable of mitigating this problem cost effectively and at scale. The installation of TES capacity allows a building to meet its on-peak air conditioning load without interruption using electricity purchased off-peak and operating with improved thermodynamic efficiency. In this way, TES has the potential to fundamentally alter consumption dynamics and reduce impacts of air conditioning. This investigation presents a simulation study of a large (46,000 m²) office building in four distinct geographical contexts: Miami, Lisbon, Shanghai, and Mumbai. The optimization tool DER-CAM (Distributed Energy Resources Customer Adoption Model) is applied to optimally size TES systems for each location. Summer load profiles are investigated to assess the effectiveness and consistency in reducing peak electricity demand. Additionally, annual energy requirements are used to determine system cost feasibility, payback periods and customer savings under local utility tariffs.

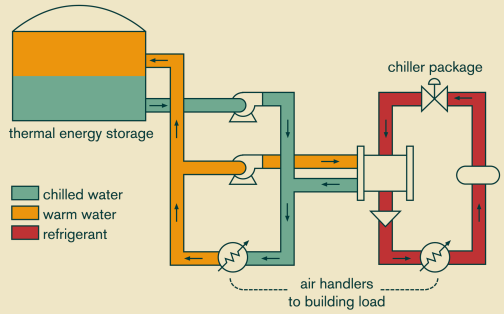


Figure 1: Schematic of thermal energy storage system integrated with building chiller plant

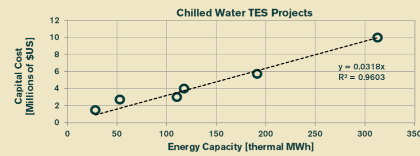
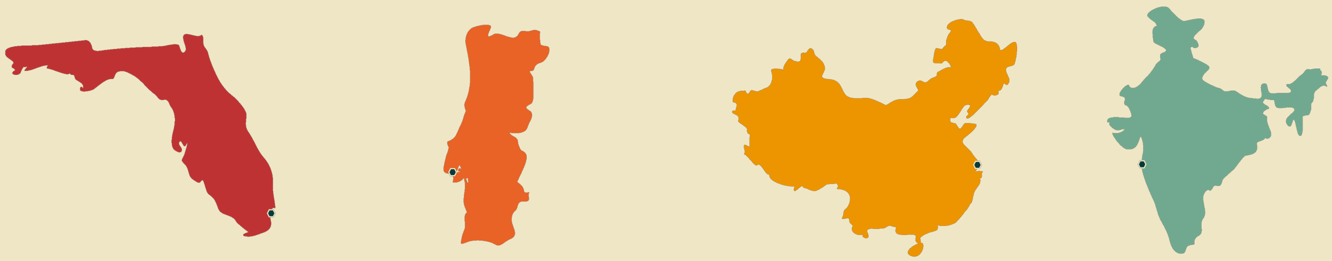


Figure 2: Cost scatter of recent U.S. TES projects show an estimated deployment cost of $32/kWh

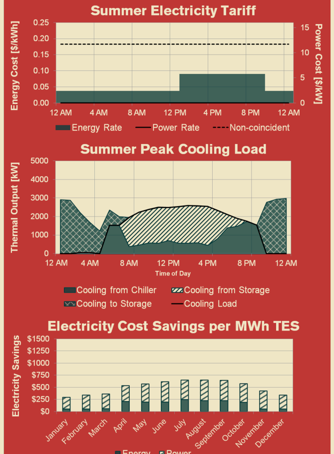
Building Envelope	Reference City	U-factor Walls [W/m²-K]	U-factor Roof [W/m²-K]	U-factor Windows [W/m²-K]	SHGC Windows [-]
High Efficiency	Miami, Lisbon	0.7	0.3	3	0.25
Medium Efficiency	Shanghai, Mumbai	2	0.6	6	0.50

Table 1: Thermal properties for building envelope by reference location



Miami Florida

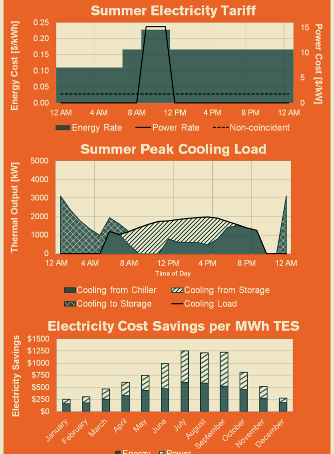
2494	35.6°C	996 kW	7.8 GWh
Cooling Degree-Days	High Temperature	Peak Cooling Load	Annual Cooling Load



TES Installed Capacity	Annual Cost Savings	Peak Demand Savings	Payback Period
21.9 MWh	6031 $/MWh	797 kW	5.3 years

Lisbon Portugal

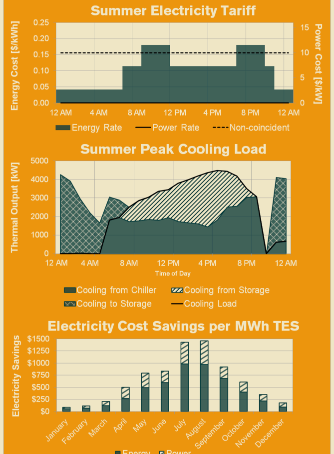
617	36°C	906 kW	3.6 GWh
Cooling Degree-Days	High Temperature	Peak Cooling Load	Annual Cooling Load



TES Installed Capacity	Annual Cost Savings	Peak Demand Savings	Payback Period
14.9 MWh	8697 $/MWh	615 kW	3.7 years

Shanghai China

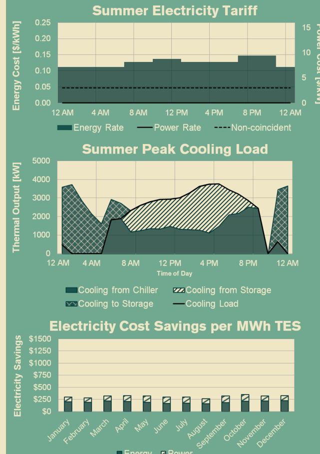
1063	38°C	1998 kW	5.5 GWh
Cooling Degree-Days	High Temperature	Peak Cooling Load	Annual Cooling Load



TES Installed Capacity	Annual Cost Savings	Peak Demand Savings	Payback Period
25.5 MWh	7498 $/MWh	1234 kW	4.2 years

Mumbai India

3355	38.5°C	1608 kW	11.5 GWh
Cooling Degree-Days	High Temperature	Peak Cooling Load	Annual Cooling Load



TES Installed Capacity	Annual Cost Savings	Peak Demand Savings	Payback Period
23.5 MWh	3756 $/MWh	1018 kW	8.5 years

TES Investment Decision-making:

Distributed Energy Resources Customer Adoption Model

The results of this investigation have been produced using the Distributed Energy Resources Customer Adoption Model (DER-CAM). Developed at Berkeley Lab, DER-CAM is an optimization tool for informing decision-making related to distributed energy resources (DER) deployment and operations. DER-CAM utilized deterministic mix-integer linear programming to generate cost or carbon optimal combinations of DER for site-specific conditions and requirements. DER-CAM takes as inputs historic end-use load data, detailed energy tariff data, local weather as well as DER technology cost and performance data. Berkeley Lab has also developed a public web-interface to DER-CAM, called WebOpt. Access to WebOpt can be found here: http://microgrid.lbl.gov/der-cam/how-access-der-cam

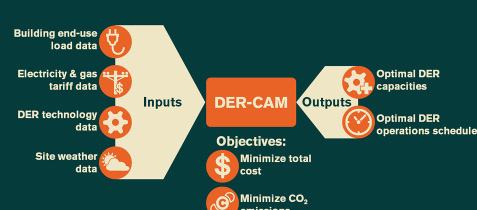


Figure 3: Diagram of major inputs, outputs and objectives in DER-CAM

Summary of Results

Reference Cities:	Miami	Lisbon	Shanghai	Mumbai
Installed TES Capacity (MWh)	21.9	14.9	25.5	23.5
Payback Period (years)	5.3	3.7	4.2	8.5
Total Annual Electricity Consumption				
Absolute Δ (MWh)	28.4	-23.5	21.4	-3.1
Relative Δ (%)	0.3%	-0.4%	0.3%	0.0%
Total Annual Electricity Cost				
Absolute Δ ($)	-$132,079	-$129,587	-$191,200	-$88,278
Relative Δ (%)	-18.7%	-9.5%	-17.1%	-6.5%
Peak Electricity Demand				
Absolute Δ (kW)	-797	-615	-1234	-1018
Relative Δ (%)	-37.3%	-30.1%	-37.7%	-36.3%

The Distributed Energy Resources Customer Adoption Model (DER-CAM) has been funded partly by the Office of Electricity Delivery and Energy Reliability, Distributed Energy Program of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.