A Mathematical Programming Formulation for Optimal Load Shifting of Electricity Demand for the Smart Grid - Appendix

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APPENDIX A
LIST OF ACRONYMS

AW	Automated Windows
AMI	Advanced Metering Infrastructure
BESS	Battery Electricity Storage System
BEV	Battery Electric Vehicle
DR	Demand Response
EV	Electronic Vehicle
FCEV	Fuel Cel Electric Vehicle
HEMS	Home Energy Management System
HVAC	Heating, Ventilation, & Air Conditioning
ICT	Information and Communication Technology
LS	Load Shifting
NS	Non-Shiftable
OLS	Optimal Load Shifting
PEV	Plug-In Electronic Vehicle
REDD	Reference Energy Disaggregation Data Set
TC	Thermal Control
TOU	Time of Use
UTC	Coordinated Universal Time

APPENDIX B
DATA

This section describes the data sources and salient characteristics for the cases, as summarized in Table VI.

A. Case 1: Boston Load Shift

A highly useful initial source of end-use data is the Reference Energy Disaggregation Data Set (REDD) [1], a publicly available data set intended for research purposes. The week of May 15-21, 2011 is selected because its data is consistently available over this time period.

B. Cases 2, 3, 4: Springfield General Data

Because of limitations of the REDD data, the project team prepared a separate set of simulated data for one house to fully exercise the OLS model features. The simulated data set is based on a combination of design choices about the location, outside temperature range, and available electricity prices. In particular, the team picked a 6-day period during August, for which weather and electricity prices could be collected directly. Actual temperature measurements were acquired from the Weather Underground, a commercial weather service that provides real-time weather information [2], most of which collected from the National Weather Service.

A Day-Ahead price scheme was chosen over a TOU scheme, because Day-Ahead prices have more resolution than just peak and off-peak values. Lastly, the assumed end-user has a plug-in electric vehicle, works a 9am-5pm job, and has a fairly basic set of end-use preferences.

1) Location: Springfield, Illinois was chosen because first, in the course of the chosen week (8/11/13-8/17/13), the climate requires both heating and cooling. Second, the local utility, called *Ameren*, provides its consumers with the option of day ahead pricing.

2) Electricity Price: The prices are the day ahead prices for Springfield during 8/11/13-8/17/13 acquired from Ameren's website [3].

3) Simulating the Appliances:

a) Washer and Dryer: A washer's wattage ranges from 350 to 500 watts and an electric dryer's wattage ranges from 1800 to 5000 watts [4]. The washer is assumed to be used 4 times a week: Sunday, Tuesday, Thursday, and Saturday. The times were set to times of the day when the end-user would be at home: 7 pm, 8 pm, 8 pm, and 12 pm, for each day, respectively, with the dryer times offset by an hour. The phantom loads for the washer and dryer were designed by looking at measured phantom loads from the REDD data set.

b) Dishwasher: A dishwasher's wattage ranges from 200 to 2400 watts [4]. The Springfield household is assumed to use its dishwasher 6 times a week: Sunday, Monday, Tuesday, Wednesday, Thursday, and Saturday. The times were set to those when the end-user would be at home: 7 pm, 8 pm, 8 pm, 7 pm, 9 pm and 6 pm, for each day, respectively. The phantom loads for the dishwasher was designed by looking at measured phantom loads from the REDD data set.

c) Electric Car: The Global EV Outlook predicts 20 million electronic vehicles[1] will be used worldwide by 2020, and U.S. consumers already represent 38% of that number [5]. The Mini E was selected to be used for the model. The Mini E gets 0.22 kWh/mile [6]. It is assumed that the Mini E must refill after 100 miles, however, in the simulation, it never reaches this level of mileage because of daily recharging and the specific homeowner's driving profile. The homeowner is assumed to be using a level 2 PEV charger [7], with maximum load of 7.68 kW [8].

d) Assumptions:

- Driver works 15 miles from his or her home.
- Driver drives 30 work miles plus a uniform random number from 0 to 10 miles on a workday

[1]Electric vehicles are defined in this report as passenger car plug-in hybrid electric vehicles (PHEV), battery electric vehicles (BEV), and fuel cell electric vehicles (FCEV).

- Driver drives uniform random number from 0 to 10 miles on a weekend.
- The PEV charges every day, and the times were 4 p.m., 6 p.m., 6 p.m., 6 p.m., 6 p.m., 6 p.m., and 8 p.m. for each day, respectively.
- No phantom loads for the PEV charging station.

e) Non-Shiftable Loads: Each day, a house has loads that cannot be shifted, including but not limited to televisions, stereos, laptops, lights, and tablet/phone charging. The non-shiftable load quantity was generated as a random multiple between 1.0 and 1.5 of the measured non-shiftable load from the REDD data set.

C. Case 4: Springfield Automated Windows

1) Time Horizon: To reduce the computation time, the time period for this case is shorter than the other cases. The time period here is 4 hours of 5-minute intervals on Tuesday evening (8/13/13) from 8 pm - 12 am. This time horizon was chosen in order to emphasize when benefits from opening and closing windows would be apparent, because the temperature begins at 60.1 degrees Fahrenheit and falls into the low 50's.

2) Electricity Prices: To avoid pre-cooling or pre-heating effects, a TOU pricing scheme was chosen instead of the day ahead scheme. The modeling horizon is a peak price period, and the price is 0.12 \$/kWh. [1]

D. Case 5: Austin Pre-Cooling

The Austin, Texas location was chosen to emphasize the pre-cooling aspect of the model. It is desirable that the external temperature range is always above the homeowner's preferred temperature range so that only cooling is exercised. Only the HVAC portion of the model is tested, and according, only real data on temperature and prices are needed. The loads in this case are also synthesized for a single house.

1) Location: Austin, Texas was chosen for its hot climate, which is beneficial because the HVAC systems must run more continuously. The model was implemented for the period of August 6, 3:00PM to August 8, 3:00 PM (Tues-Thurs).

2) Electricity Price: TOU prices during 8/6/13-8/8/13 were acquired from Austin Energy's website [9].

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