

Rate Considerations Related to Solar Distributed Generation

Presented by Adam Toth, PE | Toth & Associates, Inc.

Authors:

Adam Toth, PE

Craig Woycheese, CPA

Jeff Chapman, EI



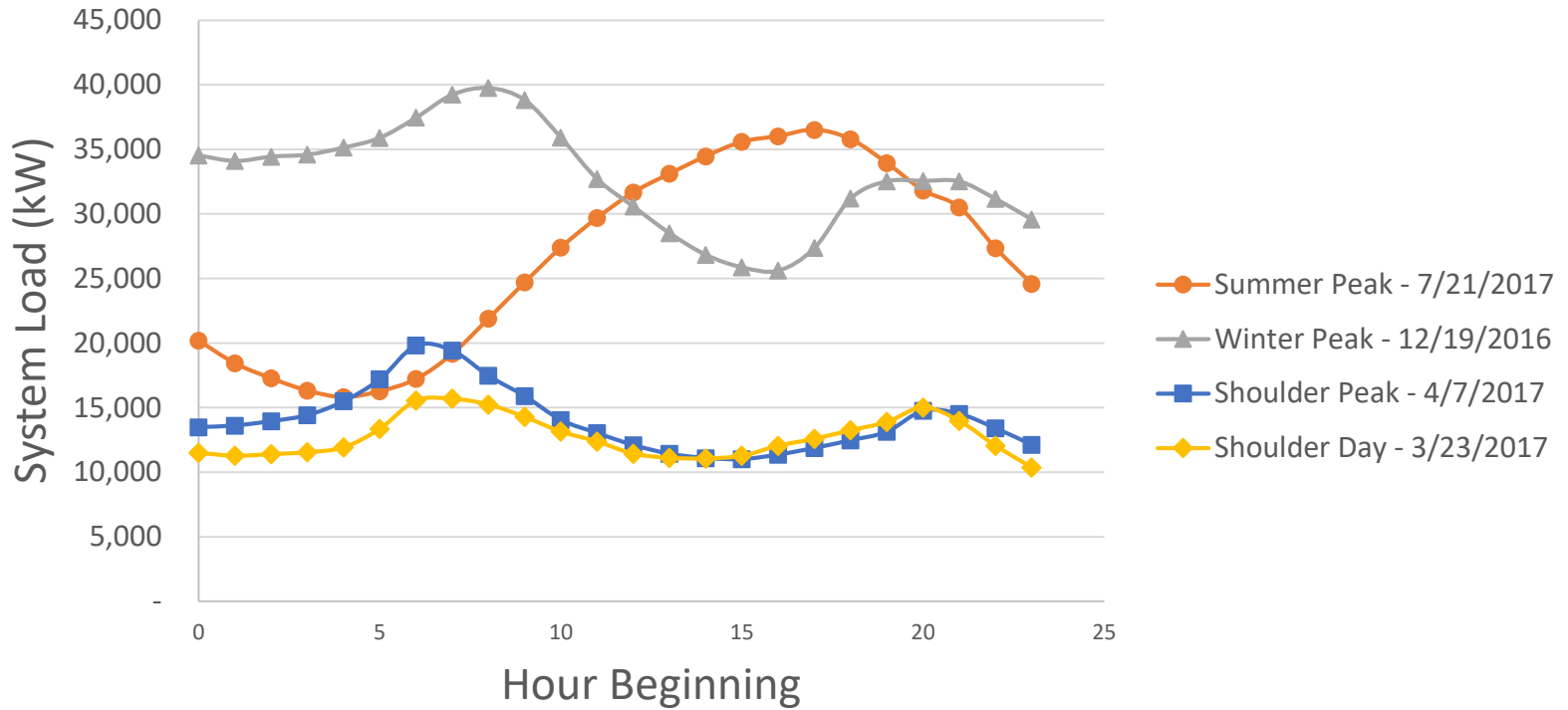
Rural Cooperative Case Study

- Analysis performed from two distinct perspectives
 - Member/Consumer
 - Cooperative Management
- Analyze economic impact on the Residential Class due to variable:
 - Levels of solar penetration
 - Configurations of Residential solar facilities
 - Billing mechanisms in place at the cooperative
 - Service Availability charges

Rural Cooperative Load Details

- Approximately 11,000 meters
- 95% belong to the Residential Class
- Average monthly Residential consumer usage is 1,023 kWh
- Typical load profile in the absence of solar distributed generation
 - Late afternoon & early evening peaking period during summer months
 - Morning & evening peaking periods during the winter months

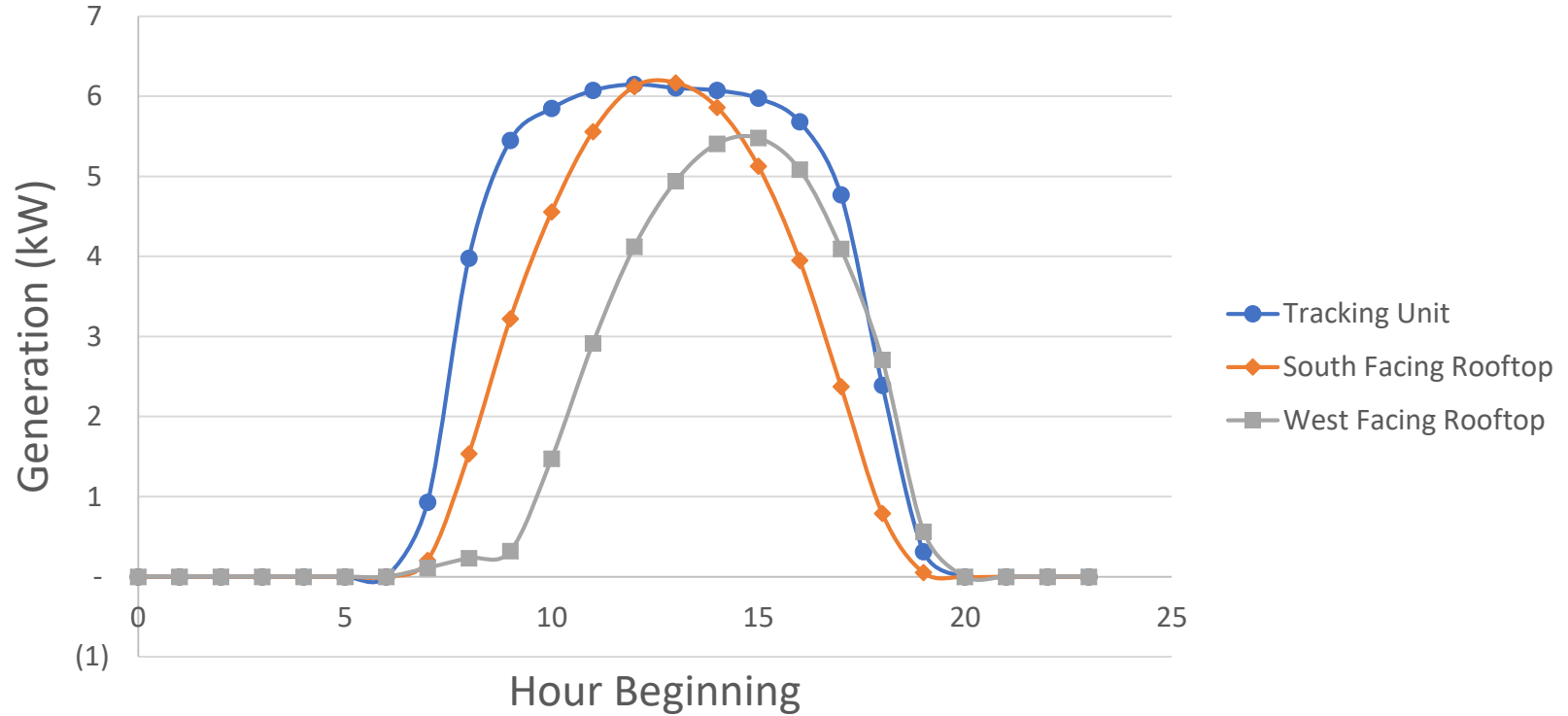
Utility Load Profile



Solar PV Generation

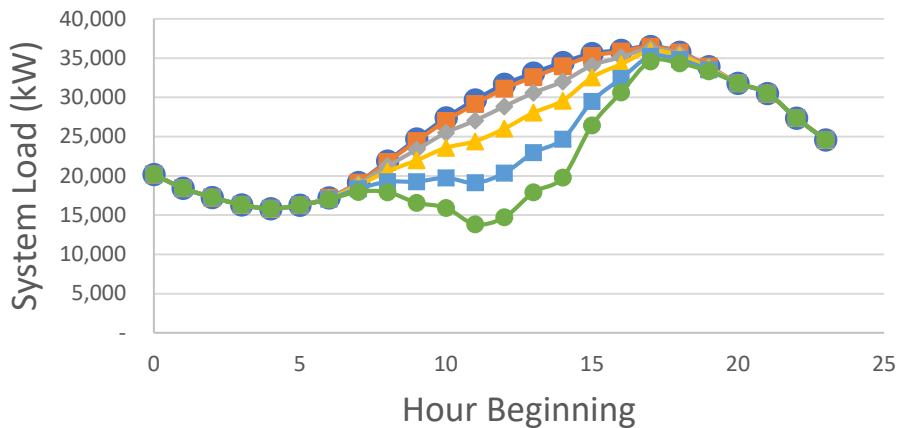
- Three distinct solar configurations utilized for analysis
 - South facing facility on the roof at 30° tilt
 - West facing facility on the roof at 30° tilt
 - South facing facility with tracking capabilities at 20° tilt
- Generation capacity of 7 kW for each configuration
- Assumed installation in Springfield, MO 65806
 - Location carries implications for weather data
- Generation data collected using PVWatts Calculator (NREL)

Solar Generation Profiles



(1)

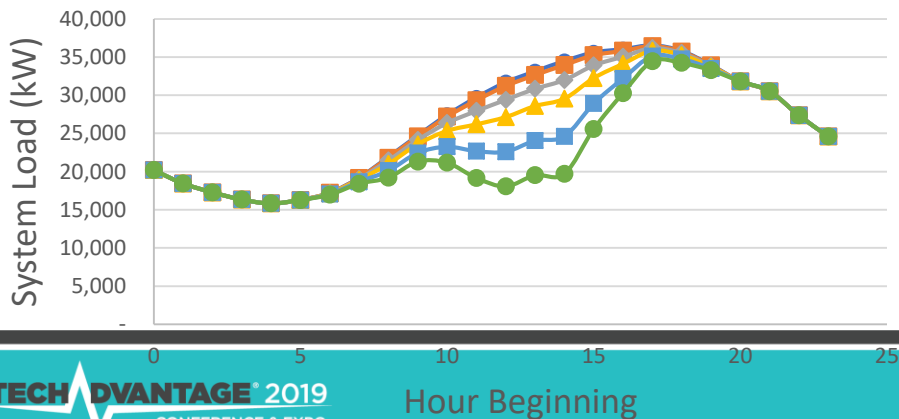
South Facing Rooftop Solar



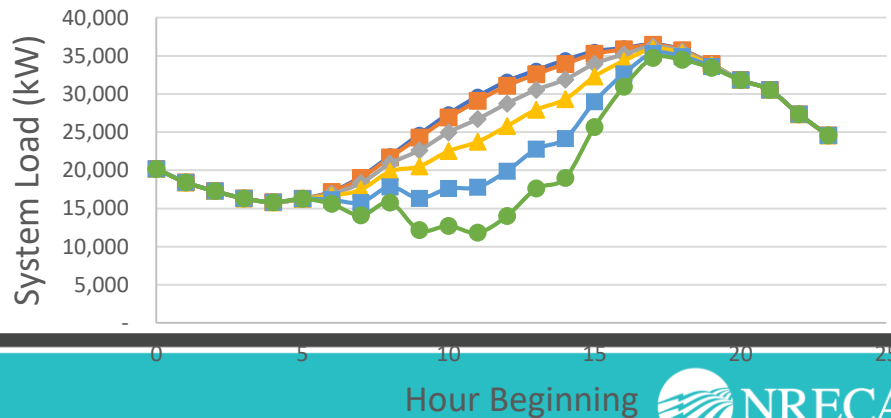
Summer Peak – 7/21/17

- No Solar
- 1% Penetration
- ◆— 5% Penetration
- ▲— 10% Penetration
- 20% Penetration
- 30% Penetration

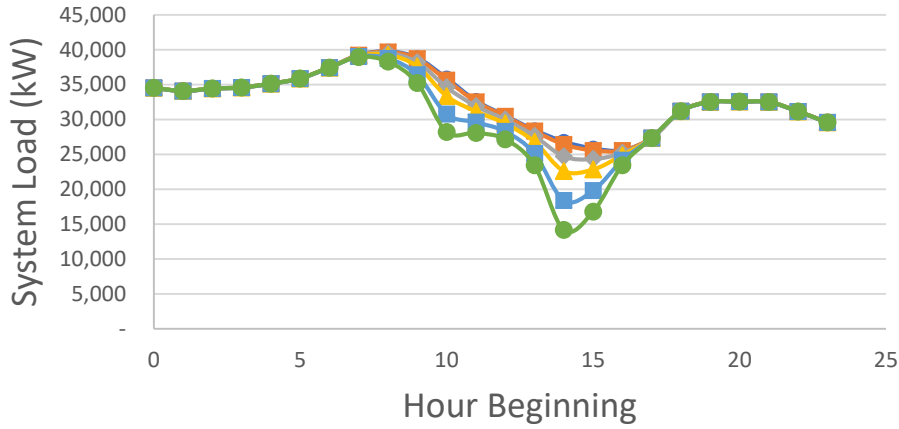
West Facing Rooftop Solar



Single Axis Tracking Solar



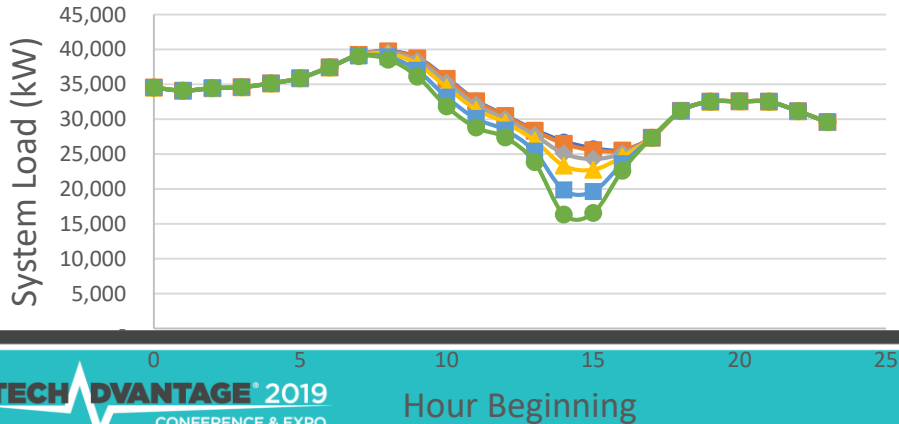
South Facing Rooftop Solar



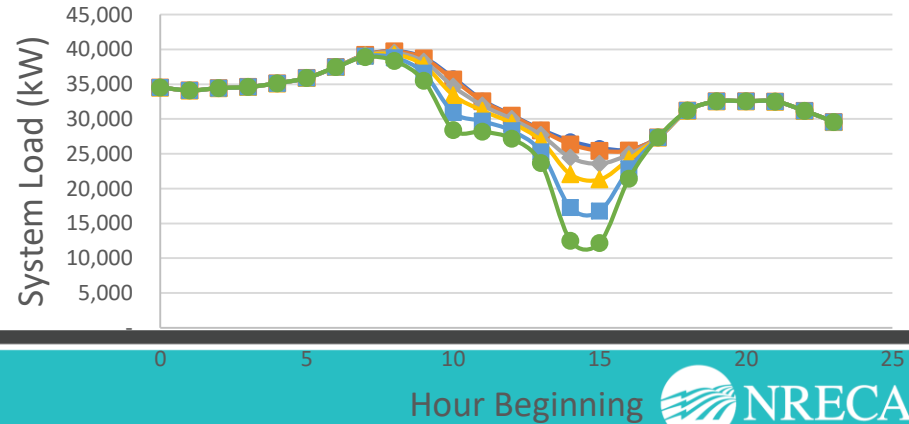
Winter Peak – 12/19/2016

- No Solar
- 1% Penetration
- ◆— 5% Penetration
- ▲— 10% Penetration
- 20% Penetration
- 30% Penetration

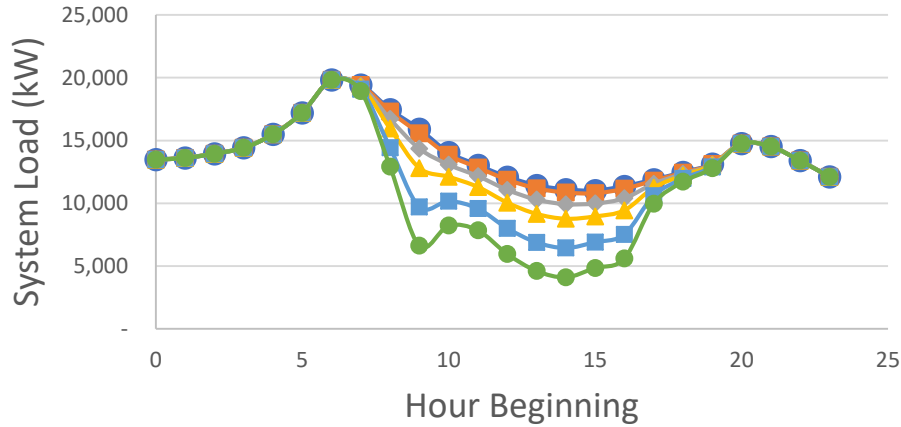
West Facing Rooftop Solar



Single Axis Tracking Solar



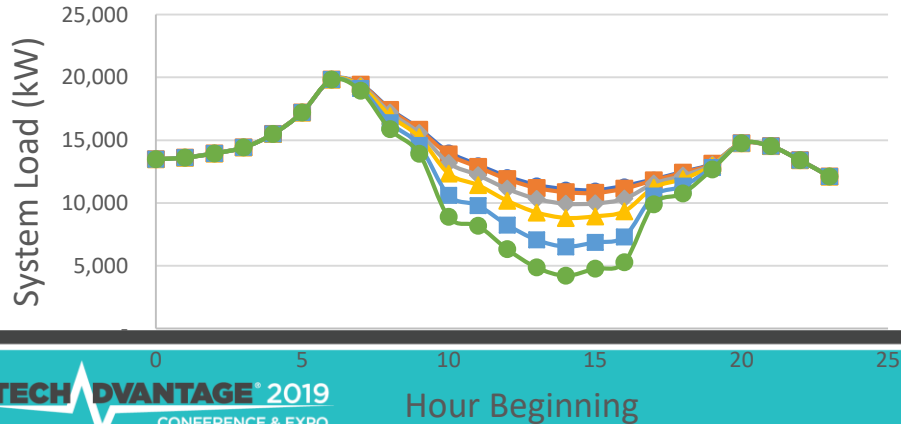
South Facing Rooftop Solar



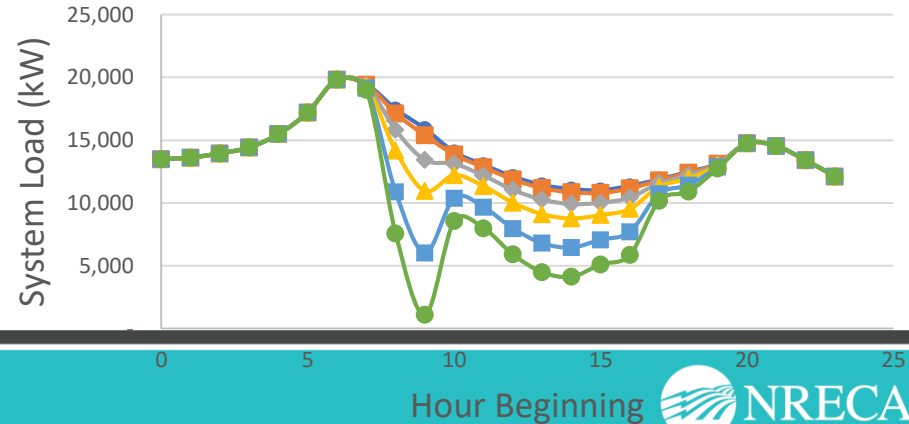
Shoulder Peak – 4/7/2017

- No Solar
- 1% Penetration
- ◆— 5% Penetration
- ▲— 10% Penetration
- 20% Penetration
- 30% Penetration

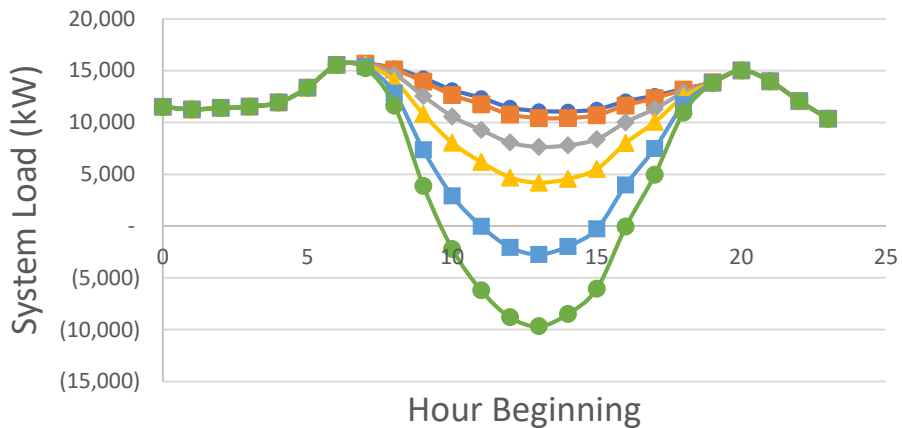
West Facing Rooftop Solar



Single Axis Tracking Solar



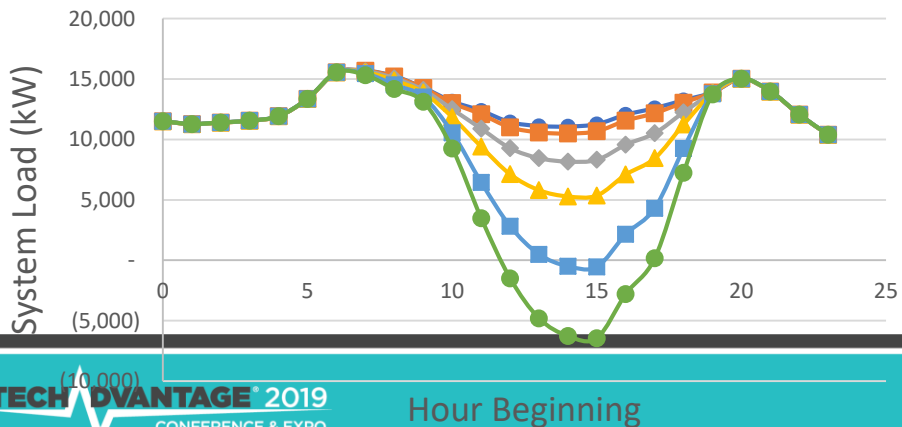
South Facing Rooftop Solar



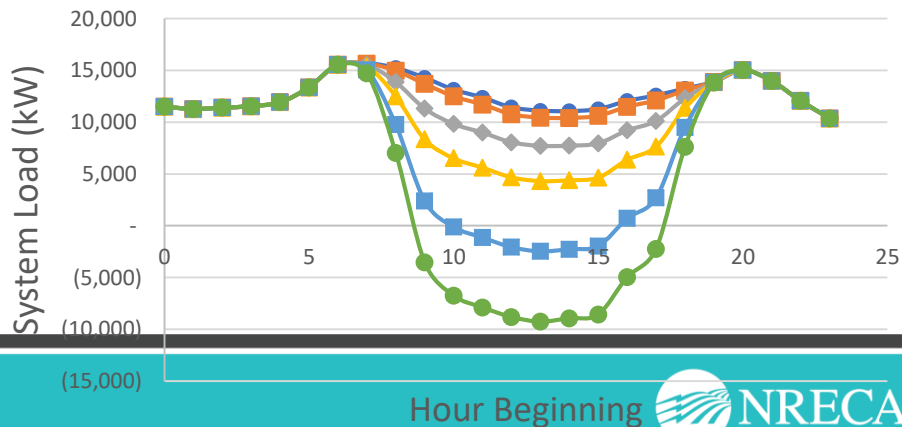
Minimal Load – 3/23/2017

- No Solar
- 1% Penetration
- ◇— 5% Penetration
- ▲— 10% Penetration
- 20% Penetration
- 30% Penetration

West Facing Rooftop Solar



Single Axis Tracking Solar



Rural Cooperative Economic Details

- Residential revenue per customer is approximately \$1,616 annually
- Allocated operating expense per customer is approximately \$1,467 annually
- 60.54% of expenses are attributable to wholesale power
- Wholesale power costs per unit sold to the Residential Class are as follows:
 - Energy costs are \$0.03895 per kWh
 - Demand costs are \$13.82 per monthly peak kW
 - Combined costs are \$0.07236 per kWh
- Residential consumers are billed according to a flat energy rate

Existing Billing Mechanism – Flat Energy Rate

	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.10623	\$108.68	\$0.12188	\$124.68
Total	-	\$134.68	-	\$134.68

Other Assumptions and Details

- Rates are designed to be revenue neutral in the absence of solar DG
- Required rate increases are calculated to maintain “Gross Margin”
 - Gross Margin: Total class revenue less wholesale power costs allocated to the class
- Wholesale power requirement is reduced based on PV Watt output
 - Demand and energy components of purchased power are reduced accordingly
- Rate impacts are analyzed at two different service availability charges
 - \$10 per month
 - \$26 per month

Net Metering

- Most common billing mechanism for DG customers
- Customer is billed only for “net” energy consumption
- Over-generation is credited to the customer at:
 - The retail rate of energy in the utility
 - The utility’s avoided cost when generation exceeds consumption
- The analysis utilizes the retail rates for energy billing and energy credits.
- Average billing kWh determinants are found below

<u>Solar Facility</u>	<u>Net Energy</u>
w/o Solar	1,023
West Roof Unit	342
South Roof Unit	193
Tracking System	17

Net Metering – Average Consumer Monthly Bill

<i>Net Metering</i>	\$26 Service Charge	\$10 Service Charge
w/o Solar	\$134.68	\$134.68
West Roof Unit	\$62.33	\$51.68
South Roof Unit	\$46.54	\$33.57
Tracking System	\$27.77	\$12.03

Net Metering – Impact to the Cooperative

<i>Net Metering</i>		Percent Gross Margin Lost		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.55%	0.33%	0.57%
	\$10	0.73%	0.47%	0.79%
5%	\$26	2.77%	1.63%	2.87%
	\$10	3.65%	2.35%	3.95%
10%	\$26	5.54%	3.25%	5.75%
	\$10	7.31%	4.71%	7.90%
20%	\$26	11.07%	6.51%	11.50%
	\$10	14.62%	9.42%	15.80%
30%	\$26	16.61%	9.76%	17.25%
	\$10	21.93%	14.12%	23.70%

Net Metering – Impact to the Cooperative

<i>Net Metering</i>		Percent Rate Increase Required		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.30%	0.18%	0.32%
	\$10	0.40%	0.26%	0.43%
5%	\$26	1.56%	0.91%	1.63%
	\$10	2.07%	1.32%	2.25%
10%	\$26	3.22%	1.87%	3.40%
	\$10	4.30%	2.73%	4.73%
20%	\$26	6.93%	3.97%	7.44%
	\$10	9.36%	5.84%	10.51%
30%	\$26	11.24%	6.33%	12.32%
	\$10	15.40%	9.43%	17.74%

Non-Coincident Demand

- Adds a demand component to traditional Residential billing schemes
- Maximum non-coincident metered demand is billed each month
- Analysis assumes \$5 charge for maximum monthly non-coin demand
 - Average Residential consumer registers 7.25 kW of monthly non-coin demand
- Customers pay a monthly service availability charge of \$10 or \$26
- Customers are billed for their net monthly energy consumption
- Billing determinants for the average consumer are found below

<u>Solar Facility</u>	<u>Net Energy</u>	<u>Non-Coin Demand</u>
w/o Solar	1,023	7.25
West Roof Unit	342	7.09
South Roof Unit	193	7.08
Tracking System	17	7.08

Non-Coincident Demand – Average Consumer Monthly Bill

<i>Non-Coincident Demand</i>	\$26 Service Charge	\$10 Service Charge
w/o Solar	\$134.66	\$134.67
West Roof Unit	\$85.64	\$74.99
South Roof Unit	\$75.08	\$62.11
Tracking System	\$62.56	\$46.82

Non-Coincident Demand – Impact to the Cooperative

<i>Non-Coincident Demand</i>		Percent Gross Margin Lost		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.16%	0.01%	0.10%
	\$10	0.34%	0.15%	0.31%
5%	\$26	0.82%	0.03%	0.50%
	\$10	1.71%	0.76%	1.57%
10%	\$26	1.64%	0.07%	1.00%
	\$10	3.41%	1.52%	3.15%
20%	\$26	3.28%	0.14%	1.99%
	\$10	6.82%	3.05%	6.29%
30%	\$26	4.91%	0.21%	2.99%
	\$10	10.23%	4.57%	9.44%

Non-Coincident Demand – Impact to the Cooperative

<i>Non-Coincident Demand</i>		Percent Rate Increase Required		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.09%	0.00%	0.05%
	\$10	0.19%	0.08%	0.17%
5%	\$26	0.46%	0.02%	0.28%
	\$10	0.95%	0.42%	0.88%
10%	\$26	0.93%	0.04%	0.57%
	\$10	1.96%	0.87%	1.83%
20%	\$26	1.96%	0.08%	1.21%
	\$10	4.16%	1.82%	3.94%
30%	\$26	3.08%	0.13%	1.94%
	\$10	6.64%	2.87%	6.38%

Non-Coincident Demand – Rate Comparison

Existing Rate				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.10623	\$108.68	\$0.12188	\$124.68
Total	-	\$134.68	-	\$134.68

\$5.00 Non-Coincident Demand Rate*				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.07078	\$13.69	\$0.08643	\$16.71
Non-Coin. kW	\$5.00	\$35.39	\$5.00	\$35.39
Total	-	\$75.08	-	\$62.11

Non-Coincident Demand Rate* Necessary to Eliminate Subsidy				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.05590	\$10.81	\$0.05545	\$10.72
Non-Coin. kW	\$7.10	\$50.26	\$9.37	\$66.33
Total	-	\$87.07	-	\$87.05

*Billing determinants used in bill calculations above consider a fixed, south facing solar installation.

Time of Use - Demand

- Time of Use (TOU) Rates are implemented for various reasons
 - Provide a more accurate portrayal of cost allocation across customer classes
 - Encourage peak load reduction with pricing signals
- Many utilities offer “opt-in” periods when rolling out a TOU rate
 - Opportunity to gauge customer interest
 - Observe effects using a small sample size; extrapolate to entire population
- Billing demand units based on maximum metered demand during peak hours
 - Study’s rural cooperative TOU hours are those hours beginning 7, 8, 16, 17, 18, and 19
- Demand charge is \$5 per unit of peak hours demand

Time of Use - Demand

- In addition to the demand billing component, customers pay:
 - Monthly service availability charge of \$10 or \$26
 - Retail rate for net energy consumed from the grid
- Billing determinants for the average consumer are found below

<u>Solar Facility</u>	<u>Net Energy</u>	<u>TOU Demand</u>
w/o Solar	1,023	7.00
West Roof Unit	342	6.86
South Roof Unit	193	6.81
Tracking System	17	6.80

TOU Demand – Average Consumer Monthly Bill

<i>Time of Use - Demand</i>	\$26 Service Charge	\$10 Service Charge
w/o Solar	\$134.66	\$134.67
West Roof Unit	\$84.91	\$74.26
South Roof Unit	\$73.97	\$60.99
Tracking System	\$61.22	\$45.48

TOU Demand – Impact to the Cooperative

<i>TOU Demand</i>		Percent Gross Margin Lost		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.18%	0.02%	0.12%
	\$10	0.36%	0.16%	0.33%
5%	\$26	0.90%	0.08%	0.59%
	\$10	1.78%	0.81%	1.66%
10%	\$26	1.79%	0.17%	1.18%
	\$10	3.56%	1.62%	3.33%
20%	\$26	3.58%	0.34%	2.36%
	\$10	7.13%	3.25%	6.66%
30%	\$26	5.37%	0.50%	3.54%
	\$10	10.69%	4.87%	9.99%

TOU Demand – Impact to the Cooperative

<i>TOU Demand</i>		Percent Rate Increase Required		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.10%	0.01%	0.06%
	\$10	0.19%	0.09%	0.18%
5%	\$26	0.50%	0.05%	0.33%
	\$10	1.00%	0.45%	0.94%
10%	\$26	1.02%	0.09%	0.68%
	\$10	2.05%	0.92%	1.94%
20%	\$26	2.14%	0.20%	1.44%
	\$10	4.35%	1.94%	4.18%
30%	\$26	3.38%	0.31%	2.30%
	\$10	6.96%	3.06%	6.78%

TOU Demand – Rate Comparison

Existing Rate				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.10623	\$108.68	\$0.12188	\$124.68
Total	-	\$134.68	-	\$134.68

\$5.00 TOU Demand Rate*				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.07201	\$13.93	\$0.08765	\$16.95
On-Peak Demand	\$5.00	\$34.04	\$5.00	\$34.04
Total	-	\$73.97	-	\$60.99

TOU Demand Rate* Necessary to Eliminate Subsidy				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.05565	\$10.76	\$0.05507	\$10.65
On-Peak Demand	\$7.39	\$50.31	\$9.76	\$66.45
Total	-	\$87.07	-	\$87.10

**Billing determinants used in bill calculations above consider a fixed, south facing solar installation.*

Time of Use - Energy

- Goals are essentially the same as those in the TOU – Demand rate
- Billing units are strictly units of energy
- Distinct on-peak and off-peak periods
 - On-Peak period includes hours beginning 7, 8, 16, 17, 18, and 19
 - On-Peak energy is billed at \$0.25000
 - Off-Peak energy is billed at \$0.07258
- Billing determinants for the average consumer without solar are found below

<u>Solar Facility</u>	<u>On-Peak Energy</u>	<u>Off-Peak Energy</u>
w/o Solar	284	739
West Roof Unit	102	240
South Roof Unit	137	56
Tracking System	27	(10)

TOU Energy – Average Consumer Monthly Bill

<i>Time of Use - Energy</i>	\$26 Service Charge	\$10 Service Charge
w/o Solar	\$134.65	\$134.66
West Roof Unit	\$63.68	\$52.89
South Roof Unit	\$63.10	\$48.33
Tracking System	\$32.16	\$15.94

TOU Energy – Impact to the Cooperative

TOU Energy		Percent Gross Margin Lost		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.33%	0.31%	0.51%
	\$10	0.53%	0.45%	0.74%
5%	\$26	1.64%	1.53%	2.57%
	\$10	2.65%	2.27%	3.68%
10%	\$26	3.27%	3.07%	5.15%
	\$10	5.29%	4.54%	7.36%
20%	\$26	6.55%	6.13%	10.29%
	\$10	10.58%	9.08%	14.72%
30%	\$26	9.82%	9.20%	15.44%
	\$10	15.87%	13.62%	22.09%

TOU Energy – Impact to the Cooperative

TOU Energy		Percent Rate Increase Required		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.18%	0.17%	0.28%
	\$10	0.29%	0.25%	0.40%
5%	\$26	0.91%	0.86%	1.46%
	\$10	1.49%	1.27%	2.09%
10%	\$26	1.88%	1.76%	3.03%
	\$10	3.08%	2.63%	4.39%
20%	\$26	3.98%	3.73%	6.61%
	\$10	6.60%	5.62%	9.73%
30%	\$26	6.35%	5.94%	10.89%
	\$10	10.69%	9.06%	16.34%

TOU Energy – Rate Comparison

Existing Rate				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.10623	\$108.68	\$0.12188	\$124.68
Total	-	\$134.68	-	\$134.68

TOU Energy Rate*				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
On-Peak Energy	\$0.25000	\$34.23	\$0.25000	\$34.23
Off-Peak Energy	\$0.05091	\$2.88	\$0.07258	\$4.10
Total	-	\$63.10	-	\$48.33

TOU Energy Rate* – Off Peak Energy at Wholesale Energy Cost to Utility				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
On-Peak Energy	\$0.28111	\$38.16	\$0.33740	\$46.19
Off-Peak Energy	\$0.03895	\$2.25	\$0.03895	\$2.20
Total	-	\$66.41	-	\$58.39

*Billing determinants used in bill calculations above consider a fixed, south facing solar installation.

Two-Channel Billing

- Channel 1 energy is *consumed from* the grid by the consumer
 - Billed at the retail rate in this analysis
- Channel 2 energy is consumer generation *fed back onto* the grid
 - Credited at another, generally lesser, rate
 - \$0.04 in the cooperative used for analysis
- Billing units for the average consumer are found below

<u>Solar Facility</u>	<u>Channel 1</u>	<u>Channel 2</u>
w/o Solar	1,023	0
West Roof Unit	629	(287)
South Roof Unit	608	(414)
Tracking System	575	(558)

Two Channel – Average Consumer Monthly Bill

<i>Two Channel</i>	\$26 Service Charge	\$10 Service Charge
w/o Solar	\$134.68	\$134.68
West Roof Unit	\$81.36	\$75.21
South Roof Unit	\$73.99	\$67.50
Tracking System	\$64.72	\$57.71

Two Channel – Impact to the Cooperative

<i>Two Channel</i>		Percent Gross Margin Lost		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.18%	0.07%	0.07%
	\$10	0.27%	0.15%	0.17%
5%	\$26	0.89%	0.33%	0.35%
	\$10	1.34%	0.75%	0.83%
10%	\$26	1.79%	0.65%	0.70%
	\$10	2.68%	1.50%	1.66%
20%	\$26	3.58%	1.31%	1.41%
	\$10	5.35%	2.99%	3.32%
30%	\$26	5.37%	1.96%	2.11%
	\$10	8.03%	4.49%	4.99%

Two Channel – Impact to the Cooperative

<i>Two Channel</i>		Percent Rate Increase Required		
Solar Penetration	Availability Charge	South Facing Rooftop	West Facing Rooftop	Single Axis Tracking
1%	\$26	0.10%	0.04%	0.04%
	\$10	0.15%	0.08%	0.09%
5%	\$26	0.50%	0.18%	0.20%
	\$10	0.75%	0.42%	0.47%
10%	\$26	1.02%	0.37%	0.40%
	\$10	1.53%	0.85%	0.96%
20%	\$26	2.14%	0.77%	0.85%
	\$10	3.23%	1.79%	2.04%
30%	\$26	3.38%	1.21%	1.36%
	\$10	5.14%	2.81%	3.27%

Two Channel – Rate Comparison

Existing Rate				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Energy	\$0.10623	\$108.68	\$0.12188	\$124.68
Total	-	\$134.68	-	\$134.68

Two Channel Rate*				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Channel 1 Energy	\$0.10623	\$64.57	\$0.12188	\$74.08
Channel 2 Energy	\$0.04000	(\$16.58)	\$0.04000	(\$16.58)
Total	-	\$73.99	-	\$67.50

Two Channel Rate* – Channel 2 Energy at Wholesale Energy Cost to Utility				
	Rate I	Electric Revenue I	Rate II	Electric Revenue II
Availability	\$26.00	\$26.00	\$10.00	\$10.00
Channel 1 Energy	\$0.10623	\$64.57	\$0.12188	\$74.08
Channel 2 Energy	\$0.03895	(\$16.14)	\$0.03895	(\$16.14)
Total	-	\$74.43	-	\$67.94

*Billing determinants used in bill calculations above consider a fixed, south facing solar installation.

Cooperative Impact Summary

<i>South Facing Rooftop Solar</i>		Percent Gross Margin Lost				
Solar Penetration	Availability Charge	Net Metering	Non-Coincident Demand	Time of Use Demand	Time of Use Energy	Two Channel
1%	\$26	0.55%	0.16%	0.18%	0.33%	0.18%
	\$10	0.73%	0.34%	0.36%	0.53%	0.27%
5%	\$26	2.77%	0.82%	0.90%	1.64%	0.89%
	\$10	3.65%	1.71%	1.78%	2.65%	1.34%
10%	\$26	5.54%	1.64%	1.79%	3.27%	1.79%
	\$10	7.31%	3.41%	3.56%	5.29%	2.68%
20%	\$26	11.07%	3.28%	3.58%	6.55%	3.58%
	\$10	14.62%	6.82%	7.13%	10.58%	5.35%
30%	\$26	16.61%	4.91%	5.37%	9.82%	5.37%
	\$10	21.93%	10.23%	10.69%	15.87%	8.03%

Cooperative Impact Summary

<i>South Facing Rooftop Solar</i>		Percent Rate Increase Required				
Solar Penetration	Availability Charge	Net Metering	Non-Coincident Demand	Time of Use Demand	Time of Use Energy	Two Channel
1%	\$26	0.30%	0.09%	0.10%	0.18%	0.10%
	\$10	0.40%	0.19%	0.19%	0.29%	0.15%
5%	\$26	1.56%	0.46%	0.50%	0.91%	0.50%
	\$10	2.07%	0.95%	1.00%	1.49%	0.75%
10%	\$26	3.22%	0.93%	1.02%	1.88%	1.02%
	\$10	4.30%	1.96%	2.05%	3.08%	1.53%
20%	\$26	6.93%	1.96%	2.14%	3.98%	2.14%
	\$10	9.36%	4.16%	4.35%	6.60%	3.23%
30%	\$26	11.24%	3.08%	3.38%	6.35%	3.38%
	\$10	15.40%	6.64%	6.96%	10.69%	5.14%

Other Considerations

- Implementation of Rate Structures
 - Survey Membership
 - Member-consumer education
 - Phase in New Rates
 - Gradually increase demand charges: Start at \$0.
- Engineering Concerns
 - High penetration levels will cause reverse power flow
 - Voltage sags/swells/flicker could be more common with high penetration levels
 - Voltage during the shoulder months
 - Minimum load with Maximum generation
 - Regulator Settings
 - Battery Technology

Questions?

Contact Information:

Adam Toth, Vice President, Toth and Associates

- atoth@tothassociates.com
- 417-888-0645

