Integrated Resource Plan

2016

Public Meeting #2

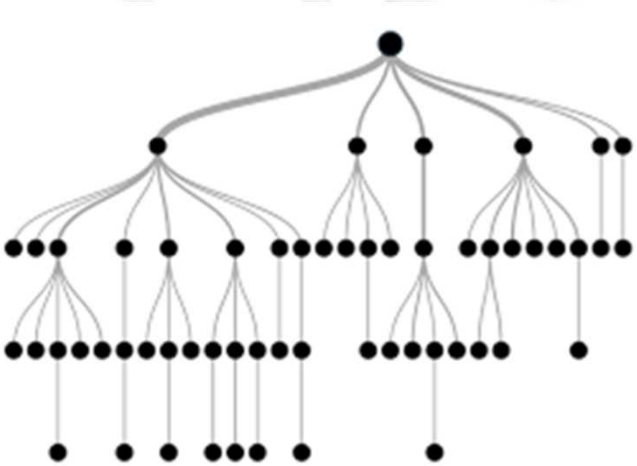
Thursday, July 16, 2015

Portland General Electric

Welcome: Meeting Logistics

- Local Participants:
  - DoubleTree facility

- Virtual Participants:
  - Place phones on mute to prevent background noise
  - Please do not use the ‘hold’ feature on your phone
  - Ask questions via ‘chat’ or ‘raise hand’ feature
  - Meeting will stay open during breaks, but will be muted



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Welcome: Today's Topics

- Welcome and safety moment
- Public process
- Load Forecast Summary
- Energy efficiency
- Distributed generation
- Supply-side resources

Safety Moment: Driving Safely

What is the top reported driver error?

Failure to avoid stopped or parked vehicle ahead

Failure to yield right-of-way

Failure to maintain lane

Ran off road

Driving too fast for conditions

Following too close

Inattention

Improper change of traffic lanes

Left turn in front of on-coming traffic

Disregarded traffic signal

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Safety Moment: Driving Safely

July 16, 2015 Slide 5

Time	Sunday	Monday	Tuesday	Wednesd..	Thursday	Friday	Saturday
1 (12AM-1AM)	124.0	52.0	82.0	57.0	62.0	84.0	128.0
2 (1AM-2AM)	104.0	32.0	51.0	51.0	57.0	85.0	134.0
3 (2AM-3AM)	151.0	36.0	48.0	37.0	44.0	60.0	138.0
4 (3AM-4AM)	76.0	40.0	33.0	29.0	36.0	44.0	76.0
5 (4AM-5AM)	62.0	37.0	53.0	42.0	42.0	44.0	67.0
6 (5AM-6AM)	55.0	86.0	86.0	80.0	90.0	109.0	78.0
7 (6AM-7AM)	55.0	177.0	202.0	197.0	189.0	185.0	80.0
8 (7AM-8AM)	96.0	408.0	453.0	407.0	400.0	419.0	139.0
9 (8AM-9AM)	88.0	386.0	439.0	381.0	423.0	382.0	172.0
10 (9AM-10AM)	162.0	305.0	359.0	324.0	326.0	321.0	226.0
11 (10AM-11AM)	190.0	328.0	323.0	300.0	262.0	346.0	294.0
12 (11AM-12AM)	259.0	374.0	352.0	417.0	409.0	472.0	370.0
13 (12PM-1PM)	356.0	460.0	463.0	453.0	419.0	496.0	424.0
14 (1PM-2PM)	400.0	465.0	489.0	455.0	451.0	577.0	459.0
15 (2PM-3PM)	378.0	554.0	517.0	562.0	509.0	634.0	474.0
16 (3PM-4PM)	364.0	641.0	653.0	658.0	624.0	878.0	464.0
17 (4PM-5PM)	410.0	702.0	679.0	664.0	750.0	853.0	445.0
18 (5PM-6PM)	372.0	776.0	820.0	833.0	826.0	894.0	431.0
19 (6PM-7PM)	308.0	436.0	474.0	515.0	545.0	621.0	386.0
20 (7PM-8PM)	257.0	267.0	298.0	272.0	271.0	367.0	268.0
21 (8PM-9PM)	206.0	199.0	204.0	224.0	199.0	259.0	250.0
22 (9PM-10PM)	162.0	158.0	158.0	174.0	195.0	254.0	234.0
23 (10PM-11PM)	118.0	122.0	121.0	130.0	148.0	211.0	229.0
24 (11PM-12AM)	100.0	97.0	106.0	111.0	112.0	166.0	183.0

- "Safer" times
  - 5a – 8a Weekends
  - 3a – 6a Weekdays
- Less safe times
  - 12p – 5p Weekends
  - 12a – 3a Weekends
  - 3p – 6p Weekdays

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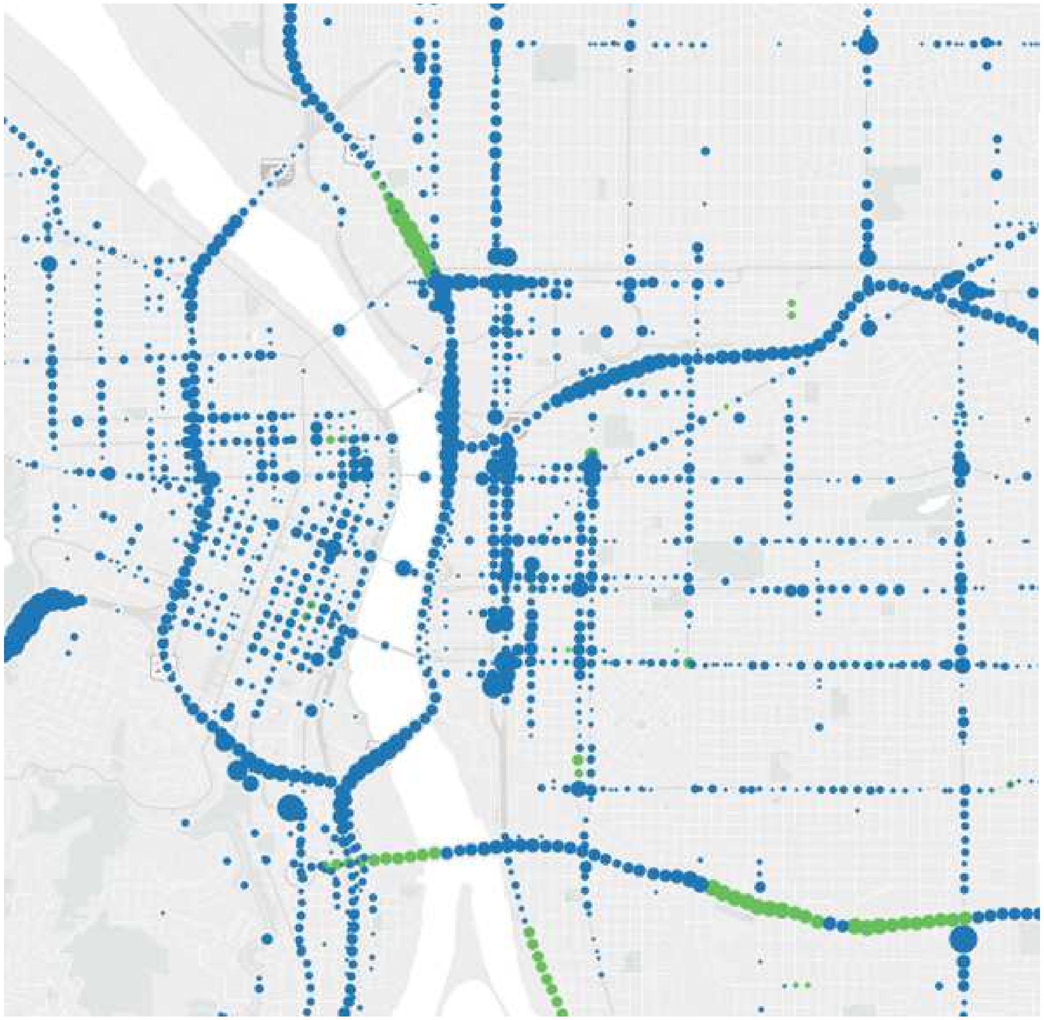
Safety Moment: Driving Safely

July 16, 2015 Slide 6



- Dot size is related to number of crashes
- Green indicates a fatality was involved
- Sunset Highway @ Vista Tunnel
- Powell Boulevard
- You are here
- DRIVE SAFELY!

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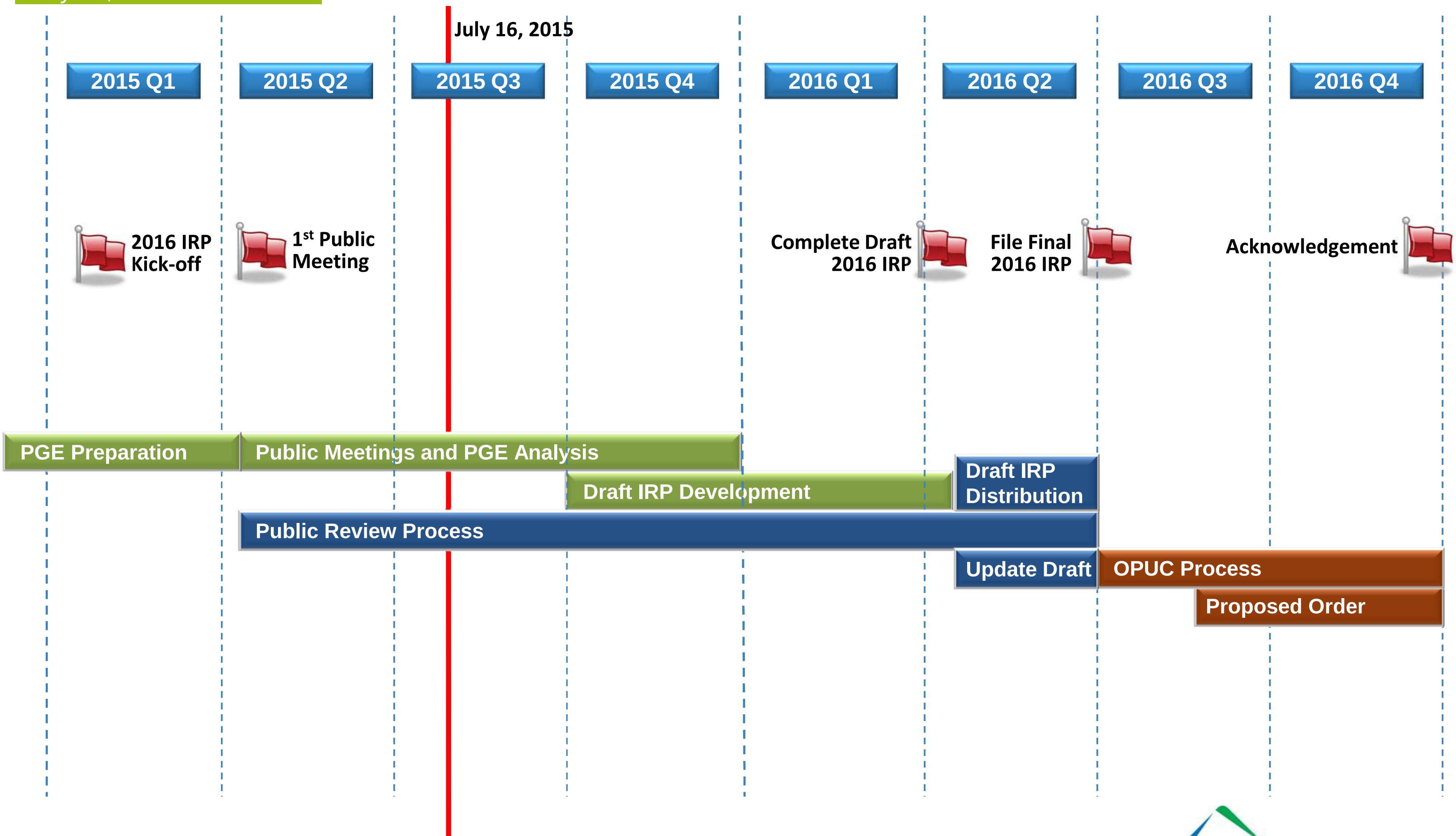
Public Process Update

2016 IRP Timeline



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2016 IRP: Meeting Schedule And Planned Topics

Q2/Q3 2015

April 2 — Meeting #1 Public
- Welcome
- Load Forecast Methodology
- Load/Resource Balance
- Environmental Policy

July 6 — Workshop #1 Commission (Salem)
- EIM Study Update
- 111(d) Representation

July 15 — Workshop #1 Technical
- Load Forecast Methodology Implementation
- Load Forecast Results

July 16 — Meeting #2 Public
- Load Forecast
- Energy Efficiency Forecast
- Supply-side Resource Assumptions
- Solar/Dist. Generation Study Presentation

Public Meeting

Technical Workshop

Technical Workshop with Commission Present

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2016 IRP: Meeting Schedule And Planned Topics

Q3 2015
(Tentative)

August 13

Meeting #3
Public

- *Development*
  - *Demand Response*
  - *Climate Study*
  - *Flexibility Study*
  - *Planning Reserve Margin*
  - *Portfolios and Futures Ideation*
- *Analysis*
  - *Load Forecast*
  - *Natural Gas Forecast*

September 25

Workshop #2
Technical

- *Development*
  - *Portfolios and Futures Update*
- *Analysis*
  - *Portfolio Analytics Methodology*
  - *VER Integration Methodology*
- *Results*
  - *Planning Reserve Margin*

October 5

Workshop #2
Commission (Salem)

- *Development*
  - *Portfolios and Futures Update*
  - *Colstrip Portfolio Representation*

Public Meeting

Technical Workshop

Technical Workshop with Commission Present

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2016 IRP: Meeting Schedule And Planned Topics

Q4 2015 (Tentative)

October 21

Workshop #3 Technical

- *Analysis*
  - *111(d) Demonstration*

October 22

Meeting #4 Public

- *Development*
  - *Conservation Voltage Reduction Update*
  - *111(d) Rule Update*
- *Analysis*
  - *Transmission*

November 20

Meeting #5 Public

- *Analysis*
  - *Final Portfolios and Futures*
- *Results*
  - *Colstrip Portfolios*
  - *Variable Resource Integration*
  - *Trigger Point Analysis*
  - *Preferred Portfolio*

Public Meeting

Technical Workshop

Technical Workshop with Commission Present

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2016 IRP: Meeting Schedule And Planned Topics

Q4 2015 (Tentative)

Date TBD

Workshop #3 Commission (Salem)

- *Results*
  - *EIM Study*

Date TBD

Additional Meetings

- *As Required*

Public Meeting

Technical Workshop

Technical Workshop with Commission Present

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2016 IRP: Status

Item	Status
Meetings	**6 Total (1 Complete, 5 Scheduled)**
Workshops	**4 Total (2 Complete, 2 Scheduled)**
Feedback Forms	**1 Received**
2013 IRP Action Plan	**5 Actions (OPUC Order No. 14-415)**
Supply Side	*In progress (Hydro contracts, portfolios, no major resources)*
Demand Side	*In progress (EE, DR, CVR)*
Enabling Studies	*In progress (Load forecast, Emerging EE, DG, EIM, Flexibility)*
Transmission	*In progress*
Other	*In progress (RPS, Clean Power Plan)*
Related Topics	*In progress [UM1713 (IEE); UM 1716 (VoS); UM 1719 (VER CC)]*
2016 IRP Development	**~13 Chapters**
Draft	*Not Started*
Final	*Not Started*

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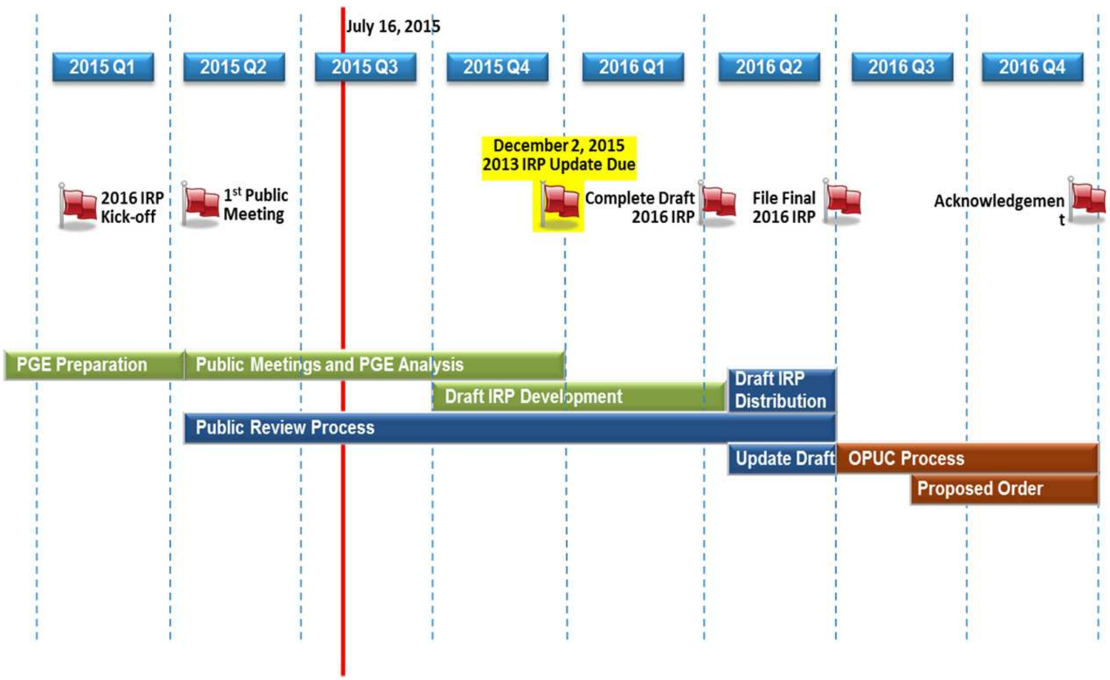
2016 IRP: Status

2013 IRP annual update due December 15, 2015

Update typically covers:

a) actions the company has taken since acknowledgement
b) changes that affect the company's selection of the resources previously identified; and
c) any deviations from the previously acknowledged action plan.



2013 IRP Action Plan did not propose any new major resources

Enabling studies initiated; updates provided through public meetings and workshops

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Load Forecast Summary

Load Forecast Update MWa

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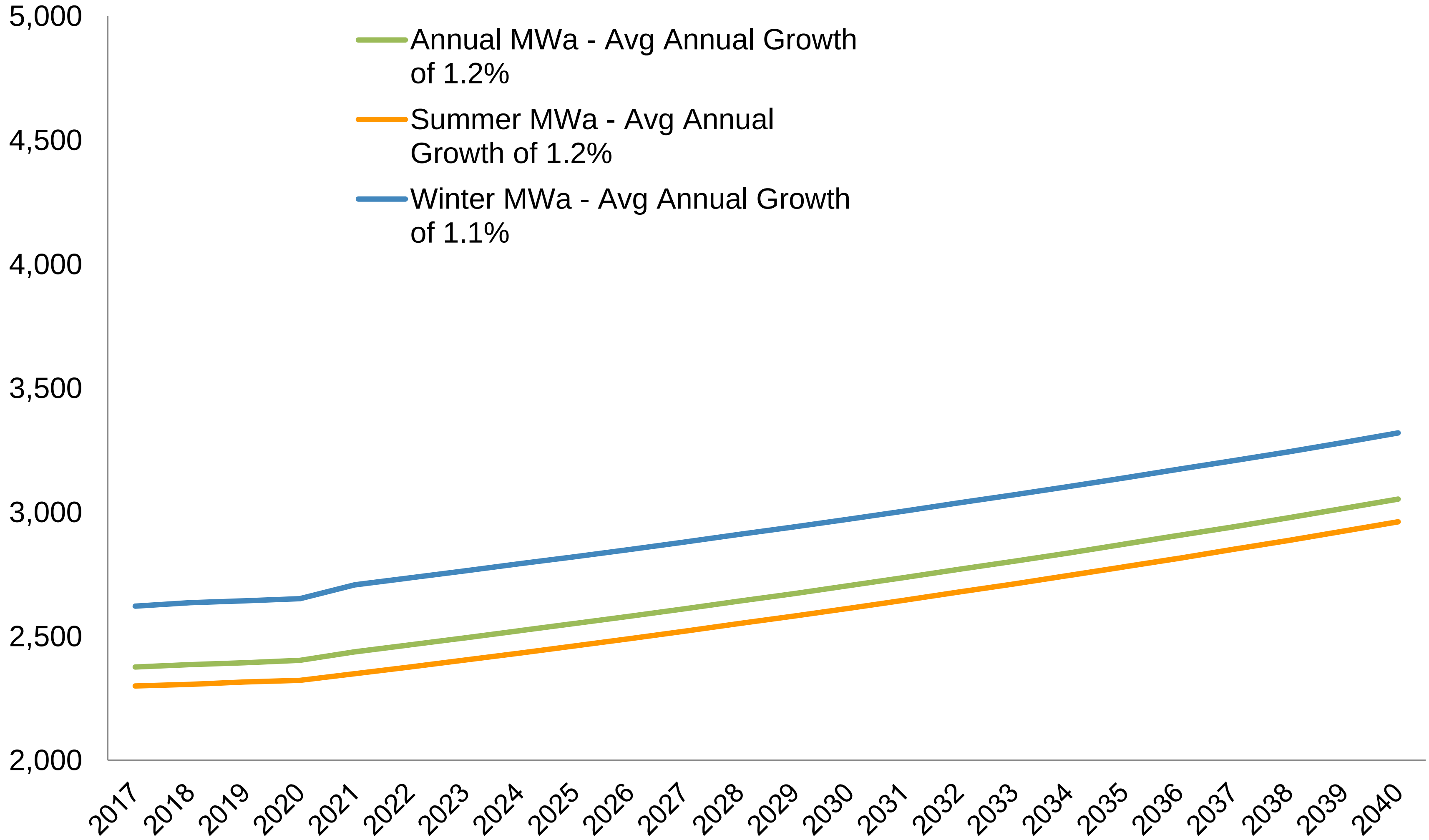

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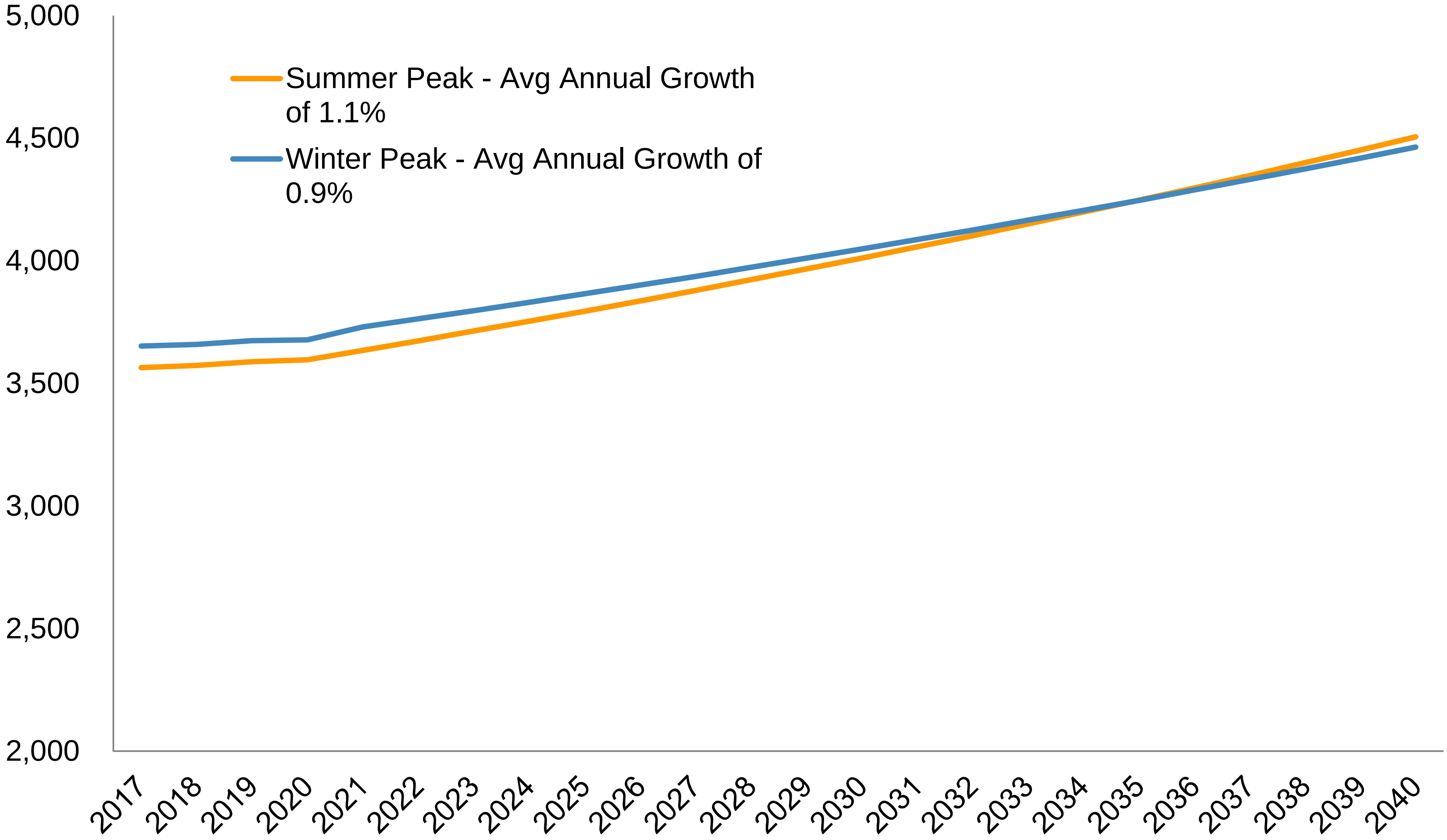
Load Forecast Update Peak MW

July 16, 2015 Slide 17



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Energy Efficiency

Energy Trust of Oregon
Energy Efficiency Resource Potential Study
July 16, 2015

Agenda

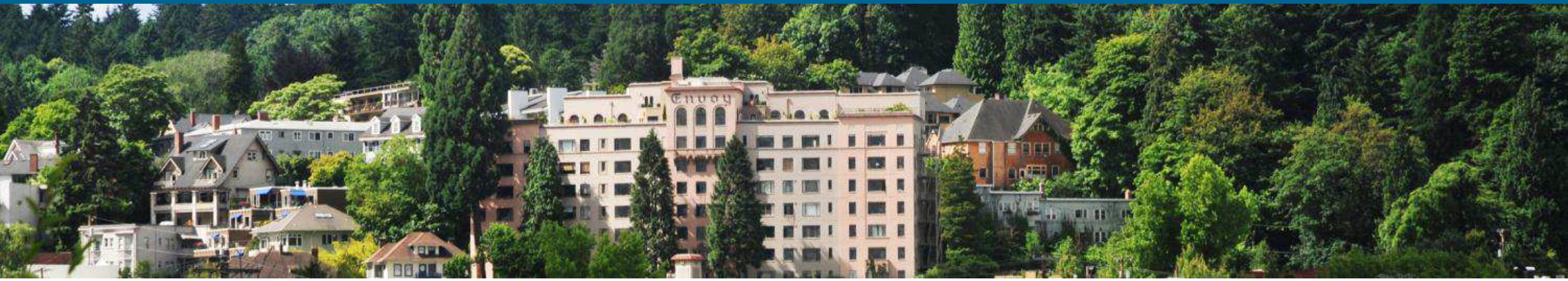
- About Energy Trust
- Purpose & background
- Process
- Results
- Questions

About

- Independent nonprofit
- Serving 1.5 million customers of Portland General Electric, Pacific Power, NW Natural and Cascade Natural Gas
- Providing access to affordable energy
- Generating homegrown, renewable power
- Building a stronger Oregon and SW Washington

Purpose & Background

- Estimate of cost-effective energy efficiency resource potential that is achievable over a 20-year period (2017-2036)
- Used a study & model with updates from Stellar Processes 2002-2013
- Issued RFP for new study & model in 2013
- Navigant Consulting selected
- Used new model in PacifiCorp and Cascade Natural Gas IRPs so far



Inputs:

- Utility Service Territory Data
  - Customer counts, 20-year load forecasts
  - Line losses, avoided costs, discount rate
- Demographic statistics
  - Heating & hot water fuel, measure saturations
- Measure assumptions
  - Savings, costs, O&M, measure life, load profile, end use, baseline, technical applicability, achievability rates

Outputs:

<table>
<tr><td>Not technically feasible</td><td colspan="3">Technical Potential</td></tr>
<tr><td>Not technically feasible</td><td>Market barriers</td><td colspan="2">Achievable Potential</td></tr>
<tr><td>Not technically feasible</td><td>Market barriers</td><td>Not cost effective</td><td>Cost-Effective Potential</td></tr>
</table>

Benefit Cost Ratio

Total Resource Cost (TRC) test

BCR = NPV of Benefits/Total Resource Cost

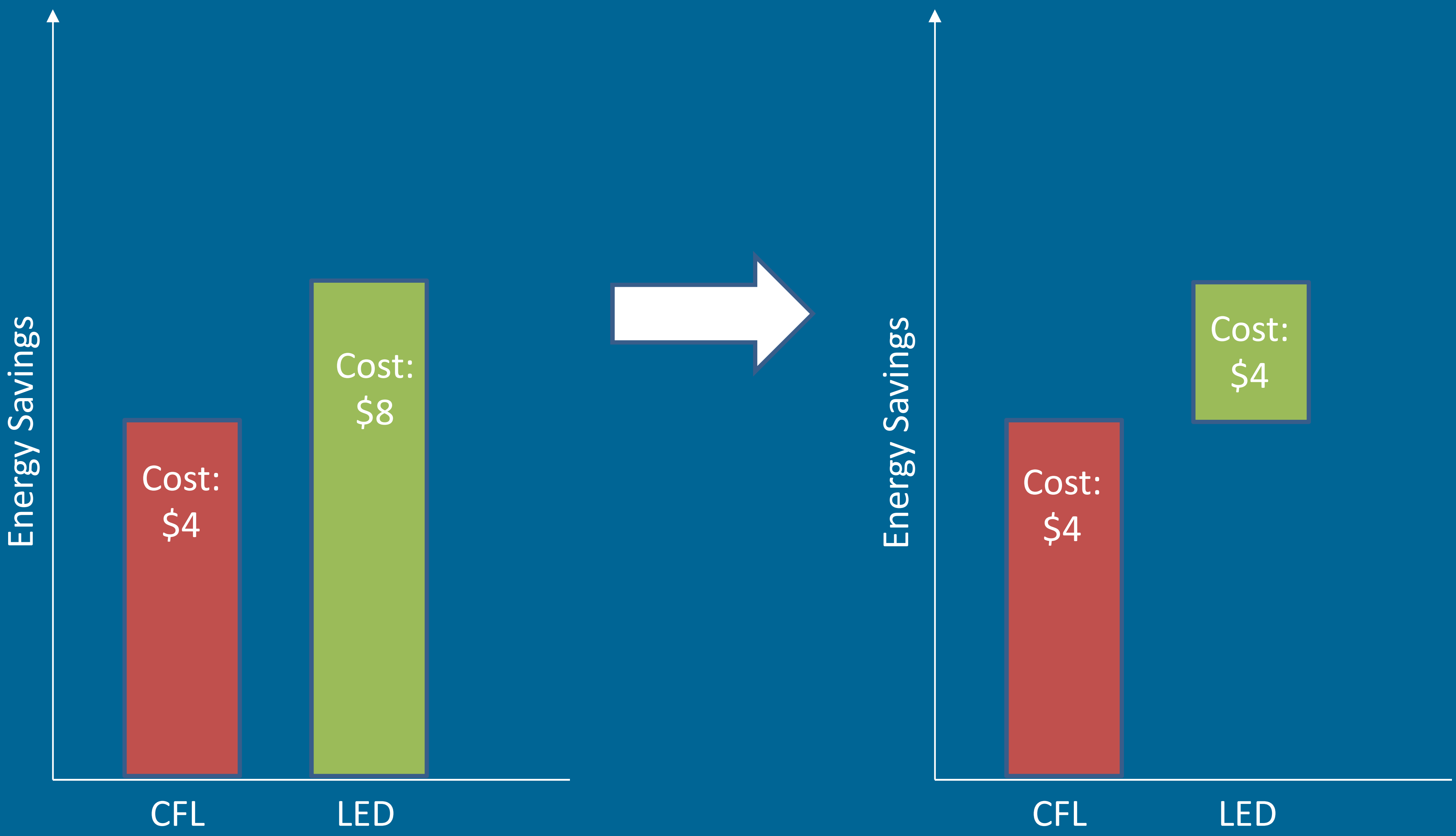
Benefits

- Savings x Avoided Costs
- Quantifiable non-energy benefits

What's new?

- Refreshed measure assumptions
- Incremental measure definitions
- Better treatment of codes & standards
- New approach to emerging technologies

Incremental Measure Definition



Numbers are for illustrative purposes only

Emerging Technologies

- Include some emerging technologies
- Factor in changing performance, cost over time
- Use risk factors to hedge against uncertainty

	Risk Factor for Emerging Technologies				
Risk Category	**10%**	**30%**	**50%**	**70%**	**90%**
Market Risk (25% weighting)	High Risk: • Requires new/changed business model • Start-up, or small manufacturer • Significant changes to infrastructure • Requires training of contractors. Consumer acceptance barriers exist.			Low Risk: • Trained contractors • Established business models • Already in U.S. Market • Manufacturer committed to commercialization	
Technical Risk (25% weighting)	High Risk: Prototype in first field tests. A single or unknown approach	Low volume manufacturer. Limited experience	New product with broad commercial appeal	Proven technology in different application or different region	Low Risk: Proven technology in target application. Multiple potentially viable approaches.
Data Source Risk (50% weighting)	High Risk: Based only on manufacturer claims	Manufacturer case studies	Engineering assessment or lab test	Third party case study (real world installation)	Low Risk: Evaluation results or multiple third party case studies

Emerging Technologies

End result:

- The estimate for any given emerging technology is not accurate
- Taken as a whole, provides a reasonably conservative estimate of what is possible

Emerging Technologies

Residential	Commercial	Industrial
• LED Lighting • CO2 Heat Pump Water Heaters • Advanced Heat Pumps • Home Automation/Controls • Advanced window and insulation technologies • Heat Pump clothes dryers	• LED Lighting • Advanced Rooftop Unit A/C • Evaporative coolers • Energy Recovery ventilators • Advanced refrigeration technologies • Smart/Dynamic windows	• LED Lighting • Advanced refrigeration controllers • Advanced motor technologies

Results

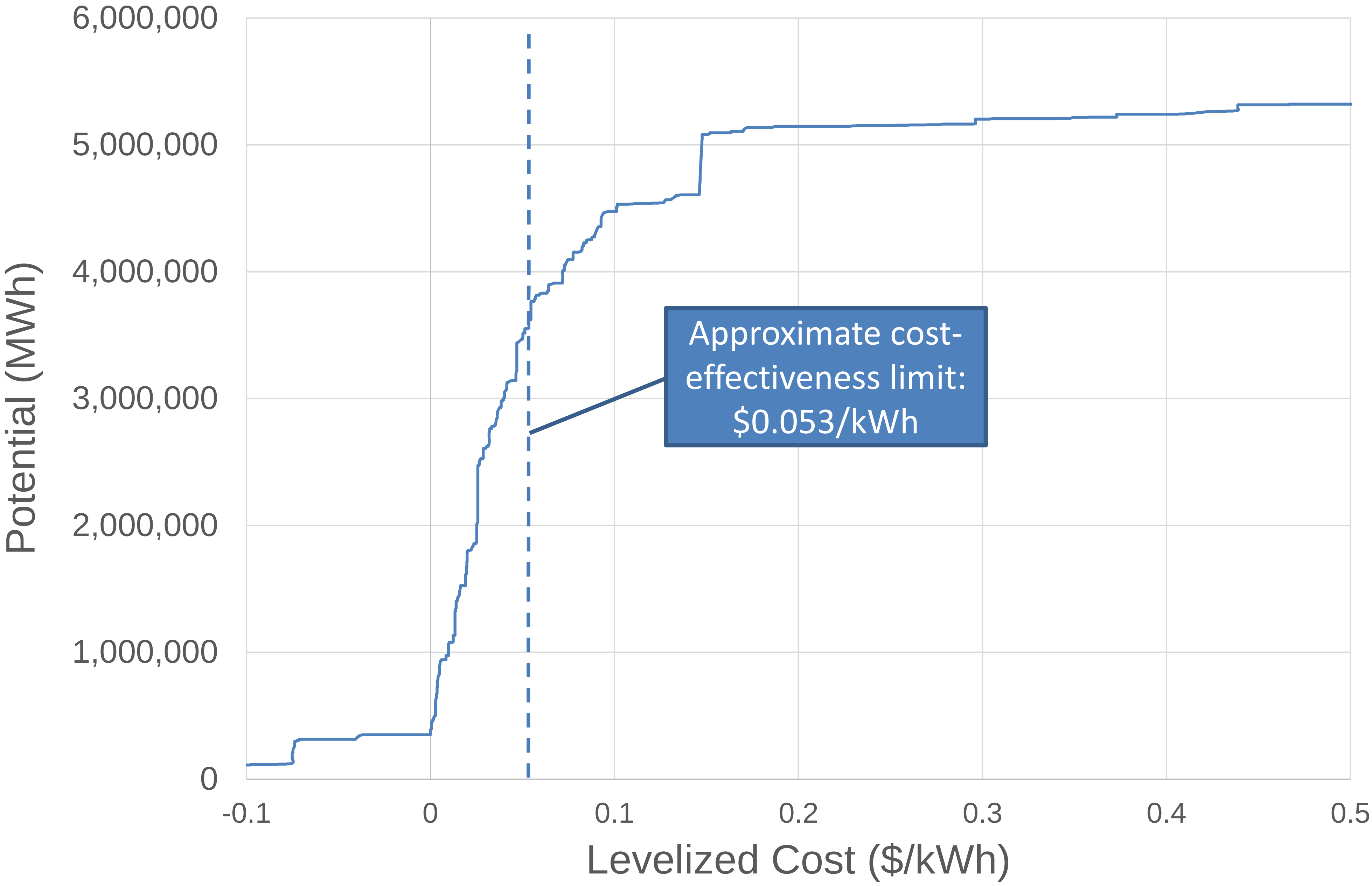
20-Year Cumulative Potential (aMW)

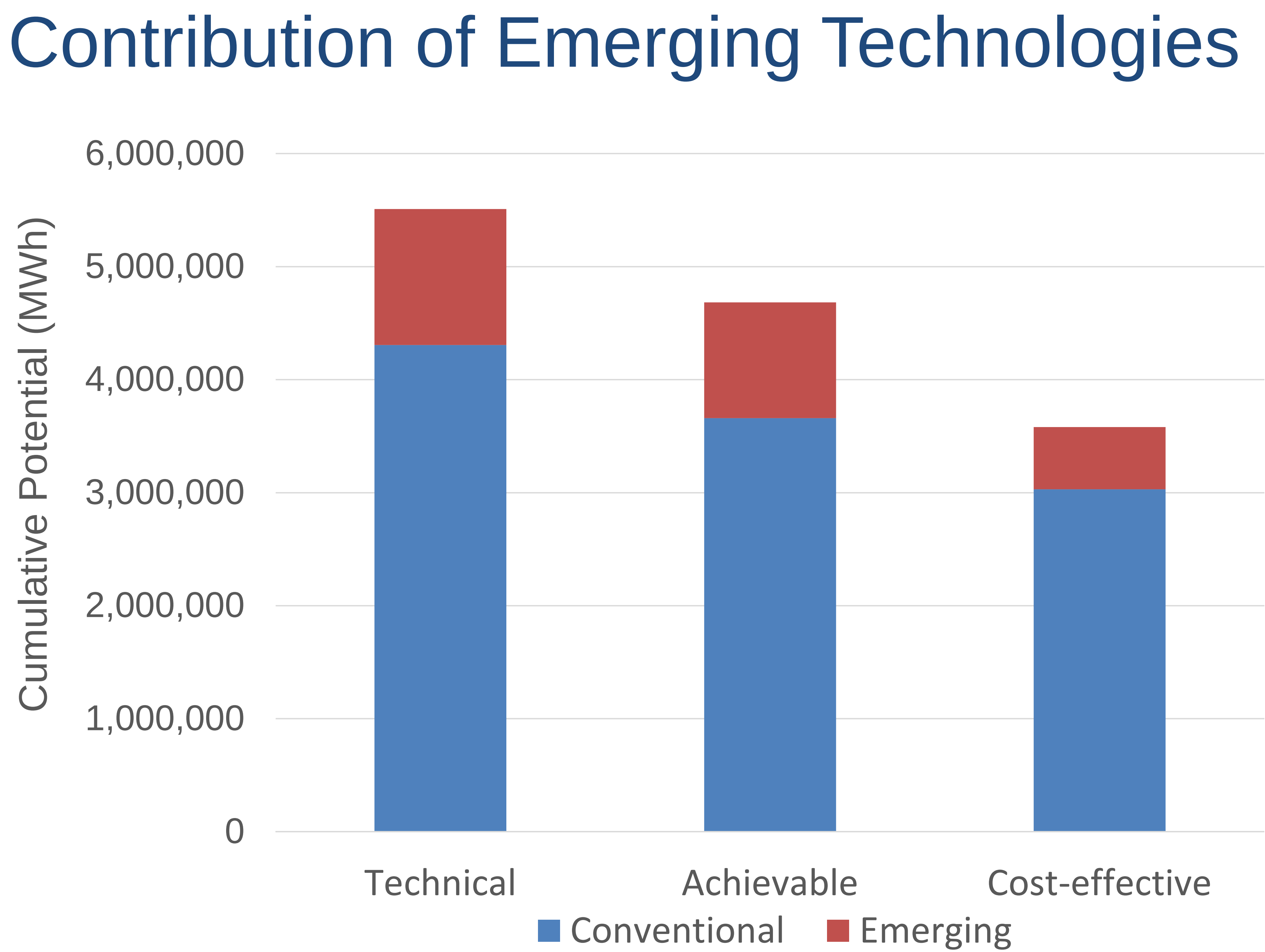
	Technical	Achievable	Cost-effective
Commercial	208	177	145
Industrial	140	119	115
Residential	281	239	148
Total	629	535	409
2013 Results	576	478	403

Highest-Saving Cost-effective Measures

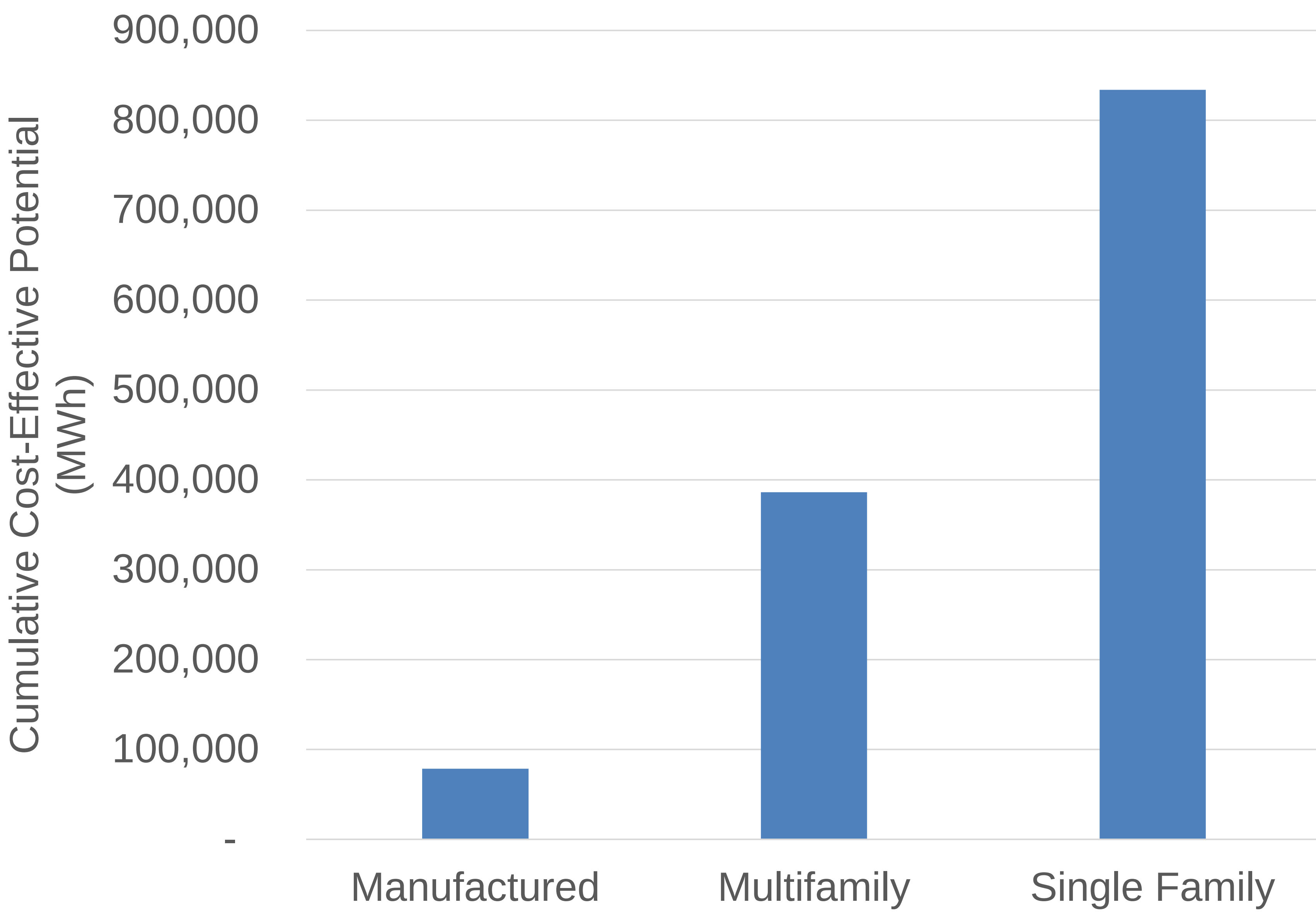
Residential	Commercial	Industrial
• CFL & LED lighting • Efficient new homes • Heat pump water heaters • Showerheads/aerators • Refrigerator recycling • Behavior Savings • Advanced power strips • Smart thermostats	• Strategic energy management • HVAC controls • Ventilation controls • LED lighting • Showerheads • Energy management systems	• Fan & pump system controls • Strategic energy management • LED lighting • Compressed air demand reduction • HVAC O&M

Energy Efficiency Supply Curve

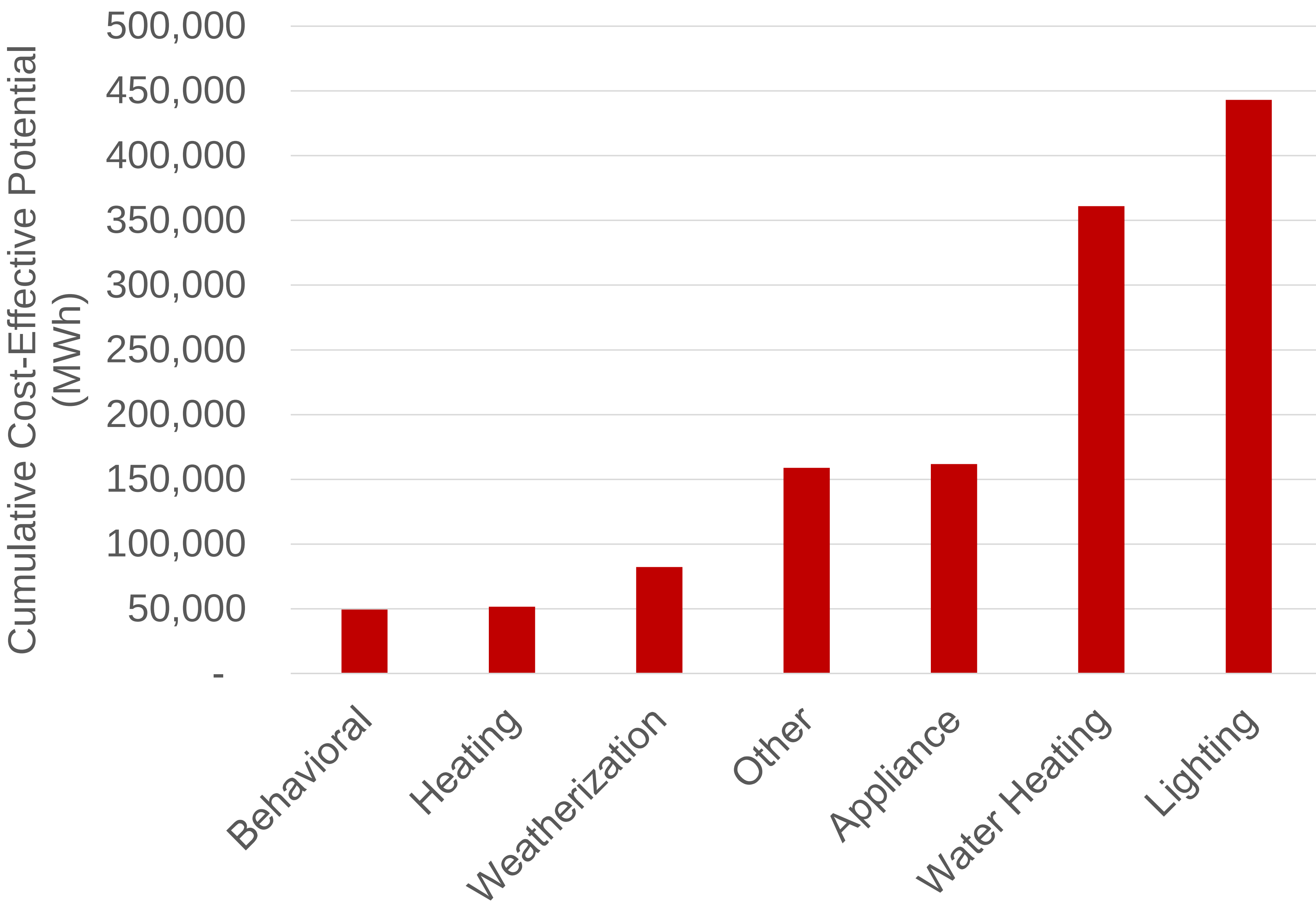



Contribution of Emerging Technologies
Cumulative Potential (MWh)
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Technical
Achievable
Cost-effective
Conventional
Emerging

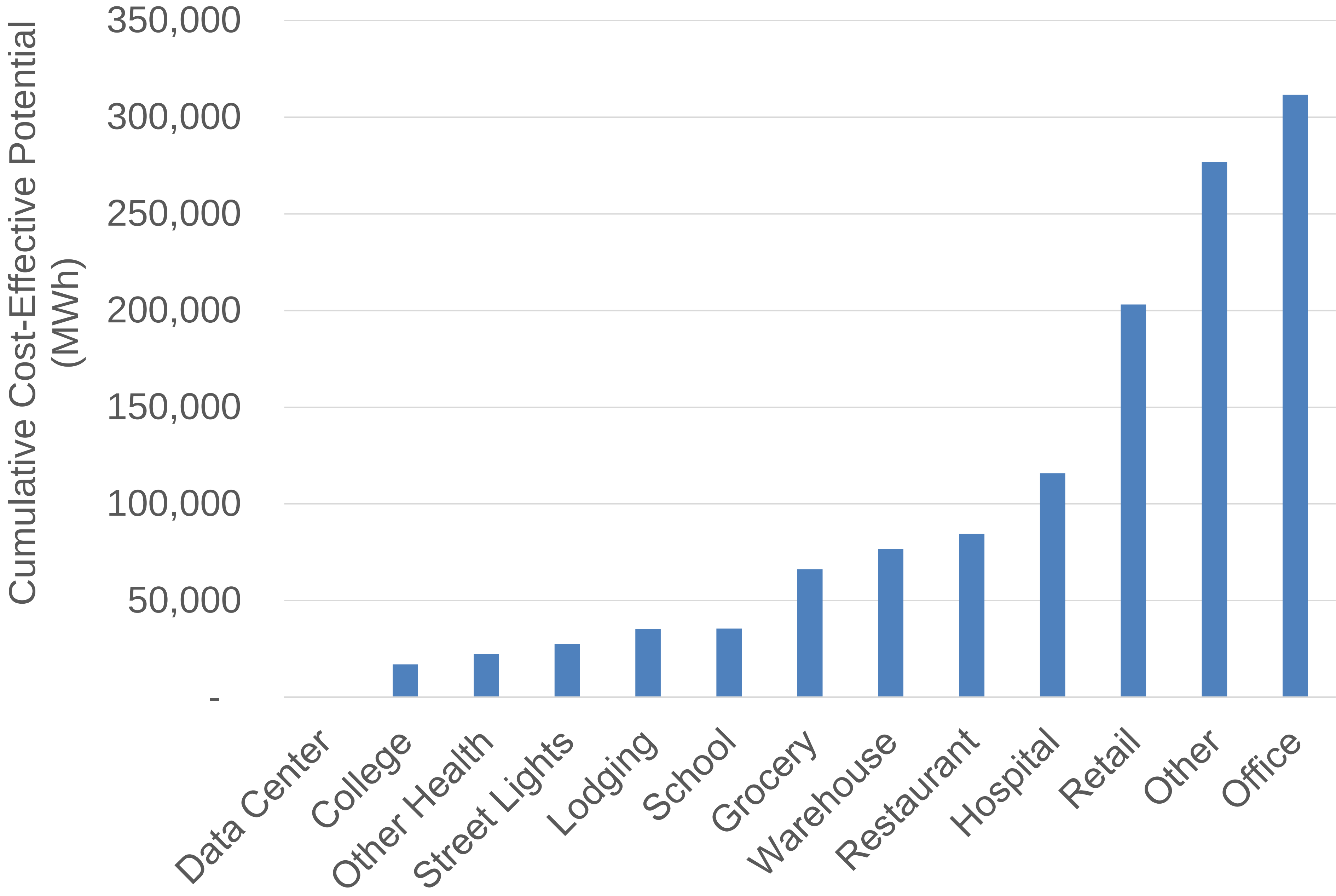
Savings Detail – Residential by Home Type



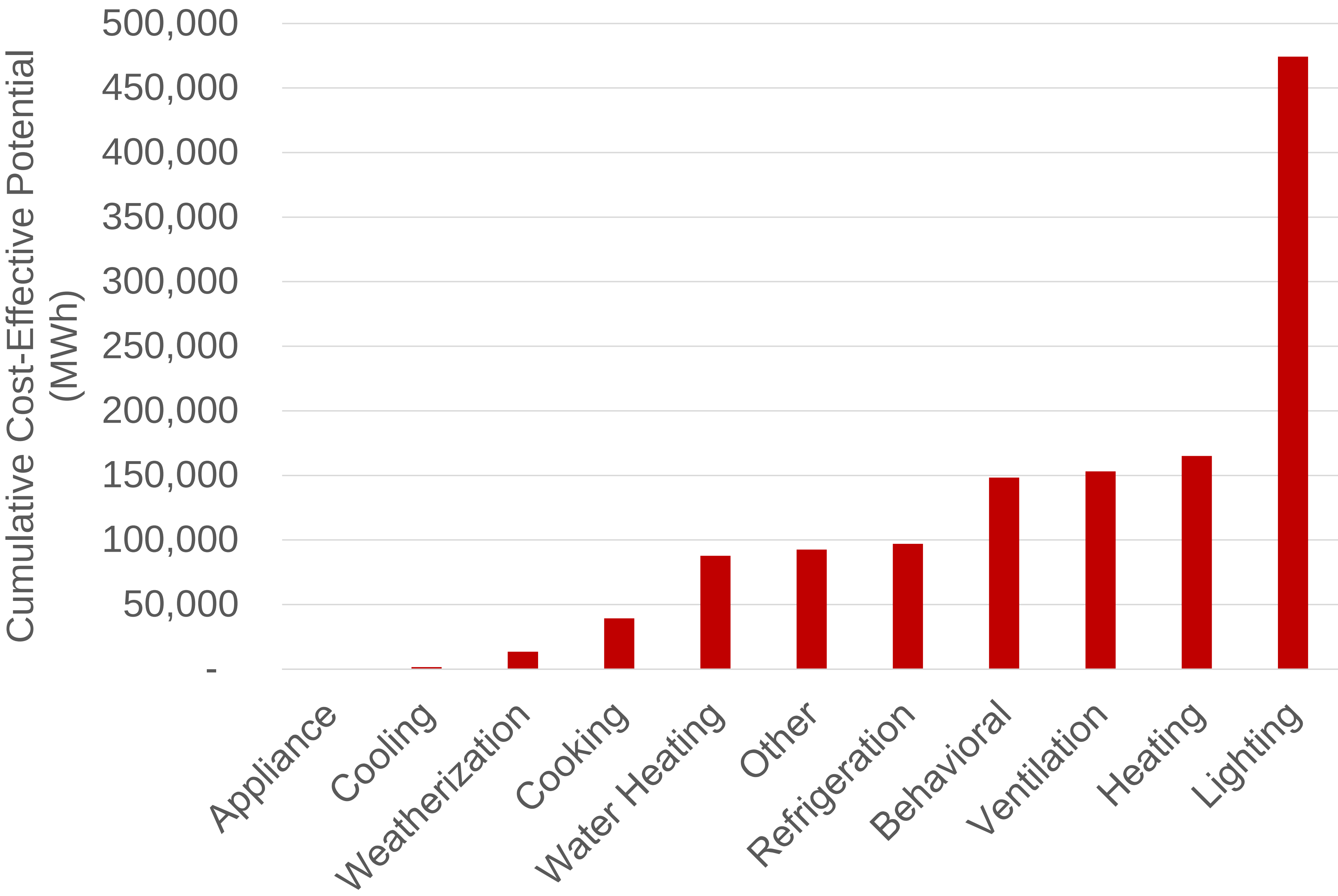
Savings Detail – Residential End Use



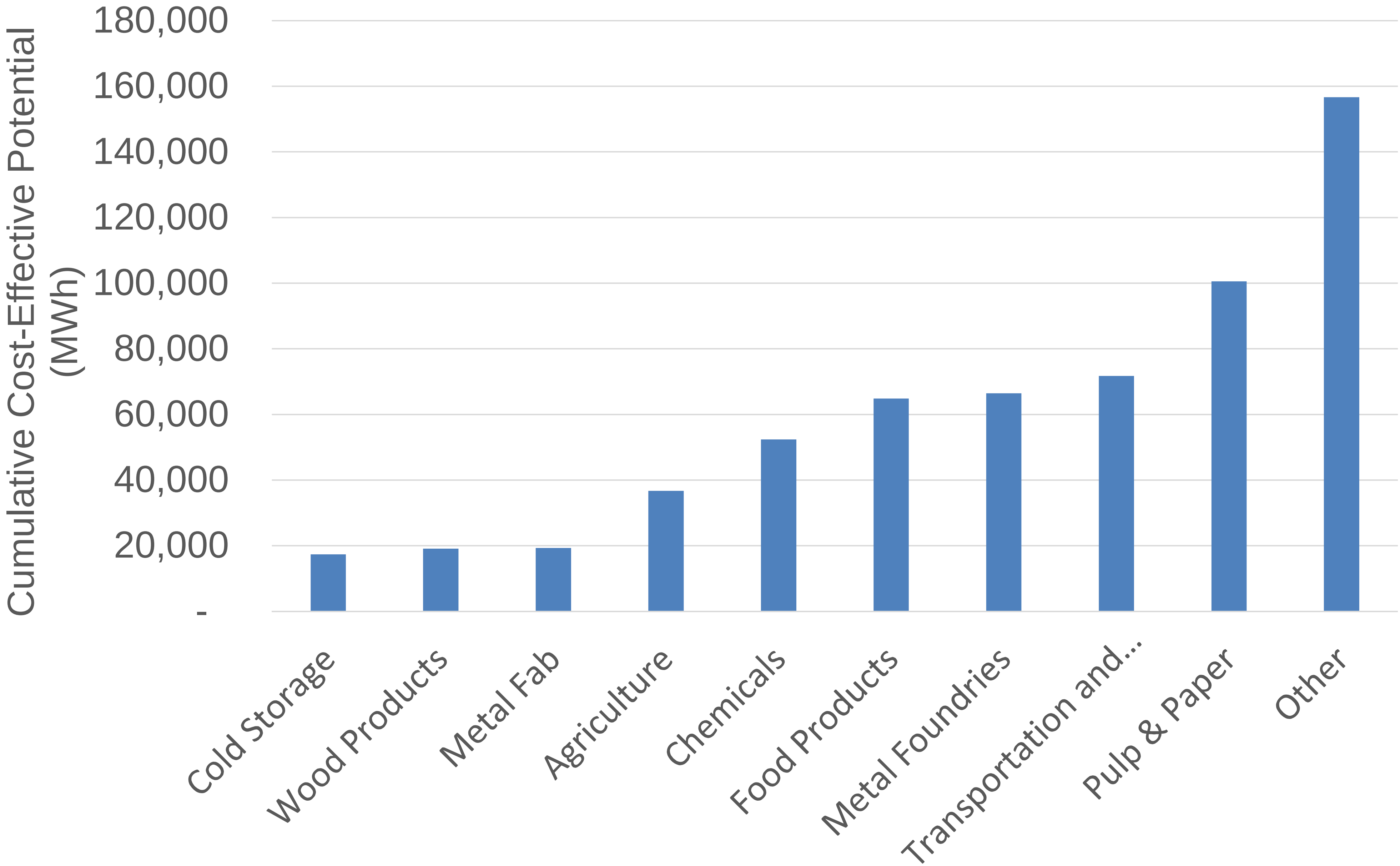
Savings Detail – Commercial Segment



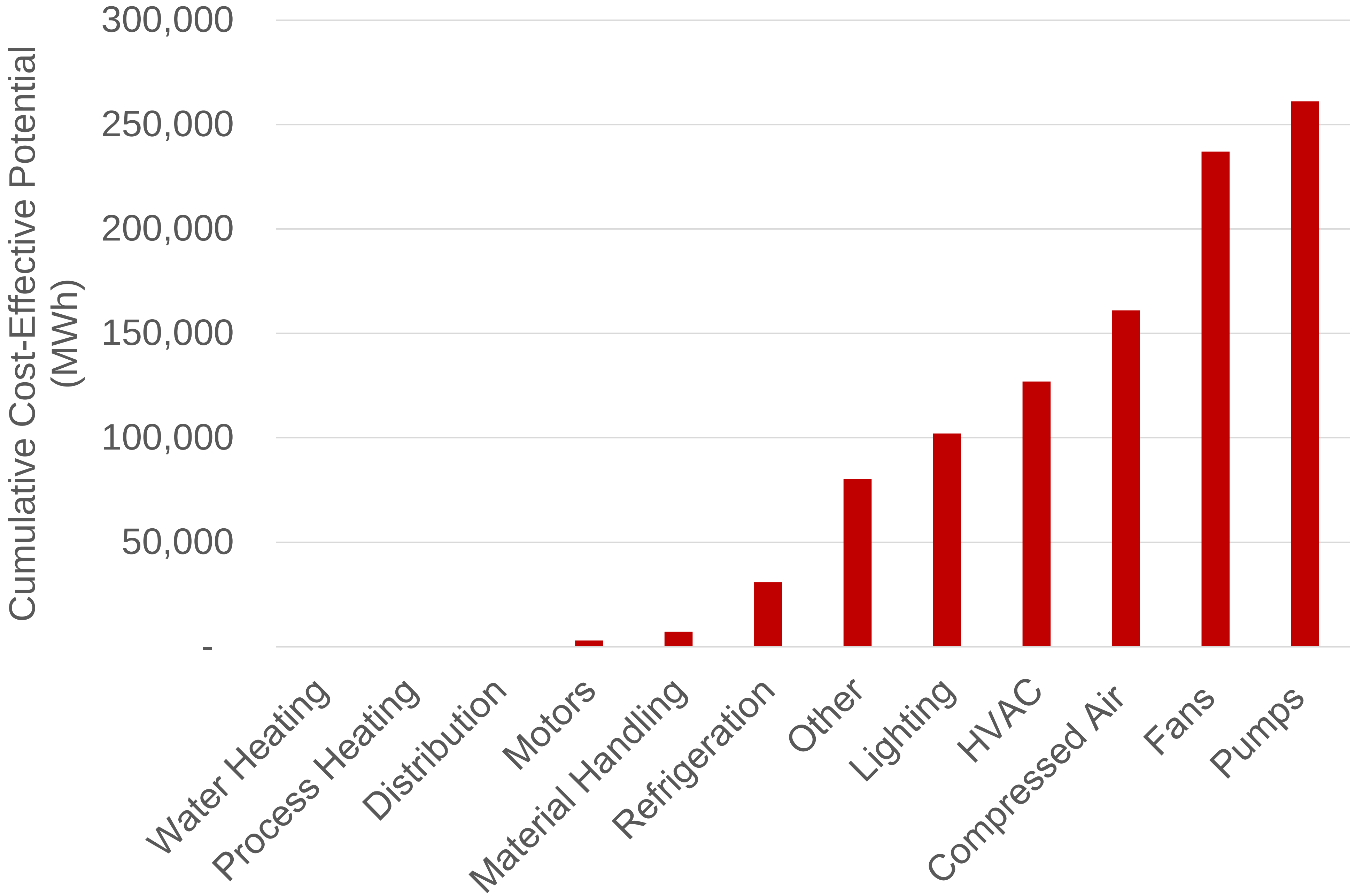
Savings Detail – Commercial End Use



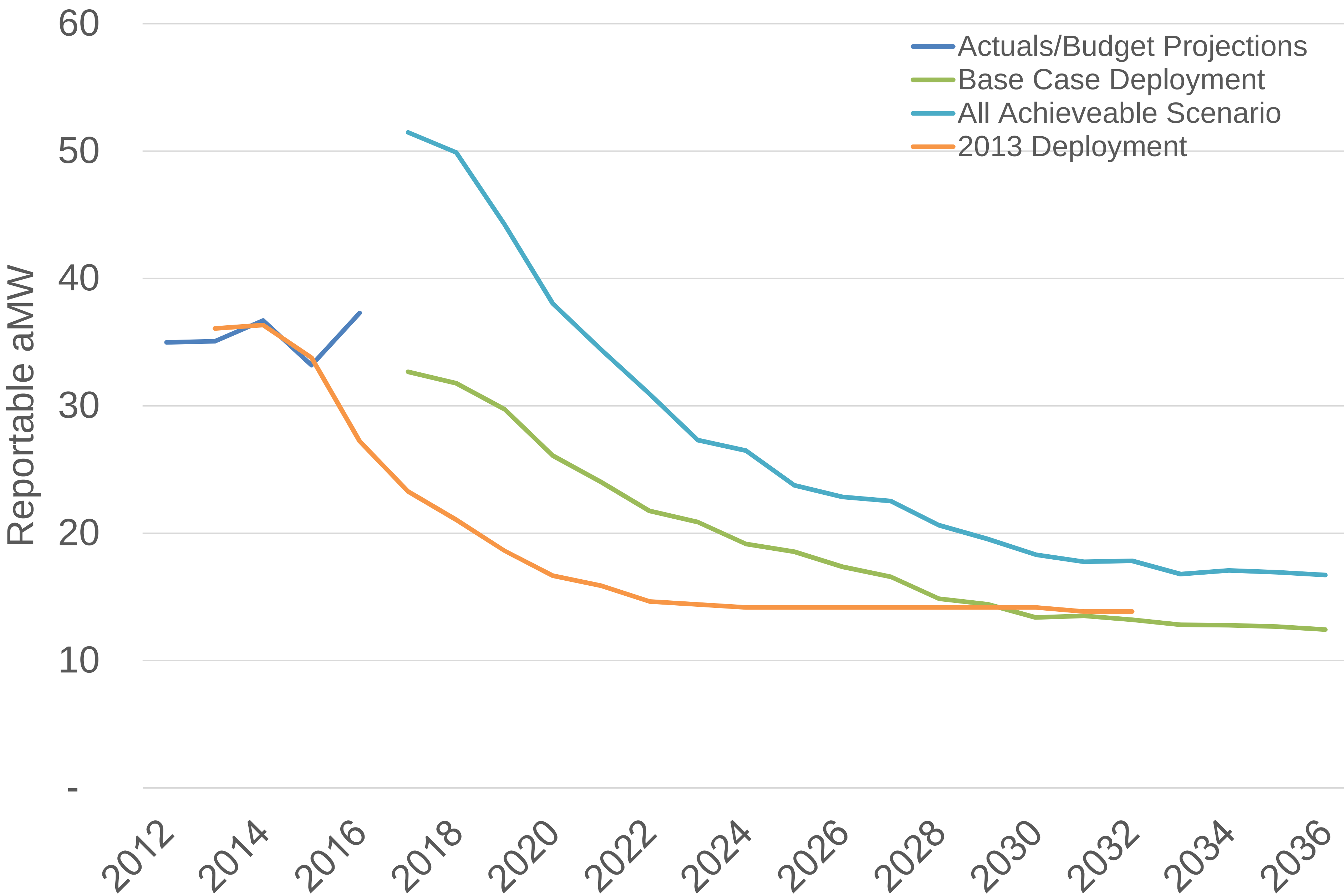
Savings Detail – Industrial Segments



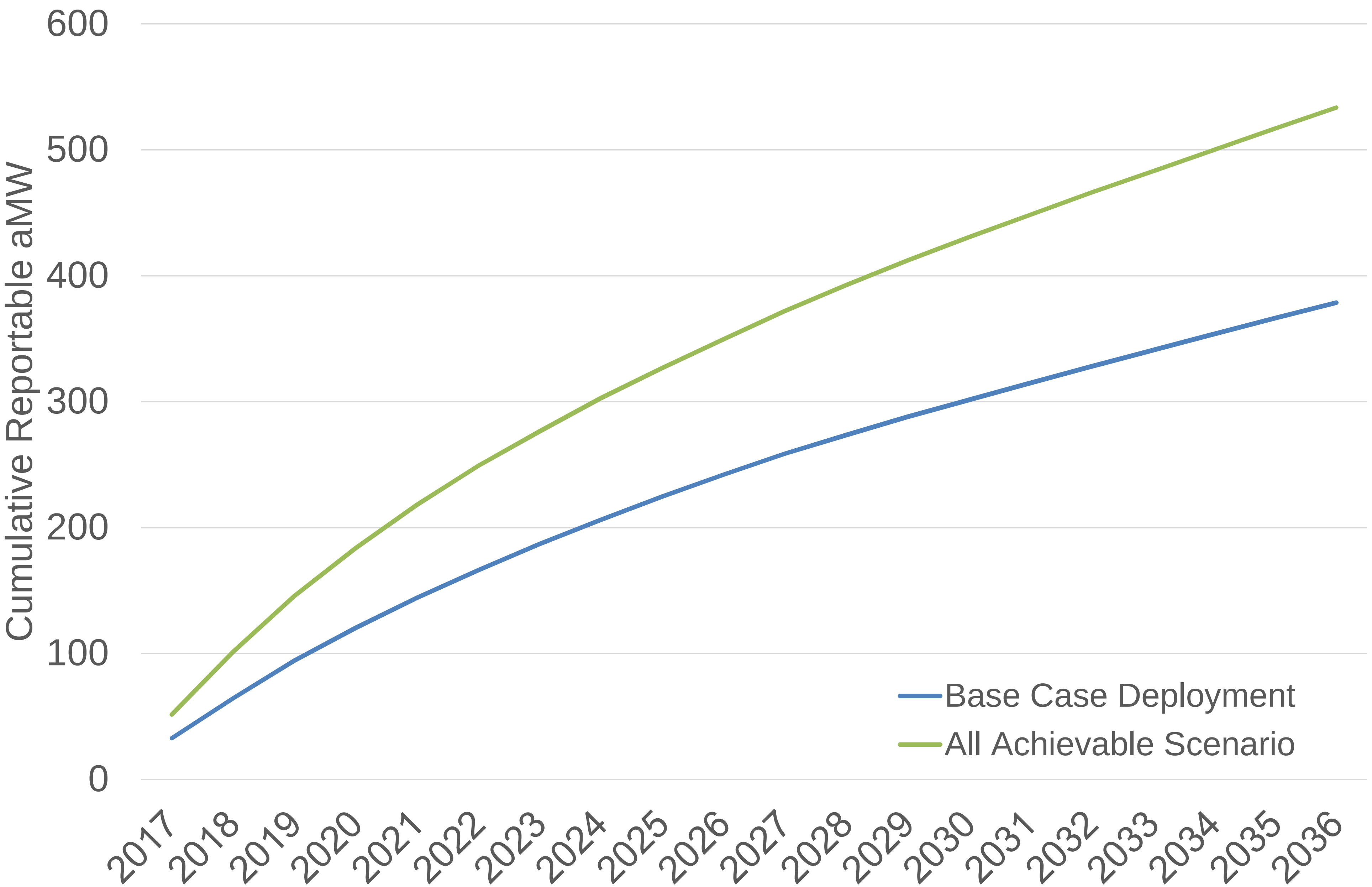
Savings Detail – Industrial End Use



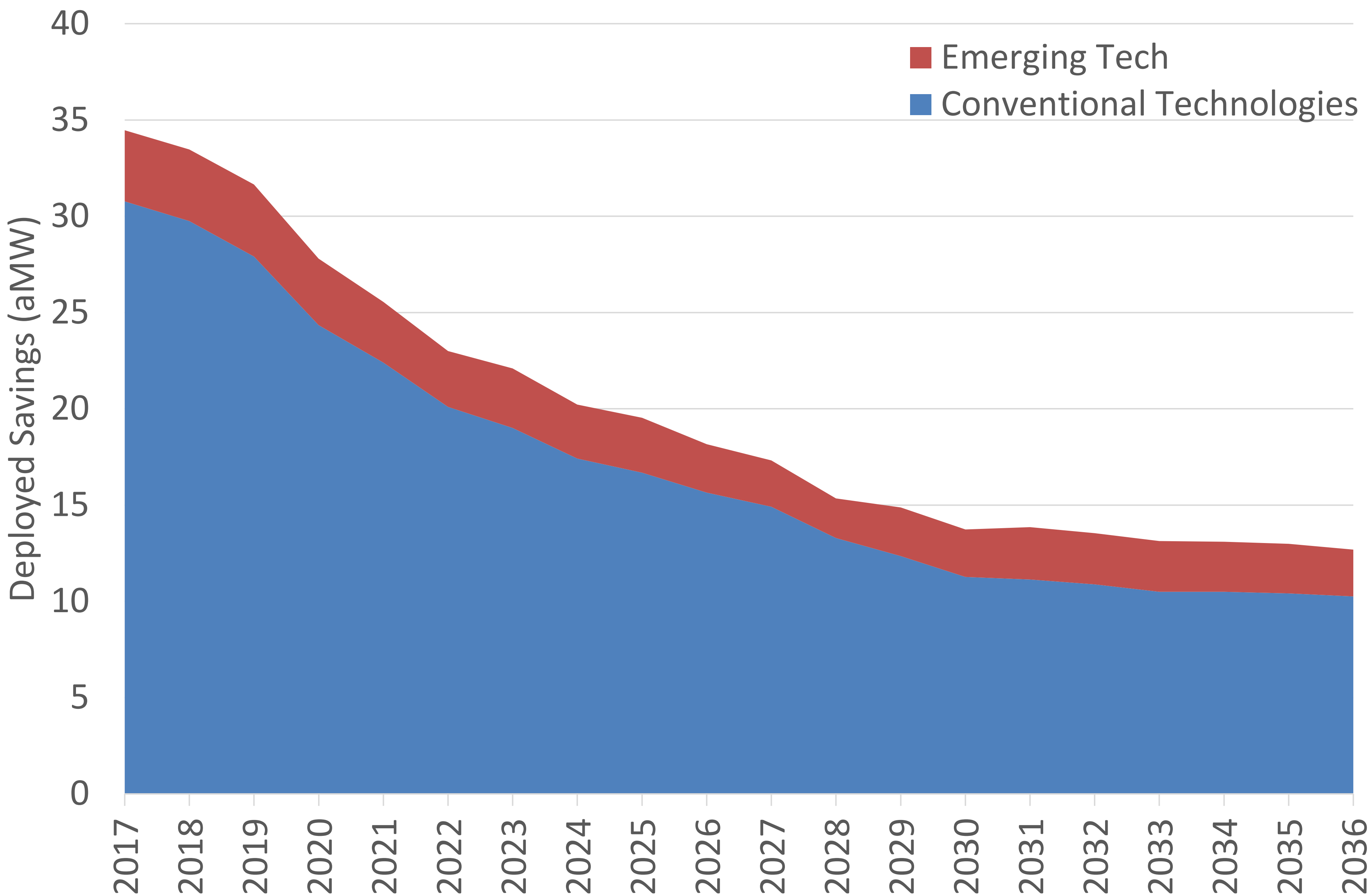
Energy Efficiency Deployment - Annual



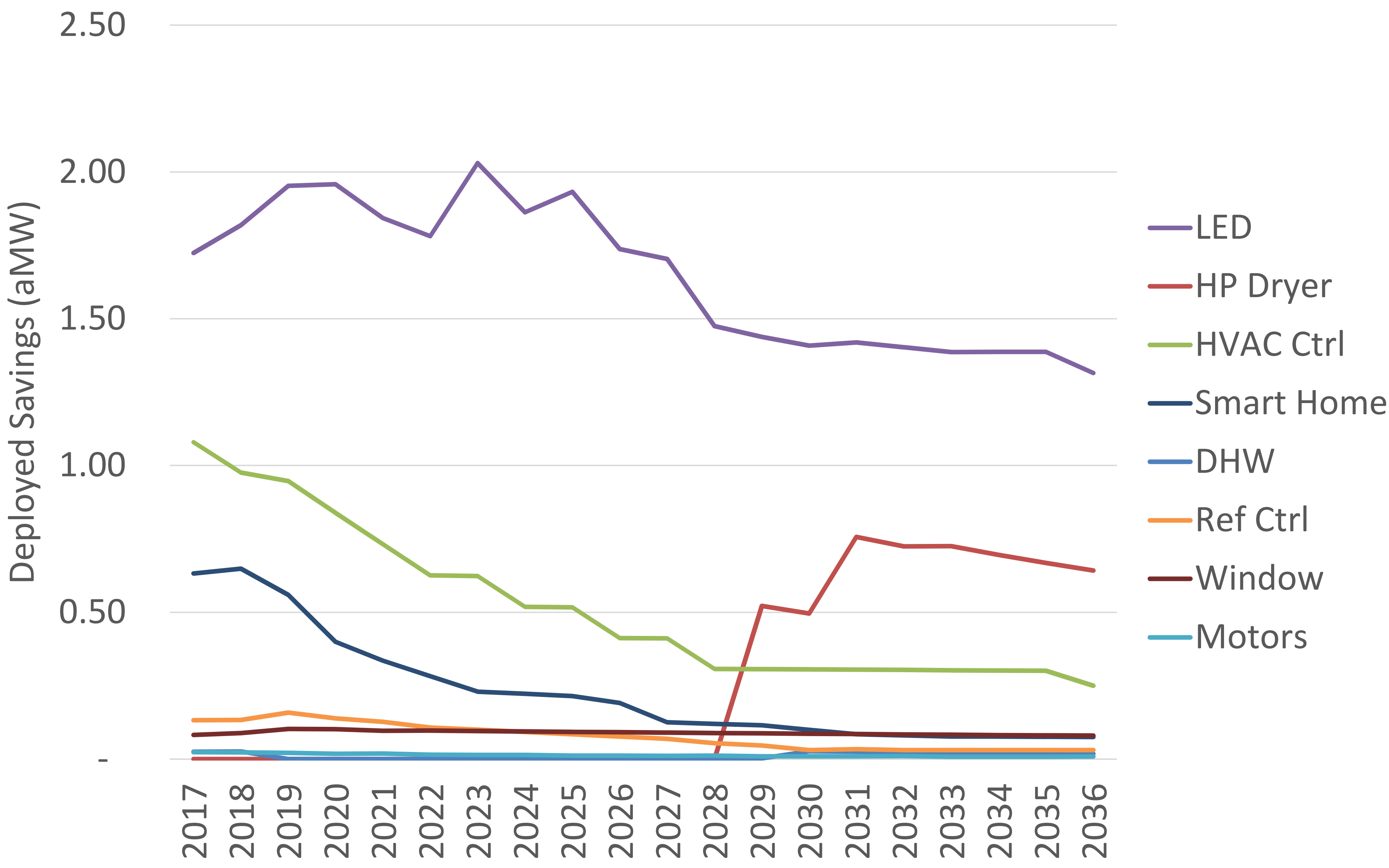
Energy Efficiency Deployment - Cumulative



Contribution of Emerging Technology



Deployed Emerging Technology Savings



Thank You

Ted Light, Sr. Planning Project Manager
Ted.Light@energytrust.org
503.445.7643

Energy Trust of Oregon

UM 1713 – Industrial Energy Efficiency

As part of SB 1149, the Public Purpose Charge for large industrial customers was capped at 3% of their electric bills. Subsequently, SB 838 provided for additional EE funding for other classes of customers, but the cap for large industrials was left in place.

- Funding from large industrials is no longer sufficient to capture all, cost–effective EE over the next few years.
- Docket UM 1713 was initiated to seek an administrative solution at the OPUC.
- In the UM 1713 workshops, stakeholders agreed that a legislative solution was both possible and preferable.
- OPUC Staff recommended that the docket be held in abeyance while stakeholders worked towards a legislative recommendation.
- On June 11th, UM 1713 was suspended until August 6th to give the parties sufficient time to reach consensus – collaboration is ongoing.


Portland General Electric

Distributed Generation

BUILDING A WORLD OF DIFFERENCE

SOLAR STUDY

RYAN PLETKA
MON-FEN HONG

July 16, 2015

BLACK & VEATCH
Building a world of difference.

TASK OVERVIEW

- **PGE's 2013 IRP Action Plan called for further investigation of solar photovoltaic (PV) in Oregon**
- **Black & Veatch commissioned to apply PV screens:**
  - Technical
  - Financial
  - Achievable
- **Two major types of PV studied:**
  - Utility-scale solar within Oregon
  - Distributed solar within PGE's service area

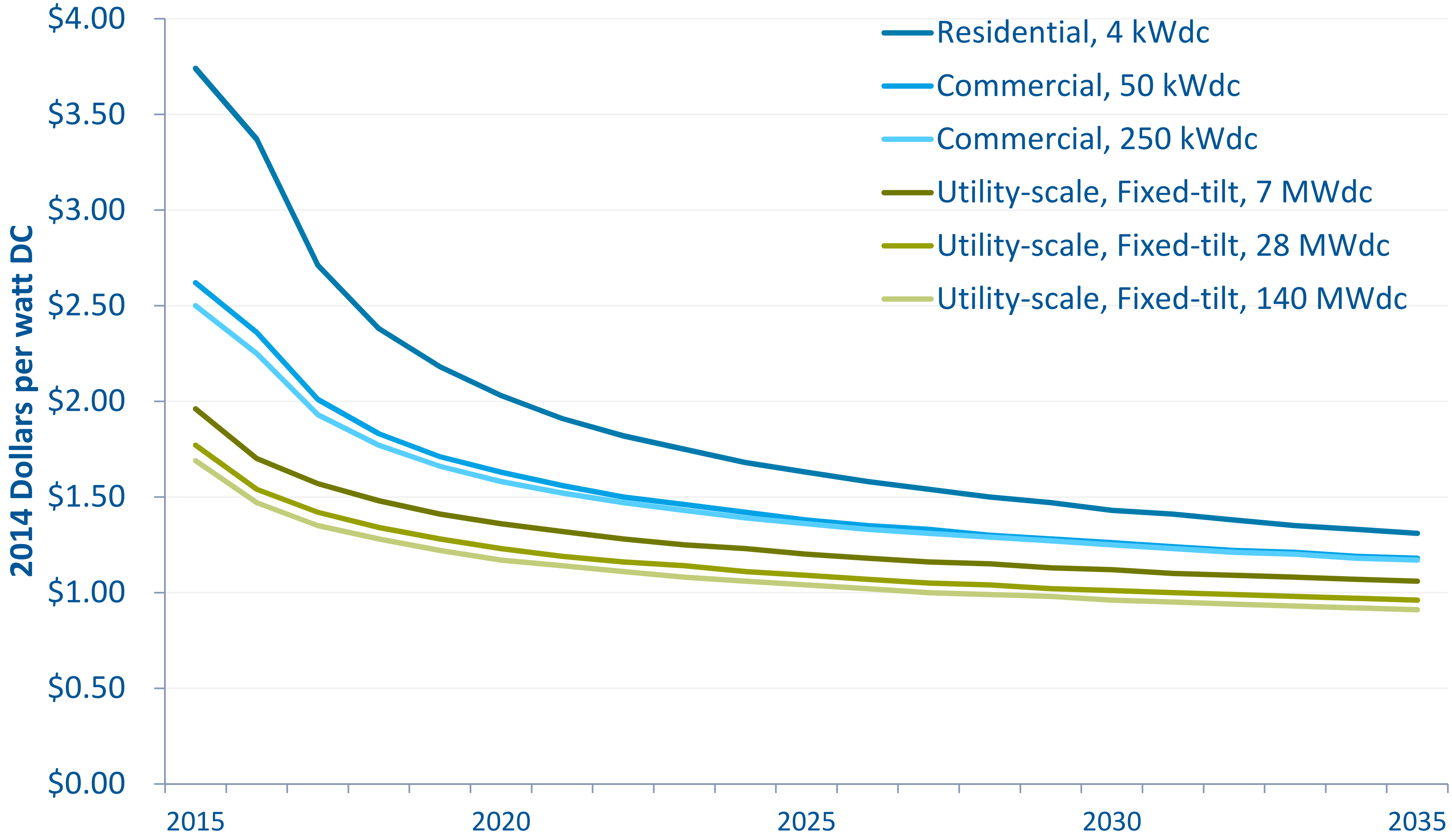
ESTIMATES FROM SCREENS

Technical Screen
- What is technically practical

Financial Screen
- What makes financial sense

Achievable Screen
- What might actually happen

SOLAR COSTS (2015-2035) ARE EXPECTED TO CONTINUE TO DECLINE



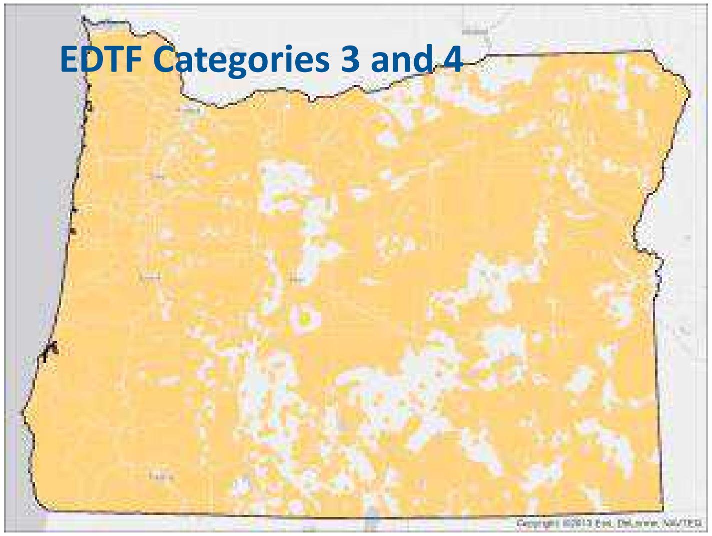
By 2035, PV system costs drop to ~$1/Wdc utility scale and ~$1.25/Wdc distributed

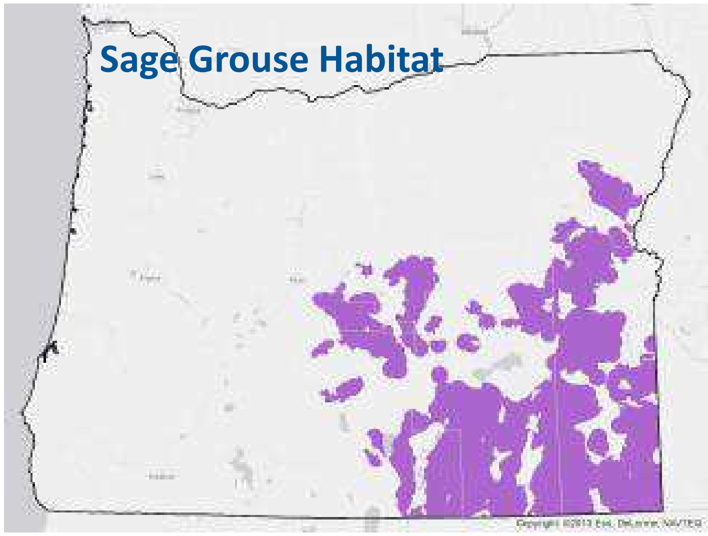
SUMMARY RESULTS PREVIEW

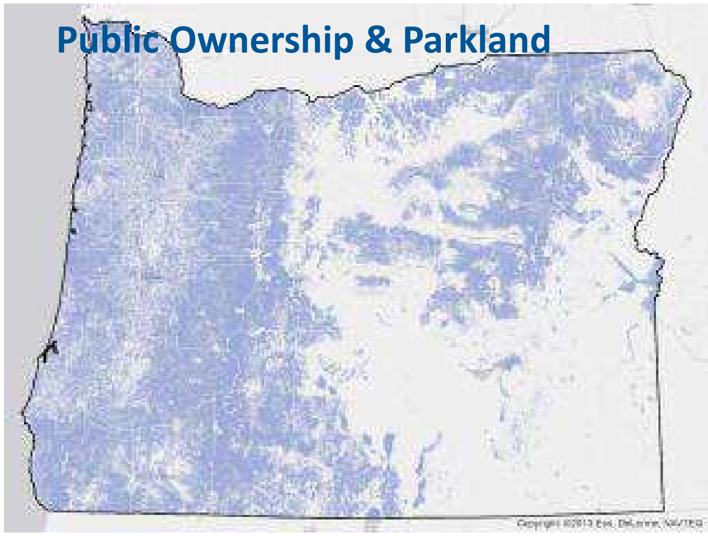
	TECHNICAL SCREEN	FINANCIAL SCREEN BY 2035	ACHIEVABLE SCREEN BY 2035
Utility-Scale (MWac)	56,000	7,500 to 17,500	100 to 369
Distributed (MWdc)	2,810	1,410	125 to 223

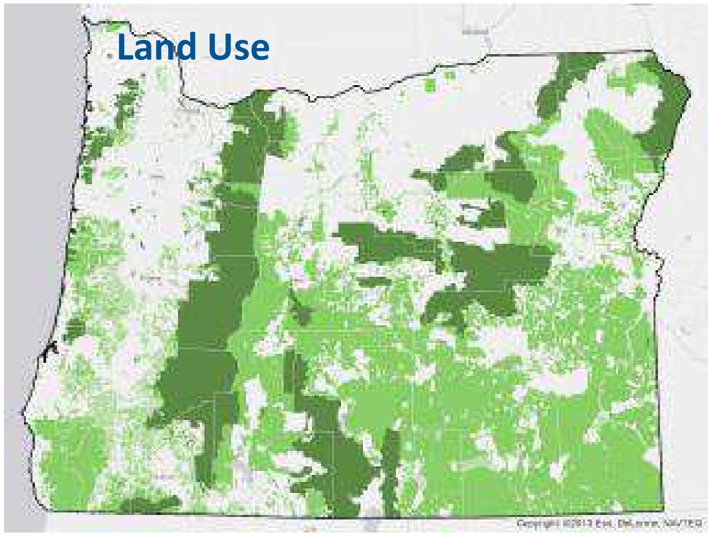
MWdc = megawatts direct current
MWac = megawatts alternating current

UTILITY SCALE TECHNICAL SCREEN – LAND AND ENVIRONMENTAL CONSTRAINTS



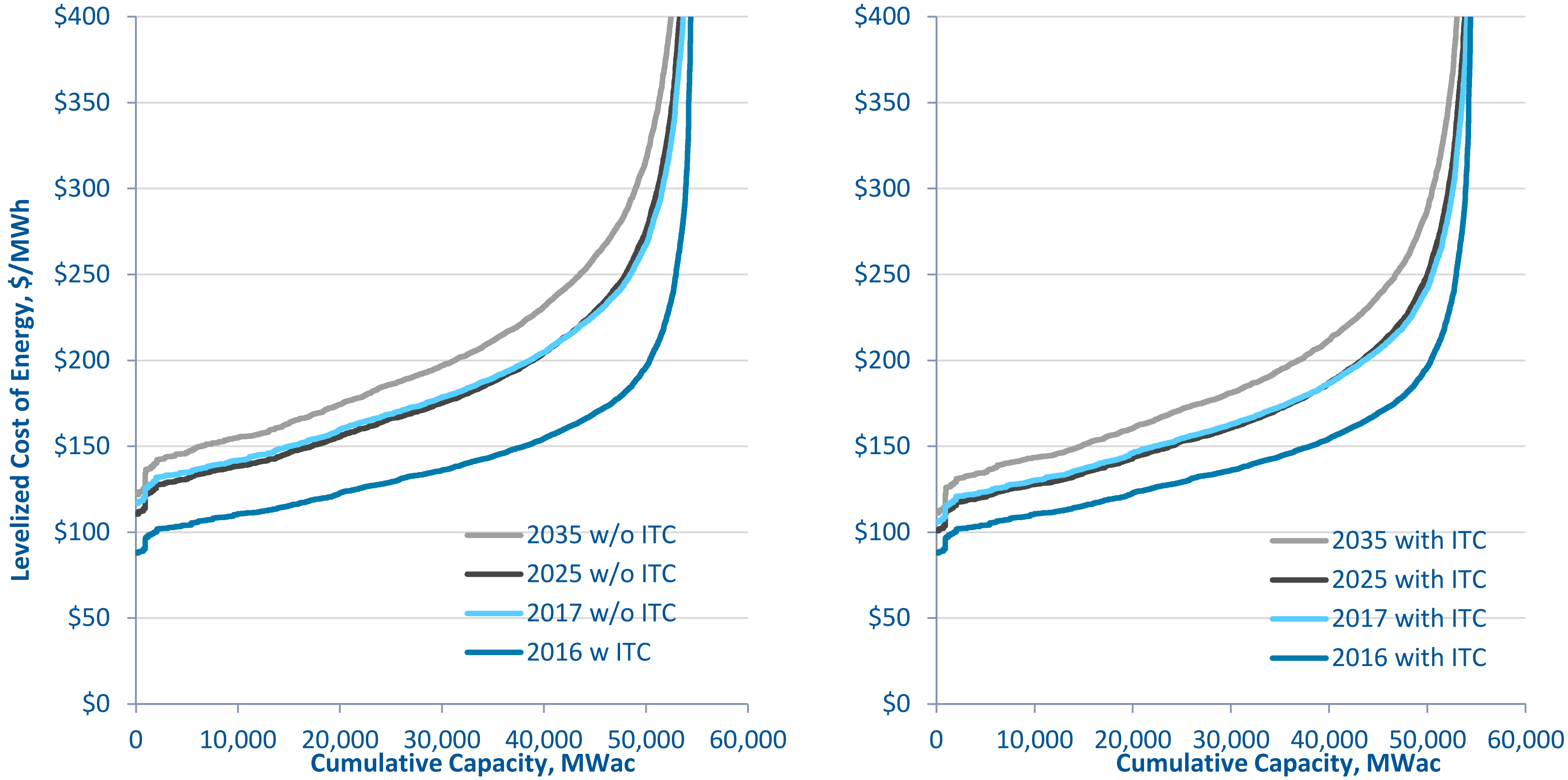






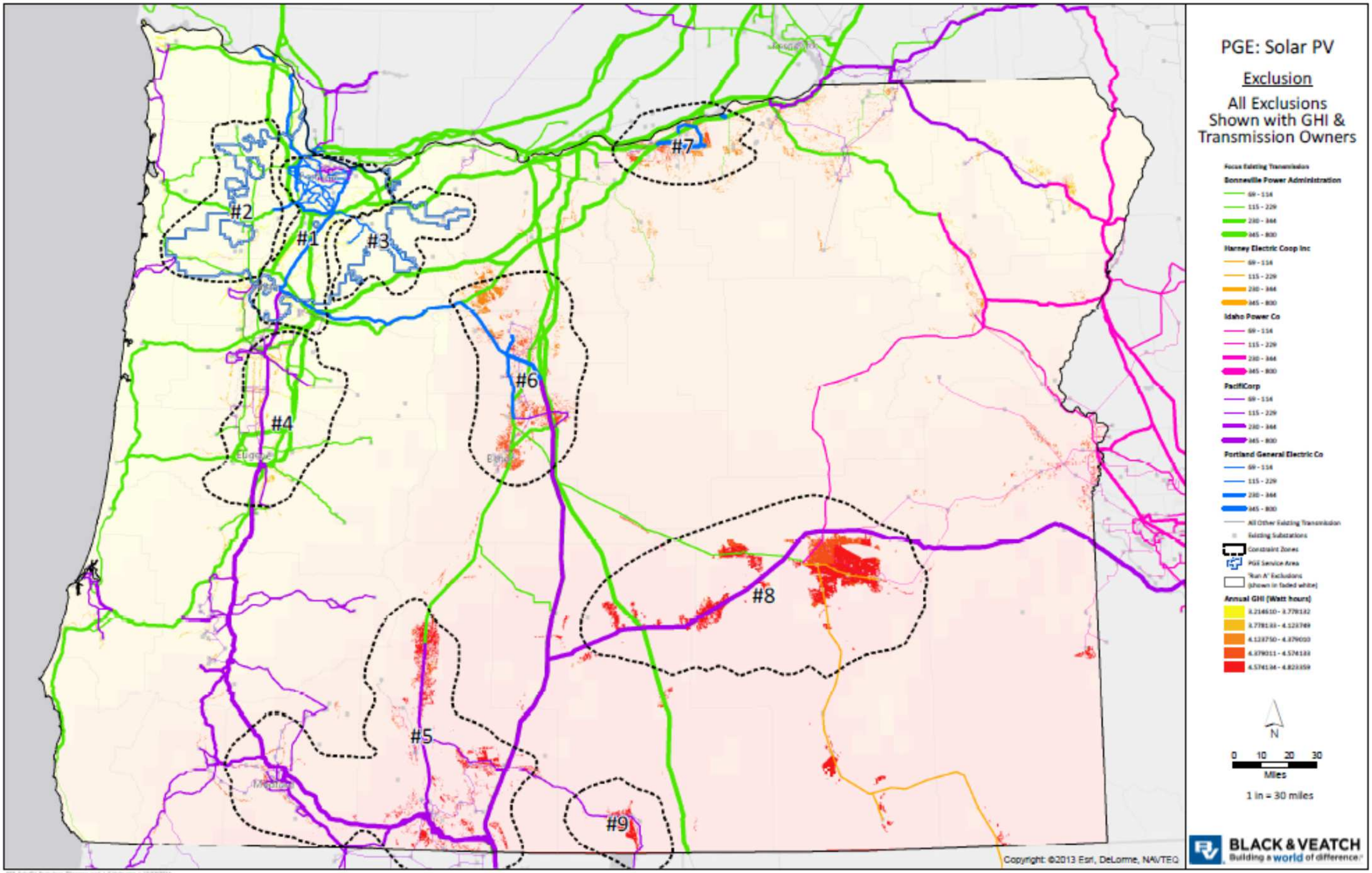
Plus: within 5 miles of transmission, slope <5%

UTILITY SCALE FINANCIAL SCREEN – SUPPLY CURVES WITH AND WITHOUT ITC



Capital cost included PV system installed cost based on size, gen-tie, and substation costs
Ongoing costs included O&M, inverter replacement, lease payment, insurance, property taxes, wheeling charges, and real power losses.

UTILITY SCALE ACHIEVABLE SCREEN – TRANSMISSION CONSTRAINT ZONES



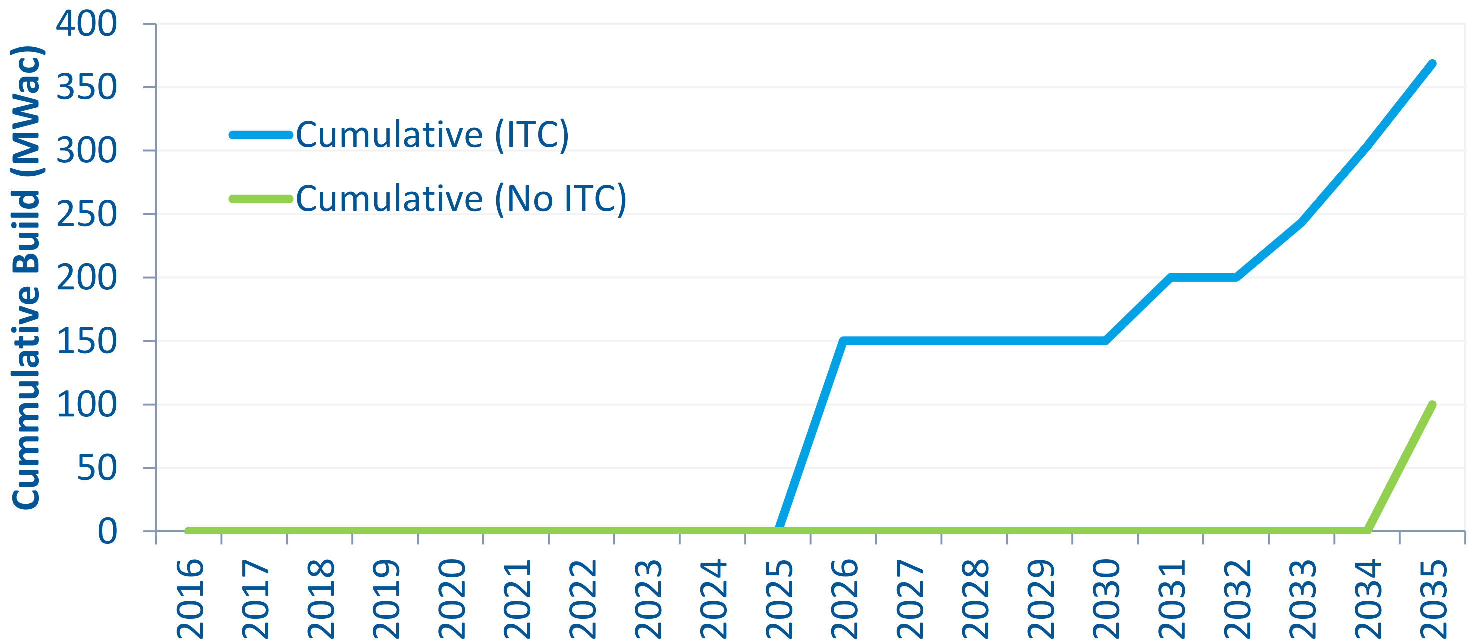
TRANSMISSION CONSTRAINTS

ZONE	NUMBER OF SYSTEMS CONNECTING AT TRANSMISSION VOLTAGE (PROJECT MAX MW)			ESTIMATED MAX EXPORT CAPACITY BY ZONE (MW)	WHEELING REQUIREMENT
	57/69 (10 MW)	115/138 (20 MW)	230 (50 MW)		
No. 1	3-7	6-10	2-4	400 – 500	None. On PGE line
No. 2	3-5	3-5		200	None. On PGE line
No. 3	3-4	1-2		100	None. On PGE line
No. 4	4-5	4-5	2-4	150	Wheeled to PGE
No. 5	5-6	4-5	2-4	200	Wheeled to PGE
No. 6	3-4	4-5	2-3	200	Wheeled to PGE (PGE lines in zone, but no capacity)
No. 7	2-3	2-4	1-2	200	Wheeled to PGE (PGE lines in zone, but no capacity)
No. 8	4-5	2-3		60	Wheeled to PGE
No. 9	2-4			40	Wheeled to PGE

Maximum system size per site based on PGE guidance

CUMULATIVE ACHIEVABLE SCREEN FOR UTILITY-SCALE SOLAR

- **Capital costs for systems were adjusted for size limitations accordingly and new supply curves created by year**
- **By 2035, this screen results in 369 MW (with ITC) and 100 MW (No ITC)**



Most cost effective zones are in 5, 6, and 8. PGE territory zones 1, 2, and 3 have worse resources.

SUMMARY CONCLUSIONS – UTILITY GENERATION

- **Major limitations to “achievable” screen are transmission availability to deliver solar from “good” resource areas to PGE territory and the added costs for wheeling and losses**
- **Long-term PGE QF pricing for variable solar appears not to be sufficient to drive solar adoption in Oregon when the ITC is not available.**
- **If the ITC is available at 10 percent, cost-effective solar becomes possible by 2026.**
- **Additional penetration may be possible if developers are willing to build projects for less than the assumed return requirements of 6.5 percent, capital costs are lower than forecasted, more value is placed on large-scale solar than just QF pricing, or additional incentives (e.g., from ETO) are available.**

DG SOLAR TECHNICAL SCREEN

Collect data*
- LiDAR data
- Building footprint
- Building parcel data

Convert LiDAR data to Digital Elevation Model (DEM)

Identify Building Type (Residential/ Commercial)

Isolate Building Footprint

Determine Tilt and Azimuth on Roof Plane

Run Area Solar Radiation Analysis for Shading

Isolate "Good" Solar Roof Areas = Pass TSRF**

Apply Additional Requirements to Determine Buildable Space

Convert remaining roof area to capacity (Wdc)

*Some data were not available for all areas in PGE service territory
** TSRF = Total Solar Resource Fraction

SOLAR MODEL WAS VERY DETAILED – DOWNTOWN PORTLAND

DISTRIBUTED-SCALE SOLAR TECHNICAL SCREEN

- About 50% of parcels (185,000) assessed by Lidar passed the technical screen
- Areas where Lidar data not available estimated based on parcel characteristics
- Resulting capacity by land-use shown below

LAND USE	LIDAR-ASSESSED AREA TOTAL CAPACITY (MWDC)	PGE SERVICE TERRITORY TOTAL CAPACITY (MWDC)
Single-Family Residential	451	631
Multi-Family Residential	125	167
Commercial	586	874
Industrial	575	869
Public/Semi-Public	62	270
Total	**1,800**	**2,810**

FINANCIAL SCREEN USED NREL'S SYSTEM ADVISOR MODEL TO CALCULATE PAYBACK

Array Characteristics
- Size
- Tilt/Azimuth
- Shading
- Technology Characteristics

Customer Load
- Customer rates
- Customer size
- Hourly profile

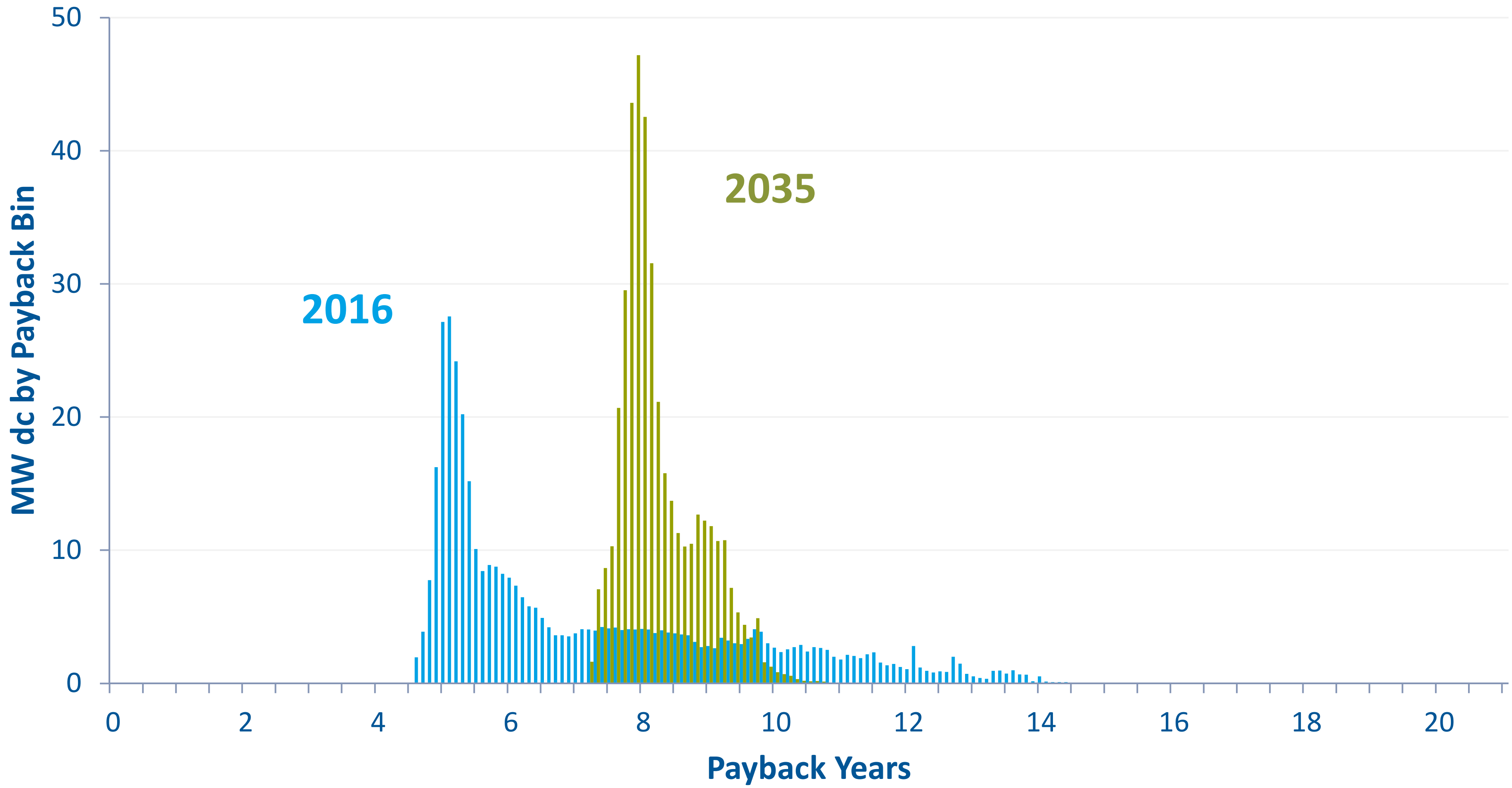
Financial Assumptions
- Tax incentives
- ETO incentives
- Capital Cost
- O&M Cost

System Advisor Model

SIMPLE PAYBACK

Multiple drivers in determining payback

EXAMPLE RESIDENTIAL PAYBACK DISTRIBUTION CASE: RATES INCREASE AT CONSUMER PRICE INDEX (CPI) + 1%



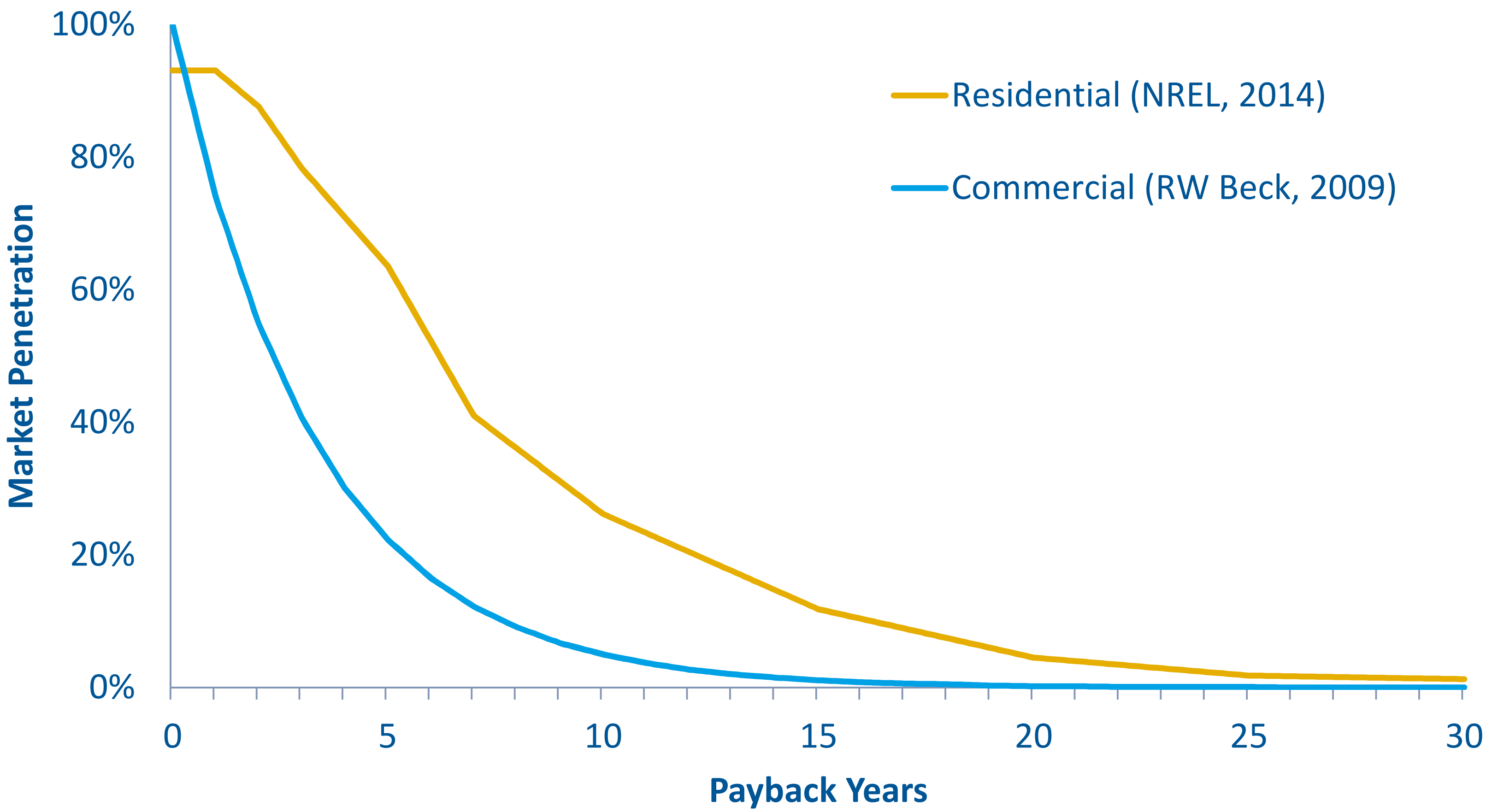
Paybacks are longer in 2035 when no incentives are available, despite lower capital costs and increased utility rates.

RESULTING FINANCIAL CAPACITY (<20 YEAR PAYBACK)

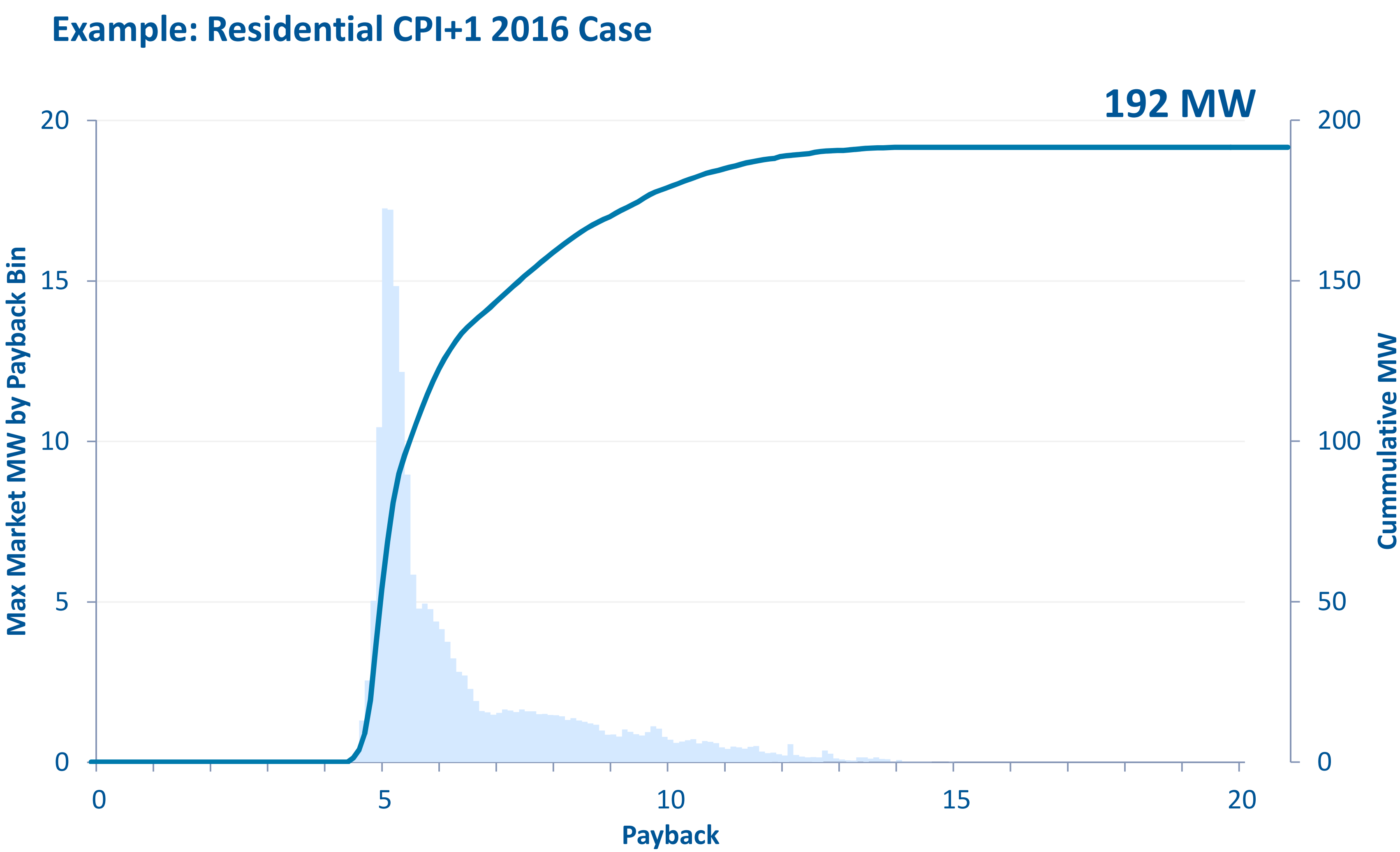
Customer Class	All Scenarios (MWdc)
Residential	415
Commercial (including industrial and public/semi-public)	995
Total MWdc	**1,410**

- Recognize that "financial" projects do not necessarily translate to customer adoption
- Additional limitations are applied during the achievable screen

TECHNOLOGY ADOPTION: DG SOLAR MAXIMUM PENETRATION BASED ON SURVEY RESULTS OF CUSTOMERS



RESULTING MAXIMUM DG SOLAR CAPACITY AFTER ACHIEVABLE SCREEN



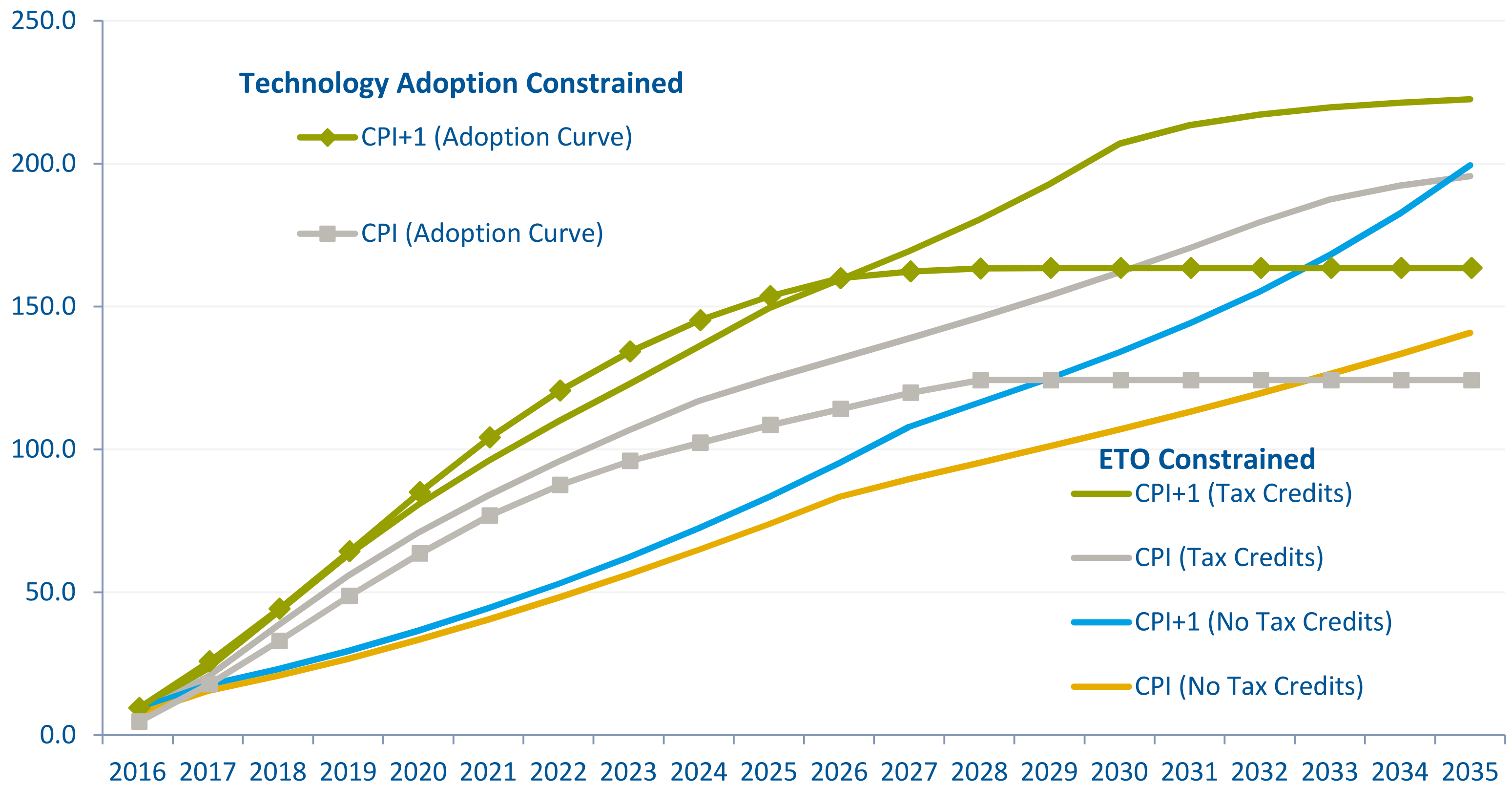
SIX DISTRIBUTED SOLAR ADOPTION SCENARIOS

	CPI	CPI+1
Technology Adoption Limited (Bottom-Up)	Market matures from incentives available in 2016 to no incentives available by 2035	Market matures from incentives available in 2016 to no incentives available by 2035
ETO Funding Limited* (Top-Down)	With Tax Credits: Federal (10% ITC) and state tax credits (residential only)** available throughout study period	With Tax Credits: Federal (10% ITC) and state tax credits (residential only)** available throughout study period
	No Tax Credits: Only ETO incentives are available	No Tax Credits: Only ETO incentives are available

*** Total annual ETO funding is capped for residential ($3 million) and commercial ($2.6 million) customers, based on 2015 ETO incentives allocated to PGE's service territory.**

**** Oregon residential tax credit is stepped down by $0.20/W per year.**

ALL 6 SCENARIOS - DG SOLAR CUMULATIVE ADOPTION (MWdc)



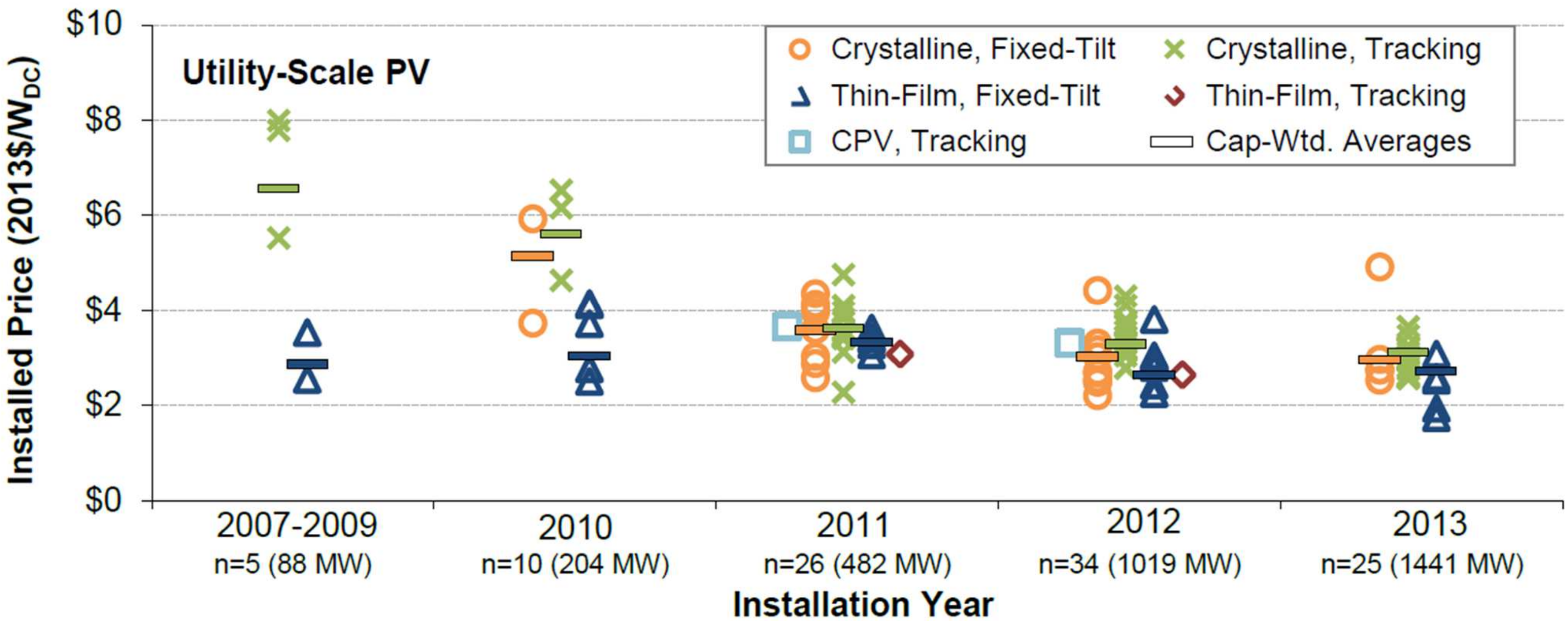
A variety of pathways to cumulative penetration of 125-223 MWdc

SUMMARY CONCLUSIONS – DISTRIBUTED GENERATION

- **Oregon's combination of low solar resource, low rates, and high subsidies results in a market largely driven by subsidies**
  - All future scenarios strongly driven by subsidy assumptions
- **Decline in PV costs not sufficient to offset loss of incentives by 2035**
  - Incentives likely needed to continue to grow market. Otherwise, pool of customers willing to adopt solar is finite.
- **Even if a project passes the "Financial" screen, it does not necessarily translate to adoption, as each customer's decision to adopt may be different**
  - Black & Veatch recommends PGE perform a survey of customers to develop PGE-specific maximum market penetration curves
- **Technical screen applied to current building stock**
  - Future analysis may incorporate new construction, changes to existing stock, solar panel efficiency, and other innovations.
- **Given increasing third party owner role in DG market, additional analysis on their impact to market adoption may be warranted**
- **Data set created for this project is rich – can be used for many other things**

FURTHER DETAIL

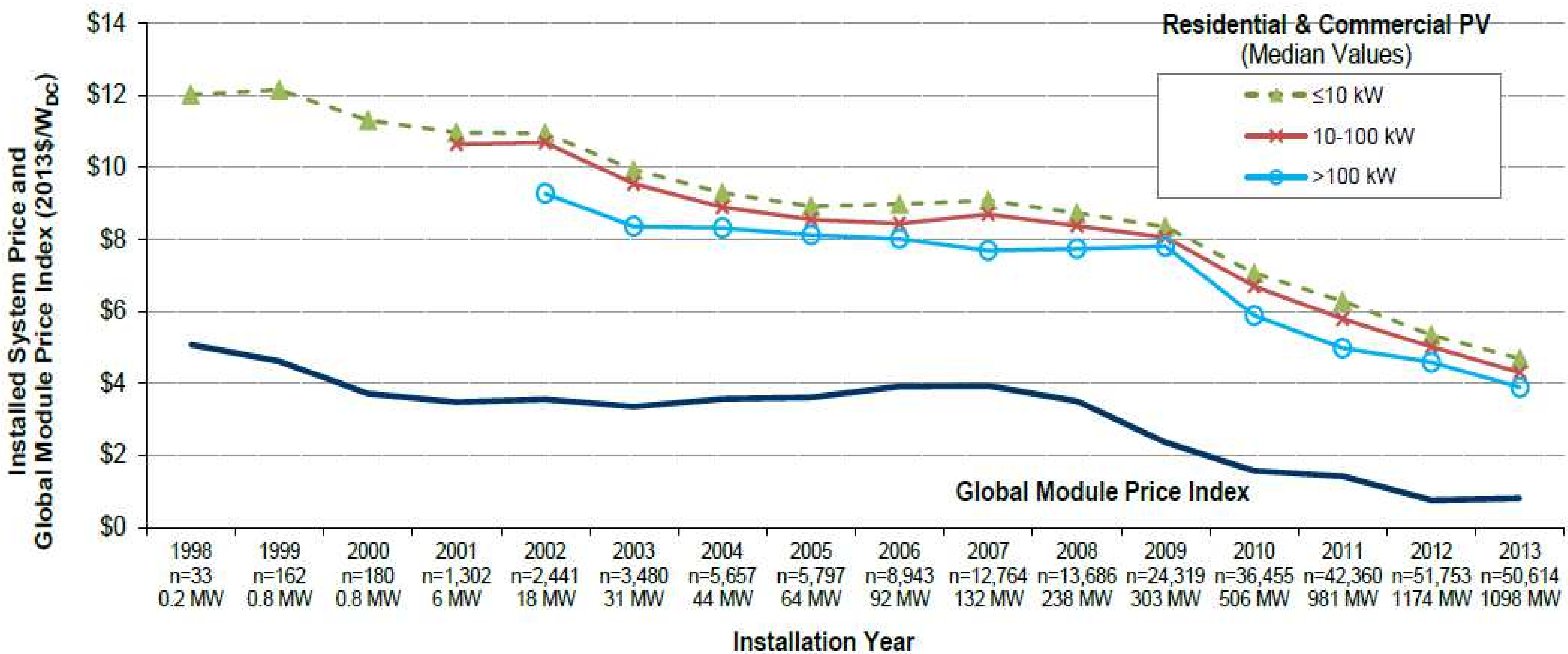
UTILITY-SCALE SOLAR COSTS HAVE BEEN DECLINING NATIONALLY



Source: Lawrence Berkeley National Laboratory/DOE

Recent Steel Bridge Solar proposed in Oregon with installed cost of $1.98/Wdc for 3.0 MWdc(2.4Wac)

DISTRIBUTED SOLAR COSTS HAVE ALSO BEEN DECLINING NATIONALLY



Note: Median installed prices are shown only if 15 or more observations are available for the individual size range. The Global Module Price Index is SPV Market Research's average module selling price for the first buyer (P. Mints).

Source: Lawrence Berkeley National Laboratory/DOE

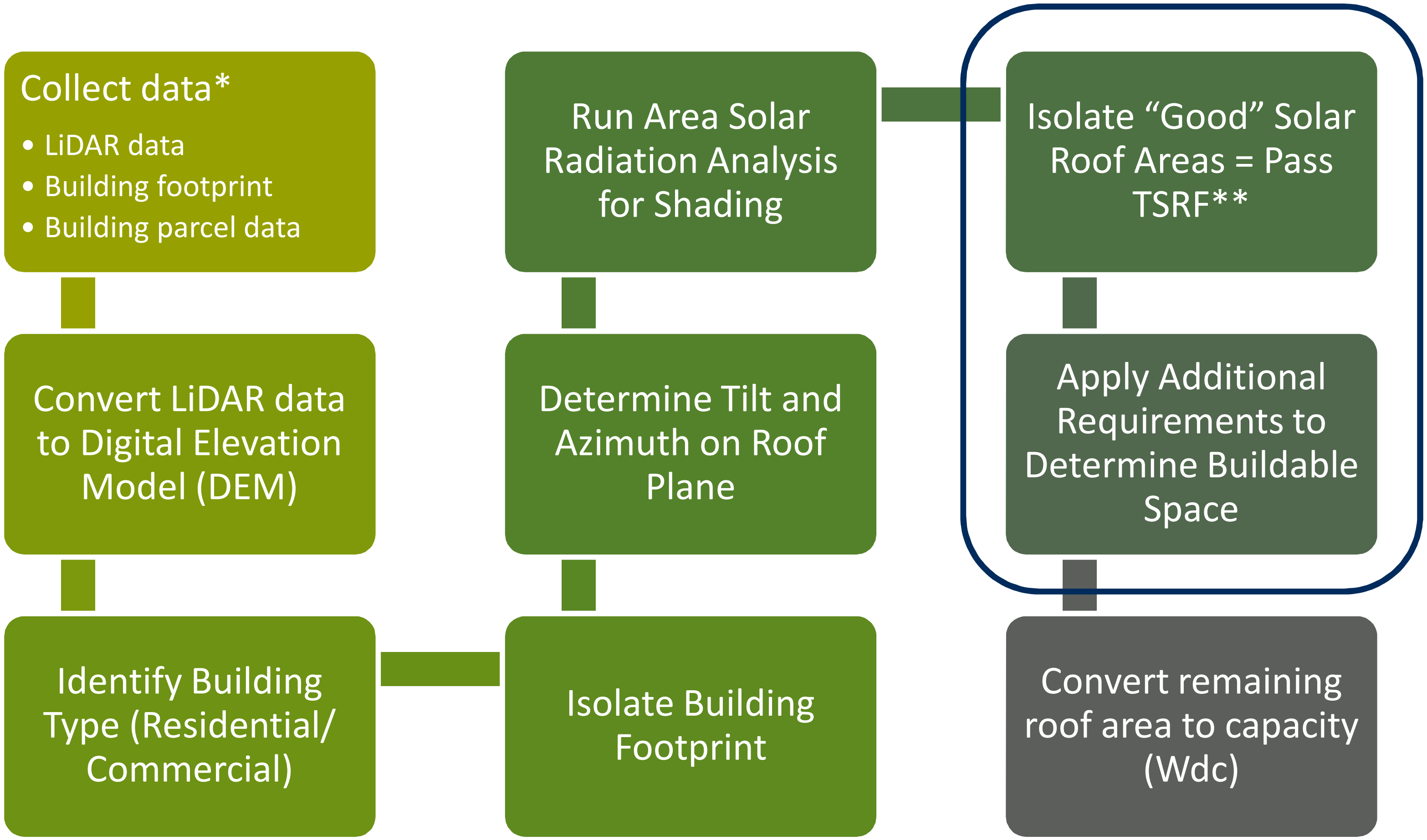
DISTRIBUTED-SCALE SOLAR SCREENS

Technical Screen
- LiDAR + shading analysis
- Urban and rural areas

Financial Screen
- Financial assumptions
- R/C/I customer load and rates
- Payback distributions

Achievable Screen
- Maximum Market Capacity
- Multiple Adoption Scenarios

TECHNICAL SCREEN



*Some data were not available for all areas in PGE service territory
** TSRF = Total Solar Resource Fraction

DISTRIBUTED-SCALE SOLAR RESULTING TECHNICAL CAPACITY

- About 50% of parcels (185,000) assessed by Lidar passed the technical screen.
- Areas where Lidar data not available estimated based on parcel characteristics
- Resulting capacity by land-use shown below

LAND USE	LIDAR-ASSESSED AREA TOTAL CAPACITY (MWDC)	PGE SERVICE TERRITORY TOTAL CAPACITY (MWDC)
Single-Family Residential	451	631
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Commercial	586	874
Industrial	575	869
Public/Semi-Public	62	270
Total	**1,800**	**2,810**

TECHNICAL SCREEN APPLIED TO CURRENT BUILDING STOCK

Factors not considered in this analysis, but could influence resulting long-term capacity:

- New construction
- Modifications to the existing building stock
- Growth/removal of trees and other shading sources
- Improvements in solar panel efficiency
- Changes in permitting/zoning requirements and restrictions
- Innovations in mounting structures, such as lower cost solar carports

B&V recommends that PGE consider these factors in future studies

FINANCIAL SCREEN USED NREL'S SYSTEM ADVISOR MODEL TO CALCULATE PAYBACK

Array Characteristics
- Size
- Tilt/Azimuth
- Shading
- Technology Characteristics

Customer Load
- Customer rates
- Customer size
- Hourly profile

Financial Assumptions
- Tax incentives
- ETO incentives
- Capital Cost
- O&M Cost

System Advisor Model

SIMPLE PAYBACK

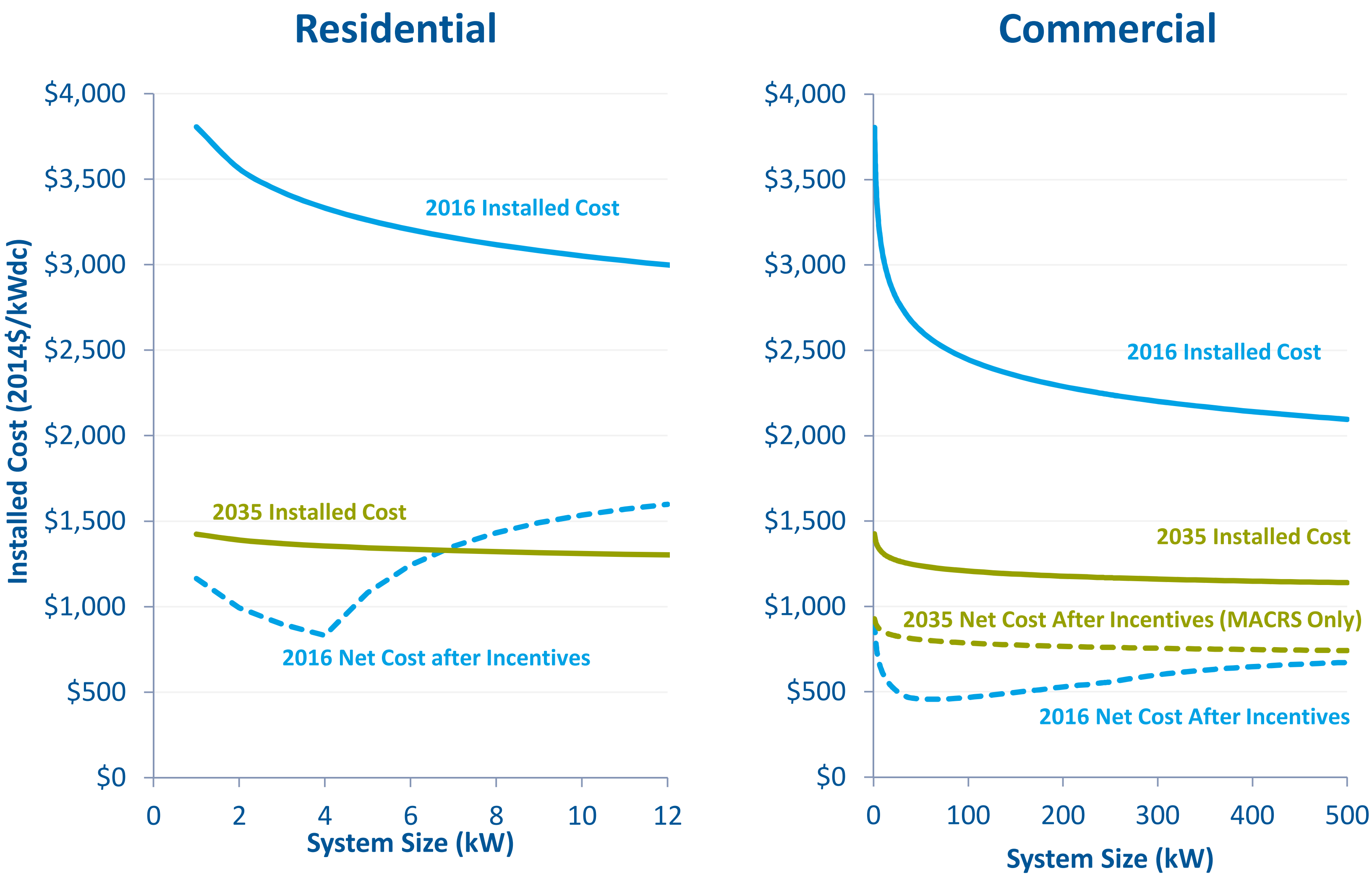
Multiple drivers in determining payback

FINANCIAL CASES AND INCENTIVES

CASES	RATES: CONSUMER PRICE INDEX (CPI)	RATES: CONSUMER PRICE INDEX + 1 PERCENT (CPI + 1)
2016*	• All incentives • 2016 cost • Utility rate escalates at CPI	• All incentives • 2016 cost • Utility rate escalates at CPI+1%
2035	• No incentives except accelerated depreciation • 2035 cost • Utility rate escalates at CPI	• No incentives except accelerated depreciation • 2035 cost • Utility rate escalates at CPI+1%
*Incentives for 2016 cases include investment tax credit (ITC), Oregon state tax credit, ETO incentives, and MACRs. Only MACRS assumed for 2035 cases. ETO Incentives were adjusted to maintain the 2014 benefit/cost ratio.		

Remainder of presentation focuses on CPI+1 case. CPI case included in appendix

NET COST IMPACT FROM INCENTIVES



FINANCIAL SCREEN ADDITIONAL CRITERIA

- Financial screen defined as payback less than project life (<20 years)
- Multi-family dwellings excluded
- Tenant-occupied buildings excluded

Owner-occupied portion by sector

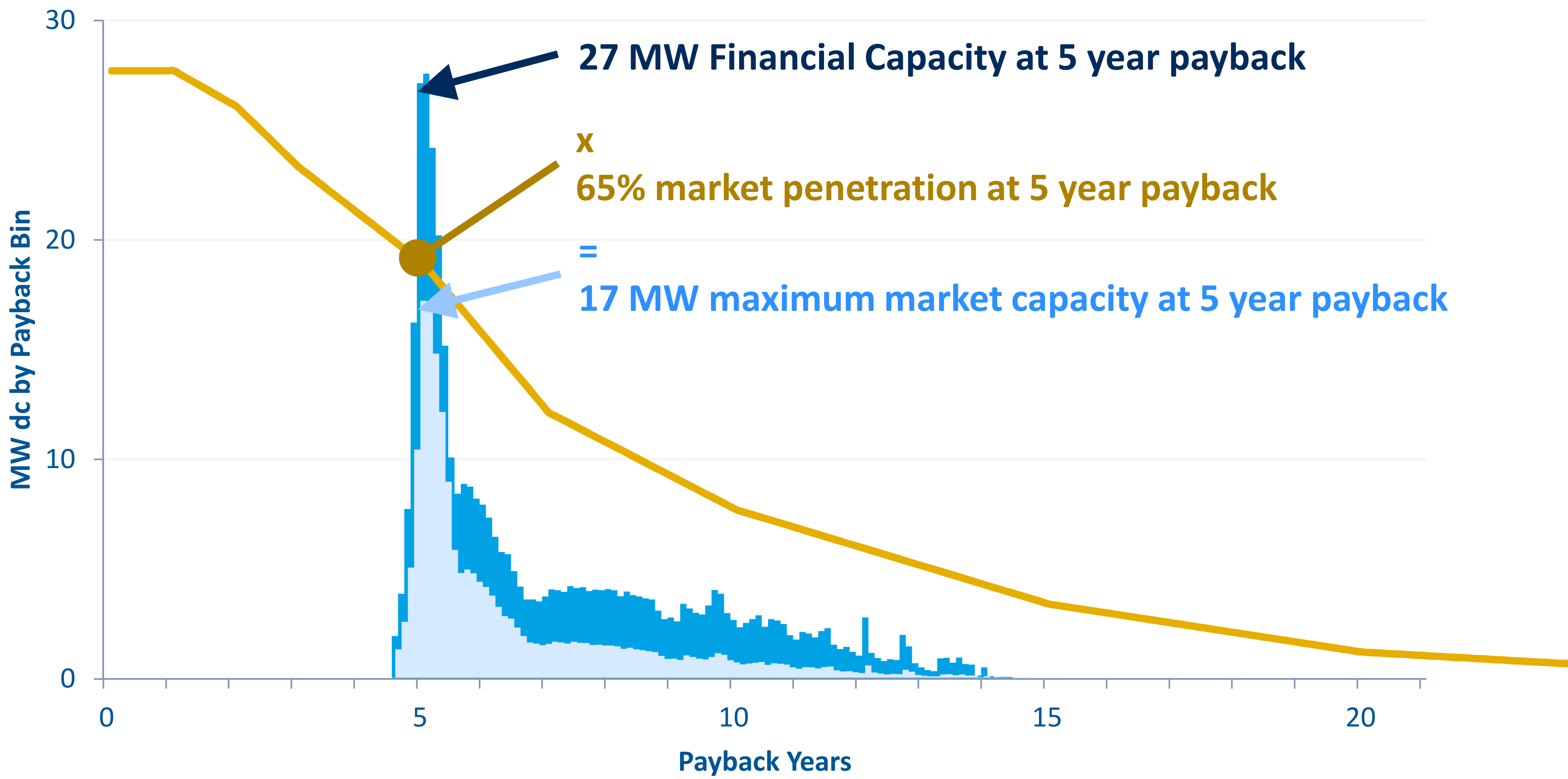
RESIDENTIAL	COMMERCIAL	INDUSTRIAL	PUBLIC/ SEMI-PUBLIC
72%	48%	48%	100%

ACHIEVABLE SCREEN

- **Two Step Process for Achievable Screen**
  1. **Maximum Market Capacity**: Given certain payback distributions, what is the total market capacity, including existing installations
  2. **Annual Adoption**: Adoption of solar over time, driven by either Technology Adoption Curve <u>or</u> ETO Funding Limitations

MAXIMUM MARKET PENETRATION CURVE APPLIED TO PAYBACK DISTRIBUTION

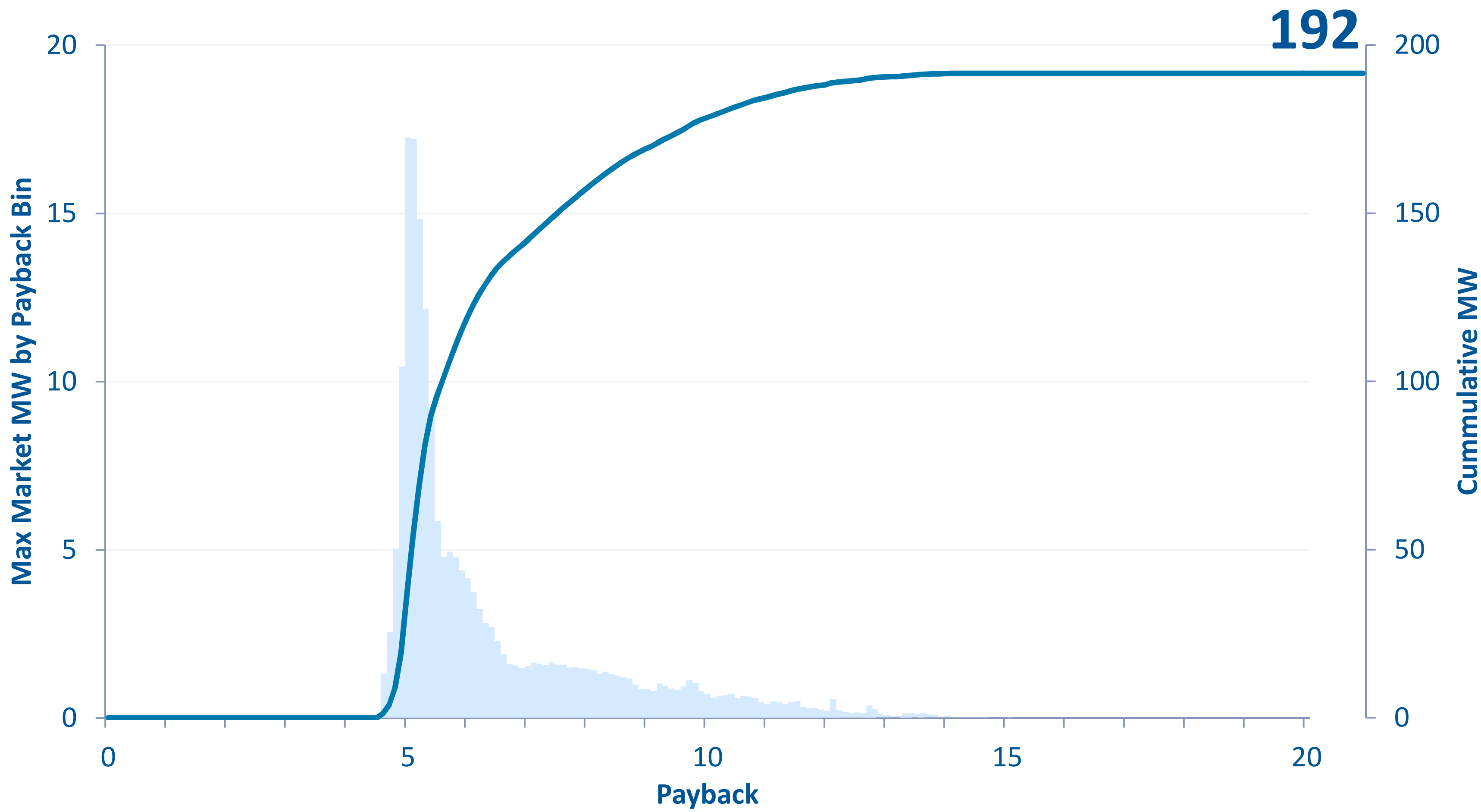
Example: Residential CPI+1 2016 Case



Multiply market penetration percentage by payback bin to calculate capacity

RESULTING MAXIMUM MARKET CAPACITY

Example: Residential CPI+1 2016 Case



RESULTING MAXIMUM MARKET CAPACITY (MWdc)

	CPI+1 CASE	
	2016	2035
Residential Capacity	192	145
Commercial Capacity	81	37
Total Capacity	**273**	**182**
Less Existing Residential	-28	-28
Less Existing Commercial	-20	-20
Remaining Capacity	**225**	**134**

SCENARIOS FOR ANNUAL ADOPTION

	CPI+1
Technology Adoption Constrained	Market matures from incentive-based in 2016 to no incentives in 2035
ETO Funding Constrained*	With Tax Credits: Federal (10% ITC) and state tax credits (residential only)** available throughout study period
	No Tax Credits: Only ETO incentives are available

*** Annual ETO funding capped at $3M for residential and $2.6M for commercial customers for PGE's service territory**

**** Oregon residential tax credit stepped down by $0.20/W per year.**

CPI scenarios identical to CPI + 1
6 scenarios total (see appendix)

RESULTING MAXIMUM MARKET CAPACITY (MWdc)

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	2016	2035
Residential Capacity	192	145
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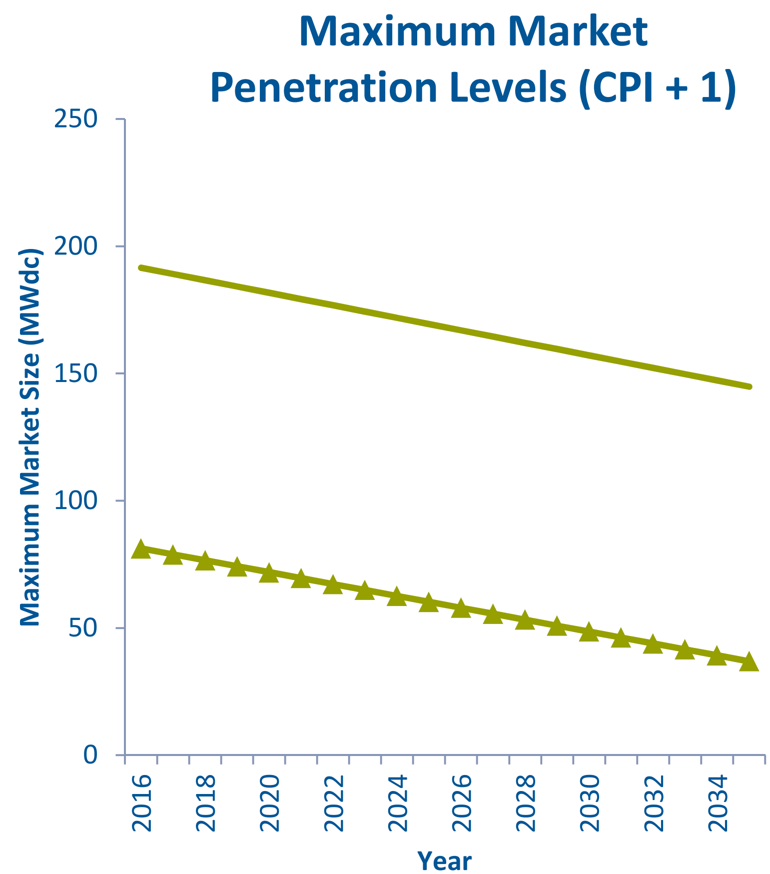


UTILITY-SCALE SOLAR SCREENS

Technical Screen

- Used GIS-based analysis
- Applied technical and environmental exclusions
- Identify areas for 5 MW or more

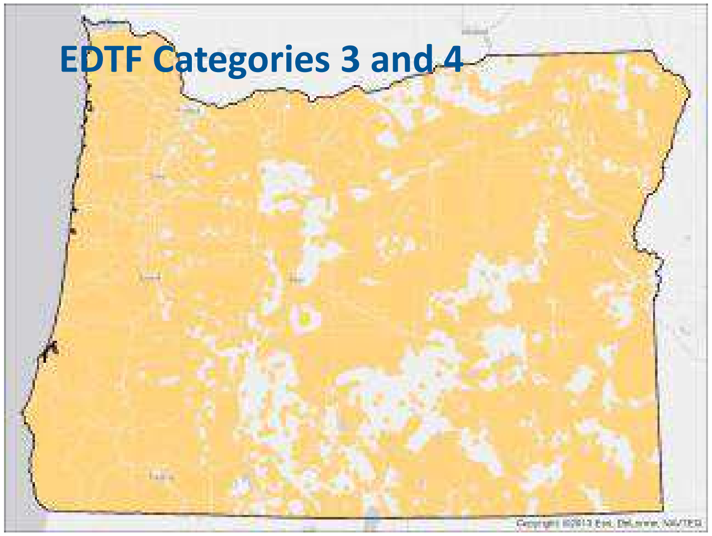
Financial Screen

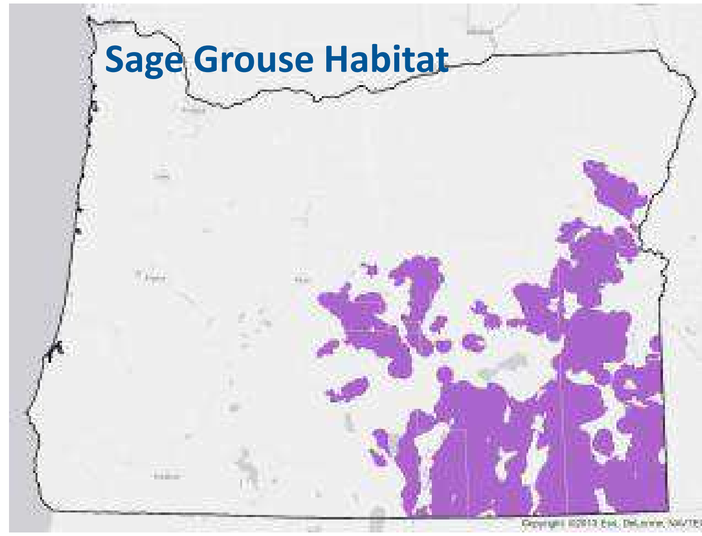
- Applied installed costs based on system size and interconnection
- Created supply curve
- Compared against forecasted QF rates

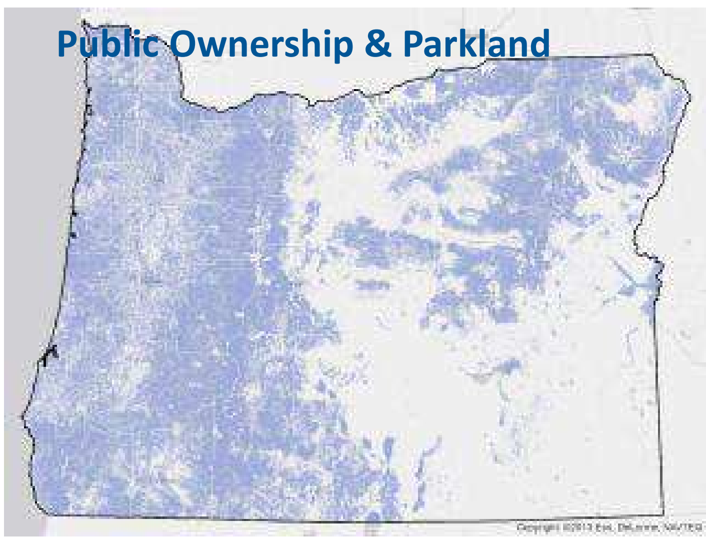
Achievable Screen

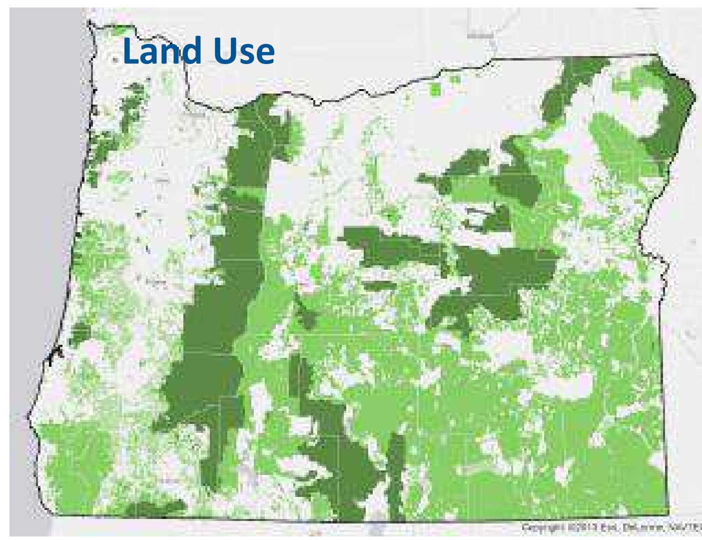
- Limited by available transmission capacity

TECHNICAL SCREEN – ENVIRONMENTAL CONSTRAINTS



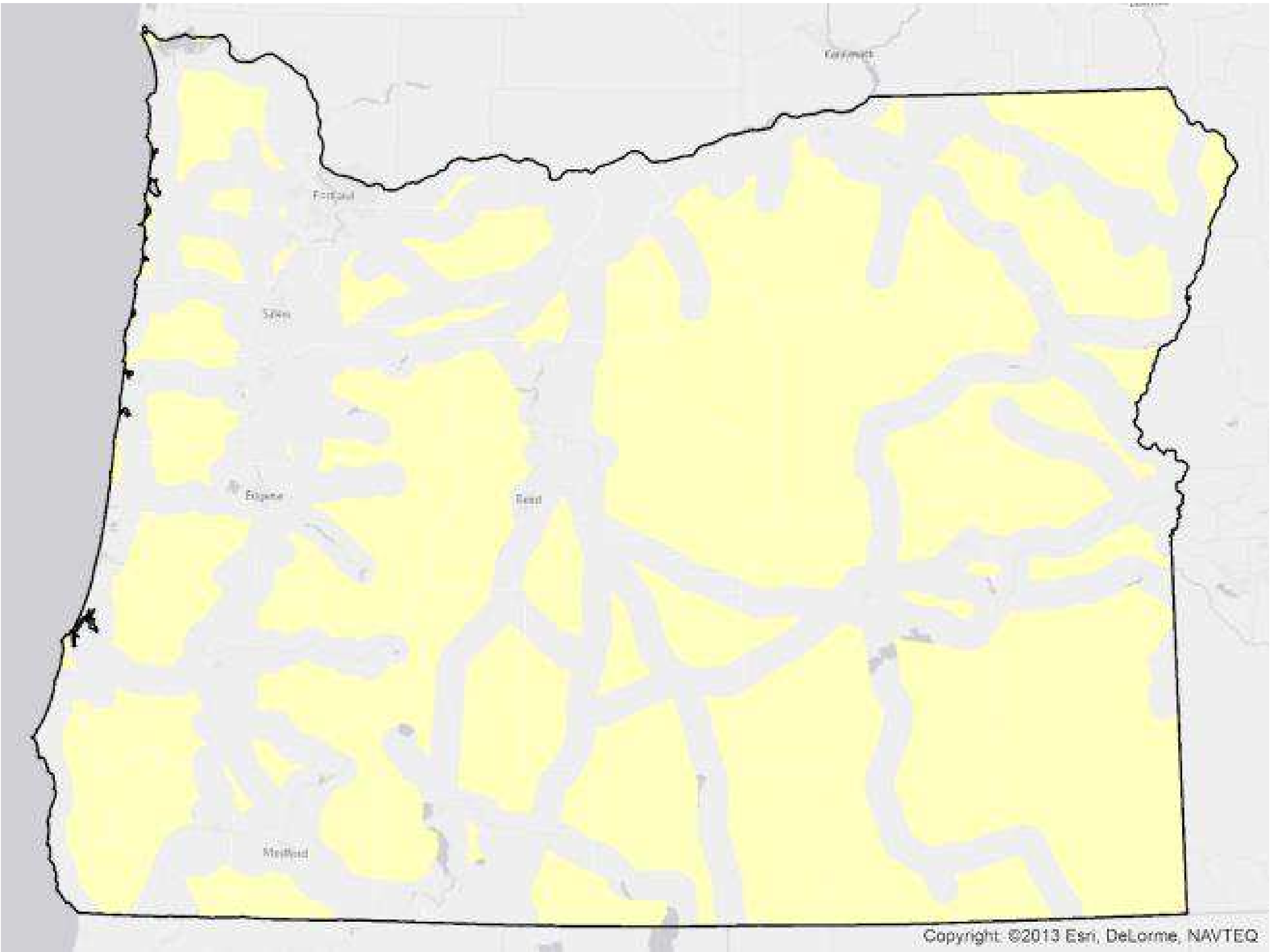


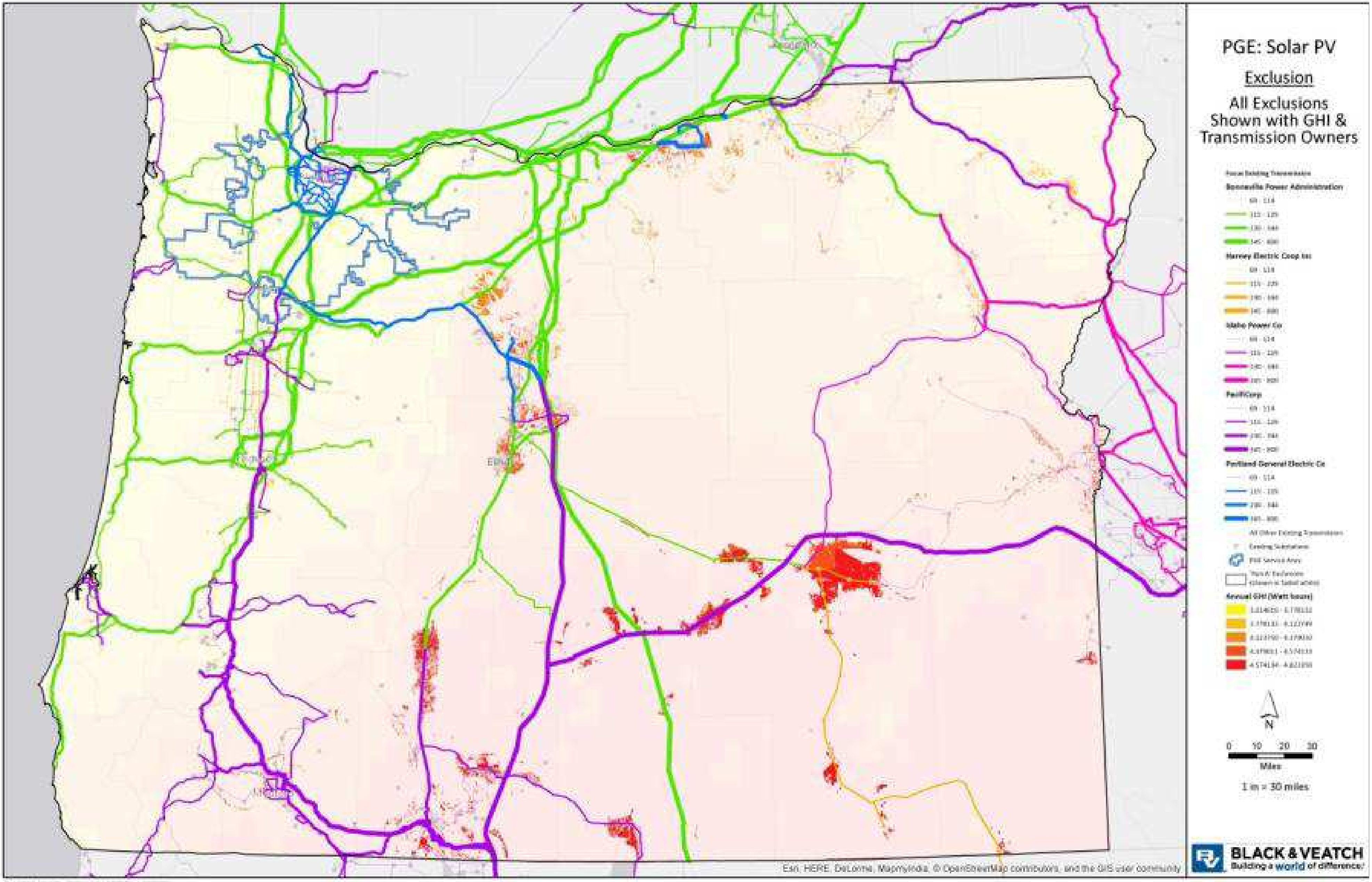




Plus: slope >5%

TECHNICAL SCREEN – TRANSMISSION CONSTRAINT





Remaining areas after exclusions

TECHNICAL SCREEN RESULTING CAPACITY OVER 56 GW

- **Applied maximum project size per site based on transmission connection voltage**
- **Resulting technical capacity shown in table**

MW BIN	NUMBER OF PROJECTS PER BIN	TOTAL TECHNICAL CAPACITY (MWAC)
<20	2,834	22,104
20-50	514	17,226
50-100	99	8,005
100-250	44	8,812
Total	**3,491**	**56,147**

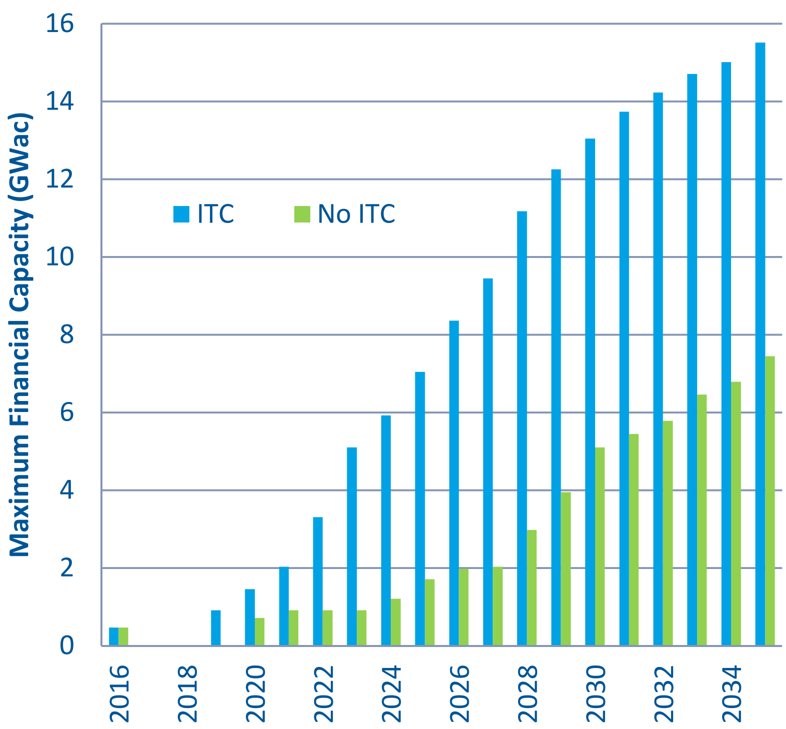
MAXIMUM FINANCIAL CAPACITY TOTAL 7.5 GW (NO ITC) AND 15.5 GW (ITC) BY 2035

PGE Solar QF Tariff Solar Wtd. and Levelized

YEAR	SOLAR PRODUCTION WEIGHTED AVERAGE PRICE	LEVELIZED COST (20 YEARS)	YEAR	SOLAR PRODUCTION WEIGHTED AVERAGE PRICE	LEVELIZED COST (20 YEARS)
2016	$40	$89	2026	$109	$127
2017	$42	$94	2027	$111	$130
2018	$45	$100	2028	$113	$132
2019	$47	$106	2029	$116	$135
2020	$96	$112	2030	$118	$138
2021	$98	$115	2031	$121	$140
2022	$100	$117	2032	$123	$143
2023	$102	$119	2033	$125	$146
2024	$104	$122	2034	$128	$149
2025	$106	$124	2035	$130	$152

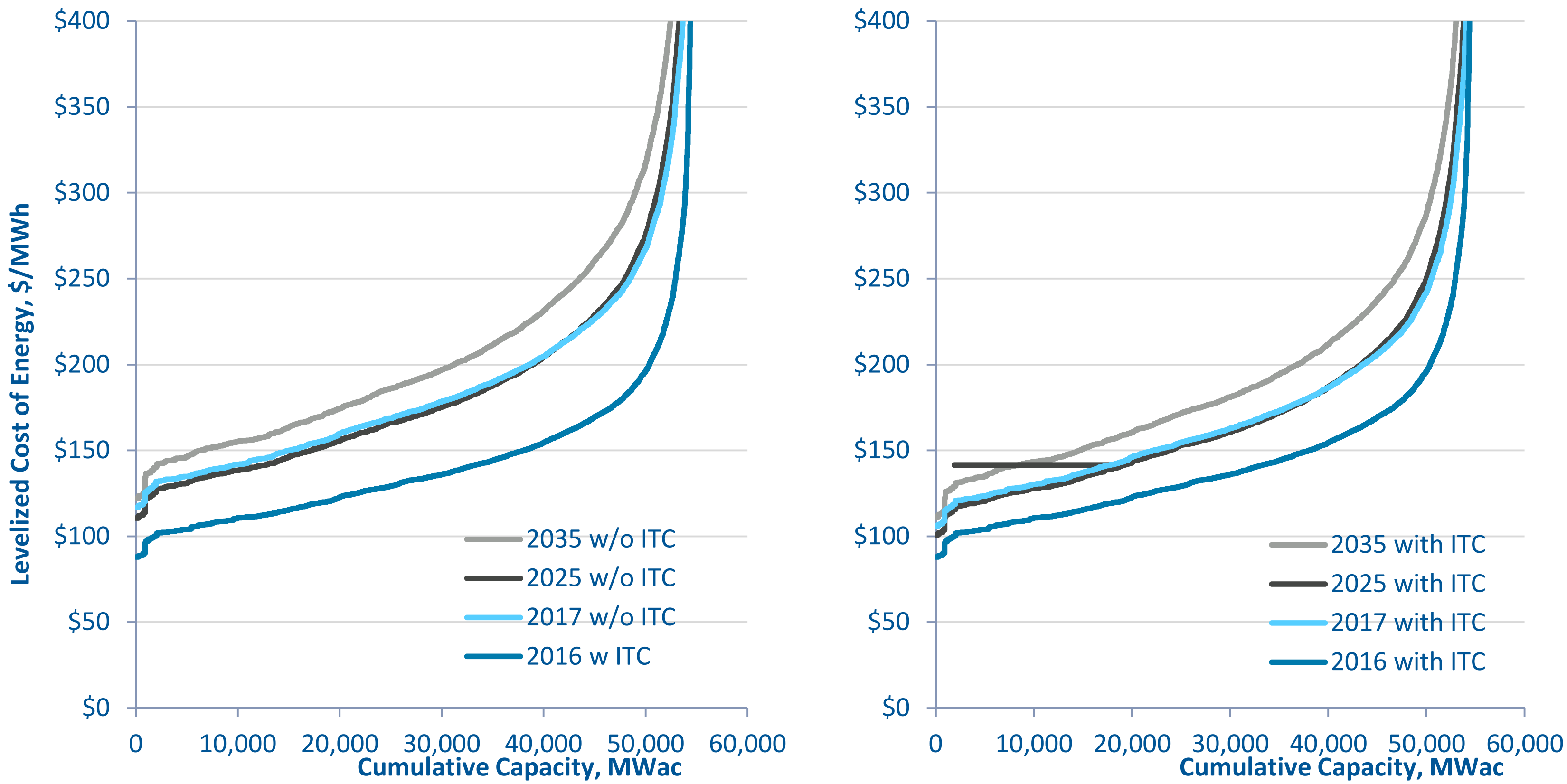
Note: Levelized cost assumes 2035 costs continue to escalate at inflation. Costs were levelized assuming a 6.5 percent discount rate.

Max Financial Capacity by Year



The financial screen does not consider transmission constraints to deliver the power to PGE's service territory.

FINANCIAL SCREEN – SUPPLY CURVES WITH AND WITHOUT ITC



Capital cost included PV system installed cost based on size, gen-tie, and substation costs
Ongoing costs included O&M, inverter replacement, lease payment, insurance, property taxes, wheeling charges, and real power losses.

BUILDING A WORLD OF DIFFERENCE

15 July 2015

NON-SOLAR DISTRIBUTED GENERATION STUDY

RYAN PLETKA
MON-FEN HONG

BLACK & VEATCH
Building a world of difference.

TASK OVERVIEW

- Apply technical, financial, and achievable screens to non-solar distributed generation for electric-only, commercial customer-sited applications
- Combined heat and power (CHP) applications were not included
- Biogas fuels were not included
- Tested Financial Cases for 2016 and 2035

DISTRIBUTED GENERATION TECHNOLOGIES INVESTIGATED

- **Battery Energy Storage Systems (BESS) (Alone and With Solar PV)**
  - Lithium ion
  - Vanadium redox flow battery
- **Fuel Cells (Natural Gas)**
  - Solid oxide fuel cells (SOFC)
  - Molten carbonate fuel cells (MCFC)
  - Phosphoric acid fuel cells (PAFC)
- **Microturbines (Natural Gas)**

All of these technologies are technically feasible and not limited by resource availability, as is the case with solar and wind resources.

ALLOWABLE INCENTIVES VARY BY TECHNOLOGY FOR 2016 CASES

TECHNOLOGY	FEDERAL ITC	FEDERAL MACRS	PROPERTY TAX EXEMPTION	ETO	NET METERING
SOFC	30%	Eligible	Eligible	Not Eligible	Eligible
MCFC	30%	Eligible	Eligible	Not Eligible	Eligible
PAFC	30%	Eligible	Eligible	Not Eligible	Eligible
Microturbine	10%	Eligible	Eligible	Not Eligible	Not Eligible
BESS	Not Eligible	Eligible	Eligible	Not Eligible	Not Eligible
BESS + Solar PV	Solar Portion Only	Eligible	Eligible	Solar Portion Only	Eligible

2035 Cases assume no incentives except MACRS

ENERGY STORAGE

Technology Characterization

Financial Screen

Achievable Screen

Vanadium Redox Flow Battery

(Source: Prudent Energy brochure)

BESS BACKGROUND

- Becoming more prevalent grid resource option
- New policies driving growth
- Companies seeking ways to mass produce batteries to drive down costs for both transportation and stationary applications.

BESS TYPICAL APPLICATIONS

Energy Applications (2hr+)

- **Time of Use (TOU) Energy Management**
- **Demand Charge Management**
- **Variable Energy Resource Capacity Firming**

Power Applications (0.5-1hr)

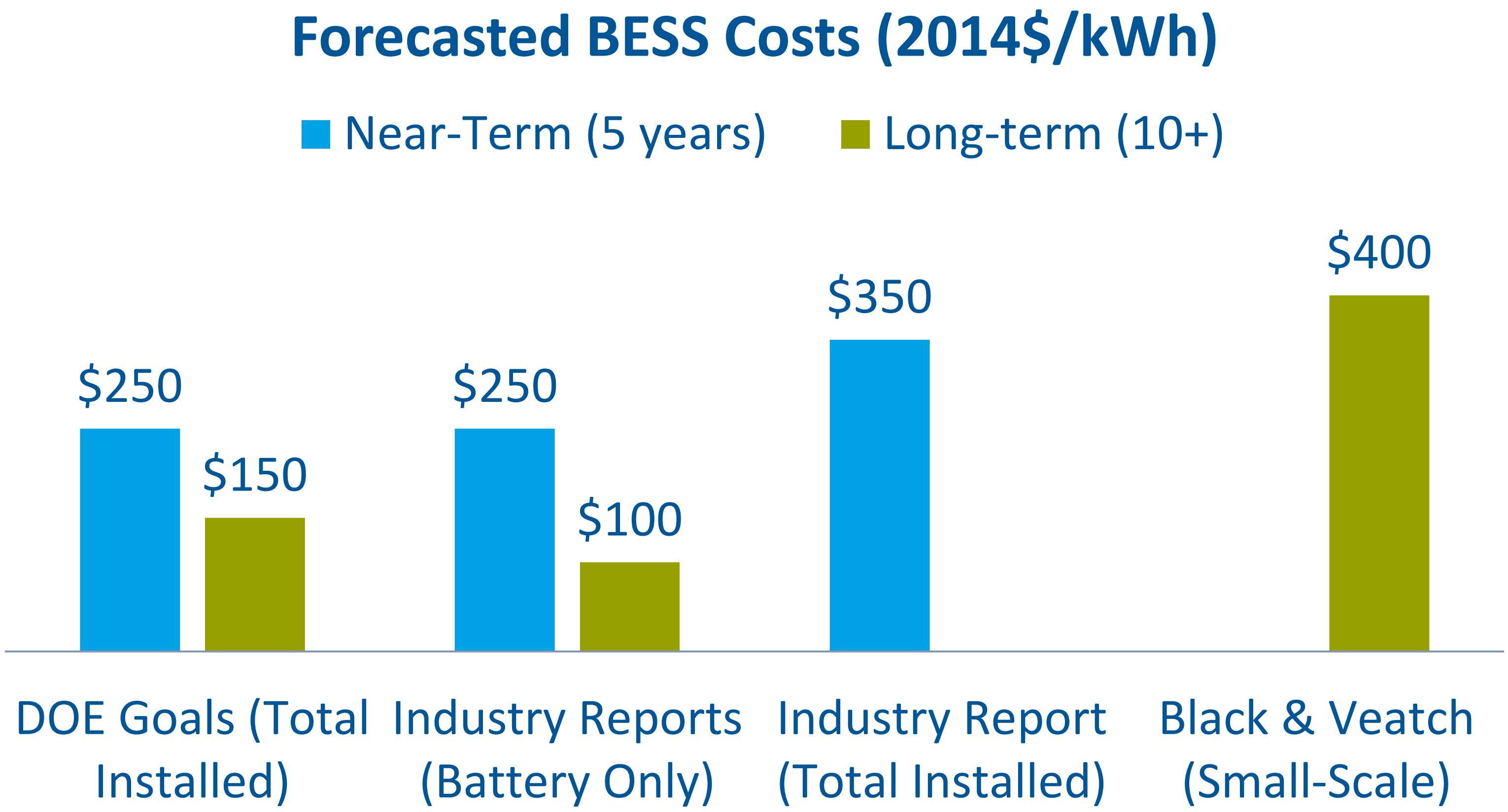
- **Electric Service Reliability**
- **Power Quality**
- **Frequency Regulation**
- **Voltage Support**
- **Variable Energy Resource Ramp Rate Control**

TECHNICAL CHARACTERISTICS

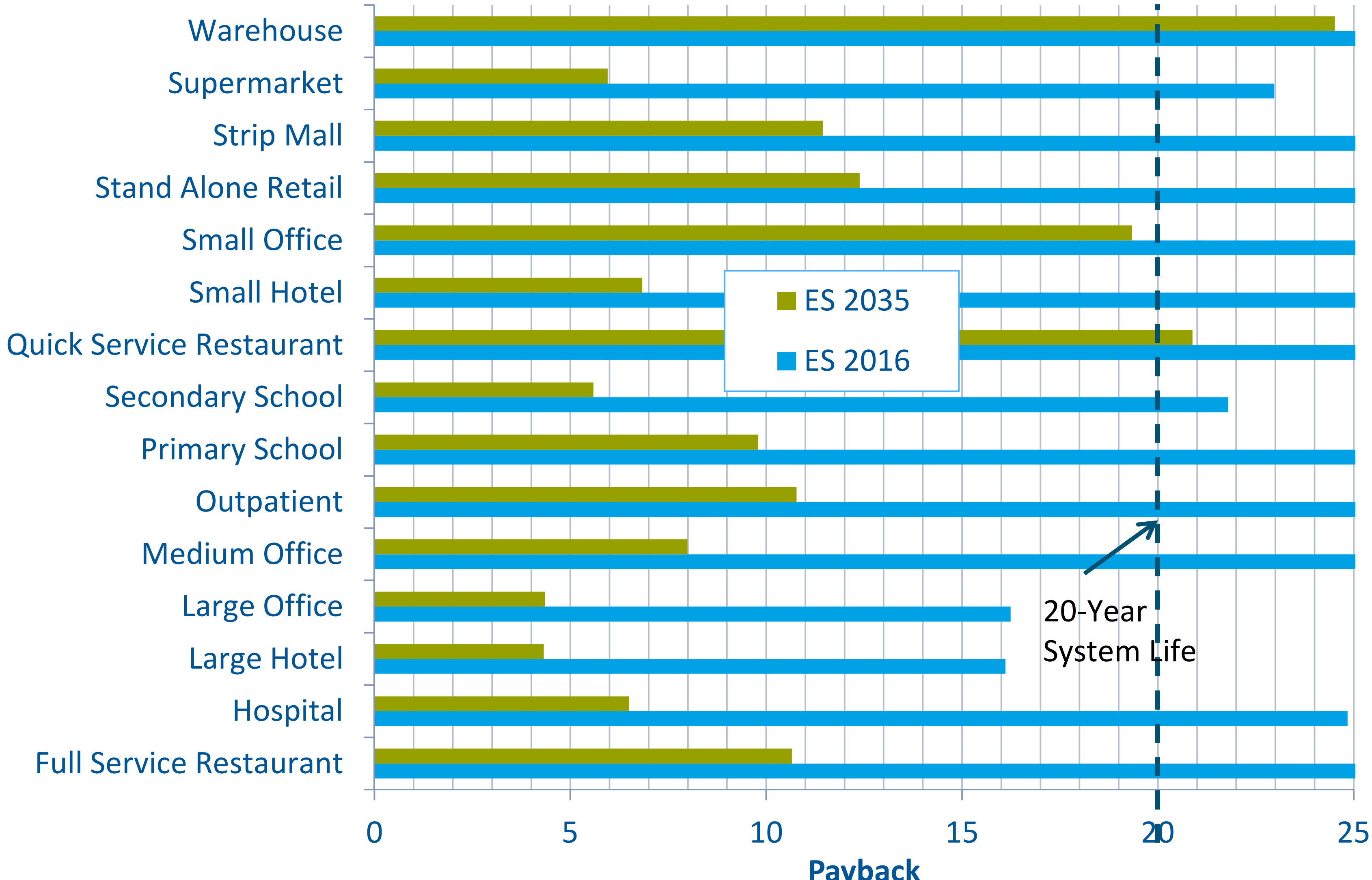
- **Both technologies are good for energy applications, though round trip efficiency for flow batteries are significantly lower**

PARAMETER	LITHIUM ION BATTERY	VANADIUM REDOX FLOW BATTERY
Power rating, MW	0.005 to 32	0.050 to 4
Energy rating, MWh	0.005 to 32	0.200 to 8
Discharge duration, hours	0.25 to 4	3 to 8
Response time, milliseconds	< 100	< 100
Round trip efficiency, %	**75 to 90**	**65 to 75**
Cycle life, cycles at 80 % DoD	1,200 to 4,000	10,000 to 15,000 (not DoD dependent)
Cycle life, cycles at 10% DoD	60,000 to 200,000	10,000 to 15,000 (not DoD dependent)

FORECASTED BESS COSTS VARY WIDELY AND REFLECT LARGER UTILITY-SCALE BESS



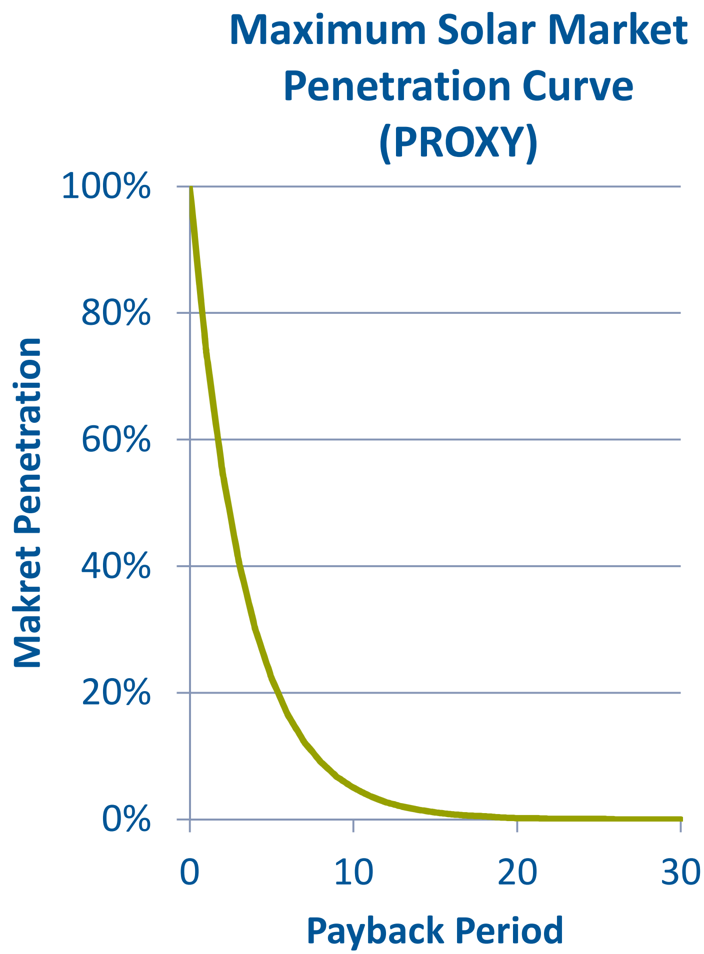
BESS RESULTS FOR CPI+1 CASE



2016 Case resulted in many paybacks exceeding system life, given lack of incentives and high capital costs. 2035 Case show much better paybacks

ACHIEVABLE SCREEN OF BESS

- **For 2035 CPI+1 case, most customer types were found to show payback periods of less than 20 years**
- **Assuming that 5 to 10 percent of PGE's commercial customers (~104,000 customers) adopt 10 kWh (5 kW) BESS in 2026-2035 period when capital costs come down.**



Achievable potential results:
52 to 104 MWh or 26 to 52 MW of installations cumulative through 2035.

FUEL CELLS

Technology Characterization
Financial Screen
Achievable Screen

Bloom Fuel Cells

(Courtesy of Bloom Energy)

FUEL CELL CHARACTERISTICS

- **Positives**
  - Relatively high efficiency
  - Quiet operations
  - Low emissions
  - Combined heat-and-power opportunities
- **Negatives**
  - High costs
  - Short fuel stack life = higher O&M costs
  - Low power density
  - Performance degradation overtime

LIMITED NUMBER OF FUEL CELL PLAYERS

- **Bloom Energy – SOFC**
  - Founded in 2001
  - Electric-only
  - Modular
  - 100 MW installed in CA
  - High investment backing
  - Goals to significantly reduce cost through mass production
- **Fuel Cell Energy – MCFC**
  - Founded in 1980's
  - CHP applications
  - 300 MW of capacity installed/backlog intl.
- **Doosan Cell Energy – PAFC**
  - Technology from 1958
  - CHP applications
  - Acquired ClearEdge and UTC (previously acquired by ClearEdge)

Unprofitable industry to date has seen bankruptcy filings and consolidation.

FINANCIAL ANALYSIS - FUEL PERFORMANCE AND COST ASSUMPTIONS

TECHNOLOGY	SIZE (KW)	2016			2035		
		CAPITAL COST ($/KW)	FIXED O&M ($/KW-YR)	HEAT RATE (BTU/KWH)	CAPITAL COST ($/KW)	FIXED O&M ($/KW-YR)	HEAT RATE (BTU/KWH)
SOFC	210	8000	1000	7000	1500	150	5600
MCFC	300	4000	300	8000	1500	150	8000
PAFC	400	6000	150	9000	1500	150	9000

LOSS CATEGORY	LOSS (%)
Nameplate Losses	99
Availability	98
De-rate for Stack Degradation – 2016 (Fuel Cell Only)	90
De-rate for Stack Degradation – 2035 (Fuel Cell Only)	95

2035 Costs and performance assume that long-term DOE goals are met, though this is highly uncertain given the state of the market

LEVELIZED COST OF ENERGY (2014$ PER KWH) FOR FUEL CELLS UNDER ALL CASES

YEAR	NATURAL GAS	SOFC		MCFC		PAFC	
		TAX-EXEMPT	TAX-PAYING	TAX-EXEMPT	TAX-PAYING	TAX-EXEMPT	TAX-PAYING
2016	Base	$0.27	$0.24	$0.14	$0.13	$0.15	$0.13
	Low	$0.26	$0.23	$0.13	$0.12	$0.14	$0.12
2035	Base	$0.08	$0.08	$0.10	$0.10	$0.11	$0.11
	Low	$0.07	$0.07	$0.09	$0.09	$0.09	$0.10

Levelized cost is higher than current Schedule 85 rates.

MICROTURBINES

Technology Characterization
Financial Screen
Achievable Screen


Microturbine with Heat Recovery

MICROTURBINE BACKGROUND AND CHARACTERISTICS

- Small combustion turbines, typically 65 to 250 kW systems
- Low electrical efficiency, but can be set up as CHP
- Small footprint
- Low emissions
- Greater fuel gas treatment

LIMITED INSTALLATIONS AND COST DATA

- **Capstone is one of the primary microturbine providers**
  - Modular configuration with Capstone C65 (65 KW) serving as the unit
- **Recently quoted equipment costs for Capstone C65 ~$2,500-$3,000 per kW**
- **California incentive data reports installed costs from $3,000 to $7,750 per kW, depending on size**

TECHNOLOGY	SIZE (KW)	2016 AND 2035		
		CAPITAL COST ($/KW)	FIXED O&M ($/KW-YR)	HEAT RATE (BTU/KWH)
Microturbine	65	4000	170	13400

Black & Veatch assumes costs are constant in real dollars over time.

MICROTURBINES ARE NOT FINANCIALLY VIABLE FOR ELECTRIC-ONLY APPLICATIONS

- **Levelized cost of energy in all cases well-exceed retail electric rates, given poor heat rate and higher retail natural gas prices.**

YEAR	MICROTURBINES (2014$ PER KWH)		
	NATURAL GAS	TAX-EXEMPT	TAX-PAYING
2016	Base	$0.16	$0.16
	Low	$0.14	$0.14
2035	Base	$0.17	$0.18
	Low	$0.15	$0.15

Combined Heat and Power

In 2014, ICF International conducted an Assessment of the Technical and Economic Potential of CHP in Oregon. 87 MW of achievable potential was identified, all of it in PGE service territory.

Electric Utility	Potential (MW) by Payback Period				Total (MW)
	<5 yrs	5 - 10 yrs	10 - 20 yrs	>20 yrs	
Portland General Electric	87	134	29	364	**614**
Pacific Power & Light	0	98	169	204	**471**
Eugene Water & Electric Board	0	0	0	84	**84**
Other	0	0	0	289	**289**
Total	**87**	**232**	**198**	**941**	**1,458**

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Supply Side Assumptions

Feedback from the 2013 IRP

"RNW recommends that PGE **retain a consultant with expertise in pricing [renewable] resources…** In addition, RNW asks PGE to test two specific resources that were not modeled in the 2013 IRP: **(1) Montana wind; and (2) energy storage technology."**

"Staff generally supports RNW's observation and has additional areas it wants PGE to examine in future IRPs. Specifically, Staff wants PGE to include in its portfolio analyses more resources, such as **distributed PV, CHP, utility scale solar, biomass, battery storage, and conservation voltage reduction.**"

OPUC Order 14-415, Page 5

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Process to Date

April 2, 2015 Slide 119

December 2014
PGE Drafts Scope of Work

March 2015
Purchase Order Issued

July 2015
Draft Cost and Performance Parameters Received

July 16, 2015
Public Meeting #2 Review

August 2015
Final Reports

Scope of Work

Thermodynamic Resources	Renewable Resources	Energy Storage Resources

- Ten Cost Parameters
  - What are the fixed and variable costs of the resource?
- Thirteen Technical Parameters
  - What are capabilities of the resource?
- Technical Maturity Outlook
  - How will the resource costs change over time?

BLACK & VEATCH

DNV·GL

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Scope of Work

Thermodynamic Resources

Technical parameters
- Capacity: MW
- 'New & Clean' net plant heat rate (HHV)
- Design life average net plant heat rate (HHV)
- **Heat rate curve: Btu/kWh = f(MW)**
- Expected forced outage rate: %
- Minimum turndown capability
- Ramp rates: MW/min
- Minimum run and down times
- Start-up time to full load: minutes
- Maintenance cycle
- Approximate footprint: Acres/MW
- Construction period, once permitted
- Water requirements

Financial Parameters
- Total overnight capital cost
- **Standard deviation of Cap Cost**
- Fixed O&M: $/MW-month
- Non-fuel variable O&M: $/MWh
- **Variable wear & tear costs: $/MWh**
- **Start-up costs: $/start**
- Approximate capital drawdown schedule
- Ongoing expected Capital
- Design life: years
- Decommissioning accrual: $/yr.

Technical Maturity Outlook

Renewable Resources

Technical parameters
- Capacity: MW
- Capacity factor
- **Power curve**
- Expected forced outage rate: %
- Panel efficiency if applicable
- Inverter efficiency
- Maintenance cycle
- Approximate footprint: Acres/MW
- Construction period, once permitted

Financial Parameters
- Total overnight capital cost
- **Standard deviation of Cap Cost**
- Fixed O&M: $/MW-month
- Breakdown of fixed O&M costs
- Non fuel variable O&M: $/MWh
- Approximate capital drawdown schedule
- Ongoing expected Capital Additions
- Design life: years
- Decommissioning accrual: $/yr.

Technical Maturity Outlook

Energy Storage Resources

Technical parameters
- Capacity: MW
- Energy capacity: MWh
- Expected forced outage rate: %
- Minimum turndown capacity
- Ramp rate
- Maintenance cycle
- Approximate footprint: Acres/MW
- Construction period, once permitted
- Round-trip efficiency

Financial Parameters
- Total overnight capital cost
- **Standard deviation of Cap Cost**
- Fixed O&M: $/MW-month
- Non fuel variable O&M: $/MWh
- Approximate capital drawdown schedule
- Ongoing expected Capital Additions
  - Asset book life: years
- Decommissioning accrual: $/yr.

Technical Maturity Outlook

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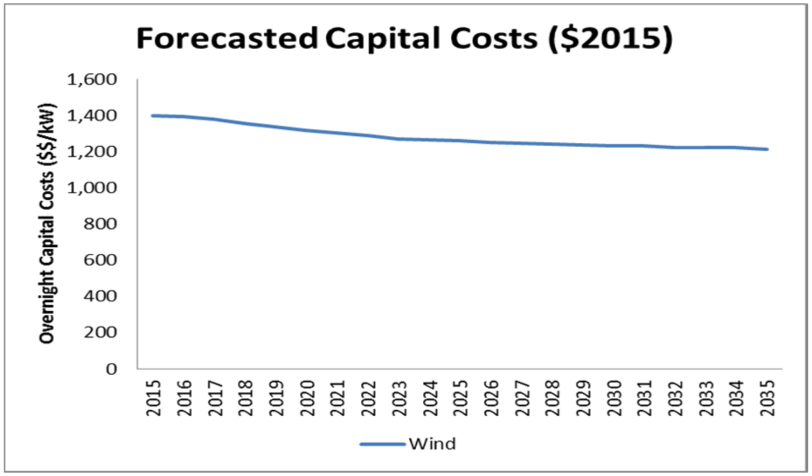
Renewable Resources

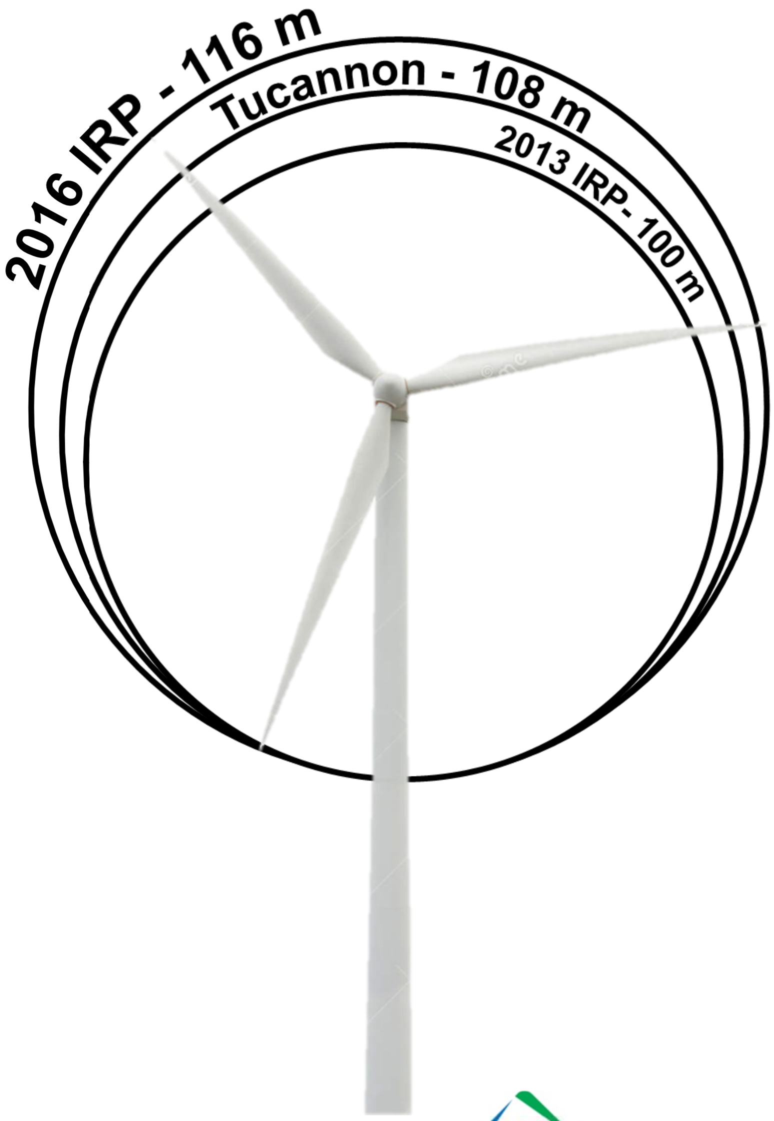
- **Wind**
  - Columbia Gorge
  - Montana
  - Offshore Coos Bay, Oregon
- **Solar**
  - Fixed Tilt Solar PV Christmas Valley, OR
  - Single Axis Tracking Solar PV Christmas Valley, OR
- **Biomass**
- **Geothermal**

Wind - Trends

- Gorge Wind
  - Draft results relative to 2013 IRP
  - 39% more cross sectional area

(2015$)	Turbine Design	Capacity Factor	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
2016 IRP	GE 2.0 118	34%	$ 1,400	$ 45.00	$5.04 + Int
2013 IRP	GE 1.0 100	33%	$ 2,284	$ 42.08	$3.75 (Int)
% Change		3%	-39%	7%	39%

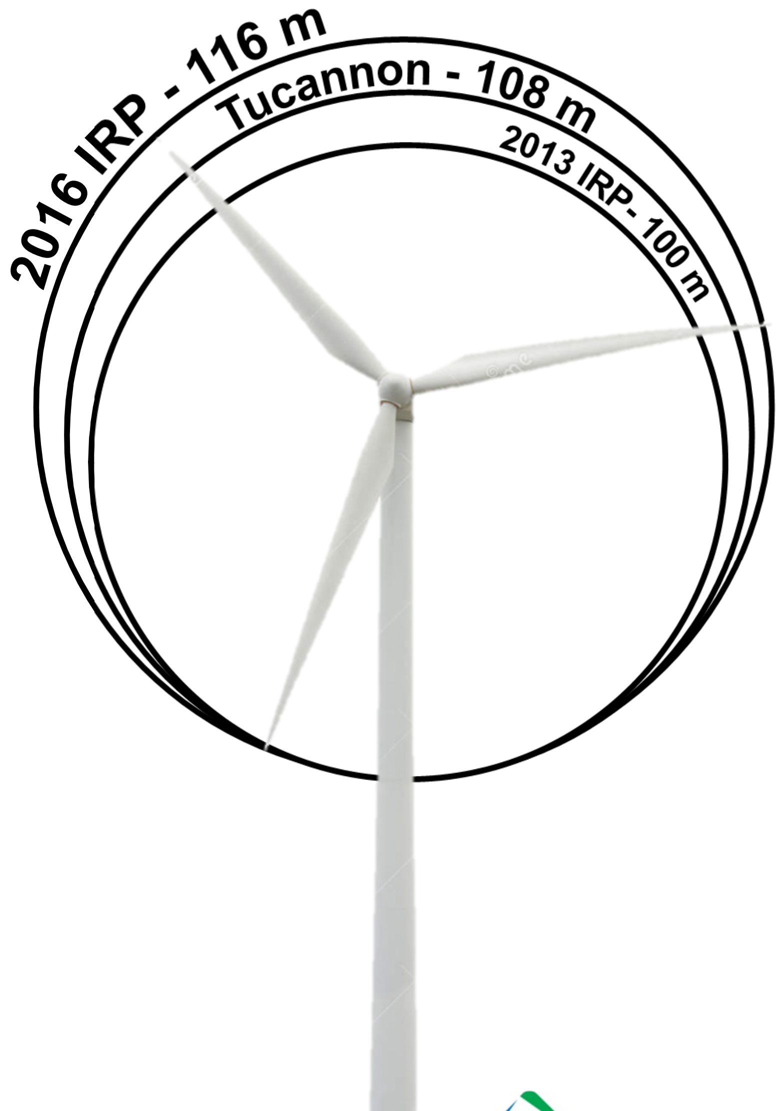




Wind - Options

- Gorge Wind
- MT Wind
- Offshore Wind

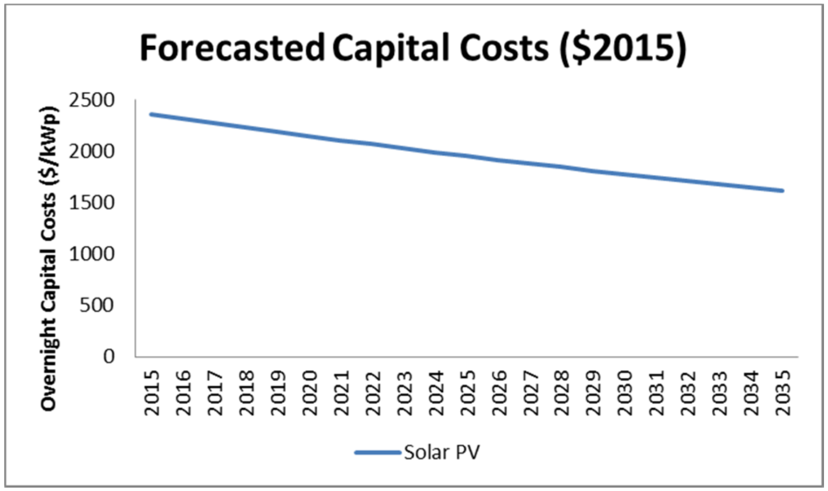
(2015$)	Turbine Design	Capacity Factor	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
Gorge Wind	GE 2.0 116	34%	$ 1,400	$ 45.00	$5.04 + Int
MT Wind	GE 2.0 116	42%	$ 1,400	$ 45.00	$5.04 + Int
Offshore Wind	Vestas V164-8.0MW	42%	$ 6,000	$ 112.50	$ TBD + Int



Solar - Trends

- Solar PV
  - Draft results relative to 2013 IRP

(2015$)	Location	Capacity Factor	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
2016 IRP	Christmas Valley	18%	$ 2,150	$ 11.90	$1.84 + Int
2013 IRP	Redmond	22%	$ 2,887	$ 18.94	$2.96 (Int)
% Change		-18%	-26%	-37%	



Solar - Options

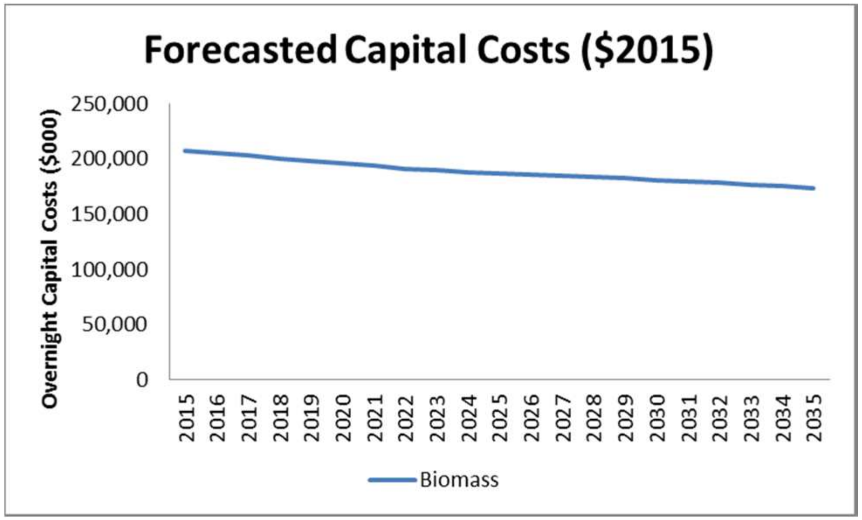
- Christmas Valley, Fixed Tilt
- Christmas Valley, Tracking

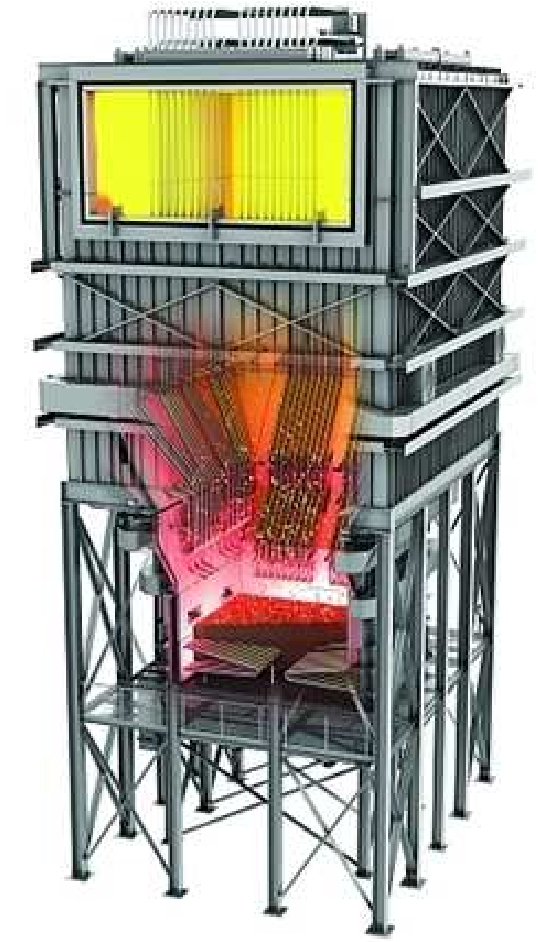
(2015$)	Location	Capacity Factor	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
Fixed Tilt	Christmas Valley	18%	$ 2,150	$ 11.90	$1.84 + Int
Tracking	Christmas Valley	20%	$ 2,380	$ 12.00	$1.90 + Int

Biomass- Trends

- Biomass – Bubbling Fluidized Bed
  - Draft results relative to 2013 IRP

(2015$)	Net Capacity MW	Heat Rate Btu/kWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
2016 IRP	35	13,350	$ 4,743	$ 1.68	$ 9.30
2013 IRP	25	13,515	$ 7,823	$ 231.44	$ 9.78
% Change	40%	-1%	-39%	-99%	-5%





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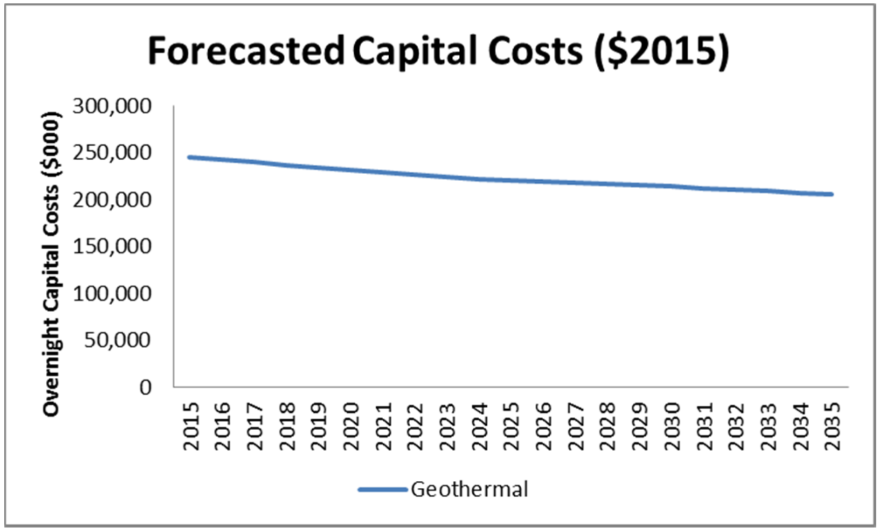
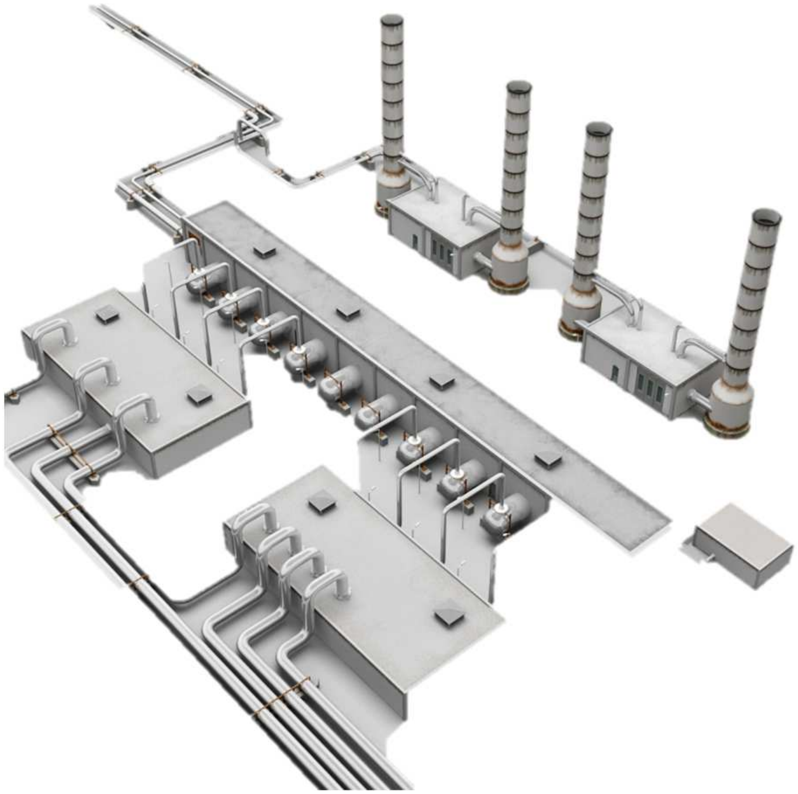
Geothermal - Trends

April 2, 2015 Slide 128

- Geothermal – Binary Cycle
  - Draft results relative to 2013 IRP

(2015$)	Net Capacity MW	Heat Rate Btu/kWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
2016 IRP	35	N/A	$ 6,543	$ 0.25	$ 26.75
2013 IRP	20	N/A	$ 9,215	$ 215.66	$ 24.30
% Change	75%	N/A	-29%	-100%	10%





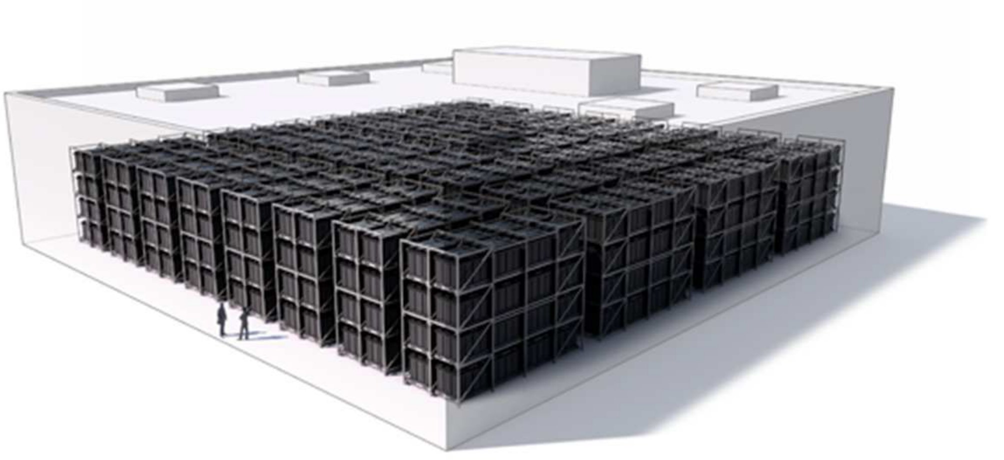
Energy Storage Resources

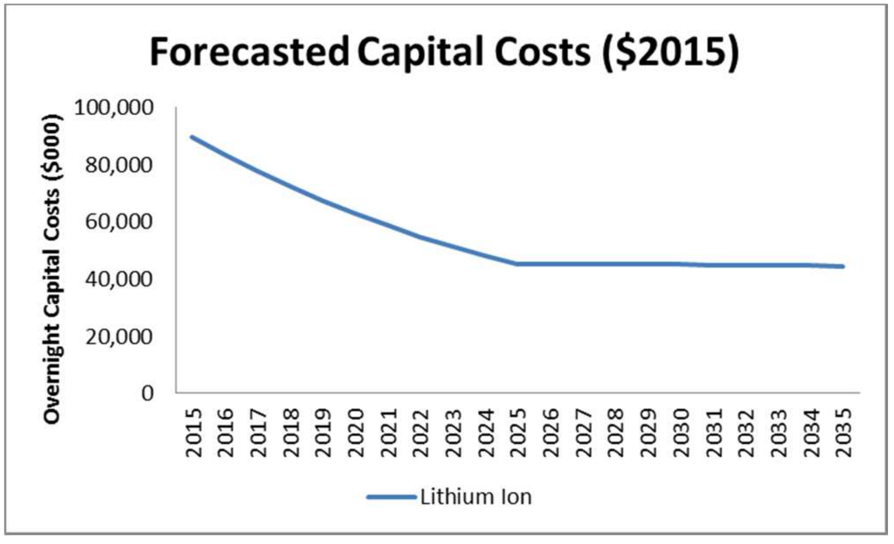
- **Pump Storage Hydro**
- **Lithium Ion Battery Energy Storage**
- **Redox Flow Battery Energy Storage**

Energy Storage - Trends

- Battery Energy Storage
  - Not evaluated in 2013 IRP

(2015$)	Net Capacity MW	Energy Content MWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
Lithium Ion	50	100	$ 1,792	$ 15.00	$ -

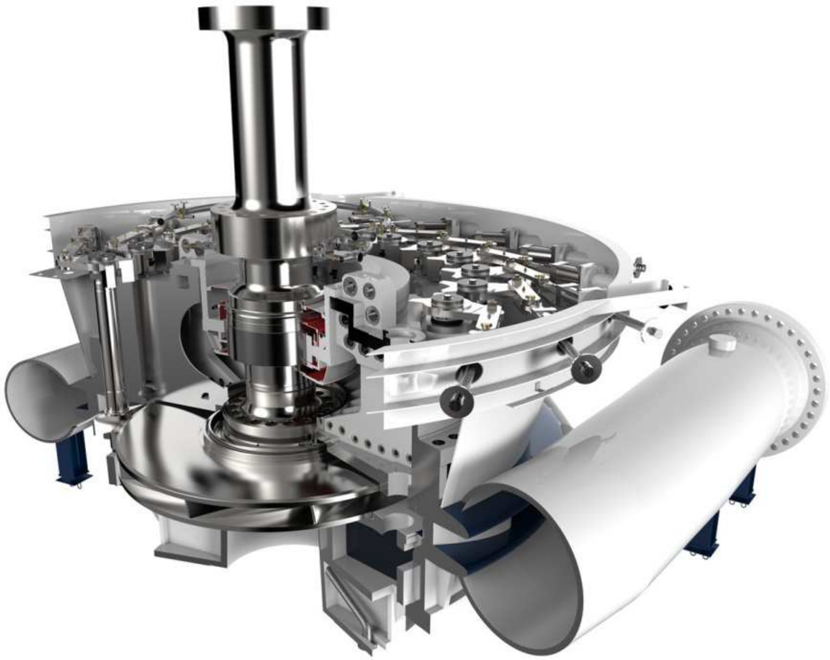




Energy Storage - Options

- Lithium Ion
- Redox Flow
- Pumped Storage

(2015$)	Net Capacity MW	Energy Content MWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
Lithium Ion	50	100	$ 1,792	$ 15.00	-
Redox Flow	10	40	$ 4,256.00	$ 30.00	-
Pump Storage	300	2400	$ 2,916.67	$ 12.00	$ 0.40



Alstom Variable Speed Pump Turbine

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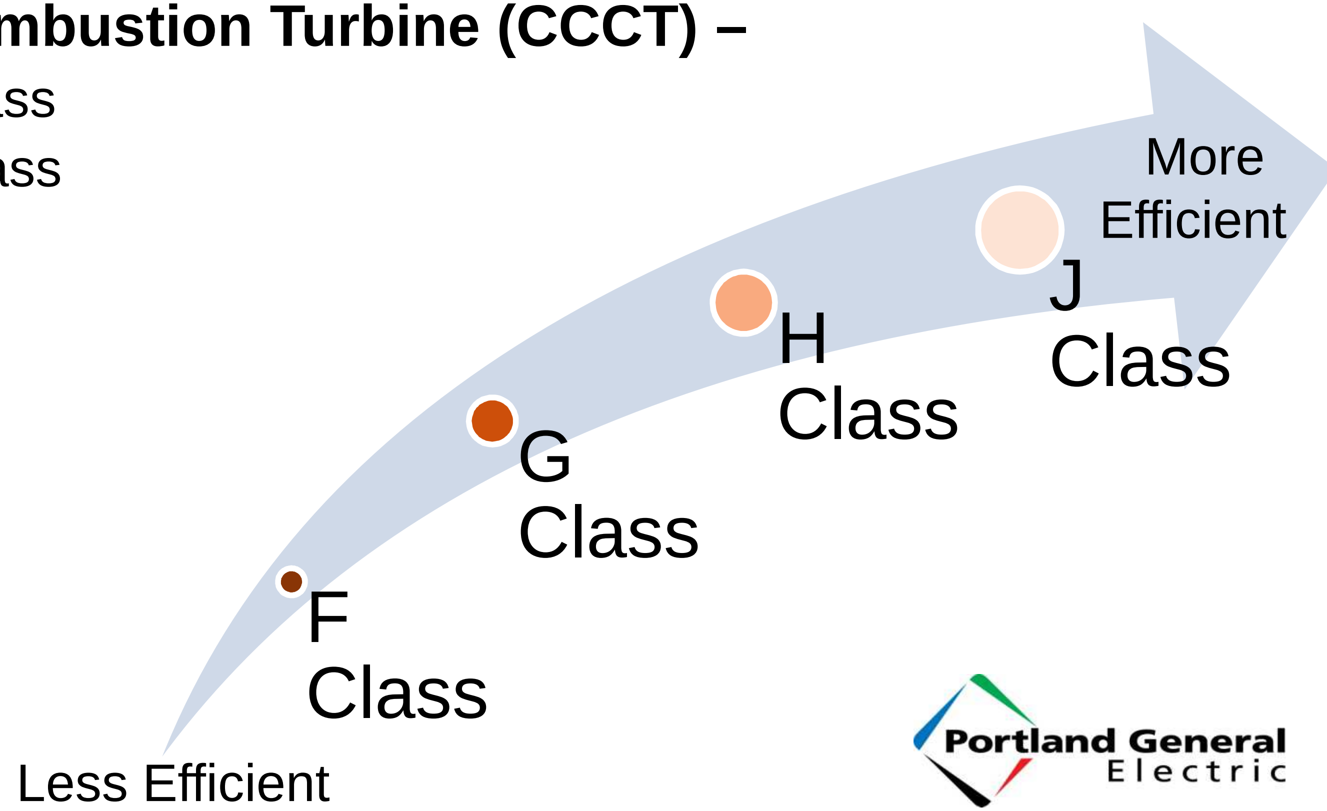
Thermal Resources

- **Simple Cycle Combustion Turbine (SCCT) –**
  - General Electric LMS100
  - General Electric 7F.05
- **Reciprocating Engine Generators –**
  - Wartsila 18V50SG
- **Combined Cycle Combustion Turbine (CCCT) –**
  - General Electric F Class
  - General Electric H Class
    - 2x1 configuration
    - 1x1configuration
  - Mitsubishi G Class
  - Mitsubishi J Class
  - Siemens F Class
  - Siemens H Class



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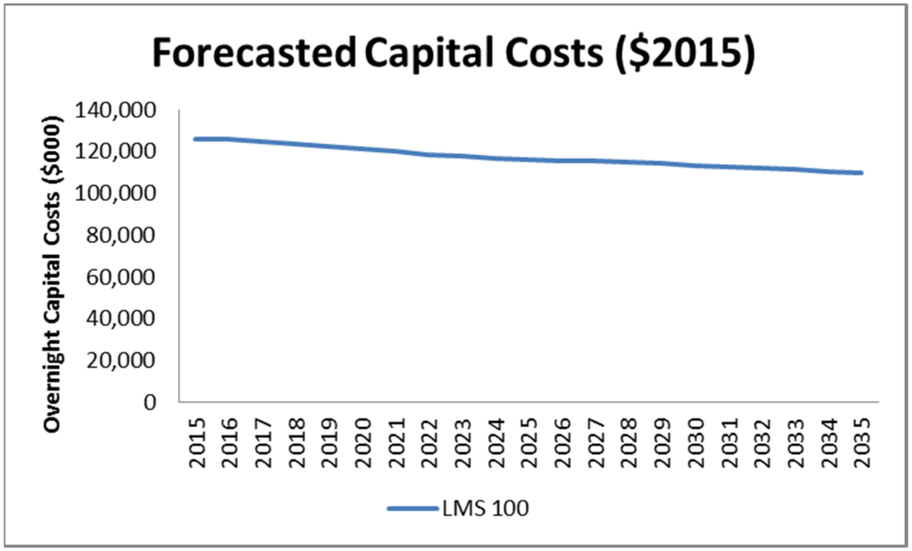
SCCT - Trends

General Electric LMS 100

- Draft results relative to 2013 IRP

(2015$)	Net Capacity MW	Heat Rate Btu/kWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
2016 IRP	100	9,176	$ 1,238	$ 3.20	$ 5.22
2013 IRP	100	9,000	$ 1,380	$ 13.11	$ 3.72
% Change	0%	2%	-10%	-76%	40%



General Electric LMS 100 Aeroderivative Gas Turbine

SCCT - Options

General Electric 7F.05

- Draft results relative to LMS 100

(2015$)	Net Capacity MW	Heat Rate Btu/kWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
LMS 100	100	9,176	$ 1,238	$ 3.20	$ 5.22
7F.05	230	9,843	$ 609	$ 3.13	$ 9.29
% Diff	-57%	-7%	103%	2%	-44%

General Electric 7F.05 Frame Gas Turbine

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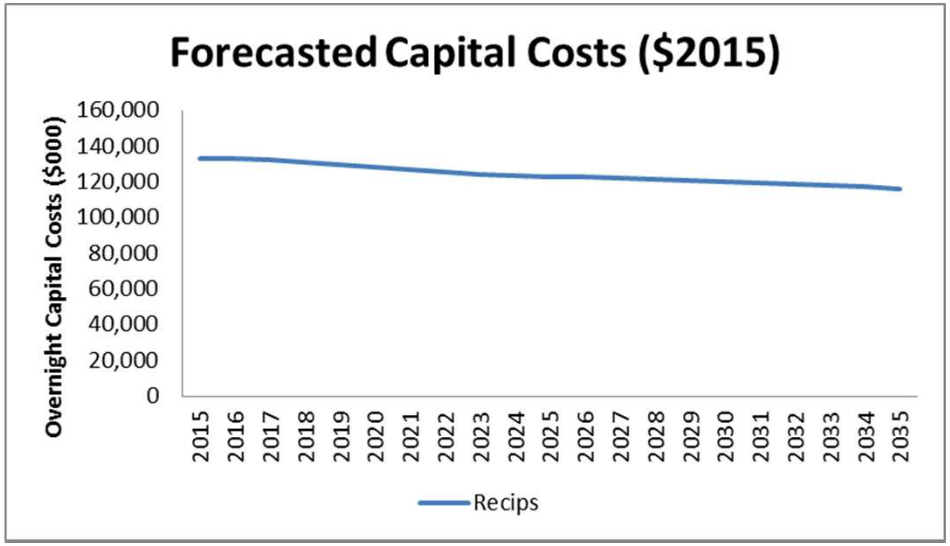
Reciprocating Engine Generators - Trends

6x0 Wartsila 18V50

Draft results relative to 2013 IRP

(2015$)	Net Capacity MW	Heat Rate Btu/kWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
2016 IRP	110	8,437	$ 1,455	$ 3.36	$ 8.93
2013 IRP	98	8,571	$ 1,762	$ 16.51	$ 9.27
% Change	12%	-2%	-17%	-80%	-4%



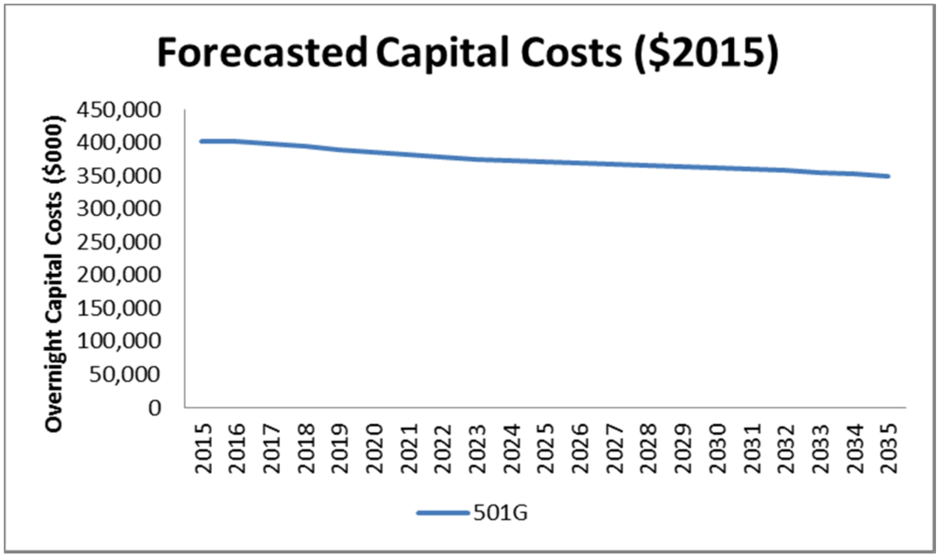
Wartsila 18V50

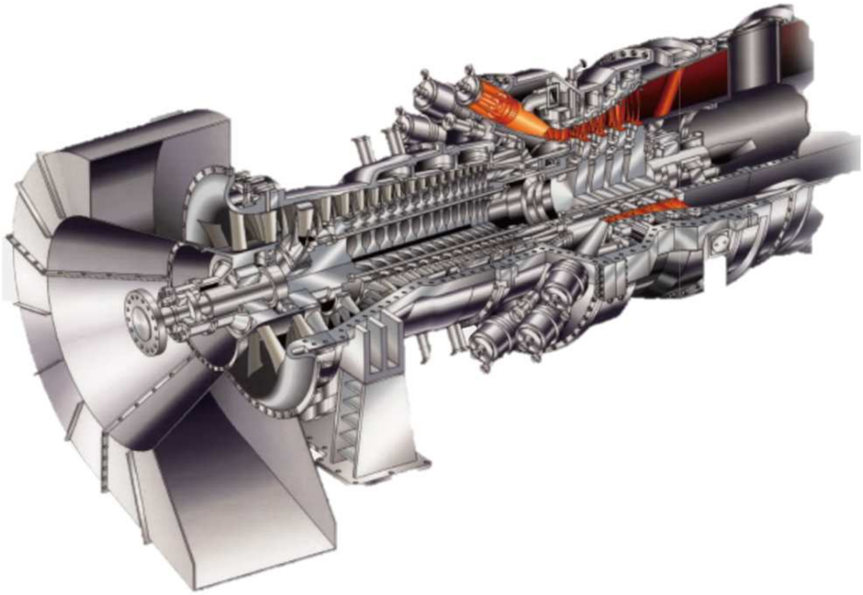
CCCT - Trends

Mitsubishi 1x1 G Class

Draft results relative to 2013 IRP

(2015$)	Net Capacity MW	Heat Rate Btu/kWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
2016 IRP	100	9,176	$ 1,238	$ 3.20	$ 5.22
2013 IRP	100	9,000	$ 1,380	$ 13.11	$ 3.72
% Change	0%	2%	-10%	-76%	40%





1x1 MHPS M501GAC Fast

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CCCT – Options

April 2, 2015 Slide 137

7 CCCT Configurations

(2015$)	Net Capacity MW	Heat Rate Btu/kWh	Overnight Capital $/kW	Fixed O&M $/kW-yr	Non-fuel VOM $/MWh
GE 7F.05	330	6809	$ 981	$ 9.60	$ 2.87
Siemens SGT6-5000F5ee	352	6902	$ 945	$ 9.05	$ 3.16
MPS 501G	365	6926	$ 1,000	$ 8.93	$ 3.00
GE 7HA.01	400	6503	$ 944	$ 8.26	$ 2.60
2x1 GE 7HA.02	810	6485	$ 873	$ 6.02	$ 2.29
Siemens SGT6-8000H	429	6644	$ 927	$ 7.58	$ 2.86
MPS 501J	442	6564	$ 896	$ 7.34	$ 3.02

GE 7HA.01

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Appendix

2016 IRP: Feedback Status

Topic	Feedback Received	Resolution	Completed
General	Passing the mic was cumbersome.	For stakeholder questions, provide a stationary microphone at a podium or mics at each table.	4/13/2015
Process	Why is schedule different on handout?	Update schedule slides to account for automation. Plan to revise and post updated slide deck to website and include summary update in ‘thank you’ email.	4/9/2015
Process	Is schedule firm or can the November 18th date be adjusted? (Power Council has important meeting on November 18)	Moved IRP meeting to November 20th.	4/9/2015
Process	Can the October 23rd date be adjusted? (CUB has important meeting on October 23)	Moved IRP meeting to October 21st.	4/9/2015
Environmental Policy	Why will climate data set be a scenario instead of a base case?	PGE to consider suggestion after vetting data.	
Environmental Policy	Does PGE place any type of weather weighting on load forecast?	PGE uses 15-year average weather, with rolling updates	

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2016 IRP: Feedback Status

Topic	Feedback Received	Resolution	Completed
Load Forecast Methodology	For future discussion, how is the ETO forecast in later years developed?	PGE to address questions about EE projection in the future. Refer to April 2nd Slide 31.	Est. 7/15/15 and 7/16/15
Load Forecast Methodology	Comment on in-fill vs. suburban sprawl – suggestion to be cautious about moving to more standard household variables	PGE to take note.	4/8/2015
Load Forecast Methodology	Request to show load growth with and without EE.	PGE to meet this request.	Est. 8/13/2015
Load Forecast Methodology	What % of PGE service territory is within the urban growth boundary?	90% of the UGB is within PGE Service Territory UGB is 822.7 sq. mi. PGE SVC Territory is 7532.2 sq. mi. Overlap is 741.6 sq. mi.	4/8/2015
Environmental Policy	Will temperature data drive (1) increased cooling demand and (2) an acceleration of cooling device purchases?	PGE to follow-up internally with load forecast staff.	Est. 8/13/2015 (with scenarios and climate change weather discussion)

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