

Willingness to Pay for Microgrids to Enhance Community Resilience

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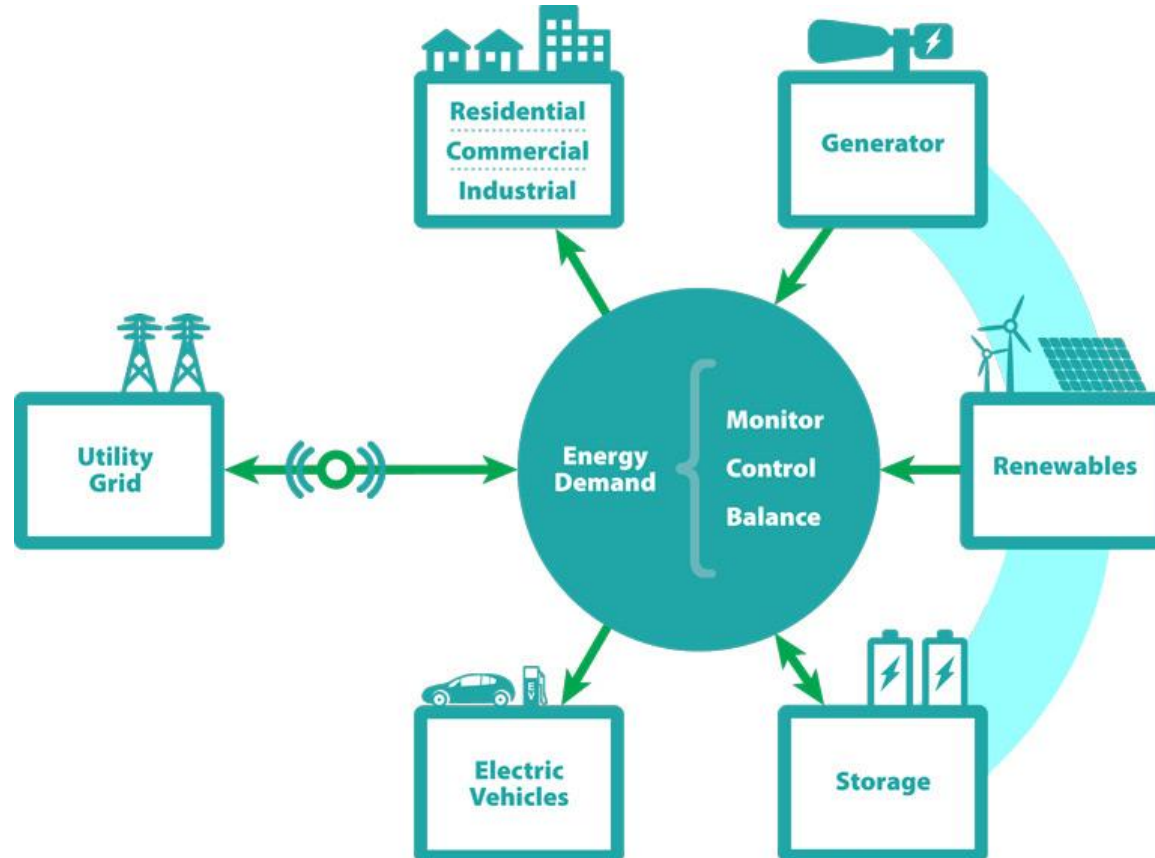


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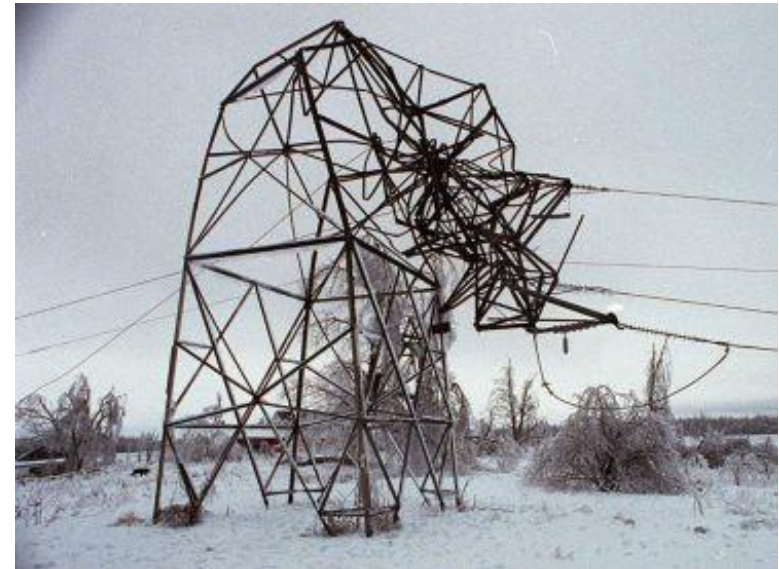
What is a Microgrid?

- A small-scale power grid meant to serve a small number of users with local generation
- Integrated into the macrogrid, but separable



Why a microgrid?

- Extreme weather events
 - Increasing intensity/frequency?
- Cyber and other attacks on grid infrastructure



Working Example

- Small town ~10,000
- Two Colleges (~7000 students), Hospital
- Large Solar Array
- Small Hydro
- Small Wind
- Diesel/Natural Gas Generators

Benefits of a Microgrids

- Allows connected users to insulate themselves from system-wide failures
- Provides electricity services to critical infrastructure during failures
- Allows for quicker service recovery, possibly system-wide

Increases community resilience to disasters

Costs and Challenges of Microgrids

- Microgrids require significant investment:
 - Local power generation
 - Resilient distribution systems
 - Buried lines
 - Grid control systems
- At community scale, require coordinating policies and institutions
 - Coordinating generation and load sources (multiple stakeholders)
 - Governance of interactions with utility services

Cost Recovery

- Feasibility requires that costs be recovered from ratepayers
- Tiered recovery
 - Different classes of users with different rate charges
 - Tier 1: Generators/Primary users
 - Large institutions including private and public sector
 - Hospitals, Universities, etc.
 - Tier 2: Non-generating users
 - Smaller users
 - Emergency services, select retail and other services
 - Tier 3: Community member non-users
 - Households and other indirect beneficiaries

Main research question

- How much are Tier 3 users (households and community members) willing-to-pay for microgrid services?
 - Emergency services
 - Hospital services
 - Water Treatment
 - Select retail services
 - Banking, groceries, pharmacy, gasoline
 - **NOT HOUSEHOLD ELECTRICITY SERVICES**
- Goals:
 - Contribute to benefit cost analysis for community microgrids by estimating benefits
 - Help communities prioritize service provision in microgrid development

Existing literature

- Extensive work evaluating WTP for avoided power outages
 - Morrissey et al., 2018; Ozbaflı & Jenkins, 2016; Hensher et al., 2014; Abdullah & Mariel, 2010; Pepermans, 2010; Carolsson & Martinsson, 2008
- Some work on value of micro-generation (not focused on grid services)
 - Rommel & Sagebiel, 2017; Scarpa & Willis, 2010
- WTP for renewable electricity
 - Borchers et al., 2007; Bae & Rishi, 2018
- WTP for backup generation - Baik et al. (2018b)
 - Value of coverage for high priority loads - \$0.75-\$1.20
 - Value of coverage for lower priority loads - \$0.35-\$0.51

WTP for Emergency Services

- Donahue and Miller (2006)
 - 72% of respondents willing to pay a monthly fee of some size to improve community disaster response
- Asgary et al. (2012)
 - Household annual WTP of \$52.43 for improved emergency services
- Dobes et al. (2012)
 - \$124 per year for faster resupply of fresh food, \$357 for faster reconnection of utilities (electricity, sewage), and \$11 per year for each additional day of police patrol services

Methodological Approach

- Stated Preference Discrete Choice Experiment
 - Survey instrument to evaluate WTP for microgrid services
 - Based on McFadden's (1974) Random Utility Model and Lancaster's (1966) Hedonic model of preferences for good characteristics
- Respondents are presented with a series of choices between varying bundles of microgrid services at different household costs
 - Their choices reflect their willingness to trade off various attributes against costs
 - Allow for the estimation of WTP for each attribute

Example Choice

“Assume a Microgrid has been proposed in your community that would provide a set of services in the event of significant power outages. These are projected to average one outage-day per year over the 20-year life of the microgrid. If implemented, there would be a surcharge on your electricity bill to reflect the costs of the system. In the choice-sets below, please choose the option you would prefer to be implemented in your community.”

Service Definition	Choice A	Choice B	Choice C
Hospital	Full Operations	ER/ICU + Patient Services	ER/ICU
Emergency Services	Normal	Normal	200%+ Delay
Water	Not Available	Not Available	Not Available
Retail	No	Yes	No
Shelter	Yes	Yes	No
Price	\$10	\$2	\$0

Attributes and Levels

Attribute	Levels	Description
Hospital	ER/ICU*	Only Emergency Room (ER) and Intensive Care Unit (ICU) are operational
	ER/ICU + Patient Services	ER, ICU and patient services are operational. (Patient services such as imaging and labs)
	Full Operations	All service departments within the hospital are operational
Emergency Services	200%+ Delay in Response Time*	Emergency personnel will take 200% longer (or more) to respond to an emergency
	50%+ Delay in Response Time	Emergency personnel will take 50% longer to respond to an emergency
	Normal Response	Emergency personnel will be able to respond normally
Water	Not Available*	Access to water, but it is not potable
	Available	Access to water and it is potable
Shelter	Not Available*	Shelter sites not available
	Available	Shelter is available for local residents who need it
Retail Services	Not Available*	Retail services not available
	Available	Retail services are available
Price	\$0*, \$2, \$5, or \$10	Monthly payment for the microgrid is either \$0, \$2, \$5, or \$10 per month on the customers' bill

Implementation

- Online sample through Qualtrics, August 2018
- 939 New York residents aged 18+
- Residents of towns, villages, or cities of <50,000 residents
- Householders, or at least some knowledge of electric bill
- Sample statistics broadly consistent with statewide averages
 - Somewhat higher income, and slightly older

Readiness and Familiarity

Variable	Categories	Count	Percent
Generator	No Generator	627	67%
	Portable Generator	120	13%
	Generator – Power a Few Appliances	102	11%
	Generator – Power Whole House	71	8%
	Solar System with Battery	12	1.28%
	Other	7	0.75%
Longest Power Outage Ever Experienced	Few minutes to 30 minutes	155	17%
	30 minutes to 4 hours	139	15%
	4 hours to 8 hours	129	14%
	24 hours	118	13%
	2 days	76	8%
	More than 2 days	322	34%
Respondent Description of Overall Energy Use	High Energy User	58	6.18%
	Moderately High Energy User	166	17.68%
	Medium Energy User	472	50.27%
	Moderately Low Energy User	185	19.70%
	Low Energy User	58	6.18%

Main Results (Mixed Logit)

	Model 1	
Variables	Mean	Standard Deviation
PRICE	-0.133***	
	(0.009)	
ASC	1.086***	3.069***
	(0.178)	(0.181)
HOSPITAL1	-0.004	0.205
	(0.040)	(0.129)
HOSPITAL2	0.250***	0.344***
	(0.044)	(0.087)
WATER	0.502***	0.629***
	(0.037)	(0.052)
EMERGENCY1	0.053	0.084
	(0.043)	(0.136)
EMERGENCY2	0.592***	0.552***
	(0.046)	(0.073)
RETAIL	0.155***	0.328***
	(0.030)	(0.059)
SHELTER	0.373***	0.279***
	(0.032)	(0.081)
AIC	8993.93	
BIC	9125.43	
N	16902	
Log-likelihood	-4479.97	
LR Chi²	1691.03	
***Significant at 1% level; **significant at 5% level; *significant at 10% level; standard errors in parentheses.		

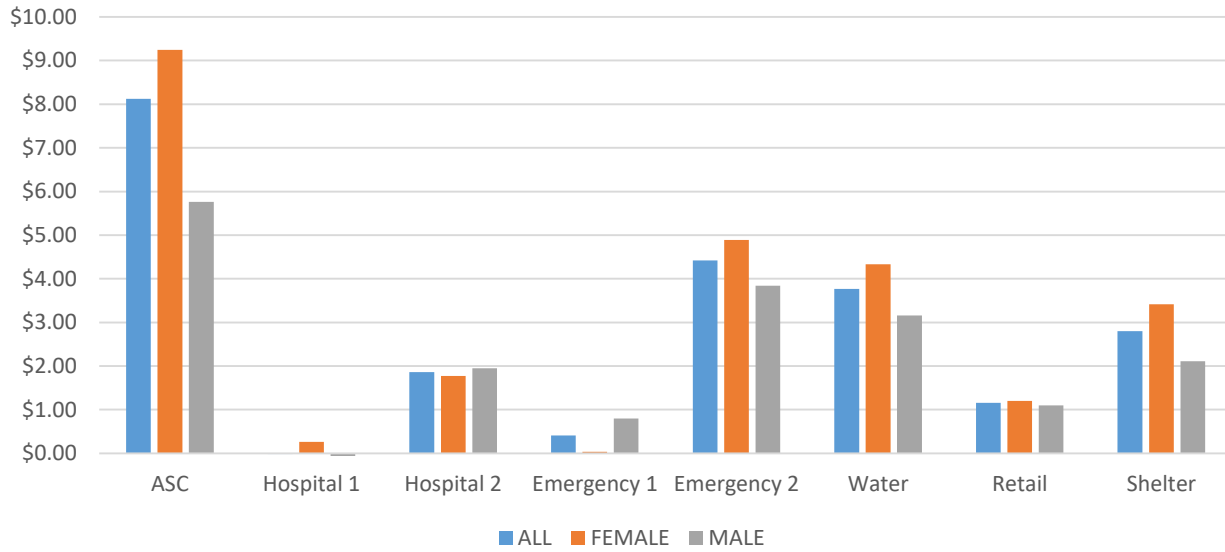
Willingness-to-Pay

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Attribute Levels in Scenario	HOSPITAL2	-	-	-	-	HOSPITAL2
	-	WATER	-	-	-	WATER
	-	-	EMERGENCY2	-	-	EMERGENCY2
	-	-	-	RETAIL	-	RETAIL
	-	-	-	-	SHELTER	SHELTER
Mean WTP:						
Household (\$/Month)	\$1.88	\$3.77	\$4.44	\$1.16	\$2.80	\$14.05
Household (\$/Year)	\$22.51	\$45.21	\$53.32	\$13.96	\$33.61	\$168.60
Lower WTP:						
Household (\$/Month)	\$1.24	\$3.14	\$3.65	\$0.71	\$2.30	\$11.05
Household (\$/Year)	\$14.90	\$37.66	\$43.81	\$8.57	\$27.62	\$132.55
Upper WTP:						
Household (\$/Month)	\$2.57	\$4.49	\$5.38	\$1.63	\$3.37	\$17.44
Household (\$/Year)	\$30.80	\$53.94	\$64.53	\$19.51	\$40.45	\$209.23

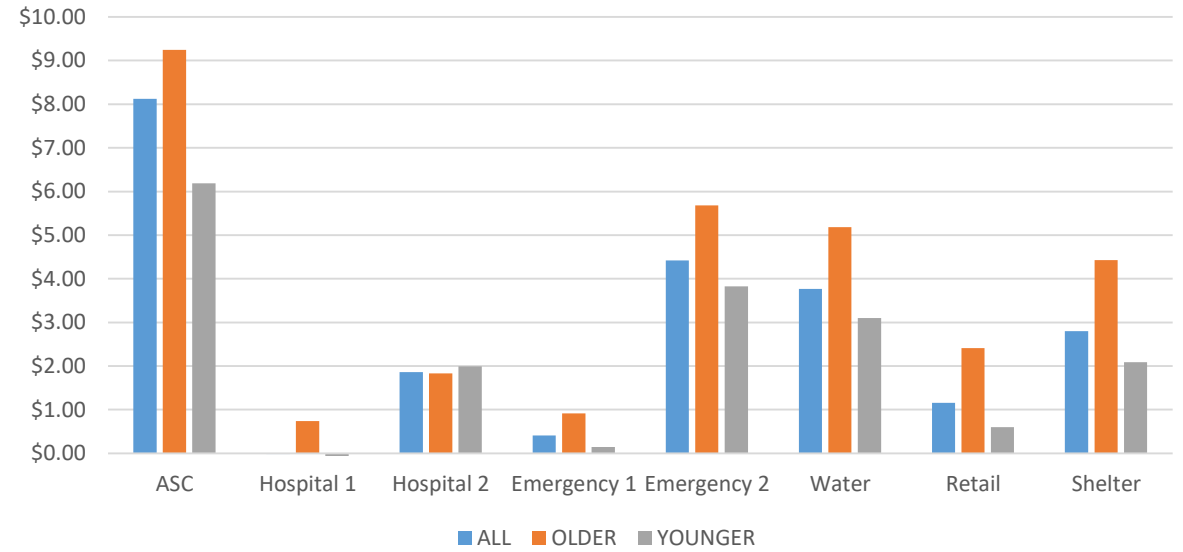
Interaction Term Results (Mixed Logit)

	Model 3	Model 4	Model 5
Variables	Mean	Mean	Mean
PRICE	-0.133***	-0.133***	-0.132***
	(0.009)	(0.009)	(0.009)
ASCMALE	-0.763**	-0.835**	-0.818**
	(0.266)	(0.262)	(0.263)
ASCAGE	-0.020*	-0.019*	-0.018*
	(0.008)	(0.008)	(0.008)
ASCEDUCATION	0.205	0.187	0.215
	(0.277)	(0.273)	(0.275)
ASCPOLSCORE	-0.201*	-0.218**	-0.183*
	(0.084)	(0.083)	(0.084)
ASCINCOME	0.220	0.277	0.202
	(0.277)	(0.274)	(0.276)
ASCGENERATOR	-0.378	-0.456	-0.461
	(0.275)	(0.271)	(0.272)
ASCENERGYUSER	0.338*	0.347*	0.351*
	(0.137)	(0.140)	(0.139)
ASCAGREEABLENESS	0.252*		
	(0.120)		
ASCEXTRAVERSION		0.199*	
		(0.101)	
ASCOPENNESS			0.366**

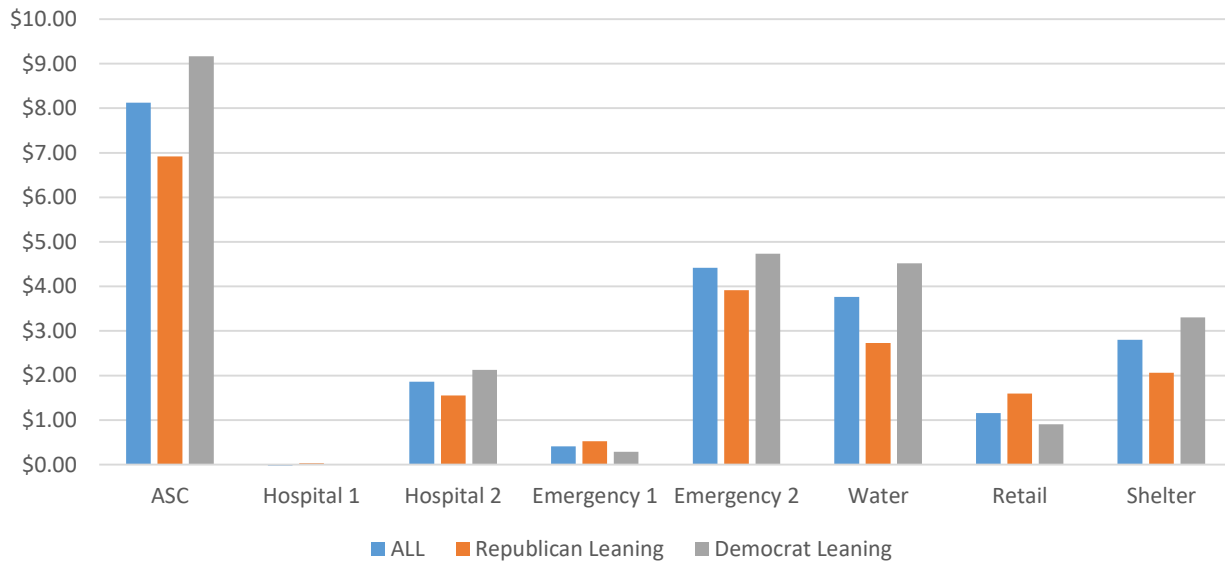
WTP by Gender



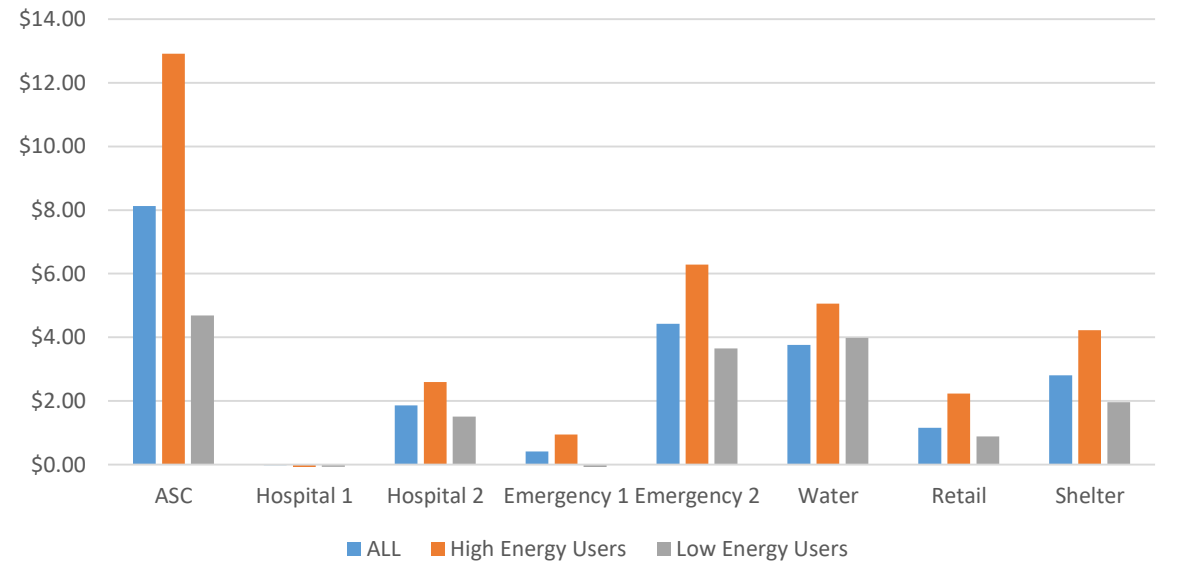
WTP by Age



WTP by Political Leaning



WTP by Energy Use



Conclusions

- There exists substantial willingness-to-pay for microgrid services, even amongst those who are not directly served
- Emergency Services > Water > Shelter > Hospital Services > Retail
- Males, Conservatives, Older citizens less likely to support
- High energy users more likely to support
- WTP can/should be balanced against system costs in any implementation

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Retail Preferences

Retail Service	1	2	3	4	5	Mean
Grocery Store	29	114	210	330	256	3.71
Pharmacy	52	137	229	288	233	3.55
Convenience Store & Gas Station	41	153	268	303	174	3.44
Bank	127	230	224	203	155	3.03

Split Sample Results

	ASC	Hospital 1	Hospital 2	Emergency 1	Emergency 2	Water	Retail	Shelter
ALL	\$8.12	-\$0.02	\$1.86	\$0.41	\$4.42	\$3.77	\$1.16	\$2.80
FEMALE	\$9.25	\$0.26	\$1.77	\$0.03	\$4.89	\$4.33	\$1.20	\$3.41
MALE	\$5.76	-\$0.21	\$1.95	\$0.80	\$3.84	\$3.16	\$1.09	\$2.11
OLDER	\$9.25	\$0.74	\$1.83	\$0.91	\$5.68	\$5.18	\$2.41	\$4.43
YOUNGER	\$6.18	-\$0.34	\$2.00	\$0.15	\$3.83	\$3.10	\$0.60	\$2.09
Income >\$75000	\$8.37	-\$0.36	\$1.99	\$0.44	\$4.48	\$3.65	\$1.42	\$3.08
Income <\$75000	\$7.70	\$0.53	\$1.66	\$0.35	\$4.32	\$3.95	\$0.81	\$2.51
Bachelors or More	\$8.20	\$0.21	\$1.60	\$0.77	\$3.82	\$3.35	\$0.62	\$2.01
Less than Bachelors	\$7.72	-\$0.18	\$2.11	\$0.06	\$5.14	\$4.25	\$1.69	\$3.57
Generator =1	\$7.08	-\$0.08	\$1.73	\$0.76	\$4.73	\$3.49	\$0.86	\$2.75
Generator =0	\$8.93	\$0.00	\$1.97	\$0.19	\$4.33	\$3.88	\$1.27	\$2.80
Republican Leaning	\$6.92	\$0.03	\$1.55	\$0.52	\$3.92	\$2.73	\$1.60	\$2.06
Democrat Leaning	\$9.17	-\$0.01	\$2.13	\$0.29	\$4.73	\$4.52	\$0.91	\$3.31
High Energy Users	\$12.92	-\$0.27	\$2.59	\$0.95	\$6.29	\$5.06	\$2.23	\$4.22
Low Energy Users	\$4.68	-\$0.07	\$1.51	-\$0.13	\$3.65	\$3.98	\$0.89	\$1.96