

# Case Studies: Customer Adoption Responses to Market Changes

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# Case Study Background / Overview

- Presented three case study “strawman” options in March 2019. The three case studies included here correspond to the third option
- Based on SDS Tool, version 2.3, publicly available. This was presented in previous Technical Committee meetings and at the MnSEIA Gateways conference
- Uses hourly load data by class provided by utilities (protected by trade secret)
- Three case studies are included:
  - Xcel Energy
  - Minnesota Power
  - Otter Tail Power
- Three scenarios are included
  - Residential Demand Rate
  - Residential TOD Rate
  - Various incentive scenarios

# SDS Planning Tool

# SDS Planning Tool Overview

Models future adoption of solar in a defined region

Forecasts “behavioral response” to cost-effectiveness

- Electric rates
- Compensation policies for excess solar
- Incentives

Uses machine-learning methods

- Logistic regression of predictor variables
- Training on historical data

# Bill Calculation: Illustration

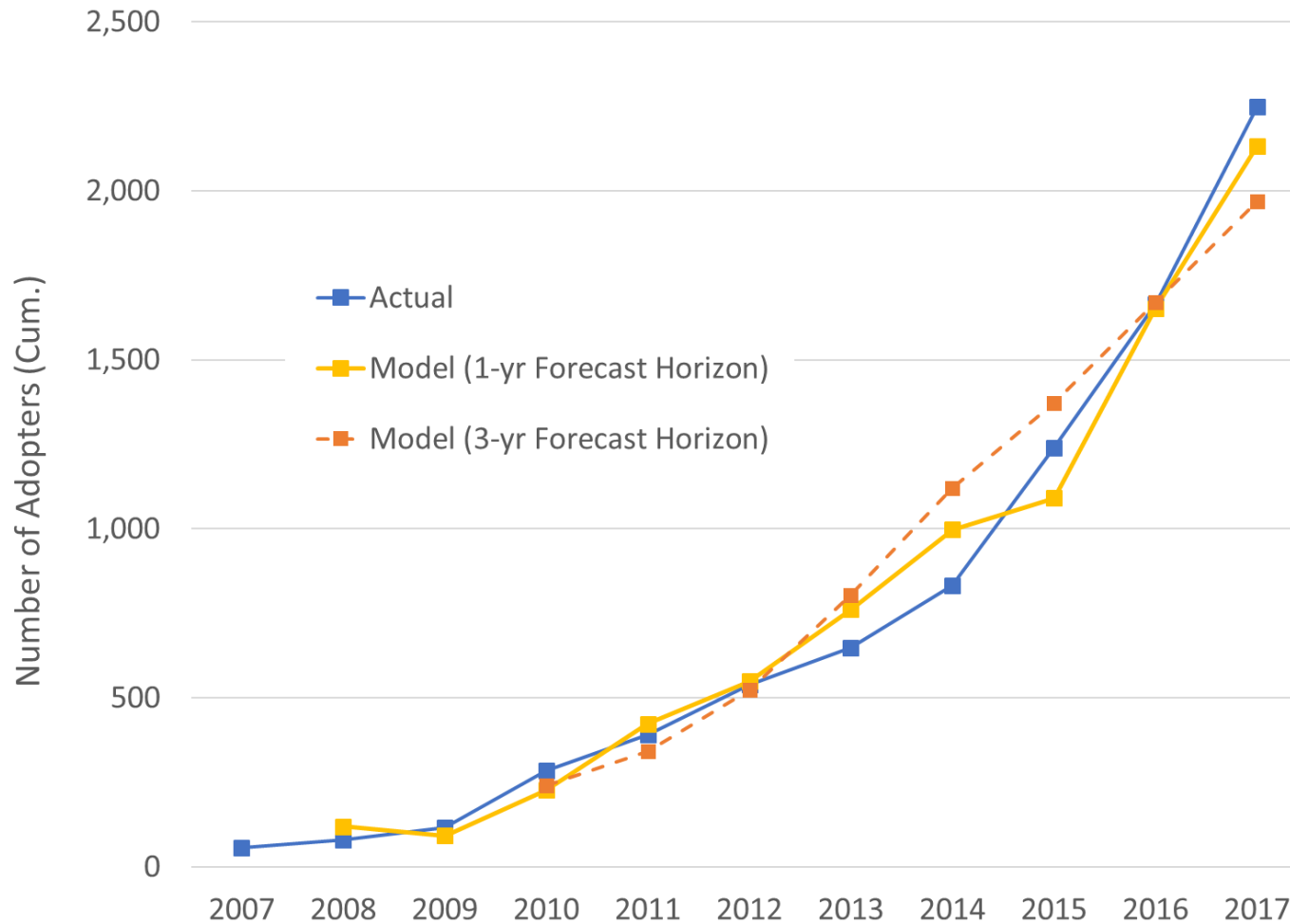
On peak billing determinants  
 June-Sept, M-F, 9 am to 9 pm

- Xcel Energy - Small General TOD Service
- 2869 Customers in class
- 14 MWh annual usage (average customer)
- Solar: South facing, 20-degree tilt angle
- Solar sized for 100% energy offset, annual basis
- Hourly load and solar profiles

	Solar Load (kWh)	Solar Prod (kWh)	Self-Cons (kWh)	Export (kWh)	Import (kWh)	Net Export (kWh)	Net Import (kWh)	Peak, No Solar (kW)	Peak, W/Solar (kW)
Jan									
Feb									
Mar									
Apr									
May									
Jun	456	990	388	602	68	534	0	2.803	2.056
Jul	495	1135	428	707	67	640	0	2.687	1.881
Aug	479	968	393	575	86	489	0	2.710	1.909
Sep	398	755	292	464	106	358	0	2.525	1.803
Oct									
Nov									
Dec									
	1,828	3,848	1,501	2,347	327	2,021	0	2.803	2.056

# Model Goodness-of-Fit

Xcel Energy, Residential



# SDS Planning Tool Inputs

## Hourly customer load profiles (8760 hours)

- User-defined profiles, or
- Utility-provided profiles by class (MSP project only, protected by trade secret)
- Selectable loads by class (from AEP Ohio rate classes)

## Hourly solar production profiles (8760 hours)

- User-defined profiles, or
- Selectable profiles (any of five orientations, CPR simulated for Minnesota)

## Electric rates

- User-defined rates

## Other (solar costs, escalation, etc.)

# Logistic Regression Model

## Predictor variables

- Simple payback period (years)
- Fraction of customers already adopted solar

## Binary response

- 0 = Non-adopter
- 1 = Adopter

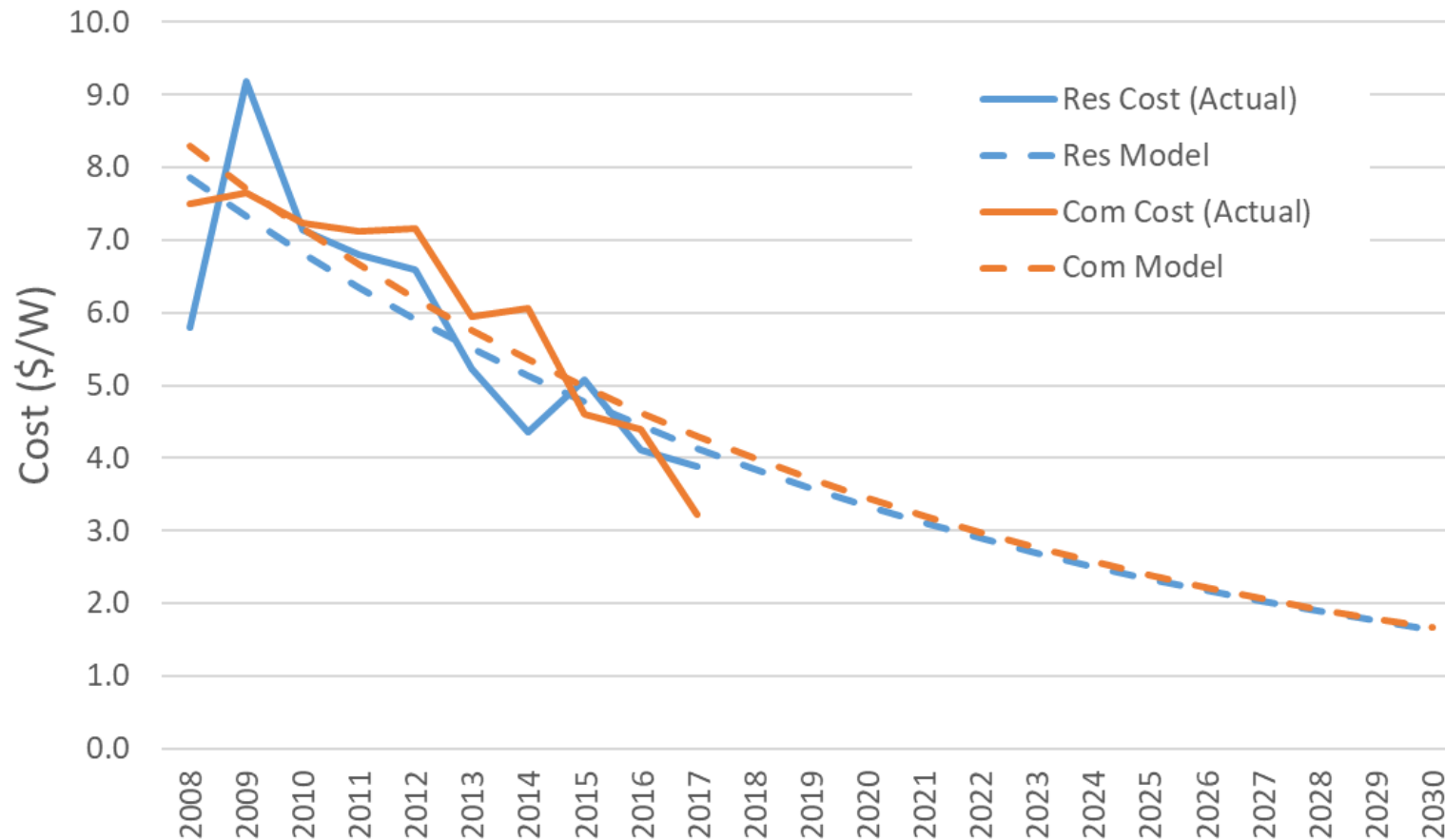
Model training produces sensitivity to the predictors

## Output

- Probability of adoption per customer
- Total adoption in study region



# MN Installed PV Costs: Historical and Projected



# Simple Payback Predictors: Model Training

Xcel Energy, Residential

2019 Energy Rate (\$/kWh)                      0.108                      (Residential)  
 PV Annual Energy (kWh/kW)                      1211                      (SW-45)  
 Escalation - Electric Rates                      2%

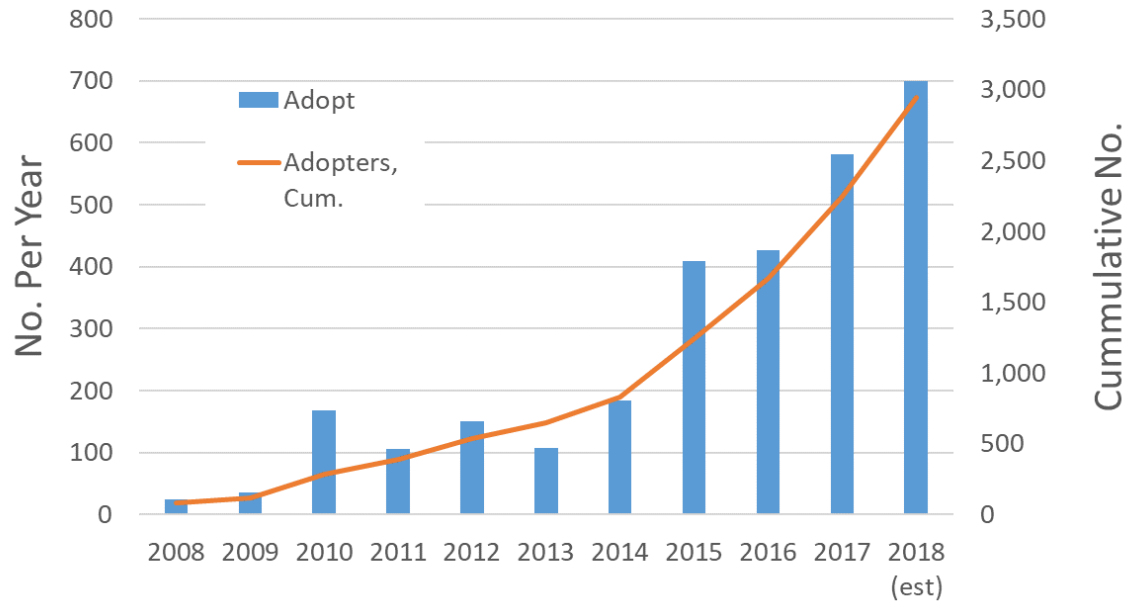
	Esc. Factor	Bill Savings (\$/W-yr)	PV Cost (\$/W)	MN Incentive (\$/W)	ITC	Payback (yrs)
2008	0.80	0.1052	5.8	0.00	0.30	39
2009	0.82	0.1073	9.2	0.00	0.30	60
2010	0.84	0.1094	7.1	2.25	0.30	31
2011	0.85	0.1116	6.8	2.25	0.30	28
2012	0.87	0.1139	6.6	2.25	0.30	27
2013	0.89	0.1161	5.2	1.50	0.30	22
2014	0.91	0.1185	4.4	1.53	0.30	17
2015	0.92	0.1208	5.1	1.53	0.30	20
2016	0.94	0.1232	4.1	1.53	0.30	15
2017	0.96	0.1257	3.9	1.53	0.30	13
2018	0.98	0.1282	3.9	1.53	0.30	13
2019	1.00					

# Xcel Energy Case Study

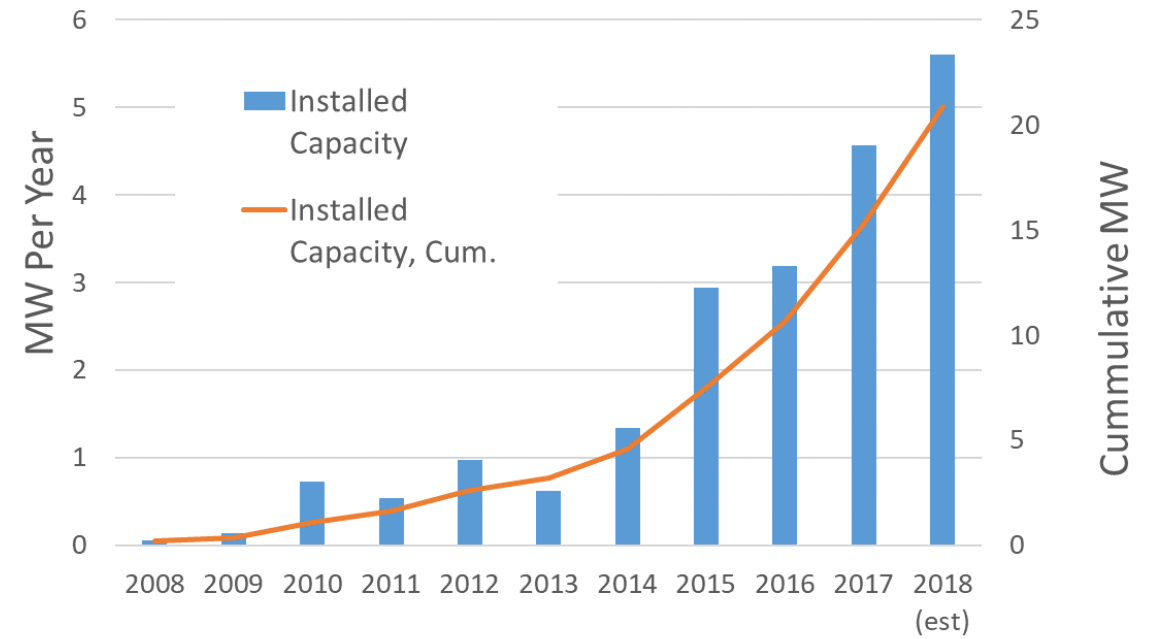
# Residential Rooftop Adoption

Xcel Energy

Adopter Count



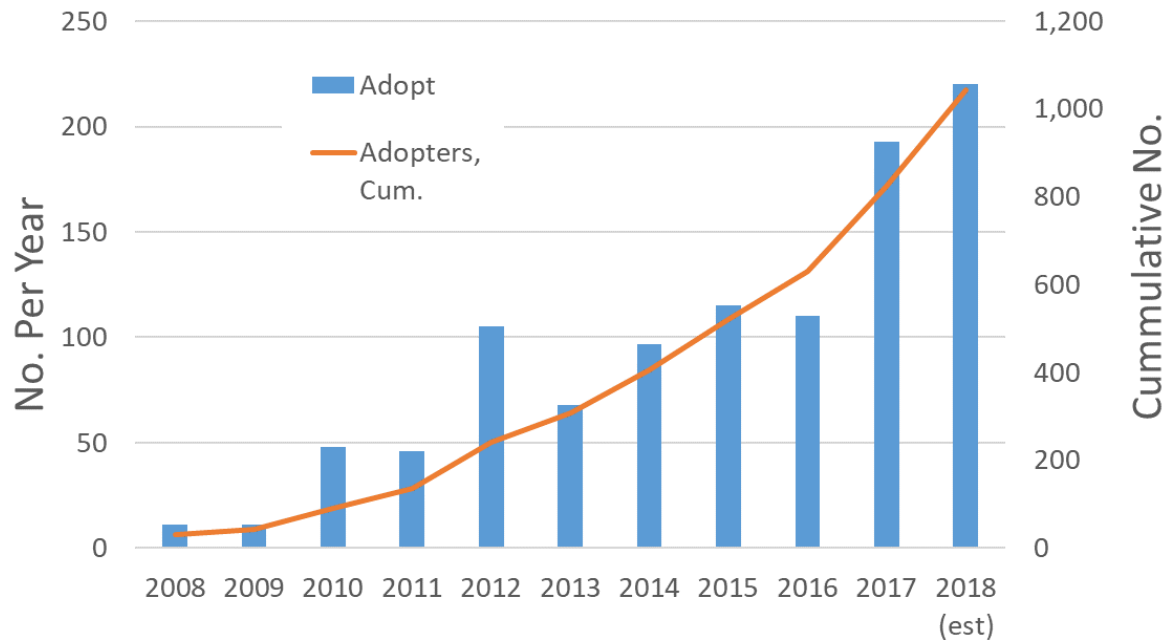
Adoption Capacity



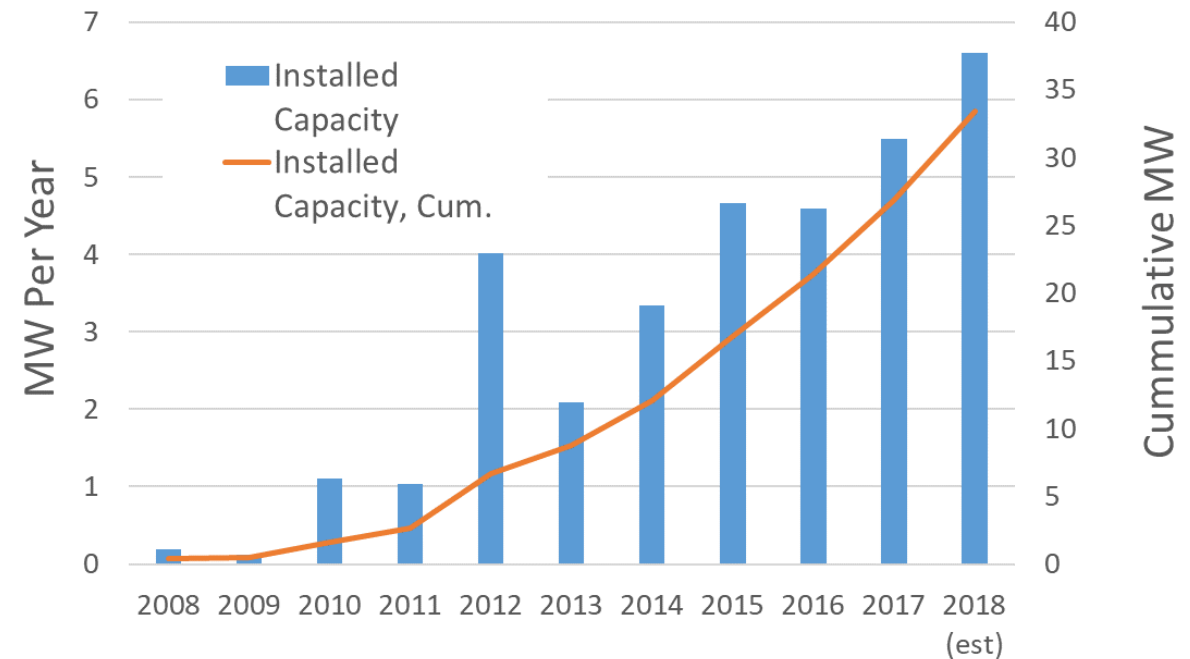
# Commercial Rooftop Adoption

Xcel Energy

Adopter Count



Adoption Capacity



# Baseline

Xcel Energy

No. of Customers	Description	Sector	Annual Usage (MWh per cust)	Electric Rate
1,132,296	Residential without Htg	Residential	7	Residential Service (A01 Std)
34,302	Residential with Htg	Residential	11	Residential Service (A01 Std)
86,088	C&I Non Demand	Commerical	10	Small General Service (A10)
45,848	Small C&I Secondary	Commerical	217	General Service (A14)
1,560	Small Interruptible Secondary	Commerical	922	Small General Service (A10)
243	Large C&I Secondary	Commerical	7,729	General Service (A14)
7	Large C&I Primary	Commerical	292,430	General Service (A14)
180	Large Interruptible Primary	Commerical	6,948	General Service (A14)

Not all electric rates were modeled. This list shows the assignments of modeled rate to customer type as performed in the study.

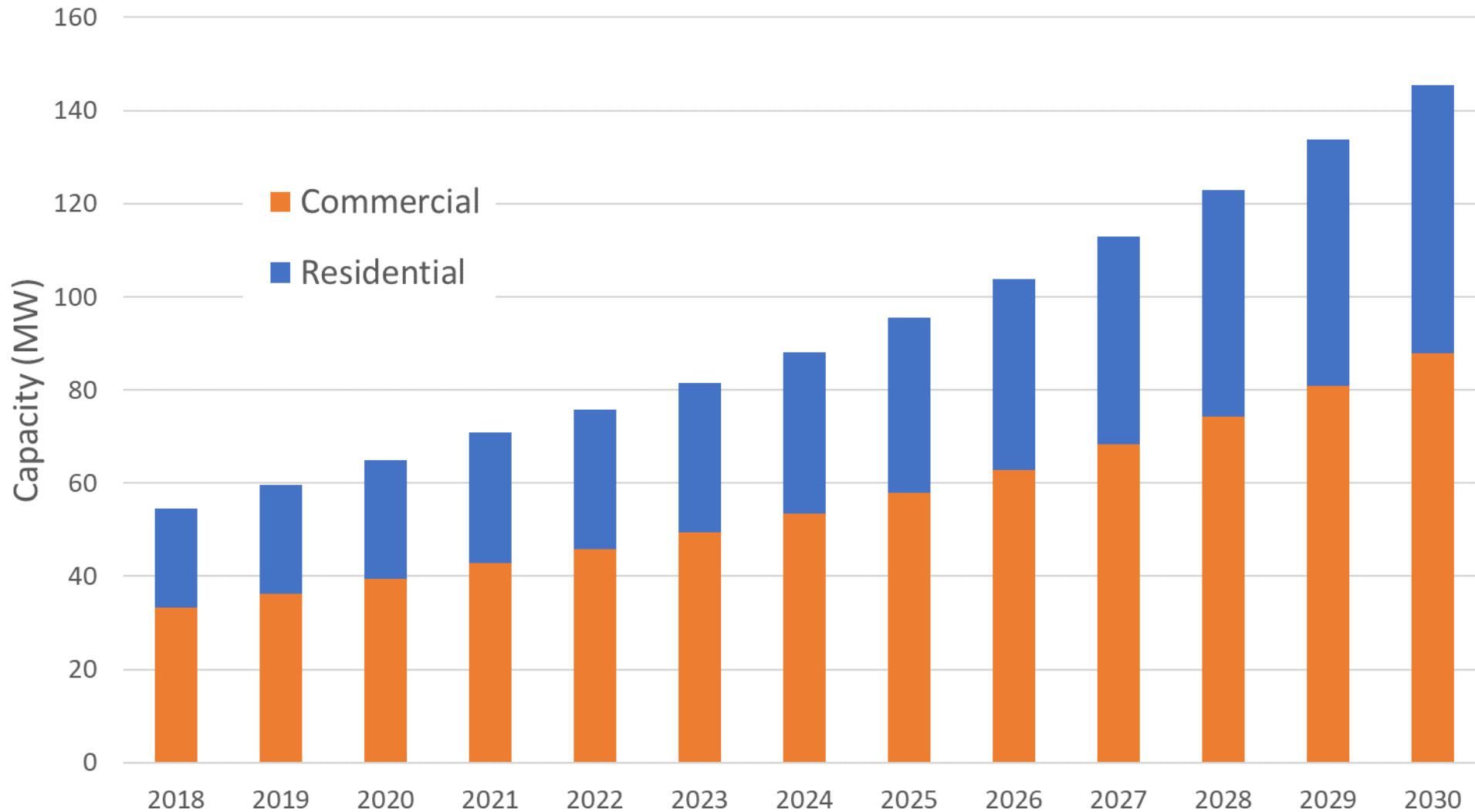
# Baseline

Xcel Energy

- Electric space heating makes up only 2.9% of the residential customers. These treated as standard customers.
- Seasonal weighting applied for non-TOD pricing and General Service demand rate.
- General Service: credit for usage above  $400 \times$  billing demand is not included. Secondary service assumed.

# Forecast: Baseline

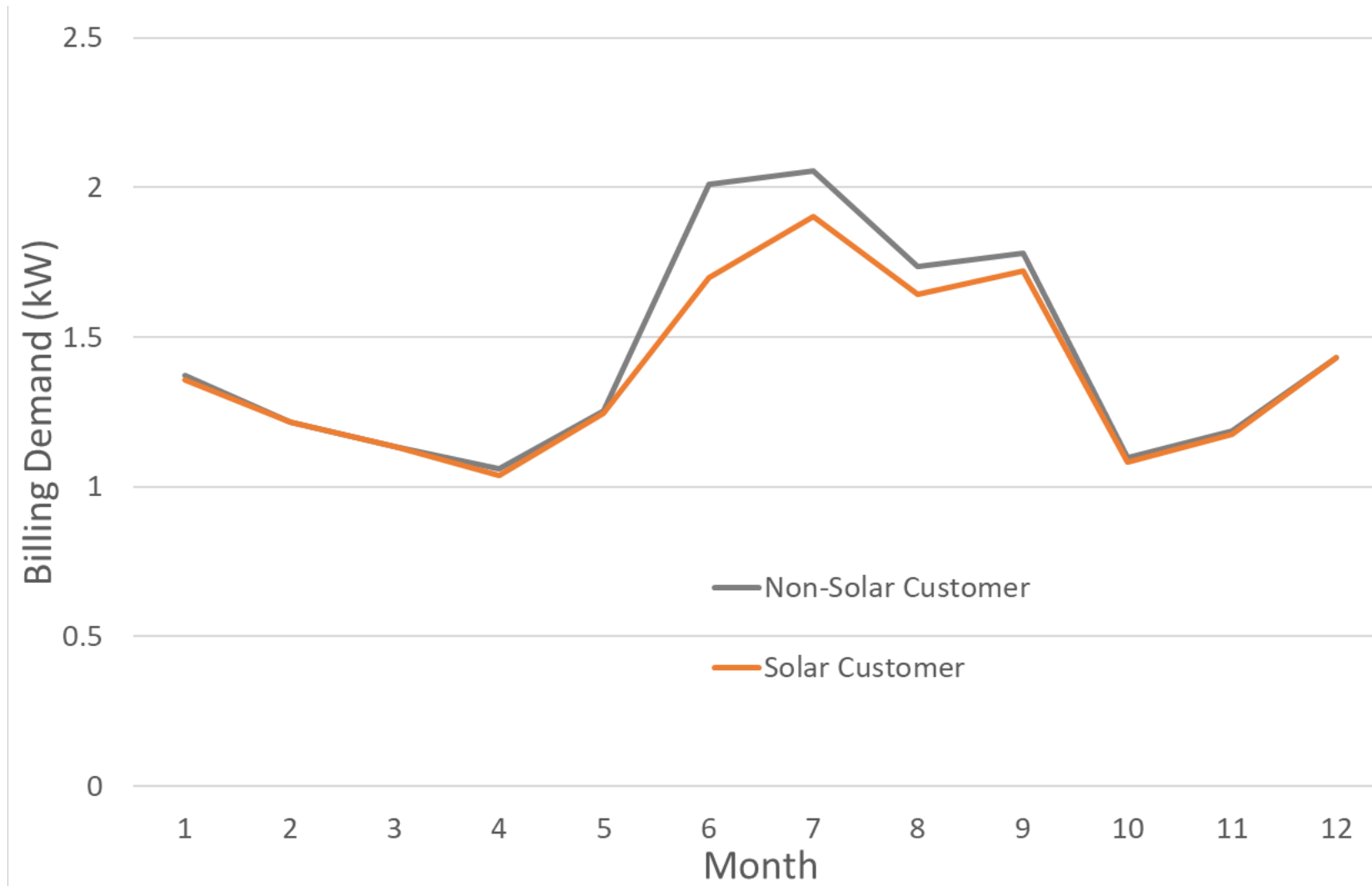
Xcel Energy, Rooftop Adoption, Cumulative





# Residential Customer Billing Demand

Xcel Energy, Residential w/o Heating, South-20, 100% Solar Offset



# Residential Demand Rate Scenario

Xcel Energy

Demand charge set such that

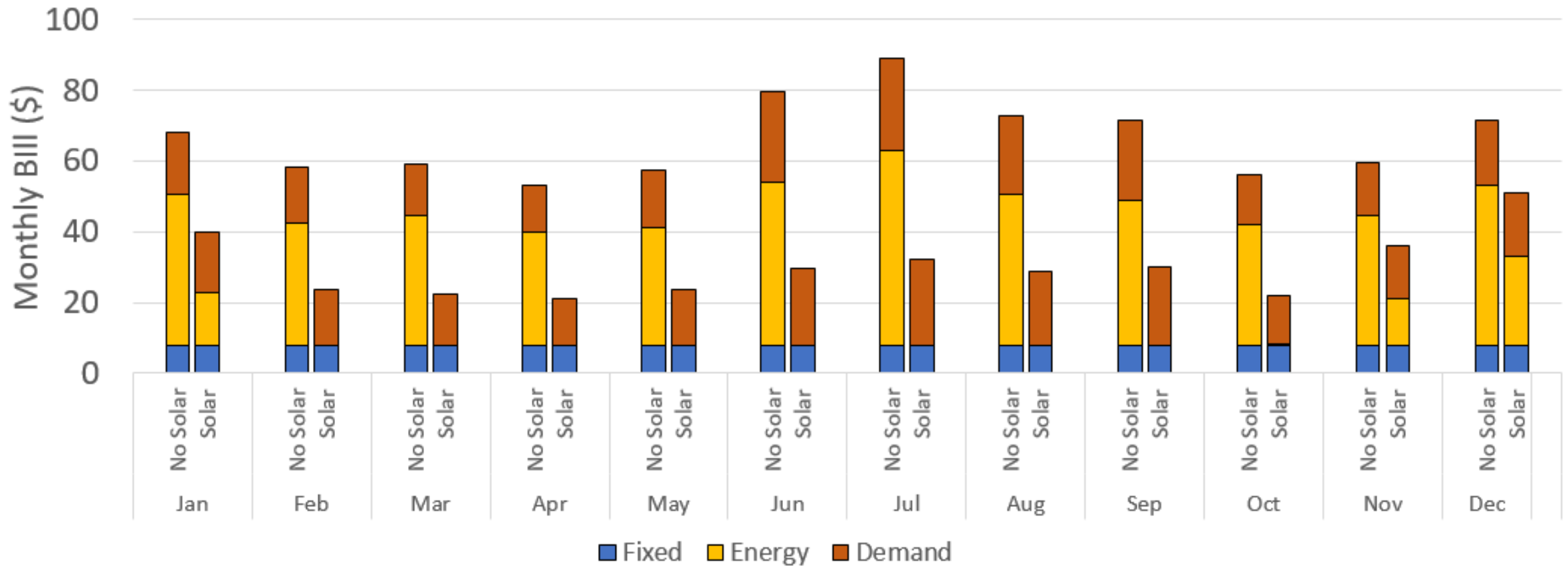
- Seasonally adjusted demand charge is the same as for General Service Customers (\$12.70) and
- Total bill for non-solar customers is not changed (\$795.63)

Demand charge applied to both standard and electric heating customers

Scenario	Pricing			Annual Bill			
	Fixed (\$)	Energy (\$/kWh)	Demand (\$/kW)	Fixed (\$)	Energy (\$)	Demand (\$)	Total (\$)
Baseline	8.00	0.09847		96.00	699.63		795.63
Residential Demand	8.00	0.06737	12.70	96.00	478.65	220.98	795.63

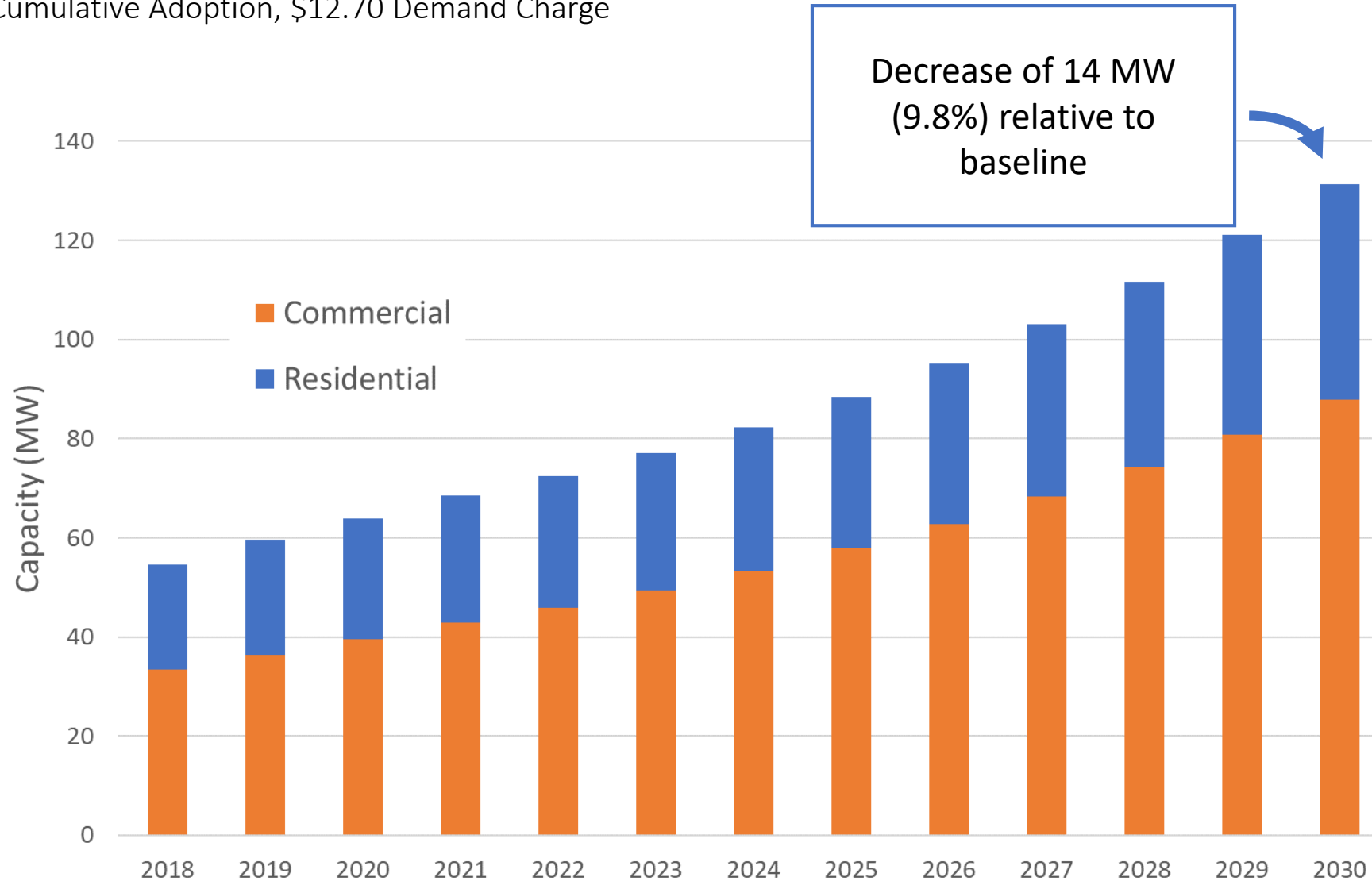
# Residential Demand Rate: Monthly Bills

Xcel Energy



# Forecast: Residential Demand Scenario

Xcel Energy, Cumulative Adoption, \$12.70 Demand Charge



# TOD Periods

Xcel Energy

Weekdays		Hour of Day																								
Month		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
	1	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3
	2	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3
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	12	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3

Weekends & Holidays		Hour of Day																								
Month		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
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	12	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Tariff book publishes separate prices for off-peak energy by season, but they are the same prices throughout year. All off-peak pricing is therefore treated as a single period.

# Residential TOD Rate Scenario

Xcel Energy

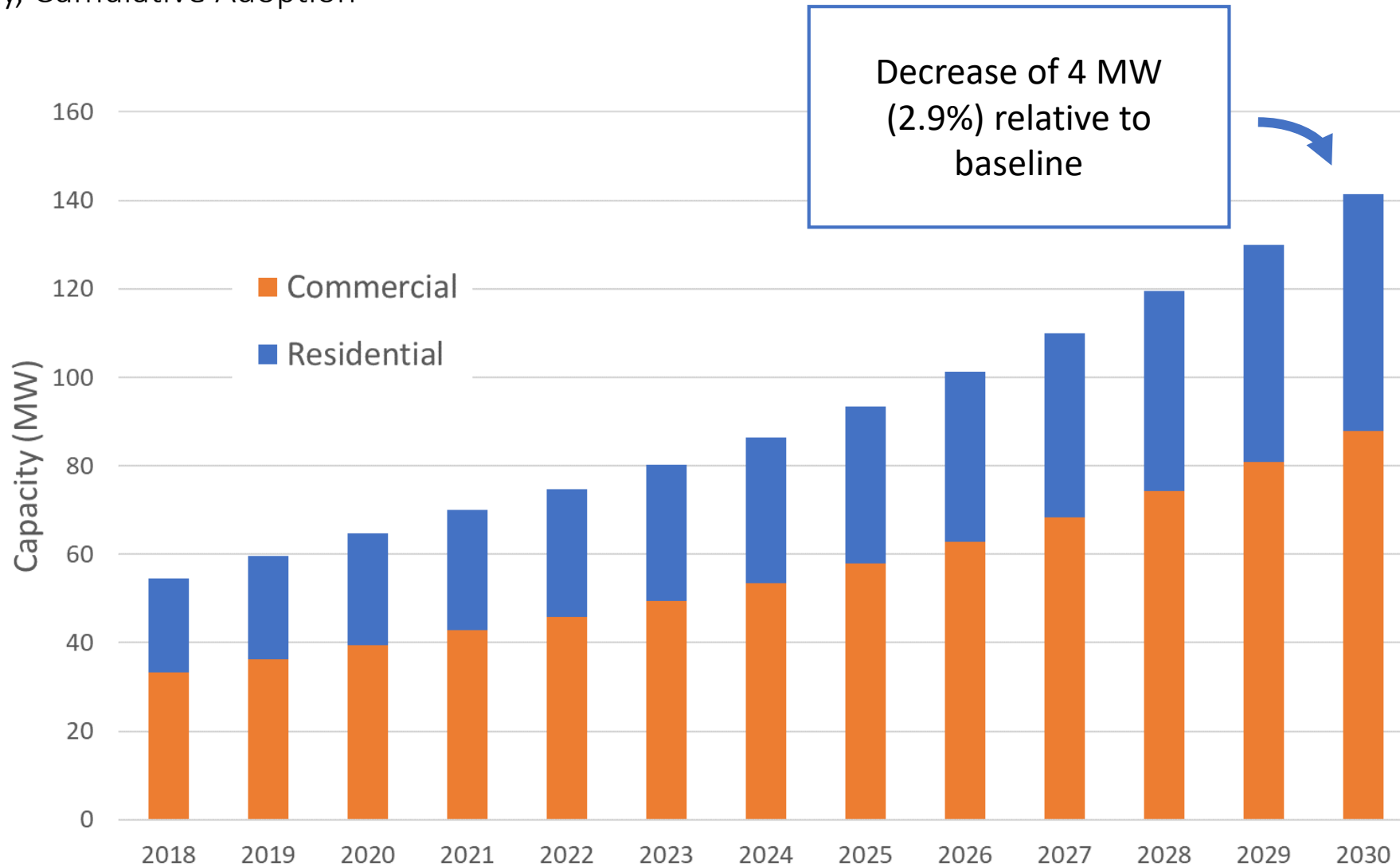
Based on existing residential TOD rate (Rate A02)

Required that all residential customers switch to TOD rate (standard and all-electric heating customers)

Scenario	Energy Pricing			
	All kWh (\$/kWh)	On-peak Jun-Sep (\$/kWh)	On-peak Other (\$/kWh)	Off-peak (\$/kWh)
Baseline	0.0985			
Residential TOD		0.2152	0.1733	0.0438

# Forecast: Residential TOD Scenario

Xcel Energy, Cumulative Adoption



# Incentives Scenario

Xcel Energy

Scenario: buy-down incentive offered to stimulate adoption of rooftop solar

Forecast of Cumulative Adoption by 2030 (MW)

Incentive	Baseline \$0/W	\$0.5/W	\$1/W	\$1.5/W	\$2/W
Residential (MW)	58	69	83	102	126
Commercial (MW)	88	103	122	149	184
<b>Total (MW)</b>	<b>146</b>	<b>171</b>	<b>205</b>	<b>250</b>	<b>311</b>
<b>Increase over Baseline (MW)</b>		25	59	104	165
<b>(%)</b>		17%	40%	71%	113%
<b>Cost (\$/W of increase)</b>		\$3.4	\$3.5	\$3.6	\$3.8

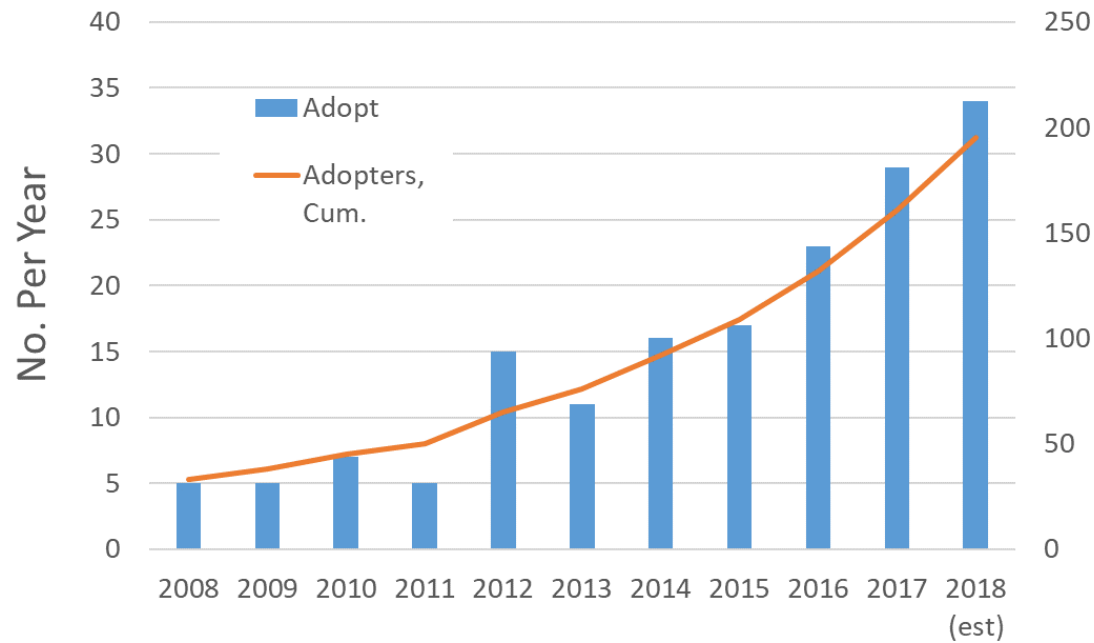


# Minnesota Power Case Study

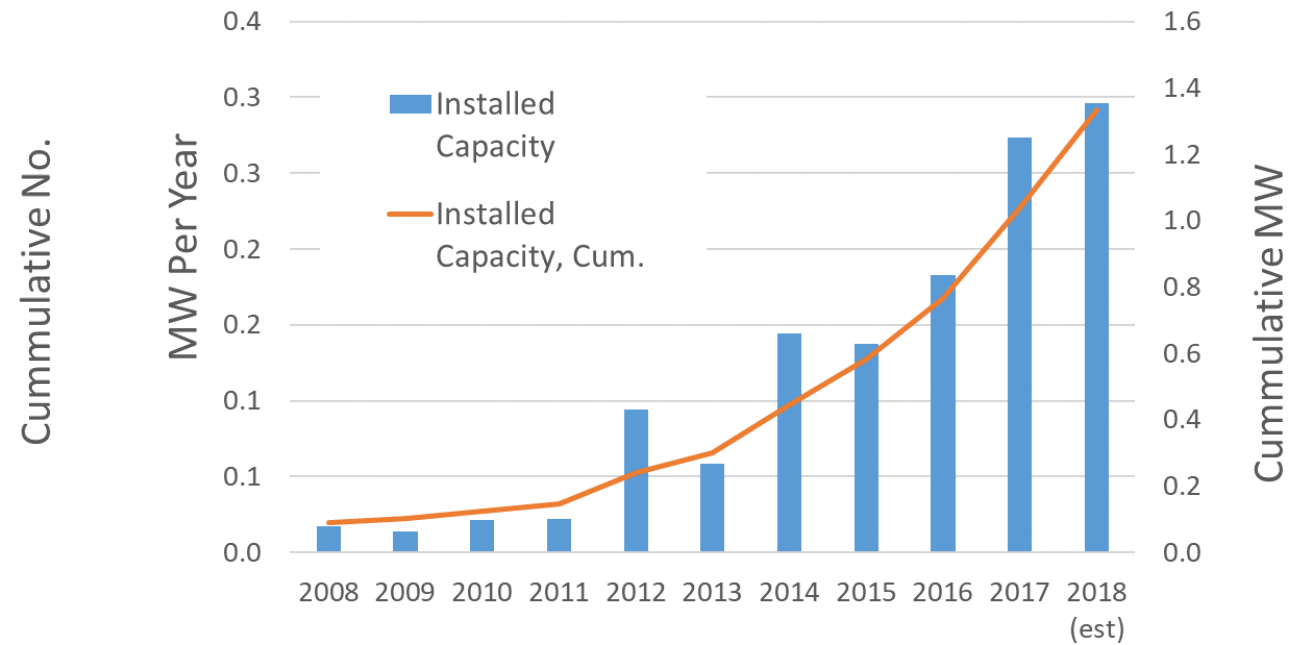
# Residential Rooftop Adoption (Historical)

Minnesota Power

### Adopter Count



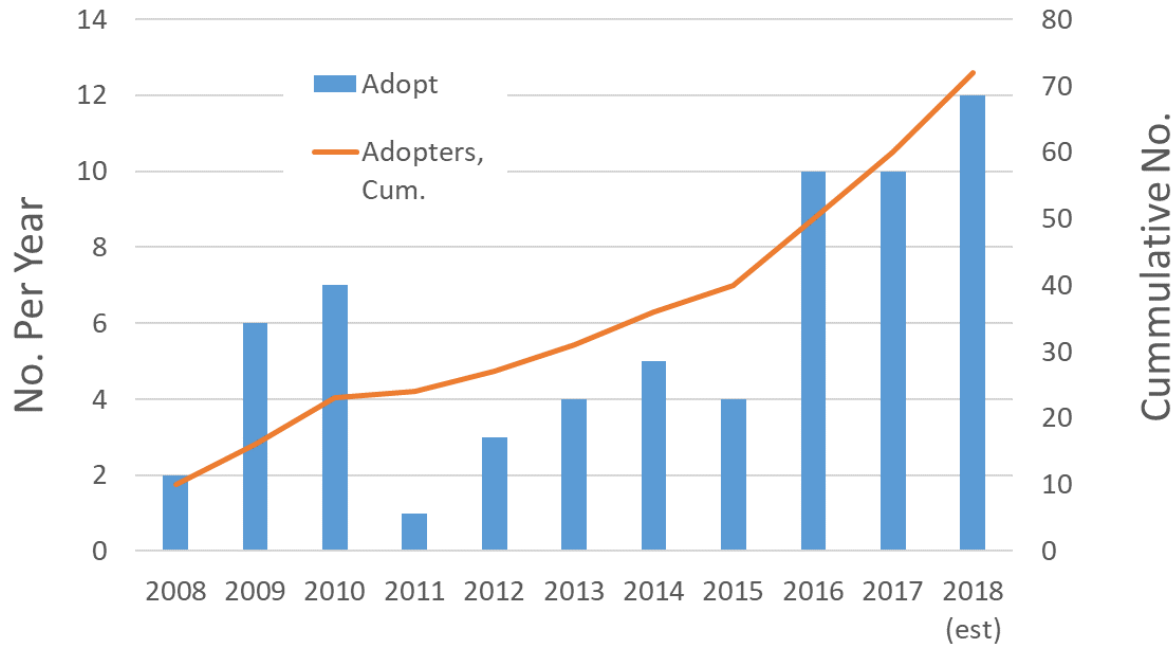
### Residential Rooftop Adoption



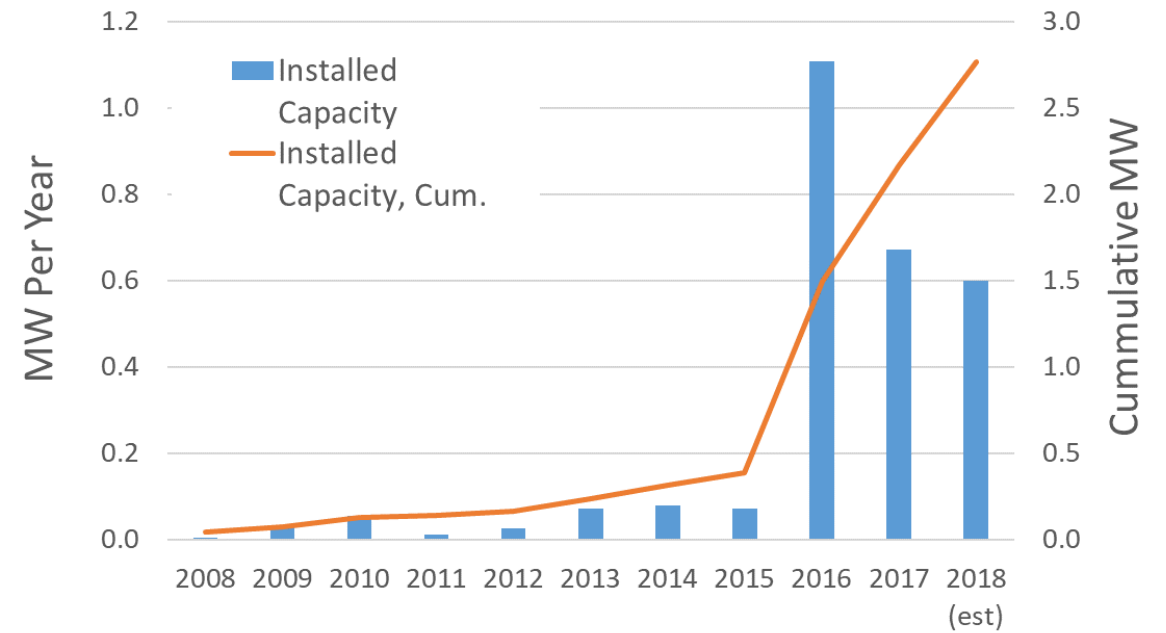
# Commercial Rooftop Adoption (Historical)

Minnesota Power

### Adopter Count



### Adoption Capacity



# Baseline

Minnesota Power

- Customer PV system costs are not reported by Minnesota Power (“trade secret”). Therefore, model coefficients are assumed to be the same as Xcel Energy
- Only residential and commercial customers are included. These represent 99.7% of customers. Industrial, mine, paper, and municipals were excluded
- Residential – Seasonal rate assumed
- SolarSense incentives continue at current rates through 2030 (more detail in incentives scenario)

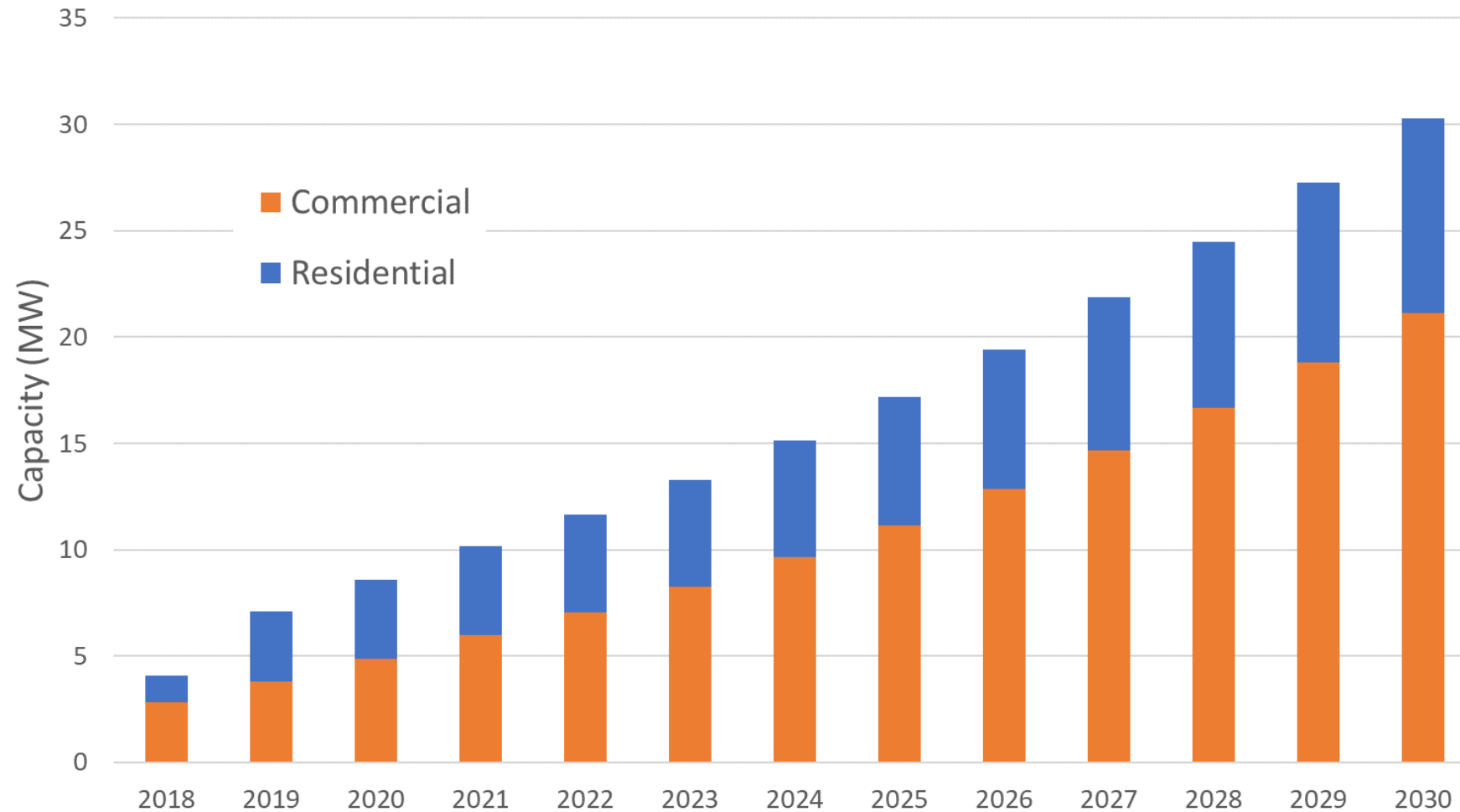
# Baseline

Minnesota Power

No. of Customers	Description	Sector	Annual Usage (MWh per cust)	Electric Rate
122,557	Residential	Residential	9	Residential (Rate Code 23)
22,834	Commercial	Commerical	54	General Service (Rate Code 25 w Demand)

# Forecast: Baseline

Minnesota Power, Rooftop Adoption, Cumulative



# Residential Demand Rate Scenario

Minnesota Power

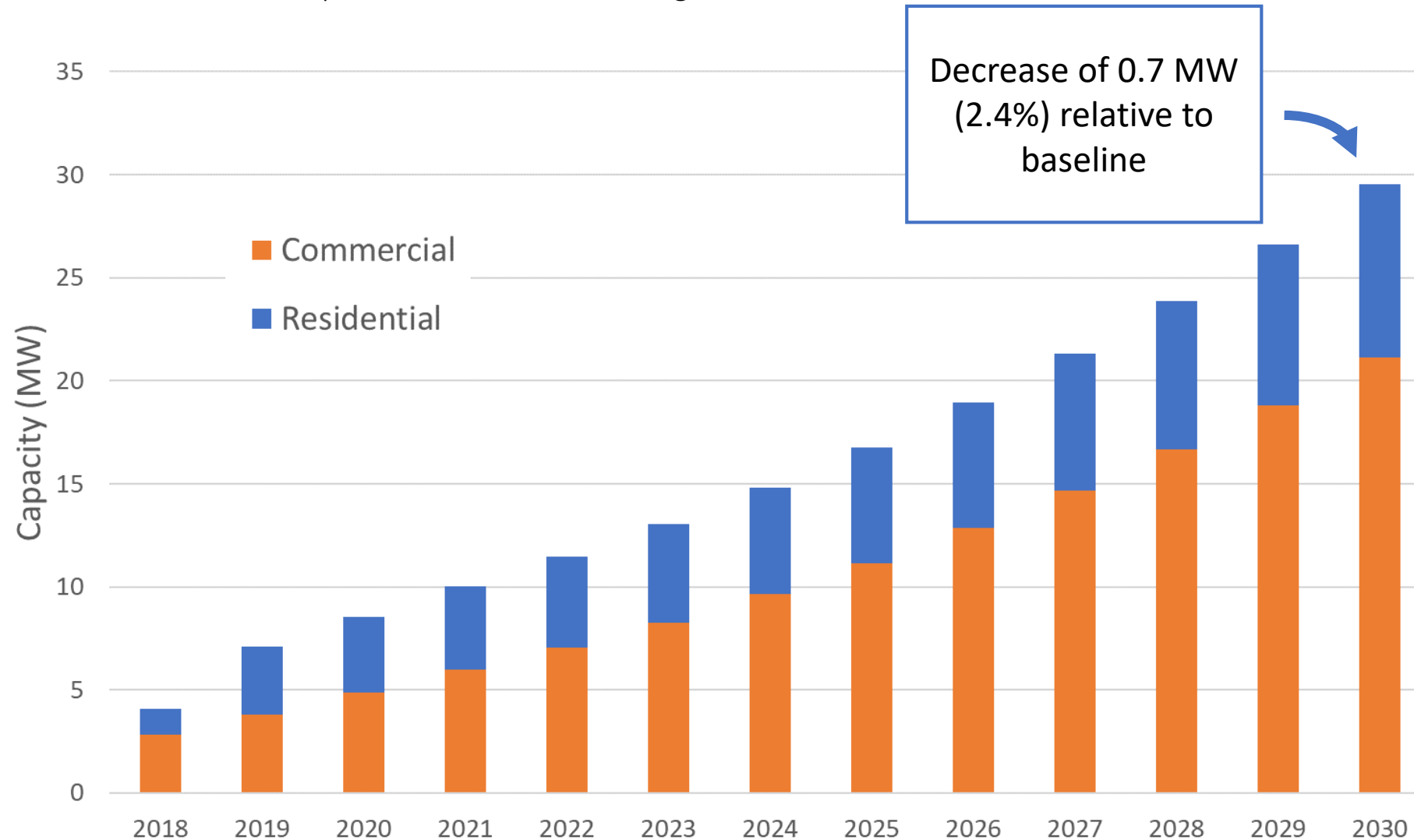
Demand charge set such that

- Total bill for non-solar customers is not changed (\$1028.30), and
- Demand charges are same percentage of bill as for Commercial/General Service customers (13%)

Scenario	Pricing			Annual Bill			
	Fixed (\$)	Energy (\$/kWh)	Demand (\$/kW)	Fixed (\$)	Energy (\$)	Demand (\$)	Total (\$)
Baseline	8.00	0.1085		96.00	932.30		1028.30
Residential Demand	8.00	0.0930	7.25	96.00	798.62	133.68	1028.30

# Forecast: Residential Demand Scenario

Minnesota Power, Cumulative Adoption, \$7.25 Demand Charge





# Residential TOD Rate Scenario

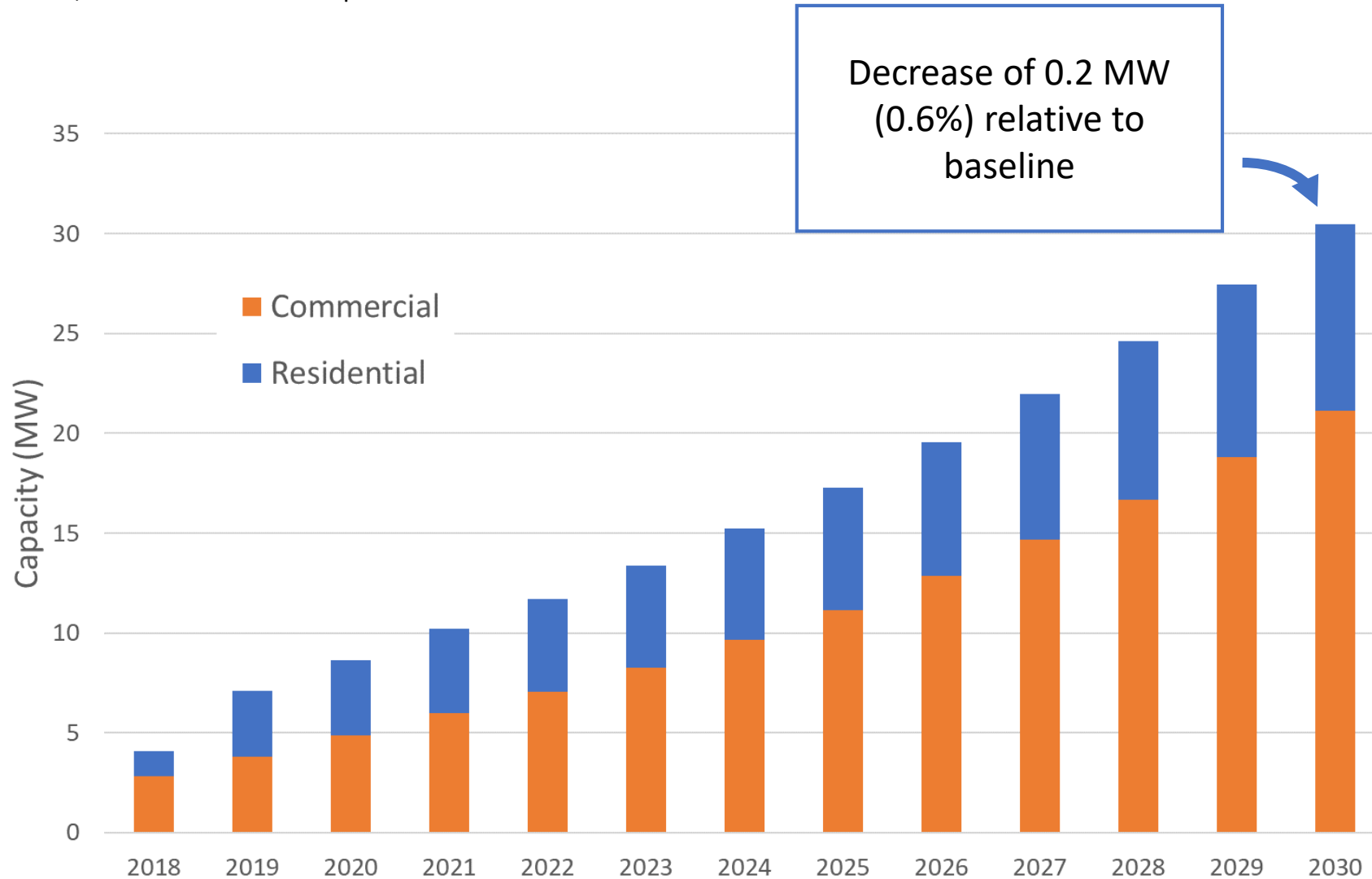
Minnesota Power

- MP’s Time-of-Day (TOD) pilot rate was used as a study scenario. All residential customers required to adopt this TOD rate
- On-peak is 8 am to 10 pm, Monday-Friday. Off-peak is all other hours and designated holidays
- CPP events not included in analysis

Scenario	Fixed Price (\$/mo)	Energy Pricing		
		All kWh (\$/kWh)	On-peak (\$/kWh)	Off-peak (\$/kWh)
Baseline	8.00	0.1085		
Residential Demand	8.00		0.1572	0.0786

# Forecast: Residential TOD Scenario

Minnesota Power, Cumulative Adoption



# Incentives Scenarios

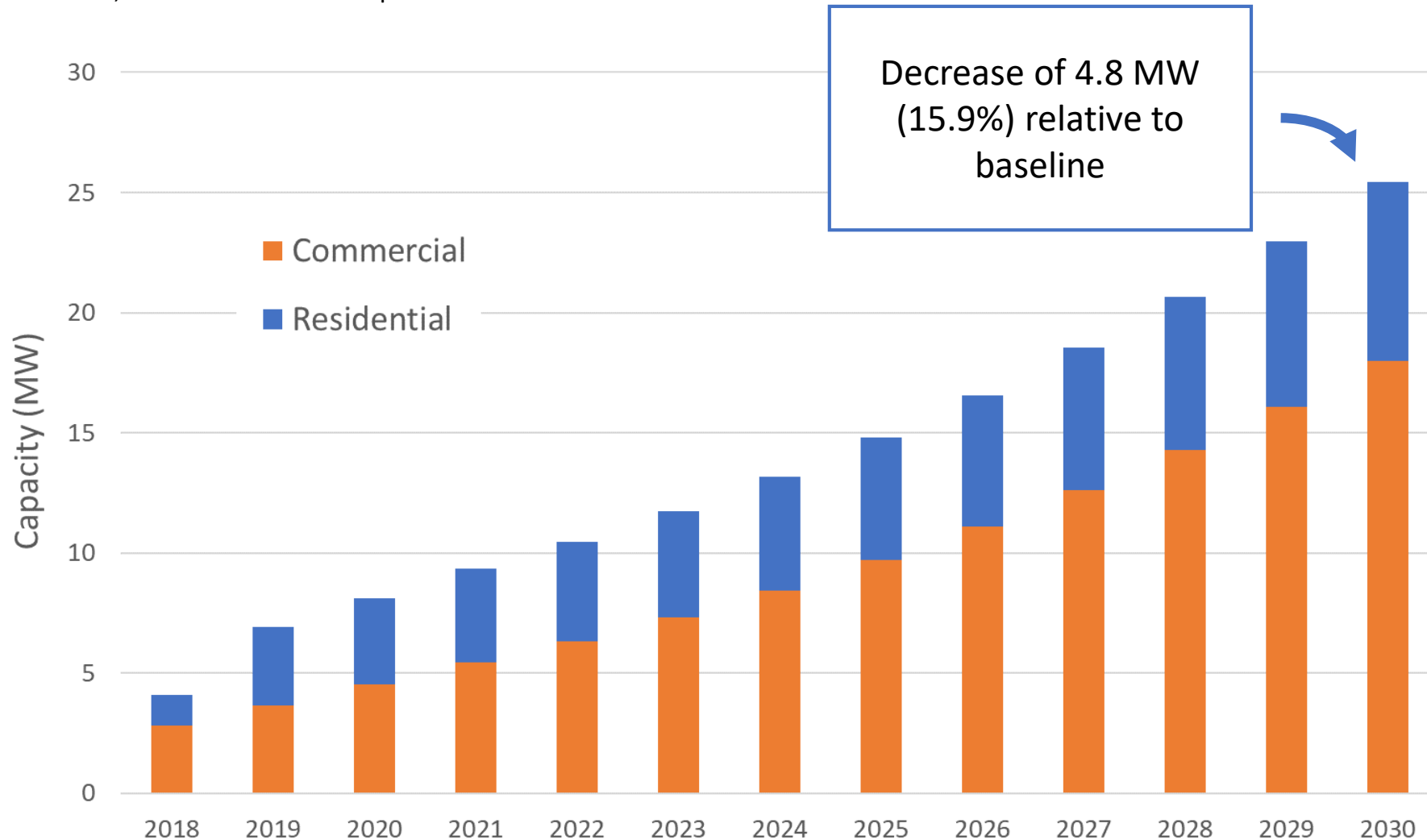
Minnesota Power

- In 2019 the SolarSense program paid \$0.78 for each estimated kWh of first year production

*Example: 8 kW system in Duluth, 20-degree tilt, 220-degree azimuth, 88% shading profile from Solar Pathfinder. PVWatts estimates 8874 kWh per year (1109 kWh per kW). Rebate is  $\$0.78 \times 8874 = \$6922$ , or **\$0.87 per W**. This is **24%** of the assumed installed cost*
- *Maximum rebate is \$20,000. For the average commercial customer with 54 MWh per year of consumption, this corresponds to a \$0.41 per Watt rebate*
- *Baseline Scenario: Assume **30% residential** rebate for every year 2020 through 2030. As price declines, incentive drops also, e.g., \$0.70 per W in 2025. Assume maximum limit of **\$0.41** per W incentive for commercial*
- *Low Scenario: assume **0%** rebate for every year 2020 through 2030*

# Low Incentives Scenario

Minnesota Power, Cumulative Adoption

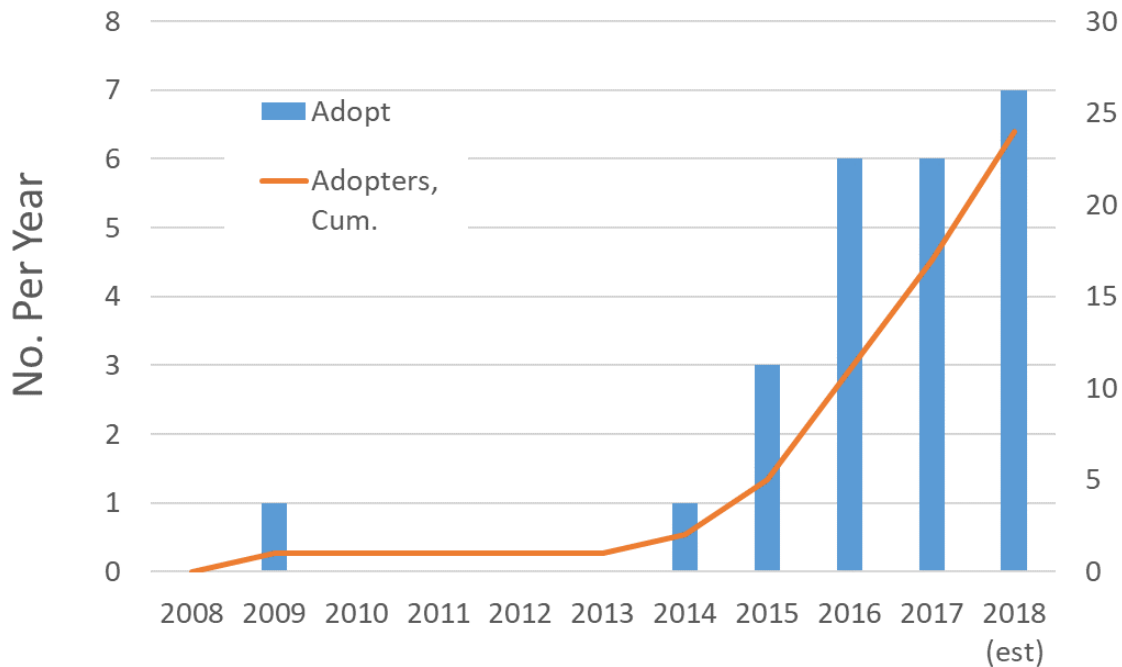


# Otter Tail Power Case Study

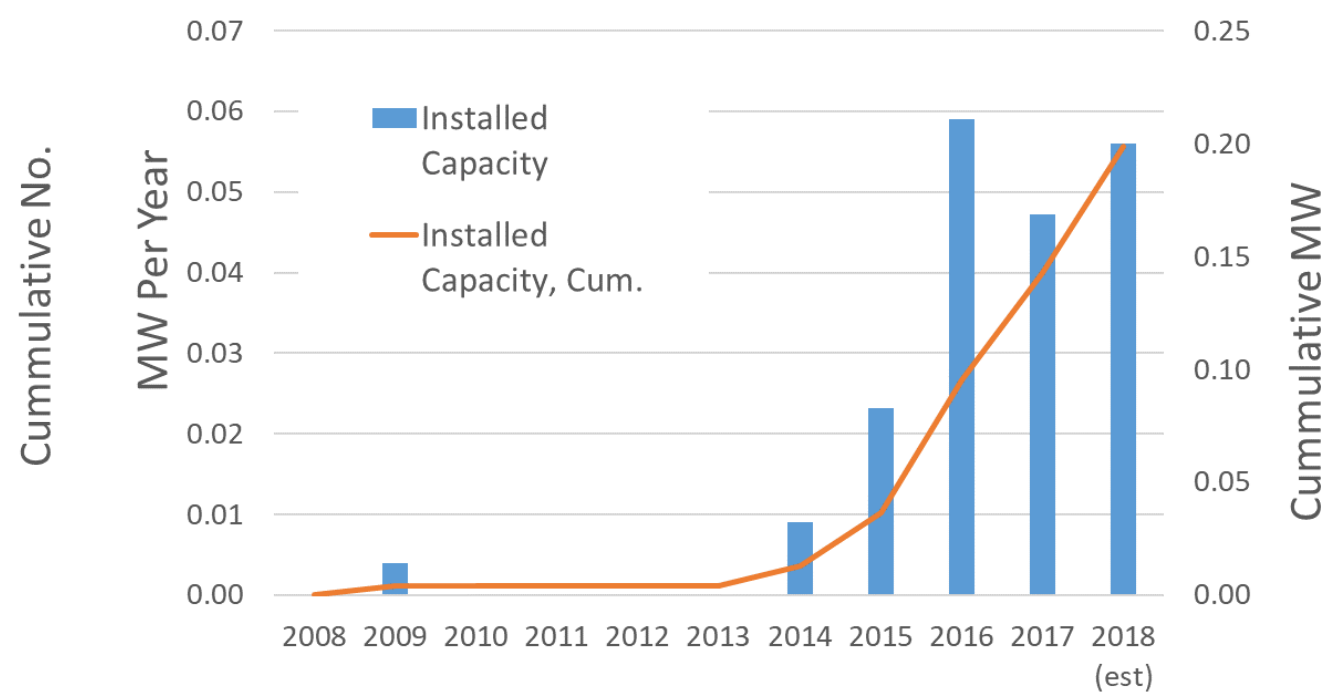
# Residential Rooftop Adoption (Historical)

Otter Tail Power

### Adopter Count



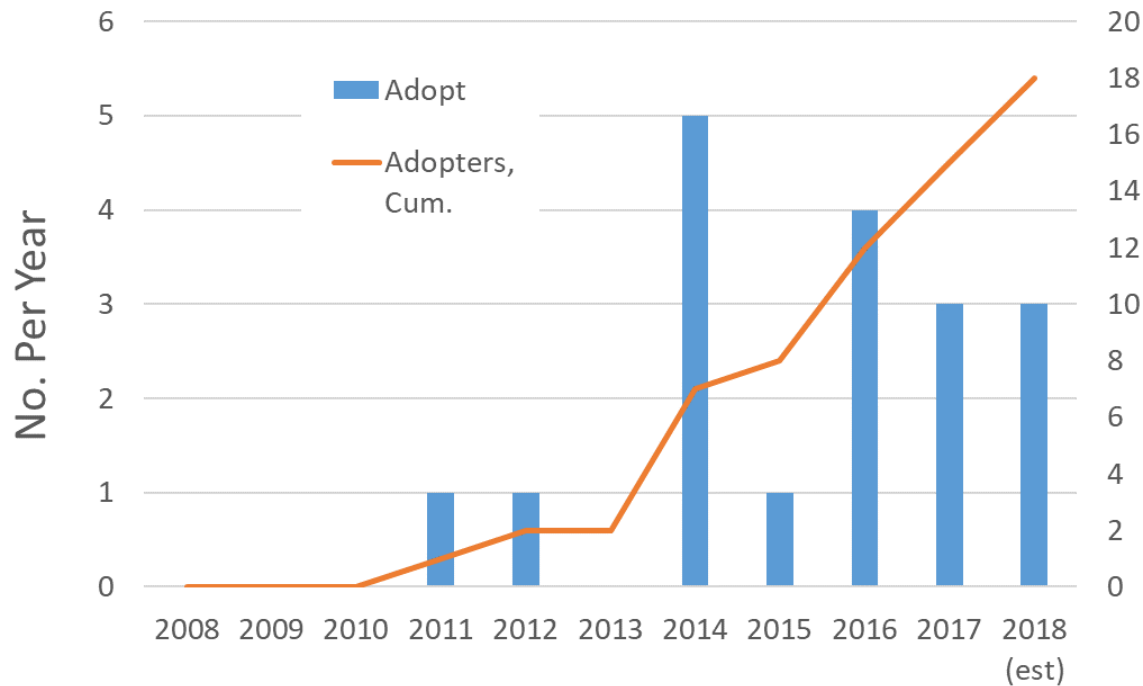
### Adoption Capacity



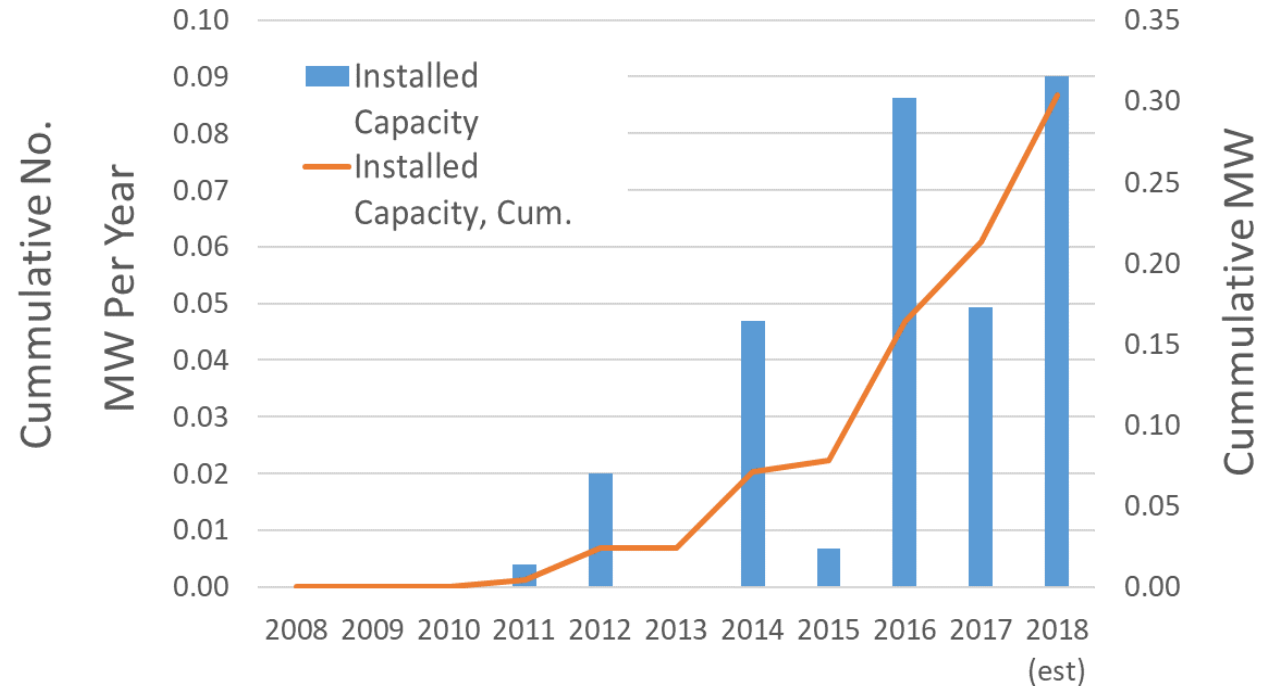
# Commercial Rooftop Adoption (Historical)

Otter Tail Power

Adopter Count



Adoption Capacity



# Baseline

## Otter Tail Power

- Historical customer PV system costs are not available, and incentive data is incomplete. Therefore, model coefficients are assumed to be the same as Xcel Energy.
- Of the 356 kW of solar capacity, 27.8% was installed on farms (3 systems). Therefore, for simplicity and consistency with the other Minnesota utilities, farm adoption is forecasted with commercial adoption.
- Customer counts taken from 2018 OTP FERC Form 1. Only residential customers on the 4 most popular rates are included (99.4% of customers). Only commercial customers on 3 most popular rates plus Large General Service are included (94.8% of customers).
- Energy and demand pricing seasonally weighted. Large General Service TOD rates seasonally weighted by period and demand price approximated.
- Customer counts on Controlled Service (14.04, 14.05, 14.06, 14.07) are not differentiated. Therefore controlled service residential customers assigned to rate 9.01 and commercial customers to rate 10.01.



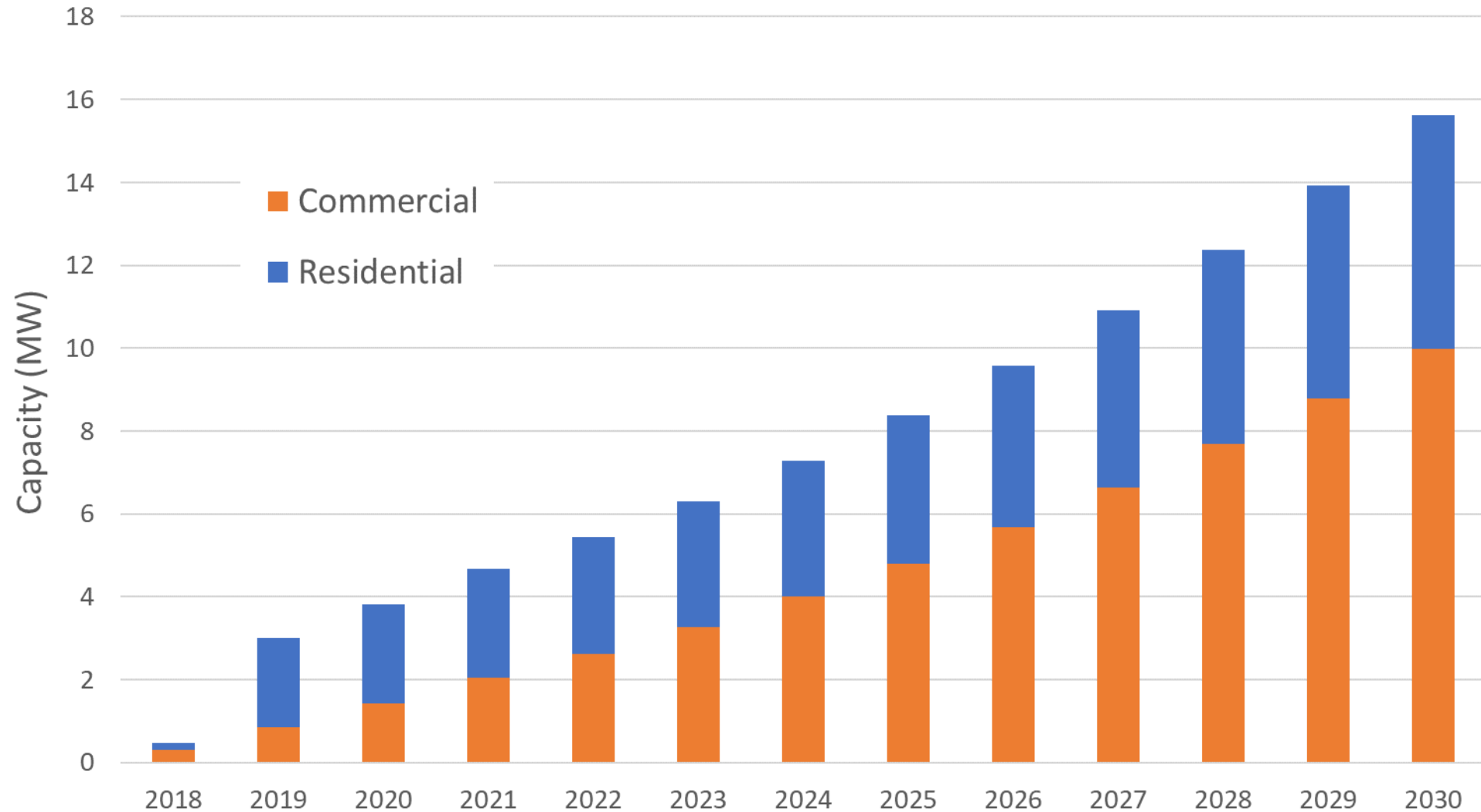
# Baseline

Otter Tail Power

No. of Customers	Description	Sector	Annual Usage (MWh per cust)	Electric Rate
98,850	Residential Service 9.01	Residential	9	Residential Service 9.01
6,134	Residential Service Controlled Demand 9.02	Residential	24	Residential Service Controlled Demand 9.02
15,335	Water Heating Controlled Off-Peak 14.01	Residential	2	Water Heating Controlled Off-Peak 14.01
13,743	Controlled Svc Res 14.04, 14.05, 14.06, 14.07	Residential	15	Residential Service 9.01
25,216	General Service 10.01, 10.02	Commerical	31	Small General Service 10.01 - Secondary
2,853	Farm Service 9.03	Commerical	27	Farm Service 9.03 - Single Phase
100	Large Gen. Serv TOD 10.05	Commerical	11,334	Large General Service TOD 10.05
5,008	Controlled Svc Com 14.04, 14.05, 14.06, 14.07	Commerical	42	Small General Service 10.01 - Secondary

# Forecast: Baseline

Otter Tail Power, Rooftop Adoption, Cumulative



# Residential Demand Rate Scenario

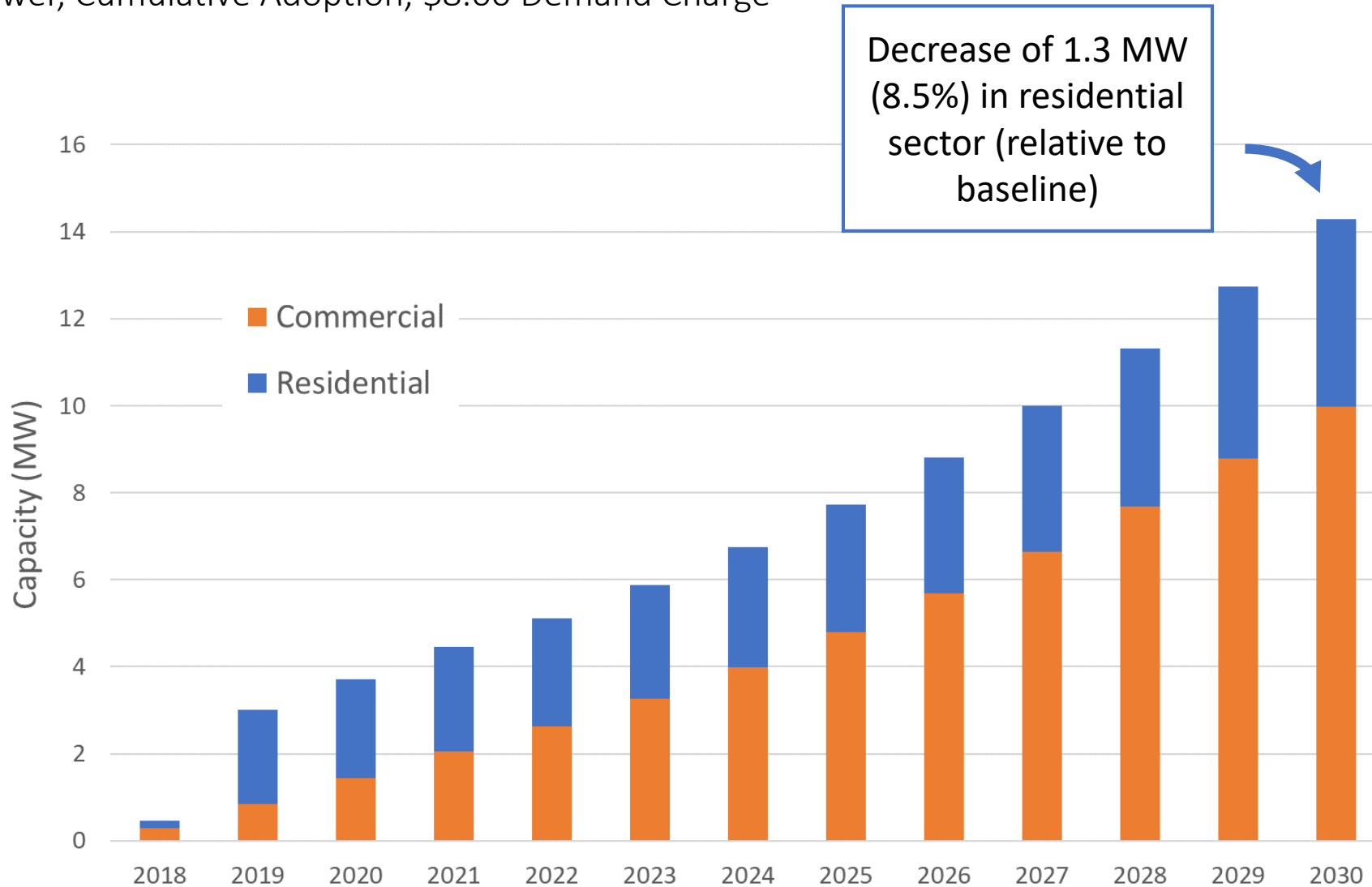
Otter Tail Power

Demand charge set to existing rate Residential Service Controlled Demand 9.02 for all residential customers

Scenario	Pricing		
	Fixed (\$)	Energy (\$/kWh)	Demand (\$/kW)
Residential Service 9.01	9.75	0.0927	
Residential Service Controlled Demand 9.02	11.00	0.0628	8.00

# Forecast: Residential Demand Scenario

Otter Tail Power, Cumulative Adoption, \$8.00 Demand Charge



# Incentives Scenarios

Otter Tail Power

Scenario: buy-down incentive offered to stimulate adoption of rooftop solar

Forecast of Cumulative Adoption by 2030 (MW)

Incentive	Baseline \$0/W	\$0.5/W	\$1/W	\$1.5/W	\$2/W
Residential (MW)	5.6	6.9	8.6	11.0	14.4
Commercial (MW)	10.0	12.2	15.0	18.4	22.7
Total (MW)	15.6	19.1	23.6	29.4	37.1
Increase over Baseline (MW)		3.5	8.0	13.8	21.5
		22%	51%	89%	138%
Cost (\$/W of increase)		2.7	3.0	3.2	3.5

# Conclusions

# Conclusions

- Completed three case studies—one for each IOU—each with three market change scenarios. Case studies use the “Solar Deployment Strategy” (SDS) tool developed under this project.
- Residential demand charges were shown to reduce adoption forecasts by 14% for Xcel Energy, 2.4% for MN Power, and 8.5% for OTP.
- Residential TOD charges were shown to reduce adoption by 2.9% for Xcel Energy and 0.6% for MN Power.
- Incentives resulting in substantial changes in the adoption forecast, depending upon level
- The SDS tool is demonstrated as a versatile way to estimate adoption impact as a function of customer payback.