Improving the Representation of DERs in Indiana Utility Integrated Resource Planning

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Study context

Indiana IRP process

- The integrated resource planning (IRP) process in Indiana seeks for "continual improvement" in the representation of supply and demand resources.
- The IRP process is used in Indiana to inform policy for distributed energy resources (DERs), as well as to identify future energy and capacity requirements where DERs are likely to provide value.
- The Indiana Utility Regulatory Commission (IURC) holds an annual technical conference to identify and discuss cutting-edge resource planning issues.

Regional and national trends

- Most states have IRP requirements and many state regulators require utilities to consider at least one type of DER in long-term planning.
- Future changes to grid resource mixes (e.g., increasing storage, renewables, and electrification) suggest impacts on hourly energy costs.
- DER deployment continues to grow and with increasing interest in flexible loads that can respond to grid needs.
- Increased awareness of distribution system planning and desire to inform IRP (and vice-versa).

Motivation and high-level considerations

- Continued IRP improvement should consider a combination of approaches and awareness of each approach's strengths and weaknesses.
- We focused on "first-order" assessments of what DER and system characteristics are likely to matter for Indiana's planning decisions.
- Outcome is a prioritization of what matters for endogenous modeling of DERs in utility planning and resource valuation models. Accordingly, we do not make recommendations on *how* to implement the approaches within the constraints of utility IRP models.
- We recognize there are many important utility-specific nuances that might impact the precision of our results.

Approach

Current DER representations and literature review

- What are the current approaches in Indiana and other states/regions and where might improvements be made?

→

Data collection

- What are the DER and system characteristics taken into account?

→

Marginal system value analysis

- What are the DER features with the highest and lowest likely system value and should be prioritized for IRP modeling?

Primary methods for assessing DER resource size and value (from Eckman et al., 2020[1])

- **System capacity expansion and market models**
  - *Most prevalent practice* –Reducing the growth rate of energy and/or peak demand in load forecasts input into the model, then let it optimize the type, amount, and schedule of new conventional resources (generation, transmission or distribution)
  - *Less prevalent practice* -Directly competing distributed energy resources (DERs) with conventional resources in the model to determine DERs' impact on existing system loads, load growth, and load shape—and thus dispatch of existing resources—and the type, amount, and timing of conventional resource development
  - Also used for utility-scale resource options analysis
- **Competitive bidding processes/auctions:**
  - Use "market mechanisms" to select new DERs, currently limited to energy efficiency (EE) and demand response (DR)
  - Also used for utility-scale resource options analysis
- **Proxy resources:** Use the cost of a resource that provides grid services (e.g., a new natural gas-fired simple-cycle combustion turbine to provide peaking capacity) to establish the cost-effectiveness of DERs (i.e., determine the amount to develop) that provide these same grid services
- **Administrative/public policy determinations**: Use legislative or regulatory processes to establish development goals (e.g., Renewable Portfolio Standards and Energy Efficiency Resource Standards)

[1] Eckman et al., 2020. Economic Valuation of Energy Resources:*Technical Assistance Opportunity for States on Enhanced Methods to Assess Utility System Value of Demand Flexibility.* Available at: https://emp.lbl.gov/publications/economic-valuation-energy-resources

Segmenting approach by DER type: Demand response

Context

- The current modeling of DR in Indiana IRPs appears acceptable, though in the context of seeking "continual improvement."

Approach

- Literature review of DR modeling improvements for future reference (see Appendix A).

Segmenting approach by DER type: Distributed generation (DG)

Context

- Current DG deployment is very small for most utilities and any noticeable impacts will primarily occur on distribution system with secondary value captured through the IRP.
- One of the most important pre-requisites to modeling DG is forecasting, which is common to both distribution system planning and IRP.

Approach

- Literature review of DG forecasts for Indiana and references for further information on DG forecasting (see Appendix B).

Segmenting approach by DER type: Energy efficiency

Context

- EE has considerable historical experience in Indiana and the IRP serves as a key determinant in the amount of cost-effective, ratepayer-funded EE administered by the Indiana utilities.
- The IURC staff seeks to improve the analytical approach for EE by representing its time-based value.
- Furthermore, the State Utility Forecasting Group (SUFG) represents EE endogenously in its dispatch models but could benefit from a prioritized list of EE measures and technologies due to computational requirements of modeling numerous distinct EE measures.

Approach

- Marginal value assessment (i.e., “price-taking” approach) to identify EE measures and technologies with highest marginal value.
- Compare across Indiana utilities and different future grid scenarios.

Current EE Representation in IRPs

	Duke 2018 IRP (July 2019)	Indiana and Michigan Power 2018-19 IRP (July 2019)	IPL 2019 IRP (December 2019)	2018 NIPSCO IRP (October 2018)	2019-2020 Vectren IRP (June 2020)
Competitive resource or load decrement?	Competitive resource	Existing program impacts included in load forecast; incremental programs modeled as non-dispatchable resource	Load decrement	New resource in portfolio optimization (non-dispatchable resource)	Competitive resource
EE measure characterization	Measures grouped into bundles and then across different participation levels; levelized bundle cost	Measures with highest achievable potential from market potential study grouped into bundles; levelized bundle cost	Load shape and levelized costs from achievable potential and grouped into bundles with similar total load reduction (0.25%)	Measures grouped in bundles by cost of lifetime saved energy; incentive cost per lifetime kWh	Realistic achievable potential estimates grouped into bundles with similar load reduction (0.25%) and additional savings and cost adjustments; low-income bundle savings assumed in all scenarios, in all time periods
Hourly EE impacts?	Yes	Yes, based on Plexos implementation	Yes	Uncertain	Yes
Change in EE impacts over time?	Duration of savings increases in later years	No	No	No	Change in costs

Marginal value approach

There is no single utility system economic value of EE and it is instead a function of:

- Timing of savings
- Location in the grid
- Grid services provided
- Expected service life
- Avoided costs

(list adapted from Eckman et al., 2020.)

- "Price-taking" based on **P x Q** in each hour
  - where P is a price representing some set of marginal utility costs (e.g., equilibrium market price, utility system lambda)
  - where Q is the quantity of DER "production" (behind-the-meter load reduction)
- Strengths
  - Can represent the time-dependent value of DERs
  - Simple to execute compared to dispatch model runs
  - Inputs are *relatively* easy to obtain
- Weaknesses
  - Includes only a subset of DER value streams for utility (e.g., typically includes energy value but excludes distribution/locational value)
  - Does not iteratively "build out" cost-effective DER resources
- Recommended interpretation of results
  - Prioritizing the types of DERs (e.g., EE measures) likely to provide greatest system value
  - Identifying system conditions that drive higher or lower DER value

Utility data summary

- LBNL sent a data request to the Indiana investor-owned utilities (IOUs) seeking information on hourly EE savings shapes and system costs (see data request in Appendix C).
  - All five IOUs responded to the data request and provided responses for all questions.
  - All but one IOU provided hourly EE savings shapes.
  - All IOUs provided descriptions of measures/technologies and one assumed future changes.
- LBNL normalized the data and calculate seasonal averages.
- LBNL also aggregated and grouped EE measures into consistent residential and commercial program types/categories.

Grid scenario definitions: 2020 and 2030 comparisons

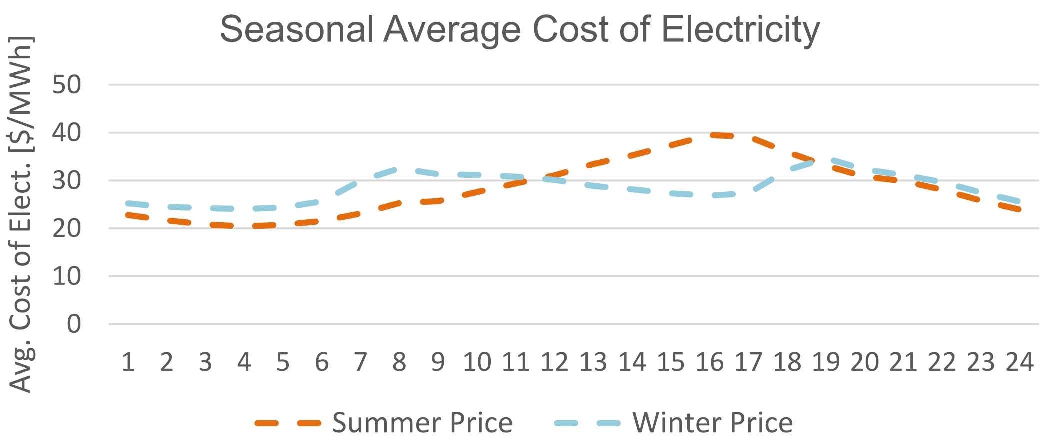
- **Indiana Utility Reference**: Based on Indiana utility-specific IRP hourly EE impacts, load, and cost projections provided in the data request.

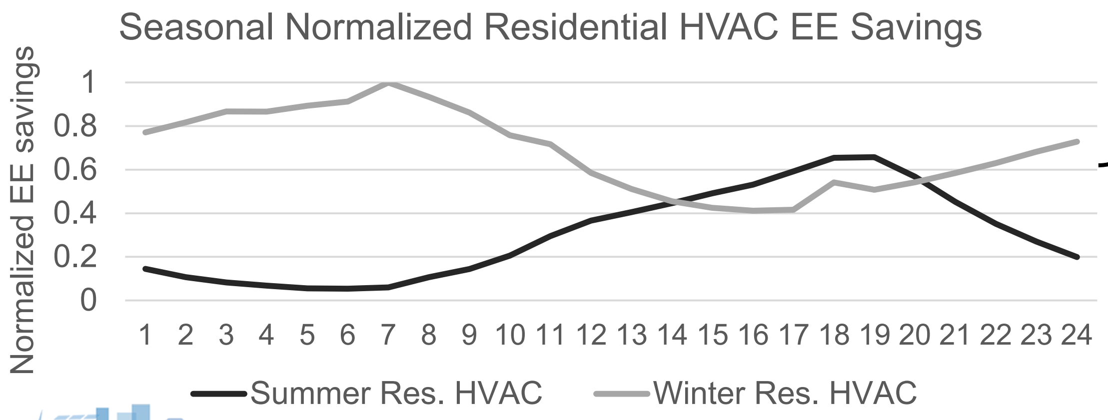
- **NREL Mid-Case**: Based on NREL Standard Scenarios* reference case assumptions for Balancing Authority-specific hourly load, energy, and capacity cost projections for a base case scenario; hourly EE impacts from Indiana utility data request.

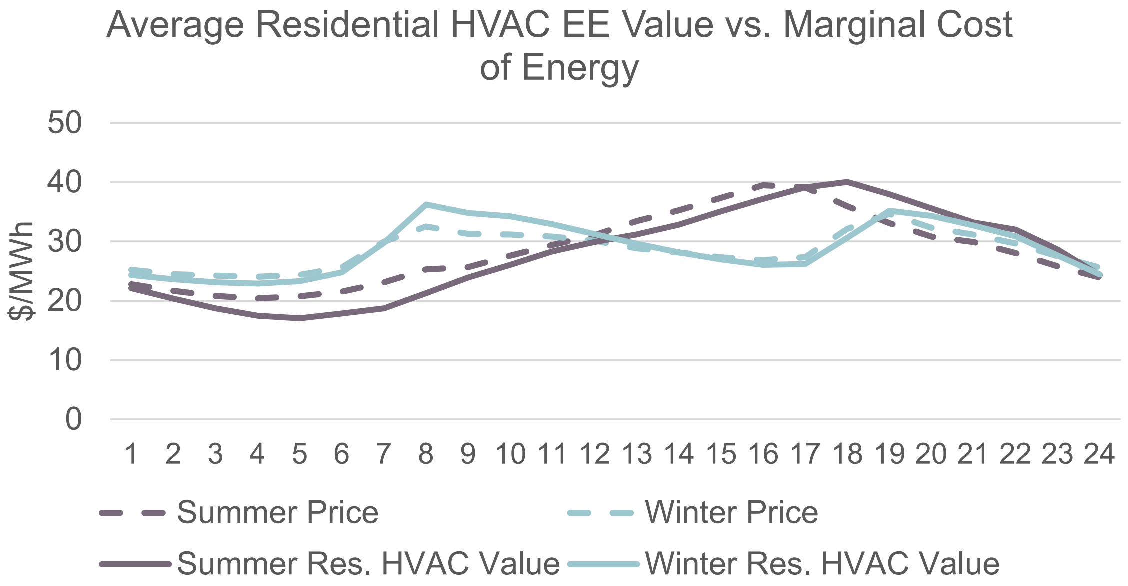
- **NREL High Renewables Cost**: Based on NREL Standard Scenarios “high renewables” case assumptions (that assume low renewables costs) for Balancing Authority-specific hourly load, energy, and capacity cost projections for a high renewable scenario; hourly EE impacts from Indiana utility data request.

*For more detail of NREL Standard Scenarios assumptions and modeling, see: https://www.nrel.gov/analysis/standard-scenarios.html

Marginal value of EE depends on both the hourly energy cost and hourly EE savings







Figures based on 2020 utility-specific IRP values

Therefore marginal EE value varies temporally, both diurnally and seasonally

Hour	January	February	March	April	May	June	July	August	September	October	November	December
1	$ 26.14	$ 24.66	$ 22.18	$ 20.40	$ 19.79	$ 20.96	$ 23.41	$ 21.93	$ 20.48	$ 20.33	$ 20.82	$ 22.21
2	$ 25.68	$ 24.14	$ 21.59	$ 19.81	$ 18.36	$ 19.18	$ 21.66	$ 20.50	$ 18.87	$ 19.45	$ 20.08	$ 21.22
3	$ 25.32	$ 23.74	$ 20.92	$ 19.20	$ 17.36	$ 17.64	$ 20.27	$ 19.26	$ 17.57	$ 18.81	$ 19.54	$ 20.59
4	$ 25.13	$ 23.57	$ 20.66	$ 18.94	$ 16.53	$ 16.57	$ 19.20	$ 18.24	$ 16.76	$ 18.46	$ 19.31	$ 20.37
5	$ 25.46	$ 23.90	$ 21.02	$ 19.44	$ 16.62	$ 16.32	$ 18.56	$ 18.14	$ 16.81	$ 18.72	$ 19.77	$ 20.81
6	$ 26.79	$ 25.55	$ 22.71	$ 21.08	$ 18.04	$ 17.32	$ 19.34	$ 18.99	$ 18.01	$ 20.26	$ 21.30	$ 22.40
7	$ 31.39	$ 31.09	$ 28.91	$ 26.82	$ 20.73	$ 18.74	$ 20.65	$ 20.44	$ 20.85	$ 24.60	$ 26.00	$ 27.13
8	$ 39.46	$ 38.35	$ 34.56	$ 29.56	$ 23.34	$ 21.86	$ 23.85	$ 22.24	$ 22.81	$ 27.72	$ 29.32	$ 31.55
9	$ 38.41	$ 36.17	$ 33.03	$ 29.45	$ 25.33	$ 24.10	$ 26.46	$ 24.06	$ 23.39	$ 26.57	$ 28.32	$ 30.57
10	$ 37.21	$ 35.29	$ 31.65	$ 29.39	$ 26.68	$ 25.98	$ 28.78	$ 26.04	$ 24.95	$ 26.67	$ 27.89	$ 29.97
11	$ 35.26	$ 33.98	$ 30.44	$ 29.07	$ 27.48	$ 27.87	$ 30.63	$ 27.78	$ 26.53	$ 27.07	$ 27.47	$ 29.12
12	$ 33.19	$ 31.94	$ 29.28	$ 28.40	$ 28.07	$ 29.34	$ 32.31	$ 29.05	$ 27.75	$ 27.16	$ 26.57	$ 28.23
13	$ 31.02	$ 30.31	$ 28.28	$ 27.53	$ 28.63	$ 30.64	$ 33.42	$ 29.99	$ 28.79	$ 26.99	$ 25.87	$ 27.10
14	$ 29.16	$ 28.86	$ 27.29	$ 27.20	$ 29.57	$ 32.25	$ 35.19	$ 31.07	$ 30.01	$ 26.93	$ 25.19	$ 26.30
15	$ 27.56	$ 27.66	$ 26.37	$ 26.79	$ 30.65	$ 34.36	$ 37.51	$ 33.18	$ 31.95	$ 27.00	$ 24.53	$ 25.58
16	$ 26.60	$ 26.74	$ 25.68	$ 26.51	$ 31.60	$ 36.42	$ 39.97	$ 34.94	$ 33.46	$ 26.92	$ 24.12	$ 25.02
17	$ 26.57	$ 26.35	$ 25.40	$ 26.32	$ 32.11	$ 37.83	$ 42.21	$ 36.68	$ 35.33	$ 26.83	$ 24.51	$ 25.37
18	$ 30.84	$ 28.01	$ 25.78	$ 26.26	$ 32.12	$ 37.97	$ 42.86	$ 37.09	$ 34.94	$ 26.75	$ 28.63	$ 30.29
19	$ 36.65	$ 34.24	$ 27.80	$ 26.58	$ 31.12	$ 35.95	$ 40.70	$ 35.22	$ 32.70	$ 27.55	$ 30.65	$ 31.95
20	$ 35.87	$ 35.42	$ 30.41	$ 26.77	$ 29.39	$ 33.23	$ 37.44	$ 32.79	$ 31.37	$ 30.89	$ 28.95	$ 30.55
21	$ 34.51	$ 32.90	$ 32.24	$ 29.91	$ 29.13	$ 30.89	$ 34.73	$ 31.43	$ 31.06	$ 28.59	$ 27.40	$ 29.32
22	$ 32.45	$ 30.98	$ 29.71	$ 28.67	$ 29.22	$ 30.07	$ 33.19	$ 30.31	$ 28.19	$ 26.16	$ 26.20	$ 28.04
23	$ 28.94	$ 27.88	$ 25.86	$ 24.29	$ 25.54	$ 27.17	$ 29.87	$ 26.94	$ 25.09	$ 23.42	$ 23.83	$ 25.41
24	$ 25.47	$ 24.63	$ 22.47	$ 21.21	$ 21.64	$ 23.11	$ 25.37	$ 23.55	$ 22.13	$ 21.04	$ 21.45	$ 22.88

EE marginal value also varies by measure

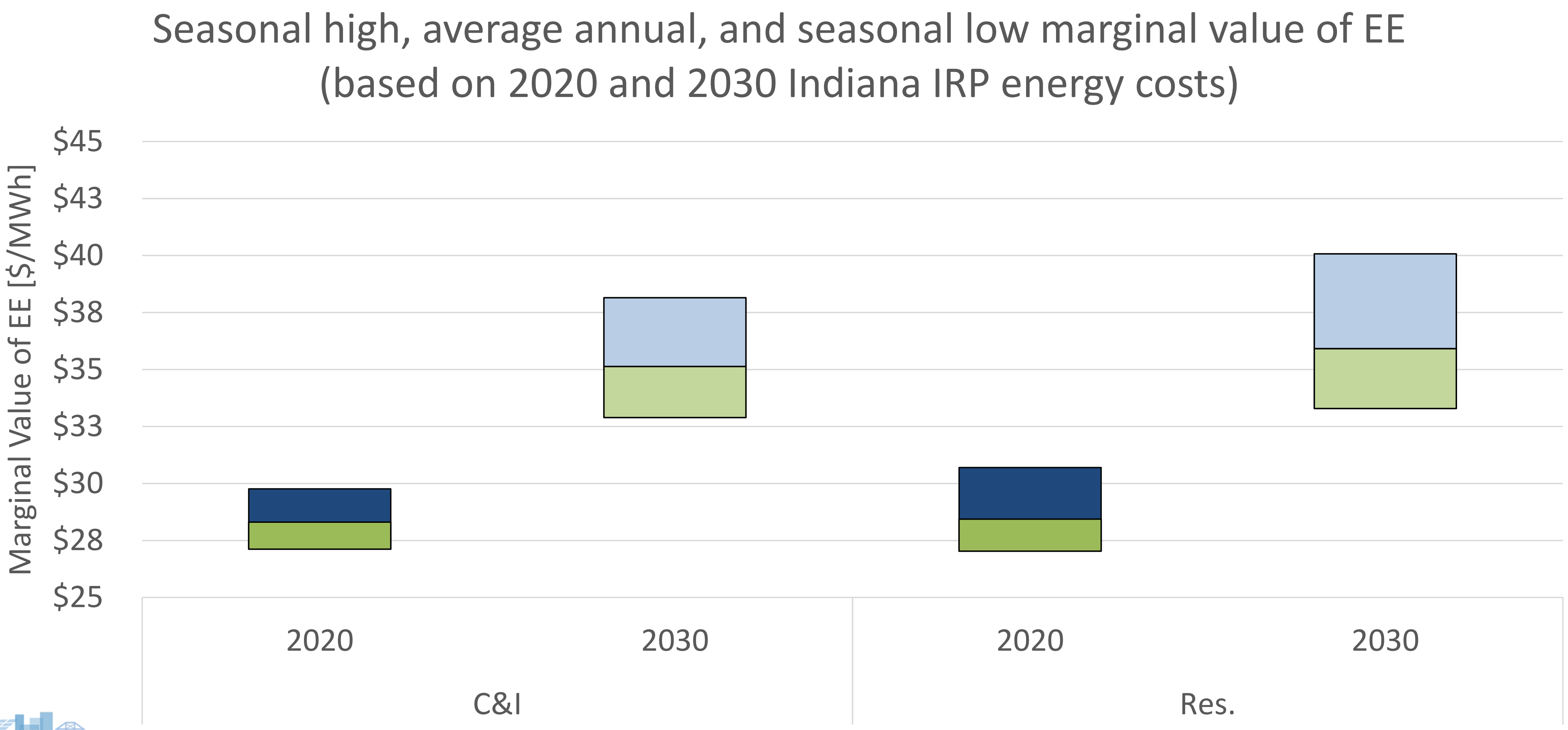
EE Measure	Max. Seasonal Value [Seasonal Avg. $/MWh]	Season of Highest Value
C&I Appliance	33.20	Summer
Res. HVAC	32.72	Summer
Res. Envelope	32.00	Winter
Res. Appliance	31.93	Winter
C&I Refrigeration	31.83	Winter
C&I Electronics	31.18	Winter
C&I Lighting	31.05	Summer
Res. Other	30.53	Summer
Res. Pool Pump	29.59	Summer
Res. Lighting	29.02	Winter
C&I Other	28.24	Summer
C&I HVAC	28.19	Summer

Marginal EE value varies considerably by season at measure-level

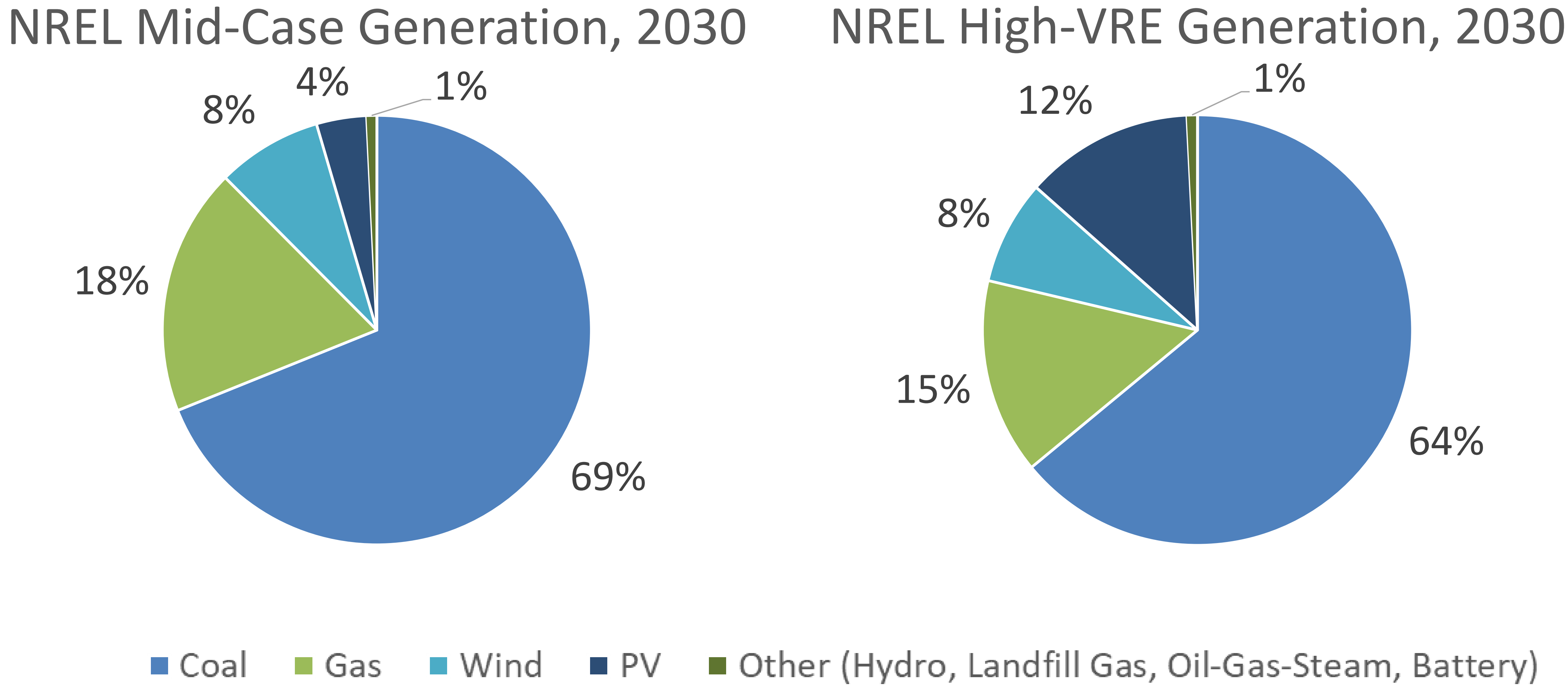
EE Measure	Avg. Annual Marginal Value [$/MWh]	Rank by Marginal Value				
		Annual	Fall	Winter	Spring	Summer
C&I Appliance	$31.94	1	1	1	1	1
Res. Envelope	$30.86	2	3	2	2	3
Res. Appliance	$30.48	3	4	3	5	4
C&I Refrigeration	$30.01	4	5	4	3	6
C&I Lighting	$29.61	5	6	6	4	5
Res. HVAC	$29.57	6	2	9	7	2
C&I Electronics	$29.07	7	9	5	6	9
Res. Pool Pump	$28.36	8	7	N/A	10	8
Res. Other	$28.33	9	8	8	8	7
Res. Lighting	$27.78	10	10	7	9	12
C&I Other	$26.51	11	12	10	11	10
C&I HVAC	$26.21	12	11	11	12	11

Green indicates higher rank than average annual and red indicates lower rank than average annual

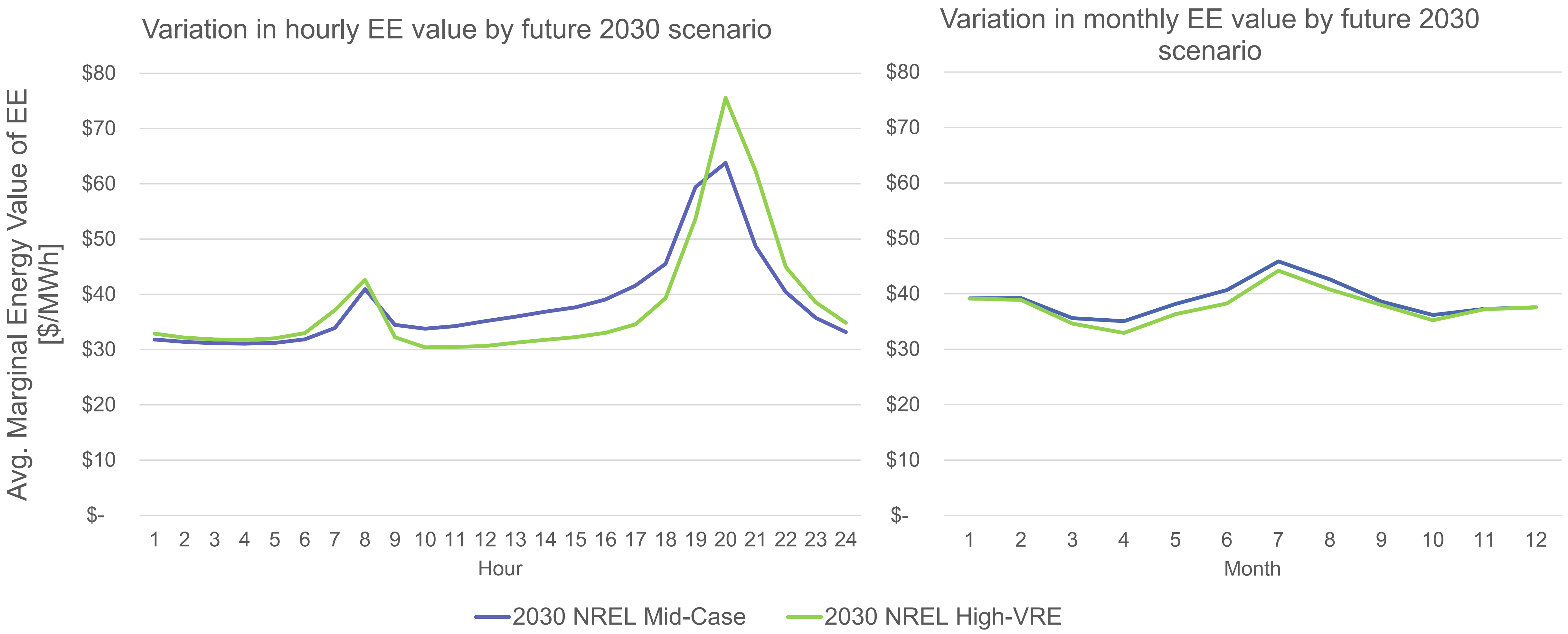
Marginal EE value generally increases over time and with greater range on a seasonal basis



NREL's 2030 high variable renewable energy (VRE) scenario for Indiana predicts an increase in solar PV and decrease in natural gas and coal



An increase in VRE penetration will shift the magnitude and timing of marginal EE value



Residential EE measures increase in value relative to C&I EE measures in a high RE future

EE Measure	Rank (2030 NREL Mid-Case)	Rank (2030 NREL High VRE)
Res. Pool Pump	1	2
Res. HVAC	2	1
Res. Envelope	3	4
C&I HVAC	4	6
Res. Appliance	5	5
C&I Appliance	6	8
C&I Refrigeration	7	9
Res. Other	8	7
Res. Lighting	9	3
C&I Electronics	10	10
C&I Lighting	11	12
C&I Other	12	11

Observations and Implications

The value of EE varies by sector, season, and hour

EE investments could focus on measures with high availability during constrained or high-value times

In order to decrease energy consumption across the entire year, a diverse bundle of EE measures would be necessary

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Modeling EE as a load decrement may over or under value resource

Program administrators must keep in mind how the incremental value of an EE measure may change with increased penetration

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Residential EE becomes more valuable over time and by season

Changing values indicate the need for EE investment to adapt to utility needs over time

Higher seasonality may necessitate season-specific EE investment since much of Indiana has both a sizable summer and winter price peak

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- EE investments could focus on measures with high availability during constrained or high-value times
- In order to decrease energy consumption across the entire year, a diverse bundle of EE measures would be necessary

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- Modeling EE as a load decrement may over or under value resource
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Residential EE becomes more valuable over time and by season

- Changing values indicate the need for EE investment to adapt to utility needs over time
- Higher seasonality may necessitate season-specific EE investment since much of Indiana has both a sizable summer and winter price peak

High VRE penetration alters the timing and magnitude of EE value

- Concentrated value in more narrow peak periods may make EE investments more targeted
- Dependencies between VRE impacts and EE value should be considered when investing in EE

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For more information

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Appendix A: Improving DR modeling in IRPs

Common approaches to account for DR in IRPs

DR as a peak load reduction	• DR resources are assumed at 100% capacity and deducted from resource plan forecasts • Assumes DR resources are perfectly coincident with utility annual peak and does not capture patterns in DR resource availability
DR competing against supply-side resources	• Supply curves of DR resources compete with supply-side resources • DR resources are used by LSEs in a different manner than supply-side resources and subject to program rules limiting their operations

Enhancing the representation of DR as a supply-side resource

Recognize the 'option value' of DR

- Capture the ability for DR resources to respond to extreme and highly uncertain events through probabilistic uncertainty analysis (e.g., Monte Carlo simulations)

Account for load building immediately before or after DR event periods

- Capture the hourly impacts of DR before/after DR event

Assess the optimal dispatch of the DR portfolio

- Identify more 'flexible' dispatch approaches

Account for the geographical distribution of DR participants

- Address transmission- and distribution-level reliability

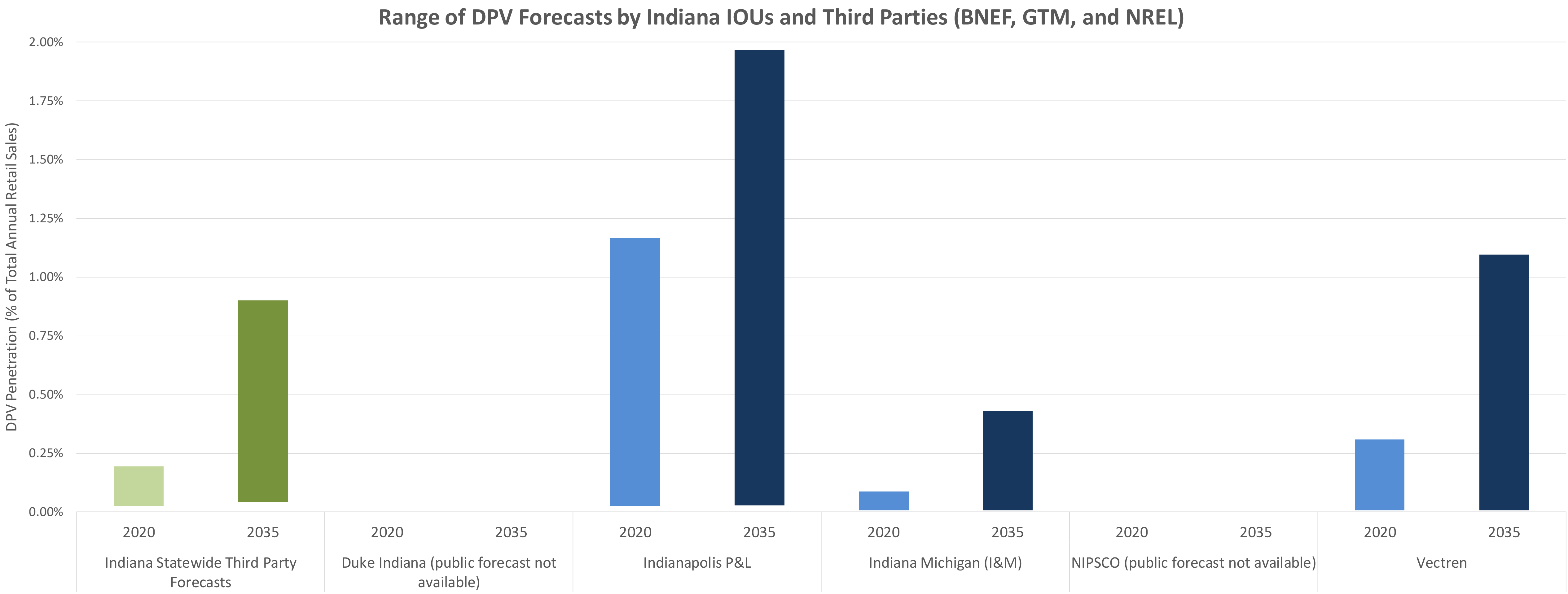
Account for the relationship between incentives and participation

- Capture the correlation between DR program participation and incentive levels

Resources for more information on DR modeling in IRPs

- Frick et al. (2017). Integrated Resource Planning: Technical Assistance to the Michigan Public Service Commission. Available at: https://emp.lbl.gov/publications/integrated-resource-planning
- Kahrl et al. (2016). The future of electricity resource planning. Available at: https://emp.lbl.gov/publications/future-electricity-resource-planning
- Satchwell et al. (2013). Analytical frameworks to incorporate demand response in long-term resource planning. Available at: https://emp.lbl.gov/publications/analytical-frameworks-incorporate
- Satchwell et al. (2013). Incorporating demand response into western interconnection transmission planning. Available at: https://emp.lbl.gov/publications/incorporating-demand-response-western
- Synapse (2013). Best practices in electric utility integrated resource planning. Available at: http://www.synapse-energy.com/project/best-practices-electric-utility-integrated-resource-planning

Appendix B: Range of distributed PV (DPV) forecasts and DG forecasting references



Indiana utility forecasts are based on IRPs as of November, 2019 and may not reflect its current IRP

Resources for more information on DG forecasting

- Mills, A.D. 2018. Forecasting load on the distribution and transmission system with distributed energy resources. Distribution Systems and Planning Training for Western States. https://emp.lbl.gov/publications/distribution-systems-and-planning
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- EPRI (Electric Power Research Institute). 2015. *Distribution Feeder Hosting Capacity: What Matters When Planning for DER?* Palo Alto, CA: Electric Power Research Institute. http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002004777.
- Navigant Consulting, Inc. 2016a. *Virginia Solar Pathways Project: Study 1 - Distributed Solar Generation Integration and Best Practices Review.* Richmond, VA: Dominion Virginia Power.

Appendix C: LBNL data request

LBNL data request to Indiana investor-owned utilities (IOUs)

1. Hourly (8760) savings for each energy efficiency (EE) measure and/or program assumed in the most recent integrated resource plan (IRP). Savings can be expressed in either energy or percentage terms. Savings should represent what is assumed to be technically achievable under baseline weather and load conditions (i.e., consistent with IRP base or baseline scenario assumptions).
2. Descriptions of the acceptable or installed technology(ies) for each EE measure and/or program (e.g. residential central air conditioner SEER rating). Explanation of whether and how the hourly savings of EE measures/programs are expected to change over the most recent IRP forecast period.
3. Annual hourly (8760) total retail load consistent with IRP base or baseline scenario assumptions for the most recent IRP forecast period. Annual hourly (8760) production costs or marginal system costs consistent with IRP base or baseline scenario assumptions for the most recent IRP forecast period.

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