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An Overall Assessment of Ice Storage Systems for Residential Buildings

Aaron Tam
Purdue University, United States of America, tam15@purdue.edu

James E Braun
Purdue University, United States of America, jbraun@purdue.edu

Neera Jain
Purdue University, United States of America, neerajain@purdue.edu

Davide Ziviani
Purdue University, United States of America, dziviani@purdue.edu

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Aaron C. TAM*, Davide ZIVIANI, James E. BRAUN, Neera JAIN

Purdue University,
West Lafayette, IN, USA
tam15@purdue.edu

* Corresponding Author

ABSTRACT

The recent availability of variable electric energy and demand rates for residential buildings is providing incentives for the application of thermal storage for cooling that previously has been limited to commercial buildings. This is particularly relevant for hot climates where air-conditioning (A/C) use is the primary cause for peak electricity demand. Thermal storage allows consumers to store "cooling" when demand is low and minimize operation of the A/C during peak periods. From an economic perspective, the use of storage can significantly reduce operating costs depending on the utility rate incentives. In addition, storage can lead to a reduction in the installed cost of the primary cooling equipment because of a reduction in the peak equipment cooling requirement. However, this reduced equipment cost is counteracted by the additional costs required for storage and a secondary loop. This paper considers the overall economics associated with a packaged A/C integrated with ice energy storage for residential cooling applications. The evaluation was performed using a model of the proposed system that estimates system performance and operating cost over a cooling season for different locations and utility rates and using a generalized control strategy presented in a companion paper. The proposed system is compared to a conventional split system A/C in terms of initial cost, operating cost, and economic payback. In addition, we investigate the trade-off between equipment cooling capacity, equipment efficiency, and storage size to determine minimum payback period for each situation. The optimization results show that systems with the shortest payback period have a high SEER rating. In addition, the payback periods are attractive in locations with favorable utility rates and long cooling seasons (i.e., hot climates).

1. INTRODUCTION

Thermal storage has been popular in commercial cooling systems; however, it is rarely considered in residential applications. One of the major reasons for this is the structure of commercial utility rates which typically include higher energy rates during certain peak periods of the day and demand charges that penalize high power use. Thermal storage allows buildings to store cooling during off-peak hours and provide cooling with the storage during on-peak hours. Residential utilities have typically offered customers only a flat energy rate, so the inclusion of a storage system would not deliver the same operating cost savings. However, in recent years, variable rates have become more available to residential customers. Growing penetration of renewable energy on the electric grid also promotes systems that can shift demand, since renewable sources such as wind and solar have mismatches between energy supply and demand. Additional benefits of cooling systems with integrated thermal storage include the ability to downsize the vapor compression system equipment as well as to use natural refrigerants. In particular, with the proposed system architecture, flammable or toxic refrigerants that otherwise have a very low global warming potential can be isolated to a sealed outdoor unit while a secondary fluid is used to deliver cooling indoors. The impact of integrating thermal storage in cooling systems for residential buildings could be significant, since the residential sector accounts for roughly the same amount of total utility consumption as the commercial sector (EIA, 2018).

Many researchers have studied the feasibility of ice storage systems for commercial buildings (Henze, 2003; Lo et al., 2016; Luo et al., 2017; Sanaye and Shirazi, 2013; Sun et al., 2006). These studies concluded that the operating cost of a cooling system can be significantly reduced in commercial buildings by incorporating thermal ice storage, and savings can be increased by utilizing advanced control strategies for the system that leverage variable electricity rates. However, ice storage is rarely seen in smaller scale applications such as residential buildings because of the limited utility rate incentives. Research on the use of thermal storage for residential buildings has largely focused on storage of energy from renewable sources. Researchers have investigated integrating thermal storage for domestic hot water and electricity production using photovoltaics in residential buildings (Kalogirou and Tripanagnostopoulos, 2006), as well as seasonal storage for solar thermal energy (Pinel et al., 2011; Wang and Qi, 2008). Although thermal storage is not yet common in cooling systems for residential buildings, some products are currently available to consumers.

In this paper, we assess the economic feasibility of an ice storage system for residential buildings for various currently available utility rates in different locations. Two different sizing approaches were considered in determining the economic payback period for ice storage systems. The first approach involved a conventional design day analysis where the storage and chiller were sized based on a design day analysis with the assumption that the chiller operates continuously at full capacity and storage operates between 0 and 80% of its available storage capacity. In the second approach, the chiller and storage capacities were sized based on an optimization to minimize the payback period. The optimization also included the equipment efficiency rating as an input.

In Section 2 we provide an overview of the system considered, residential utility rates, and the alternative sizing approaches. In Section 3 we describe the system and cost models used to estimate the operating and total installed costs. Results for different case studies are presented in Section 4.

2. BACKGROUND

2.1 Ice Storage System

The proposed system is a residential-sized cooling system. It consists of a packaged air conditioner (A/C), a water-glycol secondary loop, and an internal melt ice-on-pipe storage tank. The system schematic is shown in Figure 1. Points 1-4 in the dotted area represent the packaged A/C and points 5-8 represent the secondary loop. The secondary loop connects the outdoor packaged A/C to the ice storage tank and an indoor air handling unit. A three way valve at point 6 is used to control the charging and discharging rate of the storage.

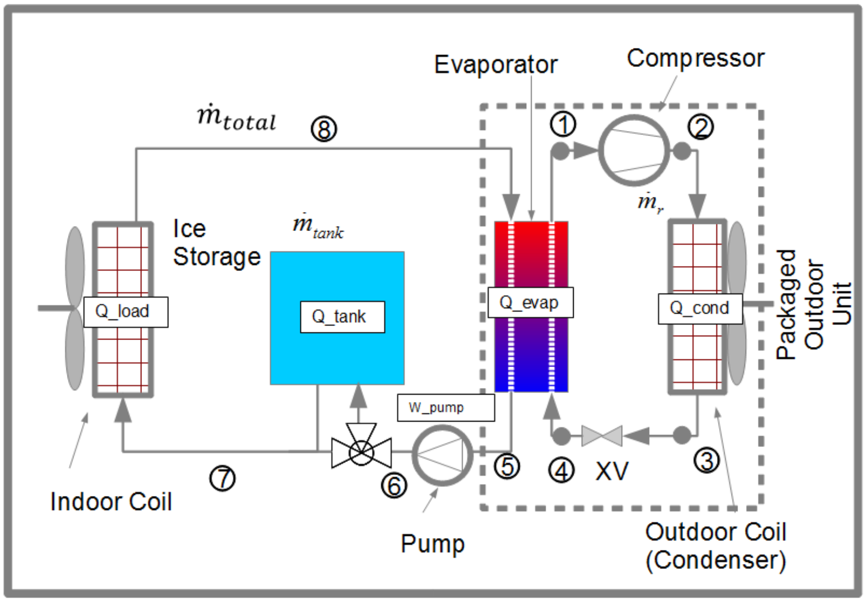

Figure 1. Schematic of the proposed cooling system with a secondary loop and ice storage.

2.2 Utility Rates in Residential Buildings

The majority of residential utility rates are flat rates in which the price is constant throughout the day but may utilize a tiered structure in which the price is based upon the total amount of energy used in the billing cycle. This type of structure does not provide an economic incentive to include storage in the cooling system because the cost of using the A/C is the same for any time of the day. While variable rates have been available to the commercial sector for quite some time, they are only recently becoming more common in the residential sector. Based on information from OpenEI.org, a utility rate database maintained by the National Renewable Energy Laboratory, there were only 25 states that had some form of variable rates for residential buildings in 2012. This number has increased significantly in recent years, and variable rates are currently available in all 50 states, and more companies are incorporating demand charges as well (NREL, 2018). We identified six different structures for residential utility rates based on combinations of energy and demand charges: 1) Flat Energy only (50 states); 2) Flat Energy with Flat demand (19: AK, AZ, CO, FL, ID, IL, IN, IA, KY, MN, ND, OH, OK, SC, SD, TX, VT, WA, WY); 3) Flat Energy with TOU demand (3: CO, FL, NC); 4) TOU Energy only (48 states); 5) TOU Energy with Flat demand (4: AL, CO, GA, SC); and 6) TOU Energy with TOU demand (4: AZ, NC, VA, WI). The most common variable rate is a *time-of-use (TOU) energy only* rate. All of these variable utility rates are optional for customers.

2.3 Approaches for System Sizing

A common practice is to size cooling systems using a design day analysis. This approach assumes that the system must be able to meet all cooling loads on the design day – the day with the highest cooling loads of the season (Hasnain, 1998; Sun et al., 2006). For cooling systems *without* storage, the system is typically sized for the highest cooling load experienced on this day. For systems *with* storage, the packaged A/C can be downsized due to the additional capacity provided by the storage. More specifically, the packaged A/C capacity can be minimized by sizing it such that it operates continuously at maximum capacity throughout the design day. Then the storage is charged if the loads are less the A/C's capacity and discharged to meet any loads greater than the A/C capacity.

However, this approach does not take into account an important design tradeoff between the size of the packaged A/C and the ice storage tank. A larger storage capacity provides more cooling during on-peak hours which can reduce the A/C output during that time, thereby leading to greater operating cost savings. However, a larger storage system also requires a larger A/C capacity that can fully charge the storage during the off-peak hours, thereby leading to a higher initial system cost. In this paper, the A/C and storage capacities as well as SEER rating are optimized to minimize simple economic payback for the ice storage system relative to a conventional split system.

3. SYSTEM MODEL

The model for the ice storage system used to determine operating costs is described in a companion paper (Tam et al., 2018). In this section, we present a model for the baseline split system against which we compare the ice storage system. We also present a cost model that is used to calculate the total installed cost of both the baseline and ice storage systems based on unit capacity and efficiency.

3.1 Baseline Split System Model

The baseline system is a conventional split system A/C. The split system was modeled using ACHP, an open source program for modeling cooling and heating equipment (Bell, 2012). The ACHP model was used to calculate system performance and capacity at different conditions and then a performance map was developed from the data using linear regression. The model presented below is based on a 3-ton system rated at 95 ˚F with a rated COP of 3. The map characterizes the effect of ambient temperature on the baseline system's cooling capacity and COP. It is normalized so that different split system sizes could be easily considered.

$$\frac{Q_{max}}{Q_{rated}} = 1.26 - \left(5.34\times10^{-3}\right)T_{amb} - \left(5.67\times10^{-5}\right)T_{amb}{}^{2} \tag{1}$$

$$\frac{COP_{actual}}{COP_{rated}} = 2.28 - (4.55\times10^{-3})T_{amb} + (2.59\times10^{-4})T_{amb}{}^{2} \tag{2}$$

The variable Q_{max} is the split system's maximum capacity in W, Q_{rated} is the split system's rated capacity in W, T_{amb} is the ambient temperature in ˚F, COP_{actual} is the split system's coefficient of performance at the specified operating conditions, and COP_{rated} is the split system's rated coefficient of performance.

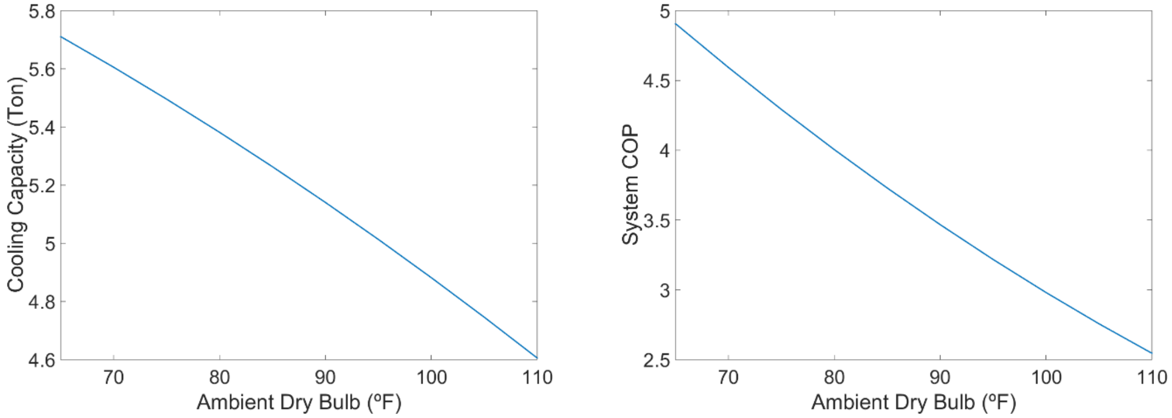

Figure 2. Capacity and COP of the modeled split system A/C at different operating conditions.

3.2 System Cost Model

An important factor in evaluating the feasibility of ice storage systems for residential applications is the total cost of the installed system as compared with the baseline system. Since the proposed system does not exist on the current market, we developed a model to estimate its cost using data from a U.S. Department of Energy (DOE) report on residential central air conditioners and heat pumps (DOE, 2016). The baseline cost is that of a split system A/C rated at 5 tons and 14 SEER. The cost for a new installation of the baseline system is shown in Table 1. Costs for an ice storage system that uses a packaged air-cooled chiller rated at 3 tons and 14 SEER with an ice storage tank of 125 gallons are also shown in Table 1. These capacities were determined through a design day analysis for Miami, FL. The cost of the proposed system is separated into that of the packaged A/C, the storage tank, the indoor air handling unit (AHU), the pump, and additional piping. The packaged unit cost was based on the DOE report (DOE, 2016). The cost of the ice storage tank was estimated using a report from the Department of the Army on the economic feasibility of thermal storage (Chang, 1995). This report provides a range of values for a given capacity of storage, and a cost of $7/gallon is common for small commercial scale storage tanks. This cost model has $9/gallon for the storage tank because cost per capacity increases as capacity decreases. Finally, the pump cost was assumed to be $80 based on products available on the market. Table 1 provides example costs for one ice storage system. The data was also used to develop a general cost model to enable design optimization for ice storage systems in terms of A/C capacity, storage capacity, and A/C efficiency that is presented in the following equations.

$$y_{proposed} = y_{chiller} + y_{storage} \tag{3}$$

$$y_{chiller} = (1.91\times10^{3}) - 41.4S_{rated} + 7.48S_{rated}^{2} + (5.89\times10^{2})Q_{rated} - 16.4Q_{rated}^{2} \tag{4}$$

$$y_{storage} = 9G \tag{5}$$

The variable $y_{proposed}$ is the proposed system's estimated cost in dollars, $y_{chiller}$ is the chiller's estimated cost in dollars, $y_{storage}$ is the ice storage's estimated cost in dollars, S_{rated} is the chiller's SEER rating at the rated conditions, Q_{rated} is the chiller's capacity at the rated conditions, and G is the ice storage capacity in gallons.

Table 1: Total installed cost comparison between proposed and baseline system

System Components	Baseline System	Ice Storage System
Split System A/C (5-ton, SEER 14)	$6175	
Packaged A/C (3-ton, SEER 14)		$4425
Ice storage tank (125 gal)		$1125
AHU and piping		$1221
Pump		$80
Total	$6175	$6851

4. ECONOMIC ASSESSMENT OF ICE STORAGE SYSTEMS

The overall economics of ice storage systems depend on the approach used for sizing, as well as the utility rates and climate. In this section, we assess the overall economics of ice storage systems for two different approaches for sizing the packaged A/C and storage. The first is a conventional approach in which the equipment capacity is minimized based on a design day analysis. For this case, the packaged A/C is assumed to have SEER rating of 14. The second approach involves the formulation and solution of an optimization problem to minimize payback period by varying both equipment and ice storage capacities, along with the SEER rating of the equipment. Payback periods for the both approaches are considered based on cooling season simulations with utility rates available in seven select U.S. cities. Table 2 summarizes the geographic locations and associated utility rate structures. For TOU energy only rates, two sample rates are included because one includes an additional mid-peak period. For TOU energy rates with flat demand, two different sample rates are selected because of significant differences in demand rates. These sample utility rates were obtained from OpenEI.org (NREL, 2018) and are provided in the Appendix.

Table 2: Sample Residential Utility Rate Structures

Location	Utility Rate Structure
Intermountain Rural Electric Association (CO)	Flat energy with flat demand
Lakeland Electric (FL-LAK)	Flat energy with TOU demand
Florida Power & Light (FL-MIA)	TOU energy with no demand
Sacramento Municipal Utility District (CA)	TOU energy with mid-peak and no demand
Alabama Power (AL)	TOU energy with flat demand
South Carolina Electric & Gas (SC)	TOU energy with flat demand
Albemarle Electric Corporation (NC)	TOU energy with TOU demand

4.1 Simple Payback with Conventional Sizing Approach

For each location associated with the sample utility rates, TMY3 weather data from the National Solar Radiation Data Base (Wilcox and Marion, 2008) were utilized, and the ice storage system was simulated over a cooling season using the model and rule-based controller described in a companion paper (Tam et al., 2018). It's important to note that the baseline system used a standard flat energy rate for each location rather than opt-in rates employed for the ice storage system. *This tends to give lower operating cost savings than if the baseline used the opt-in rates*. Nevertheless, this could be considered a more fair comparison because the baseline system is not designed to take advantage of the opt-in rates.

Operating cost savings relative to the baseline at each location are presented in normalized units of dollars per ton-hour of cooling ($/ton-h) in Figure 2. For these results, the ice storage system was sized using a conventional design day analysis, resulting in 3 tons of cooling capacity with 175 gallons of storage for California and Colorado, and 3 tons of cooling capacity with 125 gallons for Alabama, Florida, North Carolina, and South Carolina. The proposed system resulted in lower operating costs than the baseline system in only one location. This is because the proposed system operates at lower efficiencies during charging, so it uses more power than the baseline system. The utility rate incentives were not sufficient to overcome this penalty, except for the California case.

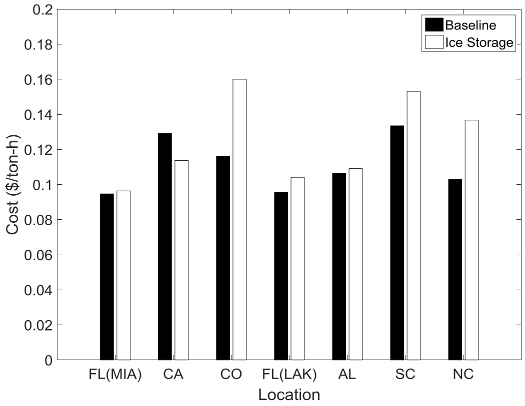

Figure 3. Operating costs for baseline and ice storage system.

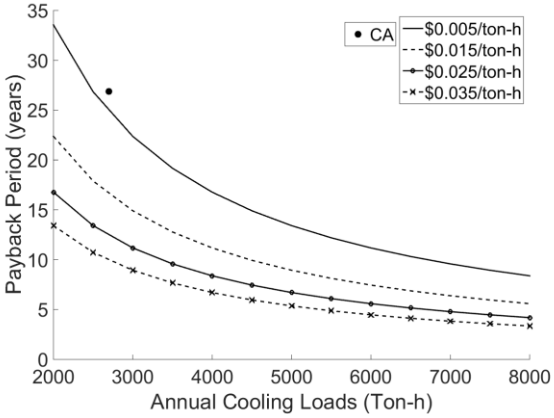

Figure 4. Estimated payback period as a function of total annual cooling load and savings.

Simple payback period is the difference in cost between the ice storage and baseline systems divided by the operating costs savings as expressed in Equation (6). For a given normalized cost savings per unit seasonal cooling ($/ton-h), the economic payback period is a strong function of the annual cooling loads. Figure 4 shows the effect of annual cooling load and normalized cost savings on the economic payback. As expected, the results show that payback period decreases with increased cooling loads and normalized operating cost savings. The latter are achieved through improved system efficiency and utility rates with greater incentives for utilization of thermal storage. The payback period result for California is superimposed on these parametric plots.

4.2 Optimal System Payback

The trade-off between installed and operating costs with changing equipment size, equipment efficiency, and storage size was evaluated by solving an optimization problem, defined as minimizing the payback period

$$J = \frac{y_{proposed}(c, G, S_{rated}) - y_{baseline}}{Q_{cooling}\, p_{savings}(c, G, S_{rated})}, \tag{6}$$

subject to the following constraints

$$2 \le c \le 5, \tag{7}$$

$$14 \le S_{rated} \le 17.5, \tag{8}$$

$$90 \le G, \tag{9}$$

$$D \le c_{storage} + c_{chiller}, \tag{10}$$

where J is the payback period in years, $Q_{cooling}$ is the total cooling load in a year for a given location in ton-hours, $y_{proposed}$ is the total installed cost of the proposed ice storage system, $y_{baseline}$ is the total installed cost of the baseline system, $p_{savings}$ is the operating cost savings for a cooling season in $/ton-h, c is the A/C capacity in tons, G is the storage capacity in gallons, S_{rated} is the SEER number of the unit, and D is the total integrated building load for the design day in tons. The baseline system is a 5-ton split A/C with a SEER rating of 14 and a total installed cost of $6175. The cost of the proposed system is a function of the unit capacity, the SEER rating, and the storage capacity. The constraints on these three variables reflect available products on the market.

The nonlinear optimization problem was solved using the function *fmincon* in MATLAB for each location. The results of the optimization solutions are shown in Table 3. With the exception of Colorado, the optimal solution results in a positive payback period for every location. The optimal solution for Colorado has a negative value for the operating cost savings, so the payback period is negative when calculated using Equation (6). The optimization resulted in systems with a much higher SEER rating, and slightly larger system capacity than the conventional sizing approach. All locations have a SEER rating of 17.5, which is the upper bound of that decision variable. This is because the proposed system experiences a decrease in efficiency when making ice (due to the need for a lower refrigeration temperature in the evaporator), so a more efficient A/C is required to yield operating cost savings. When compared to conventionally sized systems, the optimal A/C capacity is increased from 3 to 3.5 tons for California, while for the remaining locations, the optimal A/C capacity is increased from 3 to 3.2 tons. Compared to the conventional approach, the storage capacity decreased for California, Florida (Lakeland), and South Carolina, and increased slightly for Florida (Miami), Alabama, and North Carolina. The optimal storage capacity is different than that of the conventional sizing approach because of the climate and utility rate structures. In the conventional approach, storage is sized to minimize the A/C capacity. However, if the storage is only used during the on-peak hours of the day, then it only needs to meet the integrated loads during the on-peak hours. For utility rates with a shorter on-peak period, the storage size from the conventional approach can become oversized, and any additional capacity will not yield more operating cost savings. Similarly, if the on-peak hours are longer, the conventional sized storage will experience more loads than the design day, and increasing the storage capacity can yield more operating cost savings. For a given geographic location, the optimal A/C and storage capacities are dependent on the climate and variable utility rates available.

Table 3. Optimal system sizing results

Location	A/C Capacity (ton)	SEER	Storage Capacity (gal)	Simple Payback (years)
Florida (Miami)	3.2	17.5	130	12
California	3.5	17.5	170	19
Florida (Lakeland)	3.2	17.5	90	19
Alabama	3.2	17.5	130	26
South Carolina	3.2	17.5	90	28
North Carolina	3.2	17.5	130	117

In order to evaluate the sensitivity of payback period to each design variable, we conducted additional simulations in which we varied the storage and A/C capacity at different SEER ratings. Sample results for Florida (Miami) are shown in Figures 4 and 5. Figure 4 shows the simple payback of a 3.2 ton A/C system with varying capacity for storage at different SEER ratings. The storage capacity from the design day approach is 120 gallons, which leads to a slightly longer simple payback than the minimum of 130 gallons. When the SEER rating is greater than 16, additional storage capacity over 130 gallons leads to an increase of simple payback, because additional storage increases the initial cost. Moreover, the sensitivity of payback period to storage capacity increases at smaller storage, especially with lower SEER ratings. Figure 5 shows the simple payback of a 130 gallon storage with varying capacity for the A/C at different SEER ratings. The minimum A/C capacity for this location is determined to be 3 tons from the design day approach, which yields a very similar simple payback period to the optimized size of 3.2 tons. The results show that the simple payback does not change significantly until the A/C capacity is greater than 3.2 tons, and any additional A/C capacity will then increase the simple payback.

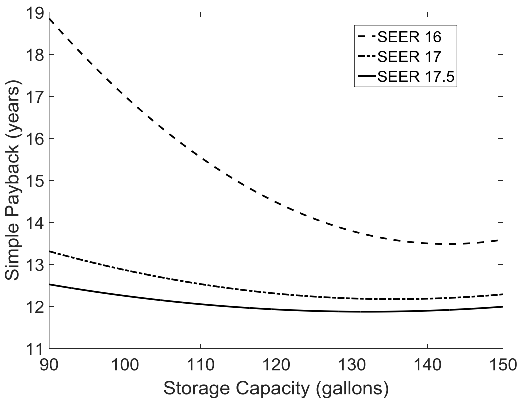

Figure 5. Simple payback for a 3.2 ton A/C system with varying storage capacity and SEER rating.

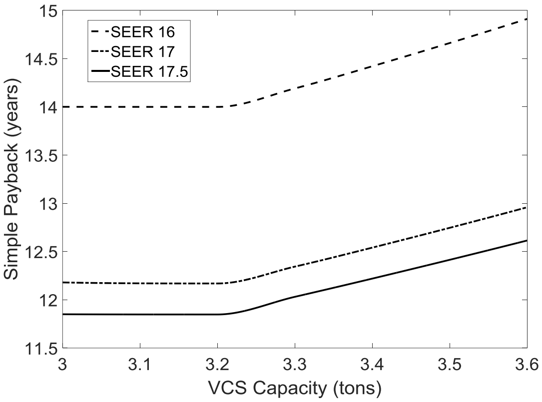

Figure 6. Simple payback for 130 gallons storage capacity with varying A/C capacity and SEER rating.

The payback period is very sensitive to SEER rating when the SEER rating is below 17. An increase in SEER rating from 16 to 17 leads to a significant decrease in simple payback. However, the decrease in simple payback is much smaller when increasing the SEER rating from 17 to 17.5. Based on this behavior, it appears that the system is approaching an optimal SEER rating, and any further increase in the SEER rating at that point will not decrease the simple payback.

5. CONCLUSIONS

In this paper, we assessed the overall economics of a packaged A/C integrated with ice storage for residential buildings. We compared this proposed system with a conventional split system in terms of operating costs and initial equipment costs. We formulated an optimization problem to evaluate the tradeoffs between the capacity and efficiency of the packaged A/C as well as the storage tank size. The optimization results showed that the optimal A/C and storage capacities are dependent on the combination of climate and variable utility rates for a given geographic location. While the combined cooling capacity must be able to meet the design day loads, the utility rate structure will determine the portion of loads met by the storage. More importantly, the results showed that a more efficient A/C can significantly reduce the economic payback period for both conventionally and optimally-sized systems.

NOMENCLATURE

c	Capacity	(ton)
COP	Coefficient of performance	(-)
D	Design day loads	(ton)
DOE	Department of Energy	(-)
J	Payback	(years)
G	Storage capacity	(gallons)
P	Cost savings	(\$/ton-h)
Q	Heat transfer	(ton-h)
S	Seasonal energy efficiency ratio	(BTU/Wh)
TOU	Time-of-use	(-)
y	Cost	(\$)

Subscript

AHU	Air handling unit
p	Packaged A/C
rated	At rating conditions
storage	Thermal storage

REFERENCES

Bell, I.H., 2012. ACHP Documentation. 1.4 [WWW Document]. URL http://achp.sourceforge.net/index.html.

Chang, W.S., 1995. FEASIBILITY STUDY OF A STORAGE COOLING SYSTEM FOR CENTRAL ENERGY PLANT. Department of The Army.

DOE, 2016. TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS: Residential Central Air Conditioners and Heat Pumps.

EIA, 2018. U.S. Energy Information [WWW Document]. URL https://www.eia.gov/

Hasnain, S.M., 1998. Review on sustainable thermal energy storage technologies, Part II: cool thermal storage. Energy Convers. Manag. 39, 1139–1153.

Henze, G.P., 2003. Parametric Study of a Simplified Ice Storage Model Operating Under Conventional and Optimal Control Strategies. J. Sol. Energy Eng. 125, 2. https://doi.org/10.1115/1.1530629

Kalogirou, S.A., Tripanagnostopoulos, Y., 2006. Hybrid PV/T solar systems for domestic hot water and electricity production. Energy Convers. Manag. 47, 3368–3382. https://doi.org/10.1016/j.enconman.2006.01.012

Lo, C.-C., Tsai, S.-H., Lin, B.-S., 2016. Ice Storage Air-Conditioning System Simulation with Dynamic Electricity Pricing: A Demand Response Study. Energies 9, 113. https://doi.org/10.3390/en9020113

Luo, N., Hong, T., Li, H., Jia, R., Weng, W., 2017. Data analytics and optimization of an ice-based energy storage system for commercial buildings. Appl. Energy 204, 459–475.

NREL, 2018. U.S. Utility Rate Database [WWW Document]. URL https://openei.org/apps/USURDB/
Pinel, P., Cruickshank, C.A., Beausoleil-Morrison, I., Wills, A., 2011. A review of available methods for seasonal storage of solar thermal energy in residential applications. Renew. Sustain. Energy Rev. 15, 3341–3359. https://doi.org/10.1016/j.rser.2011.04.013
Sanaye, S., Shirazi, A., 2013. Thermo-economic optimization of an ice thermal energy storage system for air-conditioning applications. Energy Build. 60, 100–109. https://doi.org/10.1016/j.enbuild.2012.12.040
Sun, C., Temple, K., Rossi, T., Braun, J.E., 2006. Interaction between dynamic electric rates and thermal energy storage control, Final Report for RP-1252.
Tam, A., Braun, J.E., Jain, N., Ziviani, D., 2018. A Generalized Rule-Based Control Strategy for Thermal Energy Storage in Residential Buildings. Presented at the The International High Performance Buildings Conference.
Wang, H., Qi, C., 2008. Performance study of underground thermal storage in a solar-ground coupled heat pump system for residential buildings. Energy Build. 40, 1278–1286. https://doi.org/10.1016/j.enbuild.2007.11.009
Wilcox, S., Marion, W., 2008. Users Manual for TMY3 Data Sets (Revised). National Renewable Energy Lab.(NREL), Golden, CO (United States).

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APPENDIX

Sample residential utility rates

<table>
<tr><td colspan="7">Flat energy with flat demand</td><td>Flat energy ($/kWh)</td></tr>
<tr><td></td><td colspan="3">Energy ($/kWh)</td><td colspan="3">Demand ($/kW)</td><td></td></tr>
<tr><td>Intermountain Rural Electric Association (CO)</td><td colspan="3">0.066</td><td colspan="3">14</td><td>0.123</td></tr>
<tr><td colspan="7">Flat energy with TOU demand</td><td>Flat energy ($/kWh)</td></tr>
<tr><td></td><td colspan="2">Energy ($/kWh)</td><td colspan="2">On-peak demand ($/kW)</td><td colspan="2">Off-peak demand ($/kW)</td><td></td></tr>
<tr><td>Lakeland Electric (FL-LAK)</td><td colspan="2">0.057</td><td colspan="2">5.6 (2-8pm) (30-min)</td><td colspan="2">0</td><td>0.100 (<500 kWh)
0.105 (>500 kWh &<1500 kWh)
0.111 (>1500 kWh)</td></tr>
<tr><td colspan="7">TOU energy only</td><td>Flat energy ($/kWh)</td></tr>
<tr><td></td><td colspan="2">On-peak energy ($/kWh)</td><td colspan="2">Mid peak energy ($/kWh)</td><td colspan="2">Off-peak energy ($/kWh)</td><td></td></tr>
<tr><td>Florida Power & Light (FL-MIA)</td><td colspan="2">0.184 (>1000 kWh)
0.204 (<1000 kWh)
(12-8pm)</td><td colspan="2">n/a</td><td colspan="2">0.035 (>1000 kWh)
0.055 (<1000 kWh)</td><td>0.088 (>1000 kWh)
0.109 (<1000 kWh)</td></tr>
<tr><td>Sacramento Municipal Utility District (CA)</td><td colspan="2">0.316
(4-7pm)</td><td colspan="2">0.149
(9am-4pm & 7-9pm)</td><td colspan="2">0.087</td><td>0.131</td></tr>
<tr><td colspan="7">TOU energy with flat demand</td><td>Flat energy ($/kWh)</td></tr>
<tr><td></td><td colspan="2">On-peak energy ($/kWh)</td><td colspan="2">Off-peak energy ($/kWh)</td><td colspan="2">Demand ($/kW)</td><td></td></tr>
<tr><td>Alabama Power</td><td colspan="2">0.222
(1-6pm)</td><td colspan="2">0.072</td><td colspan="2">1.5</td><td>0.105 (<750 kWh)
0.120 (>750 kWh)</td></tr>
<tr><td>South Carolina Electric & Gas</td><td colspan="2">0.096
(2-6pm)</td><td colspan="2">0.085</td><td colspan="2">12.04</td><td>0.132 (<800 kWh)
0.151 (>800 kWh)</td></tr>
<tr><td colspan="7">TOU energy with TOU demand</td><td>Flat energy ($/kWh)</td></tr>
<tr><td></td><td>On-peak energy ($/kWh)</td><td colspan="2">Off-peak energy ($/kWh)</td><td colspan="2">On-peak demand ($/kW)</td><td>Off-peak demand ($/kW)</td><td></td></tr>
<tr><td>Albemarle Electric Corporation (NC)</td><td>0.069
(2-7pm)</td><td colspan="2">0.055</td><td colspan="2">13.5</td><td>2.25</td><td>0.114</td></tr>
</table>