IRP Contemporary Issues Technical Conference - WORKSHOP 3

Translating Capacity Expansion Model Results into Efficiency Goals and Programs

12:00 -12:15 p.m.	IURC Chairman Huston
12:15 - 1:15 p.m.	Development and use of energy efficiency bundles for use in IRP optimization and translating the results to program design. Natalie Mims Frick and Tom Eckman (Lawrence Berkeley National Laboratory)
1:15 - 1:45 p.m.	Questions and comments. Eric Miller (AES Indiana) and Jeffrey Huber (GDS)
1:45 – 2:00 p.m.	Break
2:00 – 3:30 p.m.	Discussion by utility representatives and Citizens Action Coalition
3:30 – 4:00 p.m.	Questions and comments

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IRP Contemporary Issues Technical Conference

Workshop 3: Translating Capacity Expansion Model Results into Efficiency Goals and Programs

Natalie Mims Frick and Tom Eckman, Berkeley Lab subcontractor

August 19, 2021

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Agenda

- **Introduction**
- Review
- Use of gross or net savings (and cost) in capacity expansion modeling
- Key characteristics of efficiency bundles
- Considerations for creating efficiency bundles
- Considerations for translating IRP results into efficiency programs
- Examples of bundling approach results

Housekeeping

- We are recording this session.
- Please remain on mute during the presentations.
- We will monitor questions in the chat box. IURC staff will read your questions or ask you to unmute yourself and pose the question yourself.
- Please use your camera if possible when speaking.

Berkeley Lab Presenters

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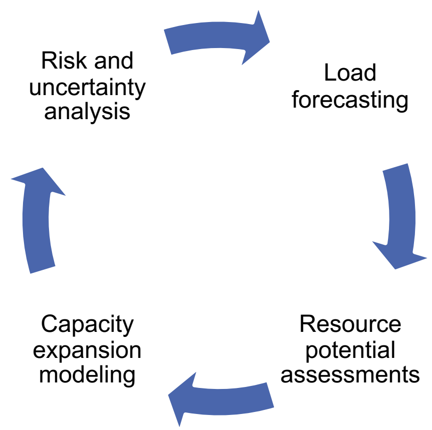
How to Model Efficiency or Other DERs as Resources

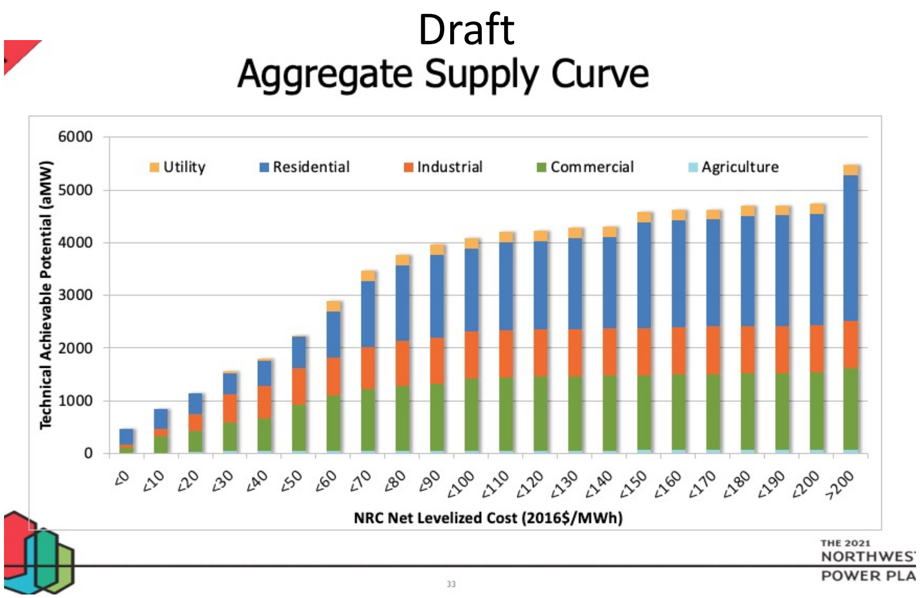
- Using energy efficiency (EE) or other DERs as a selectable resource requires a *different process* than using these resources as a decrement to the load forecast.
- Allowing a capacity expansion model (CEM) to select EE or other DERs permits optimization between *all resources* (e.g., supply and demand side).
- Over three workshops, we will discuss changes that may need to be made to four components of planning: load forecasting, resource potential assessments, CEMand risk and uncertainty analysis.
- Today we focus on translating resource potential assessments into supply curves for use in CEMs and programs.



Slides and recording from the first and second workshop are here.

Goal: Efficiency supply curves provide data comparable to that needed to model supply side resources

- The goal of creating efficiency supply curves is to characterize energy efficiency at the same level of fidelity and granularity as supply-side resources with respect to costs, load profiles, development lead times, and maximum annual and cumulative availability.
- Efficiency supply curves are made up of measure bundles or bins. Our presentation today discusses:
  - Bundle characteristics:
    - Cost
    - End use and savings load shapes
    - Annual and cumulative achievable potential
    - Measure life
  - Bundle sizing
  - Options for creating bundles



Source: [NWPCC March 2020]

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The amount of EE and other DERs are determined in a *five* step process

- *Step 1* - Estimate *Technical Potential* on a *per application* basis (i.e. savings per unit)
- Step 2 - Estimate *number of applicable units* (account for physical limits, retirements, new construction, etc.)
- Step 3 – Estimate *Technical Potential* for *all applicab*le units
- Step 4 – Estimate *Achievable* Potential for *all realistically achievable* units
- Step 5 – Estimate *Economic Potential* for *all realistically achievable* units **by competing EE (and other DERs) against supply side resources in CEM***

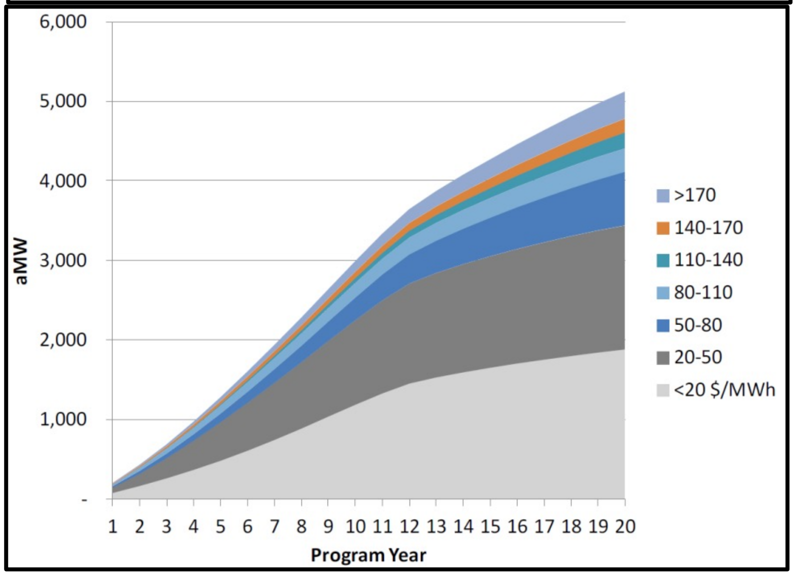
*Where EERS or RPS requirements which include distributed renewable resources exist they are modeled as "must build" resources and only additional increments above the minimum EERS/RPS "compete" against generating resources in capacity expansion modeling.

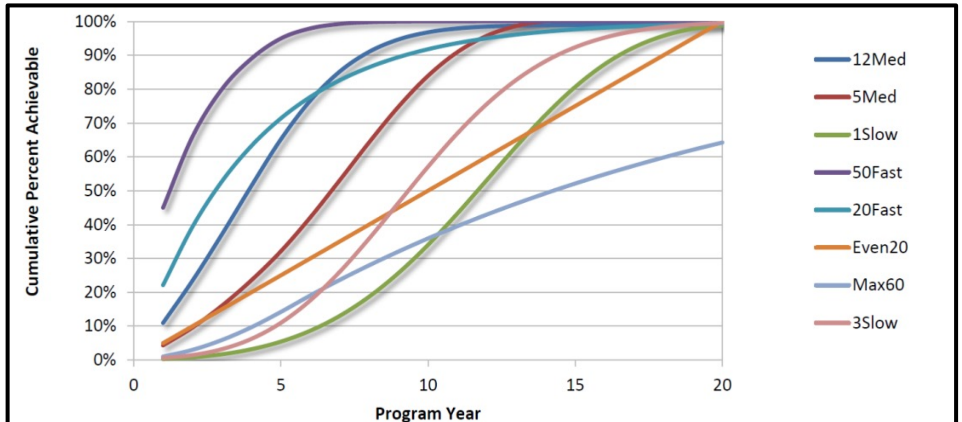
Establishing the amount and timing of EE and DR development through direct completion

- Allows *optimization* across all resources based on their cost, load shape/load following characteristics and risk
- Requires CEMs that are capable of accepting "acquisition decision and development rules" for EE and other DERs (see details at slides 36-39)
- Is less useful when deterministic (versus probabilistic) capacity expansion models or modeling methods are used
  - Because there's *no uncertainty* regarding the "optimum" type, timing and amount of resources to develop, so the risk mitigation value of EE and other DERs relative to competing resources is not tested

Step 5 – Estimate the economically achievable potential of all units - develop inputs to CEM

Maximum Annual and Cumulative Achievable Potential





Maximum Ramp Rates

We're now out of the weeds . . .

It's Time To Discuss Where We've Been and Where We Go Next

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Treatment of free-ridership in load forecasting

- Should gross or net-savings serve as the basis of "supply curves" with econometric load forecast?
  - When econometric load forecast are used, they inherently capture historical levels "free-ridership"
  - When end-use load forecasts are used their calibration with energy efficiency potential assessments is intended to capture "common practice" consumer choices
  - Common practice represents the "current market weighted average" efficiency, so it includes those consumers who are already selecting higher levels of efficiency

Econometric load forecasting models

- Most appropriate for short to medium term forecasts
- Advantages
  - Based on economic theory of how various factors are expected to affect demand
  - Moderate data requirements
  - Produce measures of fit to historical data
  - May be appropriate components of more sophisticated modeling approaches
- Disadvantages
  - Unsuited for analysis of most energy policy questions (e.g. impacts of future codes and standards, electrification, utility programs, carbon programs)
  - May not reflect structural changes in the economy (e.g. introduction of EVs, bit coin mining, electrification policies)
  - Inability to ensure consistency with energy efficiency potential analysis
  - Substantial expertise required for reliable model results

End use load forecasting models

- Energy demand is derived from production of energy services
  - D = A(Units) * B(Efficiency) * C(Utilization)
- Most appropriate for long term forecasts and policy analysis especially for residential and commercial sectors
- Advantages
  - Explicit about how energy is used and stocks of energy using equipment
  - Can evaluate the effect of equipment stock turnover.
  - Can evaluate energy policies intended to change efficiency of equipment or fuel choice
  - Permits checking consistency between load forecast and conservation potential analysis
- Disadvantages
  - Heavily data intensive (requires customer survey data)
  - Expensive to build and operate
  - Not reflective of human behavior responses, i.e. overoptimization

Alignment of incremental costs with savings

- Regardless of whether gross or net savings are included in supply curves, their should be an alignment between incremental cost with savings assumptions
  - Gross Savings = Total Incremental Cost
  - Net Savings = Total Incremental Cost, net of Cost Paid by Free Riders*

Free ridership assumes that a consumer will purchase the efficiency improvement "in a world" where there were no utility or other programs, hence their costs are not "incremental" – That is, they're in the baseline.

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Measure bundles

- Energy efficiency (and other DERs) supply curves are usually represented as the amount of resource potential available in discrete "bundles" or "bins."
- Key characteristics of bundles are shape, cost, savings potential and lifetime.
  - These characteristics support a comparable analysis between supply and demand side measures.
- There are many approaches to creating measure bundles.
  - Measures can be bundled by sector, end-use, program, measure lifetime, cost or some combination of these characteristics.
  - Utilities currently use a variety of approaches group efficiency measures together into a bundle.
- Generally, bundles that contain a large range of end use shapes and/or costs limit the ability of a CEM to select EE resources that "best fit" resource need (e.g., supply capacity when most needed, reduce GHG emissions at the lowest cost)
  - May not have as big of an impact when the costs are very high or very low as compared to other resources

Characteristics that are important to capture in bundles

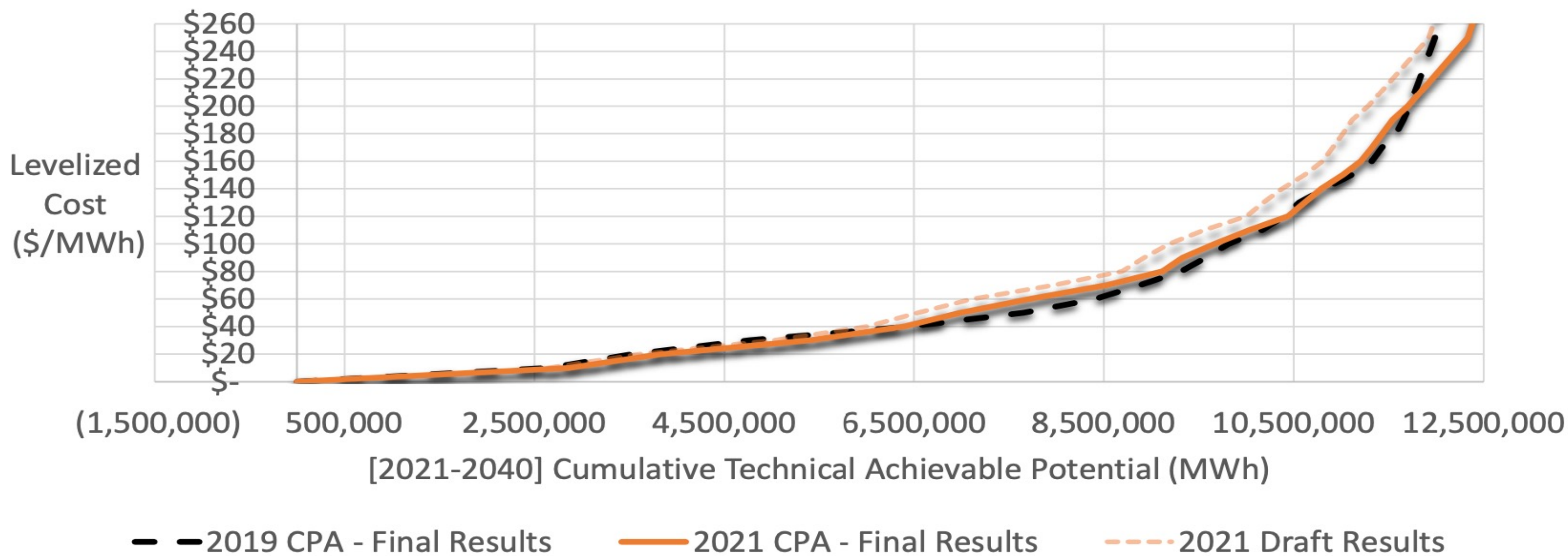
- Cost
- Load or savings shape
- Measure life
- Annual and cumulative achievable potential

Measure:	Heat Pump Water Heater		
Item	**Methods & Sources**	**Note**	**2021P Updates**
Measures Described	Tier 3 HPWH, including split system	Tier 1 &2 not included as cost is same as Tier 3, and since savings for Tier 3 are higher, levelized cost is lower for Tier 3. Thus, this tier would more likely be acquired than Tiers1&2 and should be the only one considered. Ducted excluded due to extra cost, less savings	Split-system
Energy Savings Calculation Basis	RTF Residential Heat Pump Water Heater_v4.2		
Applicable Stock	Electric WH in SF & MH & low-rise MF. High-rise MF in new construction has small applicability given WA code provisions, but pretty limited in other states. Split system only applicable for MF		
Baseline Saturation	NEEA 2018 Market Data		
Baseline HVAC Loads	SEEM Version 0.98 build May 29 2015		
Permutations	Tier 3 HPWH and split system HPWH		
Costs	Market data		
Measure Life	DOE TSD		
Savings Shape	HPWH - ERWH curve		
Achievable Ramp Rate	12MED for NC, 5 MED for Existing	Due to code options in WA & OR, HPWH are going into new homes at a higher rate of adoption than existing homes	
Max Achievability	85%	Although there is a standards play, it seems unlikely that it will impact 100% of electric WH, given space constraints in existing homes. Carve outs likely	

Source: NWPCC Residential heat pump water heater workbook

Efficiency can be acquired at a wide range of costs

- Unlike supply side resources energy efficiency (and other DERs) can be acquired across a wide range of costs (i.e., EE has a nearly continuous supply curve)
- Efficiency supply curves quantify the levels of efficiency that can be obtained at various ranges of costs.



PacifiCorp 2021 IRP efficiency supply curve

Net measure bundle cost

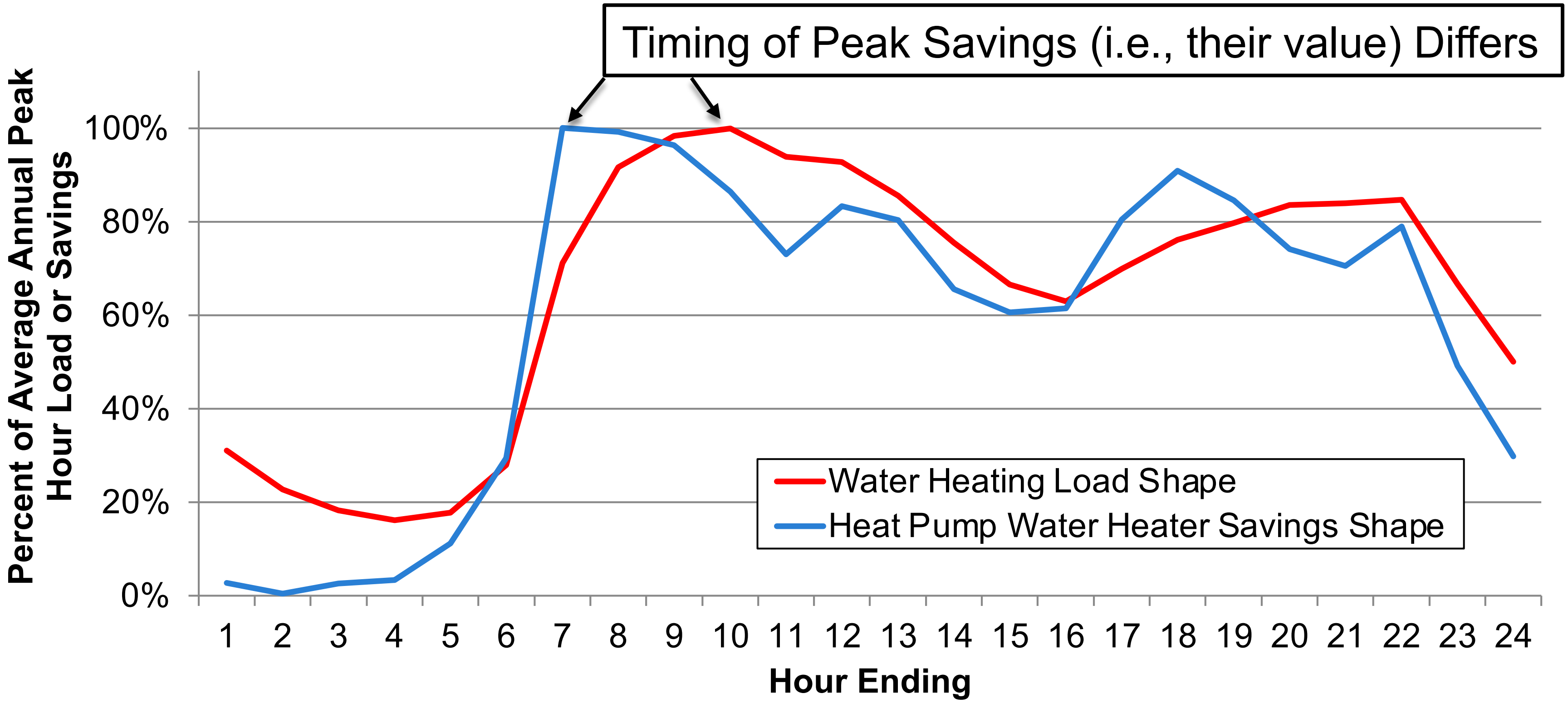
NWPC Costs*

- Capital
- Financing (if any)
- Installation Labor
- Operation and maintenance
- Periodic capital replacement
- Reinstallation cost (for measures with lifetimes less than planning period)
- Deferred distribution and transmission costs
- Quantifiable Environmental Benefits (e.g., water, natural gas, health)

**Costs are "net" of the value of all benefits not captured in the capacity expansion model (e.g., deferred T&D)*

- Costs and benefits used to create bundle costs
  - Should be consistent with state/jurisdiction's cost-effectiveness policy/requirements
  - Should reflect whether gross or net savings are used
  - Should be consistent with the cost and benefits considered for generation resource options
    - Example – If the total incremental cost of generating resources are used, then the total incremental cost of EE should be used

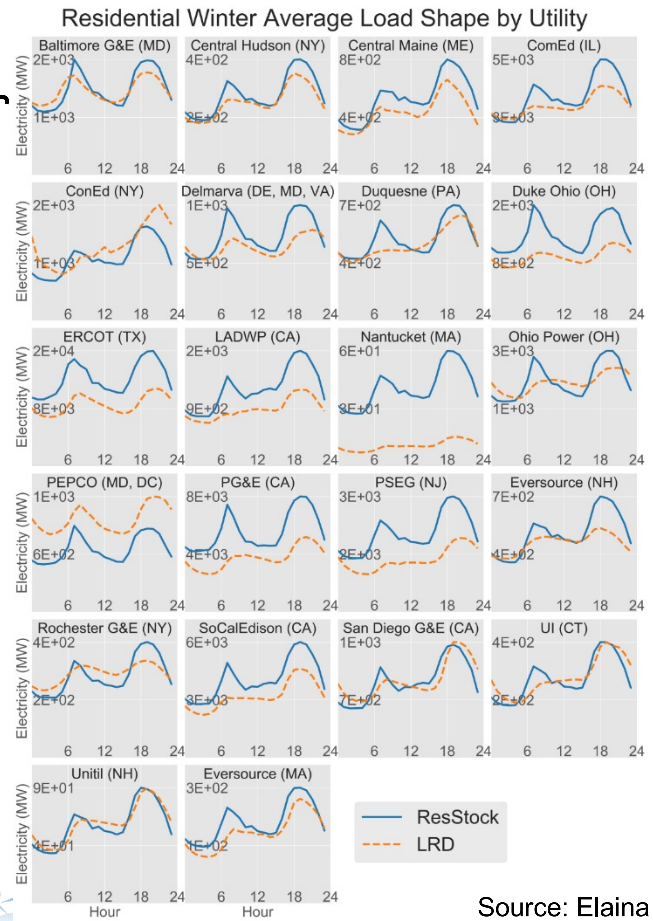
Measure shape (1)



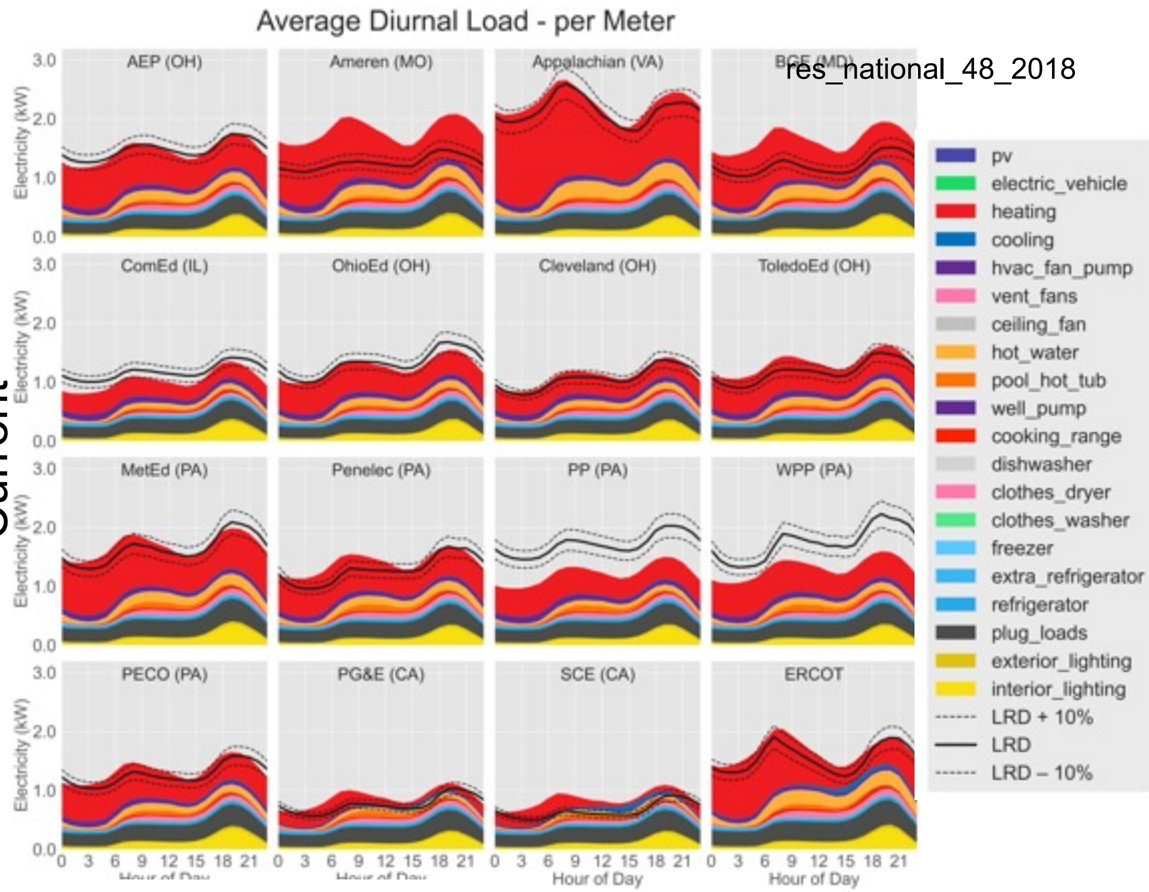
For additional information on the time sensitive value of efficiency, see Mims, Eckman and Goldman or Mims, Eckman and Schwartz.

Measure shape: [Residential and Commercial End-Use Load Profiles]

Before End Use Load Profiles Project



Current



Source: Elaina Present IEPEC

Measure lifetime informs the technical potential of a measure

New
- Homes & Commercial Buildings
- Equipment
- Appliances

Number of Units Determined by Population and Employment Growth

Natural Replacement
- Burn-out
- Remodel
- Market Shifts

Number of Units Determined by Equipment Life, Stock Turnover Rates, Consumer Preferences and Obsolescence

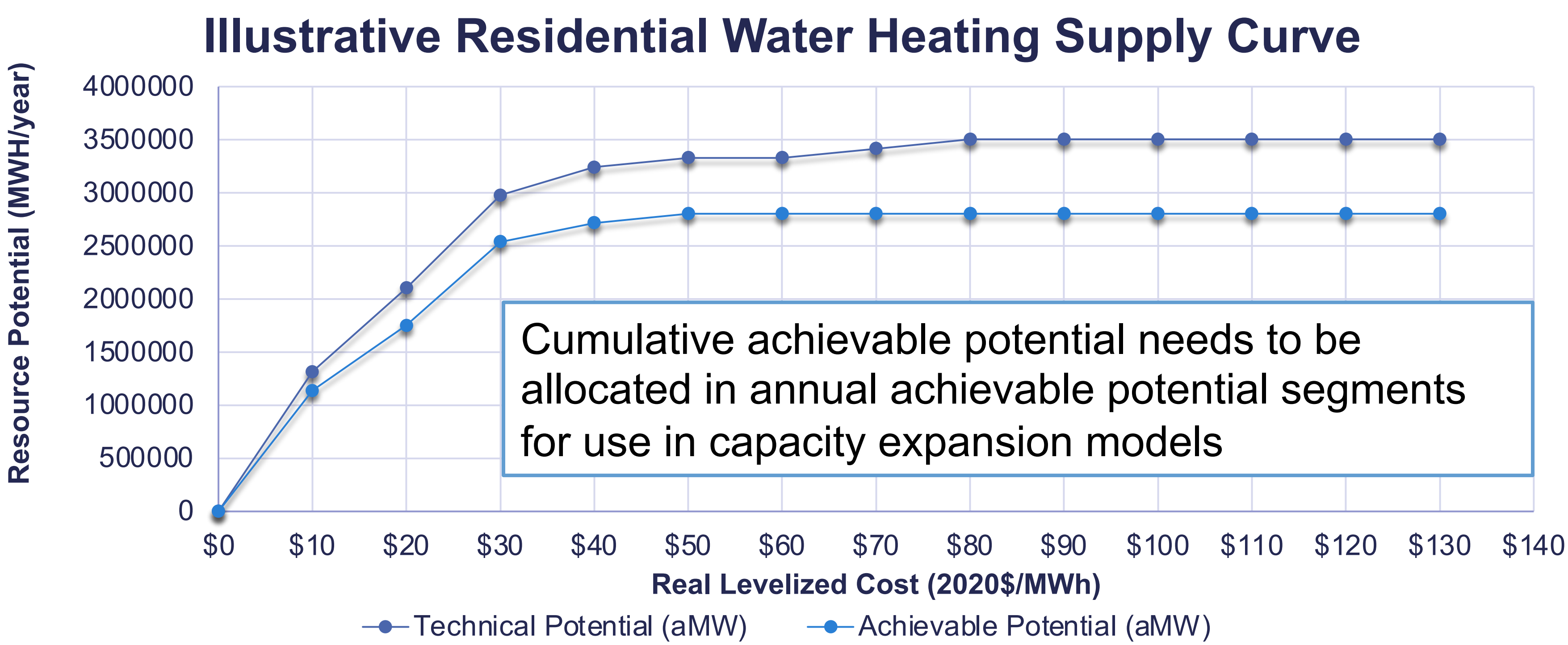
Retrofit
- Remove & Replace
- Remodel/Add-on (insulate existing home)

Number of Units Determined By Portion of Remaining Stock Adopting Efficiency Measure

Savings/Unit x Number of Applicable Units = Technical Potential

Some measures have more than one "life" within a planning period (e.g. lights, TVs, dishwashers). CEM logic and/or supply curve inputs should reflect the potential to "acquire" these measure's savings at multiple times in the planning period.

Cumulative achievable potential provides the maximum quantity of a resource available over a range of costs



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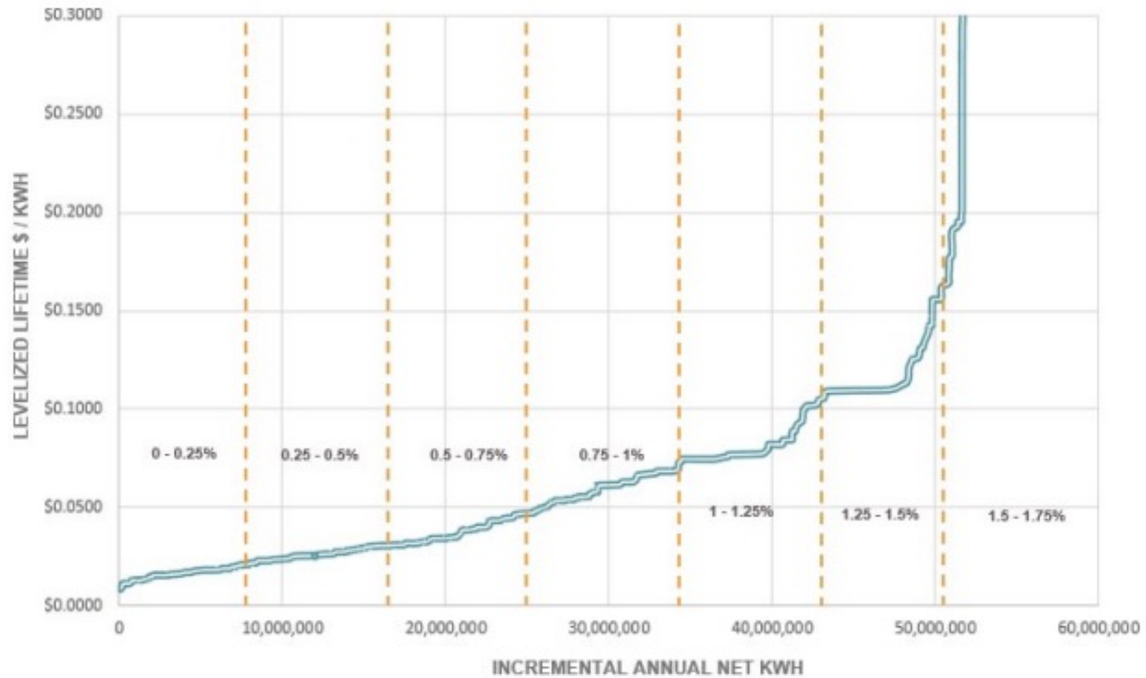
Each bundle should have a cost and load shape representative of the savings weighted cost and load shape of measures included in the bundle.

Vectren 2019-2020 IRP used bundles based on savings percentage, which masks load shapes.

Figure 6-22 – 2024 Supply Curve for Electric Energy Efficiency



Programs may be represented by either single or multiple bundles, depending upon the range of costs and load shapes of the measures in the program

Measure	Interactive Incremental Savings (kWh/yr)	Interactive Levelized Cost ($/MWH)	Share of Savings	Achievable Potential (Units)	Incremental Achievable Potential (MWH/yr.)	Load Shape
Showerhead	139	$ 15	6%	200,000	3,174	DHW
Tank Insulation	112	$ 19	4%	100,000	1,279	DHW
Tank Insulation	143	$ 29	6%	100,000	1,632	DHW
HPWH	1,854	$ 35	73%	85,000	17,990	HPWH
Clothes Washer	37	$ 95	1%	98,000	414	CW
Dishwasher	14	$ 103	1%	98,000	157	DW
Waste Water Heat Recovery	162	$ 175	6%	50,000	925	DHW
Dishwasher	19	$ 199	1%	98,000	213	DW
Clothes Washer	43	$ 302	2%	98,000	481	CW
Total Program	2,523	$ 49	100%		26,263	

Programs may be represented by either single or multiple bundles, depending upon the range of costs and load shapes of the measures in the program

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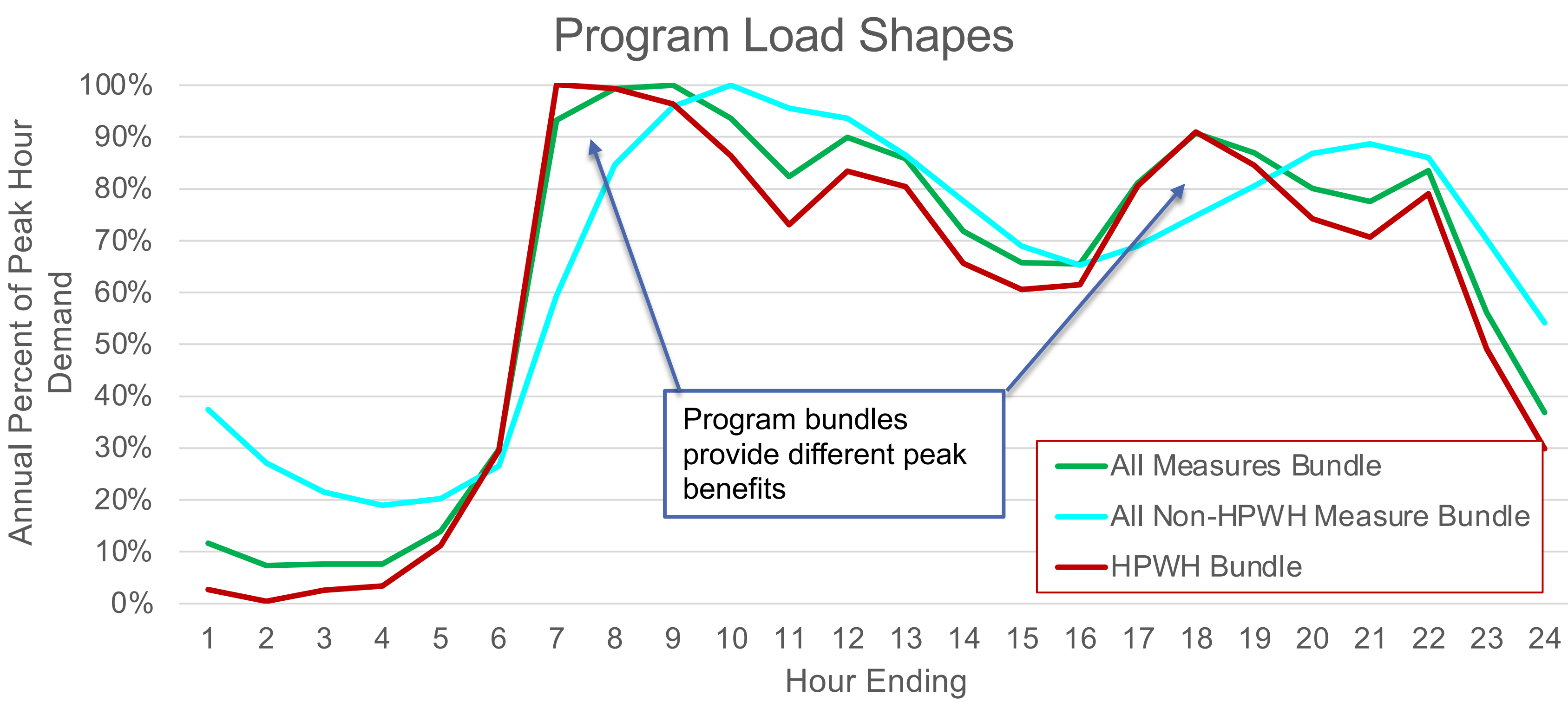
Dishwasher	14	$103	2%	98,000	157	DW
Waste Water Heat Recovery	162	$175	24%	50,000	925	DHW
Dishwasher	19	$199	3%	98,000	213	DW
Clothes Washer	43	$302	6%	98,000	481	CW
Non-HPWH Program	669	$ 87			8,273	
HPWH Program	1,854	$ 35			17,990	

Program bundles may mask costs and/or load shapes



Use of program bundles, while permitting the most direct translation for implementation also masks which measures have load shapes that best meet resource needs (1)

LCOE Methodology (Current)

- Resources are ranked and bundled by their LCOE.
- Consider the measures in the 2019 IRP Utah $60-$70/MWh bundle shown below:
  - Summer capacity contribution ranges from 0% to 86%, average 46%
  - Winter capacity contribution ranges from 0% to 84%, average 40%
  - Load factor ranges from 4% to 84%, average 39%
  - Shaped energy value ranges from $40 to $55/MWh, average $47/MWh
- The characteristics of a sample of measures:

Sample Data from 2019 IRP

Type	$/MWh LCOE	% CC Summer	% CC Winter	% Load Factor	$/MWh Energy Value
Microwave	62.39	40%	44%	19%	54.17
Strategic Energy Management	60.17	47%	27%	35%	47.06
Exterior Lighting - Bi-Level Parking Garage Fixture	65.80	48%	32%	46%	46.11
Advanced New Construction Designs	67.11	34%	30%	38%	43.61
Office Equipment - Advanced Power Strips	68.40	48%	48%	63%	43.17
Exterior Lighting - Enhanced Controls	60.74	36%	38%	48%	42.75
Insulation - Wall Cavity Installation	63.25	17%	32%	13%	50.30
Linear Lighting	63.56	35%	68%	40%	50.00
Doors - Storm and Thermal	62.44	0%	47%	15%	45.24
Space Heating - Heat Recovery Ventilator	62.95	0%	9%	4%	39.82

Note the range of energy and capacity contribution values

- Some $60-$70/MWh measures could be economic even if the entire bundle is not.

92

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Use of program bundles, while permitting the most direct translation for implementation also masks which measures have load shapes that best meet resource needs (2)

Net Cost of Capacity Bundles vs LCOE Bundles

- The figure shows how each LCOE bundle was split into Net Cost of Capacity bundles.
  - Each column sums to 100% of the LCOE bundle volume.
  - Measures in the green box are relatively economic and could now be selected before other bundles.
  - Measures in the red box are relatively uneconomic and could now be selected after other bundles.

2038 Achievable Technical Potential Savings (MWh) % by Original Bundle

LCOE Selection: Mostly Left to Right →→→

Net Cost of Capacity Selection: Top to Bottom, for each season

Sample Data from 2019 IRP

Proposed $/kW-yr	Current LCOE $/MWh <10	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	250	300	400	500	750	>1k
SA. up to -$50	86%	86%	66%	71%	20%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SB. -$50-0	0%	0%	-	0%	34%	1%	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SC. $0-25	0%	0%	0%	0%	27%	4%	0%	1%	1%	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SD. $25-50	0%	0%	0%	3%	3%	6%	4%	0%	0%	0%	0%	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SE. $50-75	0%	-	0%	0%	1%	14%	1%	0%	0%	0%	0%	0%	0%	-	0%	-	-	-	-	-	-	-	-	-	-	-	-
SF. $75-100	0%	-	-	2%	0%	32%	0%	3%	0%	0%	-	0%	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SG. $100-125	0%	-	0%	0%	0%	3%	8%	1%	1%	2%	0%	0%	-	0%	-	-	0%	0%	-	-	-	-	-	-	-	-	-
SH. $125-150	0%	-	-	0%	0%	1%	5%	0%	1%	2%	0%	0%	0%	0%	-	-	-	-	-	-	-	-	-	-	-	-	-
SI. $150-175	0%	-	-	-	0%	2%	17%	2%	0%	1%	0%	1%	-	0%	-	0%	0%	-	-	0%	-	-	-	-	-	-	-
SJ. $175-200	0%	-	0%	0%	0%	13%	2%	3%	0%	1%	3%	1%	0%	0%	0%	-	-	0%	0%	-	-	0%	-	-	-	-	-
SK. $200-250	0%	-	-	0%	0%	5%	14%	9%	4%	0%	1%	5%	1%	1%	0%	0%	4%	-	0%	0%	9%	-	-	-	-	-	-
SL. $250-300	0%	-	-	-	0%	1%	14%	27%	18%	1%	0%	0%	0%	5%	2%	1%	0%	0%	0%	-	10%	-	0%	-	-	-	-
SM. $300-400	0%	-	-	-	0%	5%	7%	26%	26%	27%	2%	1%	3%	26%	62%	1%	16%	7%	1%	2%	0%	0%	0%	1%	-	-	-
SN. $400-500	0%	-	0%	0%	1%	0%	0%	2%	28%	29%	10%	5%	1%	1%	1%	8%	15%	3%	31%	26%	5%	4%	15%	1%	0%	-	-
SO. $500-750	0%	-	0%	0%	2%	1%	0%	0%	3%	22%	44%	19%	18%	23%	5%	5%	4%	22%	7%	16%	15%	23%	3%	4%	6%	3%	-
SP. $750-1000	-	-	-	-	-	-	0%	0%	0%	-	3%	15%	32%	17%	6%	39%	7%	10%	4%	12%	7%	16%	11%	14%	17%	9%	0%
SQ. $1000-9999	-	-	-	-	-	-	-	-	-	-	-	-	4%	1%	1%	0%	11%	19%	19%	20%	19%	30%	13%	50%	43%	51%	85%
WR. up to -$50	14%	14%	33%	23%	1%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WS. -$50-0	-	-	-	0%	6%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WT. $0-25	-	-	-	0%	2%	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WU. $25-50	-	-	-	-	1%	7%	5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WV. $50-100	-	-	-	-	0%	2%	15%	10%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WW. $100-150	-	-	-	-	-	0%	1%	2%	7%	1%	-	3%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WX. $150-200	-	-	-	-	-	1%	0%	1%	5%	6%	1%	1%	-	5%	-	-	-	-	-	-	-	-	-	-	-	-	-
WY. $200-300	-	-	-	-	-	1%	2%	5%	3%	1%	28%	10%	17%	1%	2%	9%	2%	-	-	-	-	-	-	-	-	-	-
WZ. $300-1000	-	-	-	-	0%	0%	3%	8%	2%	7%	8%	38%	25%	20%	21%	34%	38%	37%	38%	22%	35%	22%	47%	0%	-	-	-
WZZ. $1000-9999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3%	2%	3%	0%	1%	1%	4%	11%	28%	34%	36%	15%

Sample Data from 2019 IRP

Number of bundles used to represent efficiency is likely constrained by model run time (1)

- More bundles present more "optimization" combinations to test.
- To reduce the number of bundles, all measures that have a levelized cost per kilowatt-hour below the present value of *system lambda** for their load shape can be combined into an individual cost bundle for each load shape.
  - This approach assumes that a CEM will always "acquire" all energy efficiency that has a cost below the present value of its annual energy savings based on "system lambda."

System lambda = the dispatch cost of the "marginal generator" (the plant used to meet the last MWh of demand for each hour)

Number of bundles used to represent efficiency is likely constrained by model run time (2)

Energy Efficiency Bundling Background

- In the past, energy efficiency measures have been grouped into 27 bundles per state by levelized cost of energy. Sample data (not final Conservation Potential Assessment) is used throughout this section:

Levelized Volume (aMW), by Levelized Cost of Energy ($/MWH) — *Bundles not selected* (columns $1000-9999 through $90-100) / **Cost Bundles Selected in 2019 IRP Pref. Port.** (columns $80-90 through up to $10)

	$1000-9999	$750-1000	$500-750	$400-500	$300-400	$250-300	$200-250	$190-200	$180-190	$170-180	$160-170	$150-160	$140-150	$130-140
CA	1	0	0	0	0	0	1	0	0.0	0	0	0	0	0
ID	4	1	0	0	1	1	1	0	0	0	0	0	0	1
WA	3	1	2	2	2	2	2	1	1	0	1	2	1	0
WY	2	1	1	0	1	1	2	0	0	0	1	0	1	0

	$120-130	$110-120	$100-110	$90-100	$80-90	$70-80	$60-70	$50-60	$40-50	$30-40	$20-30	$10-20	up to $10
CA	0	0	0	0	0	0	0	1	0	0	0	0	0
ID	0	0	0	1	1	1	1	1	1	2	1	1	5
WA	1	2	1	1	1	5	2	3	3	3	3	4	9
WY	1	2	1	5	1	1	2	4	4	3	7	10	38

Breaking out lots of high cost bundles doesn't add modeling value if none of them get picked.

Bundle sizing in $10/MWh increments leaves lots bundles with small volumes between $100-$200/MWh.

Breaking out lots of low cost bundles doesn't add modeling value if they always get picked.

- Conclusion: there are more bundles than are necessary for modeling levelized cost of energy.
- Is there another metric we can use to differentiate measures with desirable characteristics?

30 POWERING YOUR GREATNESS

Acquisition rules for the pace of acquisition

- Maximum Retrofit Pace Constraint:
  - Resource optimization models will “build” (i.e., replace all existing lamps in a single year) all retrofit EE and other DERs with cost below the marginal dispatch of existing generating resources at first opportunity – unless constrained
  - Real-world infrastructure limits maximum annual retrofit development constraints on the annual acquisition of retrofit EE and DERs must be set in the model. Limits may be grown through time or fixed for 20-yrs (i.e., assumes delivery infrastructure never expands)

- Lost Opportunity “Found Again” Acquisition Logic
  - Some lost-opportunity resources present more than one acquisition “opportunity” (e.g. water heaters are replaced on average every 12 years)
  - Due either to their high cost or, more likely constraints on their maximum achievable ramp rate these resource might not be selected when they first occur
  - Acquisition logic should permit savings that is not “acquired” at the first opportunity, be considered for acquisition at next opportunity, if it occurs within planning period.

Acquisition rules for low and high cost measures

- When efficiency supply curves are organized into "bundles" capacity expansion models will "acquire" the lowest to highest cost measures through time.
  - Real world programs (with multiple measures) don't acquire only the lowest cost measures first.
  - Reviewing CEM results can provide insights on the scope of measures to include in programs, which may vary through time.

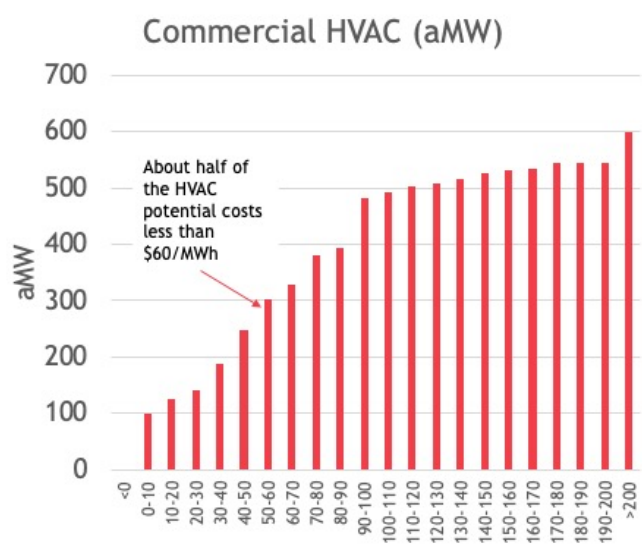
One option is to create multiple “program-like” cost bundles which meld groups of low and higher cost measures with similar load shapes

DRAFT

Commercial HVAC

Measure Category	Achievable Potential
ARC	27
Chiller-System	10
Chiller-Upgrade	8
CircPumps*	12
Commercial EM	45
Com-PTHP	17
ConnectedThermostats	14
DHP*	63
Fans	152
HeatPumps*	6
UnitaryAC*	32
VHE-DOAS	79
DCV	14
VRF-DOAS	38
Secondary Glazing Systems*	82
Grand Total	599

*Includes high cost measures (i.e., >$100/MWh)

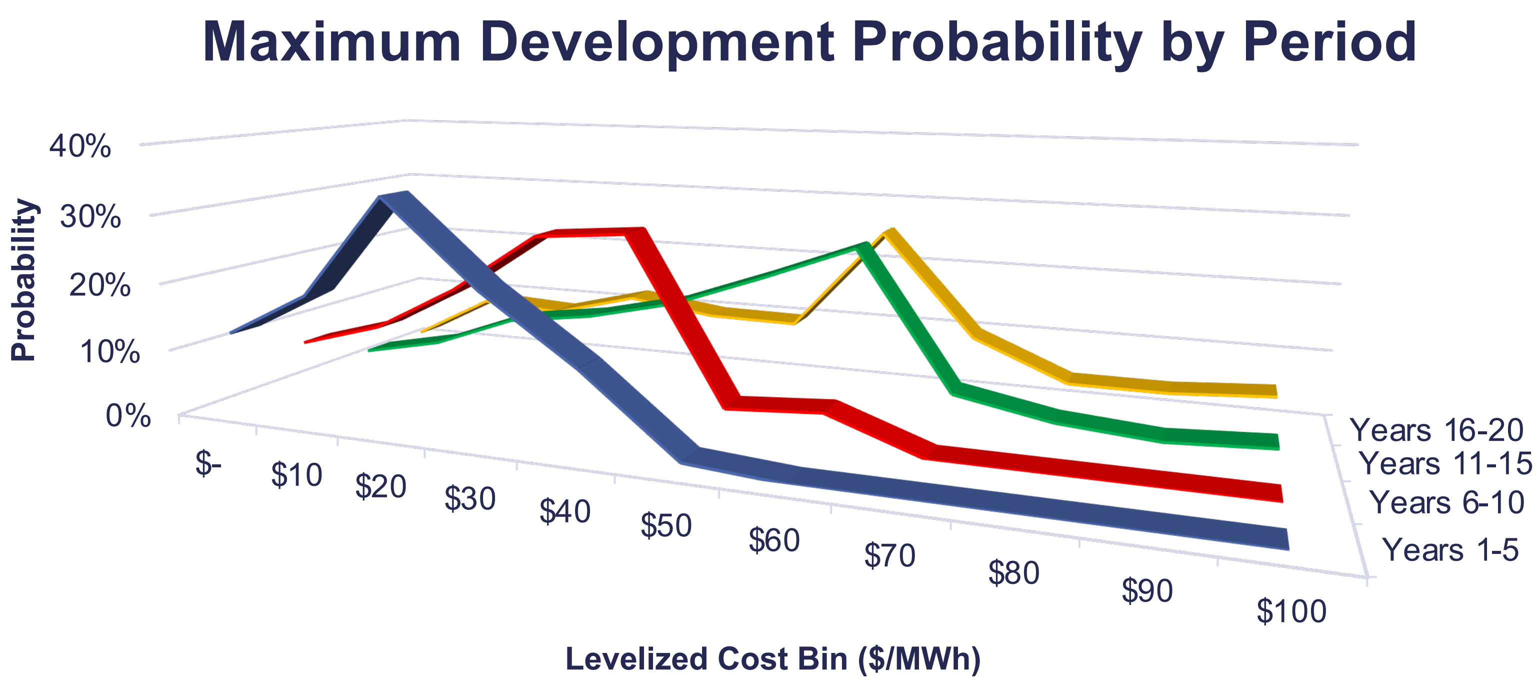


THE 2021 NORTHWEST POWER PLAN

17

Source: NWPCC March 2020

Another option is to add acquisition logic to the capacity expansion models so that it must select across a range of cost based on a probability distribution.



Agenda

- Introduction
- Review
- Use of gross or net Savings (and cost) in capacity expansion modeling
- Key characteristics of efficiency bundles
- Considerations for using programs to create efficiency bundles
- **Considerations for translating IRP results into efficiency programs**
- Examples of bundling approach results

Unless "programs" are explicitly modeled in a CEM, the model's results only provide guidance on the timing and amount of efficiency that is cost-effective to develop.

- Measure level cost-effectiveness may not be (or need to be) known

Measure	Interactive Incremental Savings (kWh/yr)	Interactive Levelized Cost ($/MWH)	Share of Savings	Achievable Potential (Units)	Incremental Achievable Potential (MWH/yr.)	Load Shape
Showerhead	139	$ 15	6%	200,000	3,174	DHW
Tank Insulation	112	$ 19	4%	100,000	1,279	DHW
Tank Insulation	143	$ 29	6%	100,000	1,632	DHW
HPWH	1,854	$ 35	73%	85,000	17,990	HPWH
Clothes Washer	37	$ 95	1%	98,000	414	CW
Dishwasher	14	$ 103	1%	98,000	157	DW
Waste Water Heat Recovery	162	$ 175	6%	50,000	925	DHW
Dishwasher	19	$ 199	1%	98,000	213	DW
Clothes Washer	43	$ 302	2%	98,000	481	CW
Total Program	2,523	$ 49	100%		26,263	

Bundles (whether grouped by costs or load shapes) selected for acquisition by the CEM may not include measures from all sectors or may be “disproportionately” represented by one sector.

Residential Cost Based Bundles

Bundle Number	Number of Measures	Total Potential (MWh)	Weighted Avg. Levelized Cost ($/MWh)	Mean Levelized Cost ($/MWh)	Range of Levelized Cost ($/MWh)
13	21	2,293	$10	$8	$0-$15
0	27	23,844	$27	$25	$17-$35
6	52	21,525	$44	$46	$36-$54
9	34	10,016	$68	$65	$56-$82
4	36	16,439	$98	$104	$104-$115
10	15	32,211	$132	$134	$125-$151
2	11	21,696	$165	$170	$160-$184
11	18	8,910	$198	$198	$185-$210
7	9	5,693	$228	$230	$222-$233
12	14	54,813	$284	$282	$266-$288
1	26	19,274	$303	$302	$293-$316
14	13	23,336	$334	$332	$318-$350
8	17	19,967	$380	$381	$364-$399
3	13	9,731	$419	$423	$402-$440
5	10	4,849	$485	$483	$464-$499

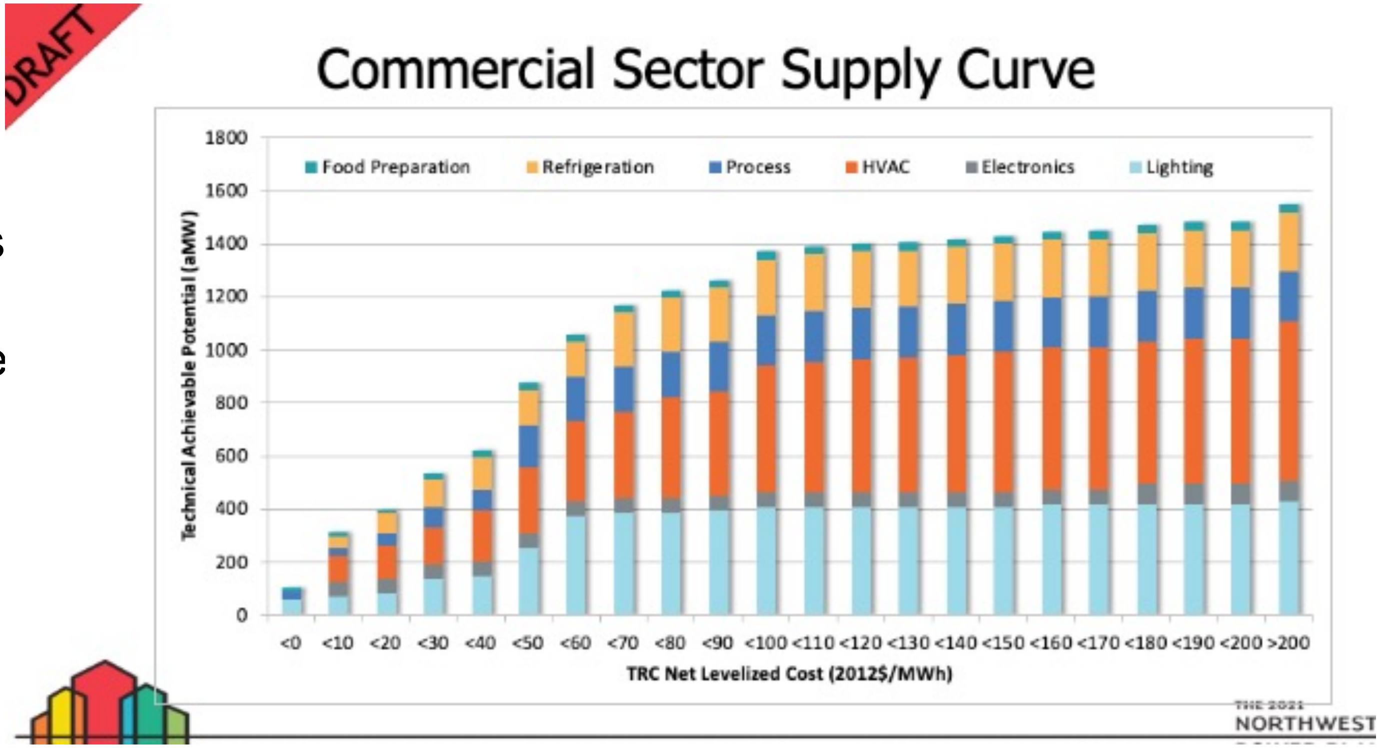
Commercial Cost Based Bundles

Bundle Number	Number of Measures	Total Potential (MWh)	Weighted Avg. Levelized Cost ($/MWh)	Mean Levelized Cost ($/MWh)	Range of Levelized Cost ($/MWh)
8	344	56,631	7	6	$0-$13
2	453	149,882	20	21	$14-$29
14	225	31,817	36	37	$29-$45
5	146	33,509	55	54	$46-$62
6	139	14,604	70	71	$63-$80
13	89	58,291	87	91	$81-$104
0	110	25,676	117	118	$106-$136
10	73	16,545	153	154	$136-$173
4	128	17,543	194	194	$176-$207
11	93	78,377	215	220	$208-$240
1	110	11,631	263	262	$241-$283
9	46	8,854	301	305	$285-$331
3	52	5,956	365	364	$336-$383
12	20	5,358	396	402	$385-$422
7	36	3,799	456	458	$430-$497

Source: Georgia Power 2021

CEM results can be used as a proxy for the "avoided cost" by load shape.

- Cost-effective programs can be designed by selecting measures with load shapes and costs that were selected for acquisition by the CEM.



Source: NWPCC March 2020

Agenda

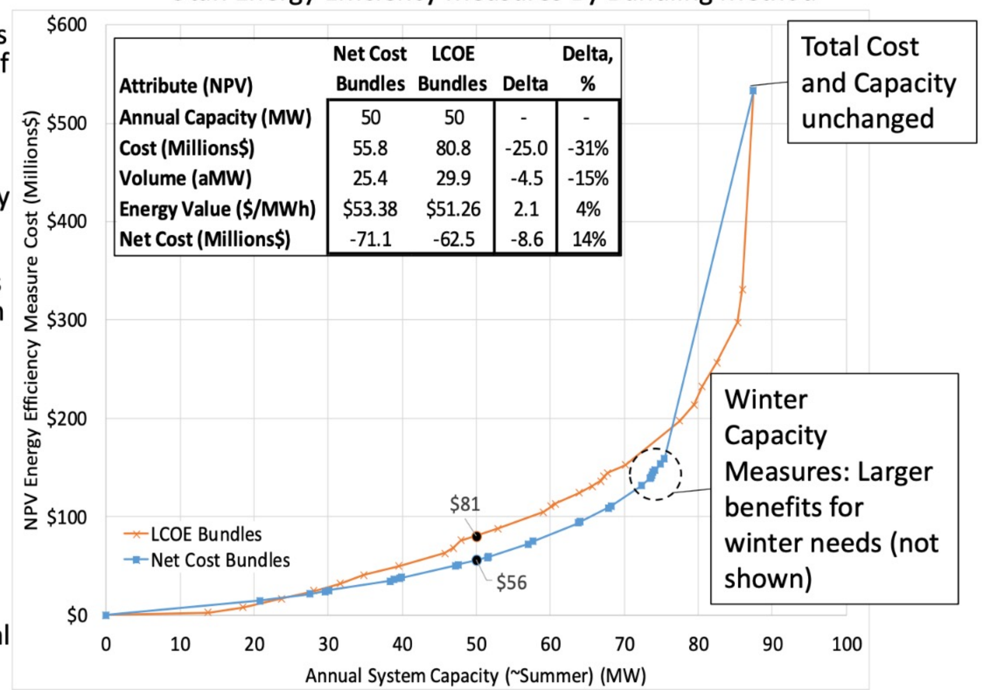
- Introduction
- Review
- Something about freeridership
- Key characteristics of efficiency bundles
- Considerations for using programs to create efficiency bundles
- Considerations for translating IRP results into efficiency programs
- **Examples of bundling approach results**

Different bundling approaches result in different quantities of efficiency available to, and selected by the model

Energy Efficiency: Why Rebundle?

- Utah EE measures provide 50 MW of capacity at 31% lower cost after rebundling.
- Rebundled energy volume is lower, but estimated value per MWh is higher at medium gas / medium GHG power prices.
- Net cost of rebundled EE is $8.6M lower.
- Targeting winter or weather measures could provide additional value.

Utah Energy Efficiency Measures By Bundling Method



Attribute (NPV)	Net Cost Bundles	LCOE Bundles	Delta	Delta, %
Annual Capacity (MW)	50	50	-	-
Cost (Millions$)	55.8	80.8	-25.0	-31%
Volume (aMW)	25.4	29.9	-4.5	-15%
Energy Value ($/MWh)	$53.38	$51.26	2.1	4%
Net Cost (Millions$)	-71.1	-62.5	-8.6	14%

- 50 MW capacity is representative, model will select volumes and timing of each bundle.

26

POWERING YOUR GREATNESS

Bundling improvement opportunity

"There are a range of capacity values embedded within each LCOE bundle – an opportunity for a more targeted approach."

Energy Efficiency: LCOE vs Net Cost

27 LCOE Bundles ($/MWh)

Net Cost of Annual (~Summer) Capacity ($/kw-yr)

↓$/kw-yr \ $/MWh-->	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	250	300	400	500	750	1000	9999	Total
<-100	26%	7.0%	3.9%	1.0%	-	-	-	-	-	-	-								-	-	-	-	-	-	-	-	-	38%
-100--75	0.9%	1.3%	1.8%	0.2%	-	-	-	-	-	-	-								-	-								4%
-75--50	0.2%	0.2%	2.6%	0.4%	0.0%	-	-	-	-	-	-								-	-								3%
-50--25	-	0.0%	0.9%	0.9%	0.6%	-	-	-	-	-	-								-	-								2%
-25-0	-	-	0.1%	1.8%	0.3%	0.2%	0.2%	-	-	-	-								-	-								3%
0-25	-	-	0.0%	0.9%	0.6%	0.2%	1.1%	1.8%	0.0%	-	-	-	-	-	-	-	-	-	-	-								5%
25-50	-	-	-	0.4%	0.3%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	-	-	-	-	-	-	-	-	-								1%
50-75	-	-	-	0.1%	0.5%	0.2%	0.2%	0.1%	-	0.0%	1.6%	1.0%	-	-	-	-	-	-	-	-								4%
75-100	-	-	-	0.0%	0.5%	0.7%	0.1%	0.2%	0.0%	-	0.0%	1.0%	0.0%	0.1%	-	-	-	-	-	-								2%
100-125	-	-	-	0.1%	0.8%	0.4%	0.0%	0.0%	0.0%	-	-	-	0.1%	0.1%	1.0%	0.2%	-	-	-	-								3%
125-150	-	-	0.0%	-	0.3%	1.2%	0.1%	0.1%	0.0%	0.0%	0.0%	-	-	-	-	0.3%	0.0%	-	-	-								2%
150-175	-	-	-	-	0.2%	0.4%	0.1%	0.0%	0.0%	-	0.1%	0.0%	-	-	-	0.0%	0.3%	0.0%	0.0%	0.2%								1%
175-200	-	-	-	-	0.0%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.2%	0.0%	-	0.0%	-	-	-	0.1%	0.8%	0.8%	-	-	-	-	-	-	2%
200-225	-	-	-	-	0.1%	0.5%	0.3%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	-	-	-	-	-	-	0.0%	-	-	-	-	-	-	1%
225-250	-	-	-	-	0.0%	0.0%	0.2%	0.2%	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	-	-	0.0%	-	-	0.8%	-	-	-	-	-	-	1%
250-275	-	-	-	-	0.1%	-	0.0%	0.2%	0.2%	0.0%	0.0%	-	0.0%	0.0%	0.0%	0.0%	-	-	-	-	0.3%	0.0%	-	-	-	-	-	1%
275-300	-	-	-	-	-	0.0%	0.5%	0.1%	0.1%	-	0.0%	-	0.0%	0.0%	-	0.0%	0.0%	0.0%	-	-	-	0.0%	-	-	-	-	-	1%
300-325					-	0.0%	0.3%	0.3%	0.1%	-	0.0%	0.1%	-	0.0%	-	0.0%	-	-	-	-	-	0.1%	-	-	-	-	-	1%
325-350					-	0.0%	0.3%	0.2%	0.3%	0.4%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.3%	0.0%	-	-	-	0.3%	0.2%	-	-	-	-	2%
350-375					0.0%	0.0%	0.2%	0.7%	0.0%	0.2%	0.1%	0.0%	0.0%	-	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	0.0%	-	-	-	-	1%
375-400					-	-	0.0%	0.2%	0.1%	0.0%	-	0.1%	0.0%	0.1%	0.6%	-	-	0.0%	0.0%	-	-	-	0.1%	-	-	-	-	1%
400-425					-	0.2%	0.0%	0.0%	0.0%	0.3%	0.0%	0.1%	0.0%	0.0%	-	-	-	0.0%	-	-	0.2%	0.0%	0.2%	-	-	-	-	1%
425-450				0%	-	-	-	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	0.0%	0.0%	0.0%	0.0%	0.0%	-	-	-	0.0%	-	-	-	-	0%
450-475					-	-	-	-	0.1%	0.0%	0.2%	0.0%	0.0%	0.1%	-	0.0%	-	-	-	0.0%	0.3%	-	0.1%	-	-	-	-	1%
475-500					-	-	-	0.0%	0.1%	0.3%	0.4%	0.1%	-	-	-	0.0%	-	-	0.0%	-	0.1%	-	-	-	-	-	-	1%
500-525				0%	-	-	0.0%	0.0%	-	0.0%	0.0%	0.0%	-	-	-	0.0%	-	-	-	-	0.1%	0.1%	-	0.1%	-	-	-	0%
525-550					-	-	-	0.0%	-	-	0.1%	0.2%	0.2%	-	0.0%	0.0%	-	-	0.2%	-	0.0%	0.0%	-	0.0%	-	-	-	1%
550-575					-	-	0.0%	-	-	-	0.0%	0.3%	0.0%	-	-	0.0%	-	-	-	-	0.1%	0.0%	-	0.0%	-	-	-	1%
575-600	-	-	-	-	-	-	-	-	0.0%	-	0.1%	0.0%	0.0%	-	-	0.0%	0.0%	0.0%	-	0.0%	0.1%	0.0%	0.0%	-	0.0%	-	-	0%
600+	-	-	-	-	0.0%	-	0.0%	0.0%	0.2%	0.7%	0.1%	0.6%	0.5%	0.1%	0.3%	0.4%	0.2%	0.6%	0.2%	0.1%	2.3%	0.9%	0.9%	1.3%	1.8%	1.0%	2.2%	14%
Total	27%	8.5%	9.3%	5.9%	4.1%	4.0%	3.8%	4.4%	1.5%	2.1%	3.0%	3.8%	1.2%	0.5%	1.9%	1.1%	0.8%	0.7%	0.6%	1.0%	5.1%	1.5%	1.5%	1.4%	1.8%	1.0%	2.2%	100%

High value EE in $80/MWh bundle

38% of Utah EE MWh have a net cost less than -$100/kw-yr, with LCOE cost up to $40/MWh

Low value EE in $80 /MWh bundle

Use cost as primary metric to create bundles…

Residential Cost Based Bundles

Bundle Number	Number of Measures	Total Potential (MWh)	Weighted Avg. Levelized Cost ($/MWh)	Mean Levelized Cost ($/MWh)	Range of Levelized Cost ($/MWh)
13	21	2,293	$10	$8	$0-$15
0	27	23,844	$27	$25	$17-$35
6	52	21,525	$44	$46	$36-$54
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4	36	16,439	$98	$104	$104-$115
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7	9	5,693	$228	$230	$222-$233
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1	26	19,274	$303	$302	$293-$316
14	13	23,336	$334	$332	$318-$350
8	17	19,967	$380	$381	$364-$399
3	13	9,731	$419	$423	$402-$440
5	10	4,849	$485	$483	$464-$499

Commercial Cost Based Bundles

Bundle Number	Number of Measures	Total Potential (MWh)	Weighted Avg. Levelized Cost ($/MWh)	Mean Levelized Cost ($/MWh)	Range of Levelized Cost ($/MWh)
8	344	56,631	7	6	$0-$13
2	453	149,882	20	21	$14-$29
14	225	31,817	36	37	$29-$45
5	146	33,509	55	54	$46-$62
6	139	14,604	70	71	$63-$80
13	89	58,291	87	91	$81-$104
0	110	25,676	117	118	$106-$136
10	73	16,545	153	154	$136-$173
4	128	17,543	194	194	$176-$207
11	93	78,377	215	220	$208-$240
1	110	11,631	263	262	$241-$283
9	46	8,854	301	305	$285-$331
3	52	5,956	365	364	$336-$383
12	20	5,358	396	402	$385-$422
7	36	3,799	456	458	$430-$497

Source: Georgia Power 2021

…Or load shapes?

Residential Load Shape-Based Bundles

Bundle Number	Number of Measures	Total Potential (MWh)	Weighted Avg. Levelized Cost ($/MWh)	Mean Levelized Cost ($/MWh)	Range of Levelized Cost ($/MWh)
8	42	25,168	$51	$28	$0-$131
3	34	14,082	$64	$67	$22-$109
4	58	25,445	$103	$95	$24-$370
0	44	46,553	$129	$67	$38-$163
2	39	30,740	$149	$150	$39-$231
12	12	5,892	$219	$286	$200-$306
6	10	1,445	$271	$278	$232-$397
7	6	17,779	$295	$301	$281-$326
5	27	34,517	$305	$307	$272-$364
9	18	58,511	$325	$351	$184-$499
1	3	5,082	$395	$407	$338-$473
11	22	6,578	$428	$431	$369-$492
10	1	2,804	$485	$485	$485-$485

Commercial Load Shape-Based Bundles

Bundle Number	Number of Measures	Total Potential (MWh)	Weighted Avg. Levelized Cost ($/MWh)	Mean Levelized Cost ($/MWh)	Range of Levelized Cost ($/MWh)
21	2	21	0	0	$0-$0
11	2	8	0	0	$0-$0
14	1	1	0	0	$0-$0
4	343	87,593	16	17	$0-$43
19	323	32,363	18	18	$0-$49
2	160	97,414	20	19	$0-$43
9	157	12,452	22	30	$0-$73
13	183	30,355	54	57	$36-$87
10	34	2,700	59	39	$18-$128
18	3	46	78	56	$0-$167
0	150	76,169	78	74	$48-$130
16	89	10,862	118	117	$75-$167
3	107	31,497	122	121	$89-$160
20	1	0	195	195	$195-$195
15	23	376	200	228	$142-$361
5	101	43,549	205	197	$159-$240
8	95	55,907	212	200	$139-$231
17	47	5,139	246	223	$173-$277
1	112	10,863	272	270	$243-$326
12	42	7,142	309	332	$286-$387
7	42	7,781	378	376	$330-$461
6	47	6,234	432	442	$387-$497

Source: Georgia Power 2021

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U.S. DEPARTMENT OF ENERGY

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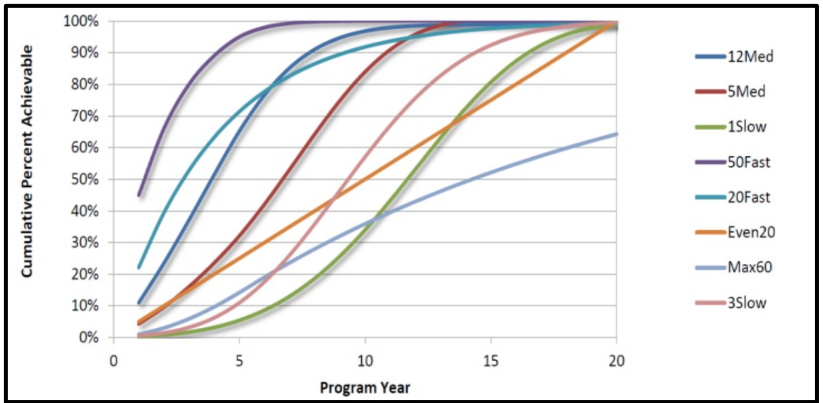
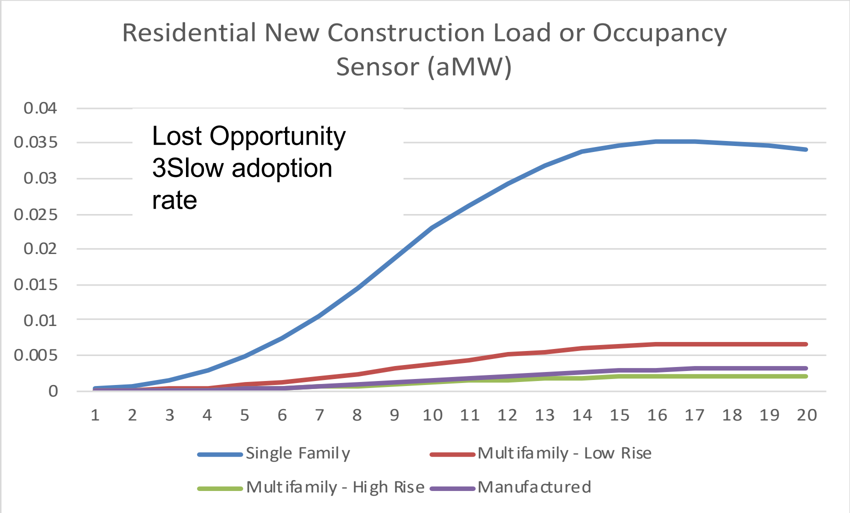
Questions?

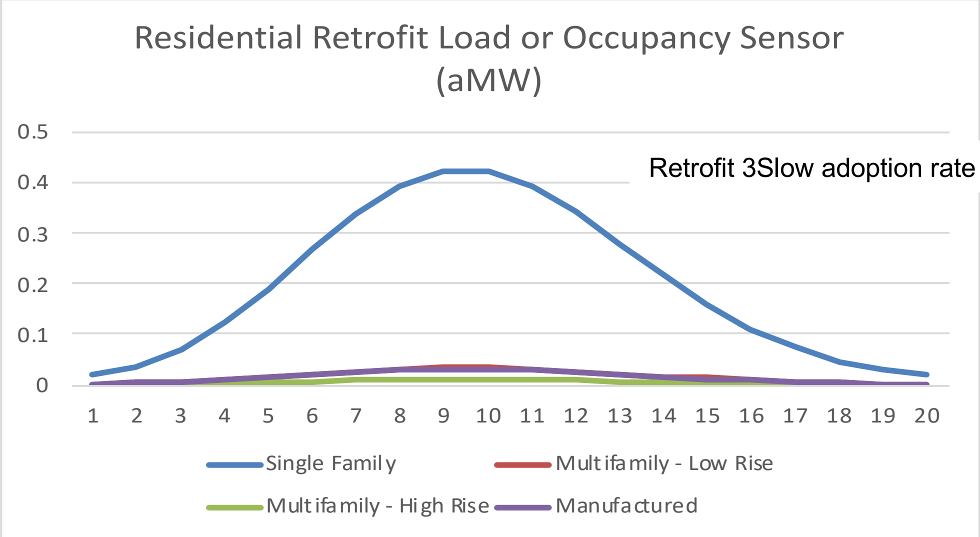
Appendix

Ramp rates influence bundle cost and timing of the savings available.



Maximum Ramp Rates





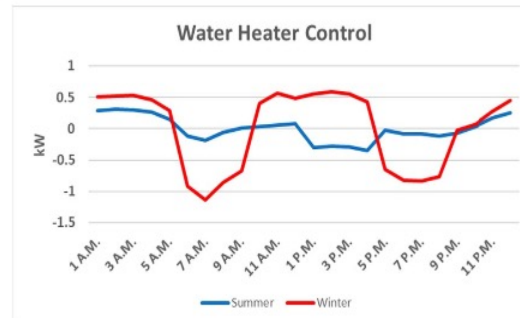
Source: NWPCC Baseline EE Curves 2020, NWPCC 7th Power Plan

Maximum adoption constraints prevent the model from selecting all low-cost resources in the first year

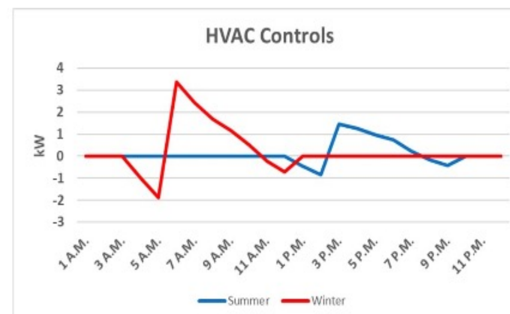
- Maximum Retrofit Pace Constraint:
  - Resource optimization models will "build") all retrofit EE and other DERs with cost below the marginal dispatch of existing generating resources at first opportunity – unless constrained
  - Real-world infrastructure limits maximum annual retrofit development constraints on the annual acquisition of retrofit EE and DERs must be set in the model. Limits may be grow through time or fixed for 20-yrs (i.e., assumes delivery infrastructure never expands)

2019 IRP Programs – Residential DR

- Hypothetical water heater control program modeled (top graph)
- Hypothetical HVAC control program included as a selectable option (lower graph)



Residential DR	Water Heater	HVAC Controls
Max Cumulative Installations	100,000	400,000
Annual Incentive Cost/Unit	$50	$60
Upfront Equipment Cost/Unit	$120	$45
Annual Incentive Cost	$5,000,000	$24,000,000



INTEGRATED Resource Plan 2019 | 116