Bringing Local Community Benefits to Prince Georges County, Maryland Through Demand Response Modeling for Electricity Usage in Buildings

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Smart Cities Roundtable

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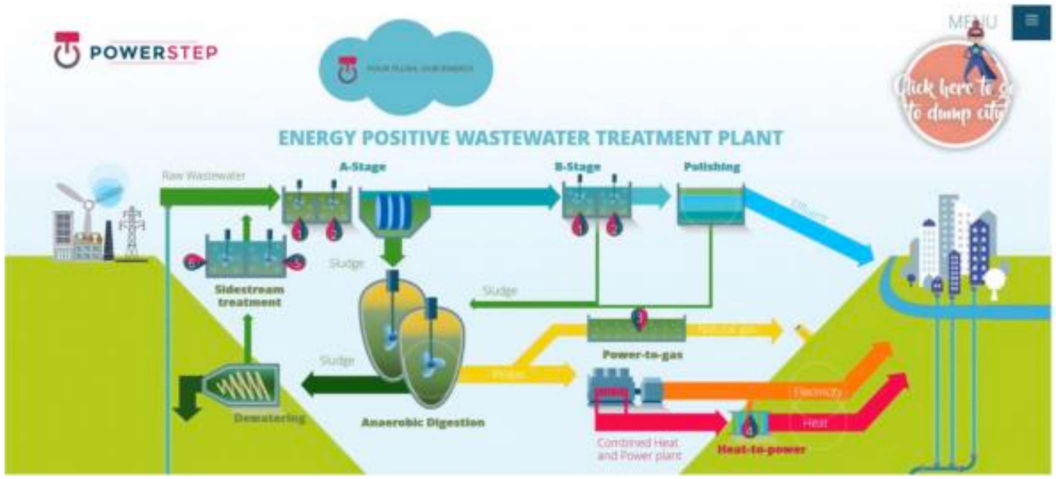
Outline

- Sustainability and economic motivation for demand response programs in the power sector
- Great opportunity for collaboration between
  - Prince Georges' County communities
  - University of Maryland Facilities Management (FM)
  - University of Maryland researchers
- Overview of the demand response residential load-shifting problem for master-metered buildings
- Selected recent results from the retail electric power provider (REP) perspective for the Texas power market
- Summary and next steps for NSF and other agencies proposal

Sustainability & Demand Response: Supply Side

- How can we mitigate intermittency for renewable energy without using fossil fuel back-up?
- Can use the supply or the demand sides of energy (or both)
- **Supply side**
  - One way is to use more biofuels– renewables but these compete with food for land
  - Another way is to use waste and convert to energy (e.g., from wastewater treatment plants)



https://www.smart2zero.com/news/wastewater-power-plant-electrical-energy-sewage-treatment-plant

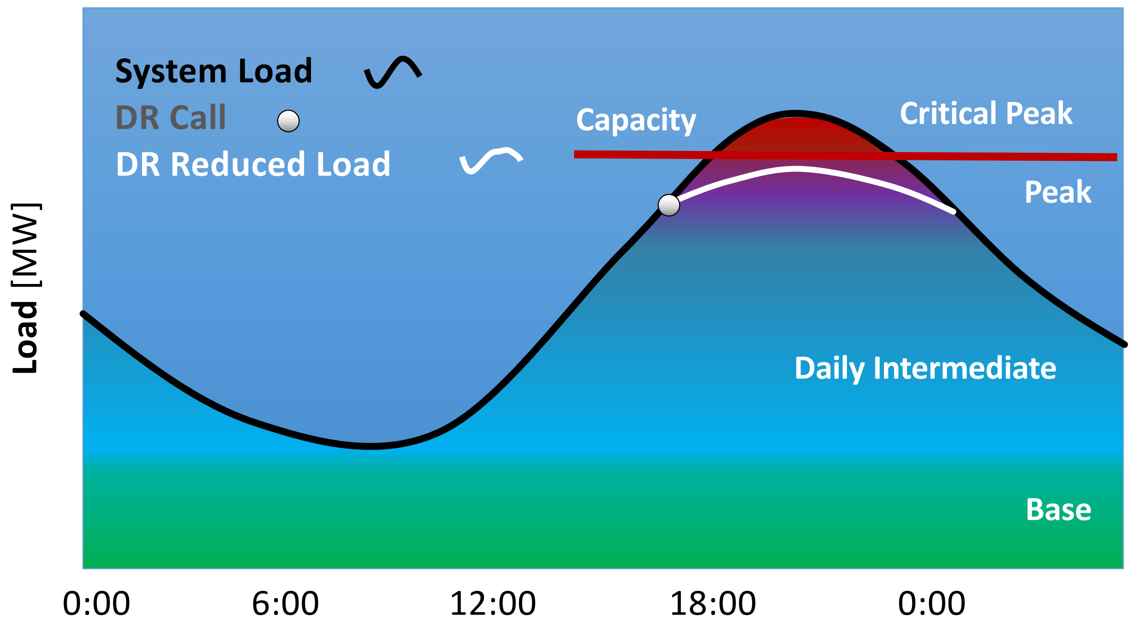
Sustainability & Demand Response: Demand Side

- **Demand side**
  - A perhaps easier way is to shift some of the load over time to avoid expensive and polluting peaking plants– this is demand response (DR)
  - DR in commercial and industrial sectors more common than in the residential one
  - Residential load is harder to predict, dependent on weather, harder to monitor
  - Smart thermostats (smart homes) allow for new residential power load-shifting via internet-based thermostats and adjustments of setpoints (e.g., for A/C) for participating customers
  - DR provides a less-polluting, more cost-effective solution given sustainability goals
  - Expanded capability with Internet-of-Things (IoT) growth, real-time aspects with IoT connection

What is Demand Response (DR)?

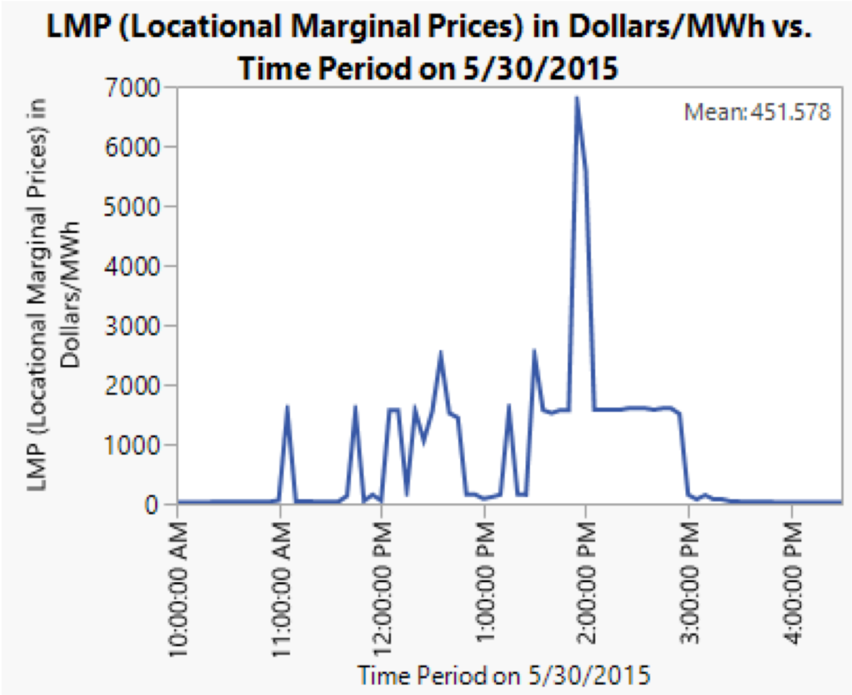
Responding to system inability to cover peak demands by reducing typical consumption

- The utility or grid operator (ISO) forecasts or observes a short in capacity to meet the demand.
- Calls on resources to reduce consumption (or provide new capacity
- System load reduced so less need for peaking power plants (e.g., gas turbines)
- **This curtailment in load can also be proposed by the users (e.g., buildings)– get a "flexibility payment"**



Economic Motivation for DR (Texas)

- Volatile market: power prices can increase by two orders of magnitude in 30 minutes
- Customers pay a constant rate, so the electric providers are fully exposed to these spikes
- Price spikes in 2011 put several retail electric power providers (REPs) out of business
- A few hours can be pivotal from a profit perspective



Houston, TX

Direct Metering vs. Master Metering for Buildings

- **Direct metering**: 1 meter per utility type or residential unit, after reading the meter, the utility charges the resident(s) directly
- **Master metering**: measure the electricity (or natural gas or water) of multiple tenants with the same meter, the owner/landlord gets the bill. Master metering gives wholesale rates which are less costly.
  - The building management assesses costs for each tenant based on sub-meters
  - Utility sub-metering allows the landlord to bill the tenants separately since the metering is done separately

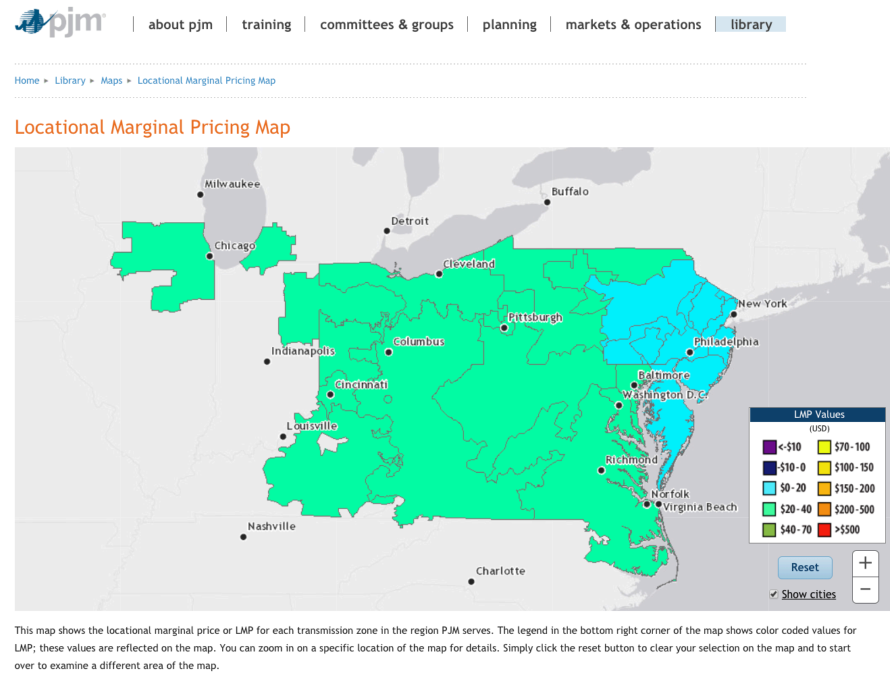
https://greencoast.org/master-metering/

Master Metering for Buildings and Demand Response Flexibility Payments

- Use the day-ahead market prices for power and commit to and deliver a reduction in power consumption and receive a payment.
- Currently University of Maryland does this and in effect gets a "check every month" that they do this for being "flexible" and committing to load reduction (i.e., decrease lighting, raise thermostat setpoints, change air flow for short periods of time)
- Illustrative example: day-ahead price is $40/MWh, master-metered building(s) commit to and deliver on 1 MW of reduction for 1 hour, get $40

Master Metering for Buildings and Demand Response Flexibility Payments

- PJM power market has curtail service providers so that this demand response can be done
- According to Dave Shaughnessy (FM) at UMD, these are sizeable payments.
- A master-metered building then could use these ”flexibility payments” to defray things like HOA or other building costs.
- Collective benefit, stronger incentive



pjm.com (June 5, 2019)

Three Potential Building Groups for Demand Response Benefits

- **Municipal buildings**: demand response payments get used for public benefit (e.g., fill budget gaps)
- **Master metered buildings**: building residents get collective benefit (e.g., less fees)
- **Single-family homes**: residents get individual benefits to use how they like
- Different incentive schemes/motivations for each of these groups
- **Main Idea: Add to existing UMD FM demand response program with reductions in power load from Prince Georges' County communities**

Selected Recent Results for Retail Electric Power Providers (REPs) for Texas Market

Monte Carlo Simulation Study (2016)

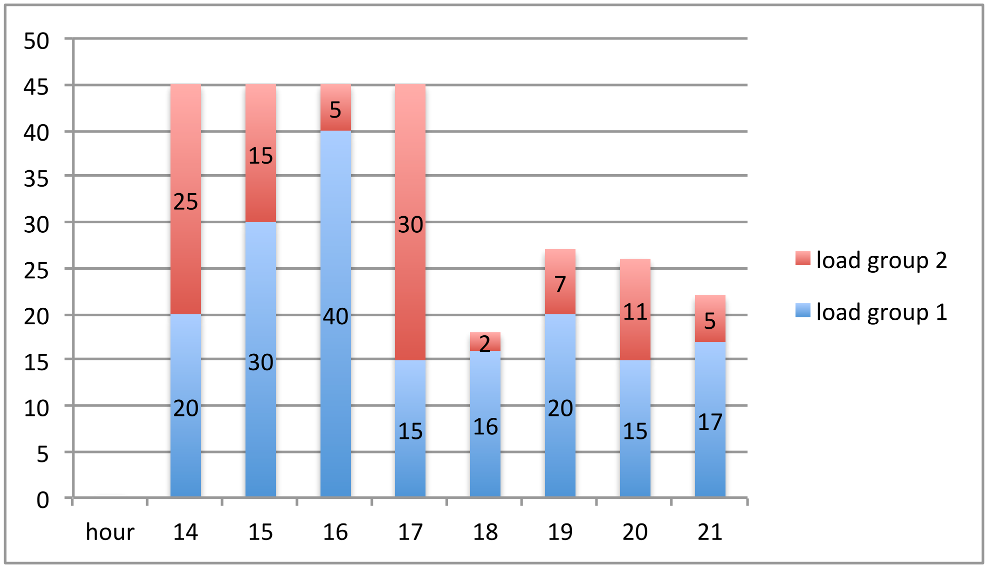
- J.R. Schaperow, S.A. Gabriel, M. Siemann, J. Crawford, 2019. "A Simulation-Based Model for Optimal Demand Response Load Shifting: Case Study for the Texas Power Market," accepted, *Journal of Energy Markets,* March 2019.

Stochastic Optimization Study (Dynamic Programming) (2018)

- R. L. Moglen, P. Chanpiwat, S.A. Gabriel, A. Blohm, 2018. "A Dynamic Programming Approach to Optimal Residential Demand Response Scheduling in Near Real-Time: Application for Electricity Retailers in ERCOT Power Markets," under review, May 2018.

- A. Blohm, J. Crawford , S.A. Gabriel, 2019. "Demand Response as a Risk-Reduction Measure for Retail Electricity Providers: ERCOT Market Case Study," under review, March, 2019.

Overview of DR Modeling and Results from 2016 Monte Carlo Simulation Study



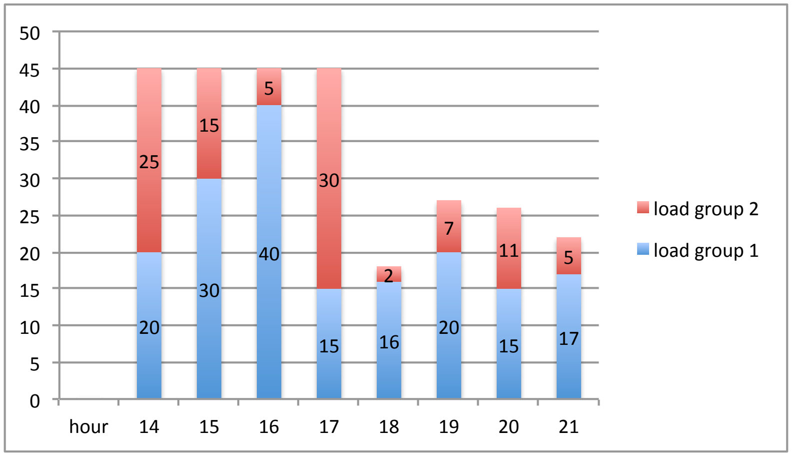
Typical day considered:

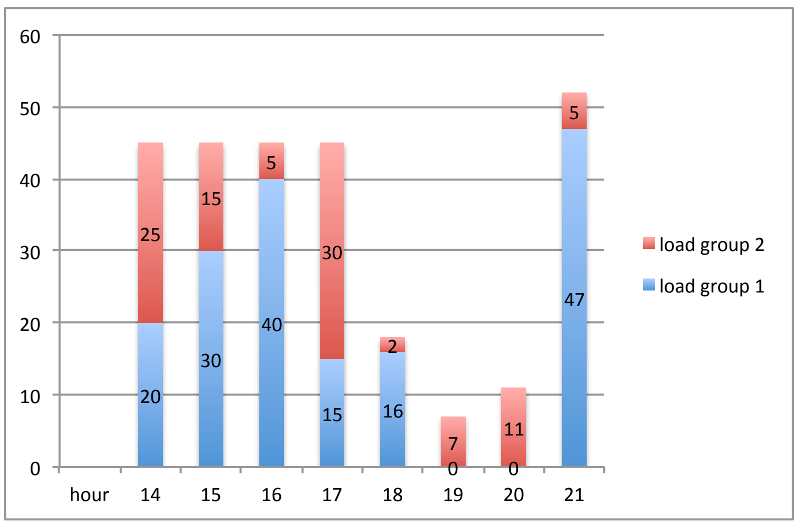
- Hours ending 14-21

- **Central Question:** How much of each customer group's load (2 shown here) should be shifted from a current hour(s) to a contiguous hour? The shifted load will be reduced by a certain factor (thermostat setpoints, etc.)

- **Benefits**: If the load is shifted to a less expensive hour, then retail electric providers (REPs) will be able to procure the needed power for less money. Even though less load, the overall effect may be beneficial in terms of expected profit and financial risk, less need for peaking machines for the energy producer, less negative environmental impacts.

Example of 2-Hour Load Shift





- Original load by group
- Group 1's load in hours ending 19 and 20 is 35 MW

- Group 1's load for hours 19 & 20 shifted to hour 21
- 35 MW reduced to 30 MW

23 Possible Shifts (for each customer class)

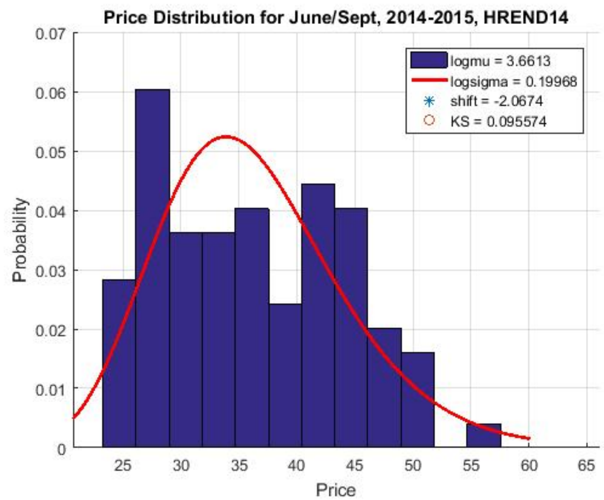
- No shift
  - #1
- 1-hour shifts:
  - #2, 14->15
  - #3, 15->16
  - #4, 16->17
  - #5, 17->18
  - #6, 18->19
  - #7, 19->20
  - #8, 20->21
- 3-hour shifts:

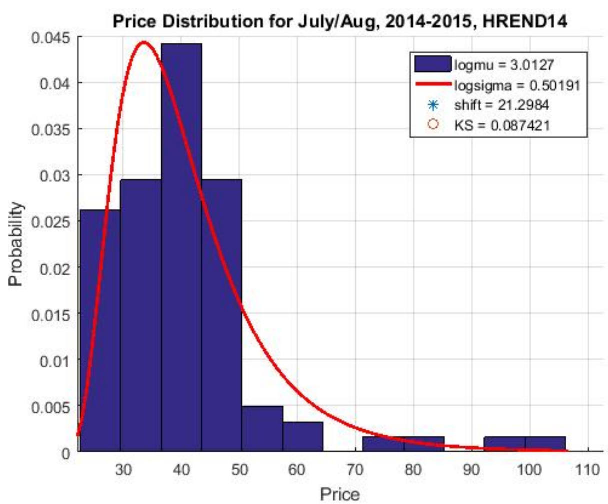
  #15, (14,15,16)->17
  #16, (15,16,17)->18
  #17, (16,17,18)->19
  #18, (17,18,19)->20
  #19, (18,19,20)->21

- 2-hour shifts:
  - #9, (14,15)->16
  - #10, (15,16)->17
  - #11, (16,17)->18
  - #12, (17,18)->19
  - #13, (18,19)->20
  - #14, (19,20)->21
- 4-hour shifts:

  #20, (14,15,16,17)->18
  #21, (15,16,17,18)->19
  #22, (16,17,18,19)->20
  #23, (17,18,19,20)->21

Settlement Price Probability Distributions





- Lognormal distribution (tail to the right)
- Law of Proportionate Effect
- Relatively good numerical fit

- Different lognormal distributions for Month
  - June/September
  - July, August
  - Year (2014-2015)
  - Hour (14-21)
- Also different distributions for customer load statistically fit

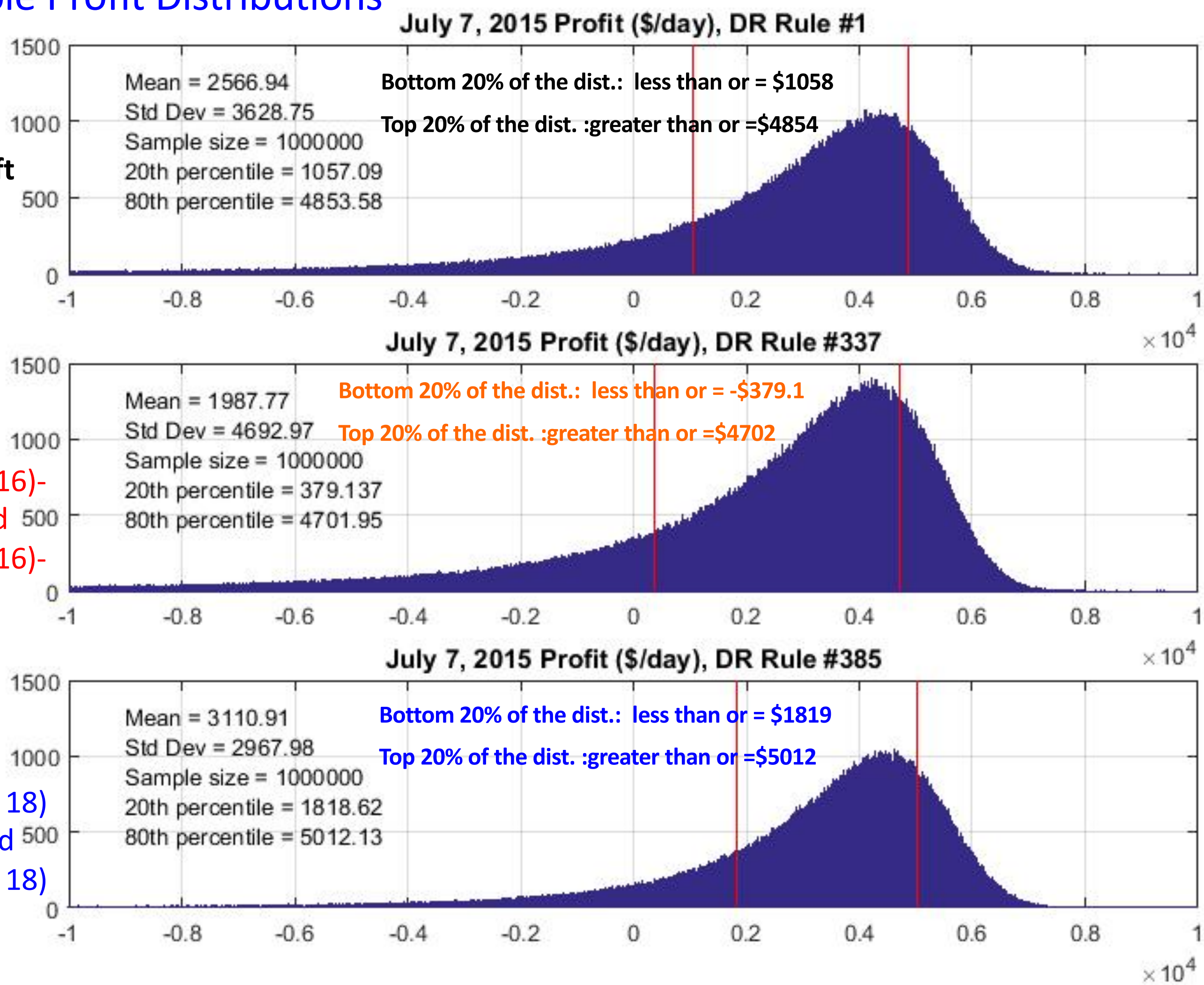
Profit Distribution from Simulation

Sample Profit Distributions

Base Case No shift

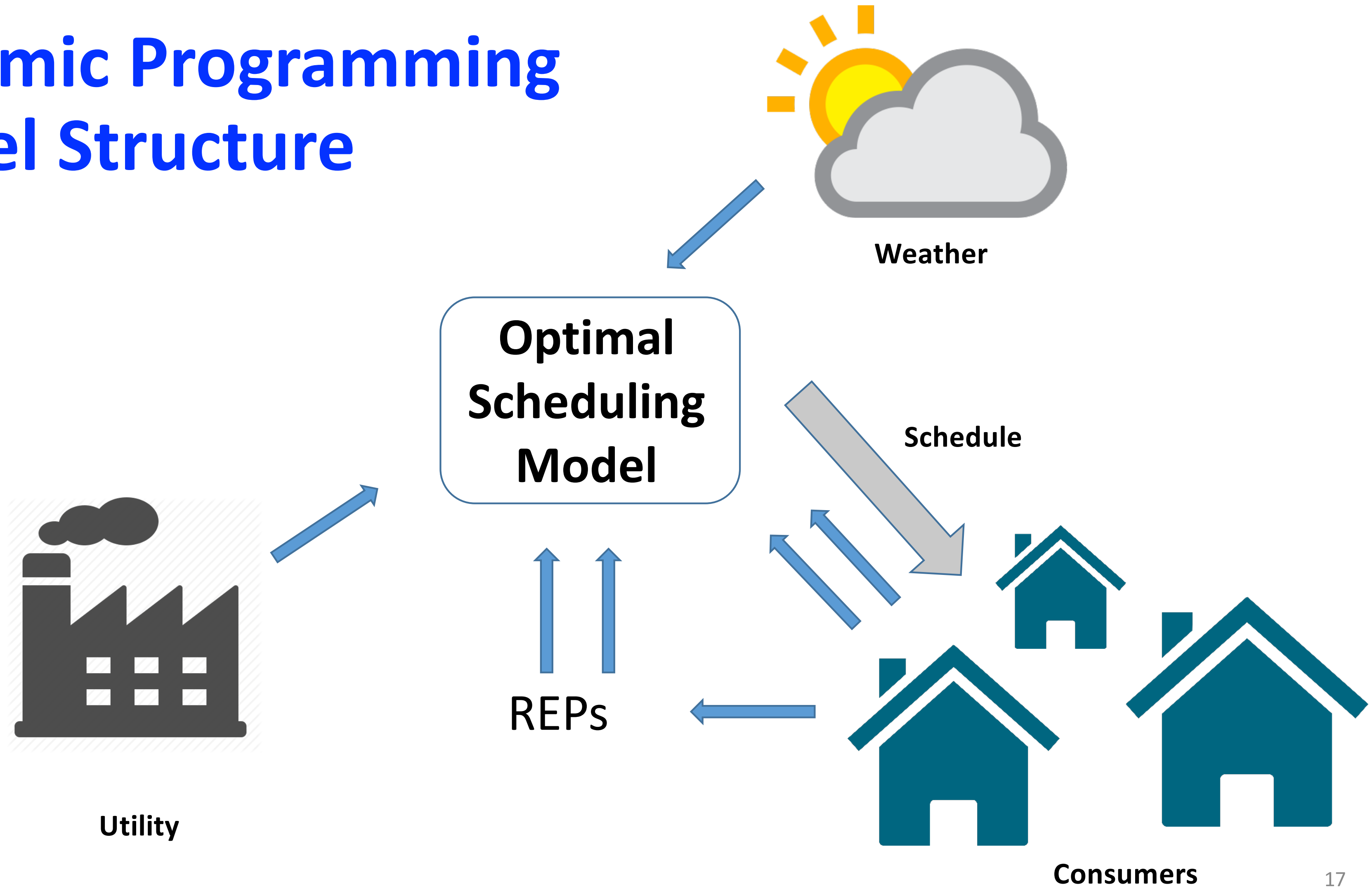
Worst #337, (14,15,16)->17 and (14,15,16)->17

Best #385, (16, 17, 18) ->19 and (16, 17, 18) ->19



- Better strategies to shift the load compress this distribution and move it to the right
- Bottom 20% of the distribution shifted (CVaR improvement)
- Less risk for the REP

Dynamic Programming Model Structure

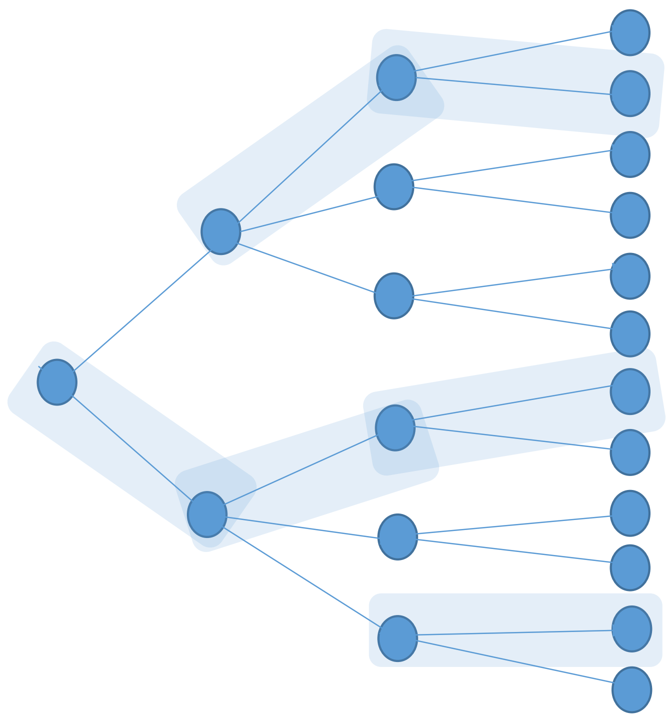


A Scheduling Problem

- Prices are volatile
- Plan optimal DR schedule by shifting load around high prices
- 17 possible schedules for 5 time periods (no DR, 1-hour, 2-hour, 3-hour, 4-hour load shifts)
- **5.9 million schedules for 24 time periods**

Time Period				
1	**2**	**3**	**4**	**5**
0	0	0	0	0
1	0	0	0	0
0	1	0	0	0
0	0	1	0	0
0	0	0	1	0
1	0	1	0	0
1	0	0	1	0
0	1	0	1	0
2	0	0	0	0
2	0	1	0	0
2	0	0	1	0
0	2	0	0	0
0	0	2	0	0
1	0	2	0	0
3	0	0	0	0
0	3	0	0	0
4	0	0	0	0

Why Dynamic Programming?



- One gets a "roadmap" of optimal decisions (based on Bellman's Principle of Optimality)
- Simplification from exponential solving time to linear solving time w.r.t number of stages
- **Stages**: hours or half-hours (time t)
- **States**: S_t which DR events running at time t
- **Actions:** A_t 0, 1, 2,3, 4-hour DR
- **Reward function** (at a given state S_t):
  - Single-objective version: deterministic, maximize REP profit $F_t(A_t)$
  - Bi-objective: stochastic, maximize REP profit $F_t(S_t,A_t)$ $\boldsymbol{\beta}$ is weight, minimize risk, $R_t(S_t,A_t)$ $(1-\boldsymbol{\beta})$ is weight
  - $\boldsymbol{\beta}$ in [0,1]

Conclusions for Optimization Study

- DP viable for **real-time** DR scheduling
- Savings of **$10-$25/ customer/ year**, or **10%- 25% additional savings possible on top of profit margins of $100/ customer annually**
- Less risky to call 1-hour events in the evening
- Morning events are the riskiest
- Historically:
  - **1-hour events** would have generated the most savings
  - The **shoulder season** had the most potential savings
  - Few events generated the vast majority of potential savings

Summary

- **Summary**
  - Using demand response for Prince Georges' County buildings towns/cities can have real "flexibility" payments
  - University of Maryland has expertise in DR (via FM)
  - Use this knowledge to build smart communities in Maryland to adopt demand response for collective benefit to municipal, master-metered buildings as well as single-family homes
  - Demand response can also help with sustainability goals

Next Steps

- **Next Steps/Ongoing Steps**
  - Meeting with communities in MD to see about adopting such DR programs
    - Need information on potential buildings: energy usage, building aspects that can be adjusted for demand response)
    - **Need all this information by January 31, 2020**
  - Meeting with University of Maryland FM personnel to gain more knowledge on the practical aspects of how to optimize DR
    - Monthly brown bag to discuss proposed work
    - **Need to write up the current program details by February 28, 2020**
  - Contact NSF program manager in early Spring (**March 2020**)
  - Write up and submit proposal to NSF (or other State/Federal agencies)- **Summer 2020**