Integrated Resource Planning

Roundtable 18-1
Day 2

February 15, 2018

Meeting Logistics

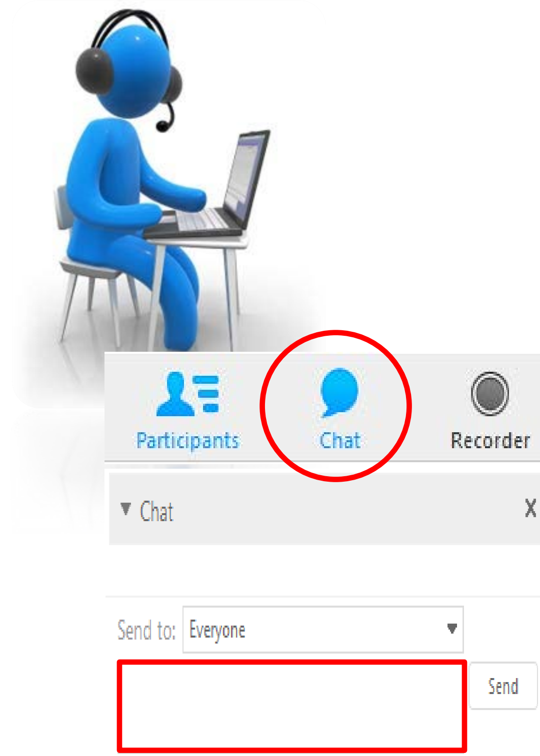
Local Participants:

- World Trade Center facility
- Wireless internet access
  - Network: 2WTC_Event
  - Password: 2WTC_Event$
- Sign-in sheets

Virtual Participants:

- Ask questions via 'chat' feature
- Meeting will stay open during breaks, but will be muted
- Electronic version of presentation: *portlandgeneral.com/irp*

\>> *Integrated Resource Planning*



Safety Moment

Have you ever stopped to think how clean your workplace really is?

Source: https://www.essystems.co.uk/2015/06/04/how-clean-is-your-work-space/

Today’s Roundtable Topics

- ❑ Welcome / Safety Moment
- ❑ 2016 IRP Update Introduction
- ❑ Need Assessments and Sensitivities
- ❑ Capacity Contribution
- ❑ Supply Side Resources
- ❑ Energy Trust EE Forecast
- ❑ Distributed Resource & Flexible Load Study
- ❑ Load Forecast
- ❑ Load Forecast Workshop
- ❑ Next Steps/Wrap-Up

PGE will seek acknowledgment of various updates so they may be incorporated into the May 1 Schedule 201 Avoided Cost filing.

Update to PGE's 2016 IRP

- PGE plans to file a focused Update to its 2016 IRP (LC 66) in March
- The Company is seeking acknowledgment of updated:
  - Supply Side Resource Costs and Parameters
  - Carbon Offset Costs
  - Financial Parameters
  - Incremental Wind & Solar Capacity Contributions

➢ PGE is seeking acknowledgment of these updates so they may be incorporated into the May 1 Avoided Cost filing

2016 IRP Update

Informational reporting in Update:

1. **Action items and Order requirements**
2. **Need assessments**
3. **Gas and power prices**

Informational Reporting
▪ Status updates on action items and Order requirements
▪ Updated capacity, energy, and RPS need assessments and sensitivities
▪ Updated gas and wholesale market prices

No Change Requested
▪ 2016 IRP flexibility need assessment
▪ CO_2 pricing
▪ Acknowledged action plan

2016 IRP Update Proposed Schedule

2016 IRP Update Scheduling Conference Call

Friday
Feb. 16
11 a.m.

Date	Item
March 8	PGE Files IRP Update
March 29	Staff and Stakeholder Comments Due
April 5	PGE Reply Comments Due
April 12	Staff Report Due
April 20	OPUC rules on acknowledgment at Public Meeting

2016 IRP Update
OPUC Proposed Schedule

2016 IRP Update Scheduling Conference Call

Friday
Feb. 16
11 a.m.

Date	Item
March 8	PGE Files IRP Update
March 13	PGE Presents IRP Update at Regular Public Meeting
March 29	Stakeholder Comments Due
April 6	PGE Reply Comments Due
April 17	Staff Report Due
April 24	Decision at Regular Public Meeting

Need Assessments and Sensitivities

Kate

2016 IRP Update
Need Assessments

Need Assessments will be refreshed for the IRP Update

No proposed changes to the acknowledged 2016 IRP Actions

- Need Assessments for capacity, energy, and RPS in the Update are based on the same methodologies as the 2016 IRP, but with refreshed inputs to include the December 2017 load forecast, an updated contract snapshot, and final 2016 REC inventory.
- We anticipate posting the results of assessments with the updated contract snapshot to the IRP website next week.

Sensitivities

- The IRP Update will also include **sensitivities of need assessments and capacity contribution values**. These will expand on the sensitivities included in the Renewables Addendum.

Renewables Addendum – December 2017			
	QF Completion Rate		
	100%	75%	50%
RPS Compliance (MWa)			
2025 Physical RPS Need	71	109	148
Resource Adequacy (MW)			
2021 Capacity Need	461	503	551
Energy (MWa)			
2021 Energy Need	75	113	152

2016 IRP Update Sensitivities

- **QF Completion Rate**
- **QF Queue Execution Rate**
- **Renewable RFP**
- **Energy Storage**
- **Zero Load Growth**
- **Expanded Energy Efficiency**

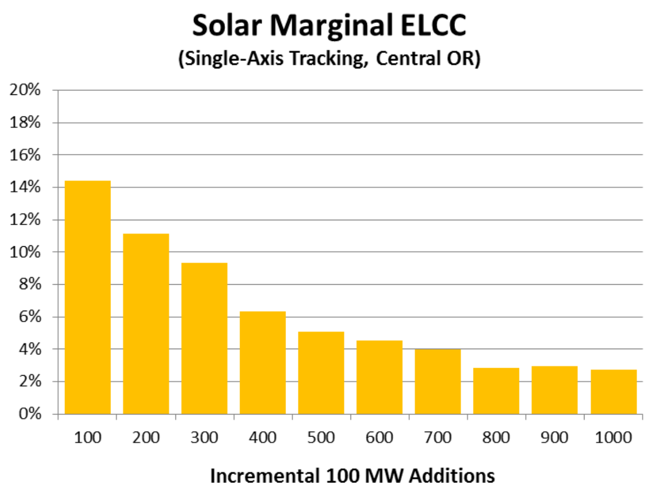
Capacity Contribution

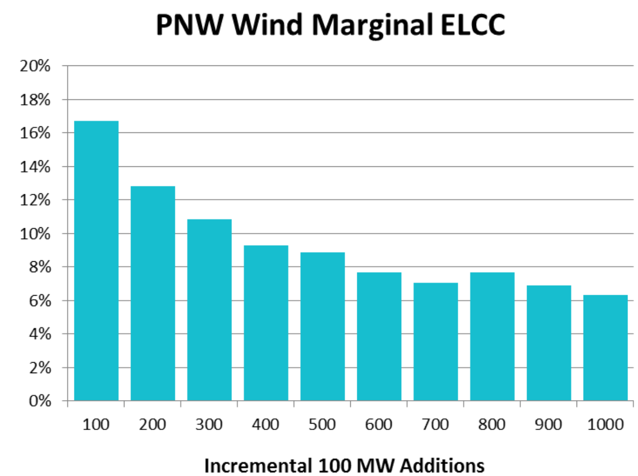
Kate, Jessie, Shauna

Wind and Solar Incremental ELCC

PGE requests acknowledgment of the updated capacity contribution values for incremental wind and solar resources

- The capacity contribution values for incremental wind and solar resources were updated based on the refreshed RECAP model (December 2017 loads, updated contract snapshot).





Supply Side Resources & Financial Parameters Update

Brad Carpenter

From this section, PGE will seek acknowledgment of the updated:

- Supply Side Resource Costs and Parameters
- Carbon Offset Costs
- Financial Parameters

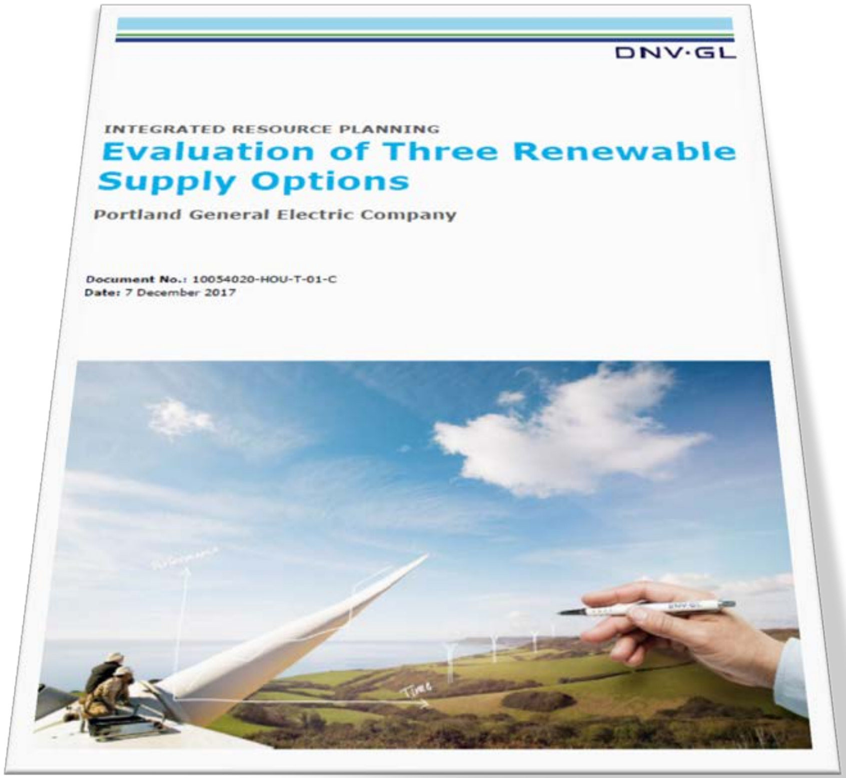
Information posted on IRP website on January 25

Overview

- PGE based the 2016 IRP supply side resource costs and parameters on studies conducted by Black & Veatch and DNVGL
    - In 2017, PGE requested updated studies for three thermal resources (B&V) and three renewable resources (DNVGL)
- The economic lives assumed for the six resources have been updated to tie with PGE's depreciation study filed in UM 1809
- Carbon Offset Costs were updated to reflect rules amended in October, 2017
- PGE has also updated financial parameters to reflect changes to the federal tax law and the Company's allowed ROE from UM 319

➢ ***<u>The various updates contain elements that both increased and decreased resource costs</u>***

Consultant Supply Side Studies



DNV·GL

INTEGRATED RESOURCE PLANNING

Evaluation of Three Renewable Supply Options

Portland General Electric Company

Document No.: 10054020-HOU-T-01-C
Date: 7 December 2017

FINAL

CHARACTERIZATION OF SUPPLY-SIDE OPTIONS (2017)

B&V PROJECT NO. 196332
B&V FILE NO. 40.0000

PREPARED FOR

Portland General Electric

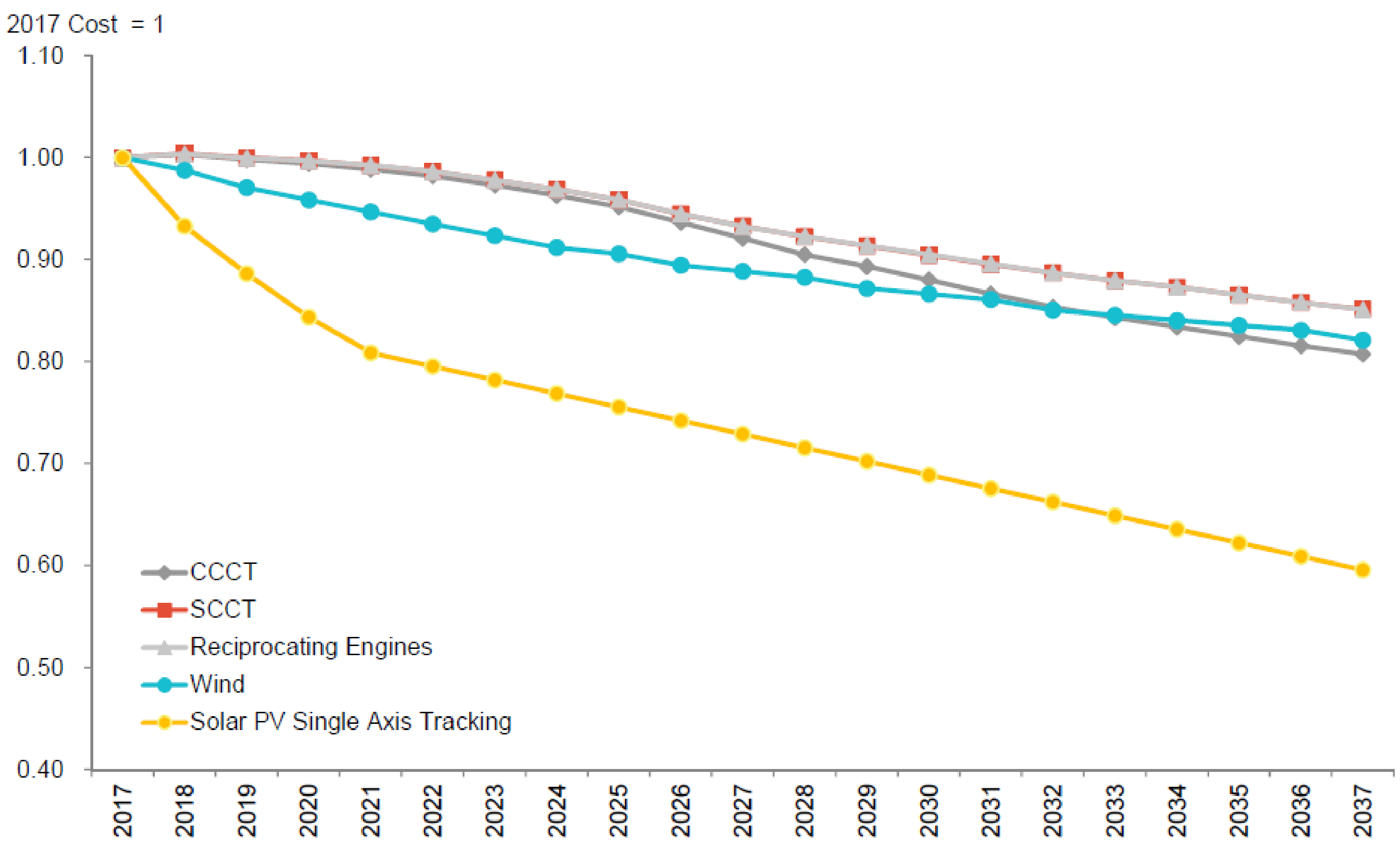
Portland General Electric

4 OCTOBER 2017

BLACK & VEATCH

Studies available on IRP website

O/N Cost of Capital Technical Maturity Outlook



Source: Black & Veatch and DNVGL Supply Side Option Studies, Fall 2017

EFSC CO_2 Offset Payments

EFSC Rates Updated October 2017

Monetary Path Requirements	7HA.01 CCCT	7F.05 SCCT	Wärtsilä
$ Million	$6.75	$3.17	$2.15
$ / MW	$15.93	$13.73	$19.53

- These are permitting costs and are included in the Overnight Cost of Capital estimates in the Supply Side Resource Summary table (not in the consultant studies).
- PGE has included updates from rules amended on October 23, 2017 and updated thermal parameters.

Updated Financial Parameters

Resource cost calculations refreshed to use updated financial parameters

Cost of Capital Components	%
Composite Income Tax Rate[1]	27.08%
Incremental Cost of Long-Tem Debt	4.97%
Allowed Return on Equity[2]	9.50%
Long-Term Debt Share of Capital Structure	50.00%
Equity Share of Capital Structure	50.00%
Weighted Cost of Capital	7.24%
Nominal Weighted After-Tax Cost of Capital	6.56%
Long-Term General Inflation	2.00%
Economic Lives[3]	**Years**
Thermal Plants	38
Solar	20
Wind	30

Notes

1. Reflects December 2017 changes to federal tax law.
2. Allowed ROE from UM 319.
3. Depreciation Study filed in UM 1809.

Supply Side Resource Summary

Updated Resource Assumptions -- COD 2021										
2018$	Update or 2016 IRP	New & Clean Nameplate MW	Degraded Nameplate MW	Degraded Heat Rate Btu / kWh	Expected Availability % [1]	Economic Life Years [2]	Overnight Capital Cost $ / kW [3]	Fixed O&M $ / kW-yr [4]	Variable O&M $ / MWh [5]	Real Levelized Fixed Cost $ / kW-yr [6]
Renewable Resources										
Central Station Solar Tracking PV	Updated	103	103	N/A	23%	20	$1,471	$8.57	$0.87	$152
	2016 IRP	103	103	N/A	24%	25	$1,911	$10.61	$0.87	$176
Wind Plant PNW	Updated	332	332	N/A	35%	30	$1,475	$44.88	$0.87	$188
	2016 IRP	338	338	N/A	34%	27	$1,664	$47.75	$0.87	$222
Wind Plant Montana	Updated	240	240	N/A	42%	30	$1,493	$44.88	$0.87	$190
	2016 IRP	236	236	N/A	42%	27	$1,713	$47.75	$0.87	$225
Thermal Resources										
Natural Gas CCCT-H	Updated	424	400	6,450	90%	38	$1,370	$8.00	$3.37	$172
	2016 IRP	400	387	6,503	95%	35	$1,125	$9.06	$2.76	$164
Wärtsilä Reciprocating Engine	Updated	110	107	8,470	98%	38	$1,364	$11.53	$7.34	$175
	2016 IRP	110	110	8,437	96%	30	$1,508	$3.57	$9.48	$193
SCCT - Frame 1x0 GE 7F.05	Updated	231	218	10,170	96%	38	$648	$7.24	$7.04	$124
	2016 IRP	230	224	9,981	98%	30	$648	$3.41	$9.86	$126

Notes:

1) Expected Availability is expected capacity factor for Wind and Solar PV. For 2016 IRP Thermal Resources, Expected Availability is capacity adjusted for scheduled maintenance and the forced outage rate. For the updated Thermal Resources, Expected Availability is capacity adjusted for scheduled maintenance and forced outage during periods of demand.
2) Economic life assumptions updated to PGE's depreciation study filed in UM 1809.
3) Capital Costs include OEFSC payments to Climate Trust of Oregon. Carbon Offset cost updated to the 2017 schedule.
4) Based on degraded MW.
5) Variable O&M includes integration costs from the Variable Energy Integration Study.
6) Includes fixed capital carrying and operating costs, which include fixed O&M, fixed gas transpiration, wheeling, ongoing capital additions, and land lease payments as applicable. Updated costs incorporate BPA wheeling rates from the BP-18 rate case, with later years escalated at the inflation rate. The Montana Wind resource includes the cost of one segment of BPA wheeling, but does not include any additional transmission expenses.

Energy Trust Energy Efficiency Forecast

Peter Schaffer

Energy Trust of Oregon

Energy Efficiency Resource Assessment Study

February 15th, 2018

EnergyTrust of Oregon

Agenda

- About Energy Trust
- Overview and background
- Methodology and updates
- Results
- Questions/Discussion

About us

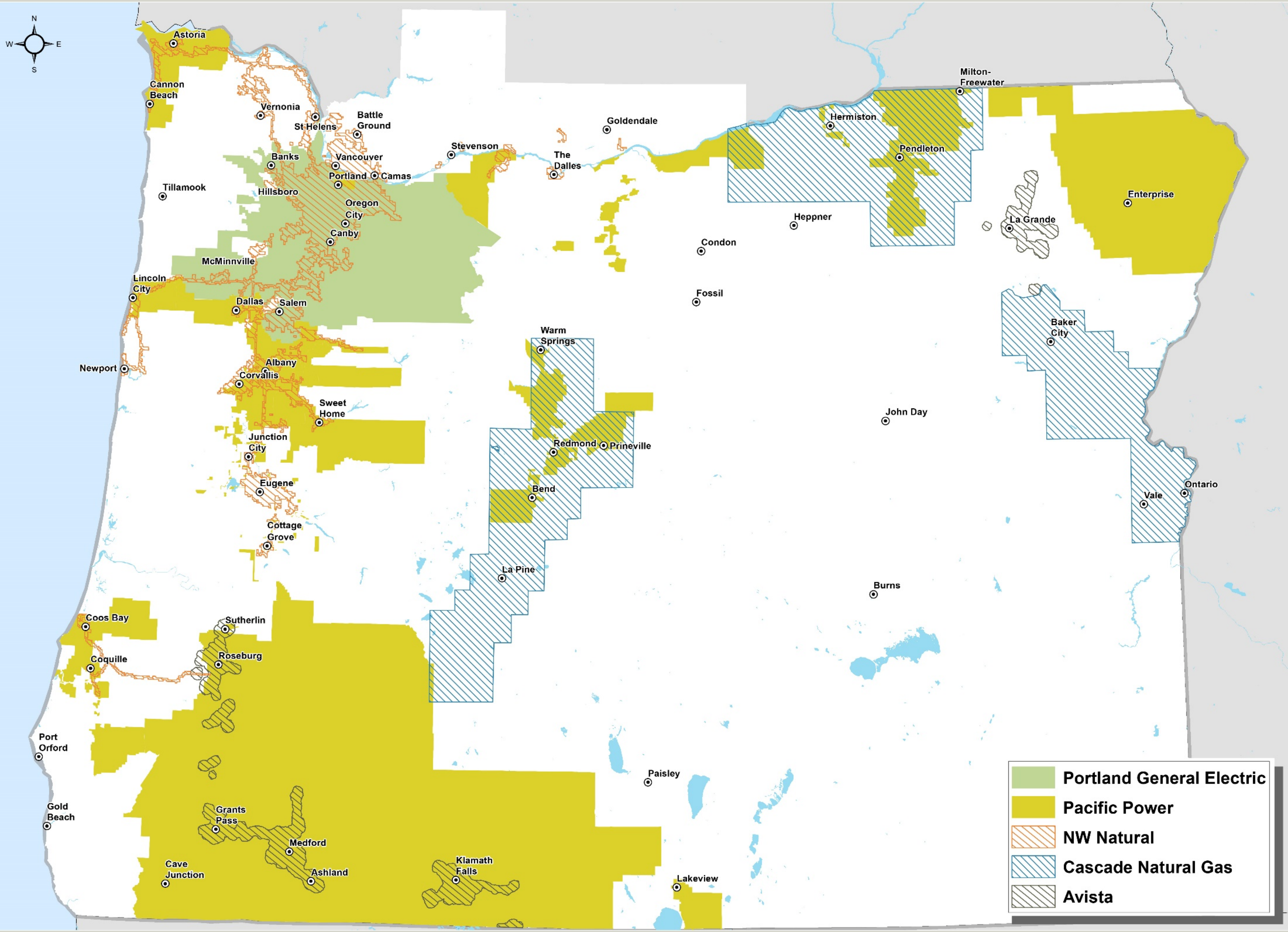
Independent nonprofit

Serving 1.6 million customers of Portland General Electric, Pacific Power, NW Natural, Cascade Natural Gas and Avista

Providing access to affordable energy

Generating homegrown, renewable power

Building a stronger Oregon and SW Washington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Vernonia
St Helens
Battle Ground
Banks
Vancouver
Portland
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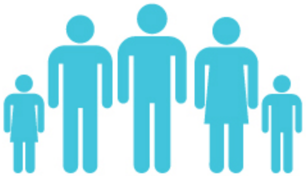
The Dalles
Milton-Freewater
Hermiston
Pendleton
Tillamook
Hillsboro
Oregon City
Canby
Heppner
Condon
La Grande
Enterprise
McMinnville
Lincoln City
Dallas
Salem
Fossil
Warm Springs
Baker City
Newport
Albany
Corvallis
Sweet Home
John Day
Junction City
Redmond
Prineville
Eugene
Bend
Ontario
Vale
Cottage Grove
La Pine
Burns
Coos Bay
Sutherlin
Roseburg
Coquille
Port Orford
Paisley
Gold Beach
Grants Pass
Medford
Ashland
Klamath Falls
Cave Junction
Lakeview
Portland General Electric
Pacific Power
NW Natural
Cascade Natural Gas
Avista

15 years of affordable energy

From Energy Trust’s investment of $1.5 billion in utility customer funds:



Nearly 660,000 sites transformed into energy efficient, healthy, comfortable and productive homes and businesses

10,000 clean energy systems generating renewable power from the sun, wind, water, geothermal heat and biopower

$6.9 billion in savings over time on participant utility bills from their energy-efficiency and solar investments

20 million tons of carbon dioxide emissions kept out of our air, equal to removing 3.5 million cars from our roads for a year

A clean energy power plant

607 average megawatts saved

121 aMW generated

52 million annual therms saved

Enough energy to power **564,000** homes and heat **100,000** homes for a year

Avoided **20** million tons of carbon dioxide

Purpose, Overview and Background

Resource Assessment (RA) Purpose

- The resource assessment provides PGE with estimates of energy efficiency potential that will result in a reduction of load on their utility system.

- Estimates of energy efficiency potential are in gross savings as that is what will be reflected on the PGE system.

- The purpose is to help PGE strategically plan future investment in both supply side and demand side resources.

Resource Assessment Overview

- What is a resource assessment?
  - Estimate of energy efficiency resource potential at a range of costs that is achievable over a 20-year period
  - Provides a cost-effective resource estimate

- Energy Trust uses a model in *Analytica* that was developed by Navigant in 2014

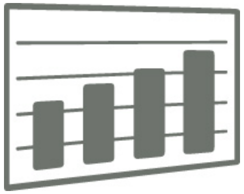
- Inputs and assumptions in the model are updated in conjunction with Integrated Resource Plan every two years.

Background – How is RA used?

- Informs utility IRP work & strategic planning / program planning.
- Provides estimates of potential load reduction from energy efficiency on the utility system.
- Does not dictate what annual energy savings are acquired by programs
- Does not set incentive levels

Methodology and Updates

Model inputs



- Utility Service Territory Data
  - Customer counts, 20-year load forecasts
  - Avoided costs, line losses, and discount rate

- Demographic statistics
  - Heating & hot water fuel splits, measure saturations, and baseline conditions.
  - Energy use intensity for commercial and industrial

- Measure assumptions
  - Savings, costs, O&M, measure life, load profile, end use, baseline information, technical applicability, achievability rates

- Energy Trust assumptions
  - Program forecasts for years 1-5, alignment with program measure assumptions and uptake and saturation adjustments based on prior program activity.

Model Assumptions and Updates

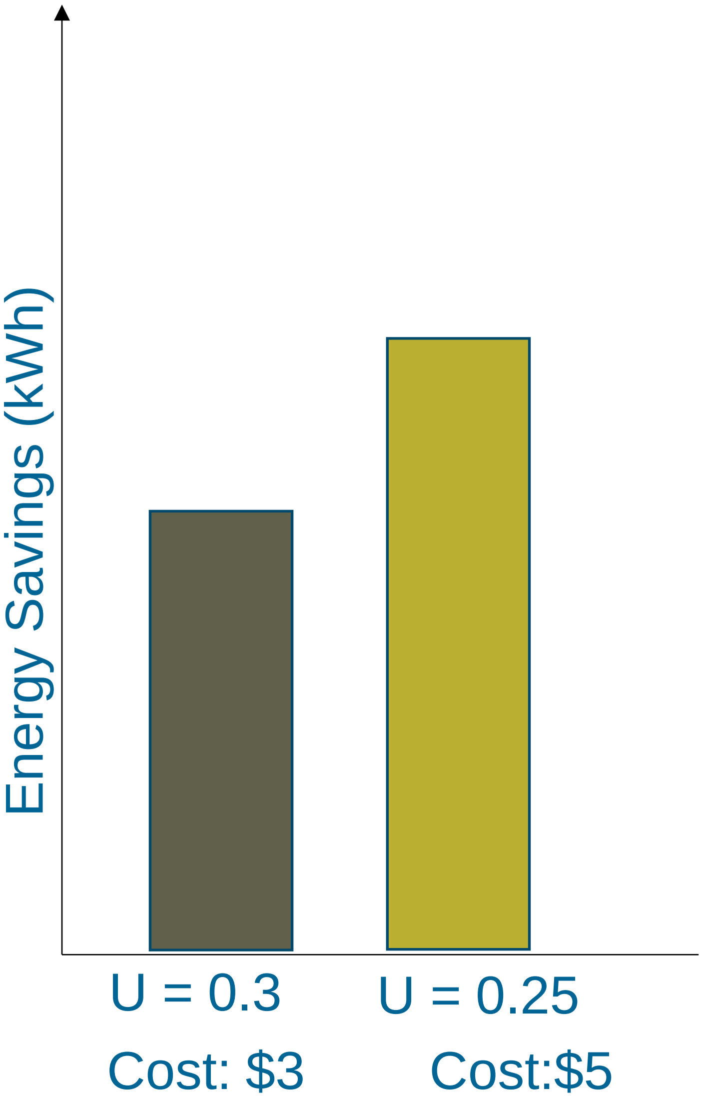
- Cost-effective potential may be realized through programs or codes and standards efforts.
- Includes assumptions about transforming retail lighting markets via regional efforts and EISA lighting standards.
- Uses CBSA EUI data to translate utility load forecasts to stock forecasts. Utilizes 3rd party research and survey work to inform measure saturation and density (e.g. RBSA)
- Looks to align with high-level 7th Power Plan deployment rates for market sectors and replacement types.
- Measure updates and new emerging technologies included in model

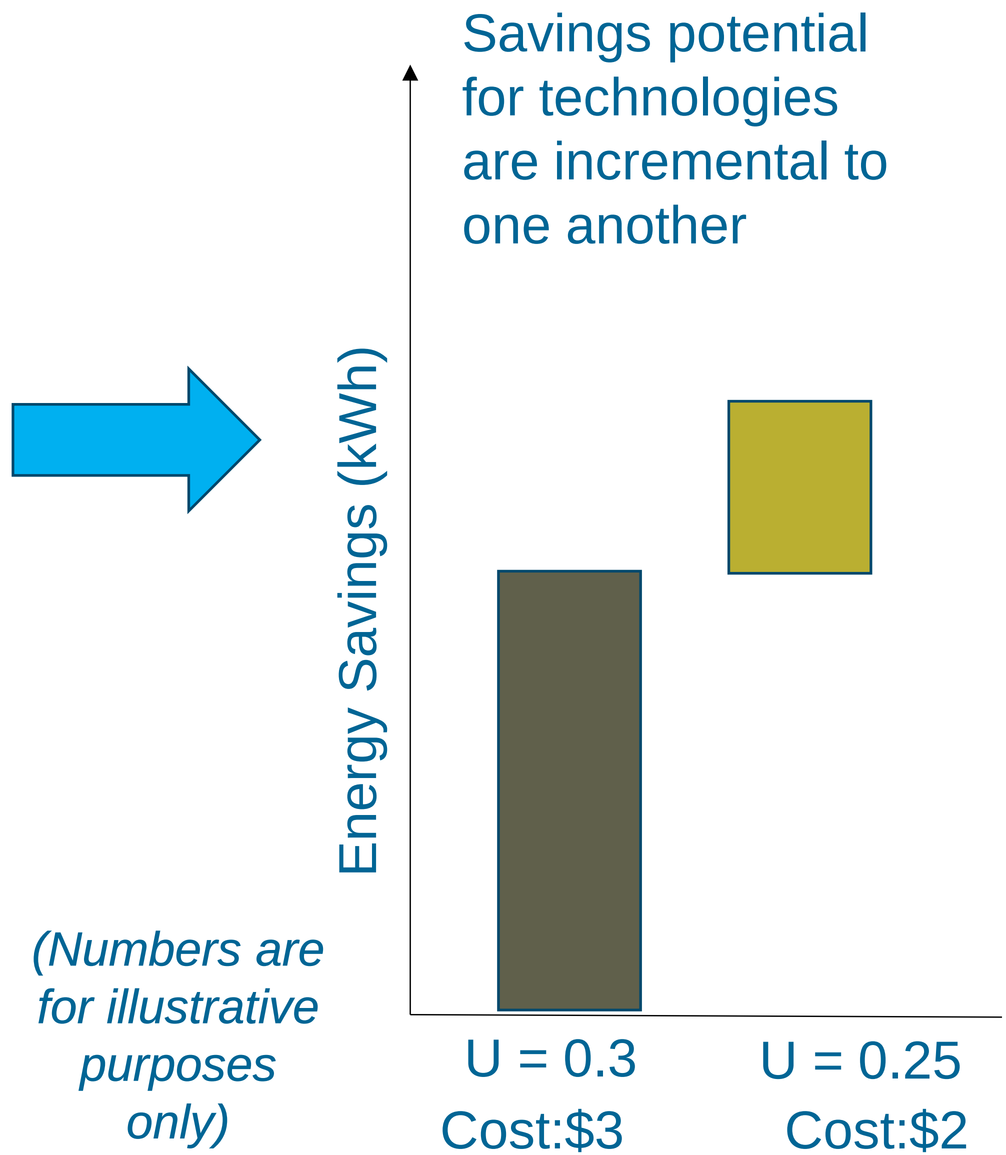
Example Measure: Residential Heat Pump Water Heater- Tier 1, Heating Zone 1

Key Measure Inputs:

- Baseline: 0.95 EF Water Heater ($590)
- Measure Cost: $1,230
- Competing Measures: All Electric Water Heaters
- Lifetime:13 years
- Conventional (not emerging, no risk adjustment)
- Customer Segments: SF, MF, MH
- Program Type: Replacement on Burnout
- Savings: 1,112 – 1,483 kWh
- Density, saturation, suitability
- No Non-Energy Benefits or O&M savings

Incremental Measure Savings Approach (competition groups)



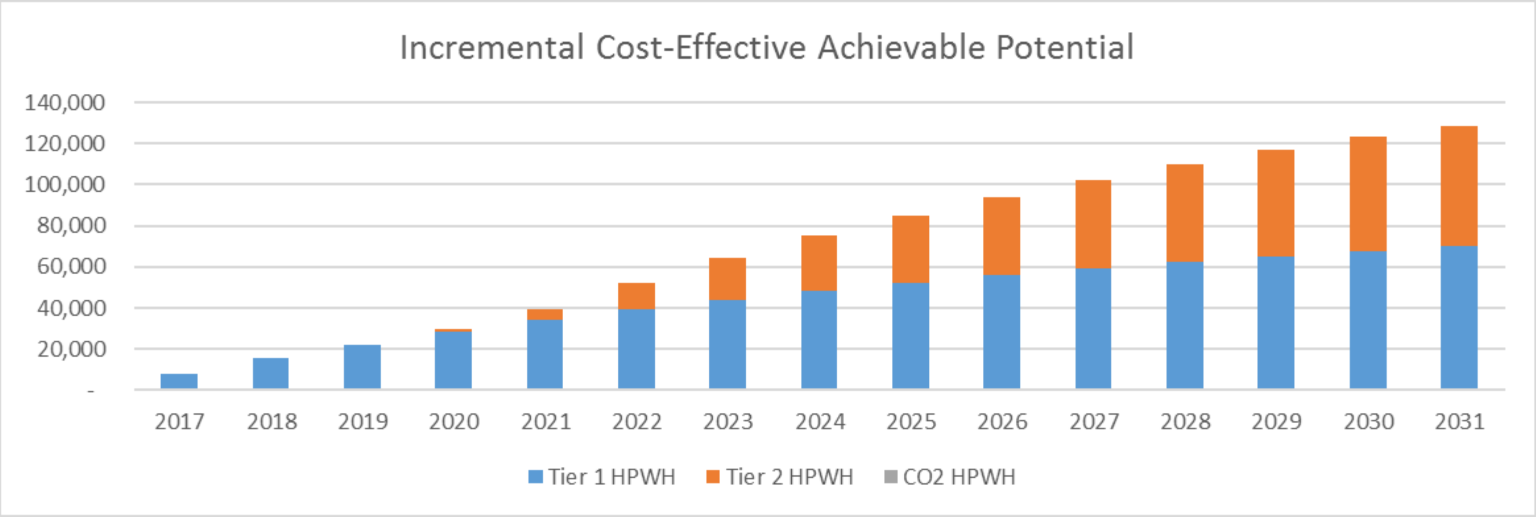


(Numbers are for illustrative purposes only)

Example Measure - Incremental Savings

Tier 1 Z1 Residential HPWH Measures	TRC	Cumulative CE Potential (MWh)	2017	2018	2019	2020	2021	2022	2023
Tier 1 HPWH Z1- Manuf.	2.66	7,741	782	1,500	2,157	2,760	3,312	3,818	4,282
Tier 1 HPWH Z1- Multifamily	2.70	30,274	3,060	5,865	8,436	10,792	12,953	14,933	16,749
Tier 1 HPWH Z1- Single Family	2.51	41,398	4,184	8,019	11,535	14,758	17,712	20,420	22,903
Total		**71,672**	**8,026**	**15,384**	**22,128**	**28,310**	**33,977**	**39,172**	**43,934**

Competing Measures	TRC	Cumulative CE Potential (MWh)	2017	2018	2019	2020	2021	2022	2023
Tier 2 HPWH Z1- Manuf.	1.10	9,957		-	-	1,095	2,099	3,019	3,863
Tier 2 HPWH Z1- Multifamily	1.06	29,621		-	-	-	3,420	6,554	9,428
Tier 2 HPWH Z1- Single Family	1.04	31,753		-	-	-	-	3,630	6,958
Advanced CO2 HPWH Z1- Manuf	0.22	-	-	-	-	-	-	-	-
Advanced CO2 HPWH Z1- Multifamily	0.22	-	-	-	-	-	-	-	-
Advanced CO2 HPWH Z1- Single Family	0.22	-	-	-	-	-	-	-	-



Cost-effectiveness screen – Total Resource Cost Test

Benefits

- Savings x Avoided Costs per kWh
- Quantifiable non-energy benefits (NEBs)

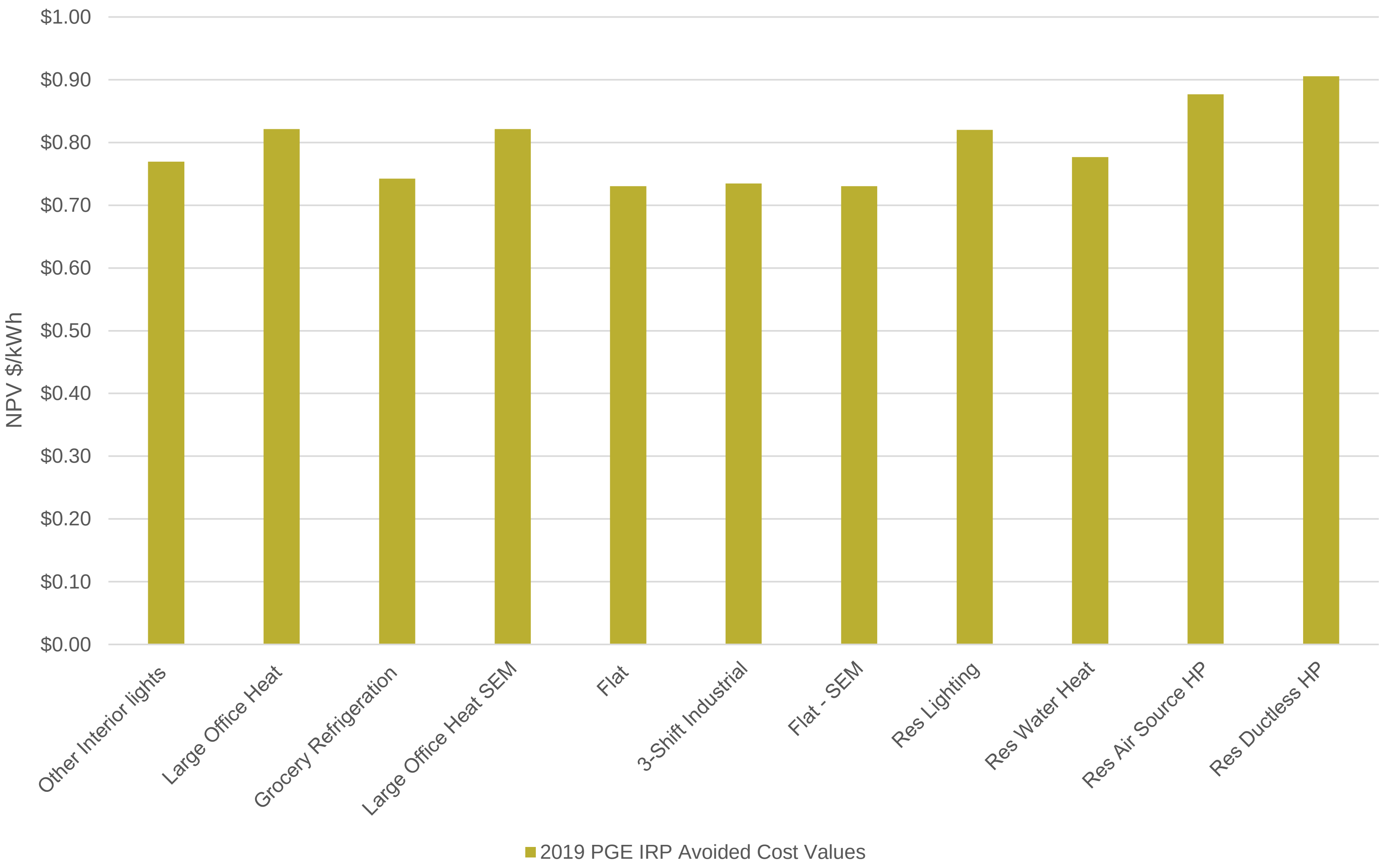
Total Resource Measure Costs

- Full cost of EE measure or incremental cost of installing efficient measure over baseline measure

Total Resource Cost (TRC) BCR =

$$\frac{(Lifetime\ Savings\ *\ Avoided\ Costs) + NEBs}{Total\ Cost\ of\ Measure}$$

NPV Avoided Cost $/first-year kWh for Selected Profiles with 15 year measure life



Cost-Effectiveness Override in Model

Energy Trust applied this feature to measures found to be NOT Cost-Effective in the model but are offered through programs.

Reasons:

1. Blended avoided costs may produce different results than utility specific avoided costs
2. Measures expected to be cost-effective in the future are sometimes offered under an OPUC exception per UM 551 criteria.
3. For commercial new construction, bundled prototypes may screen as cost-effective for the program, but the individual measures may not screen as cost-effective in the model.

Emerging Technologies

Residential	Commercial	Industrial
• Window Replacement (U<.20) • Advanced Insulation Technologies • Smart Devices Home Automation / Controls • EPS Pathway Homes • New Mobile Home Packages • CO2 Heat Pump Water Heater	• Advanced Packaged A/C RTU • Advanced Ventilation Controls • Smart/Dynamic windows • Energy Recovery Ventilator • Zero Net Energy • DOAS/HRV systems	• Advanced refrigeration controls • Switched reluctance motors • Wall Insulation

- Model includes savings potential from emerging technologies
- Factors in changing performance, cost over time
- Use risk factors to hedge against uncertainty

	Risk Factors for Emerging Technologies				
Risk Category	**10%**	**30%**	**50%**	**70%**	**90%**
Market Risk (25% weighting)	Requires new/changed business model Start-up, or small manufacturer Significant changes to infrastructure Requires training of contractors. Consumer acceptance barriers exist.		Training for contractors available. Multiple products in the market.	Trained contractors Established business models Already in U.S. Market Manufacturer committed to commercialization	
Technical Risk (25% weighting)	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	Proven technology in target application. Multiple potentially viable approaches.
Data Source Risk (50% weighting)	Based only on manufacturer claims	Manufacturer case studies	Engineering assessment or lab test	Third party case study (real world installation)	Evaluation results or multiple third party case studies

Model 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
85% of Technical</td></tr>
<tr><td>Not technically feasible</td><td>Market barriers</td><td>Not cost effective</td><td>Cost-Effective Potential</td></tr>
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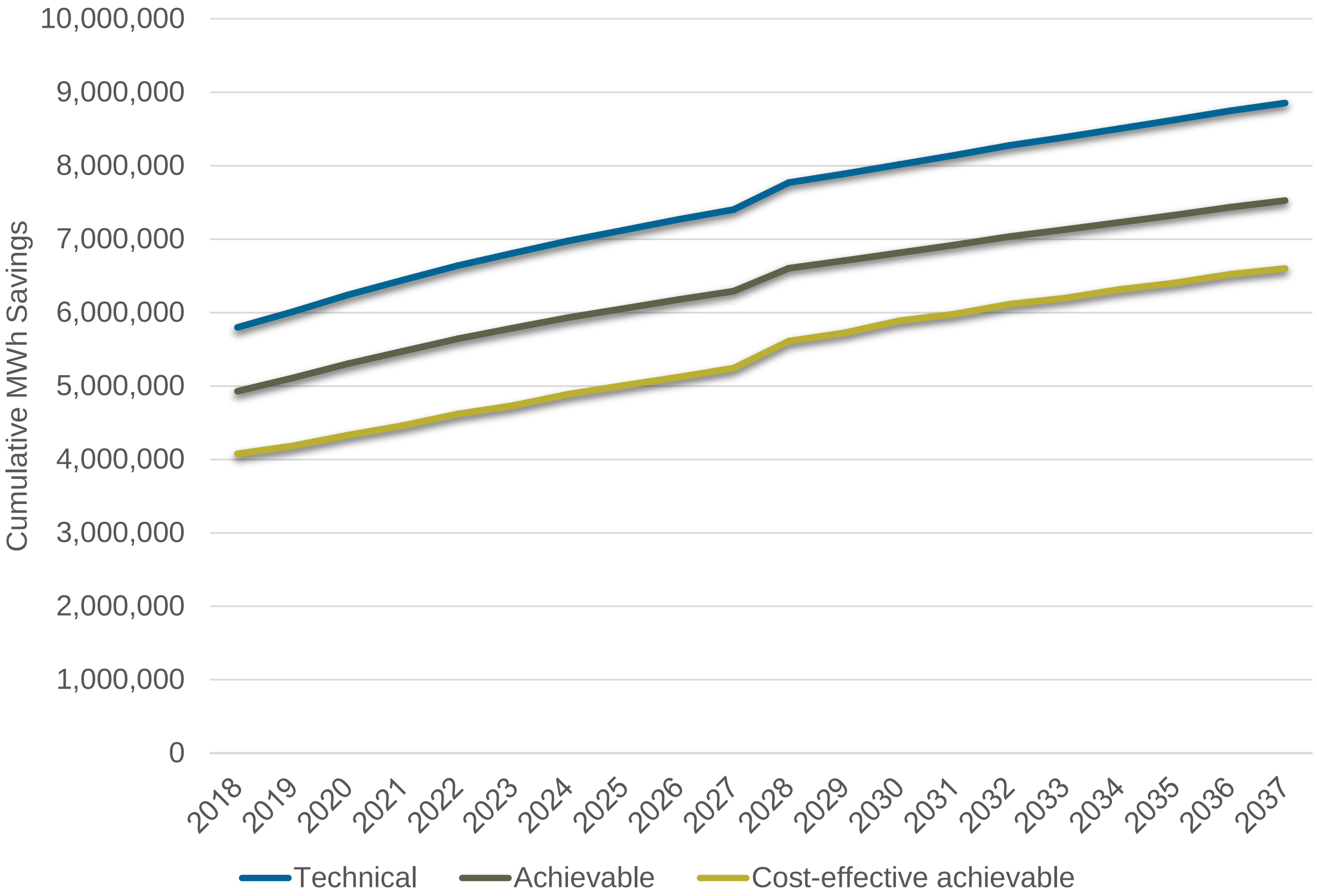
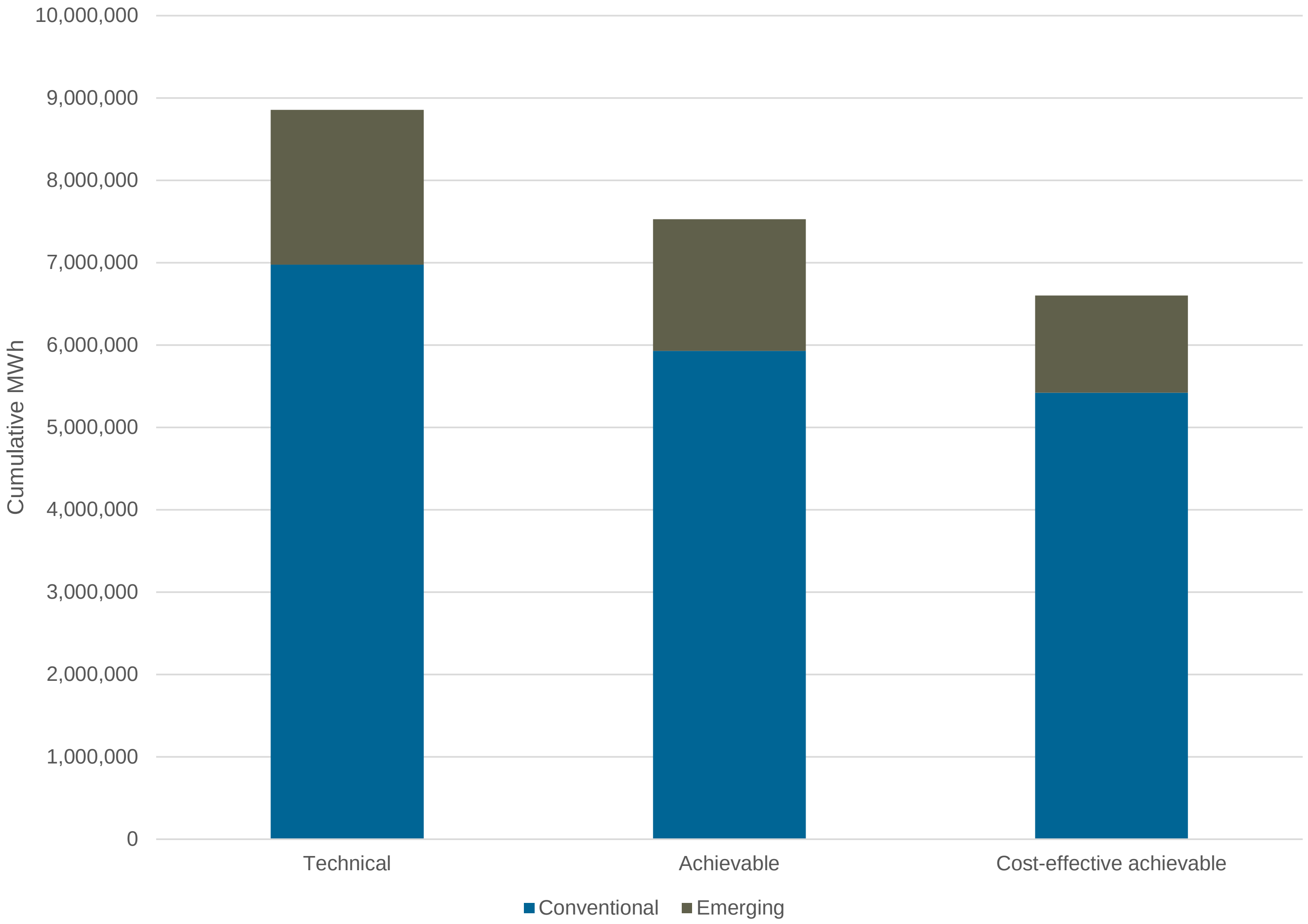
Results

Cumulative Potential by Type and Year



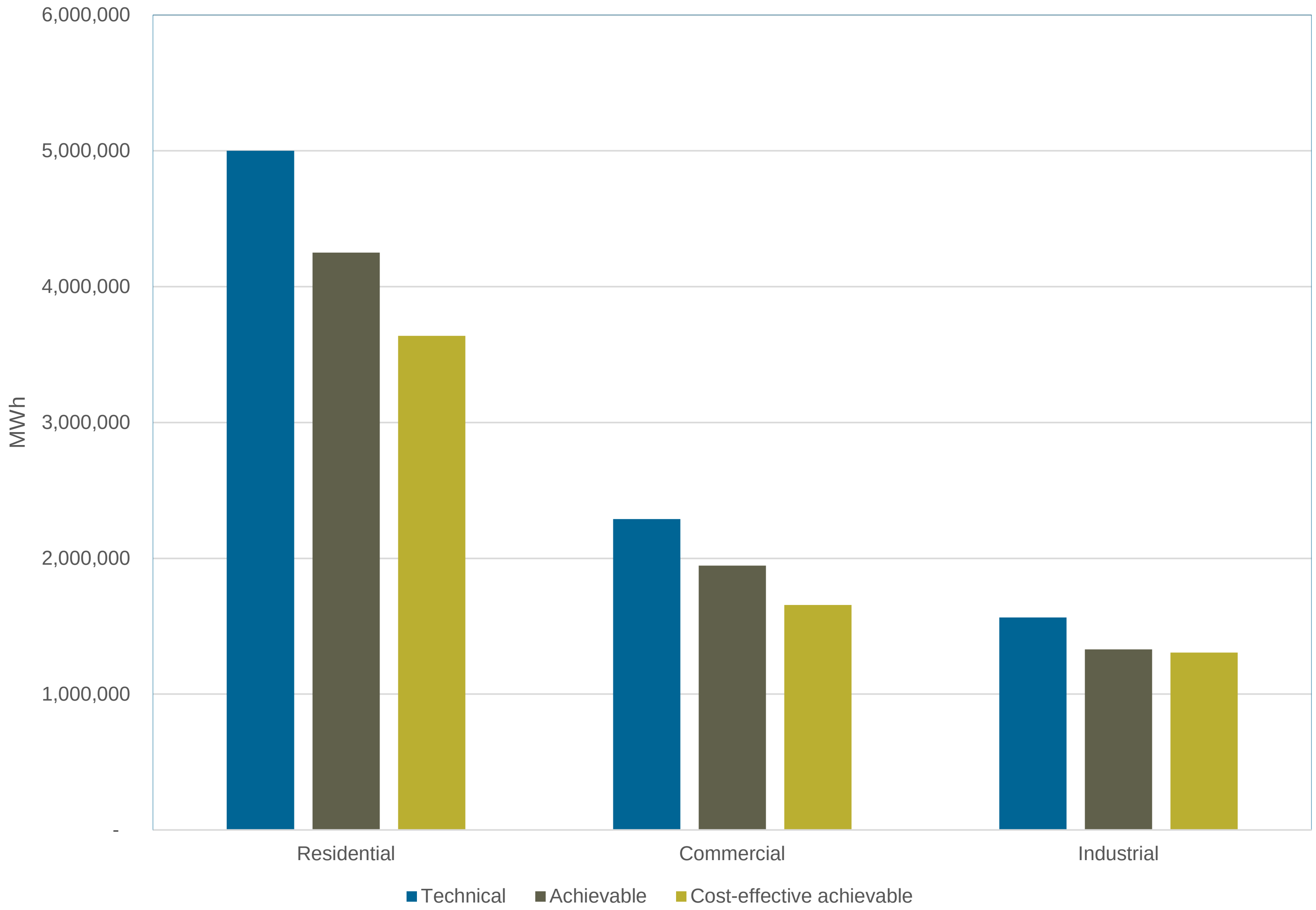
Cumulative Emerging Technology Contribution



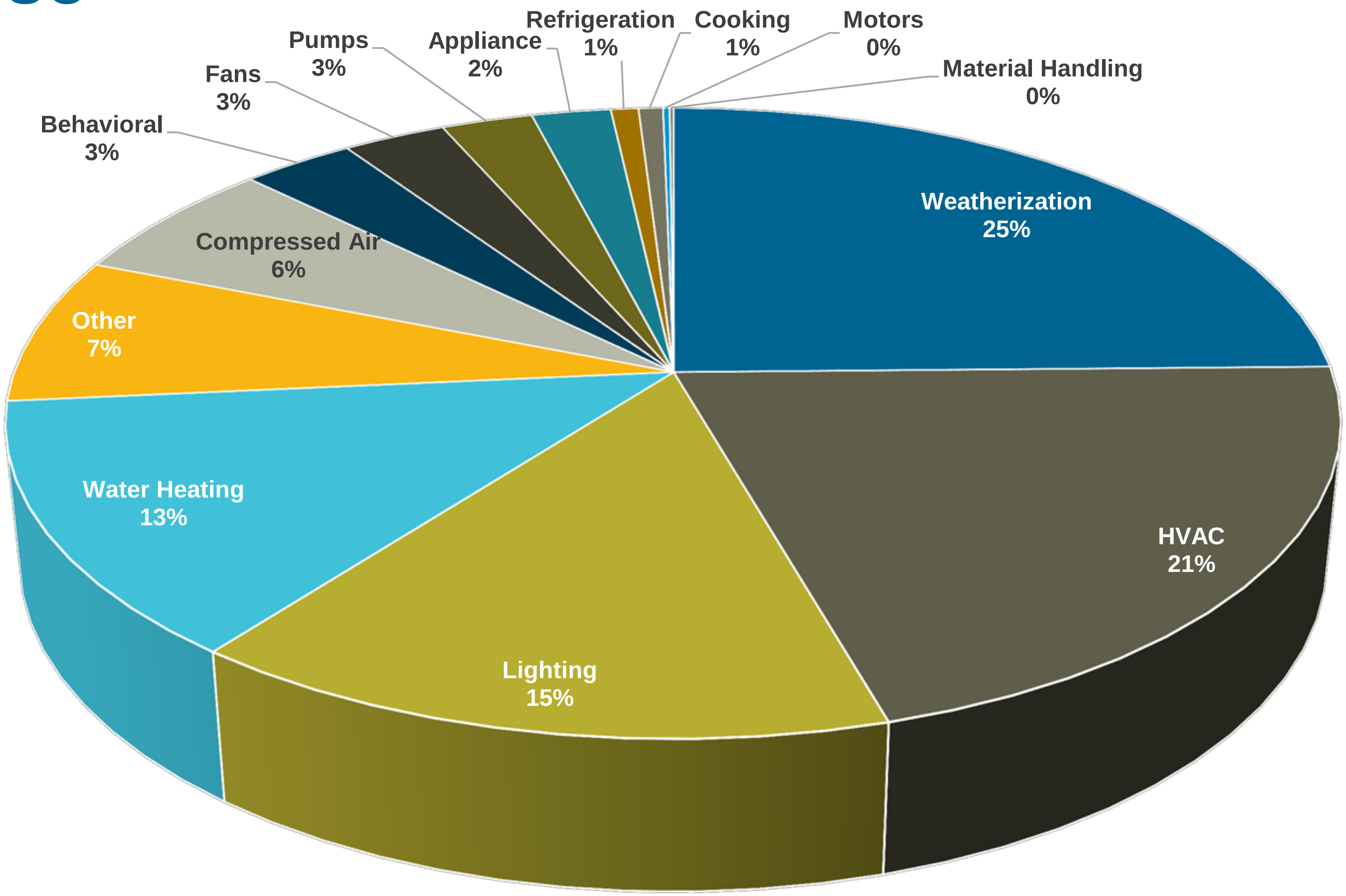
Cost-Effective Override – aMW Cost effective potential

Sector	Total with CE Override	No CE Override	Difference (total CE potential with override)
Residential	415	388	28
Commercial	189	184	5
Industrial	149	117	32
Total DSM:	**754**	**689**	**65**

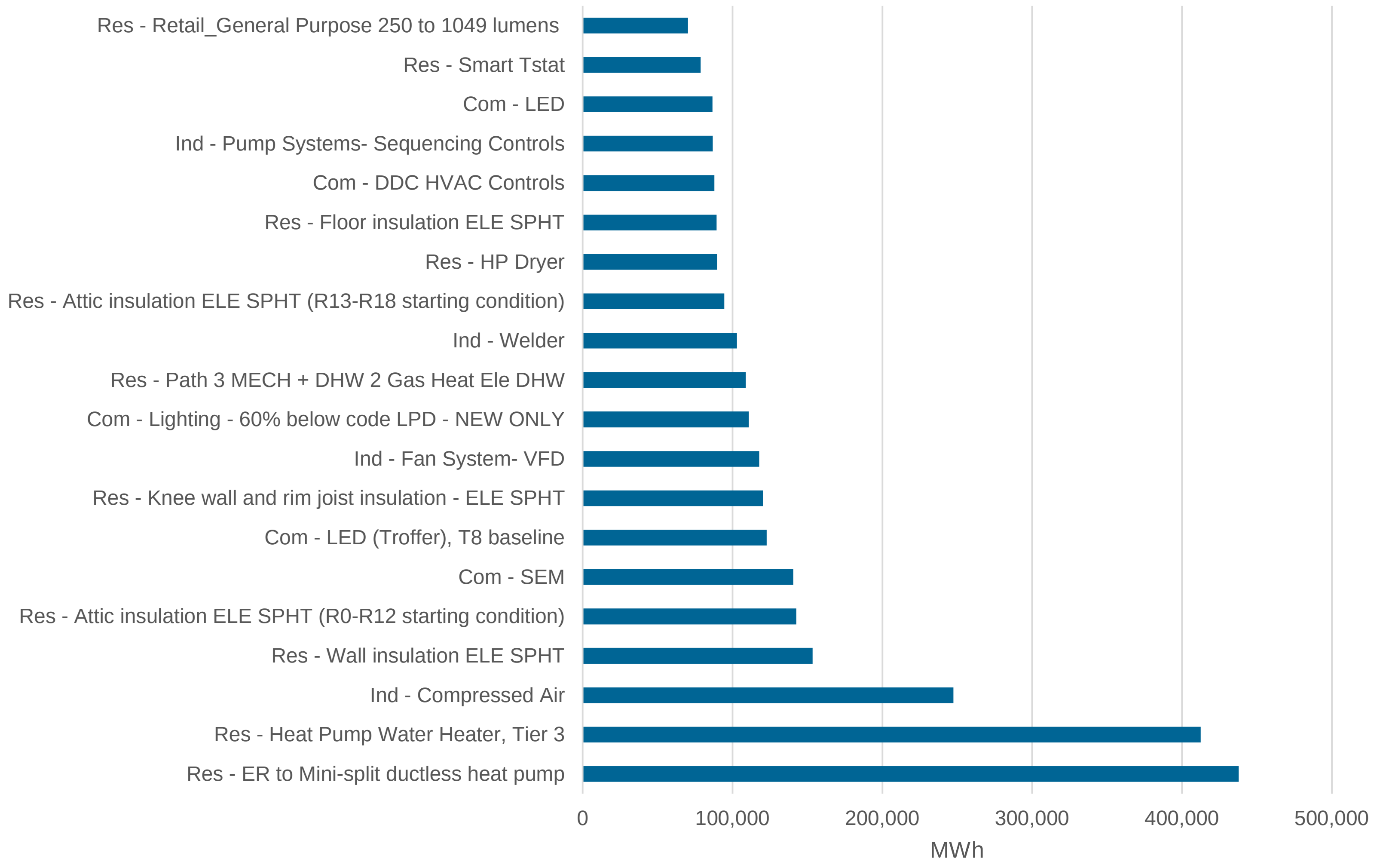
Cumulative Potential by Sector and Type



Cumulative Cost-effective Potential by End Use



Top-20 Measures – Cost-Effective Cumulative Potential



Think about forecast in three time periods…

- 1-2 years (short term)
  - Programs know best
- 3-5 years (mid term)
  - Programs and planning work together
- 6-20 years (long term)
  - Planning forecasts long-term acquisition rate

Energy Trust Savings Projection

- Energy Trust sets the first five years of energy efficiency acquisition to budget goals for the first two years (2018 and 2019) and programs/planning working together to forecast 2020-2022

- Years 6-20 (2023 – 2037) are set to mostly align with power council assumptions about EE resource acquisition.

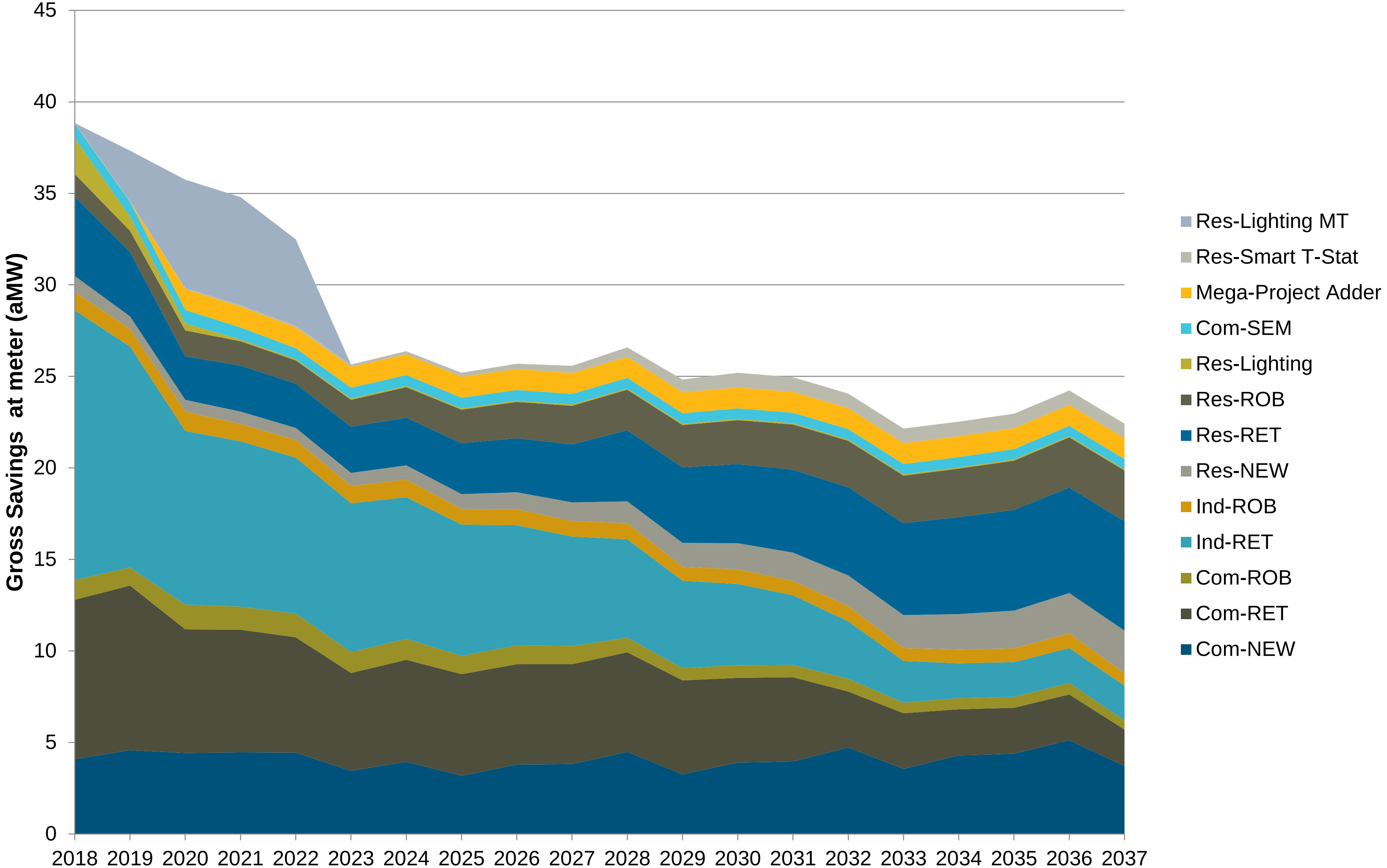
Types of Potential

Not technically feasible	Technical Potential			
Not technically feasible	Market barriers	Achievable Potential		
Not technically feasible	Market barriers	Not cost effective	Cost Effective Potential	
Not technically feasible	Market barriers	Not cost effective	Program design, market penetration	Program Savings Projection

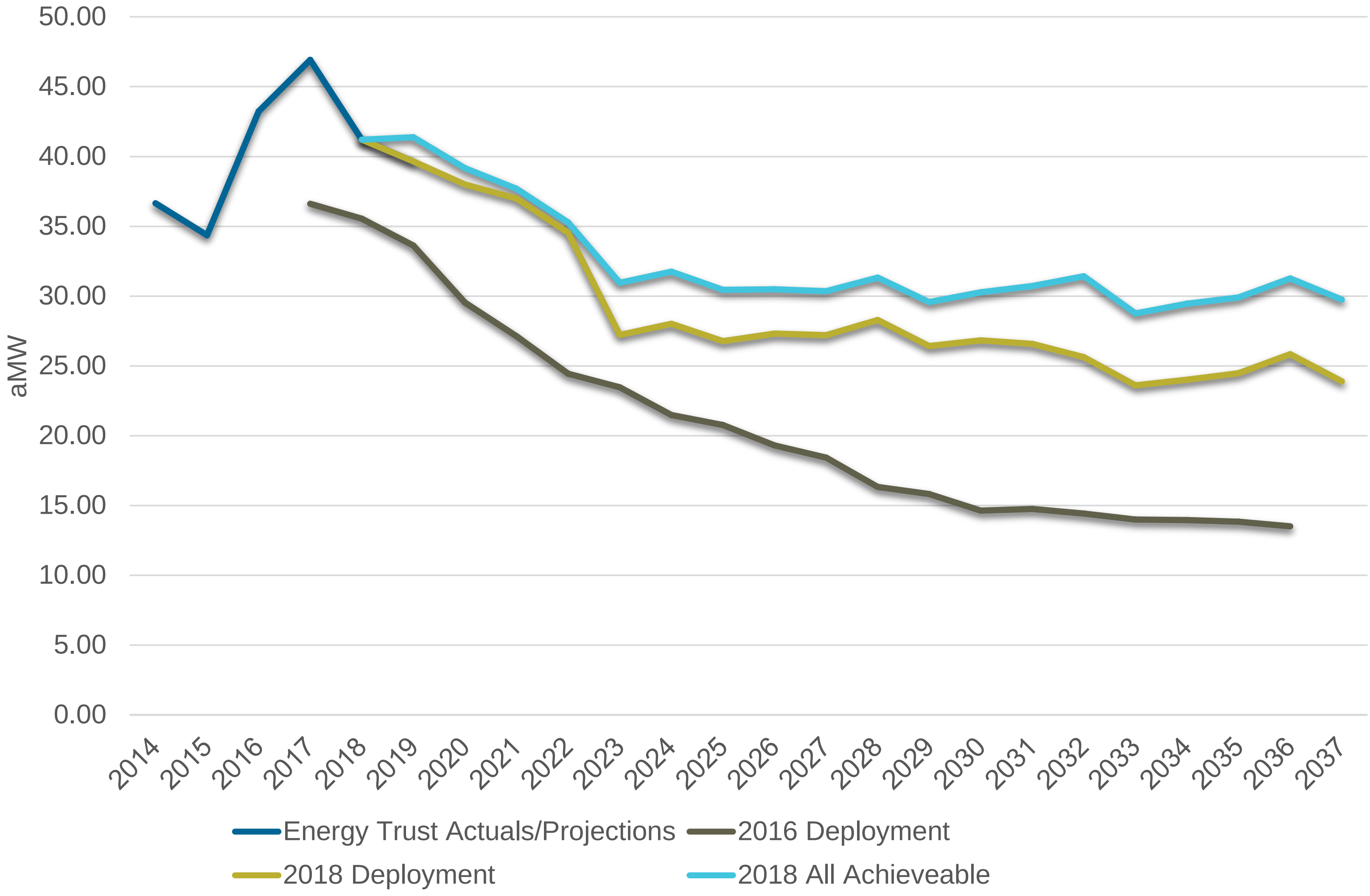
20-Year Cumulative Potential by Type - aMW

	Technical	Achievable	Cost-effective	Energy Trust Savings Projection
Residential	571	485	415	189
Commercial	261	222	189	226
Industrial	179	152	149	167
All DSM	**1,011**	**859**	**754**	**582**

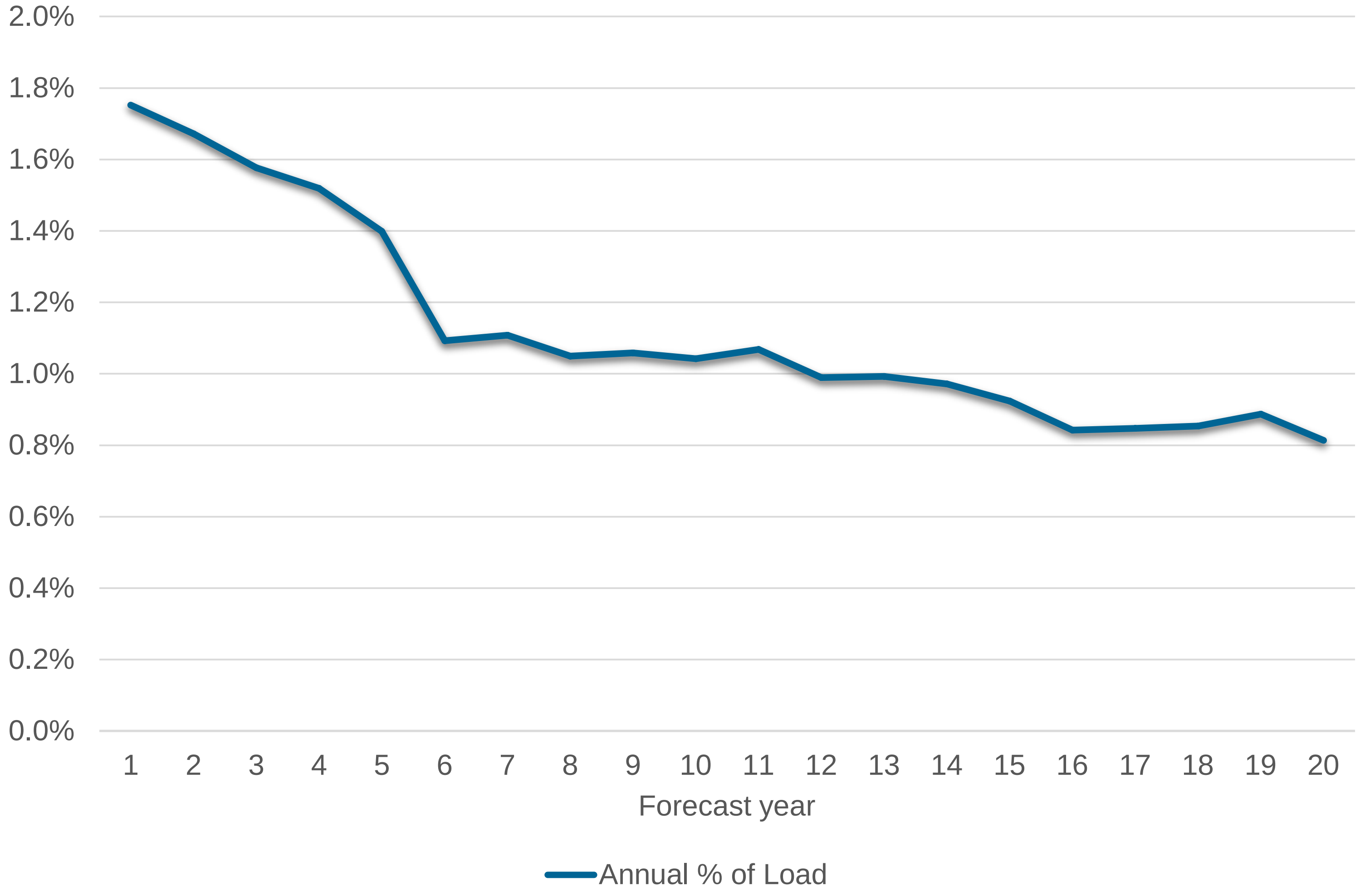
Cost-Effective PGE Deployment Results 2018-2037



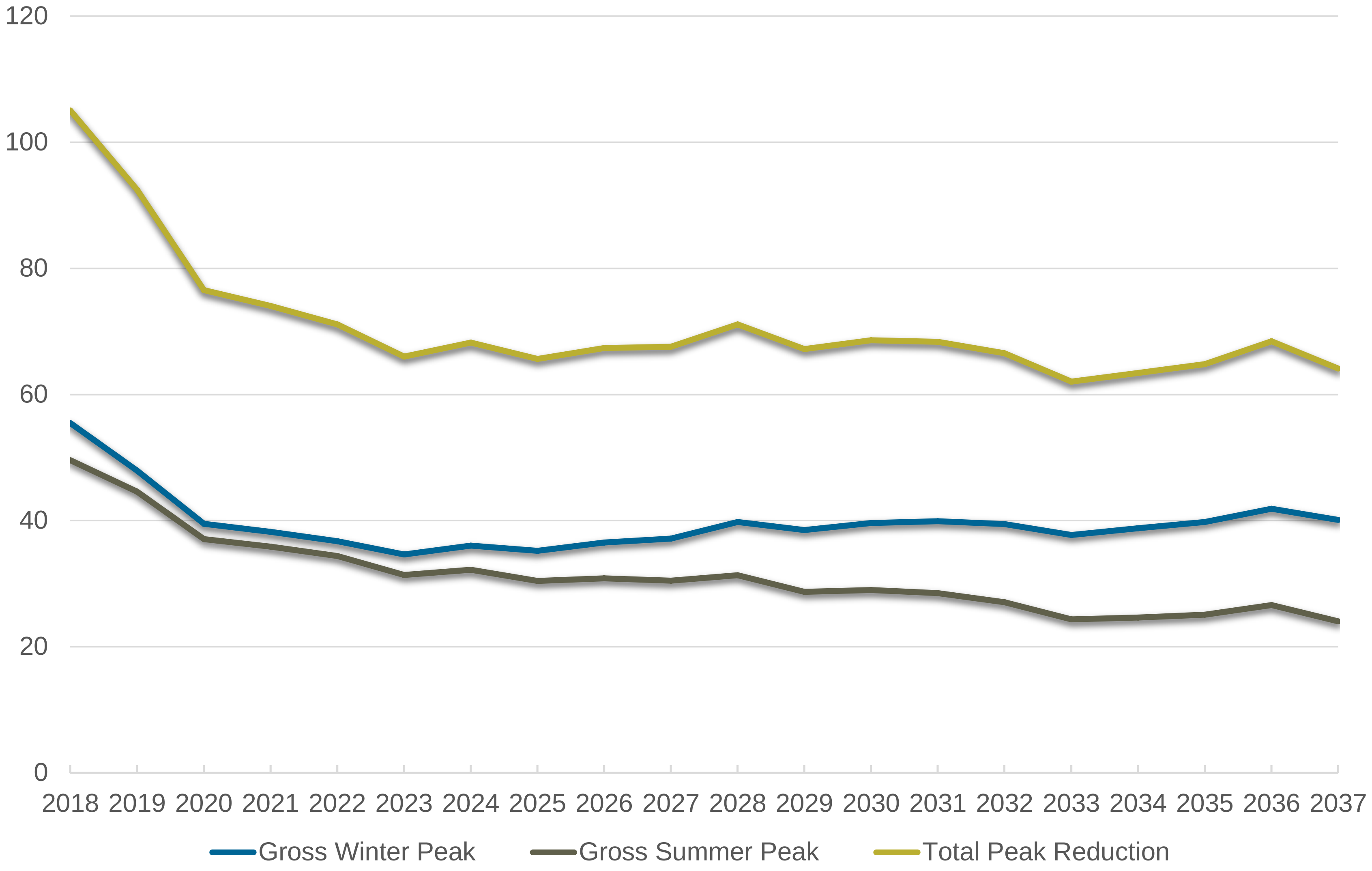
2016 vs. 2019 IRP Cost-Effective EE Savings Projections and Actuals



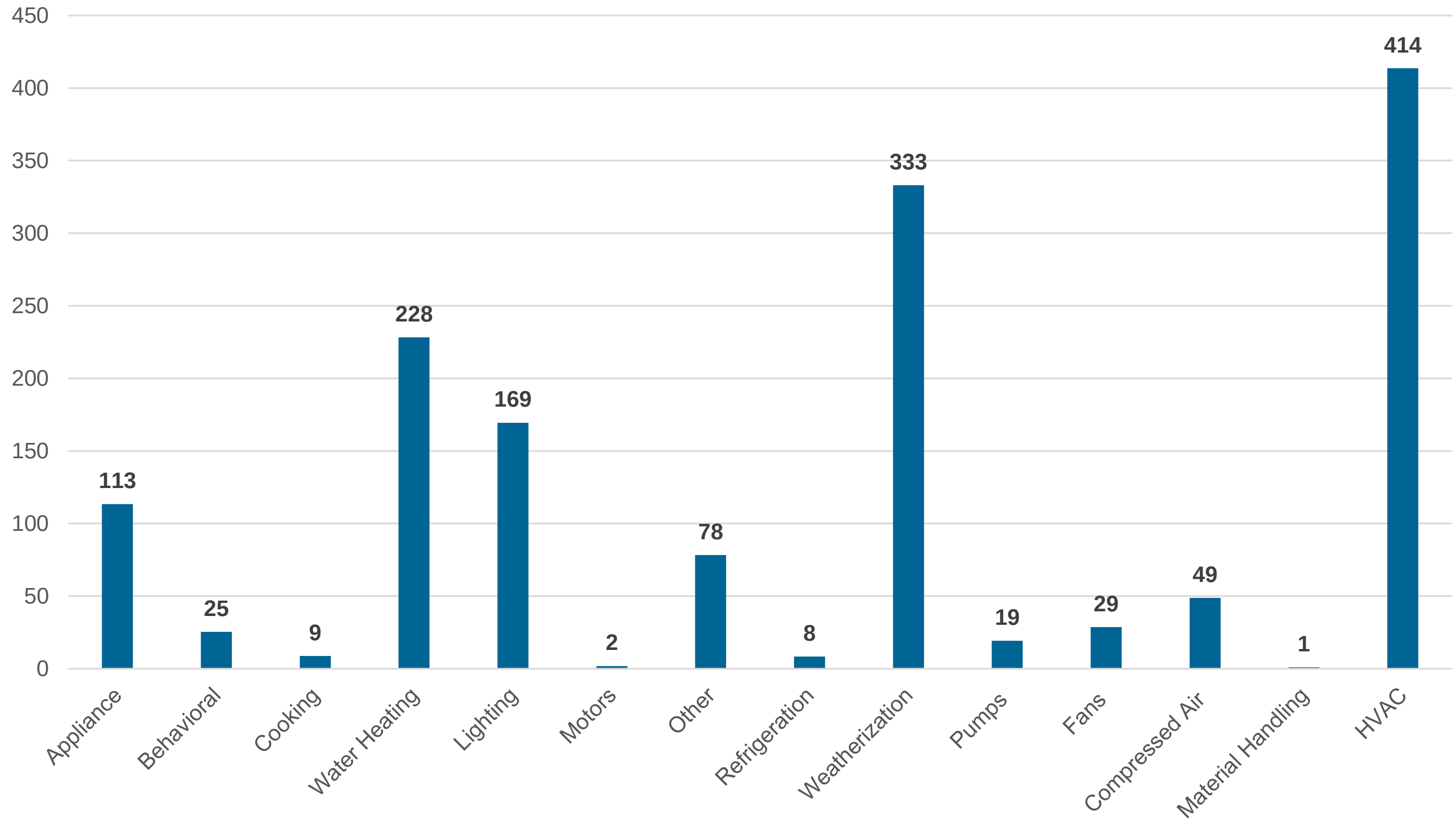
Annual Projected Savings as Percent of PGE's Annual Load Forecasts



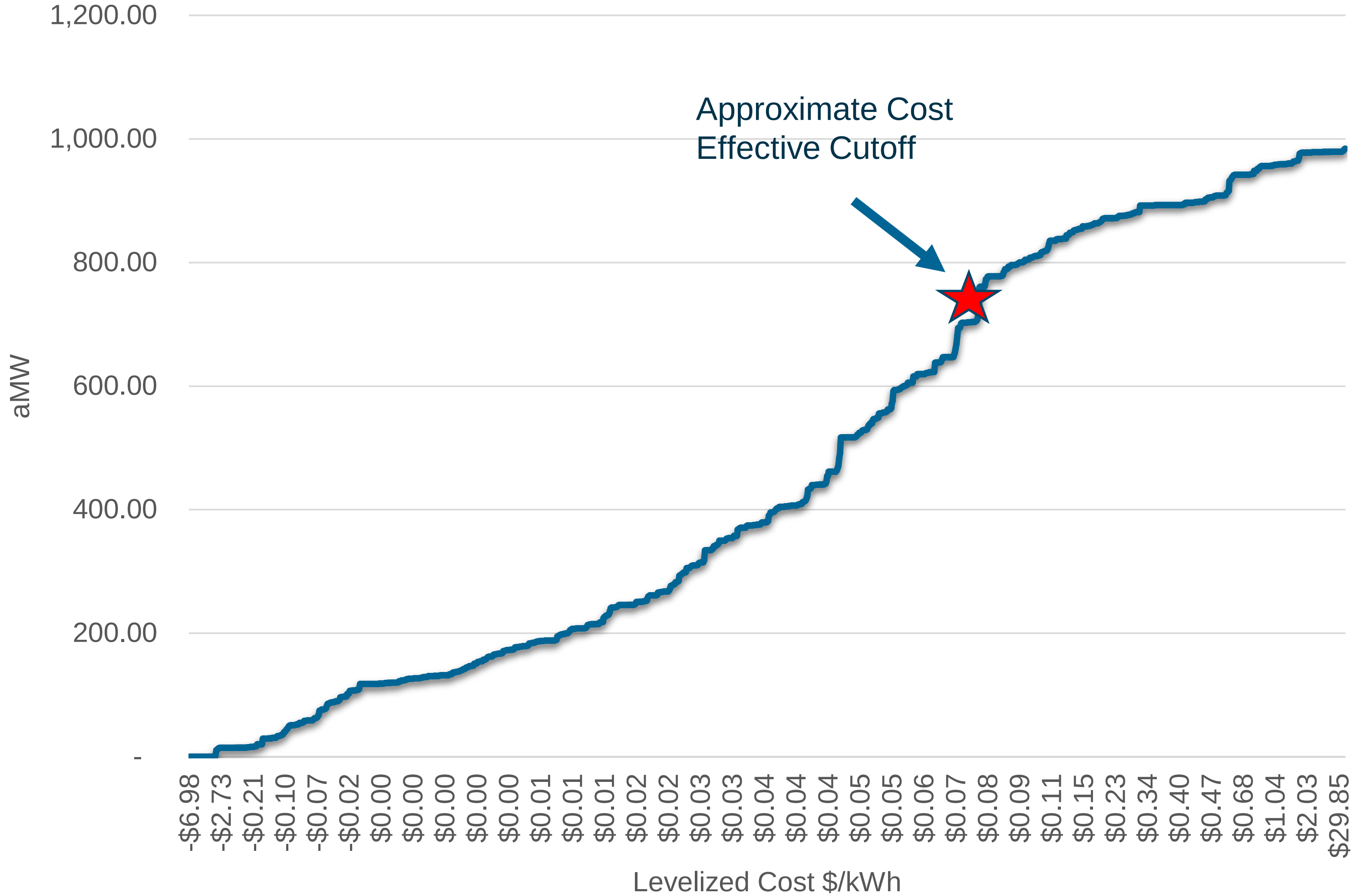
Total Deployed Peak Savings – MW per year

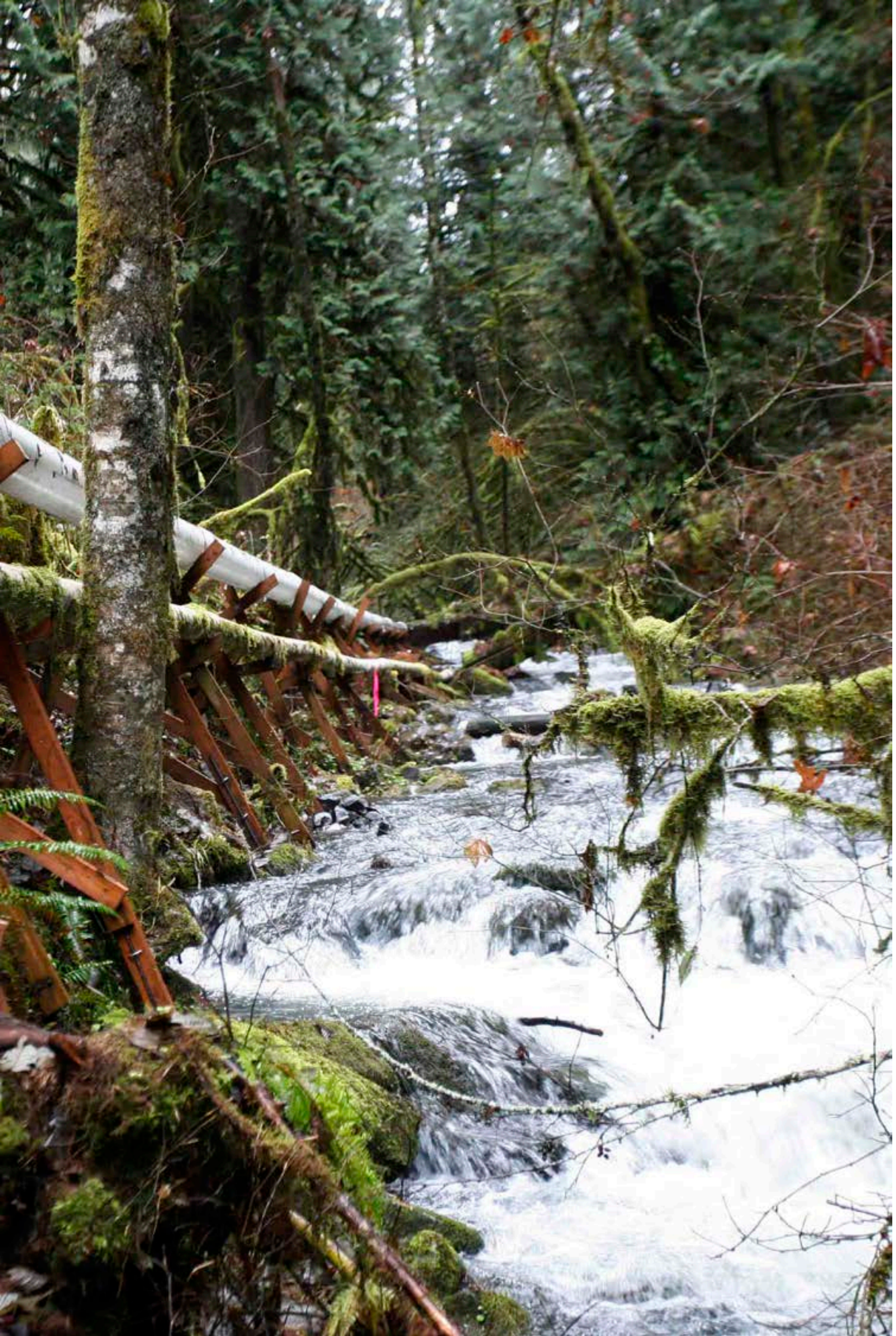


Cumulative Cost-effective Peak Savings Potential by End-use



2018 Supply Curve – 20 Year Technical Potential by Levelized Cost of Energy





Thank you

Peter Schaffer, Planning Project Manager

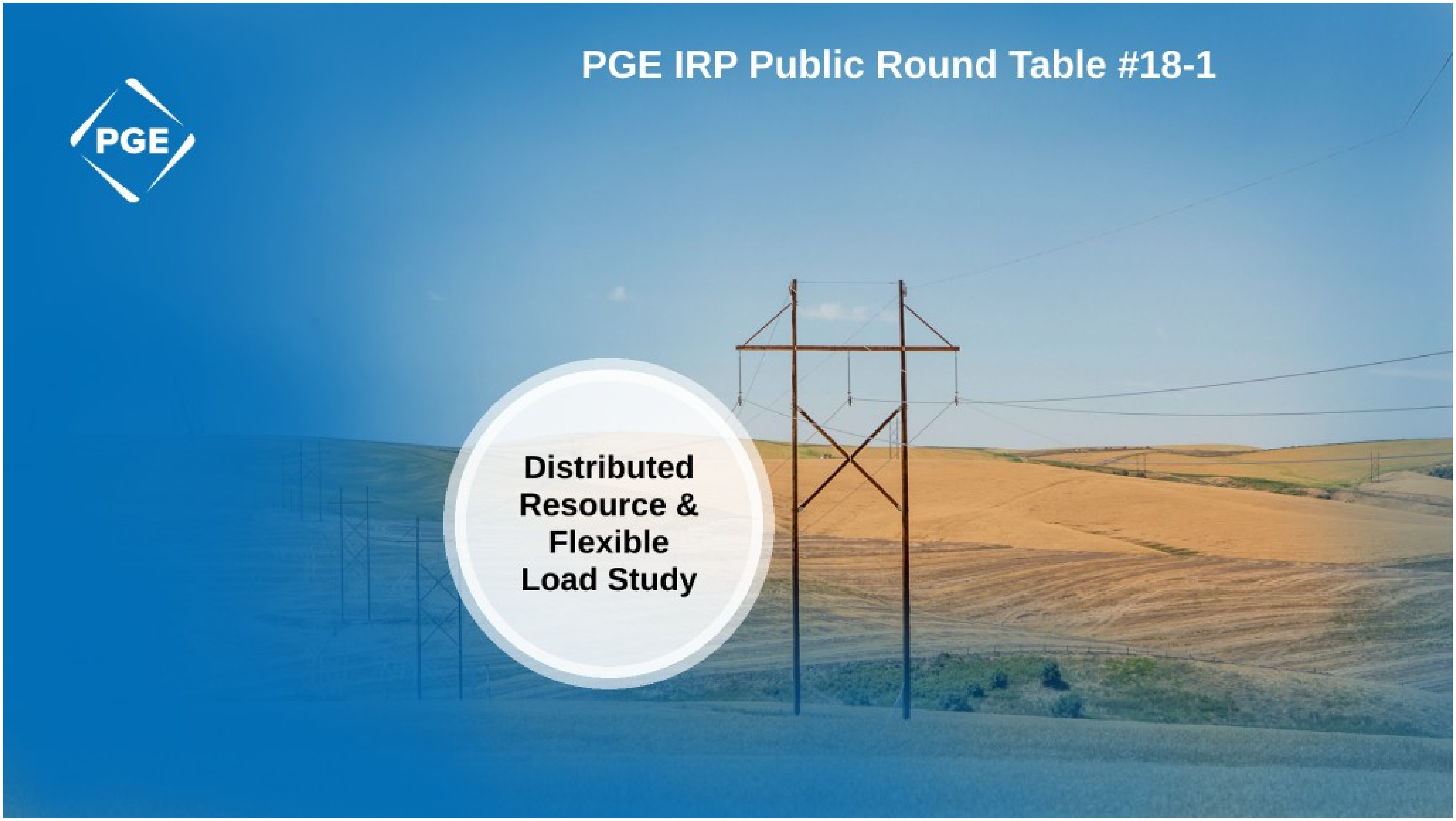
Peter.Schaffer@energytrust.org

503-546-3637

Energy Trust of Oregon

Distributed Resource Modeling

Shauna Jensen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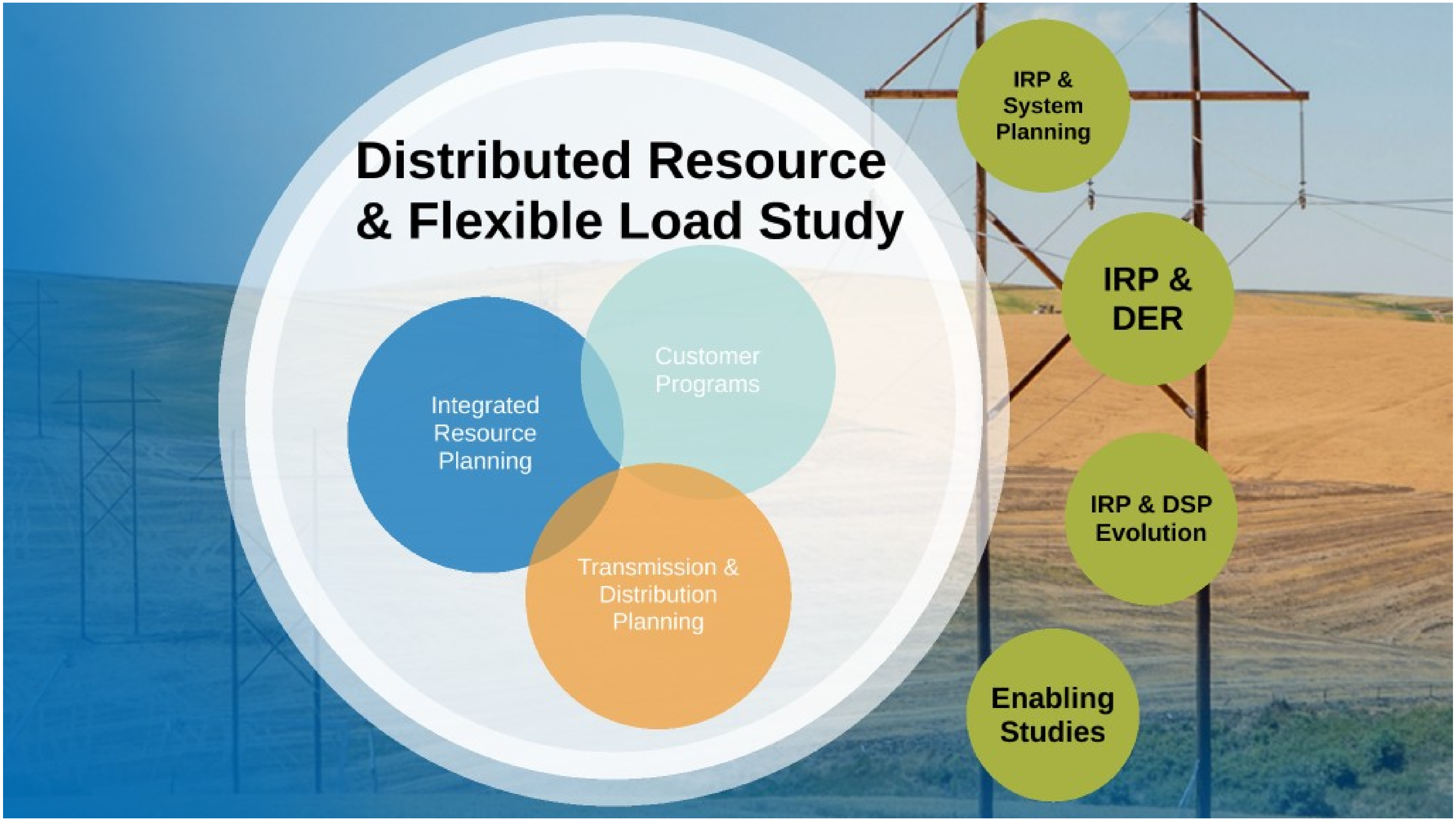
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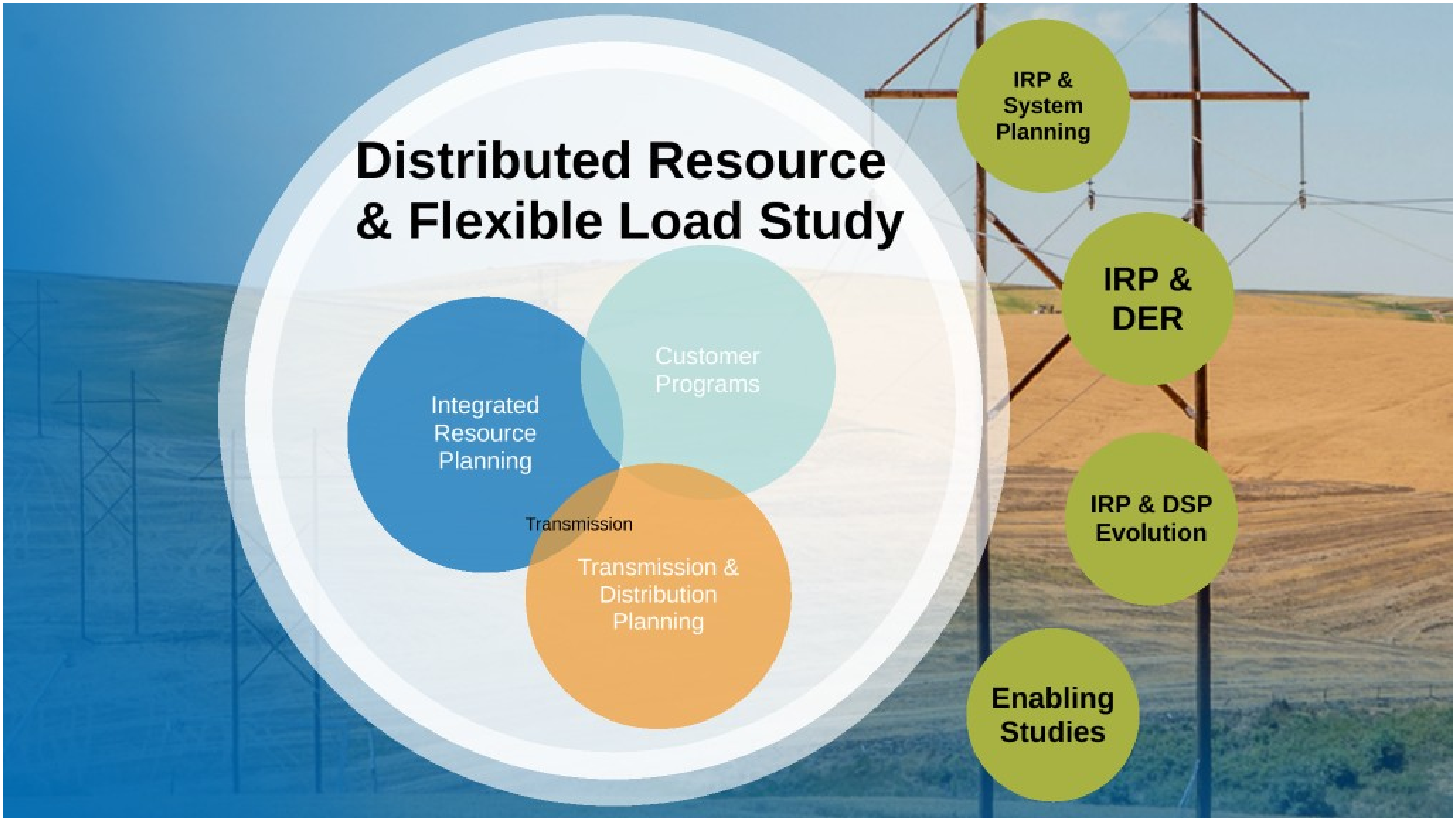
Customer Programs
Transmission & Distribution Planning
IRP & System Planning
IRP & DER
IRP & DSP Evolution
Enabling Studies



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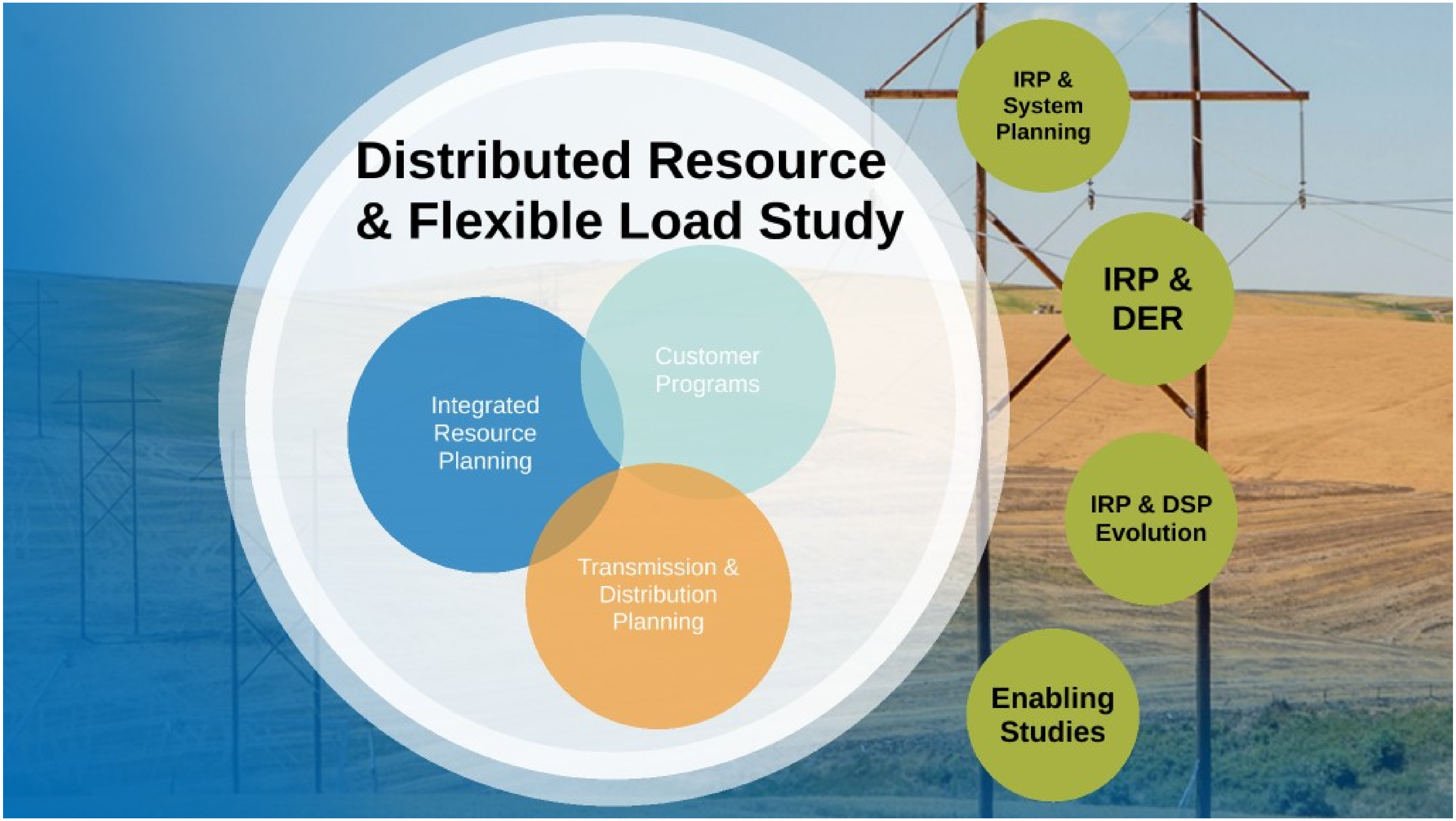
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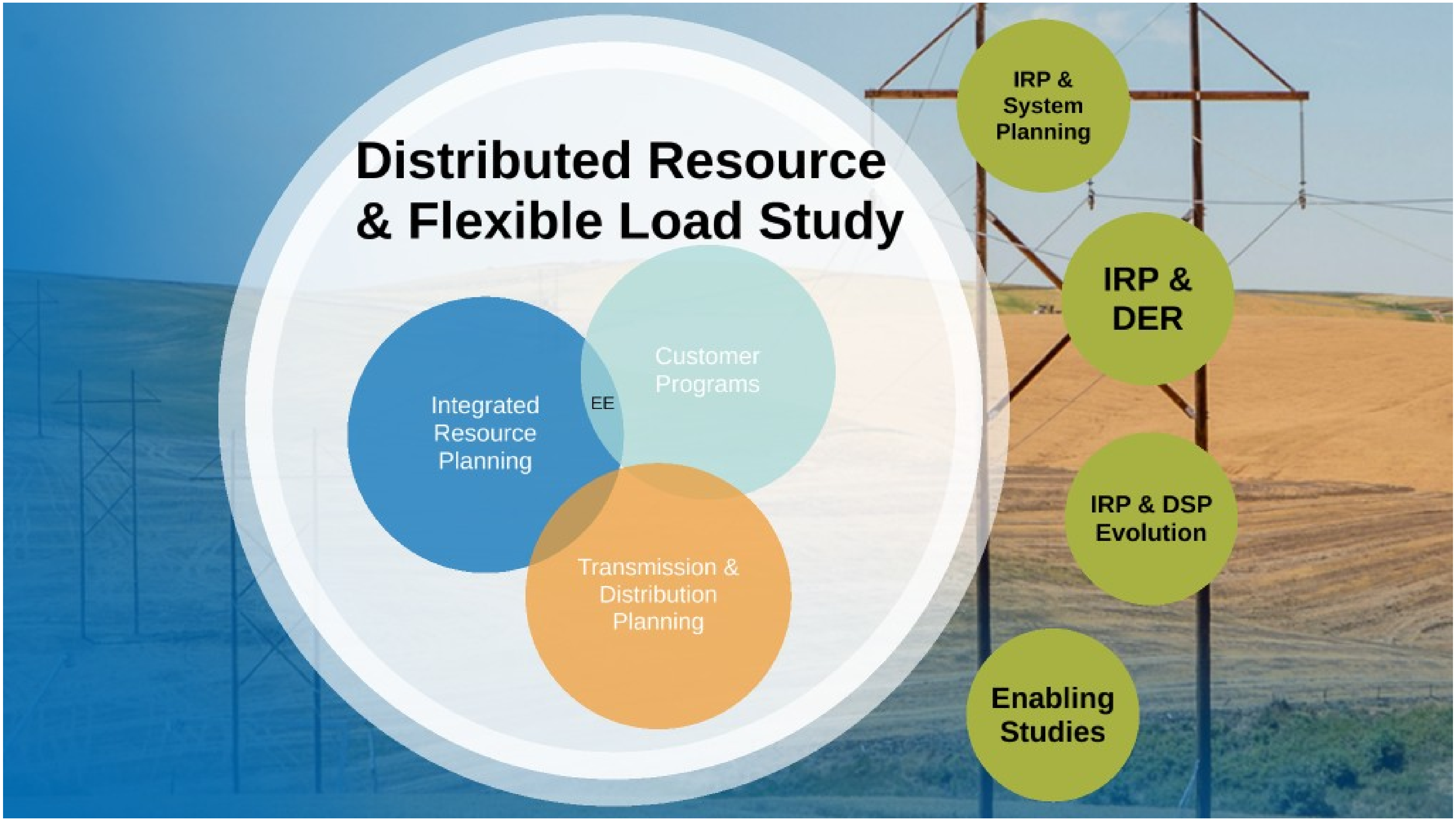
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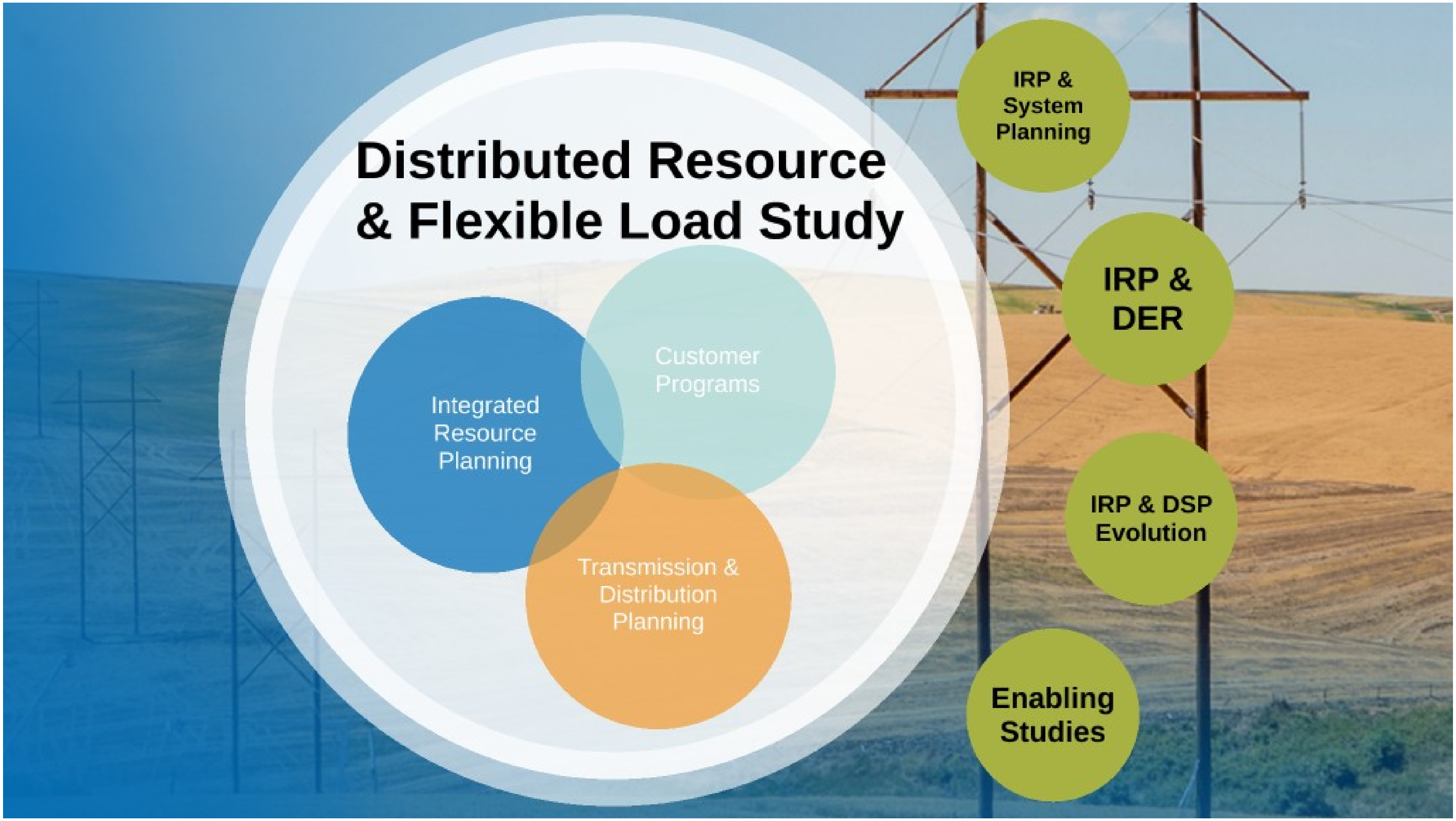
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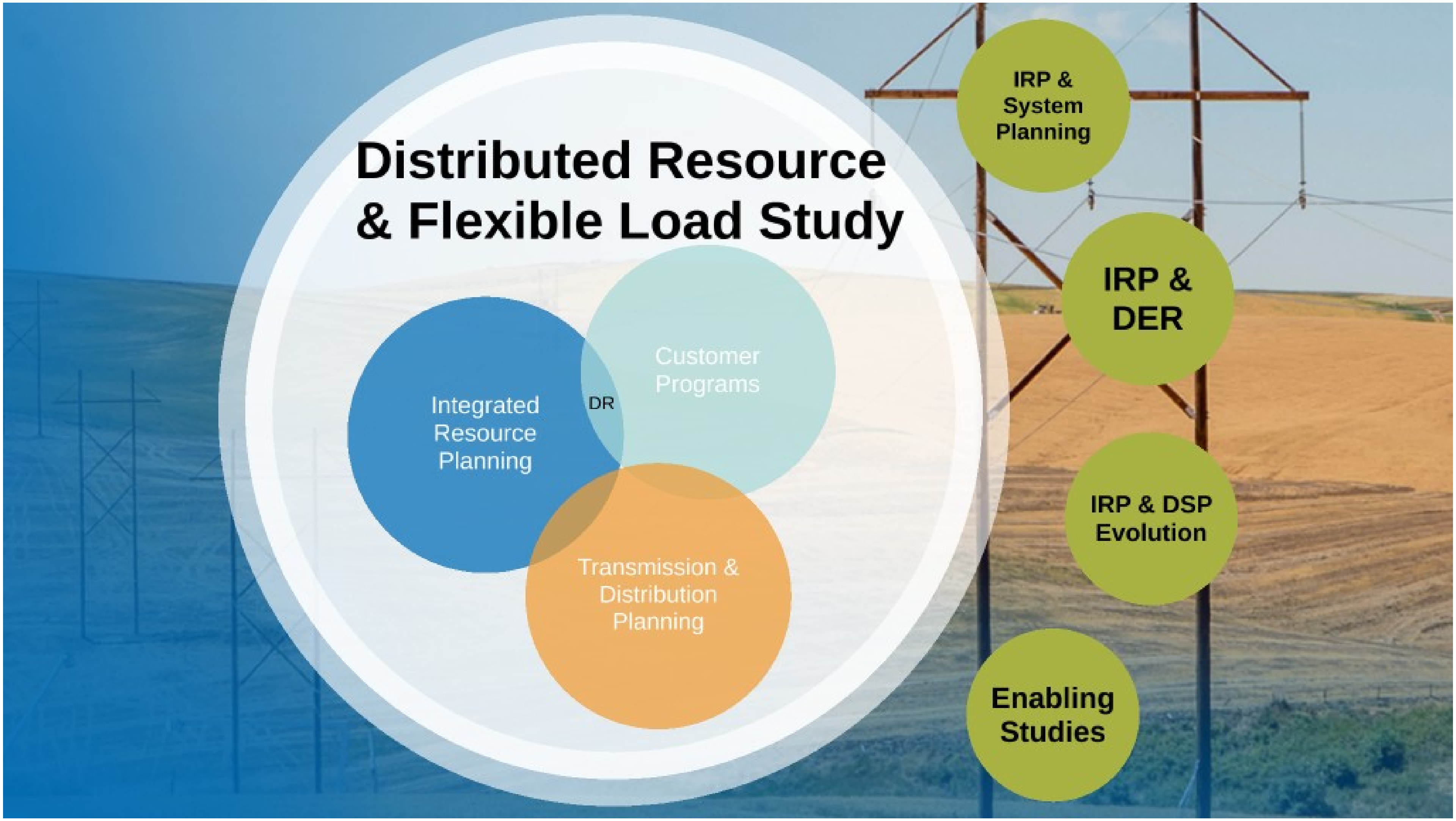
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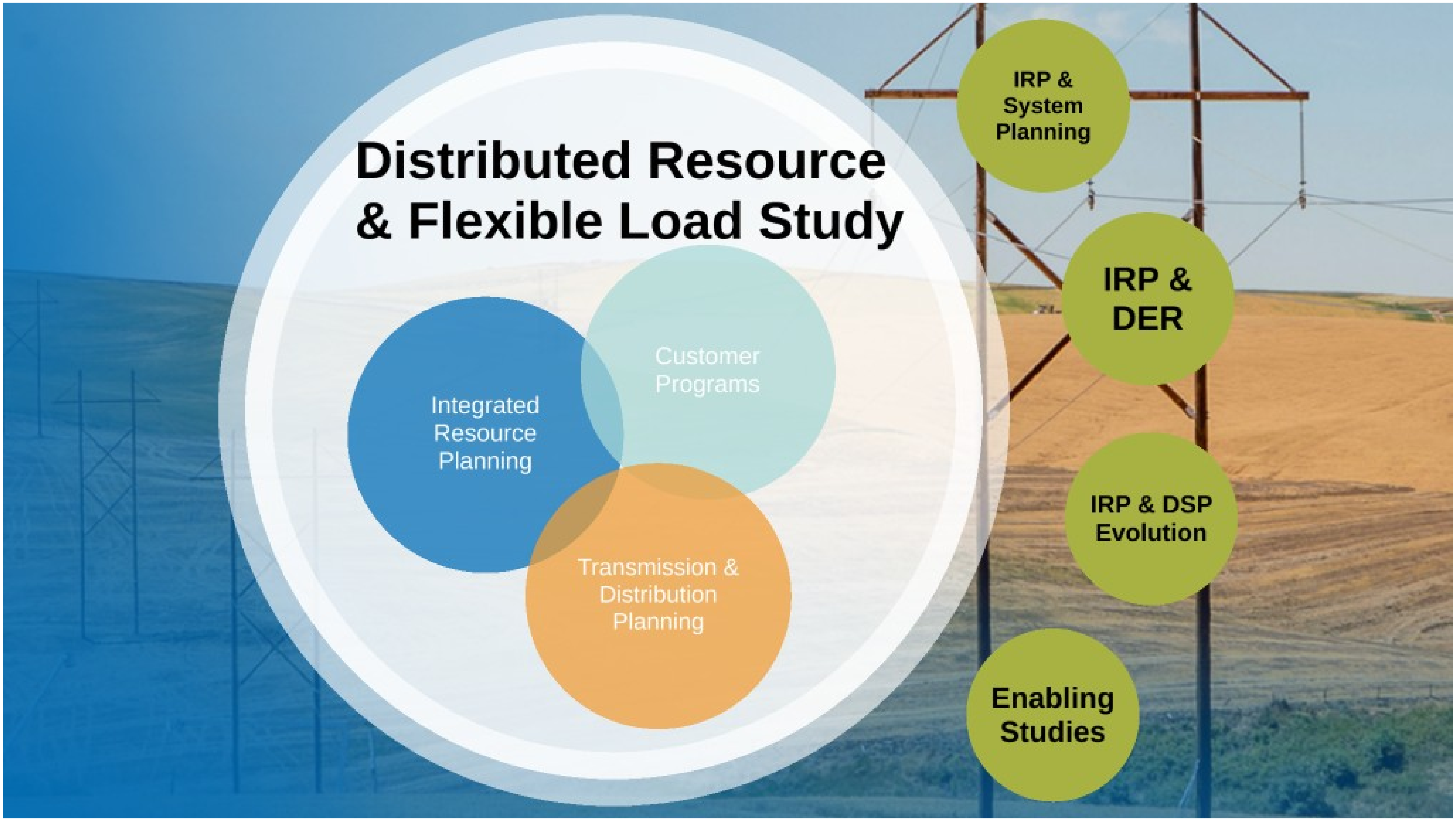
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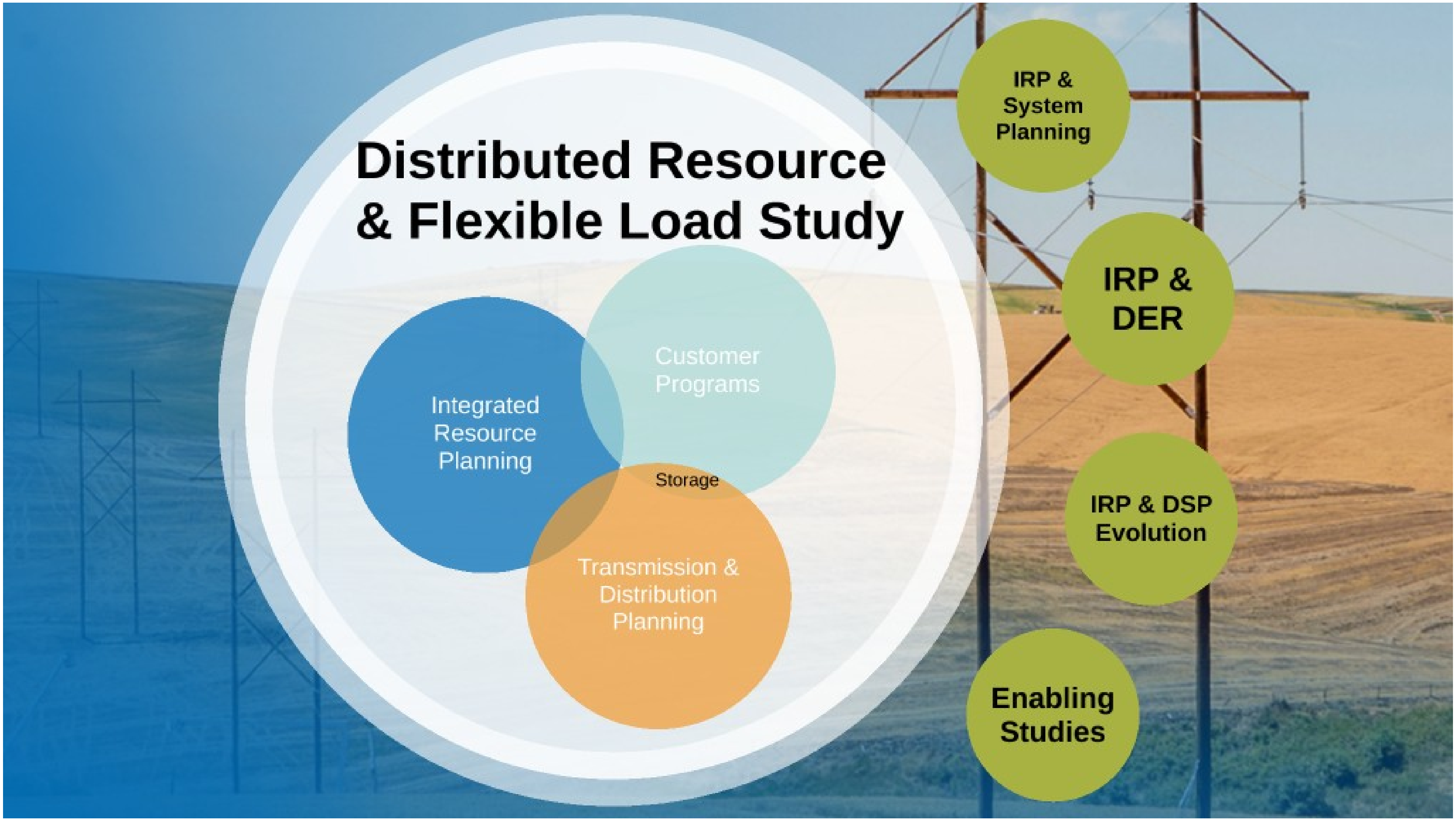
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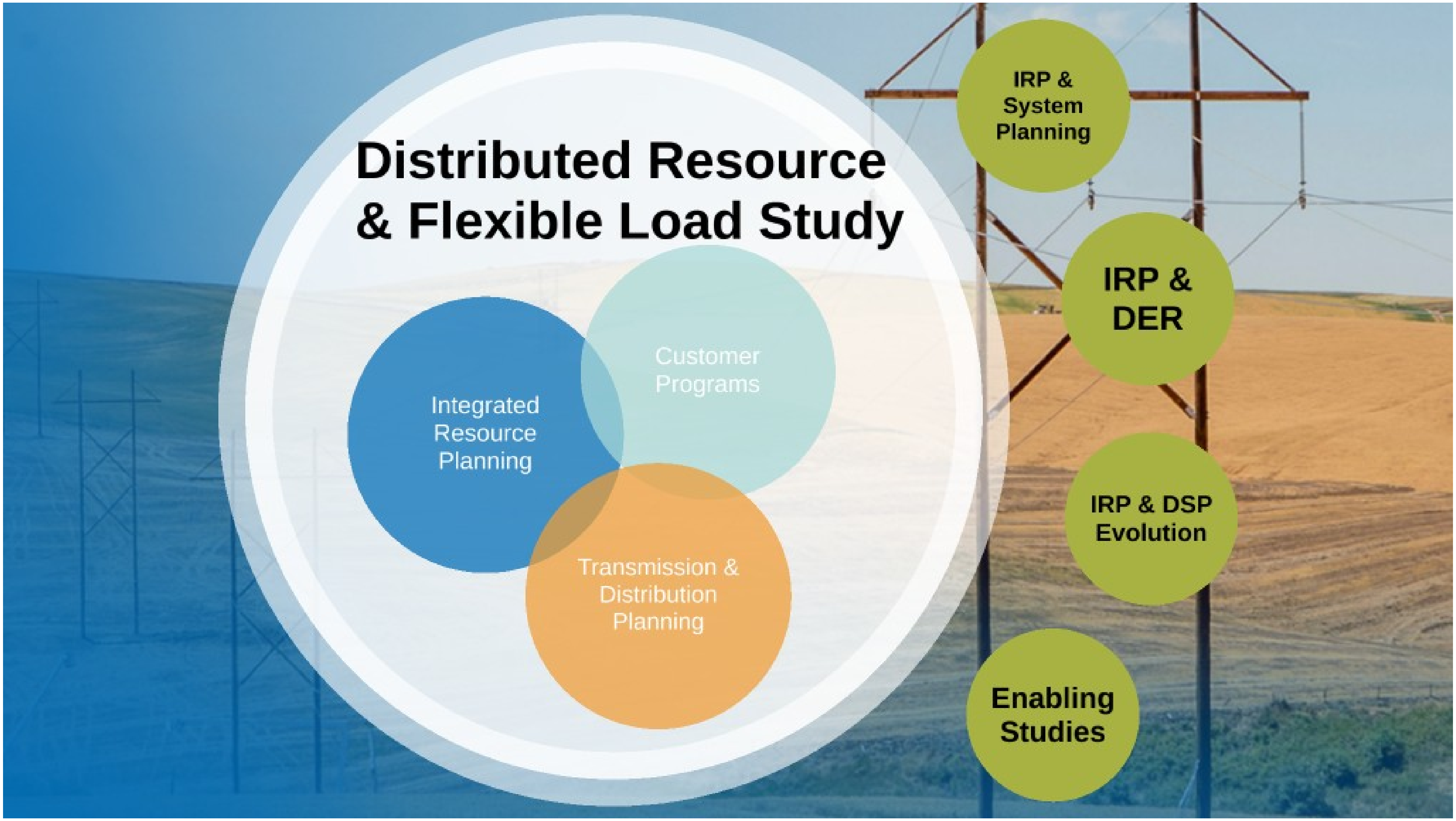
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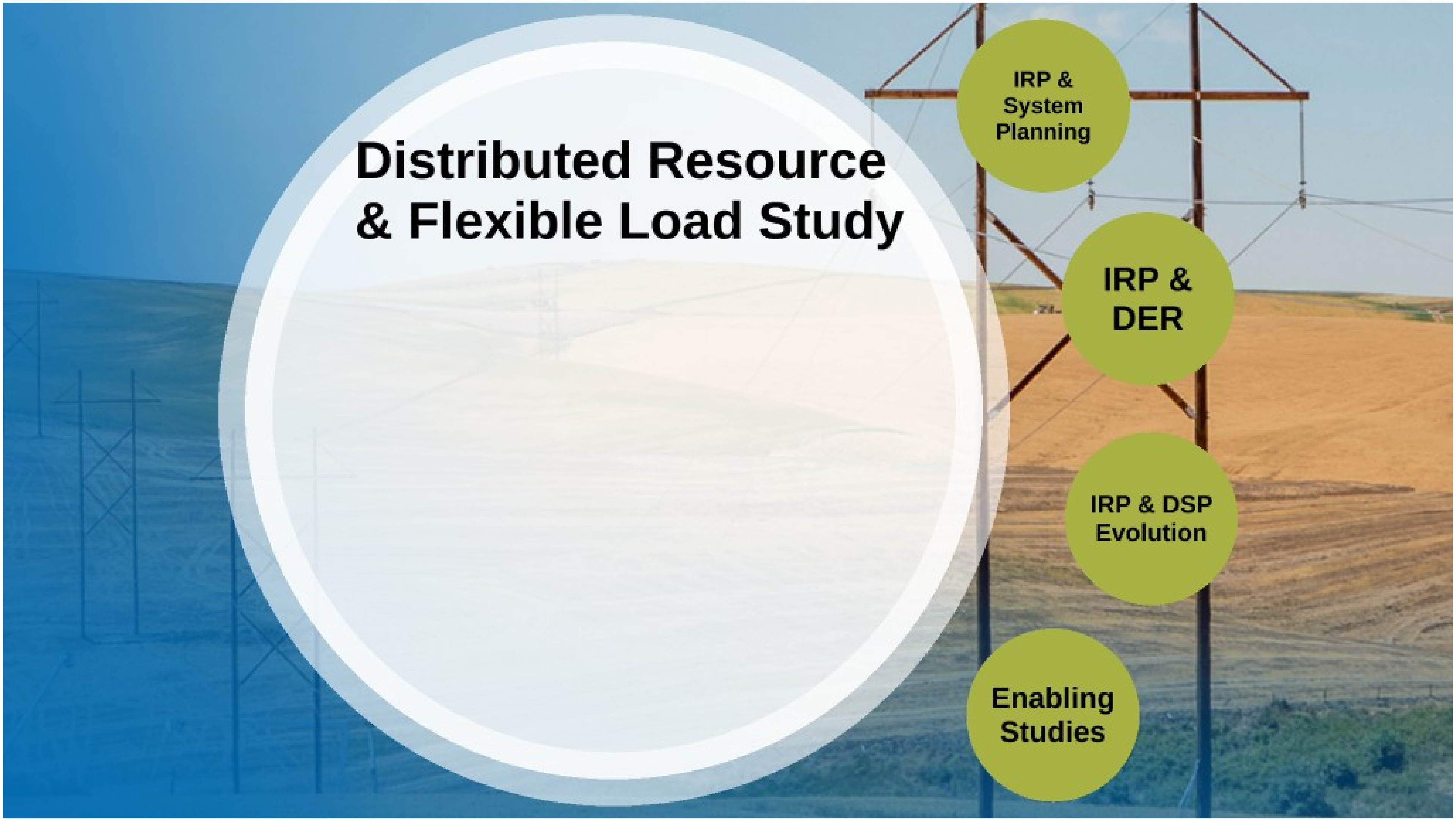
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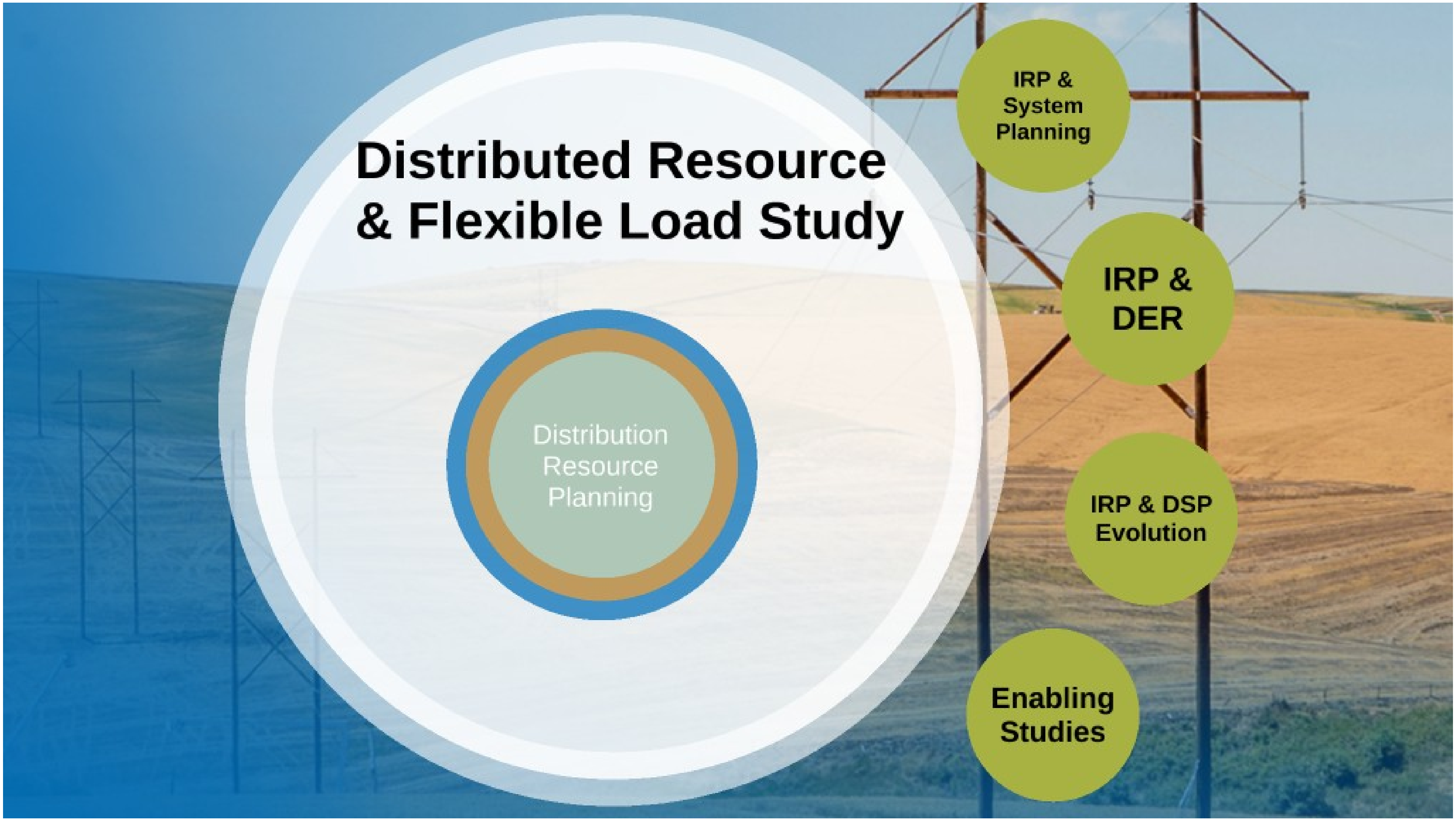
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DER
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Evolution
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IRP & System Planning

Existing:

- IRP accounts for:
  - Transmission projects.
  - Distribution-sited programs.
- IRP does not account for:
  - Distribution system infrastructure investments.
  - System hardening, modernization, and smart grid.
  - Required upgrades for distributed generation & flexible loads.

IRP & System Planning

IRP & System Planning

Evolving:

Iterative cross-departmental feedback process.

- Distribution System Planning Department.
- Customer Programs Department.
- Integrated Resource Planning Department.

IRP & DER

Existing:

- Forecasts of distribution resource development create dispatch load modifiers.
- Separate forecasts for all distribution resource programs compiled in IRP dispatch model.
  - Does not fully account interactive effects.
  - Uses forecasts from varied sources.

IRP & DER

IRP & DER

Evolving:

- Two ends of DER design.
  - Distribution Planning DER optionality.
  - DER program design, paired with T&D locational value assessment.
- DER portfolio compilation shared by Customer Programs and T&D, incorporated into IRP resource stack.

IRP & DSP Evolution

Customer Programs:

- Identifies services specific DERs can provide.
- Designs applicable pricing structures.
- Designs programs to maximize value of resources.

IRP & DSP Evolution

Customer Programs:

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Distribution Planning:

- Locates areas on the system that provide best use of specific attributes.
- Screens projects for reliability, infrastructure upgrade requirements, changes in outage risk, and comparison to alternative projects.

IRP & DSP Evolution

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- Locates areas on the system that provide best use of specific attributes.
- Screens projects for reliability, infrastructure upgrade requirements, changes in outage risk, and comparison to alternative projects.

Integrated Resource Planning:

- Integrates development forecasts, attributes, and dispatch characteristics of all DERs developed by Customer Programs and T&D into dispatch models as resource options.
- IRP reports value of resources based on dispatch results.

IRP & DSP Evolution

Customer Programs:

- Identifies services specific DERs can provide.
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Integrated Resource Planning:

- Integrates development forecasts, attributes, and dispatch characteristics of all DERs developed by Customer Programs and T&D into dispatch models as resource options.
- IRP reports value of resources based on dispatch results.

Customer Programs and T&D refine program development targets, based on specification of IRP.

Enabling Studies

Distributed Resource & Flexible Load Study:

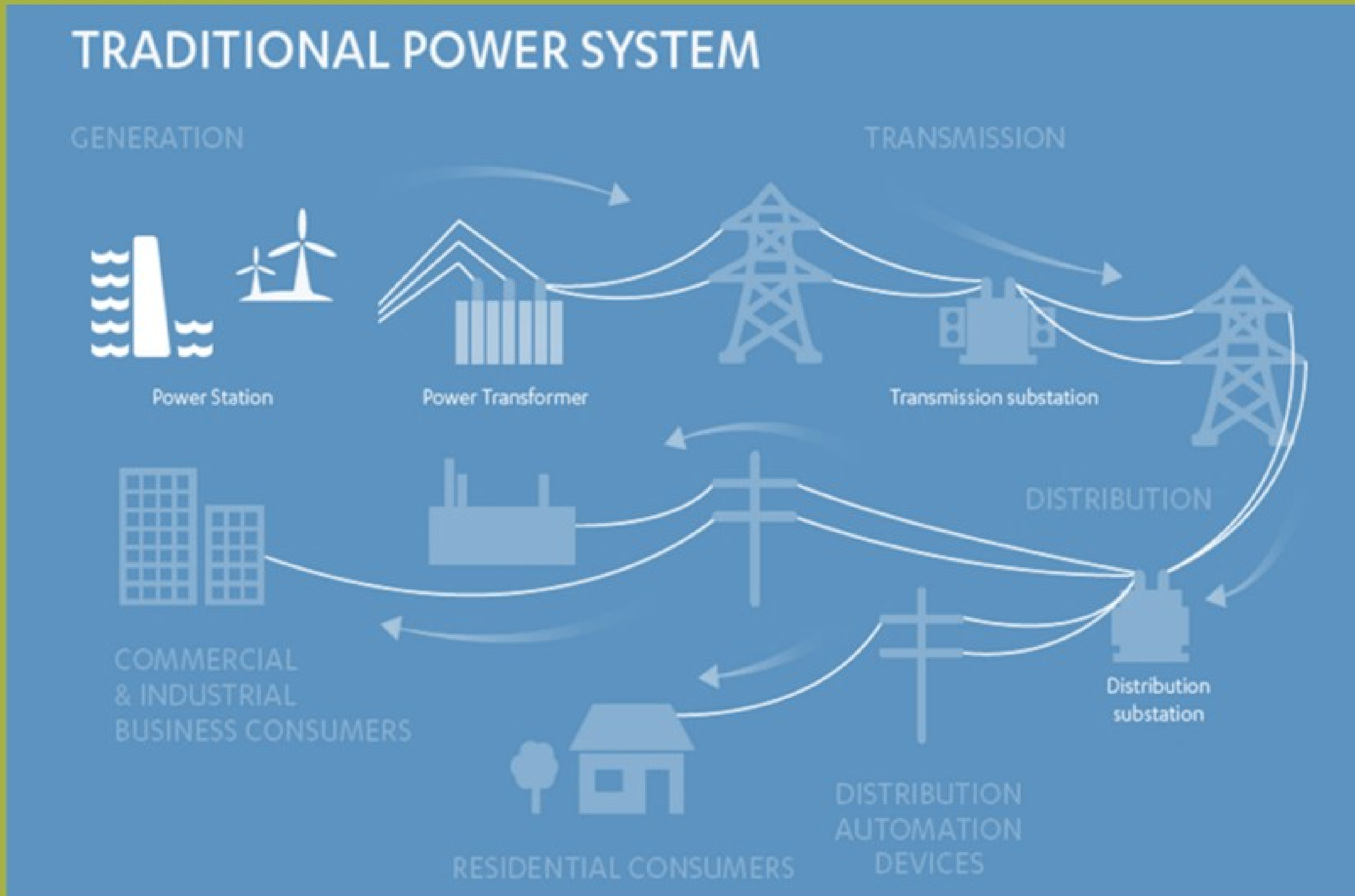
- Scenario-based forecasts for several DERs and flexible loads in conjunction.
  - Interactive effects.
  - Coordinated development.
  - Phased granularity.
  - Top-down and bottom-up.
- Inter-Departmental.
  - Integrated Departments: Customer Programs, T&D, IRP, Load Forecasting.
  - Iterative shared analysis.
  - Departments feed each other.
  - Added value from use case perspectives.

Enabling Studies

Distributed Resource & Flexible Load Study Intended Outcomes:

- Interrelation accounting.
  - Resources.
    - Demand-side.
    - Supply-side.
  - End-Uses.
- Load shapes.
- Near-term (0-5yrs) to long-term (6-30 years).
  - Near: bottom-up, granular, hourly data.
  - Long: macro-economic, annual data.
- Annual forecasts.
  - Through2050.
  - Every year.
  - Low, med, high adoption scenarios.
- Reporting level.
  - System.
  - Feeder.
  - Substation.
  - By technology; by scenario.
- Portfolio options based on resource values.

Modified from: UK National Infrastructure Commission: Smart Power



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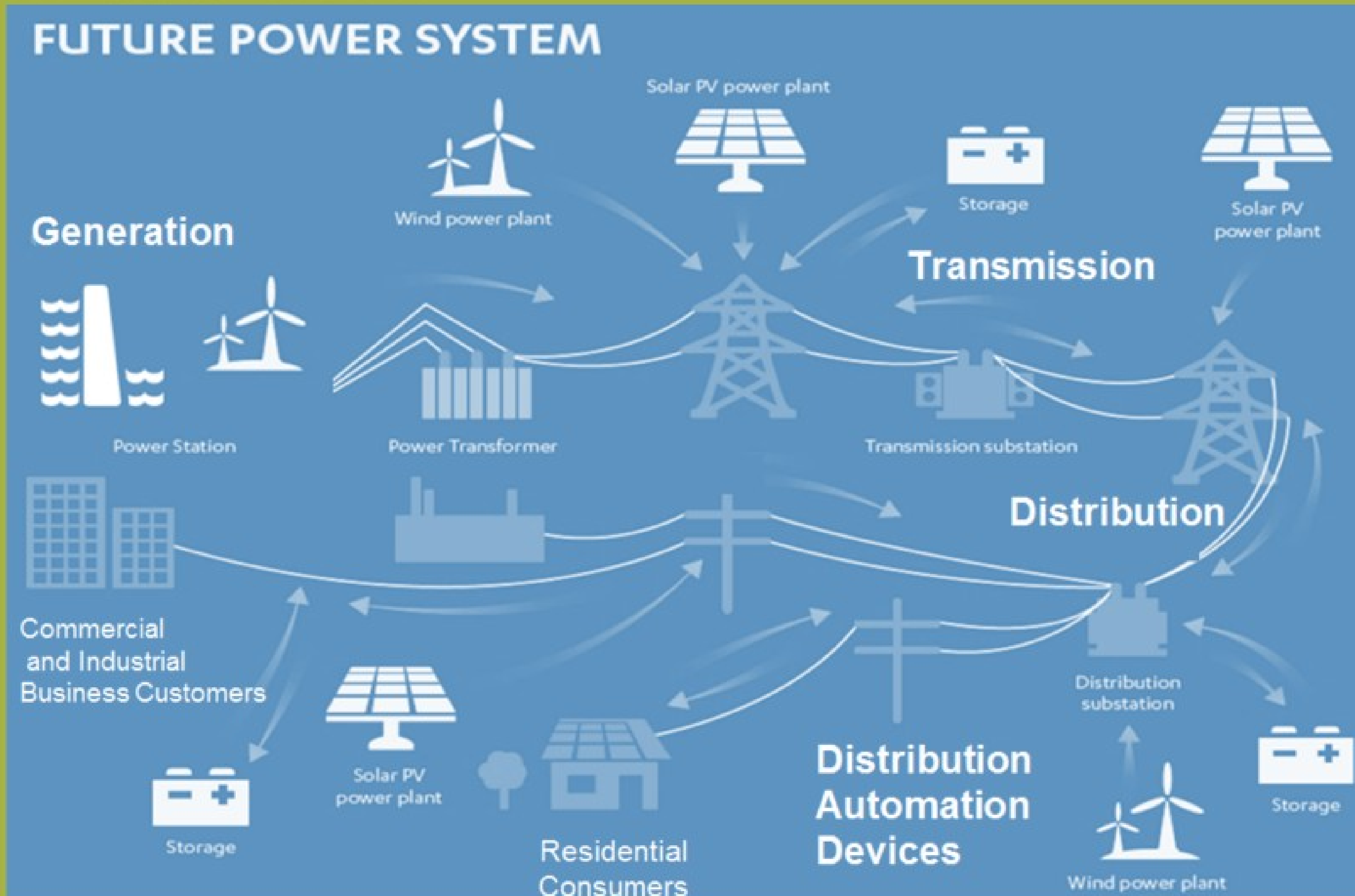
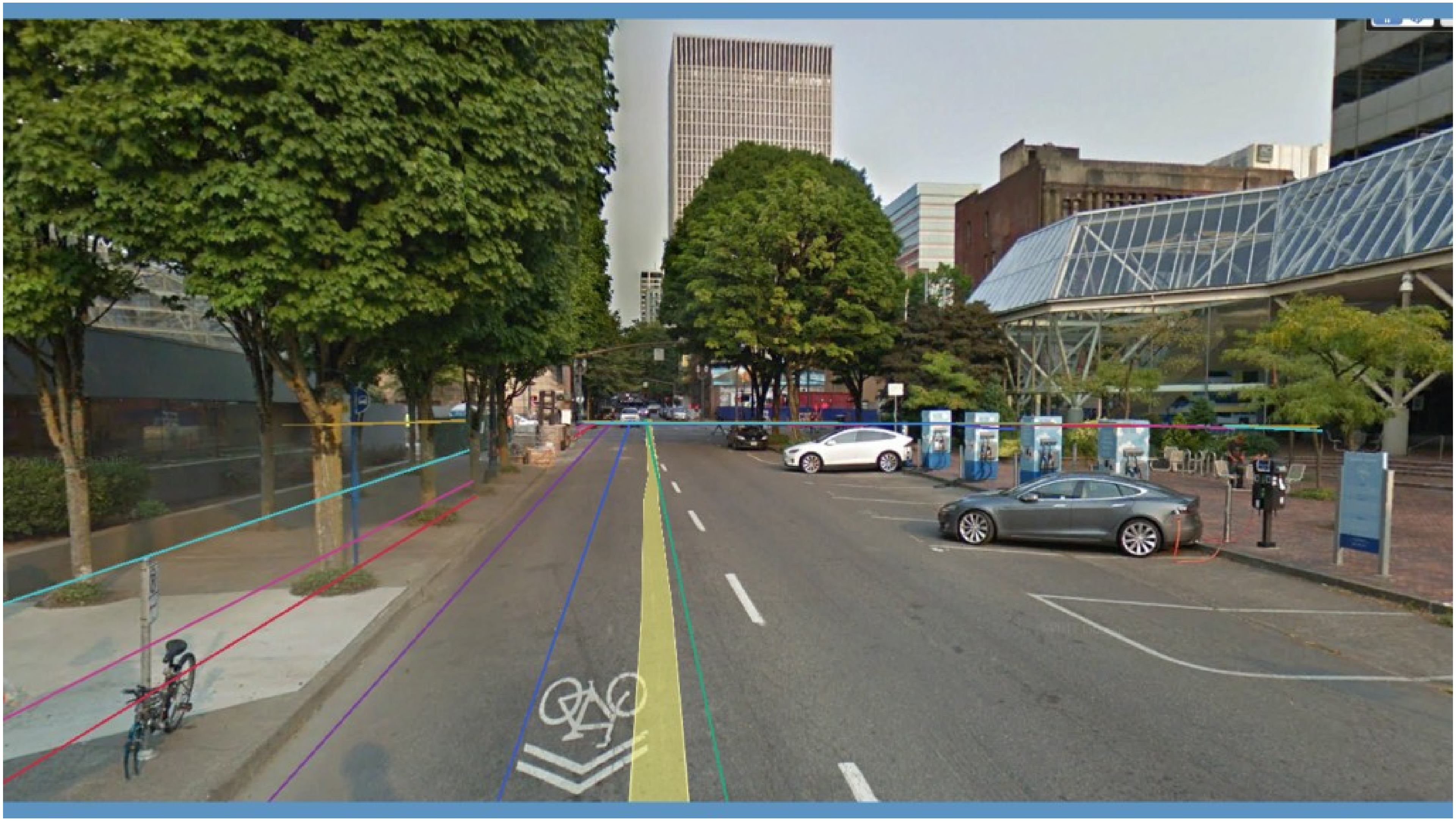




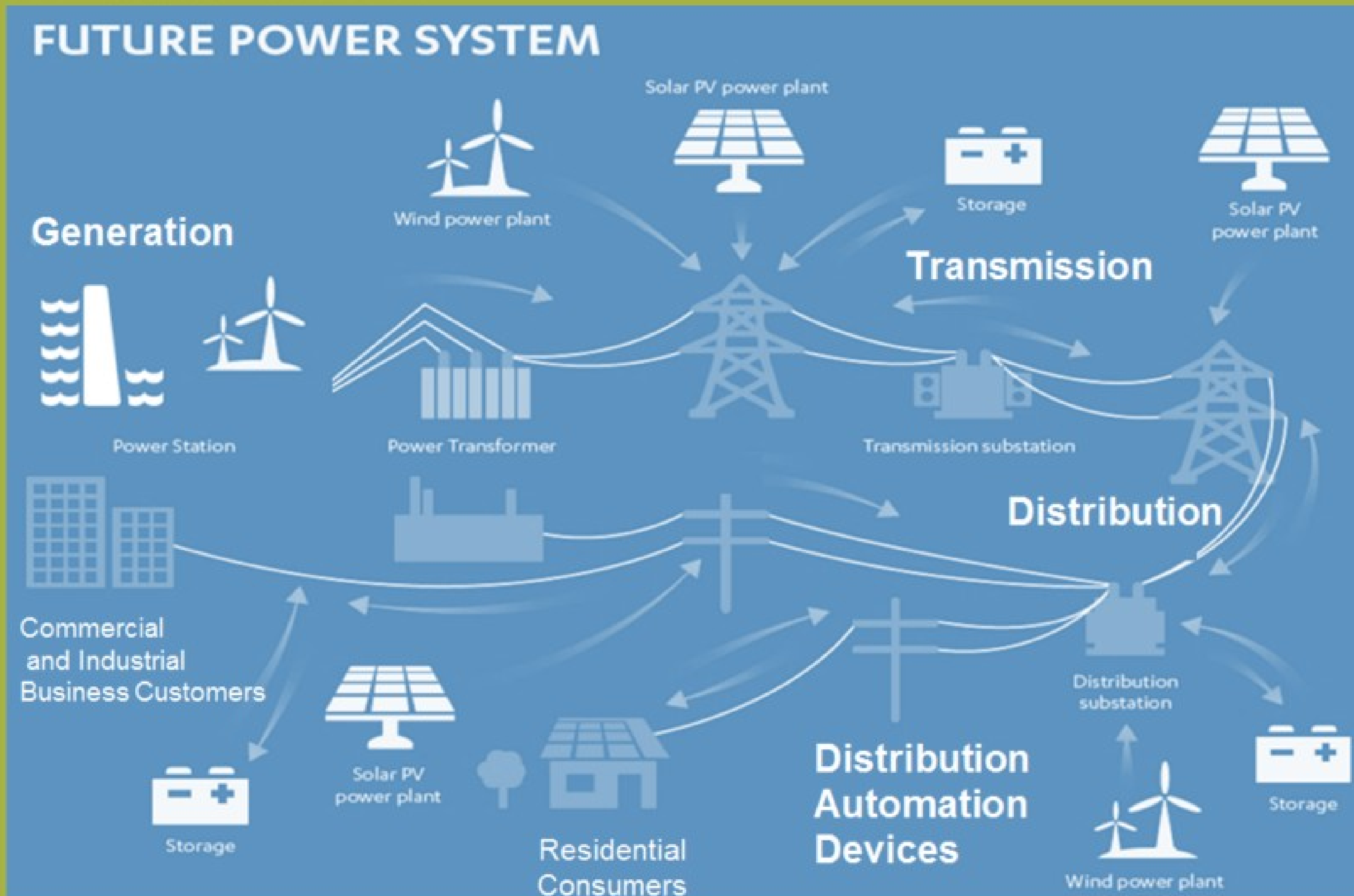
Distributed Resource & Flexible Load Study Scope:

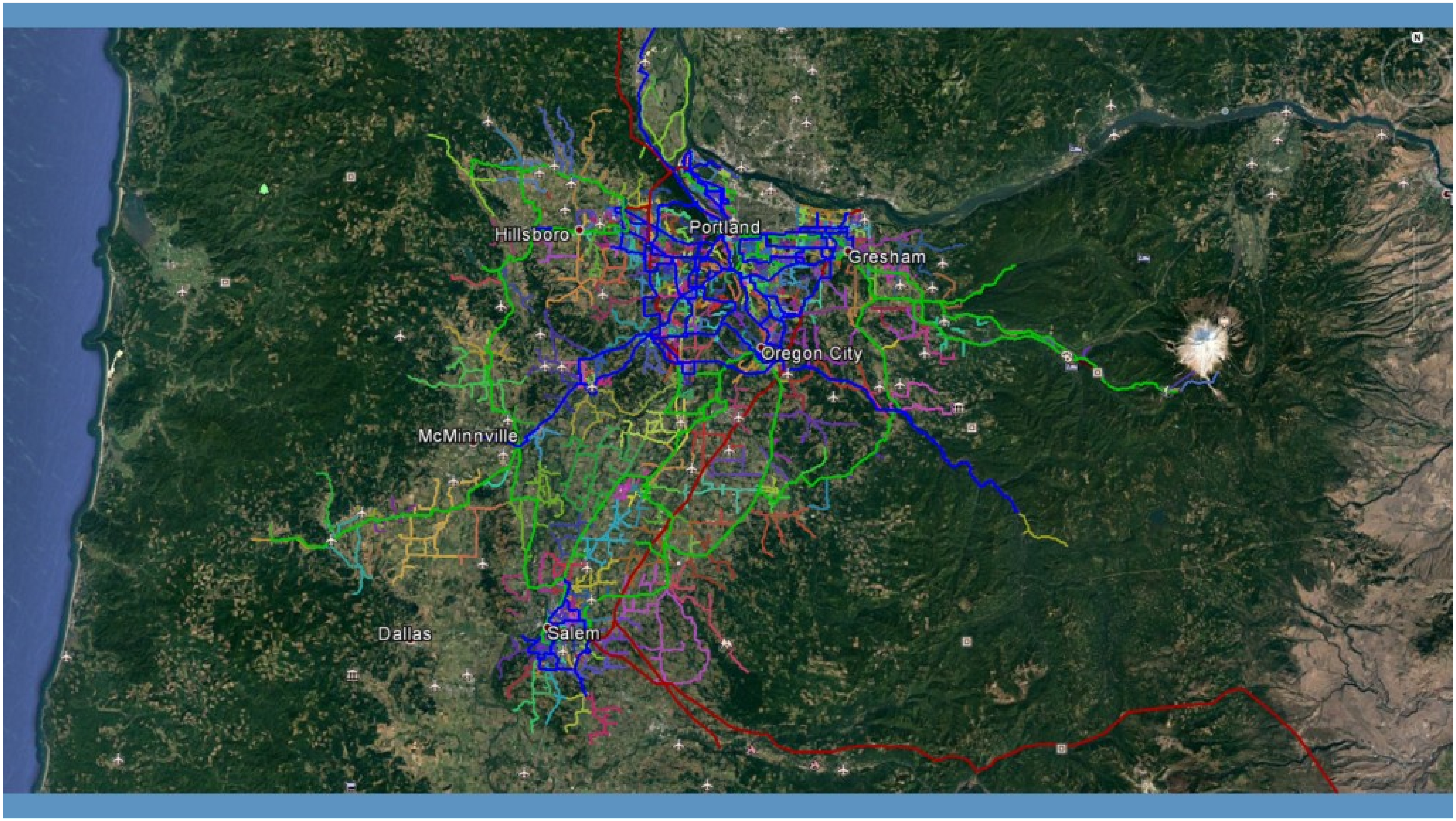
Phase 1: Electric Mobility.

- High, mid, and low adoption forecasts.
    - Light Duty (Car).
    - Med Duty (Bus).
    - Heavy Duty (Freight).
    - Chargers.
- Accounting for possible scenarios and sensitivities.

  **NOTE: Options below are proposed and not yet final.
    - Carbon policy.
    - Technical potential.
    - Adoption propensity.
- Completion expected end of Q1 2018.

Modified from: UK National Infrastructure Commission: Smart Power

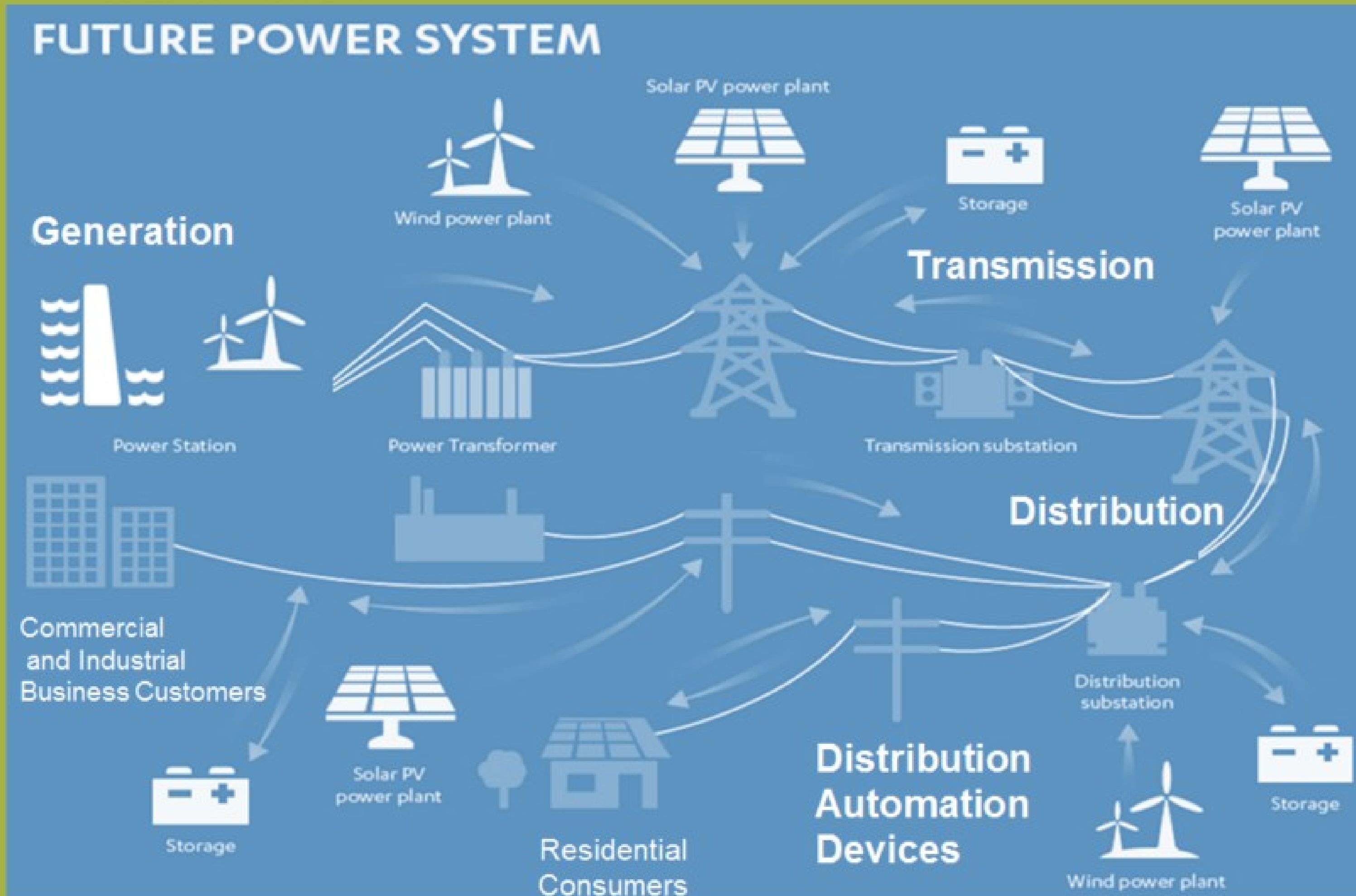



Portland
Hillsboro
Gresham
Oregon City
McMinnville
Dallas
Salem

Distributed Resource & Flexible Load Study Scope: **Phase 2:** System-Level Cumulative Forecasts (IRP).

- Energy efficiency.
- Demand response.
- Distributed energy resources.
  - Solar.
    - Distribution connected.
    - Customer connected.
    - Co-located solar + storage.
  - Wind.
  - Engines.
- Non-firm resources.
  - Pricing scenarios.
- Energy storage (distribution connected and customer connected).
  - Electrochemical.
  - Thermal.
- Electric mobility.
- Enabling technology scenarios.
  - Smart inverters.
- Completion expected end of Q2 2018.

Modified from: UK National Infrastructure Commission: Smart Power

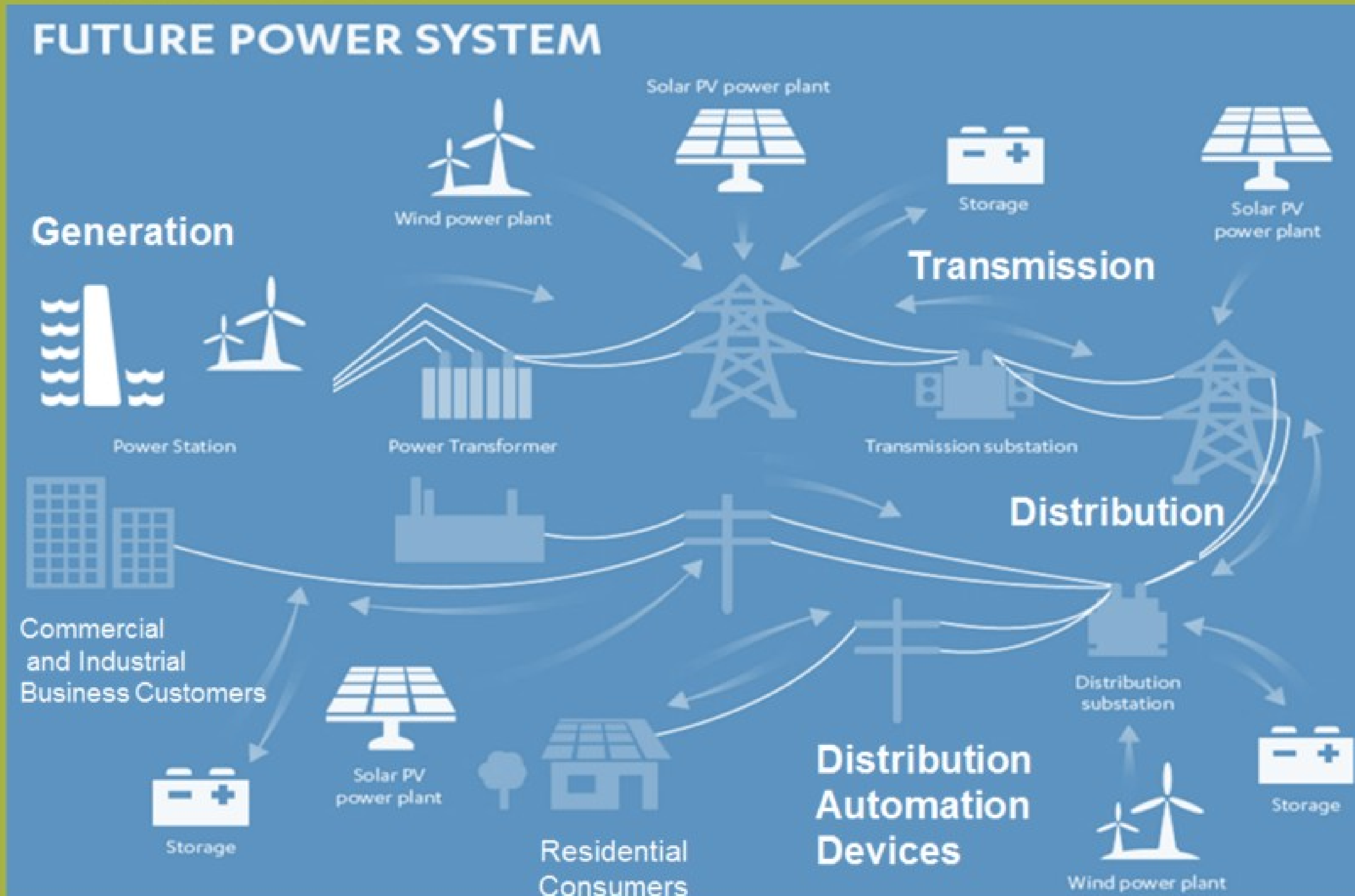


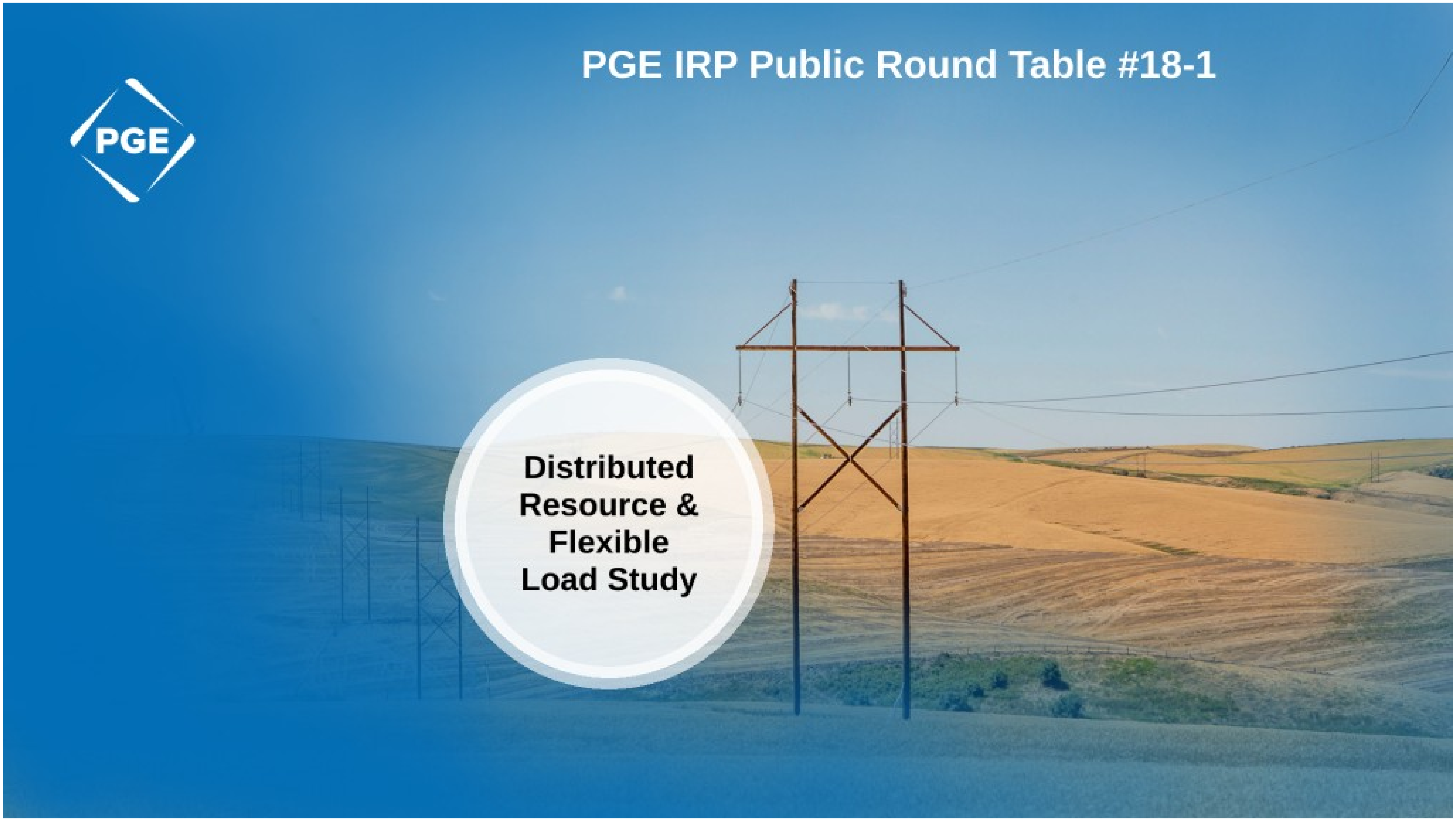

Goose Hollow
Pearl District
Portland
Old Town Chinatown
Downtown
World Trade Center Portland

Distributed Resource & Flexible Load Study Scope: **Phase 3:** Granular Bottom-up Forecasts (CP, T&D).

- Likelihood of adoption.
  **NOTE: Options below are proposed and not yet final.
    - Customer type.
    - Hosting capacity.
    - Technology cost futures.
    - Integration options.
    - Other.
- Accounting for all technologies and scenarios researched in Phase 2.
- Interactive effects.
    - Programmatic.
    - Locational.
- Applied to actual resource deployment and program design.
- Completion expected end of Q3 2018.

Modified from: UK National Infrastructure Commission: Smart Power

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PGE
Distributed Resource & Flexible Load Study

Load Forecast

Amber Riter/Alison Lucas

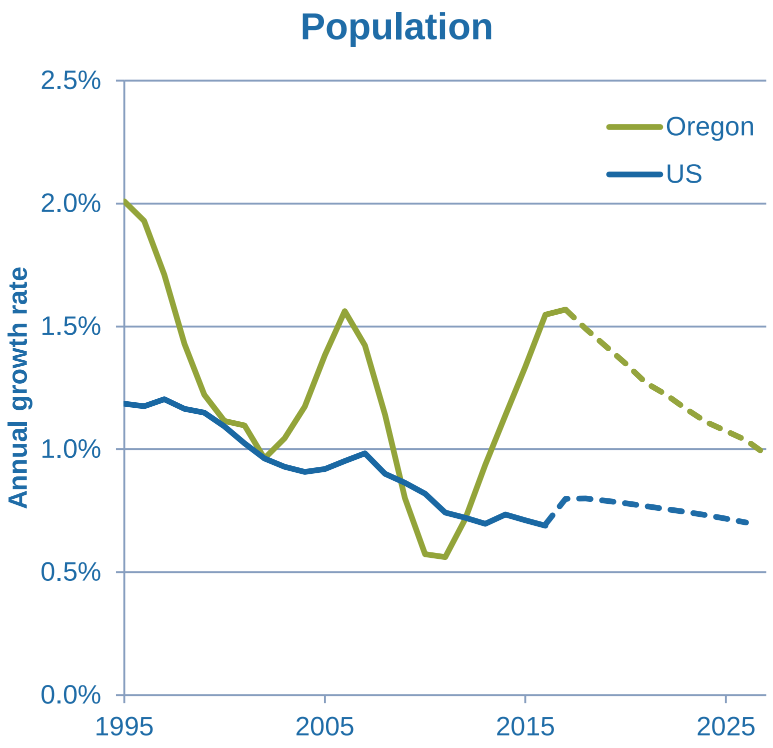
Agenda

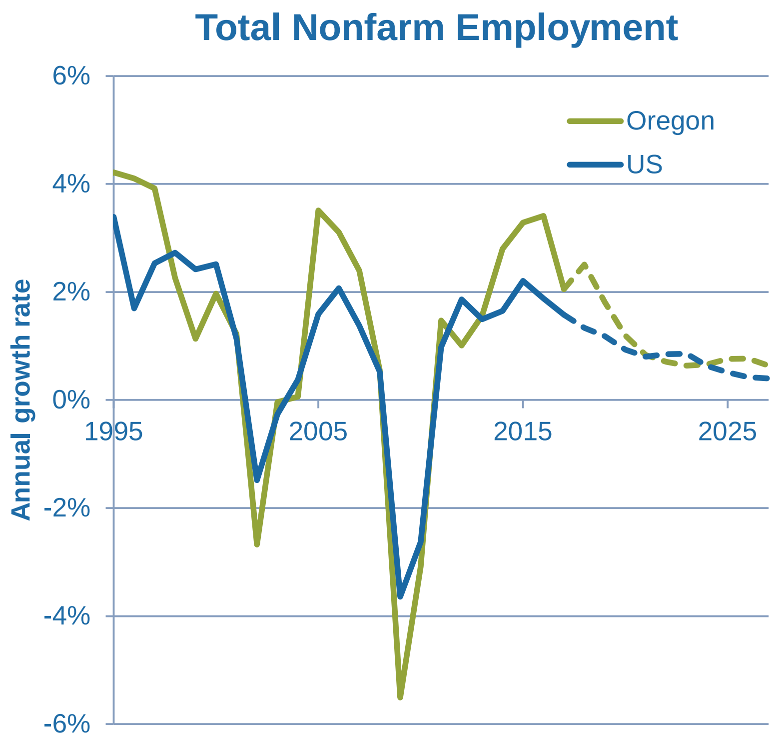
1. Fundamentals and recent trends
    a) Customer growth
    b) Residential, commercial, and industrial characteristics
    c) Peak demand
2. Load forecast model structure
3. Normal weather assumption
4. 2016 IRP Load Forecast Action Items
    a) Ongoing workshops
    b) Probabilistic loads
    c) Out-of-sample testing
    d) Technical appendix

Load Forecast Fundamentals and Recent Trends

Load Forecast: Customer Growth

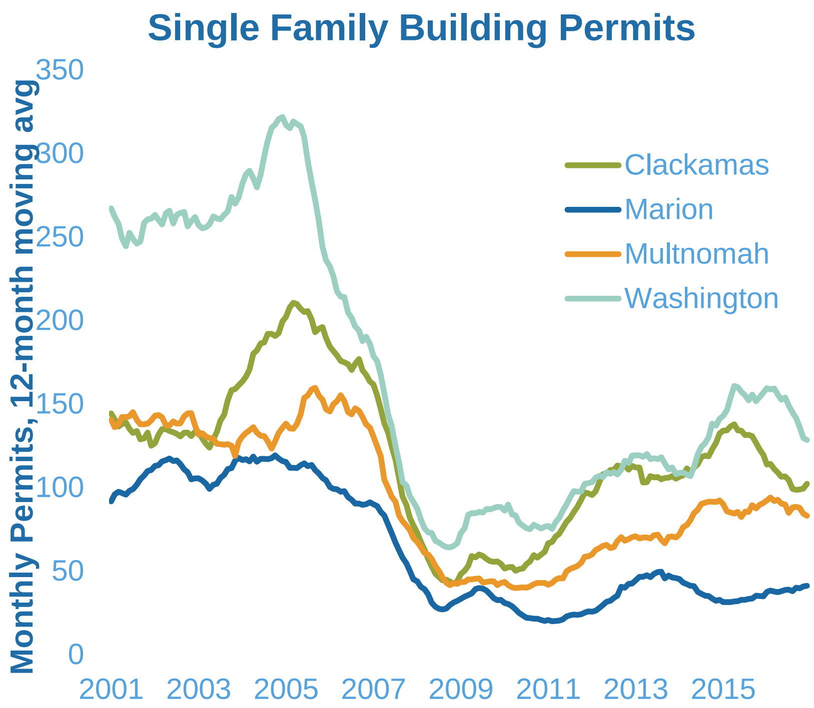
Oregon growth advantage over US

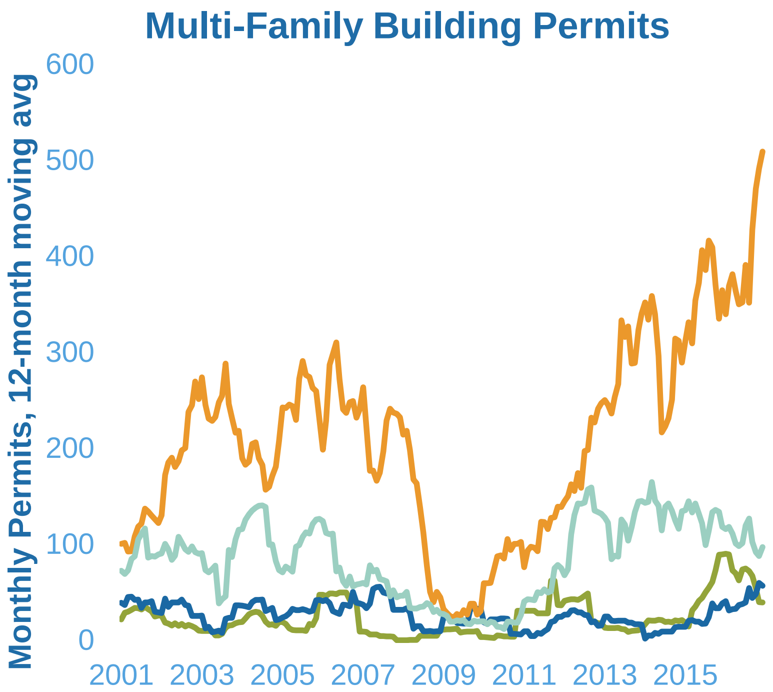




Load Forecast: Customer Growth

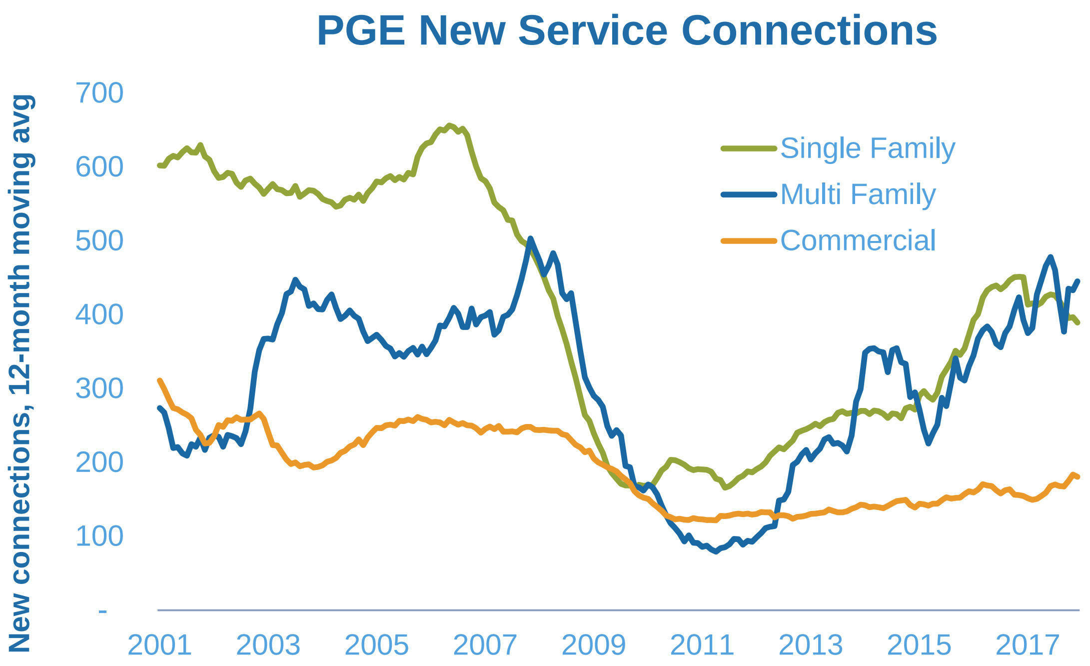
Growth varies by region, is strongest in metro areas

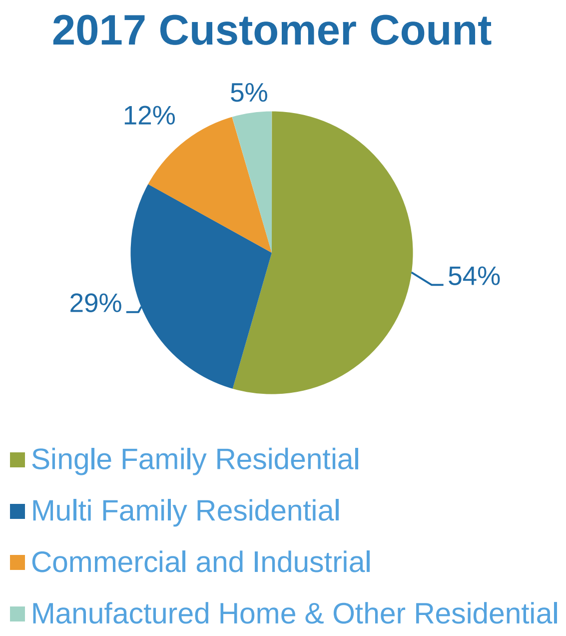




Load Forecast: Customer Growth

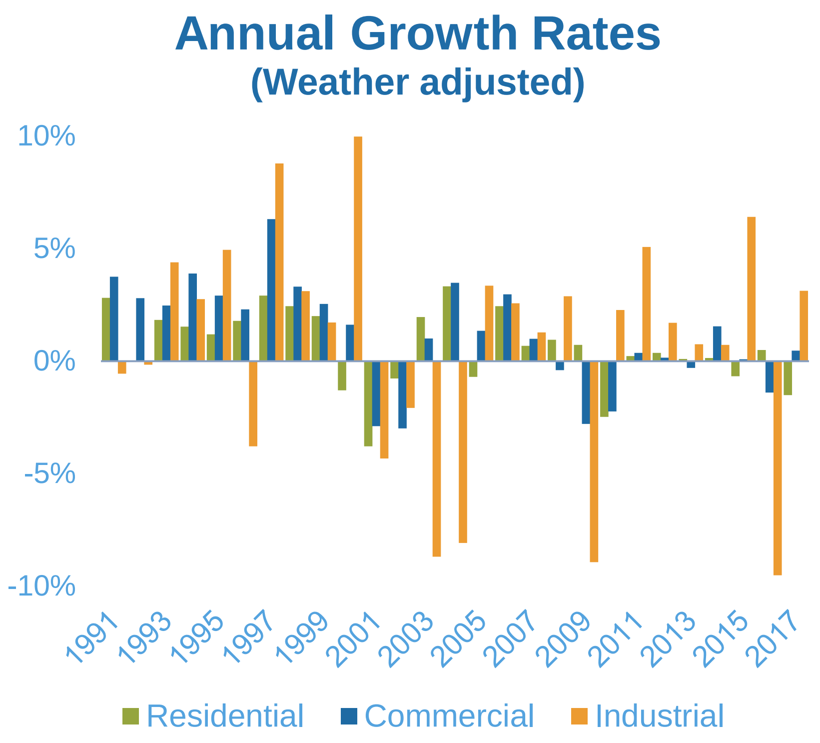
Multi family new service connections keeping pace with single family in the current construction cycle

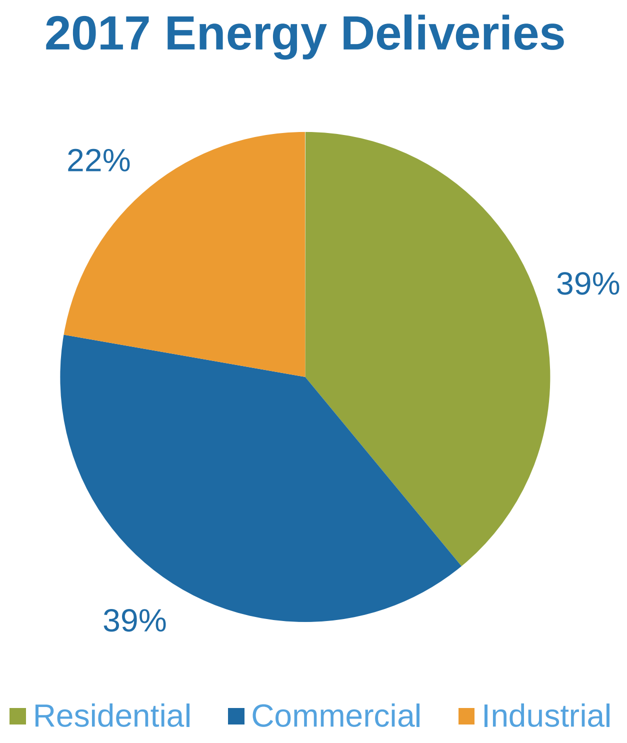




Load Forecast: Customer Composition

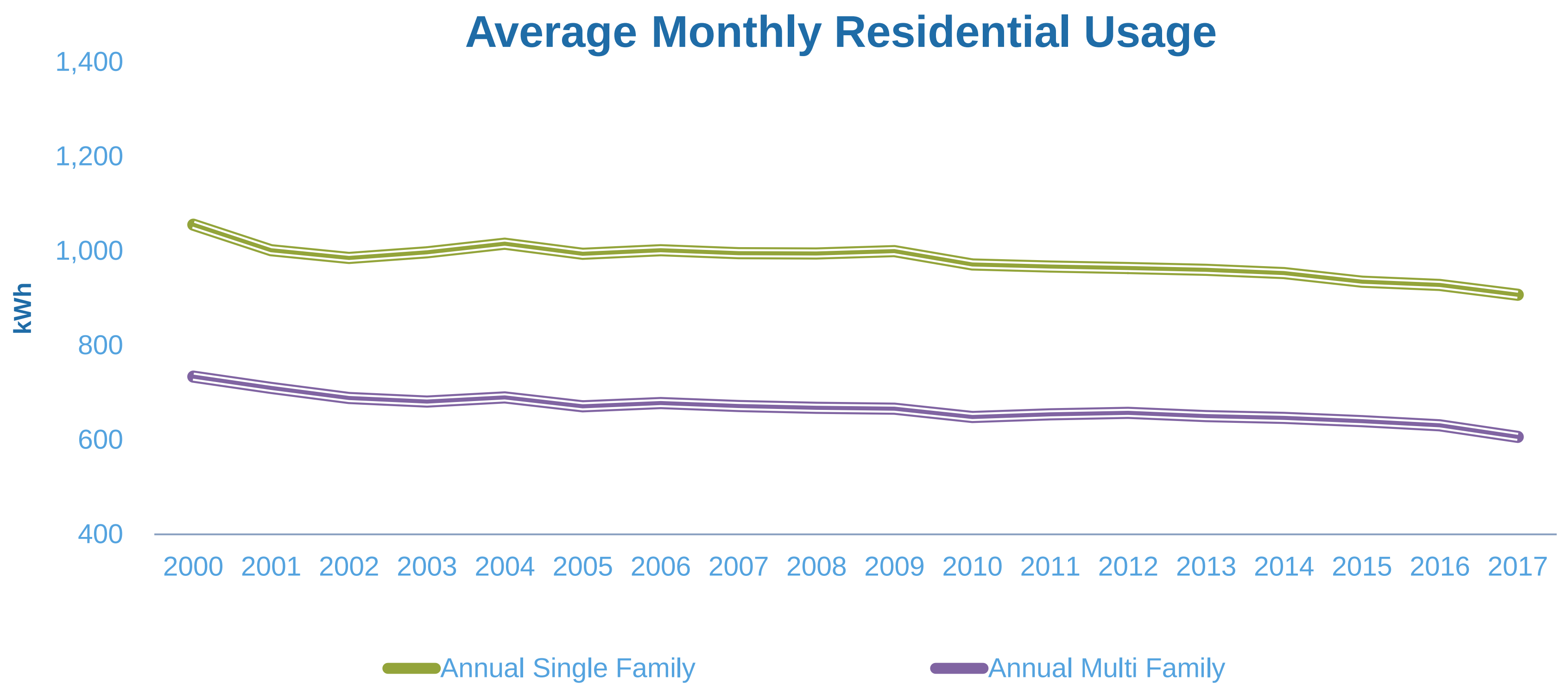
PGE's industrial class is the smallest class and has also experienced volatile growth rates





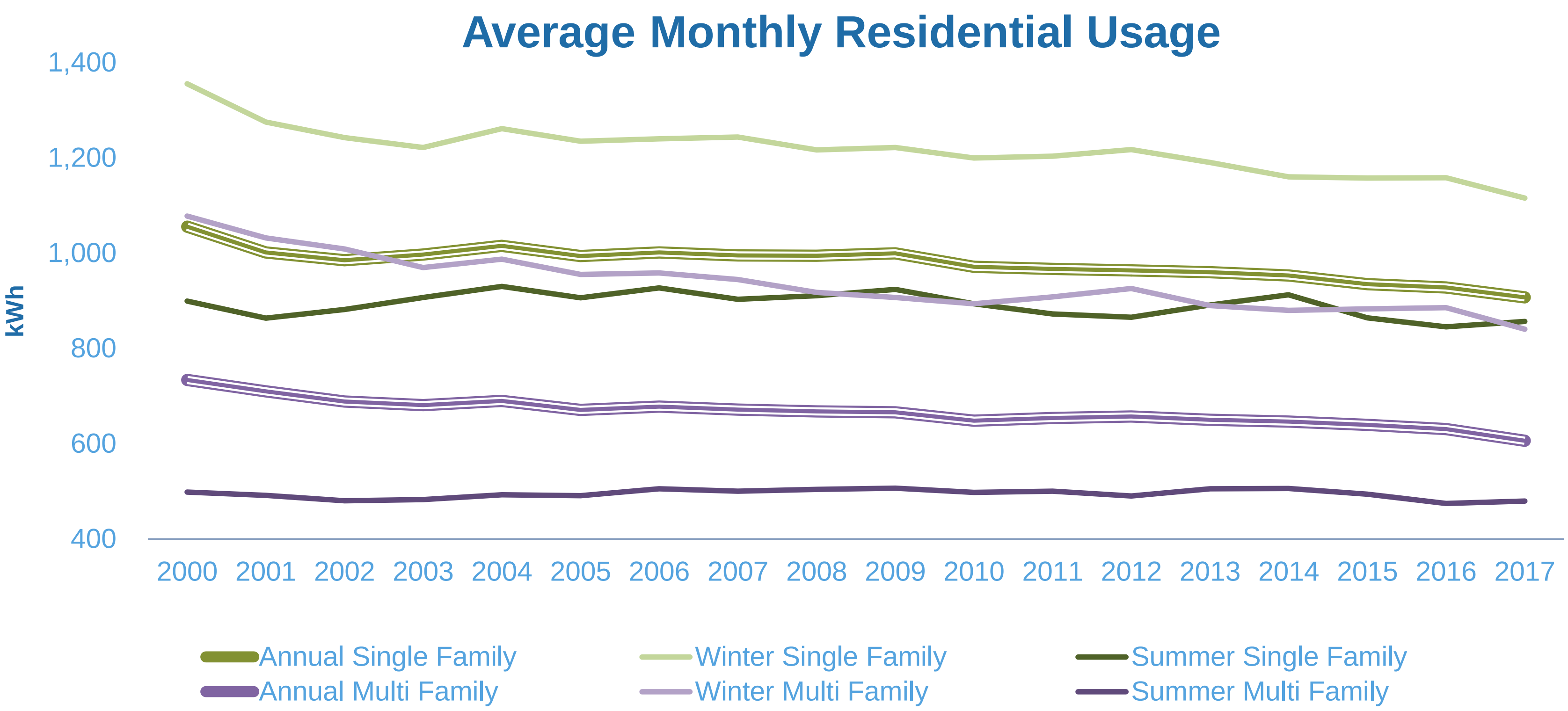
Load Forecast: Residential Fundamentals

Long term decline in average use-per-customer



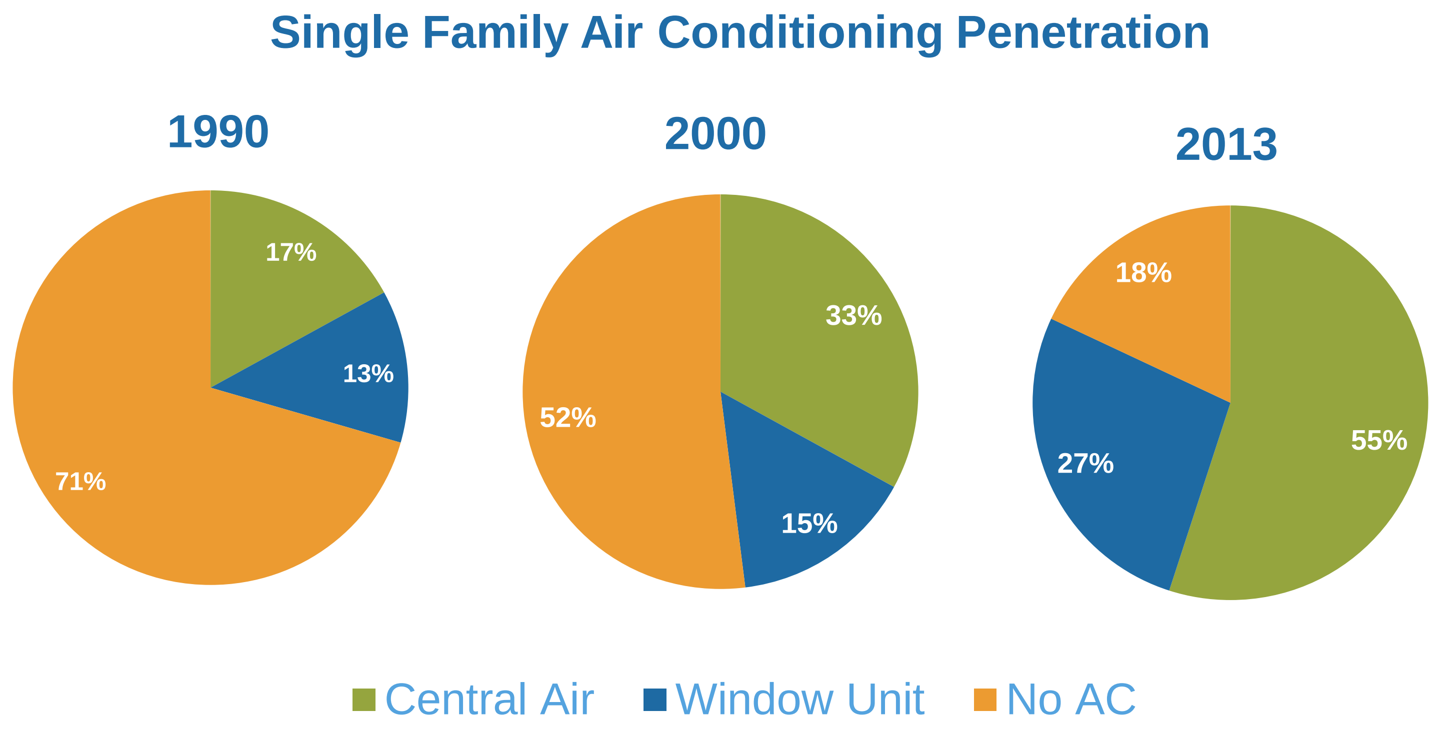
Load Forecast: Residential Fundamentals

Winter average use-per-customer is much higher than summer and is also declining more dramatically



Load Forecast: Residential Fundamentals

PGE’s Residential Appliance Saturation Survey (RASS) finds significant increase in A/C penetration



Load Forecast: Commercial Fundamentals

Changing commercial segment

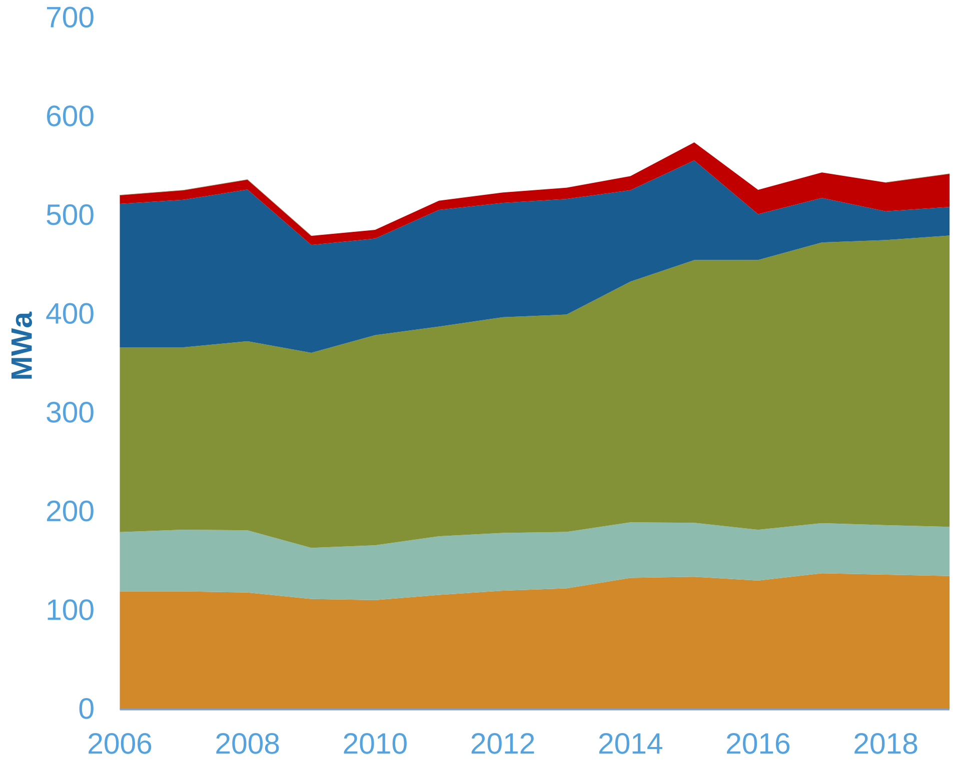
Emerging segments:
- Data centers
- Distribution centers
- Cannabis growers

Population driven services:
- Healthcare
- Local government
- Schools

Offsetting factors:
- Strong gains in energy efficiency
- Consolidation of food stores
- Retail merchandise stores: online shopping vs. brick and mortar stores

Load Forecast: Industrial Fundamentals

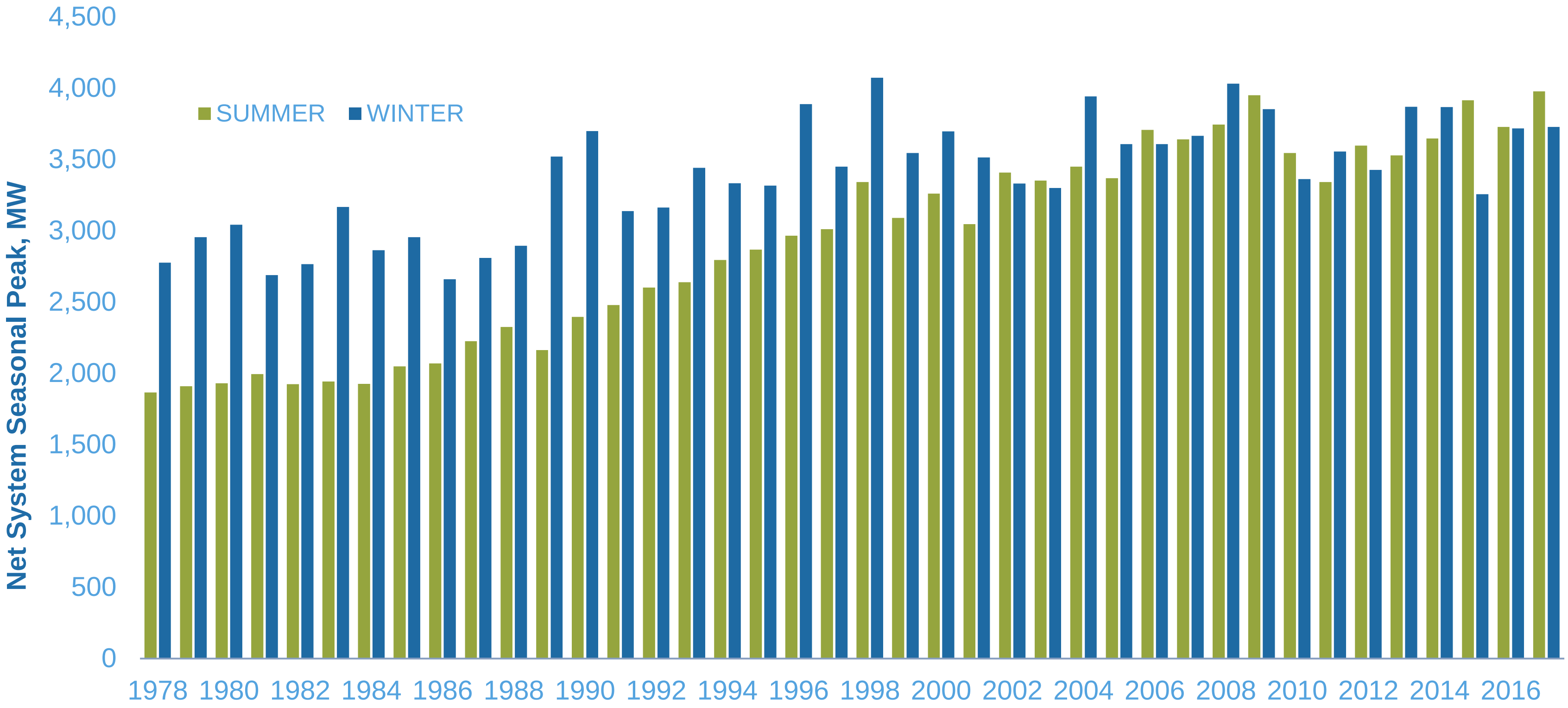
Strong growth of high tech manufacturing and data centers partially offset by declines in traditional manufacturing segments



Sector		Change 2012 - 2017 MWa	Change 2012 - 2017 CAGR
	Data Centers	14	63%
	Paper & Lumber	-71	-17%
	High Tech Manufacturing	66	5%
	Metals	-8	-3%
	All Other Industrial	18	3%

Load Forecast: Peak Demand

Increasing regional A/C saturation has noticeably impacted summer electric demand



PGE’s Load Forecast Models

Energy Deliveries Forecast: Approach

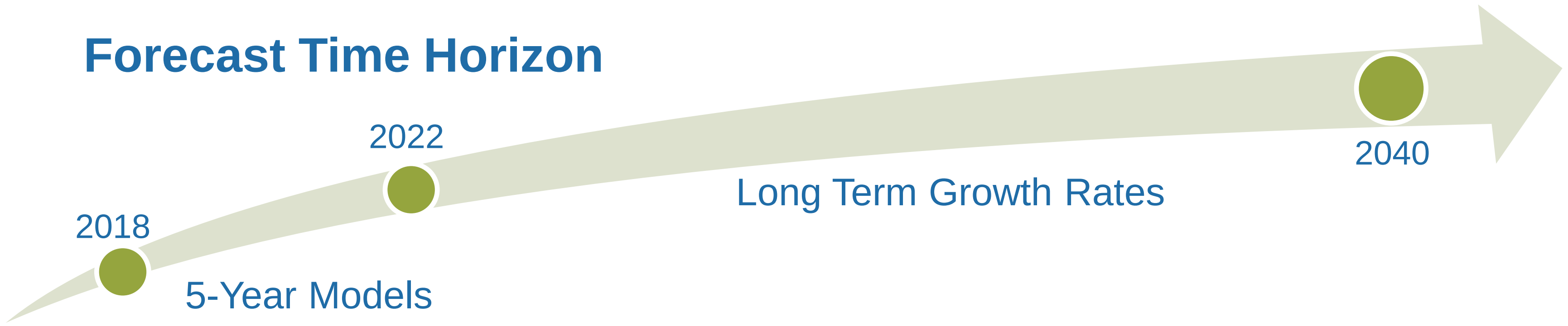
Near Term (1-5 Years)

- 25 regression-based monthly energy deliveries models
- Business cycle influences energy deliveries
- Adjusts for any known large customer changes and miscellaneous schedules
- Explicitly removes incremental energy efficiency
- Updated multiple times per year

Long Term (5+ Years)

- Convergence to long term growth rates, agnostic to business cycle and specific customer changes
- Three aggregated customer class models (by energy deliveries voltage, or revenue class) determine long term growth rates
- Assumes energy efficiency is embedded in growth rates
- Updated for IRP Cycle

Forecast Time Horizon



Near-term Model: Forecast Groups

Residential	Commercial	Manufacturing
Single-Family:	Food Stores	Food Processing
Space Heat	Govt. & Education	High Tech
Non-Space Heat	Health Services	Lumber
Multi-Family:	Lodging	Metal
Space Heat	Misc. Commercial	Other Manufacturing
Non-Space Heat	Merchandise Stores	Paper
Manufactured Home:	Office & F.I.R.E.[(1)]	Transportation Equipment
Space Heat	Other Services	
Non-Space Heat	Other Trade	
Other (e.g., House Boats)	Restaurants	
	Trans., Comm. & Utility	

Near-term Model: Inputs

Forecast Drivers

- Oregon Office of Economic Analysis economic forecast

Input Data and Other Components

- Billing cycle actuals
- Energy efficiency deployment from ETO
- Large customer forecast for large, concentrated loads
- Miscellaneous schedules (Irrigation, Area Lighting, Street Lighting, Traffic Signals)
- Normal weather assumption

Near-term Model: Functional Form

Residential

Energy (MWh) is modeled as monthly use-per-customer (UPC) times customer count.

$$energy = customers \ * UPC$$

$$customers_t = fn\ (customers_{t-1}, new\ connects)$$

$$UPC = fn(weather\ drivers, seasonal\ controls, trend)$$

Commercial and Manufacturing

Energy (MWh) is modeled directly as a function of economic, weather, seasonal and trend drivers. Drivers vary by forecast group, employment drivers may include similar NAICS groupings, and weather sensitivity is determined by group. Some segments are expected to be stable.

$$energy = fn(weather\ drivers, seasonal\ controls, economic\ drivers, trend)$$

Long-term Model: Forecast Groups

Regression Models (MWh)	Assume Constant (MWh)	Peak Demand Regression (MW)
Residential	Sub-Transmission	Net System Model
Commercial	Street and Area Lighting	
Industrial		

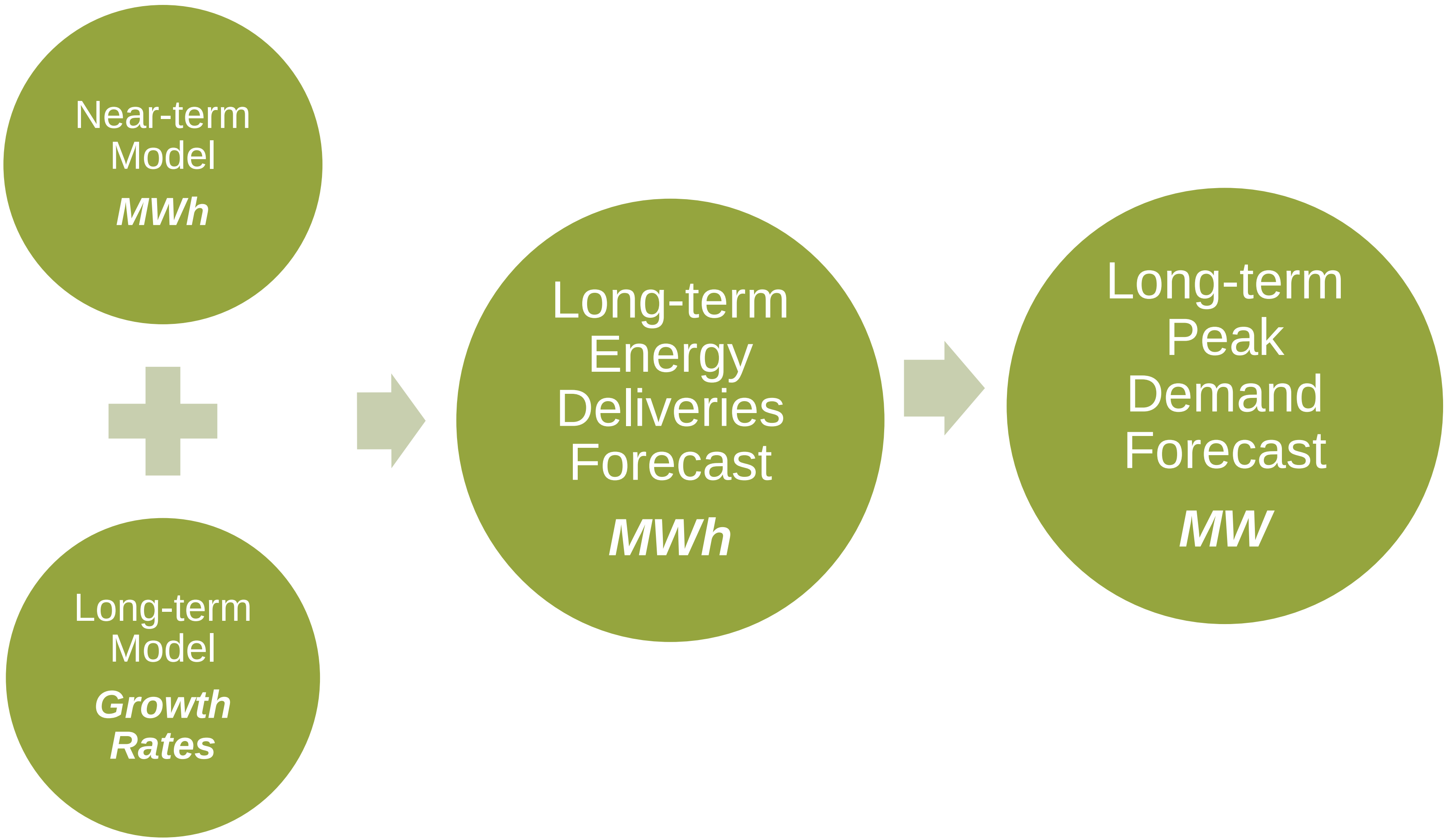
Energy is modeled at a revenue class aggregation. Monthly energy deliveries (MWh) is the dependent variable:

$$energy = fn(weather\ drivers, seasonal\ controls, ecnonomic\ drivers, trend)$$

Peak demand is modeled at a net system level. Monthly peak demand (MW) is the dependent variable:

$$monthly\ peak\ demand$$
$$= fn(daily\ weather\ drivers, seasonal\ controls, monthly\ energy\ deliveries, trend)$$

How the near-term and long-term models come together



Cost-of-service vs Direct Access demand

Up to 300 MWa may opt out of PGE's cost-of-service rates to be served by an Electric Service Supplier (ESS) under current program.

All load forecast modeling is at the net system level, regardless of direct access service elections.

In the load forecast

- One-year opt outs are considered COS after the first year
- Long term elections are assumed to remain on a Direct Access, non-COS schedules

Normal Weather Assumption

PGE’s Normal Weather Assumption

What is a normal weather assumption?

- Reflects the typical or baseline year
- A 50/50 assumption, with variability expected above and below
- Since 2006, PGE has used a 15-year rolling average of historical temperature

The concern:

- Observed warming trend in our region and globally
- 15-year rolling average is cold-biased
- Results in underestimating cooling loads and overestimating heating loads

PGE’s Normal Weather Assumption

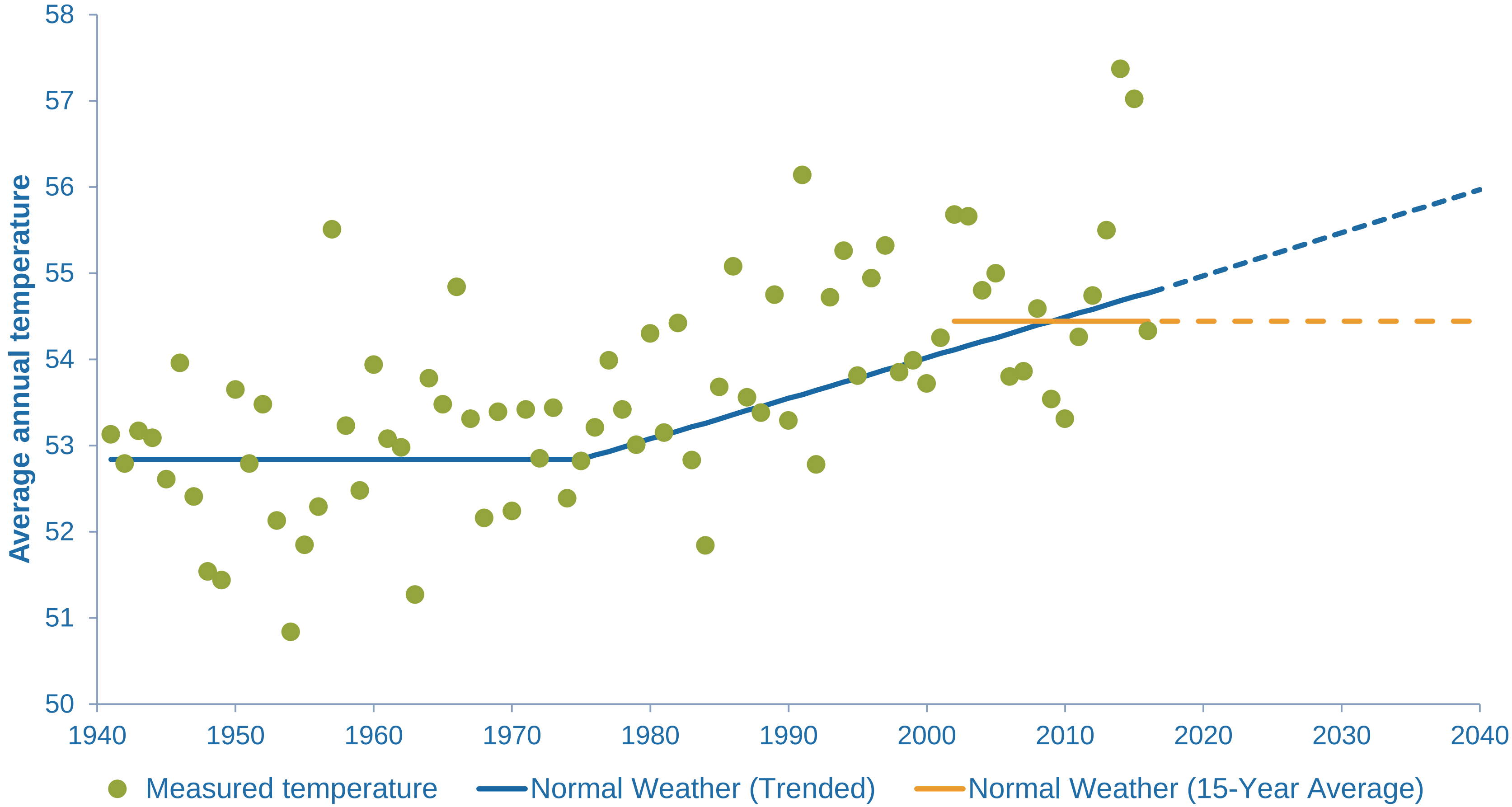
Action taken:

- Following suggestion of NOAA researchers, PGE has applied a segmented linear fit to temperature data from 1941 to present
  - Breakpoint or “hinge” at 1975
  - Assumes stationary normal temperature 1941-1975 and gradually increasing temperatures after
- Results in a normal weather assumption that gradually warms over the forecast period

Impacts:

- Increases forecasted summer load, decreases forecasted winter load
- Impacts residential and weather-sensitive commercial loads, less meaningful for industrial loads

Historical Weather Data and Assumption



PGE's Load Forecast
2016 IRP Action Items

Load Forecast Action Items from LC 66 Order

1. Conduct ongoing workshops, including consideration of probabilistic forecasts, with interested stakeholders to improve PGE’s forecasts

2. Conduct out-of-sample testing and select models based on these results

3. Include a technical appendix that describes forecast methodology and contains a list of the forecast modeling assumptions (and explanations) and the model specifications (equations)

Load Forecast Action Items from LC 66 Order

Schedule

- The load forecast is an early input assumption for IRP modeling, it is required to determine energy and capacity needs.
- PGE updates its full long term forecast once per IRP cycle
- PGE updates its 5-year forecast 2-4 times per year for other business purposes, allowing for a refresh of resource need focused on the action window.
- ***2019 IRP load forecast needs to be finalized in early June of 2018***

Action Item 1 → Part 1

Conduct ongoing workshops, including consideration of probabilistic forecasts, with interested stakeholders to improve PGE's forecasts

How frequently would you like to hear about PGE's load forecast?

Proposal:

1. Workshop to review load forecast process once per IRP cycle
2. Technical workshop, going into mathematical detail on the models, once per IRP cycle
3. Resource needs update as needed, to be included as brief roundtable agenda item

Action Item 1 → Part 2

Conduct ongoing workshops, including ***consideration of probabilistic forecasts***, with interested stakeholders to improve PGE's forecasts

What are probabilistic forecasts?

Several general methods to consider alternate outcomes:

- High / low alternates based on historical observation (PGE's "jaws")
- Confidence intervals based on model error
- Confidence intervals based on stochastic simulations
- Scenario testing (e.g., high/low EV penetration, high/low economic growth)

Reminder: *RECAP model captures weather variability.*

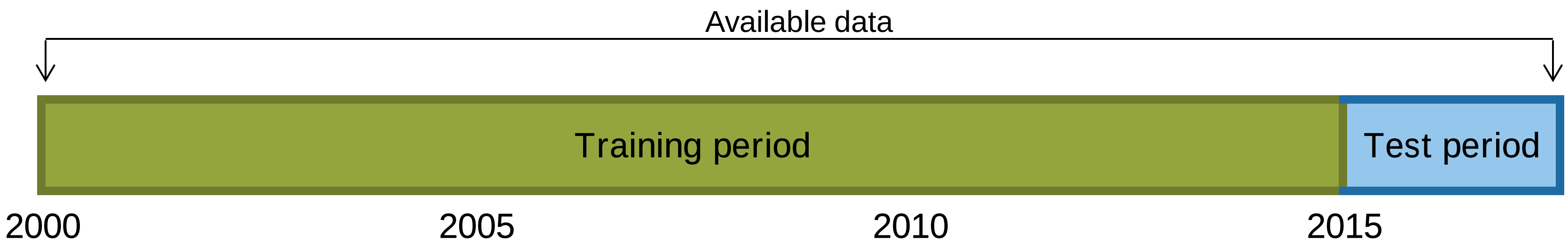
What would stakeholders like to see?

Action Item 2

Conduct out-of-sample testing and select models based on these results

What is out-of-sample testing?
An approach to testing model performance which withholds data from the regression estimation and then tests performance using the withheld set.

PGE's Proposed Approach
In work papers, PGE will document this testing and how the results informed its model selection for its 2019 IRP forecast.



Action Item 3

Include a technical appendix that describes forecast methodology and contains a list of the forecast modeling assumptions (and explanations) and the model specifications (equations)

PGE's Proposed Approach

PGE has developed a set of work papers that document its forecasting process in greater detail, including showing the results of diagnostic testing.

PGE will also include with the 2019 IRP a technical appendix discussing model equations, assumptions, and results.

Propose release of this appendix with the IRP draft in Q2 of 2019 for stakeholder input.

Thank You!