**Energy Conservation Behavior**

What follows is an annotated bibliography on the literature collected in Panagiota and Seng’s literature folder from the NSF S&CC proposal dropbox. I’ve organized it as a table of contents with a brief description and APA in-text citation, followed by a more in-depth description of each folder and article with APA references. This doesn’t represent every study in the folder, but the ones that stood out as most useful towards our research questions. As such, these appeared to be the most relevant towards understanding the gap between observed knowledge and behaviors, and optimal energy consumption.

**Brief Overviews**

**Decision making and building energy use**

Anderson & Lee (2016). Modelling study on the impact of three different interventions on energy consumption, including normative feedback interventions.

Chen, J., Taylor, J. E., & Wei, H. H. (2012). Modelling study on the energy consumption impact of different social network distributions.

Froehlich, J., Findlater, L., & Landay, J. (2010). Meta-analysis which discusses the impact of various psychological mechanisms like norms, commitment, and various levels of feedback impact individuals’ use of eco-technology.

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). A discussion of psychological mechanisms that make individuals act against their expressed desires and against their best financial interest in the context of energy consumption. Includes policy/application recommendations.

Wilson, C., & Dowlatabadi, H. (2007). An article overviewing how different psychological traditions have approached conceptualizing decision making.

**Behavior impact on energy consumption**

Barthelmes, V. M., Becchio, C., & Corgnati, S. P. (2016). This study modelled how high, medium, and low consumption users would impact energy consumption in a sustainable house.

Brenner, B. (2013). This is a pop-sci article talking about how households tend to use the most energy.

Ehrhardt-Martinez, K. (2015). A study looking at potential energy savings for cities (20-30%) based on residential behavior changes.

Ehrhardt-Martinez, K. E. (2014). An example report from Ehrhardt-Martinez (2015) specifically for Baltimore.

Sadeghi, S. A., Karava, P., Konstantzos, I., & Tzempelikos, A. (2016). This is a study Panagiota was second author on, which looked at how different controls related to lighting (e.g. electric shades vs. overhead lighting).

Todd, A., Stuart, E., Goldman, C., & Schiller, S. (2012). A report by the State and Local Energy Efficiency Action Network on what methodologies and measurements are appropriate for studies on energy savings.

**Community goals research**

Rathnayaka, A. J. D., Potdar, V. M., Dillon, T., Hussain, O., & Kuruppu, S. (2014). This article created a framework for balancing and coordinating energy consumption goals amongst consumers who are conservation-minded and generate their own energy.

**Ontology research**

Hong, D’Oca, Taylor-Lange, Turner, Chen, & Corgnati, (2015). This article was a review of literature aiming to describe the factors influencing occupant driven energy consumption.

Mahdavi, A., & Taheri, M. (2016). This article lays out suggestions for how best to collect and analyze energy consumption, with a focus on environmental factors of importance, such as inhabitants, indoor environment conditions, external environment conditions, control devices, equipment, and energy flows.

**Research on feedback mechanisms**

Anderson, K., Song, K., Lee, S. H., Krupka, E., Lee, H., & Park, M. (2017). Two year long longitudinal studies of dormitory energy use and the impact of normative feedback.

Asensio, O. I., & Delmas, M. A. (2016). A study on 118 houses over 9 months, comparing financial, health, and environmental feedback.

Ayres, I., Raseman, S., & Shih, A. (2013). A study on how peer comparisons provided with energy bills either monthly or quarterly impacted individuals’ energy consumption over the course of a year.

Ehrhardt-Martinez, K., Laitner, J. A., & Donnelly, K. A. (2011). A 5-chapter report by Dr. Ehrhardt-Martinez, looking at common sources of energy consumption and breakdowns of those sources.

Iyer, M., Kempton, W., & Payne, C. (2006). An observational study on various comparison group references for analyzing energy consumption bills and their impact on behavior.

Karlin, B., Zinger, J. F., & Ford, R. (2015). A meta-analysis on energy consumption feedback and proenvironmental behavior. Found that, while most studies were significant, they varied in their effect size.

Jain, R. K., Gulbinas, R., Taylor, J. E., & Culligan, P. J. (2013). A 47-day study which surveyed the social network of a NYC apartment building, comparing the network to energy consumption.

Grossberg, F., Wolfson, M., Mazur-stommen, S., Farley, K., & Nadel, S. (2015). An overview of studies on 22 different gamifications of energy consumption.

Khosrowpour, A., Xie, Y., Taylor, J. E., & Hong, Y. (2016). A study on 35 variously low, medium, and high engagement consumers for 69 days. They found that different levels of engagement impacted the effectiveness of their feedback intervention.

Nilsson, A., Jakobsson, C., Thuvander, L., Andersson, D., Andersson, K., & Meiling, P. (2014). An unsuccessful study investigating continuous feedback interventions (a display constantly giving information feedback to half of residents) in two town homes and then thirty-some individual houses.

Vellei, M., Natarajan, S., Biri, B., Padget, J., & Walker, I. (2016). A study on room conditions, participant’s perception of thermal comfort, and energy usage.

Xu, X., Arpan, L. M., & Chen, C. (2015). Online study that looked at the differences perceived between financial and environmental feedback based on participants’ environmental concern and political orientation.

**Game theory**

Chen, T., Member, S., Pourbabak, H., Member, S., & Su, W. (2016). A comparison of on how to integrate prosumers (consumers generating energy) into an energy consumption system.

Dimitrokali, E., Mackrill, J., Jennings, P., Khanna, S., Harris, V., & Cain, R. (2015). An analysis of users’ perceptions of smart energy consumption technology.

Kashif, A., Ploix, S., Dugdale, J., Reignier, P., & Kashif, M. (2015). A simulation of energy consumption based on interaction with what the researchers call a ‘serious game’, which is intended as a feedback tool to educate consumers.

**Research on low-income residents**

Langevin, J., Gurian, P. L., & Wen, J. (2013). Explicitly discusses knowledge gaps for lower income tenets.

**Probabilistic Programing**

Chen, J., Jain, R. K., & Taylor, J. E. (2013). These researchers create a random social network generator called the ‘block configuration model’ to help researchers model energy consumption behavior.

Gulbinas, R., Jain, R. K., Taylor, J. E., & Golparvar-Far, M. (2012). The researchers describe a web service designed to provide real time feedback to individuals about their energy usage as well as other residents in their building.

**Residential energy data mining**

Carlson, D. R., Matthews, S. H., & Bergés, M. (2013). A critique on using RECS data to make individualized models.

Abreu, J. M., Câmara Pereira, F., & Ferrão, P. (2012). Discusses findings regarding how individual habits and weather conditions account for a large amount of energy consumption data, and how to predict these patterns based on collected data.

Albert, A., & Rajagopal, R. (2015). Fairly technical report of how to separate energy readings from smart meters to see when thermal changes are due to individual decision making to consume thermal energy (HVAC in particular).

Kwac, J., Flora, J., & Rajagopal, R. (2016). Another technical report on the predictability of consumer behavior (i.e. future energy needs in a system) based on energy readings.

**Social Norms**

Bradley, P., Leach, M., & Fudge, S. (2014). A report from a research team with a good overview of various psychological mechanisms influencing individual consumption and how to measure normative interventions.

Allcott, H. (2009). A study on 80,000 Minnesotan households receiving mailed feedback from an energy company at various intervals.

**Detailed overviews and citations**

**Decision making and building energy use**. These articles look at factors influencing decision making in regards to energy consumption. They vary in approaches, from psychological, to network analyses, to behavioral economics.

Anderson, K., & Lee, S. H. (2016). An empirically grounded model for simulating normative energy use feedback interventions. *Applied Energy*, *173*, 272–282. <http://doi.org/10.1016/j.apenergy.2016.04.063>

A study on various intervention models, simulating five intervention strategies using existing data on intervention impact. They found that normative feedback was most effective when targeting underperforming individuals. Their energy savings were modelled to be around 2-5% depending on who was targeted.

Chen, J., Taylor, J. E., & Wei, H. H. (2012). Modeling building occupant network energy consumption decision-making: The interplay between network structure and conservation. *Energy and Buildings*, *47*, 515–524. http://doi.org/10.1016/j.enbuild.2011.12.026

Models occupant behavior as part of a network of decisions, looking at how various behaviors from certain actors impact other actors in the network. In particular, they looked at network degree (one measure of the cohesion of the network) and weight. They propose that the use of models is useful for experimental designs that want to test interventions by giving them a baseline to compare their intervention to.

Froehlich, J., Findlater, L., & Landay, J. (2010). The design of eco-feedback technology. *Proceedings of the 28th International Conference on Human Factors in Computing Systems - CHI ’10*, 1999. http://doi.org/10.1145/1753326.1753629

Metaanalysis which discusses the impact of various psychological mechanisms like norms, commitment, and various levels of feedback impact individuals’ use of eco-technology. They report that investigations of feedback interventions should use baseline explorations, targeted rather than generalizable feedback, learning systems, and modelling to flesh out their analysis of interventions. Carlin, Ford, and McPherson (2015) is another one that looks at assessing behavior initiatives more broadly.

Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). Household energy use: Applying

behavioural economics to understand consumer decision-making and behaviour. Renewable and Sustainable Energy Reviews, 41, 1385–1394. <http://doi.org/10.1016/j.rser.2014.09.026>

A discussion of psychological mechanisms that make individuals act against their expressed desires and against their best financial interest in the context of energy consumption. Includes policy/application recommendations. Discusses 11 biases overall and how they should be accounted for in interventions.

Wilson, C., & Dowlatabadi, H. (2007). Models of Decision Making and Residential Energy Use. *Annual Review of Environment and Resources*, *32*(1), 169–203. http://doi.org/10.1146/annurev.energy.32.053006.141137

An article overviewing how different psychological traditions have approached conceptualizing decision making. While we will take our own perspectives to it, I think that these are useful for thinking about how to contextualize our findings and seeing how these perspectives would frame the tasks that we decide to have subjects do.

**Behavior impact on energy consumption.** These studies conceptualizing and measuring various individual energy consumption behaviors. Studies not included in this bibliography mostly had to do with predicting and modelling occupancy in overall residential energy consumption.

Barthelmes, V. M., Becchio, C., & Corgnati, S. P. (2016). Occupant behavior lifestyles in a

residential nearly zero energy building: Effect on energy use and thermal comfort. Science and Technology for the Built Environment, 22(7), 960–975. <http://doi.org/10.1080/23744731.2016.1197758>

This study modelled how high, medium, and low consumption users would impact energy consumption in a sustainable house. While the findings (how consumption is impacted) may not be of interest to us, the various behaviors they modelled may be.

Brenner, B. (2013). The Short List. *Leadership & Management in Engineering*, *13*(4), 280–281. http://doi.org/10.3200/ENVT.50.5.12-25

This was in the policy and building energy use folder, but I felt it was more appropriate here. This is a pop-sci article talking about how households tend to consume energy. A large focus is on the use of appliances and their impact on consumption. There is a little bit on thermostat usage as well. There are citations to back their figures up if we want to cite recommendations towards various energy conservation behaviors.

Ehrhardt-Martinez, K. (2015). Behaviour wedge profiles for cities. *Eceee Summer Study Proceedings*, (2008), 691–702.

This article discusses potential energy savings for cities (20-30%) based on residential behavior changes. Of particular interest, it outlines a methodology for assessing the importance of various energy consumption behaviors based on the savings potential of various behaviors (including heat use) and current behavior practice amongst cities’ citizens.

Ehrhardt-Martinez, K. E. (2014). Residential energy savings opportunities in the city of Baltimore, Marlyand. Municipal Behavioral Wedge Report, Garrison Institute & Human Dimensions Research Associates

Her public report as an example of a wedge report. It has estimates about Baltimore residents’ energy use behaviors, and recommendations for what individuals should do in order to become more efficient. Cites EPA recommendations for thermostat usage (58 at night and away, 68 when people are home). Also has recommendations for conserving heat in the house.

Sadeghi, S. A., Karava, P., Konstantzos, I., & Tzempelikos, A. (2016). Occupant interactions with shading and lighting systems using different control interfaces: A pilot field study. *Building and Environment*, *97*, 177–195. http://doi.org/10.1016/j.buildenv.2015.12.008

This is a study Panagiota was on which looked at how different controls related to lighting (electric shades vs. overhead lighting) and found that less energy was consumed when individuals had access to easy to control shading. May be of use in talking about alexa control vs. tablet control. Note that there is a 2017 article by Ilias, Panagiota, and then two other authors (Seyed Sadeghi and Nimish Awalgaonkar) that extends this study by modelling their findings and including external variables of how sunny or shady a given day is.

Todd, A., Stuart, E., Goldman, C., & Schiller, S. (2012). Evaluation, measurement, and verification EM&V) for behavior-based energy efficiency programs: issues and recommendations. *Proceedings of the 2012 ACEEE Summer Study on Energy Efficiency in Buildings*.

A 60+ page report by the State and Local Energy Efficiency Action Network on what methodologies and measurements are appropriate for studies on energy savings. Has chapters on concepts and issues in energy saving contexts, and then two chapters on internal and external validity respectively. This may be a useful piece of literature when trying to contextualize our findings and moving findings to in-the-field studies.

**Community goals research.** This research is mostly focused around community goals balancing and description with a focus on prosumer (consumers who also generate energy through means like solar panels).

Rathnayaka, A. J. D., Potdar, V. M., Dillon, T., Hussain, O., & Kuruppu, S. (2014). Goal-oriented prosumer community groups for the smart grid. *IEEE Technology and Society Magazine*, *33*(1), 41–48. http://doi.org/10.1109/MTS.2014.2301859

This article created a framework for balancing and coordinating energy consumption goals amongst consumers who are conservation-minded and generate their own energy (through means such as solar panels), which the article labels as prosumers. This study builds upon Rathnayaka, Potdar, Dillon, Hussain, and Kuruppu (2011) which set out to model Australian prosumers’ energy behaviors across two seasons. Rathnayaka, Potdar, and Ou (2012) builds on the 2011 article as well in the context of balancing energy consumption and input from prosumers using a smart grid.

**Ontology research.** These articles focus on describing the environment of relevant factors in residential energy consumer behavior. Studies not included in this bibliography largely focused on how to use ontological reasoning in smart technology on both the system consumption side and user side.

Hong, T., D’Oca, S., Taylor-Lange, S. C., Turner, W. J. N., Chen, Y., & Corgnati, S. P. (2015). An ontology to represent energy-related occupant behavior in buildings. Part II: Implementation of the DNAS framework using an XML schema. *Building and Environment*, *94*(P1), 196–205. <http://doi.org/10.1016/j.buildenv.2015.08.006>

This article was a review of literature aiming to describe the factors influencing occupant driven energy consumption. It does not describe what occupants should do, but aims to provide a thorough explanation of relevant factors in what people actually do. They posit *drivers*, *needs, systems*, and *action* as relevant factors. Examples of drivers are the building, occupant (age, gender), environment (such as indoor air temperature or season), system (are windows open, ect.), and time as factors driving energy changes. Need represents comfort or necessities of the occupant. System represents the iterative nature of the residential environment. Action represents what the occupant can do as influenced by the other three factors (opening a window, turning down thermostat).

Mahdavi, A., & Taheri, M. (2016). An ontology for building monitoring. Journal of Building

Performance Simulation, 0(0), 1–10. <http://doi.org/10.1080/19401493.2016.1243730>

This article lays out suggestions for how best to collect and analyze energy consumption, with a focus on environmental factors of importance, such as inhabitants, indoor environment conditions, external environment conditions, control devices, equipment, and energy flows. We could use this as well as the Hong et al. (2015) articles as guidelines for what influential cues we may need to account for in individual’s decision making.

**Research on feedback mechanisms.** This research looks at how specific types of feedback impact consumer behavior. I thought this may be of interest to Dr. Raymond. There were some articles on forecasting that I cut out, as well as those on social messages from resident to resident.

Anderson, K., Song, K., Lee, S. H., Krupka, E., Lee, H., & Park, M. (2017). Longitudinal analysis of normative energy use feedback on dormitory occupants. *Applied Energy*, *189*, 623–639. http://doi.org/10.1016/j.apenergy.2016.12.086

Shows that normative feedback can produce long term change via two year long studies on normative feedback in dormitories. This may be very useful in any studies in the honors’ college. Found that normative feedback was not helpful in the short term, but had a treatment effect of 14% savings over the course of the year for those individuals with a high concern for social norms, and a 5% change in those with low concern towards social norms.

Asensio, O. I., & Delmas, M. A. (2016). Journal of Economic Behavior & Organization The dynamics of behavior change : Evidence from energy conservation. *Journal of Economic Behavior and Organization*, *126*, 196–212. http://doi.org/10.1016/j.jebo.2016.03.012

This is the closest to what we’d like to do, an experimental design approach to various feedback mechanisms. Could be good as a template paper. It’s a study on 118 houses over 9 months, comparing financial, health, and environmental feedback. They found 8-10% energy savings over 100 days. They interpret their results to indicate support for better results from stressing environmental feedback, and health feedback in particular.

Ayres, I., Raseman, S., & Shih, A. (2013). Evidence from Two Large Field Experiments that Peer Comparison Feedback Can Reduce Residential Energy Usage. *Journal of Law, Economics, and Organization*, *29*(5), 992–1022. http://doi.org/10.1093/jleo/ews020

A study on how peer comparisons provided with energy bills either monthly or quarterly impacted individuals’ energy consumption over the course of a year. They found 1-2% energy saved. They used a smiley-frowney spectrum to represent consumers’ orientation towards their peers.

Ehrhardt-Martinez, K., “Laitner, J. A., & Donnelly, K. A. (2011). *Beyond the Meter*. *Energy, Sustainability and the Environment*. Elsevier. http://doi.org/10.1016/B978-0-12-385136-9.10010-5

Another article by Dr. Ehrhardt-Martinez, this one looks at common sources of energy consumption and breakdowns of those sources. Specifically, this one looks at the sorts of energy draws that aren’t usually seen by consumers, such as applicance energy use. This report is split into five chapters outlining ‘invisible’ energy usage (appliances as a salient example), smart meters and displays, historical data, the impact of consumer behaviors, and the scope of potential savings.

Iyer, M., Kempton, W., & Payne, C. (2006). Comparison groups on bills: Automated, personalized energy information. *Energy and Buildings*, *38*(8), 988–996. http://doi.org/10.1016/j.enbuild.2005.11.009

Looks at comparison groups on energy consumption bills and the impact on behavior. They provide suggestions on how to avoid misleading consumers, and how to use various energy outputs on the macro-level (meters at street v. residential level) to compare groups of individuals. It is worth noting that either Panagiota or Seng highlighted a section of the background section that discussed how geographically proximate consumers tended to have similar energy attitudes.

Karlin, B., Zinger, J. F., & Ford, R. (2015). The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin*, *141*(6), 1205–1227. http://doi.org/10.1037/a0039650

A meta-analysis of 42 studies from 1972-2010 that looked at energy consumption feedback and proenvironmental behavior. They found that, while most studies were significant, they varied in their effect size. They found that frequency, medium, comparative messages, durations, and intervention combinations all moderated the impact of feedback as a significant impactor of energy savings. They stress that this shows support for feedback as an intervention.

Jain, R. K., Gulbinas, R., Taylor, J. E., & Culligan, P. J. (2013). Can social influence drive energy savings? Detecting the impact of social influence on the energy consumption behavior of networked users exposed to normative eco-feedback. *Energy and Buildings*, *66*, 119–127. http://doi.org/10.1016/j.enbuild.2013.06.029

A 47-day study which surveyed the social network of a NYC apartment building, comparing the network to energy consumption. Their hypotheses about edges (ties) impacting one another was significant, indicating more support that social norms can impact our energy consumption behavior.

Grossberg, F., Wolfson, M., Mazur-stommen, S., Farley, K., & Nadel, S. (2015). Gamified Energy Efficiency Programs, (February).

An overview of studies on 22 different gamifications of energy consumption. These include rewarding participants for specific energy saving activities, competition between teams towards energy savings, real-time feedback, and the use of virtual worlds. They note that some games worked on a narrow band of participants, but worked well (upwards of 10% reduction in energy consumption) while more generalizable games garnered a more reliable but modest portion of savings (3-6% savings).

Khosrowpour, A., Xie, Y., Taylor, J. E., & Hong, Y. (2016). One size does not fit all: Establishing the need for targeted eco-feedback. *Applied Energy*, *184*, 523–530. http://doi.org/10.1016/j.apenergy.2016.10.036

A study on 35 variously low, medium, and high engagement consumers for 69 days. They found that different levels of engagement impacted the effectiveness of their feedback intervention. This builds support for engaging different types of consumers with different strategies to maximize savings. It may be of interest to us, at some point, to see if we can use our data to measure individuals’ engagement levels.

Nilsson, A., Jakobsson, C., Thuvander, L., Andersson, D., Andersson, K., & Meiling, P. (2014). Effects of continuous feedback on households ’ electricity consumption : Potentials and barriers. *Applied Energy*, *122*, 17–23. http://doi.org/10.1016/j.apenergy.2014.01.060

A study investigating continuous feedback interventions. They had two test beds; two town homes with 40 residents, and 32 households. They followed up with nine participants for interviews. In particular, they implemented a device in half the houses that continually gave visual feedback information. They found no significant savings benefits, and proposed that that understanding displays and being interested/engaged in the displays (and seeing benefits of changing habits) were significant barriers to the intervention impact.

Vellei, M., Natarajan, S., Biri, B., Padget, J., & Walker, I. (2016). The effect of real-time context-aware feedback on occupants’ heating behaviour and thermal adaptation. *Energy & Buildings*, *123*, 179–191. http://doi.org/10.1016/j.enbuild.2016.03.045

Looked at at optimizing consumer decisions via instant feedback to 15 volunteer subjects living in an apartment over 6 months. The study in particular investigated the role of thermal comfort in influencing individuals’ thermal energy usage, and establishing measures and ranges for what was considered acceptable. This could be a useful article for establishing measures and operationalizations of ‘comfort’.

Xu, X., Arpan, L. M., & Chen, C. (2015). The moderating role of individual differences in responses to benefit and temporal framing of messages promoting residential energy saving. *Journal of Environmental Psychology*, *44*, 95–108. http://doi.org/10.1016/j.jenvp.2015.09.004

Looked at the differences between financial and environmental feedback for 461 online participants. In particular, they surveyed political and environmental orientations and found that environmentally framed feedback was seen more positively for individuals with moderate environmental concern as opposed to those with low or high concern.

**Game theory and gamification.** Looks at literature on game theory. I took out the papers describing game theory without any direct application to energy consumption, and most papers focused on game theory from the electricity supplier side.

Chen, T., Member, S., Pourbabak, H., Member, S., & Su, W. (2016). A Game Theoretic Approach to Analyze the Dynamic Interactions of Multiple Residential Prosumers Considering Power Flow Constraints.

This is an example of a supply-side game theory paper, albeit with some relevance to consumer behavior. A comparison of simulations using 33 nodes over 20-some iterations. It looks at how to integrate prosumers (consumers generating energy) into an energy consumption system. I’m not sure if this will be useful to us (will the final development have individual ways to generate behavior?).

Dimitrokali, E., Mackrill, J., Jennings, P., Khanna, S., Harris, V., & Cain, R. (2015). Indoor and Built Exploring homeowners ’ perception and experiences in using a domestic smart home heating controller, *24*(7), 1010–1032. http://doi.org/10.1177/1420326X15606186

An analysis of users of smart energy consumption technology. They surveyed demographics, habits, and post-adoption satisfaction and feedback. They found that 70% of their 71 respondents were satisfied with the technology. Don’t know why it was in this section, but it does a good job looking at perceptions of smart tech use in energy consumption.

Kashif, A., Ploix, S., Dugdale, J., Reignier, P., & Kashif, M. (2015). Virtual simulation with real occupants using serious games. Laboratory of Grenoble for Sciences of Design, Optimisation and Production ( G-SCOP ) University of Grenoble , Grenoble Informatics Laboratory ( LIG ) University of Agder , Norway, 2712–2719.

A simulation of energy consumption based on interaction with what the researchers call a ‘serious game’, which is intended as a feedback tool to educate consumers. They cite Wood et al (2014), which lays out criteria for evaluating these types of games. If we go this route, that paper will be important.

**Research on low-income residents.** Research specifically on the energy consumption behaviors of low-income residents. I found one article of use to us, which looks at specific obstacles and worries low-income individuals have about energy conservation.

Langevin, J., Gurian, P. L., & Wen, J. (2013). Reducing energy consumption in low income public housing : Interviewing residents about energy behaviors. *Applied Energy*, *102*, 1358–1370. <http://doi.org/10.1016/j.apenergy.2012.07.003>

These researchers interviewed 50 low-income tenets and analyzed the interviews for themes of energy consumption behavior and knowledge. Explicitly discusses knowledge gaps for lower income tenets. Notes that comfort and finances are issues in adoption of energy conservation behaviors.

**Probabilistic Programing.** Largely a combination of Taylor, Jain, and their colleagues talking about how to program smart technology for energy consumption. Only two appeared to be relevant to the studies we’d want to do, so I’ve included those below.

Chen, J., Jain, R. K., & Taylor, J. E. (2013). Block Configuration Modeling: A novel simulation model to emulate building occupant peer networks and their impact on building energy consumption. *Applied Energy*, *105*, 358–368. <http://doi.org/10.1016/j.apenergy.2012.12.036>

These researchers create a random social network generator called the ‘block configuration model’ to help researchers model energy consumption behavior. The paper is largely their discussion of random generation of various network components and interactions.

Gulbinas, R., Jain, R. K., Taylor, J. E., & Golparvar-Far, M. (2012). web-based eco-feedback, 13070.

The researchers describe a web service designed to provide real time feedback to individuals about their energy usage as well as other residents in their building. They note that their system was used in other research by Jain and colleagues in college dormitories and does reduce energy usage. This is somewhat similar to what we discussed with the honor’s college, where we might give individuals log-ins to a system to see their energy usage.

**Residential energy data mining.** This section largely had to do with how to collect and measure hvac and energy consumption data. I focused on those which reported findings relevant to understanding residential energy consumption behaviors.

Carlson, D. R., Scott Matthews, H., & Bergés, M. (2013). One size does not fit all: Averaged data on household electricity is inadequate for residential energy policy and decisions. *Energy and Buildings*, *64*, 132–144. <http://doi.org/10.1016/j.enbuild.2013.04.005>

This article discusses how some users skew the average appliance energy consumption as measured by RECS (not necessarily the instrument itself, but the data collected using it for the RECS national census). They note that this is important in that researchers should not try to model individual residential energy usage based on aggregate census data.

Abreu, J. M., Câmara Pereira, F., & Ferrão, P. (2012). Using pattern recognition to identify habitual behavior in residential electricity consumption. *Energy and Buildings*, *49*, 479–487. http://doi.org/10.1016/j.enbuild.2012.02.044

Discusses findings regarding how individual habits and weather conditions account for a large amount of energy consumption data. They study also aims to be able to predict patterns based on data-collection. They found that they could create baselines for general energy consumption without occupants (appliances on stand-by as an example), cold weekends, cold work-days, and temperate days.

Albert, A., & Rajagopal, R. (2015). Thermal profiling of residential energy consumption using smart meter data, *30*(2), 1–10.

Fairly technical report of how to separate energy readings from smart meters to see when thermal changes are due to individual decision making to consume thermal energy (HVAC in particular). I’ll admit this one went over my head, but it may be useful in interpreting individual behavior out of energy consumption data we get from the developments.

Kwac, J., Flora, J., & Rajagopal, R. (2016). Lifestyle segmentation based on energy consumption data. *IEEE Transactions on Smart Grid*, *3053*(c), 1–1. <http://doi.org/10.1109/TSG.2016.2611600>

An extension of Albert & Rajagopal (2015) looking at how to predict and interpret individual behavior based on energy data. The idea behind it is to allow for more efficient energy supply based on predicted usage. Again, not sure how helpful this article is for forming theoretical arguments, but could be of use down the road in measurement.

**Social Norms.** Studies on social psychology and how norms might be useful in creating behaviorally-sustainable energy conservation.

Bradley, P., Leach, M., & Fudge, S. (2014). The Role of Social Norms in Incentivising Energy Reduction in Organisations. *Centre for Environmental Strategy Working Paper 01/14*. Retrieved from http://www.surrey.ac.uk/ces/files/pdf/0114\_Bradley\_et\_al\_SocialNorms.pdf

A 50-page report with a good overview of various psychological mechanisms influencing individual consumption and how to measure normative interventions. This appears to be very useful in outlining various social mechanisms we’d want to investigate, including attitudes, group identity, and descriptive v. injunctive norms.

Allcott, H. (2009). Social Norms and Energy Conservation. *Center for Energy and Environmental Policy Research*, (October), 1–35. <http://doi.org/10.1016/j.jpubeco.2011.03.003>

A study on 80,000 Minnesotan households receiving mailed feedback from an energy company. Allcott estimates that 1.9 to 2% monthly energy efficiency was gained by the program. One future direction proposed is that, based on the data, consumer-types can be profiled for more targeted feedback.

**System Design & Virtual.** Really not much in this folder for us, these studies were more about the technical side of making smart and eco-friendly energy consumption interfaces and systems.