

Potential Factors Influencing Student Rental Housing Participation in Demand-Side Management Strategies

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ABSTRACT

Buildings are responsible for the largest portion of energy consumption on U.S. electric grids. The wide participation of buildings in demand side management (DSM) through modulating or shifting electricity end uses, particularly in homes, can support decarbonization goals and increase reliability of electric power supply. The awareness and willingness of households to adjust internal loads, housing occupancy, and household energy consumption patterns all play an important role to support the potential for DSM. A particularly challenging type of housing to reach in DSM is rental housing. Historically this type of housing has been plagued by split incentives that limit the motivation of home owners (landlords) to improve the energy performance of these buildings since they often do not pay the utility bills. DSM presents an opportunity to support reducing the utility bills of renters through controls adjustments rather than requiring the landlord to invest in energy efficient technologies. This study aims to identify household occupancy schedules and potential factors that may influence willingness to participate in DSM among renters, in particular college students. A survey-based method was conducted among 55 college students majoring in civil, environmental, and applied engineering and showed that, while the targeted population has low awareness about DSM strategies, they would be willing to participate in a DSM in the future. The factors that appear to drive willingness to participate in DSM for this population were related to the potential reduction of electricity costs and energy savings.

KEYWORDS

Demand-side management; Occupancy; Survey

INTRODUCTION

Buildings play a significant role as the largest consumers of energy on the electricity grid, accounting for approximately 70% of total energy consumption. Among the building sectors, residential buildings account for about 35% of the total energy consumption of the electricity grid (U.S. EIA, 2021). As major energy consumers connected to the electric grid, the active participation of buildings in demand-side management (DSM) is capable of supporting decarbonization of electric power and the use of power generated from clean energy resources (Koul et al. 2021). Demand-side management includes a range of possible strategies to help to

optimize energy consumption by effectively shifting or adjusting the timing of energy-consuming systems within a building (Smith et al, 2016). Several electric utility companies offer DSM or demand response (DR) programs. These programs are designed to encourage consumers to modify their level and pattern of electricity usage, which can be a mechanism to support balancing available electricity supply with grid loads, particularly under peak demand scenarios (Wijaya et. al, 2013). This limits the use of carbon-intensive power plants (e.g. diesel generators) by prioritizing energy demand when more renewable resources are available, and limiting demand when the lower-carbon intensive energy generation is already at maximum generation capacity.

Participation in DSM can be influenced by different factors, including occupancy patterns, electricity-consuming end-use loads, and preferences of households with different socioeconomic characteristics. As examples of prior research in this area, a survey including building characteristics, occupants' behavior, and socio-demographic questions was conducted in Athens. Results showed that energy behavior is complex and is strongly associated with socio-demographic characteristics. The authors also found that the socio-demographic profile of occupants, such as gender, age, educational level, number of members per household, and income, were correlated with energy use patterns and potential for savings through DSM (Vogiatzi et. al, 2018). Another survey-based study was performed in Turkey and demonstrated that there is a large potential to save energy in homes via behavioral change, but that homeowners need more information on how they can improve energy consumption. Results from the survey also revealed that despite of households consume a significant amount of electricity during peak periods, they would be willing to change their habits and reduce their use at peak time (Tumbaz et. al, 2018).

There are several challenges and barriers that can affect DSM participation, such as differences among household patterns, rental housing, and lack of knowledge or awareness of these programs. A study performed in Australia showed that households with children experienced the afternoon and early evening of weekdays the busiest periods in the household. This "family peak" coincided with the "peak demand" periods on the electric grid. In addition, survey respondents reported limited flexibility in terms of shifting their weekday routines outside of the peak period (Nicholls et. al, 2015).

Aside from recognizing that household occupancy and energy use patterns can influence DSM participation, rental housing and the tenants that inhabit these housing units presents particular challenges unique to this housing scenario. In rental housing, tenants may either indirectly pay for their utility costs through their rent, where the costs are included, or directly pay for their utility bills. In the U.S. the second scenario is more common. When renters are not responsible for paying their own electricity bills, there can be a lack of interest towards load flexibility. When renters do pay their utility bills there is likely interest in reducing these bills, however since renters have a limited ability to change anything in the housing unit itself because they do not own it, this has historically limited this type of housing's participation in DSM, and in particular energy efficiency upgrades. Utilities companies have been developing efforts to reduce demand in the grid, especially during peak-load periods, through initiatives such as demand-side management programs (Carliner, 2013). However, there is only a limited number of utility companies that offer DSM or DR programs for renters. Additionally, in some cases tenants need permission from landlords or property owners to participate in these specific programs (Consumers Energy – Smart Thermostat Program).

The lack of knowledge and awareness from consumers, among other possible barriers, all limit potential DSM participation. In addition, a lack of information on renters' energy use makes it more difficult to accurately assess the benefits of energy conservation programs at the utility level (Macedo et. al, 2015). Lack of awareness of the population about DSM was also a barrier

reported in a study in India. Uncertainty about the efficiency of technologies of DSM and lack of trust were the main barriers reported by the authors (Harish et. al, 2014). In order to understand and investigate the awareness and willingness of renter populations in the U.S., in particular college students, in adjusting internal loads, this study aims to identify household occupancy schedules and potential factors that may influence willingness to participate in DSM.

METHODOLOGY

A survey-based methodology was chosen for this study. The survey was developed using Qualtrics, a web-based survey tool that allows the development of survey research and other types of data collection (Qualtrics, 2020). An online survey with multiple choice, side by side, text entry and matrix table type of questions was developed, and an anonymous link was provided such that participants could access the survey. Participants were asked to answer approximately 50 questions with an approximate completion time of 20 minutes. Questions were divided into three main sections in an effort to understand household occupancy schedules, familiarity and willingness to participate in DSM, and demographic factors. Figure 1 illustrates the structure of the survey.

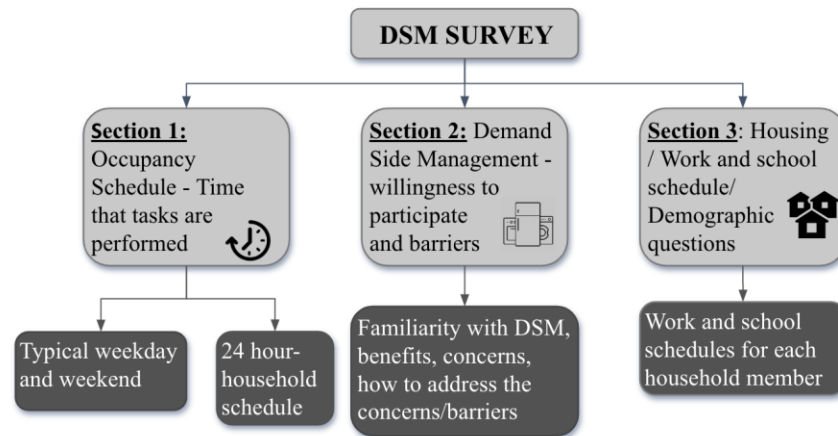


Figure 1. Demand-side management survey structure

In order to understand potential differences in times that energy consuming tasks are performed and when household members were/were not present, occupancy schedules were measured for both weekdays and weekends. The online survey was sent to students of selected courses with students majoring in civil, environmental, and applied engineering at Michigan State University.

The survey remained open for approximately 20 days and was carried out during the month of March 2023. A total of 55 students responded to the survey. A similar number of female and male students participated, and 98% were between 18 and 24 years old. In addition, 85% of respondents stated they rent their place of residence and only 17% reported having their utility bills included in their rent. Nearly 58% live in a detached type of house (e.g. single family home) or apartment with 5 units or more, and 49% of participants live with 4 people or more – most of them with roommates or friends.

The data collected from Qualtrics was exported to a CSV file format and analyzed using Excel. For questions that allowed for the selection of multiple options, the percentages were adjusted to reflect the total number of participants. The results section includes the findings related to occupancy schedules at the household level and demand-side management perceptions.

RESULTS

Household occupancy schedules. Occupancy schedules were first determined by asking participants when their home was unoccupied during weekdays and weekends. Table 1 presents the percentage of unoccupied households for each portion of the day throughout the week. The bolded values in Table 1 represents the times of the day when the home was most unoccupied. On weekdays, the afternoon was the period when most households were not present in their home, followed by the morning. This is likely related to their schedules as college students, where they attend classes in person during these periods. On weekends, Saturday late afternoon and night were when these homes was most unoccupied. This can be attributed to the demographic characteristics of the surveyed population, which primarily consists of younger students who likely prefer to be doing activities outside their home on the weekend. In addition, nearly 30% of the participants reported spending a least of 20 hours per week outside their homes due to work or school activities. Weekends are also the period of time when the home is occupied most part of the day.

Table 1. Period of time that homes are unoccupied during weekdays and weekends

	Early morning	Morning	Afternoon	Late afternoon	Evening	Always occupied
Monday	9.3%	37%	51.8%	16.7%	5.5%	29.6%
Tuesday	12.9%	37%	48.1%	22.2%	3.7%	33.3%
Wednesday	11.1%	38.9%	51.8%	24%	11.1%	31.5%
Thursday	11.1%	37%	48.1%	25.9%	7.4%	33.3%
Friday	7.4%	29.6%	37%	14.8%	9.3%	44.4%
Saturday	7.5%	3.7%	9.4%	24.5%	43.4%	45.3%
Sunday	9.4%	7.5%	9.4%	20.7%	16.9%	60.4%

Participants were also asked to state the time they perform various energy-consuming tasks throughout the day on weekdays and weekends. In order to understand energy usage patterns, the following household-level tasks were considered: sleeping, personal hygiene, cooking, running the dishwasher, running the washer and dryer, and using the television and computer. Figure 2 and 3 show the results of these questions for weekdays and weekends, respectively.

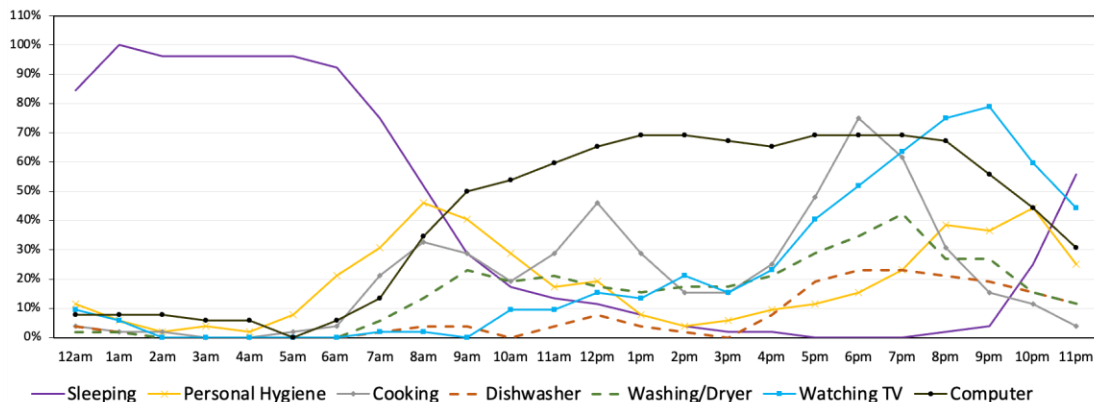


Figure 2. Time that different tasks are performed throughout the day on weekdays

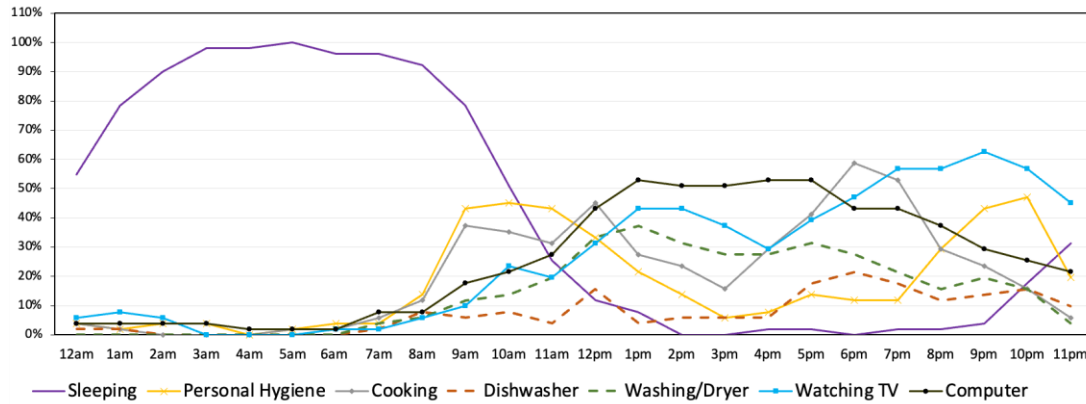


Figure 3. Time that different tasks are performed throughout the day on weekends

There is a small difference in when some of the tasks are performed between weekdays and weekends. In the morning, it is possible to observe that during weekends the time of performing tasks starts slightly later compared to the weekdays. In addition, nearly 57% and 48% of participants reported running dishwasher and washer and dryer between 4pm to 10pm during the weekdays, which is usually the periods of time when there are higher demands on the electric grid. While on weekends, considering this same period of 6 hours, there was a 14% and 8% decrease in households that reported running the dishwasher and washer and dryer, respectively, as compared to weekdays. It was observed that during the weekends the energy-consuming tasks were more distributed throughout the day, with most of them more prevalently completed in the afternoon and evening.

Considering that the energy usage patterns were investigated in a household level and schedules might not always be consistent among all household members, participants were asked to rate the consistency of their schedule. On a scale of 0 to 10, where 0 is “not consistent” and 10 is “extremely consistent”, 5 being “somewhat consistent”, approximately 54% of respondents consider their schedule to be at least somewhat consistent during the weekends. During the weekdays schedules were reportedly more consistent, with 74% of respondents considering their household’s schedules to be at least somewhat consistent, representing an increase of 20%. This is expected since people likely have more consistent schedules during the weekdays due work and school activities.

Further, participants were asked if they would be willing to adjust the time that energy-dependent tasks are completed in their home. Four statement options were given: “must be completed at stated times”, could be completed at other times, but original time is preferred”, “can be performed at any time of the day”, and “not applicable/task not performed”. Results for weekdays are plotted in Figure 4 (a) and for weekends in Figure 4 (b).

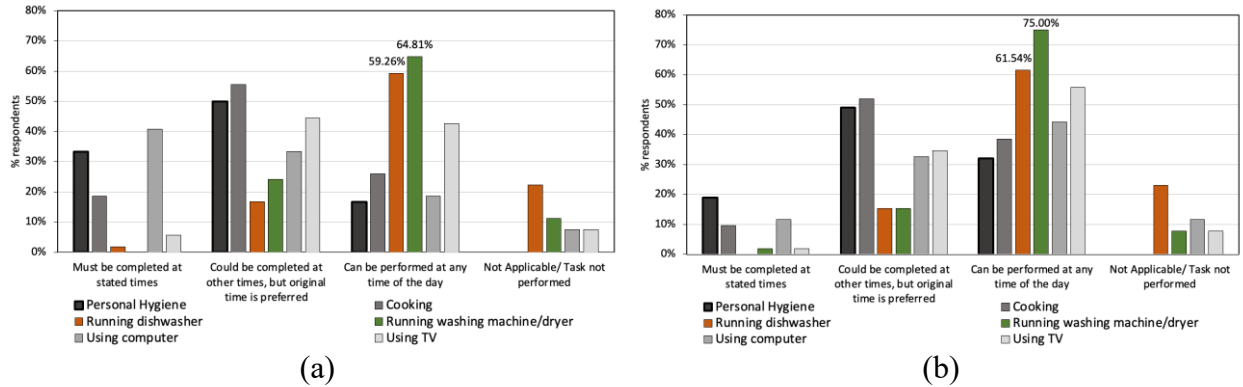


Figure 4 (a) Willingness to change the time energy-consuming tasks are performed during weekdays and (b) during the weekends

It can be seen in these plots that tasks, such as personal hygiene, cooking, and computer usage are preferred to be performed at their original times, which is expected. This preference is observed for both weekdays and weekends, with slightly greater flexibility during weekends. Running the dishwasher, washer and dryer are the tasks with more flexibility reported by the participants. Regarding weekdays, at least 60% of participants stated they could perform these tasks (dishwasher, washer/dryer use) at any other time of the day. This flexibility is increased during the weekends, where 75% of respondents reported to be willing to adjust operating hours of the washers and dryers. As for the use of television, participants expressed different opinions, with some willing to adjust and others preferring the maintain the use at their original time. Overall, the tasks that are usually performed once a day or are not performed daily, such as running a dishwasher, washer and dryer are those that have the greatest flexibility to be completed at other times of the day, which could help to support DSM.

The peak times, when the demand for electricity is high, typically occur during weekday afternoons throughout the summer. The occupancy schedules shown in Figure 2 as well as the willingness to change the time that tasks are performed (Figure 4a) reveal that there is an opportunity for this specific target population to participate in DSM. Pearson's correlation analysis was performed to check for any correlation between participants' demographics and characteristics, and their willingness to change the time they run the dishwasher and washer/dryer machine (the two appliances where there is the highest willingness to adjust). For this analysis, hours away from home, relationship with other people living in the house, number of adults, age, gender, and housing tenure were analyzed. Tables 2 and 3 present the results.

These results show that there seems to be a stronger correlation between the willingness to change the time to run the dishwasher and the hours people are away from home when compared to the other variables. A similar trend is observed when analyzing the willingness to change the time to run washer/dryer machine and the hours away from home. Since it is a negative correlation, it suggests that, as the number of hours a person spends away from home increases, the willingness to change the time to run the dishwasher or the washer/dryer in the home tends to decrease. This may, in part due to the more limited time the person has to use these appliances if they are home less. More research could help understand this relationship further.

Table 2 – Correlation between demographics and willingness to change dishwasher run time

	<i>Hours away from home</i>	<i>Relation</i>	<i># Adults</i>	<i>Age</i>	<i>Gender</i>	<i>Tenure</i>	<i>Dishwasher</i>
Hours away from home	1						
Relation	-0.1922	1					
# Adults	0.0893	-0.3590	1				
Age	0.0825	0.2550	-0.1858	1			
Gender	0.0809	0.0165	-0.1227	0.1232	1		
				-			
Tenure	-0.3425	0.2743	-0.1289	0.3873	-0.0723	1	
				-			
Dishwasher	-0.3136	0.0392	0.1058	0.0089	-0.0720	0.1203	1

Table 3 - Correlation between demographics and willingness to change washer/dryer run time

	<i>Hours away from home</i>	<i>Relation</i>	<i># Adults</i>	<i>Age</i>	<i>Gender</i>	<i>Tenure</i>	<i>Washer/ Dryer</i>
Hours away from home	1						
Relation	-0.1922	1					
Adults	0.0893	-0.3590	1				
Age	0.0825	0.2550	-0.1858	1			
Gender	0.0809	0.0165	-0.1227	0.1232	1		
Tenure	-0.3425	0.2743	-0.1289	-0.3873	-0.0723	1	
Washer/dryer	-0.1614	0.0533	0.0418	0.0346	-0.0014	0.0192	1

In order to understand how participants use their heating and cooling systems, they were asked the average temperature they set on their thermostats during summer and winter months. Surprisingly, the average temperature they set on the thermostats was very similar during the winter and summer months. Nearly 75% of participants reported an average temperature setpoint that ranges from 66°F to 70°F throughout the year. In addition, this group of participants indicated they were willing to adjust their thermostats several degrees (while keeping the home comfortable) to reduce electricity bills and the high demand of electricity at specific time periods.

Demand-side management perceptions. Demand-side management familiarity was first investigated. A brief explanation of DSM and DR strategies was provided to respondents while taking the survey to ensure that they were not misled by the nomenclature. This can be attributed to the fact that many DSM/DR utility programs have specific titles, which can sometimes lead to confusion among individuals due to the nomenclature. Approximately 78% of respondents reported little or no familiarity with DSM, as well as 98% reported never having participated in any DSM programs. When participants were asked why they were not participating or had never enrolled in any DSM programs, lack of awareness was the top response followed by being in a

rental housing unit. 85% of participants stated they rent their living place, however 17% have their utility bills included in their rent, while the remainder pay their utility bills separately.

Rental housing can be a challenge to increase DSM participation. However, the lack of awareness and knowledge about these programs appears to be the main reason why survey respondents never enrolled in DSM/DR programs. When asked about their interest in participating in the future, 30% of the respondents reported no interest. This could be correlated with the split belief among respondents as to the benefits of participating in DSM programs. 55% of respondents believe that there are benefits, while 45% were unsure. In addition, the limited interest of DSM participation may also be correlated with the half of participants were unsure about concerns they might have about DSM. When asked to rate their concerns regarding various factors that could affect their interest in participating, the participants indicated that “being unaware of programs/incentives”, followed by “worried about schedule control” were of most concern. Other factors, such as “privacy concerns”, “costs”, and “lack of available programs in the region”, were also observed but to a lesser extent. In order to better understand what could contribute to address these concerns, participants were given several options, the results of which are in Figure 5.

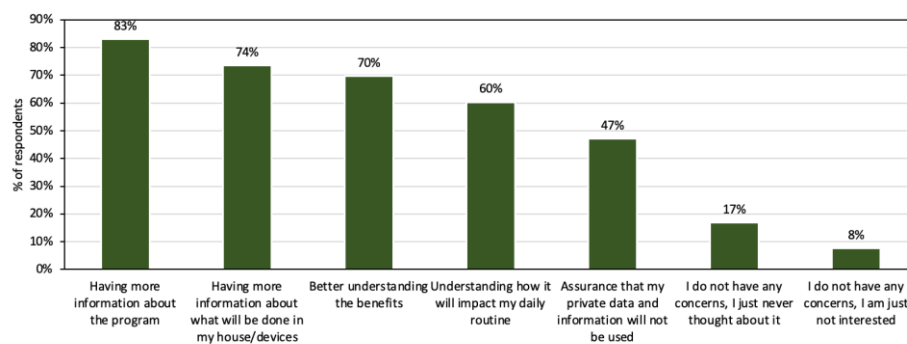


Figure 5. Actions to help to address concerns regarding DSM

Results show that having more information about the programs and impacts from participation would help to address concerns people might have. In addition, a better understanding of the benefits associated with participation in DSM and how it affects daily routines at the household level can help to overcome these issues. Figure 6 shows the different benefits and how each could encourage DSM participation.

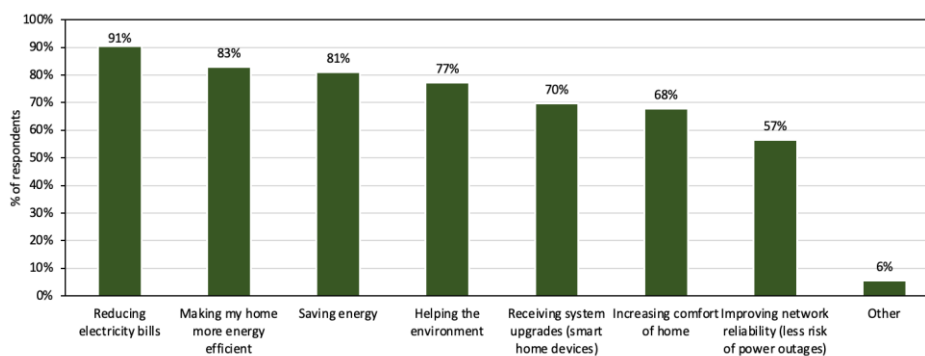


Figure 6. Benefits that could encourage DSM participation

There is a fairly consistent number of participants who reported almost every benefit as being a way of encouraging them to participate. Reducing electricity bills was the top benefit, with

91% respondents reporting that this could encourage them to participate in DSM. The alternative, “making my home more energy efficient” was the second highest rated benefit followed by “saving energy”. As mentioned, DSM/DR are strategies support optimizing energy use in the homes by enabling the adjustment of time that tasks are performed to align with electric grid needs. This means that the electricity consumption over time may be similar for each home whether or not they participated in a DSM/DR program, but the time when systems consume this energy may be adjusted. If the program in which a household participates includes a rate structure that varies by time of day (often called “time-of-use” or TOU), there is a reduction in consumers' electricity bills associated with differentiated tariffs for consumption at “off” and “on” peak hours. Overall, these results show that there are some misconceptions about people's perception of the DSM/DR and reinforce that the lack of knowledge reported above can be a barrier to broad participation in the DSM. This also suggests that more broad education of DSM/DR programs is needed to support increased participation.

CONCLUSIONS

Flexibility in energy consumption and adjusting internal loads through DSM strategies can bring benefits for both consumers and the electric grid. By embracing these practices, consumers can enjoy a range of advantages while contributing to the stability and efficiency of the grid. In order understand the willingness and awareness of the target population, as well as the challenges associated with rental housing and occupancy schedules, a survey was conducted among 55 students to assess their perceptions about DSM. The following conclusions could be made based on the results:

- Occupancy schedules may differ based on weekdays and weekends. The afternoon, followed by the morning are the periods when most housing units were unoccupied. Saturday night and late afternoon was when the home was most unoccupied during weekends.
- There is a slightly difference in when some of the energy consuming tasks are performed during weekdays and weekends. During the weekends the distribution of tasks was more spread out throughout the day, with most of them being initiated in the early afternoon.
- Nearly of 57% and 48% of participants reported running dishwasher and the washer and dryer between 4pm to 10pm during the weekdays, which is usually when peak electric grid loads occur.
- Occupancy schedules and time that tasks are performed tend to be more consistent on weekdays compared to weekends. 20% more of participants reported consistency in their schedules during the weekdays.
- Running the dishwasher, and the washer/dryer are the tasks with more flexibility reported by the participants.
- Approximately 78% of respondents reported little or no familiarity with DSM, as well as 98% reported never having participated in any DSM programs. 55% of respondents believe that there are benefits in participating in DSM programs, while 45% are unsure about it. More than half of participants were unsure about concerns they might have about how DSM works.
- Having more information about the programs and about what will be done in the home would likely help to address concerns people might have. A better understanding of the benefits associated with participation in DSM and how it will affect daily routines at the household level can also help to overcome these issues.

- The primary benefit that could motivate students to participate in DSM is the reduction of electricity bills. This is followed by the desire to make their homes more efficient and to save energy.

The results presented in this paper are only preliminary. Studies with a larger sample and other targeted populations, such as underserved, lower-income urban, rural, and remote populations across the U.S are ongoing to better evaluate the potential DSM participation of diverse residential buildings.

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