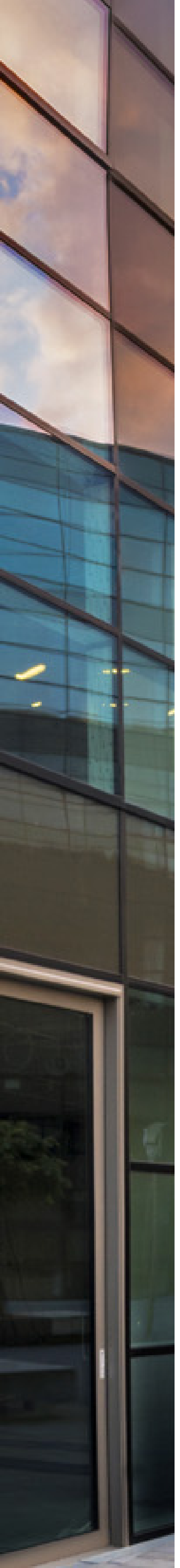

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ECOTOPE

Building Energy Codes: GEB and Electrification

August 12, 2021

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Pacific Northwest National Lab

Mark Frankel,
Ecotope

U.S. DEPARTMENT OF ENERGY BATTELLE

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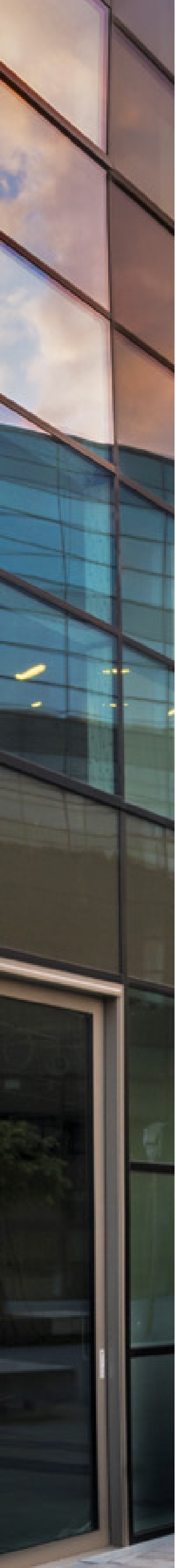
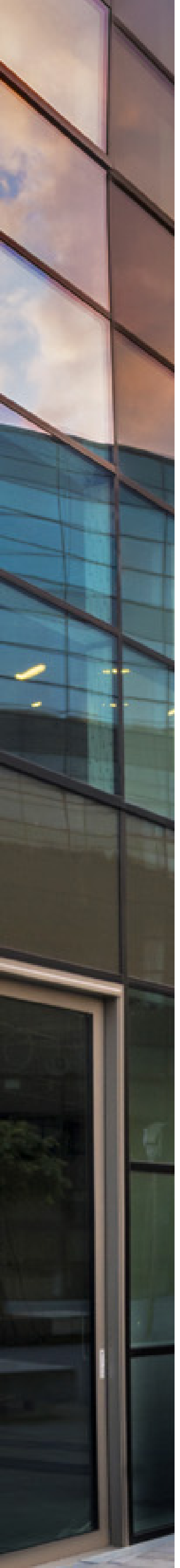
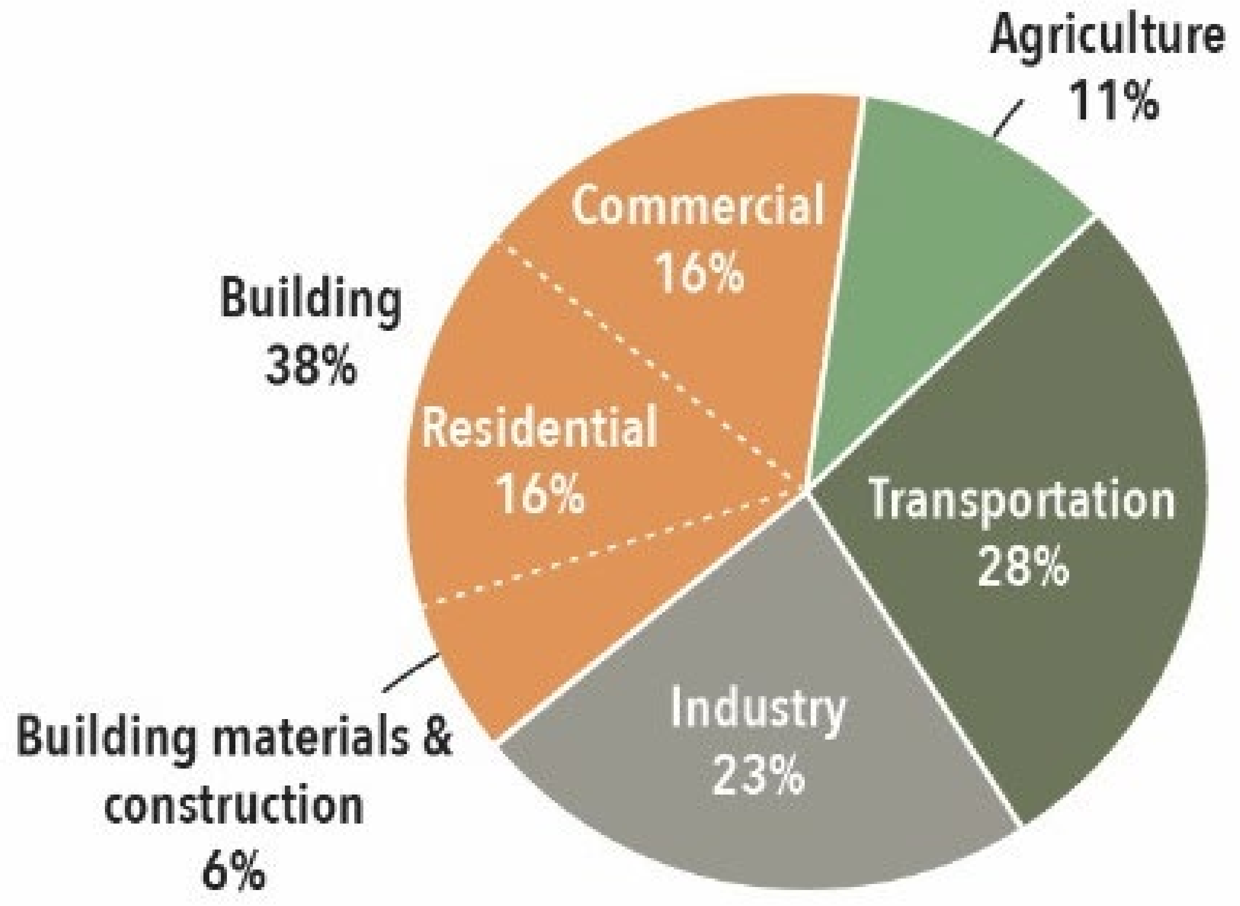


GEB and Electrification in Energy Codes

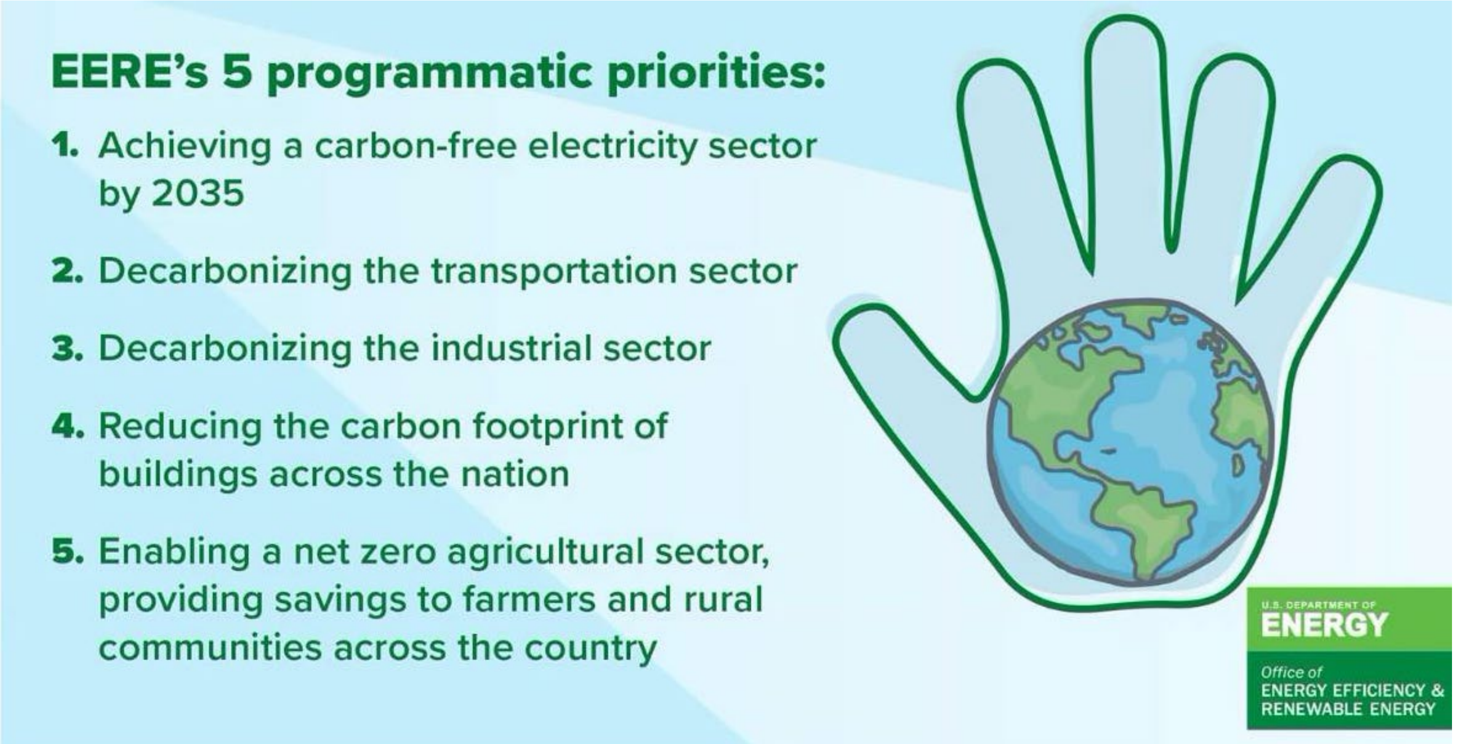
Purpose: Discuss the role of building and energy codes in advancing connected buildings, how electrification will necessitate this effort, and the grid-interactive building (GEB) technology currently being adopted at the state and local level.

DOE Energy Efficiency and Renewable Energy (EERE): Programmatic Priorities

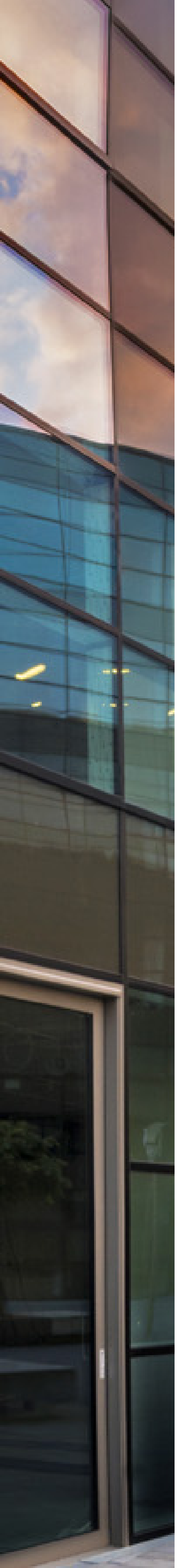




U.S. GHG emissions with industry production for building reassigned



SOURCE: Carnegie Mellon Center for Building Performance and Diagnostics (2020).



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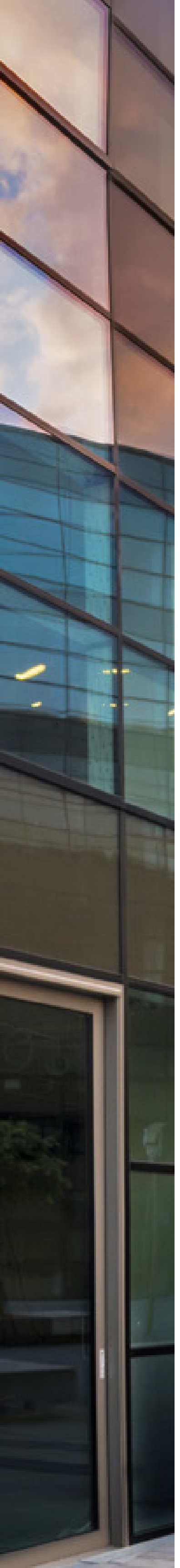
DOE Supports the Advancement of Building Energy Codes

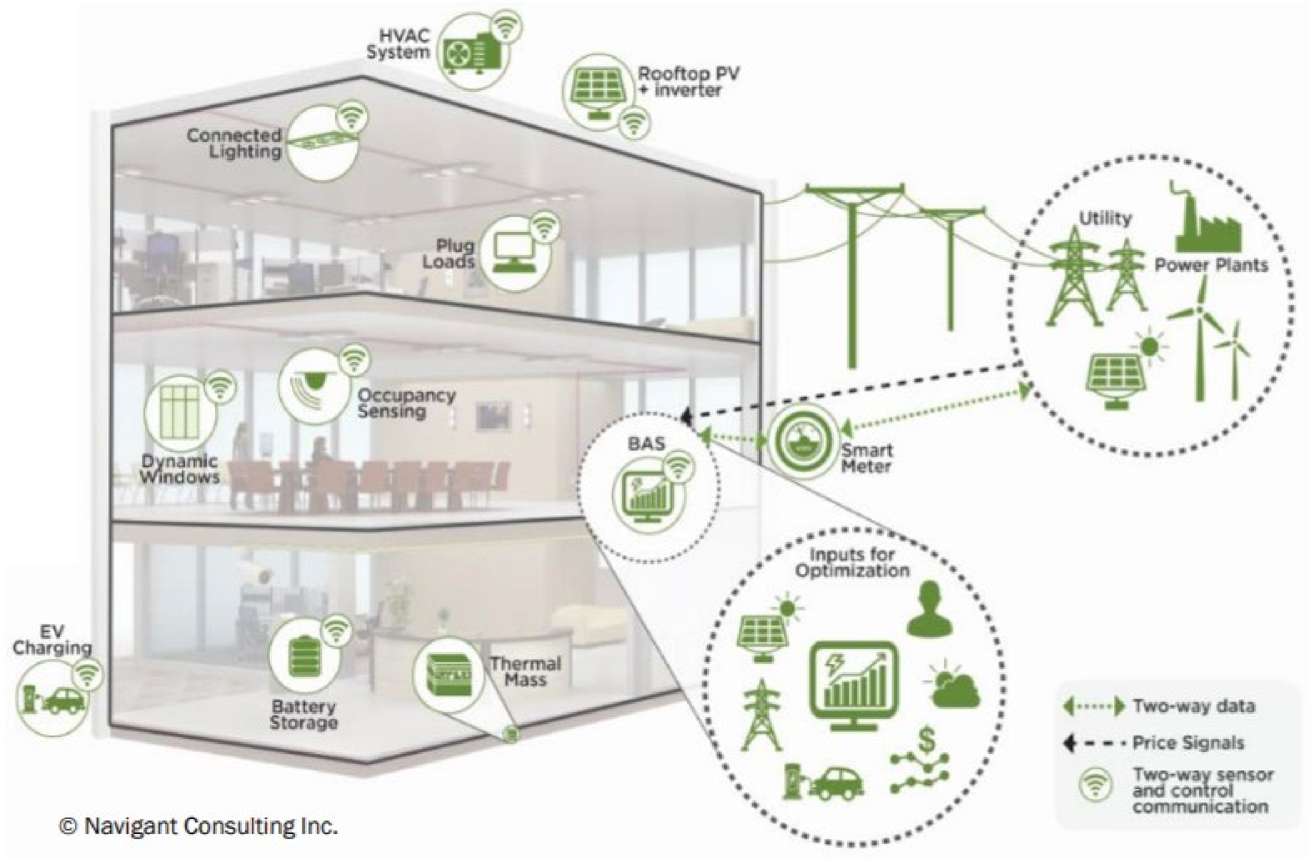
As part of its legislative mandate to advance building energy codes, the U.S. Department of Energy (DOE) is accelerating efforts to make American buildings more efficient, resilient, and clean

"More efficient building codes are key ways to eliminate wasted energy, lower Americans' energy bills, and reduce carbon emissions that contribute to climate change," said **Secretary Granholm**. "These efforts to help states and localities adopt new, more efficient codes – along with President Biden's plans to produce, preserve, and retrofit millions of homes – will provide Americans safer, healthier, and more comfortable places to live, work, and play."

- Press Release from July 21, 2021

Characteristics of Grid-Interactive Efficient Buildings





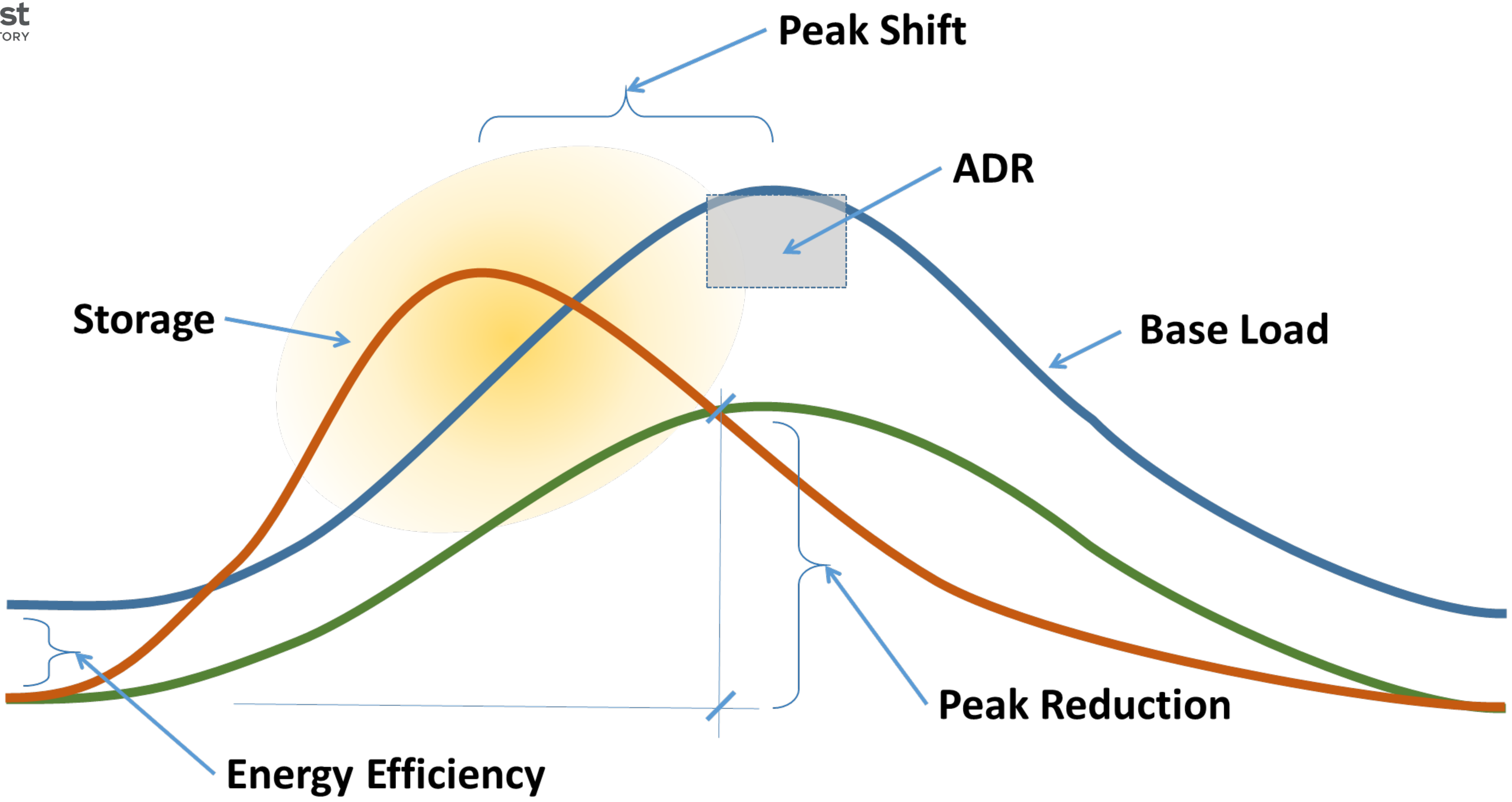
Source: DOE EERE. 2019. *Grid-Interactive Efficient Buildings Technical Report Series: Overview of Research Challenges and Gaps*.

Accessed at https://www.energy.gov/eere/buildings/geb-technical-reports

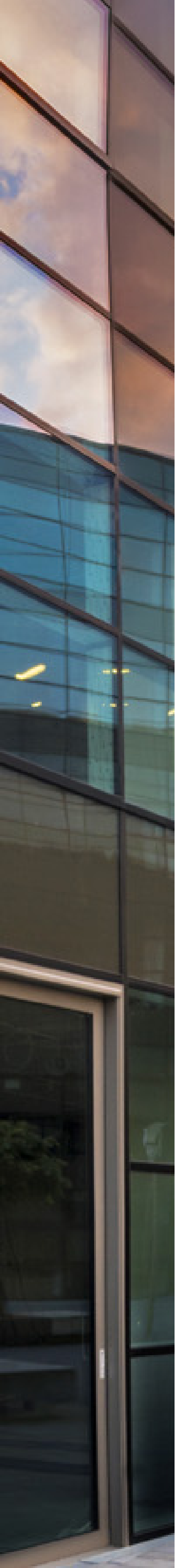
Grid-interactive efficient buildings (GEB) are:

1. **energy-efficient** to reduce energy use and peak demand
2. **flexible** using on-site distributed generate/storage and demand-side management strategies
3. **connected** with two-way communication to support the grid and occupants' needs,
4. **smart** with analytics, sensing, and controls that manage strategies and co-optimize costs, use, and comfort

GEB Technology Impacts on Building Load Shape



Source: New Buildings Institute, GridOptimal



GEB Technologies

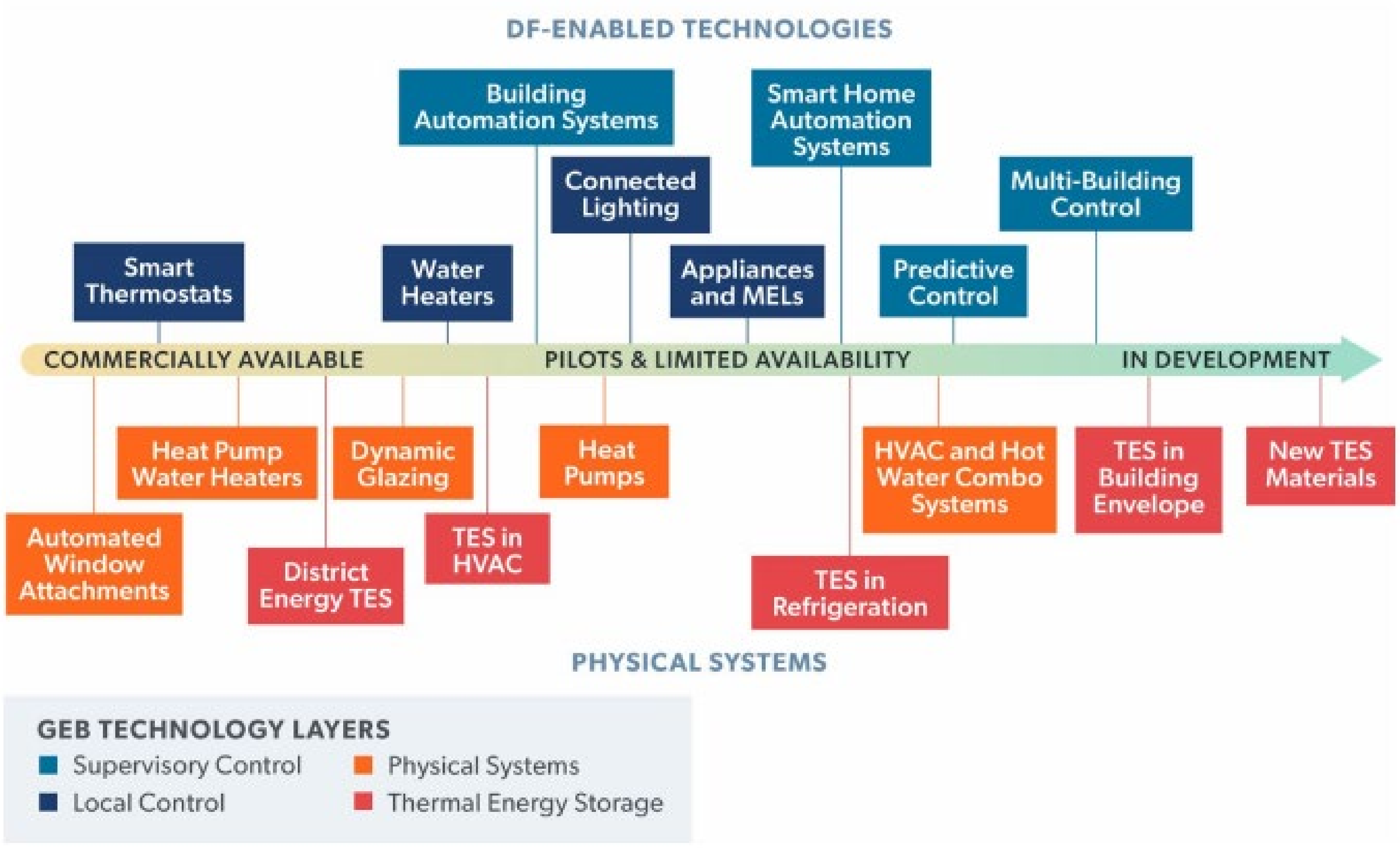


FIGURE 9: TECHNOLOGY PIPELINE EXAMPLES FOR EACH GEB LAYER

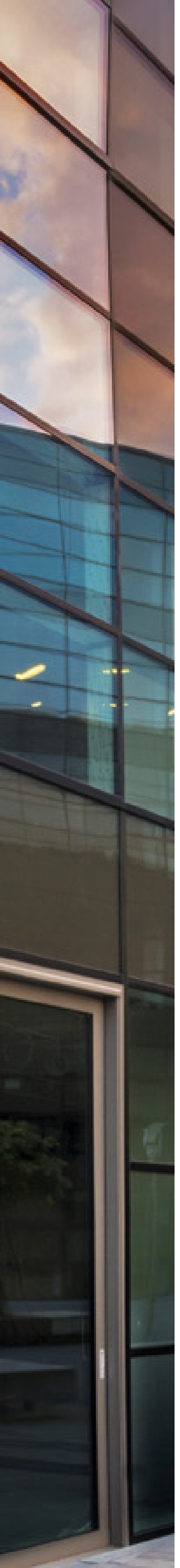
Note: TES integrated with HVAC is available in large commercial buildings but rare in small commercial or residential buildings.

Source: DOE's National Roadmap for Grid-interactive Efficient Buildings, May 2021. Accessed at https://www.energy.gov/eere/articles/does-national-roadmap-grid-interactive-efficient-buildings

GEB Technology Impact Potential

FIGURE 4: PUTTING THE GEB POTENTIAL ESTIMATES INTO HISTORICAL CONTEXT

Source: DOE's National Roadmap for Grid-interactive Efficient Buildings, May 2021. Accessed at https://www.energy.gov/eere/articles/does-national-roadmap-grid-interactive-efficient-buildings

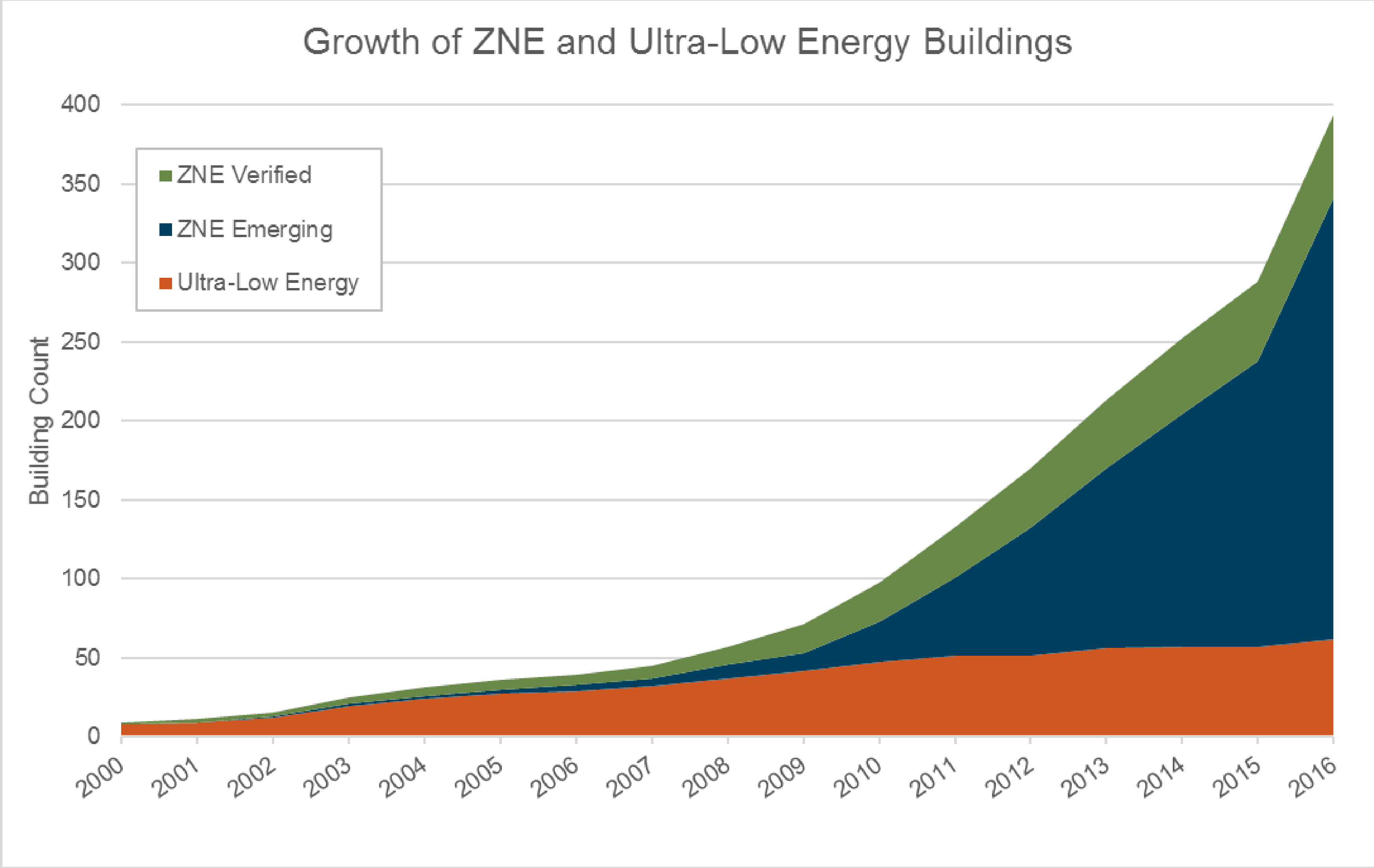


Trends and Drivers for Grid-Interactive Efficient Buildings

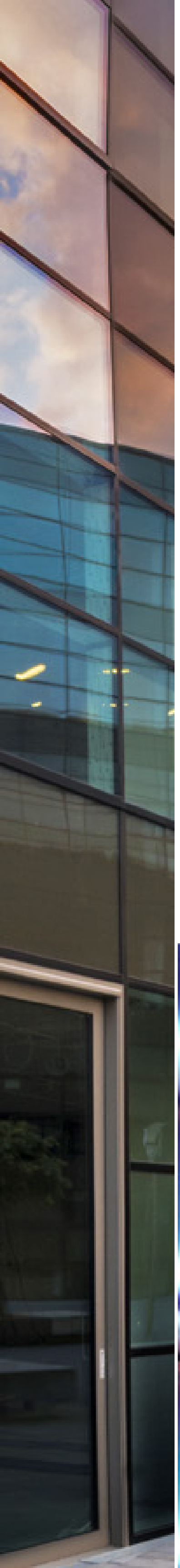
Macro-Trends Affecting Buildings and the Grid

- ZNE Proliferation
- Building Decarbonization
- Vehicle Electrification
- Energy Resiliency
- Grid Decarbonization

Proliferation of ZNE and the 2030 Challenge



Hood River Middle School
Photo: Michael Mathers



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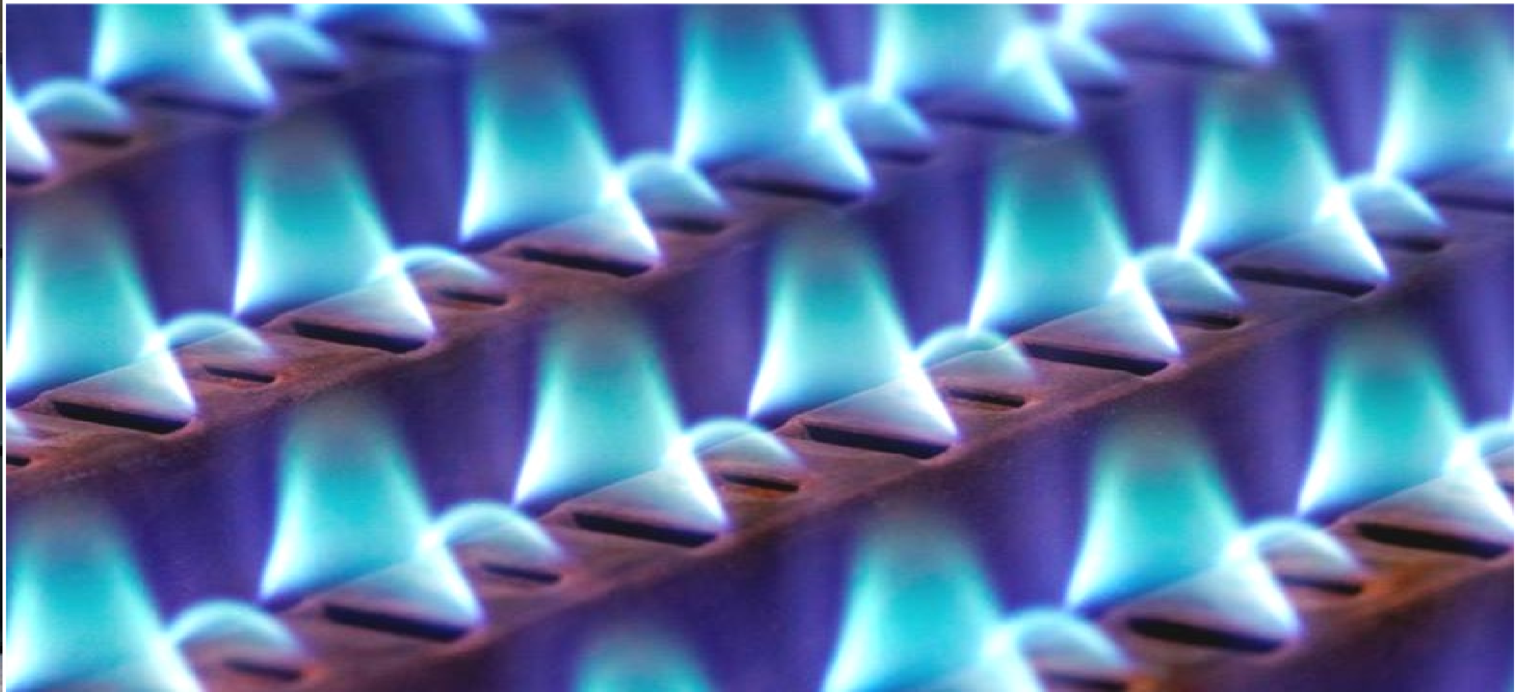
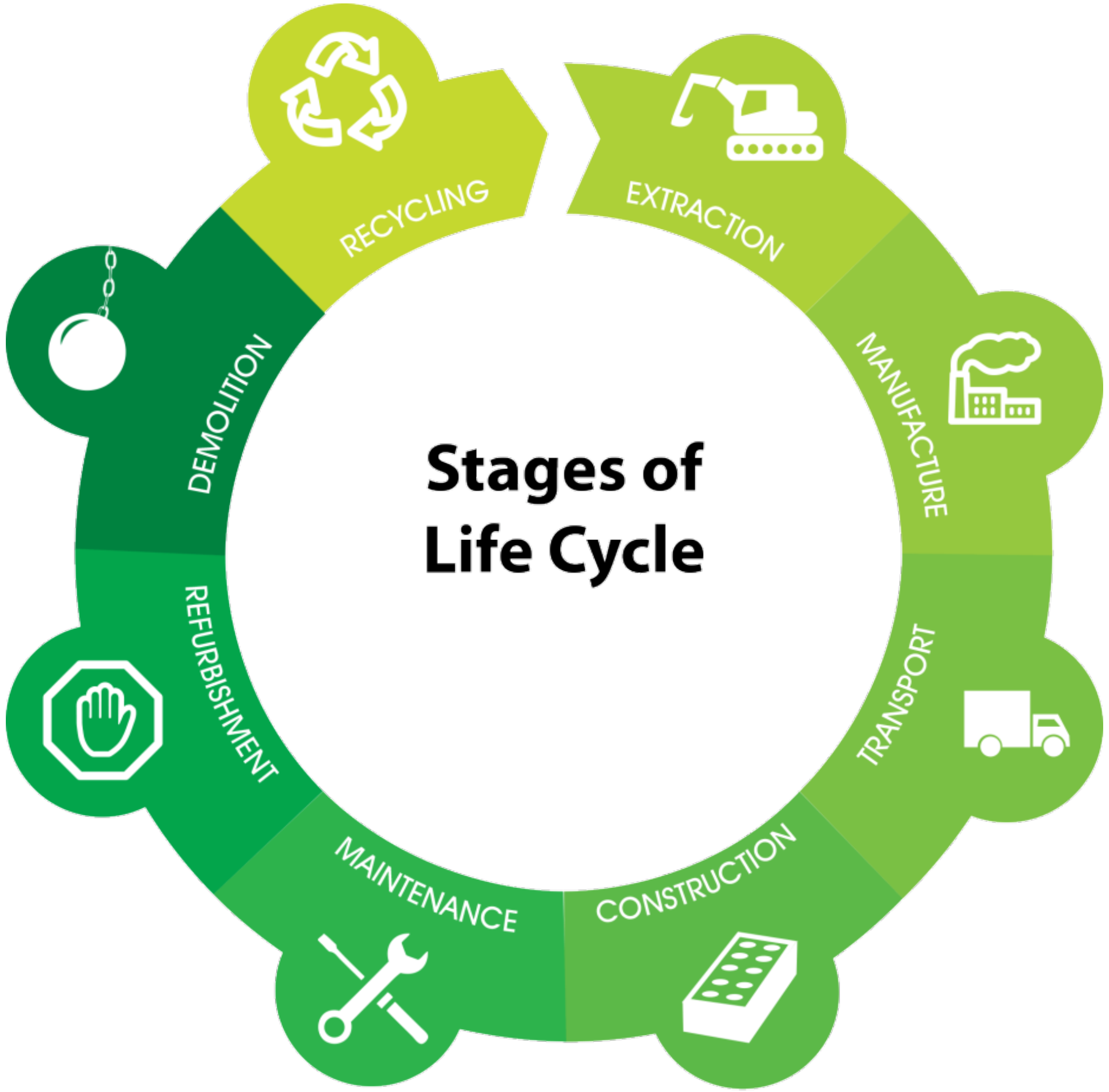
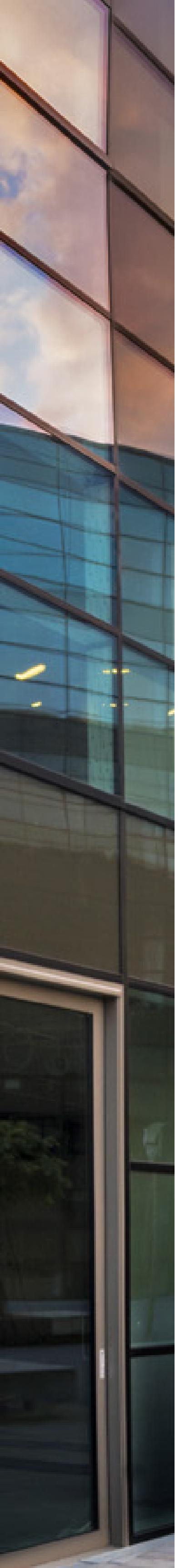
Building Decarbonization

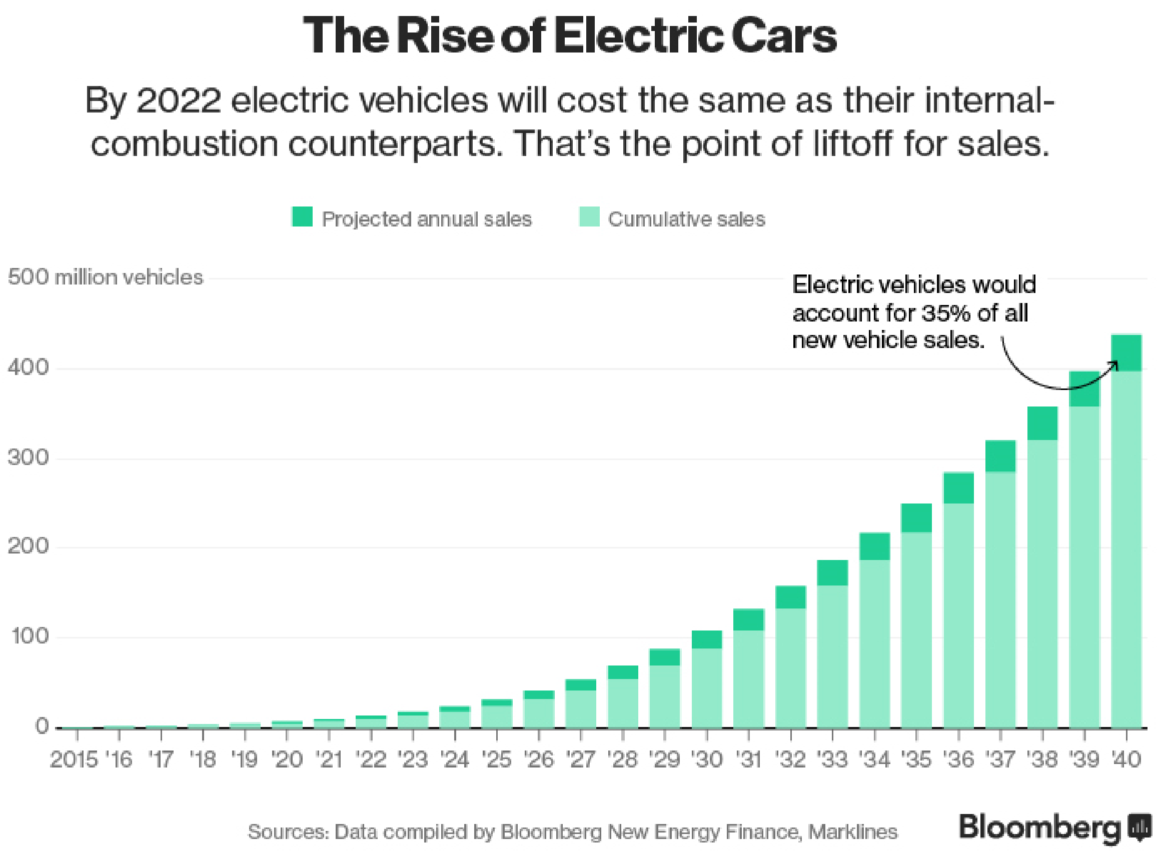
- Eliminate Building Combustion
- Reduce Embodied Carbon



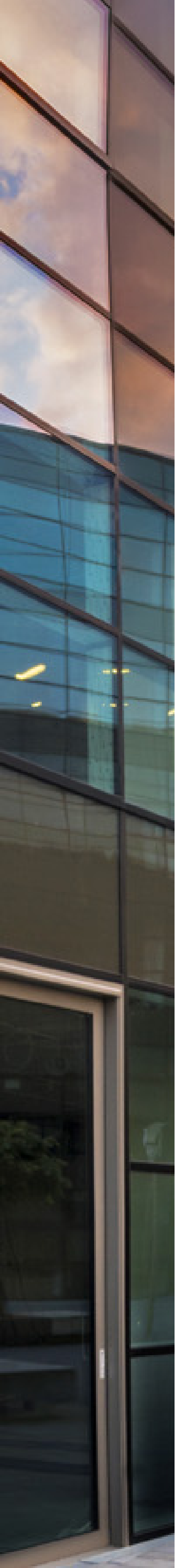


Vehicle Electrification





Thomas Edison with an electric car in 1914. In 1900, 1/3 of cars in NYC were electric



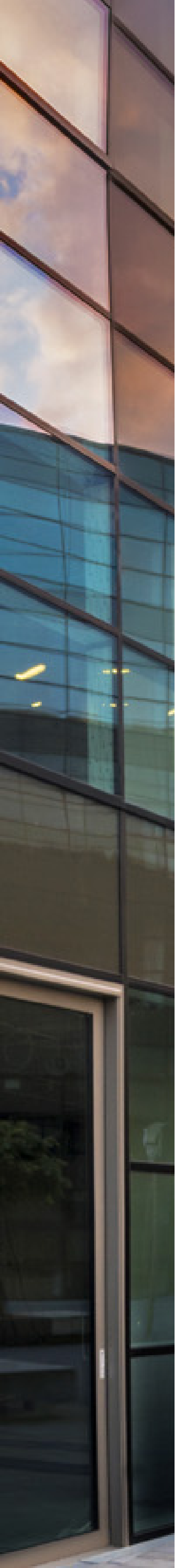
Energy Resiliency

- Independent power sources (PV) may allow grid-independent operation (islanding)
- Passive features support building habitability during no-power operation
- Staged start up capabilities can support faster grid recovery after outages
- On-site energy storage and V2G can provide emergency support for communities (communication, refrigeration, etc.)

Puerto Rico, 9/22/17 (NBC)

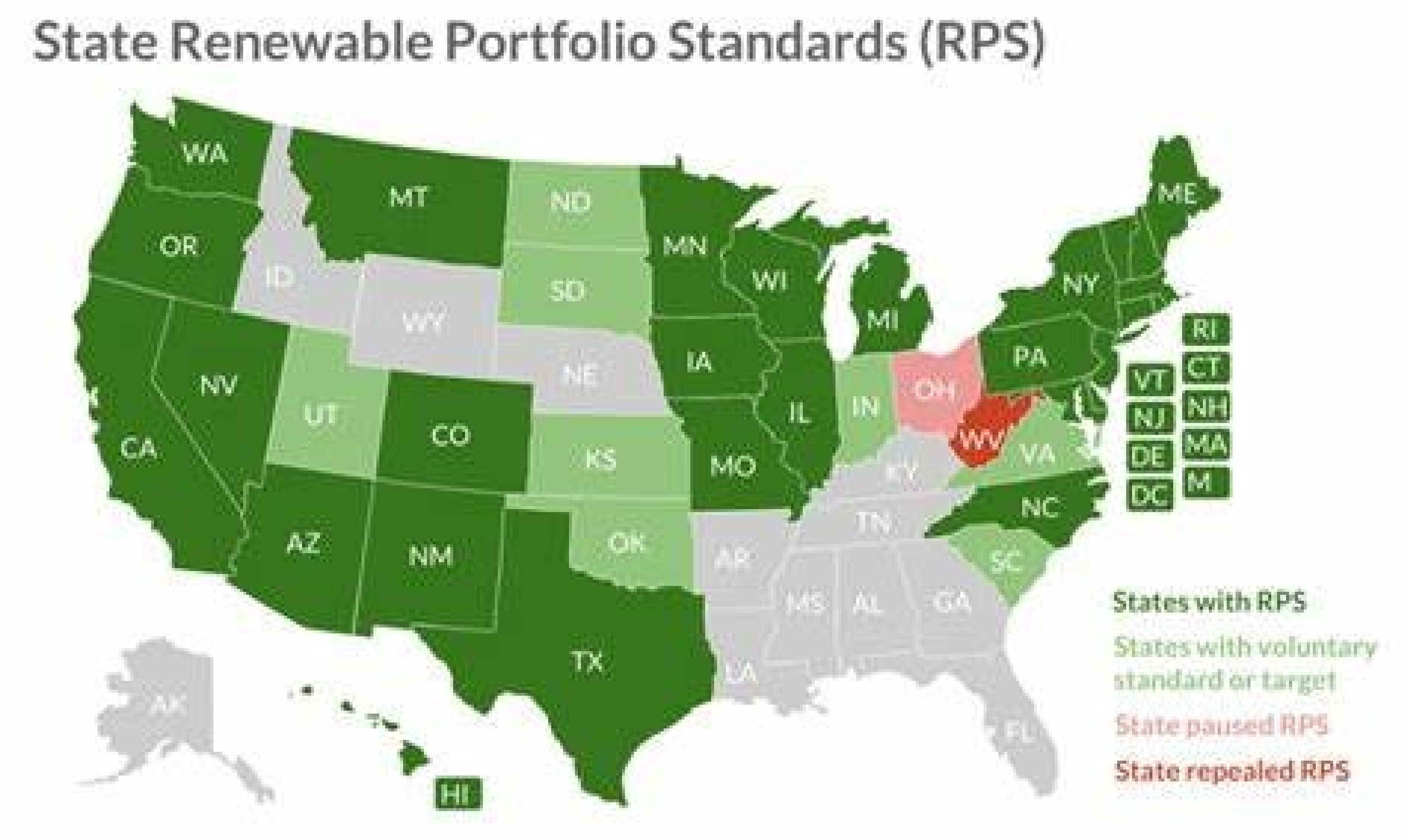
"Tempers Flare as Millions in CA Endure Power Outages from PG&E";

LA Times 10/10/19



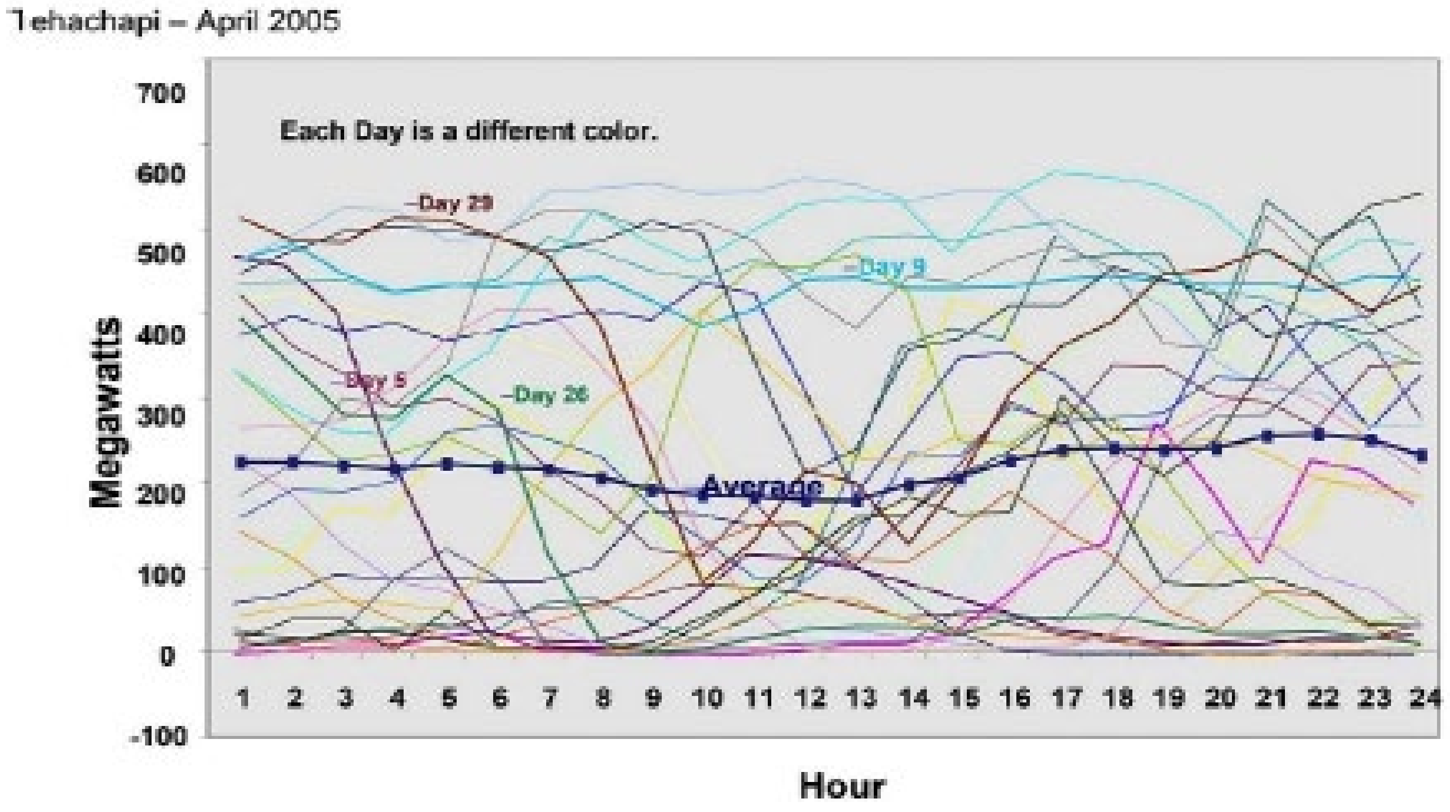
Grid Decarbonization Mandates

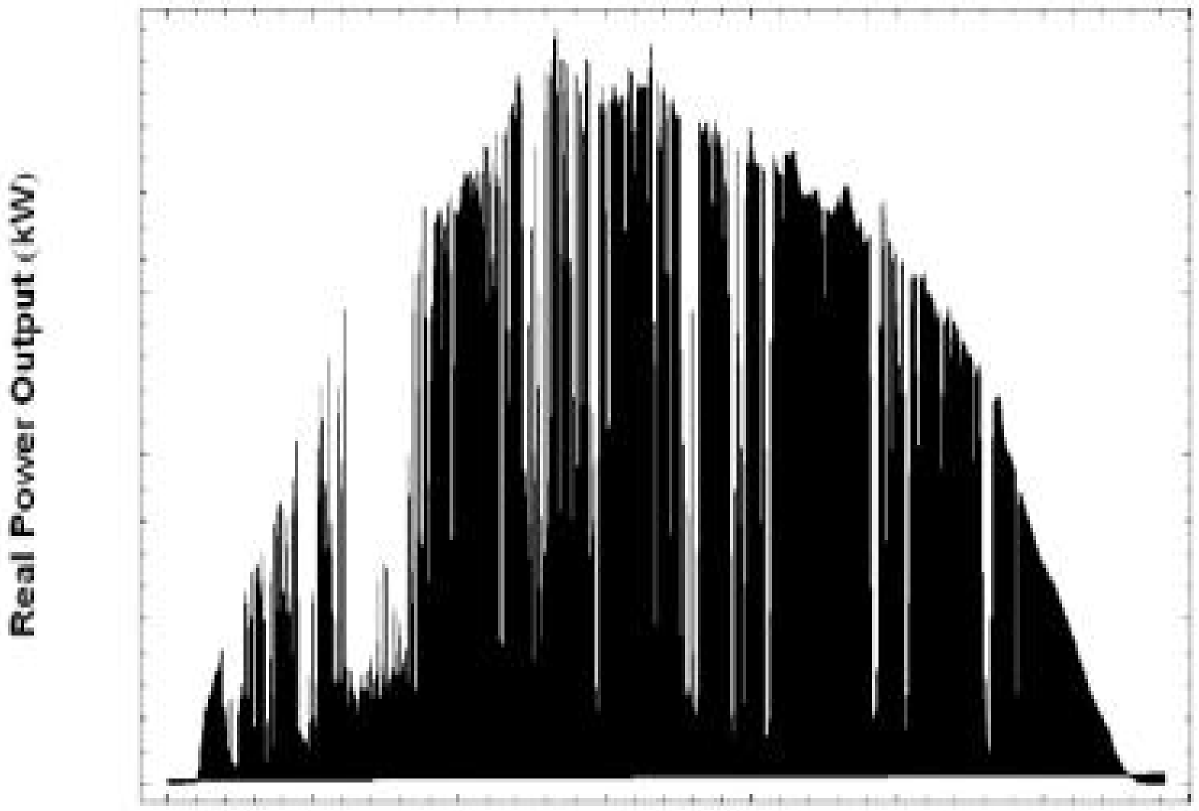
- Renewable Portfolio Standards
- State Climate Goals: WA, CA, NY, OR, HI, VT…
- 287+ Cities



WE ARE STILL IN

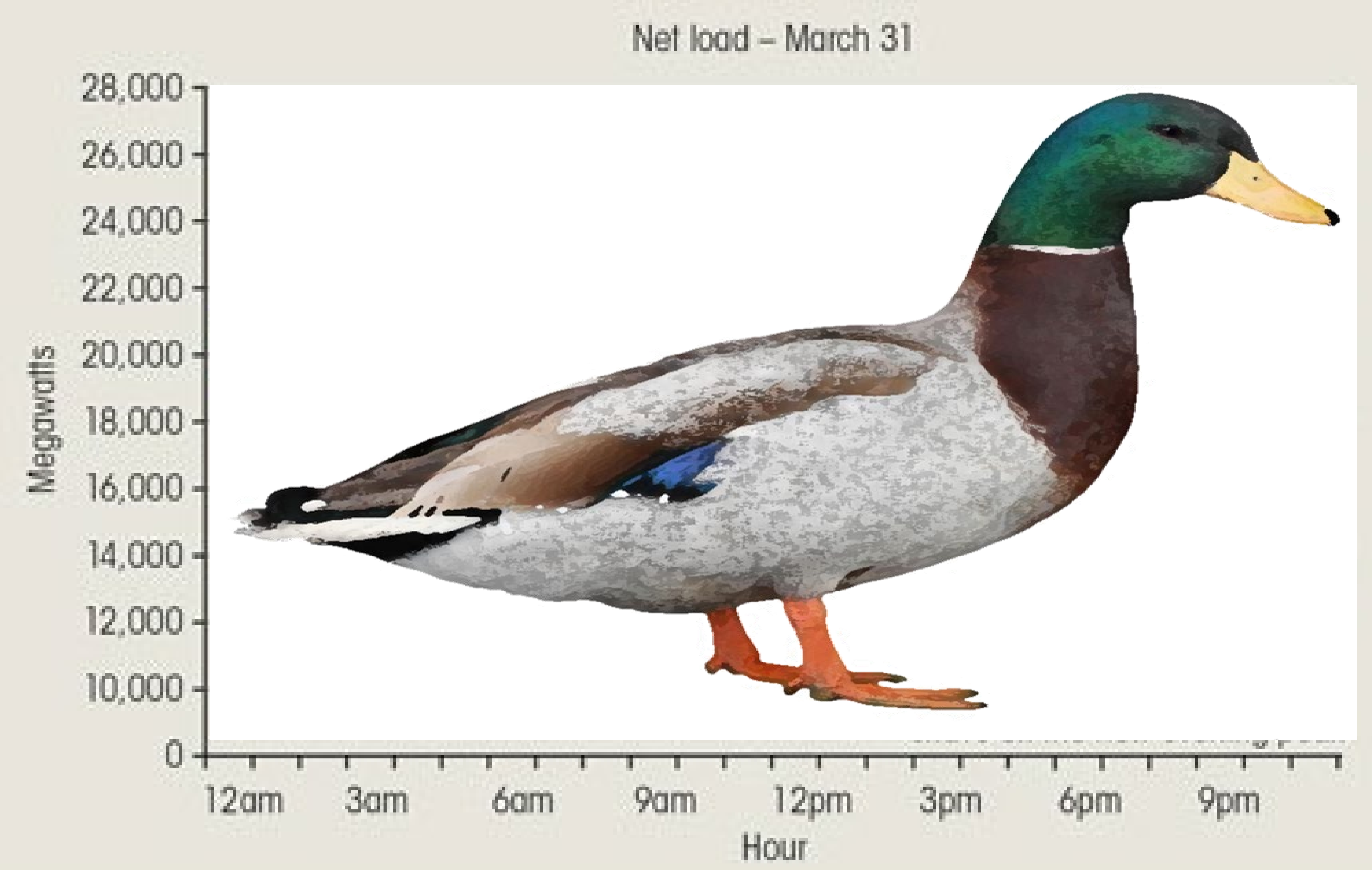
Variable Renewable Supply Characteristics





"Curtailment" and "Intermittency"

The Ominous "Duck Curve"



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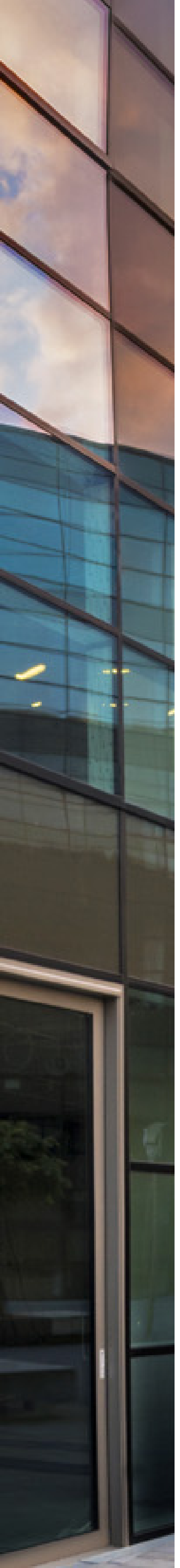
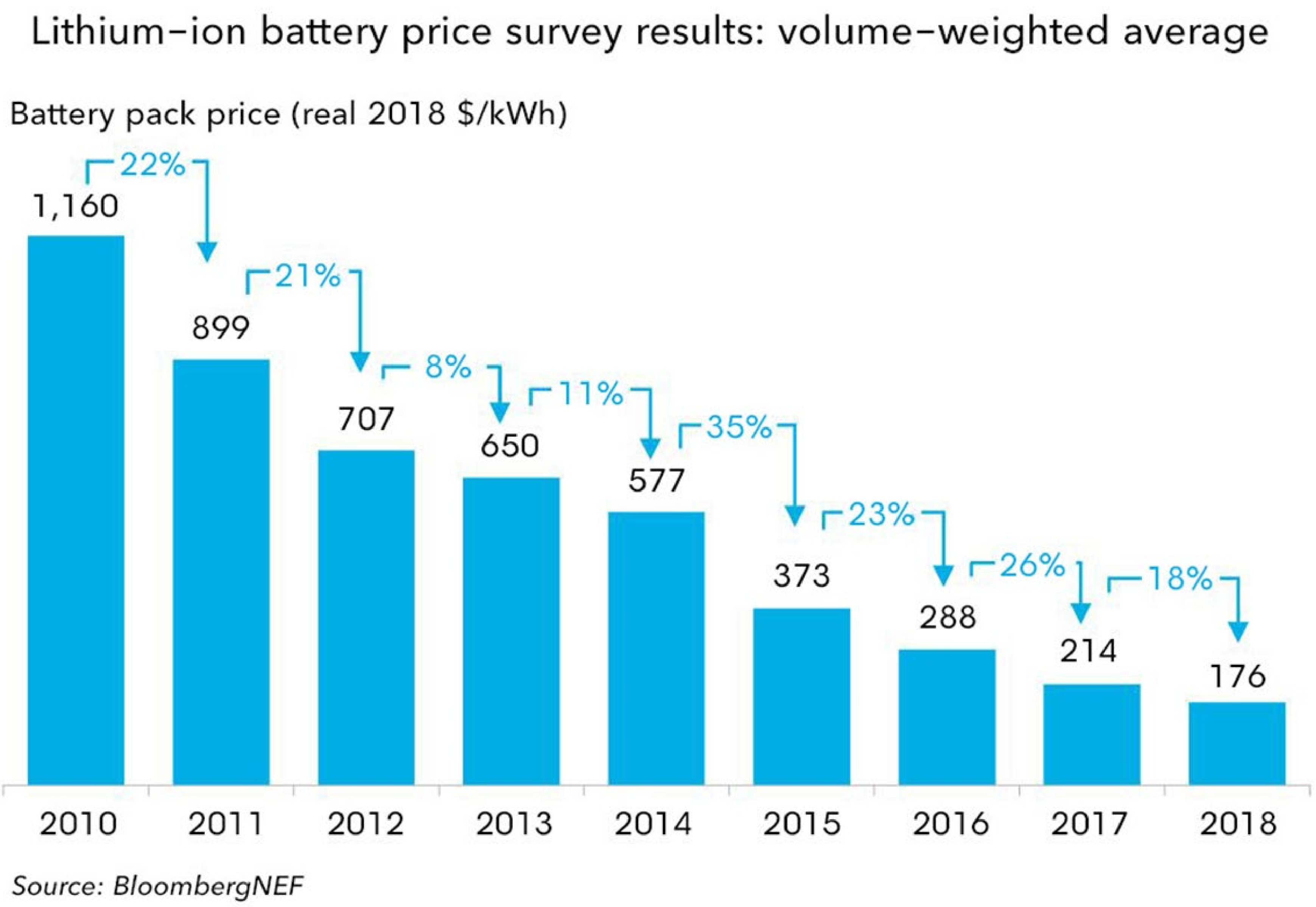
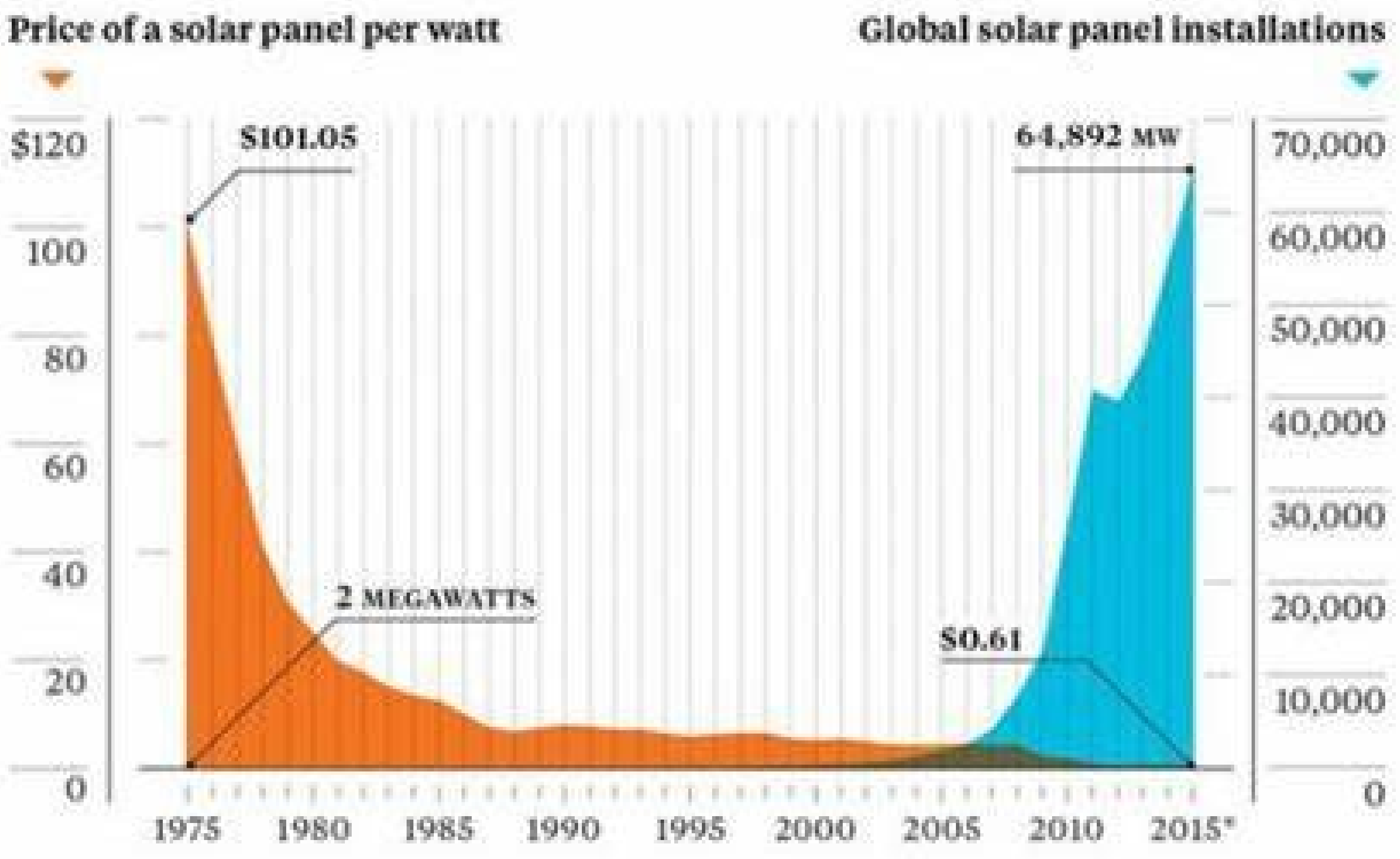
Battery Cost



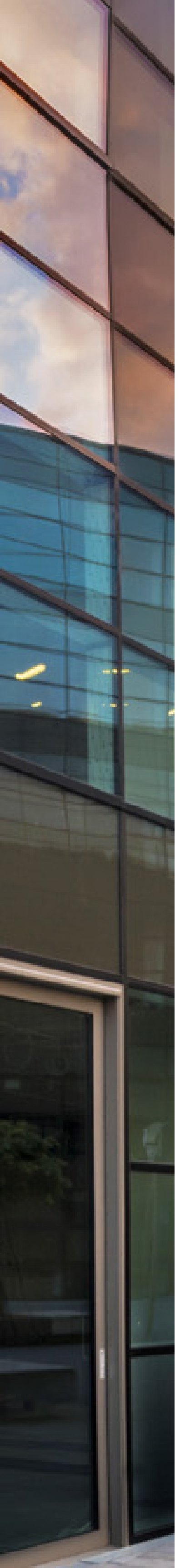


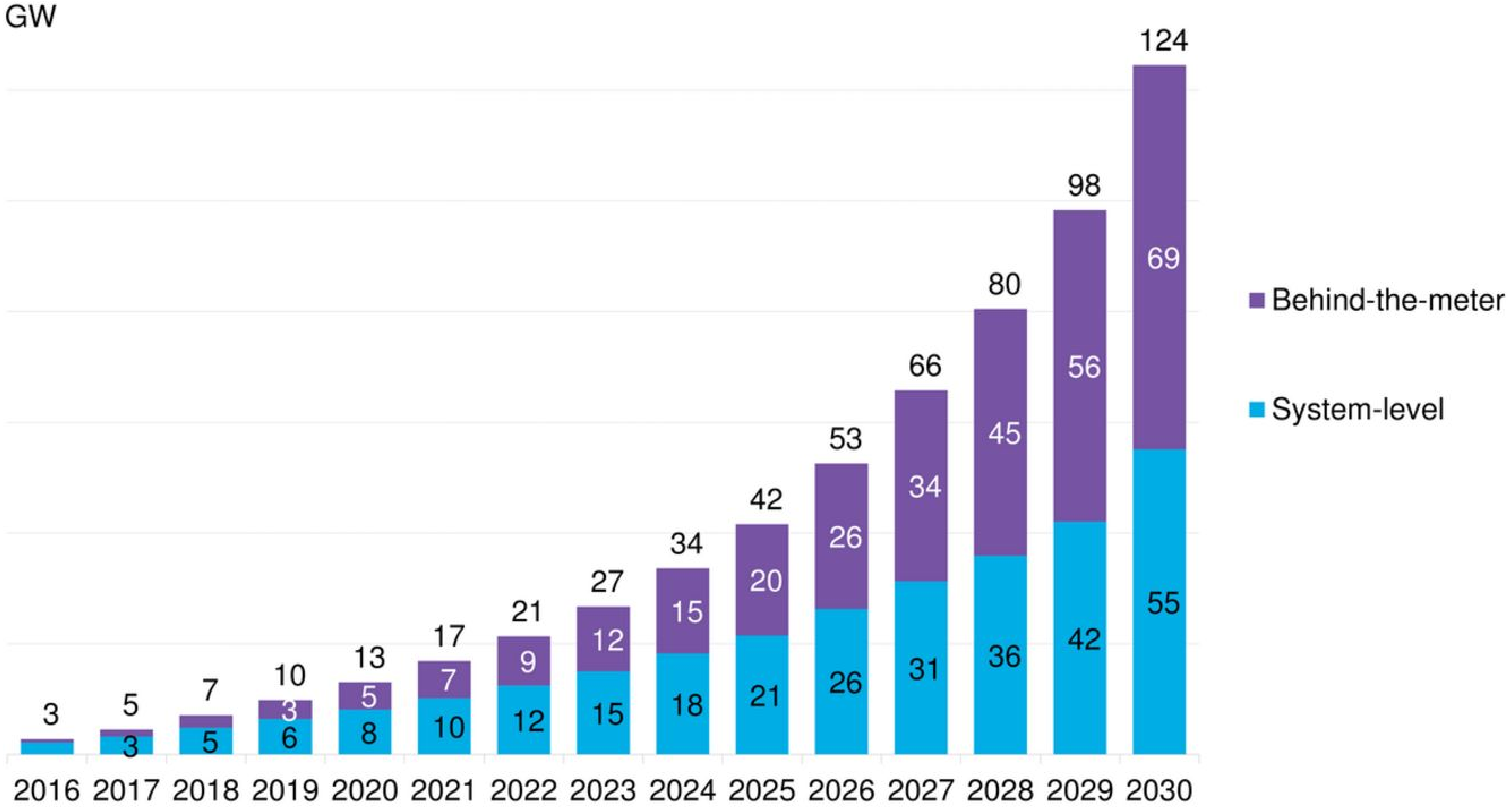
Price of batteries is ***halved*** every 3 years!

Solar Power Tipping Point

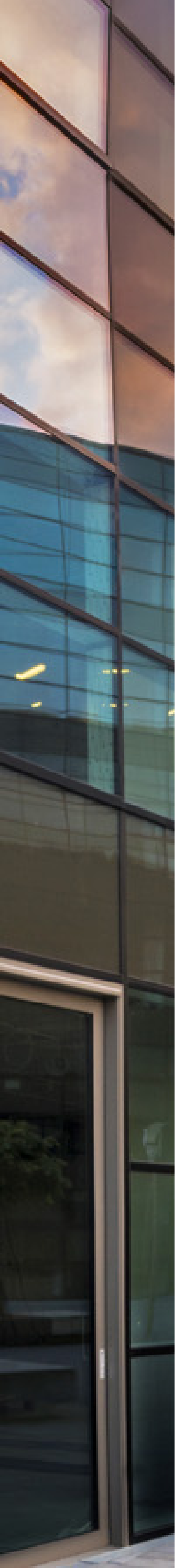


Buildings are becoming part of the storage and distribution system



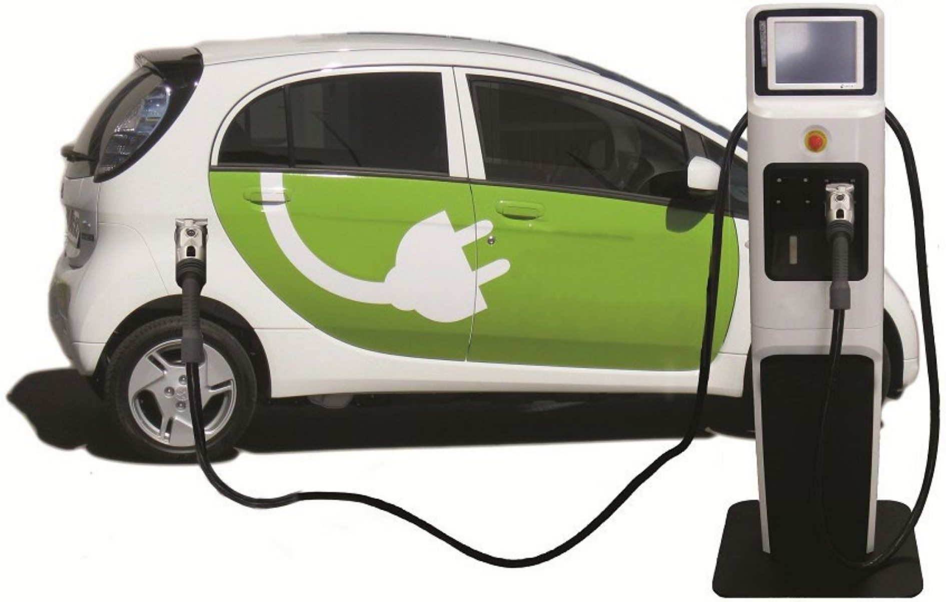


BNEF projections of storage deployment over the next decade

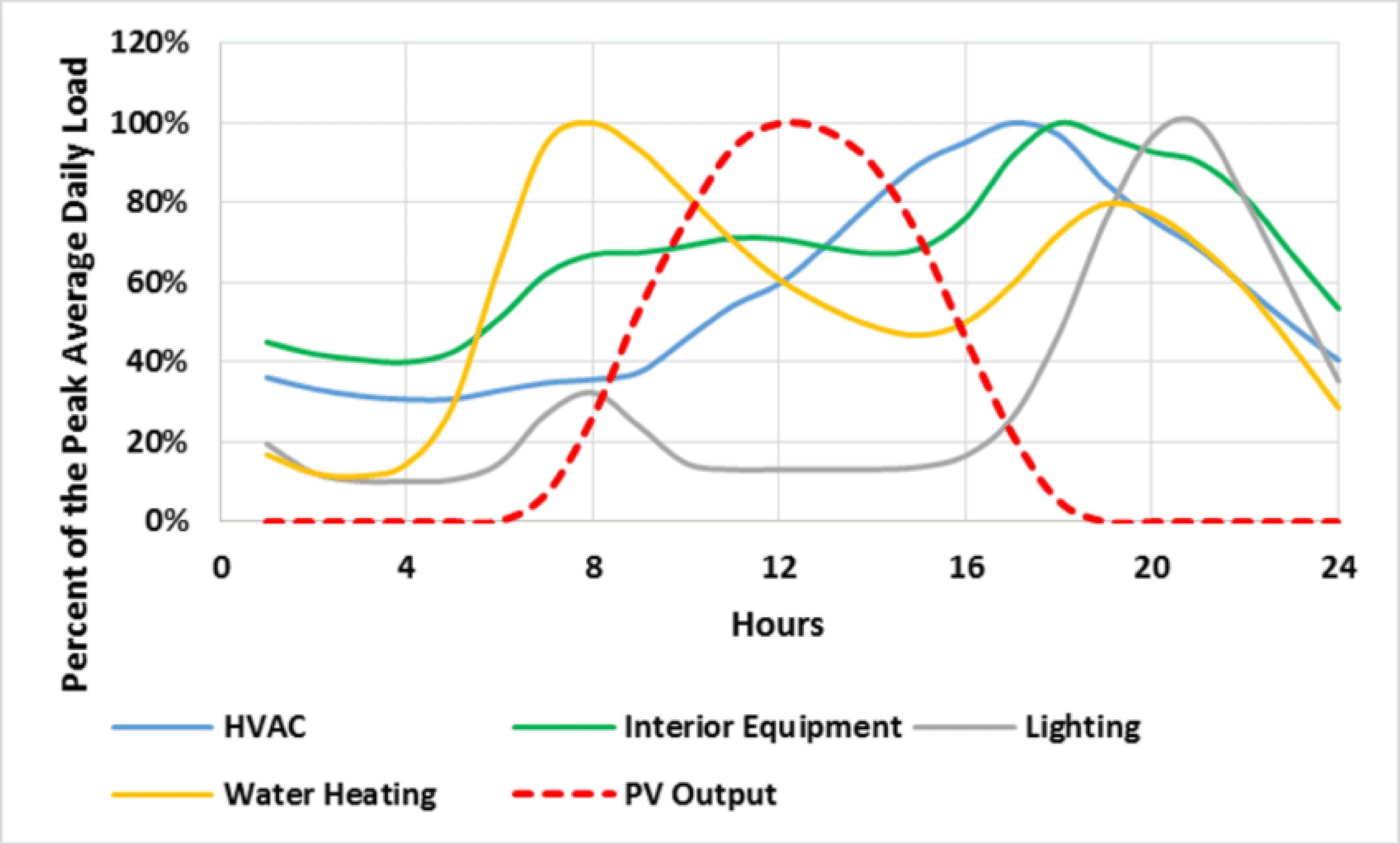


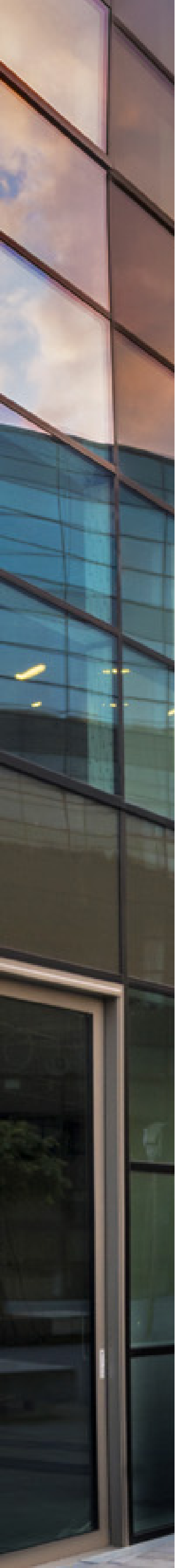
Opportunities for Building Integration with Grid

- **Permanent Efficiency**
  - Reduce building energy loads…
- **Peak Shifting**
  - Design to modify time of peak building energy use to adapt to grid…
- **Dynamic Response**
  - Actively reduce building energy use in response to short-term grid constraints…
- **Dispatchable Energy Storage**
  - Actively manage energy use patterns based on grid signals…

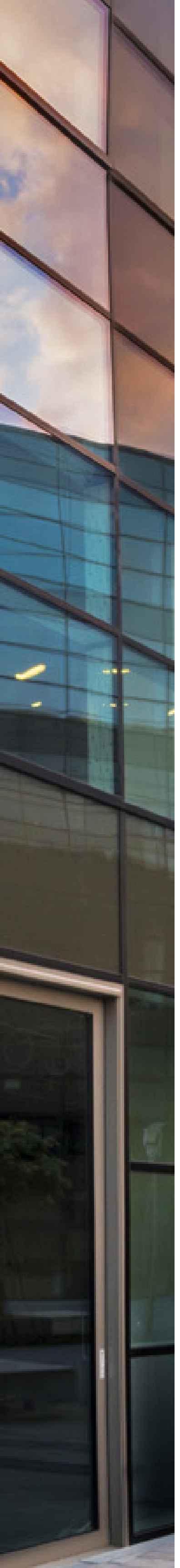


Residential Loads Peak at Different Times



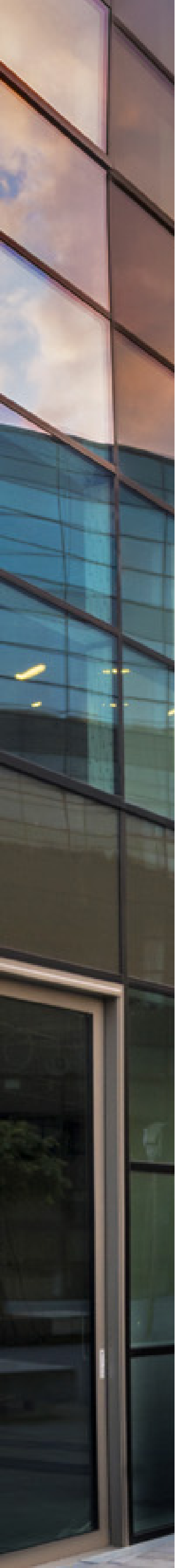


Considering GEBs in Standards and Energy Codes



Codes and Standards 101

- Standards
  - Referenced in codes
- Building Energy Codes
  - Prescriptive and performance-based compliance paths
  - Mandatory requirements apply to both
- Model Energy Codes
  - International Energy Conservation Code – Residential (2021 IECC-R)
  - ASHRAE Standard 90.1 (90.1-2019; referenced by 2021 IECC-C)
- Advanced Energy Codes
  - International Green Conservation Code (2021 IgCC)
  - California Title-24 (Title-24 2019)
  - NBI Building Decarbonization Code
- Voluntary Programs
  - LEED Grid Integration Pilot Credits
  - NBI GridOptimal



Model Building Energy Codes IECC-Residential 2021 and ASHRAE 90.1-2019

The current published versions of the model energy codes do not include requirements for dynamic flexible-load measures or on-site renewable energy systems. Several provisions could provide GEB value if smart control requirements are added.

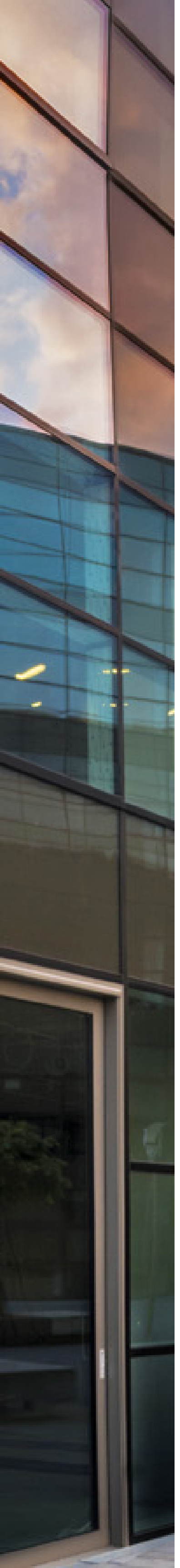
Example related requirements in IECC-R 2021

System	Code Section	Related Requirement
Systems	R403.1.1	Programmable thermostat
	R403.10.2	Time switches on pool heaters
Compliance	R406.3	Energy Rating Index and EV controls
Compliance	R406.4	Energy Rating Index and on-site renewable energy

Example related requirements in ASHRAE 90.1-2019

System	Related Requirement
HVAC	Heat pump supplementary heat control
	Night fan control
	Optimal start controls
	Parking garage fan controls
	Snow and ice-melting system control
	Thermostatic zone control
	Multiple chiller flow reduction
	Cooling tower variable speed control
	Multiple boiler flow reduction
	Demand control ventilation
	Thermostat setback
	Unoccupied space damper control
	Vestibule heating controls
	Guestroom thermostat and ventilation control
	Adjustable airflow control
Lighting	Display lighting control
	Task lighting control
	Daylighting control
	Occupancy sensor control
	Exterior lighting control
Power	Plug load controls

Source: Franconi, E, M Rosenberg, and R Hart. 2021. *Building Energy Codes and Grid-Interactive Efficient Buildings*. PNNL-28605. Pacific Northwest National Laboratory, Richland, Washington. [Publication Pending]



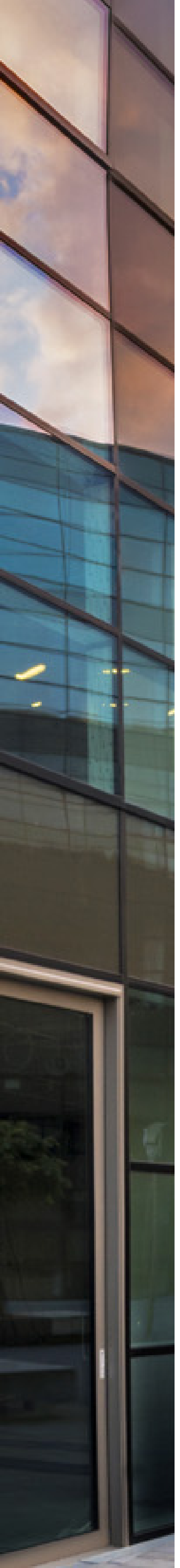
Advanced Energy Codes: Title-24 2019 Residential

GEB considerations in the Title 24 2019 residential code include:

- Adherence to the OpenADR communication protocol
- Prescriptive requirement for on-site solar energy systems
- Solar-ready requirements for residences that do not install PV systems
- Solar thermal water heating requirement for buildings with multiple dwelling units
- A PV/flexibility design rating that contributes to meeting performance-based compliance

System	GEB Measure	Subsection Label	Requirement Type	Overview
	Energy use measurement with remote communication capability	701.3.3(7.3.3)	Mandatory	Measurement devices with remote communication capability to the data acquisiton system shall be provided to collect and report energy consumption data for each energy supply source and subsystems that exceed the specified thresholds
	Solar ready buildings: production requirement	701.4.1.1.1 (7.4.1.1.1)	Prescriptive	Building projects shall contain on-site renewable energy systems that provide not less than than 6.0 kBtu/ft2 (20 kWh/m2) for single-story buildings and 10.0 kBtu/ft2 (32 kWh/m2) x the gross roof area for all other buildings
		701.4.1.1.2 (7.4.1.1.2)	Prescriptive	On-site renewable energy production requirements are reduced by ~ 30% for building projects that comply with additional equipment, SWH, and ENERGY STAR® efficiency requirements.
	Solar ready buildings: solar zone	701.3.2 (7.3.2)	Mandatory	Infrastructure must be allocated for renewable energy systems to produce the annual energy production requirements specified.
	Solar ready buildings: interconnection pathways	701.3.2 (7.3.2)	Mandatory	Space must be allocated for renewable energy systems to produce the annual energy production requirements specified based for the building.
	Electric-vehicle charging infrastructure	501.3.7.3.b	Mandatory	For buildings with greater than 100 occupants, install 2 or more electric-vehicle charging stations
HVAC	Demand responsive controls: HVAC	701.3.4.1 (7.3.4.1) 701.3.4.2 (7.3.4.2)	Mandatory	The building controls shall be designed with automated demand-response (DR) infrastructure capable of automatically implementing load adjustments to the HVAC (system zone set points and VSD equipment).
		701.4.3.4 (7.4.3.4)	Prescriptive	Exceptions to economizer requirements include choosing the renewable approach and meeeting additional cooling equipment efficiency requirements.
		Table B101.4 (table B-4, footnote b)	Prescriptive	Room air conditioners connected to utility programs are allowed a lower CEER value if in compliance with and certified per EnergyStar version 4.0 for connected equipment.
SHW	Demand responsive controls: SWH	Table B101.8 (TableB-8)	Prescriptive	The uniform energy factor (UEF) listed for electric-resistance grid-enabled water heaters supercedes ASHRAE Standard 90.1 that mandates heat-pump water heaters for > 75 gal storage (verify)
Lighting	Demand responsive controls: lighting	701.3.4.3 (7.3.4.3)	Mandatory	The building controls shall be designed with automated demand-response (DR) infrastructure capable of automatically implementing load adjustments to a centrally controlled lighting systems, excluding daylight-controlled areas

Source: Franconi, E, M Rosenberg, and R Hart. 2021. *Building Energy Codes and Grid-Interactive Efficient Buildings*. PNNL-28605. Pacific Northwest National Laboratory, Richland, Washington. [Publication Pending]



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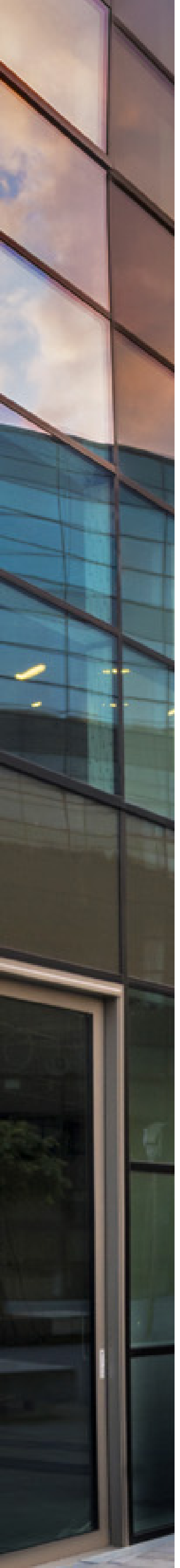
Advanced Energy Codes:
Title-24 2019 Commercial and IgCC 2018*

Requirement	Title-24 2019 Commercial	IgCC 2018
DR control communication protocol	OpenADR	
On-site renewable energy production	√	√
Solar Ready Buildings	√	√
Electric vehicle charging infrastructure		√
Demand responsive thermostats	√	√
Demand responsive HVAC	√	√
Demand responsive lighting	√	√

Source: Franconi, E, M Rosenberg, and R Hart. 2021. *Building Energy Codes and Grid-Interactive Efficient Buildings*. PNNL-28605. Pacific Northwest National Laboratory, Richland, Washington. [Publication Pending]

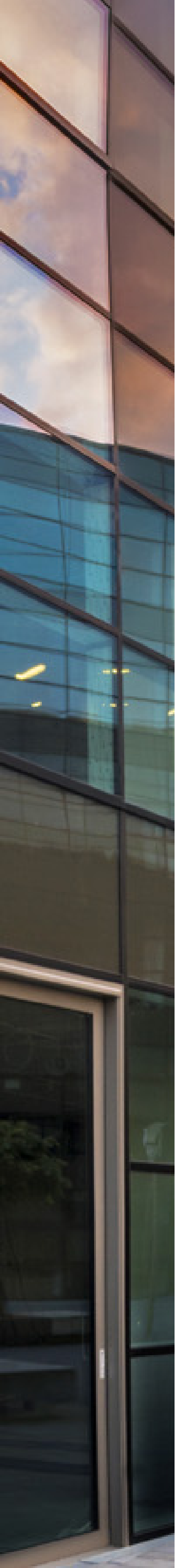
*The International Green Conservation Code is powered by ASHRAE Standard 189.1, which references ASHRAE Standard 90.1



GEB Elements in Washington State Energy Code

WSEC 2021 Code Proposal

- Requirement for load management capability in response to utility signal or TOU rate for one or more of the following:
  - Lighting
  - HVAC
  - Automatic Shading
  - Electric or Thermal Energy Storage
  - Service Hot Water Storage
  - Building Thermal Mass
- Required deployment of on-site renewables

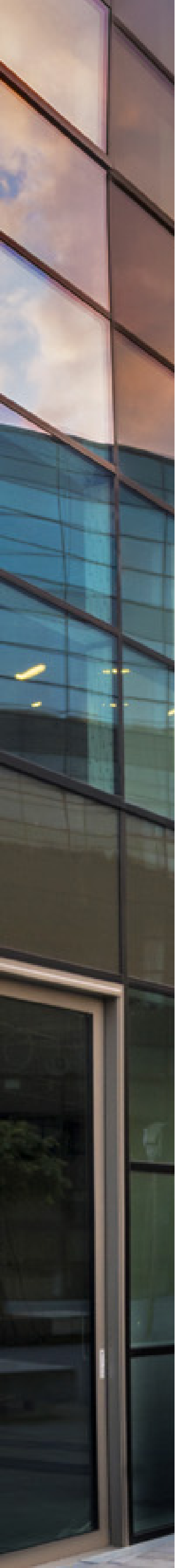


NBI Decarbonization Code

Overlay code language for IECC-R and IECC-C that addresses:

- Demand responsive water heating compliant with ANSI/CTA-2045
- Demand responsive thermostats
- Demand responsive HVAC
- Demand responsive lighting
- Building electrification
- On-site renewable energy
- Energy storage infrastructure
- Electric vehicle infrastructure

Source: New Buildings Institute, Building Decarbonization Code; available at https://newbuildings.org/resource/building-decarbonization-code/



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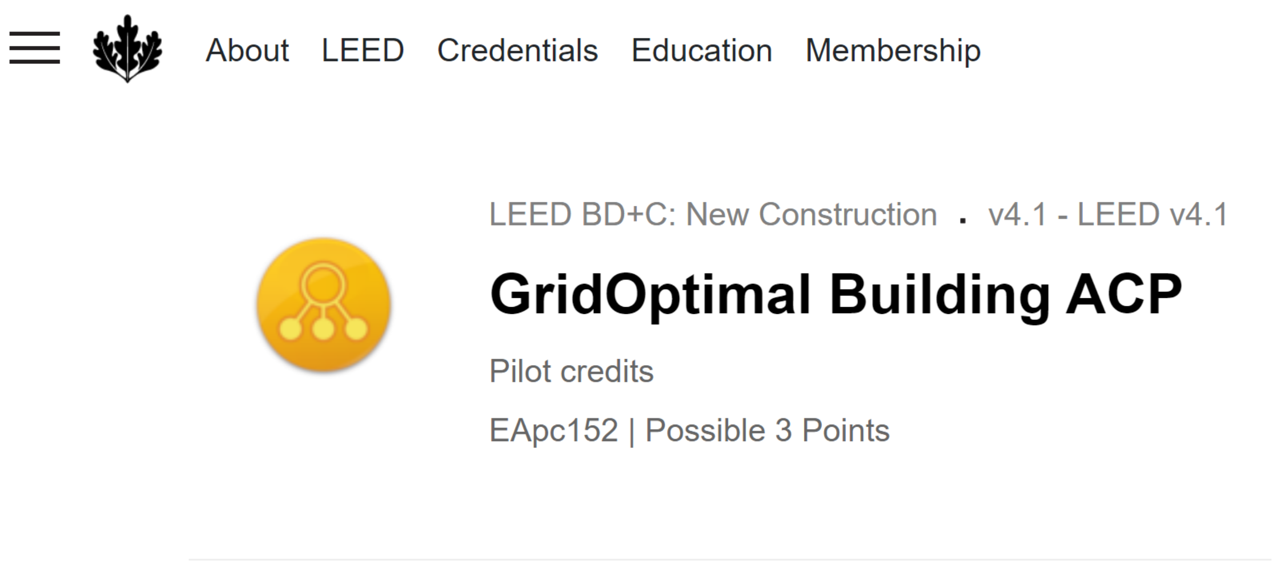
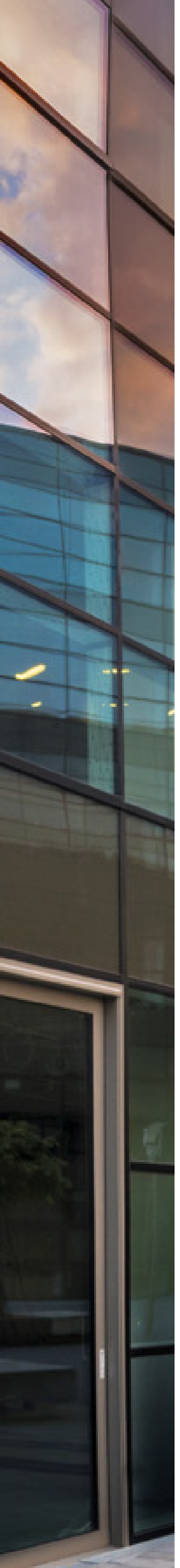
LEED Grid Integration Pilot Credits and NBI Grid Optimal Buildings Initiative

- Uses building simulation results to calculate and document GridOptimal metrics to earn pilot credit points.

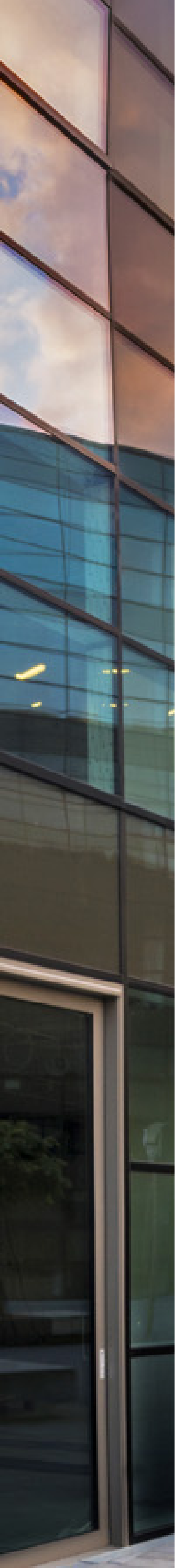
GridOptimal metrics include:

1. Grid Peak Contribution
2. Grid Carbon Alignment
3. Site Renewable Utilization Efficiency
4. Short-Term Demand Flexibility
5. Long-Term Demand Flexibility
6. Dispatchable Demand Flexibility





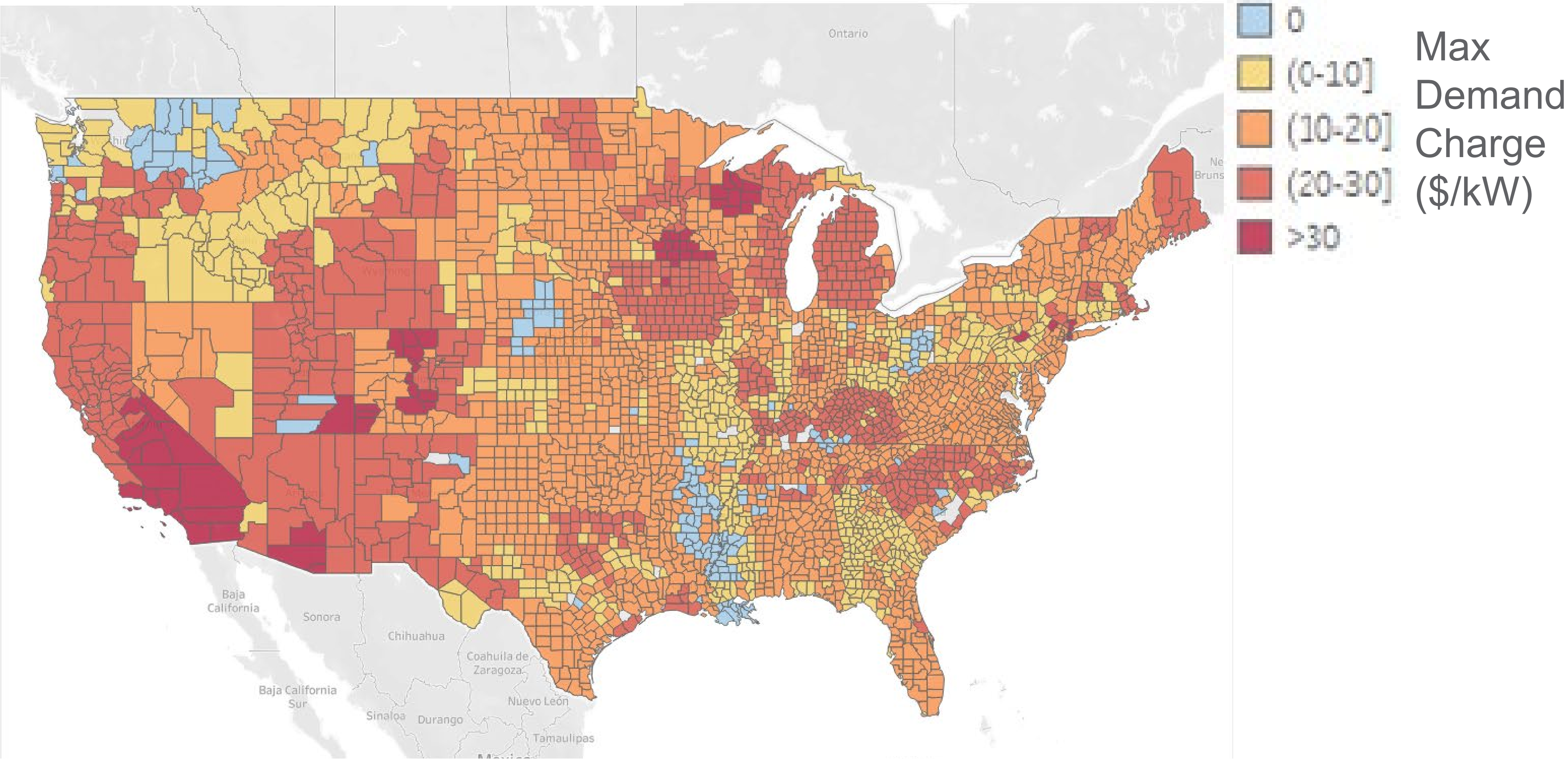
Challenges and Opportunities



Overview

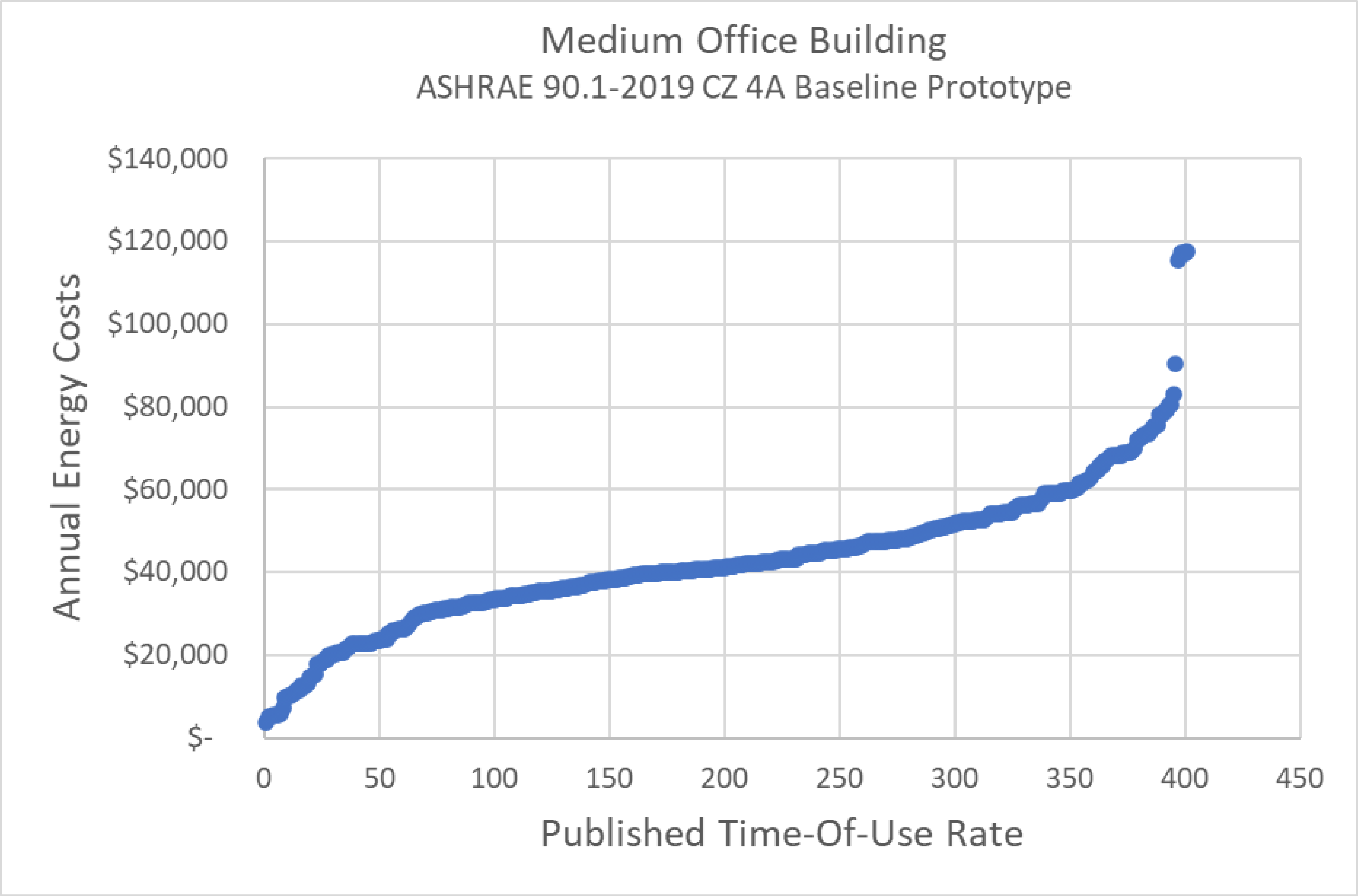
- Challenges
  - Large variations in utility rates
  - Utility rates don't reflect electricity carbon emissions
  - Prescriptive path doesn't account for variability in rates or carbon
- Opportunities
  - Lower cost GEB technologies
  - New energy code compliance mechanisms
  - Targeted analysis to inform GEB advancement in code

Demand Charges Are All Over the Map



Source: PNNL; mapping of max demand charges in published commercial building utility rates as indicated in the OpenEI utility rate database (https://openei.org/apps/USURDB)

Large Variations in Utility Rates Impact Energy Costs and GEB Cost Effectiveness

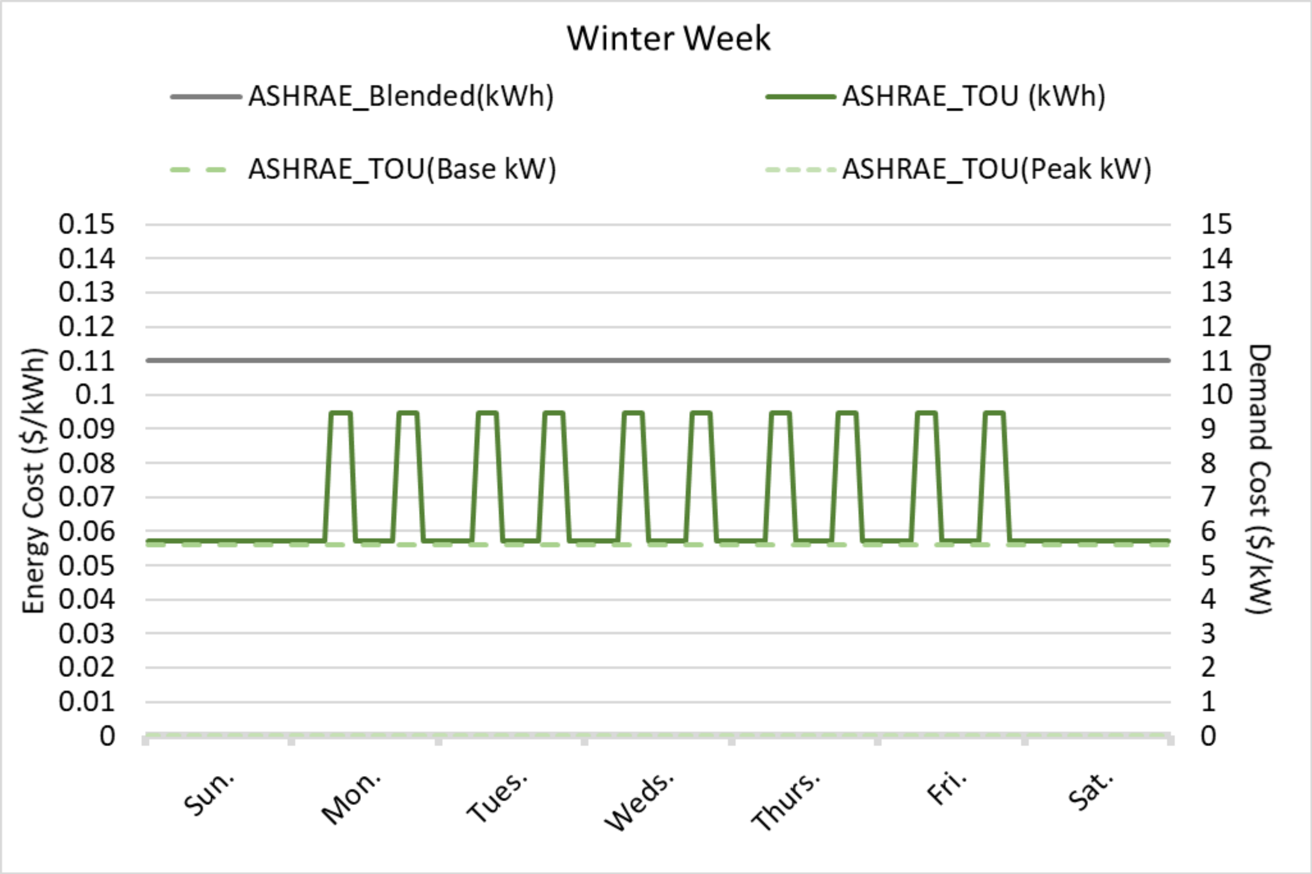


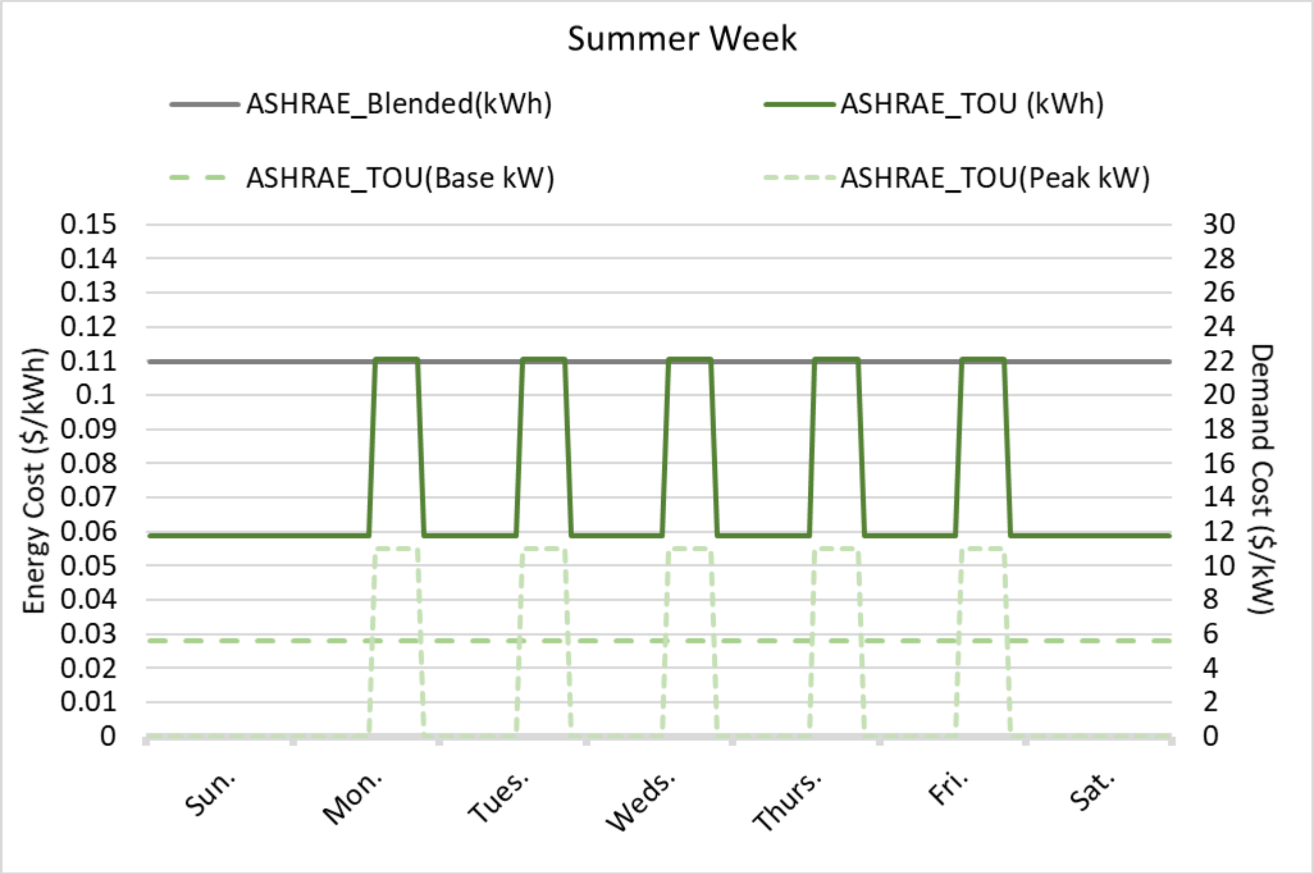
Annual electricity costs determined for 401 U.S. TOU rates published in the OpenEI Utility Rate Database.

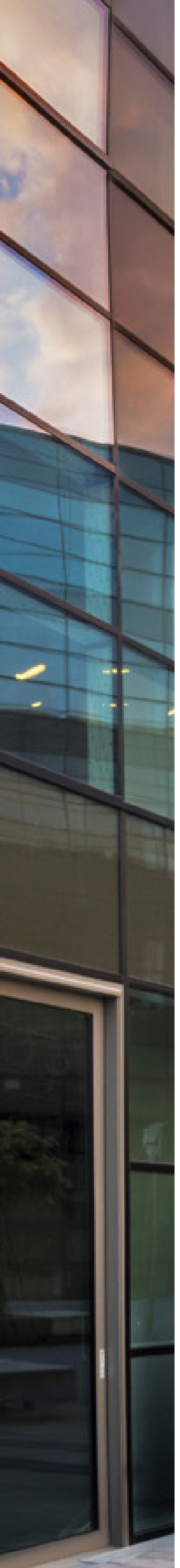
- Total Cost Data
  - Gas: $2,062
  - Electricity
    - Average: $ 43,034
    - Median: $ 41,199
    - Minimum $ 3,533
    - Maximum $117,521

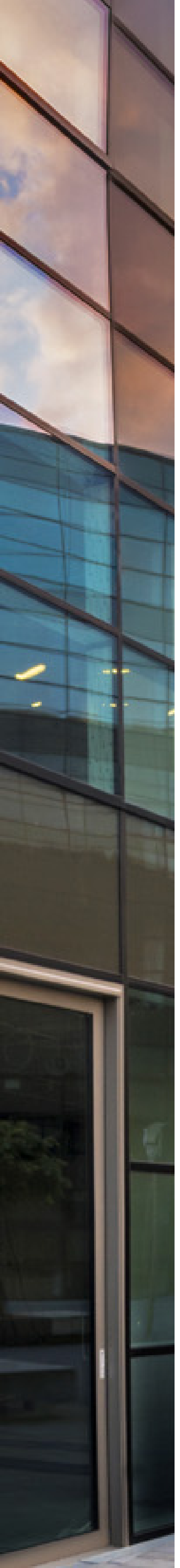
Use a Representative TOU Rate

Accepted as part of the ASHRAE 90.1-2022 Work Plan is a TOU rate that can be used as an optional alternative to the traditional blended energy rate for demonstrating the cost effectiveness of new code change proposals.







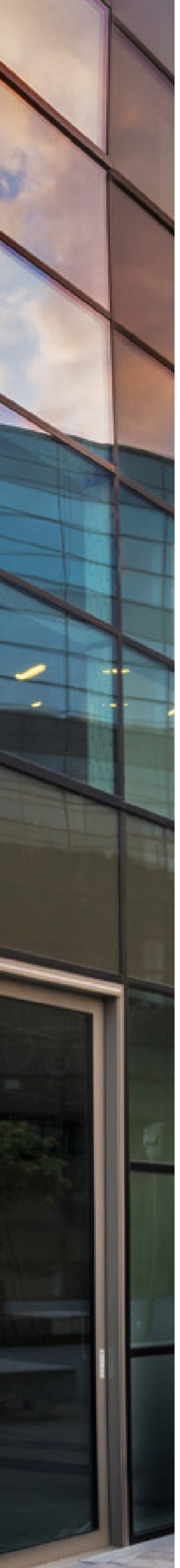


Rates Matter Less for Lower Cost GEB Measures

Medium Office Prototype Analysis

	First Cost	GEB Measure	Net LCC ($)	
			Blended Rate	ASHRAE TOU
Climate Zone 4A	Lower	Setback heating w/ pre-heating	(2,248)	(9,801)
		OA ventilation ramp down	(4,293)	(7,117)
		20% light power reduction	(4,999)	(10,769)
	Higher	SHGC decreased by 10%	5,588	4,470
		EER increased by 20%	48,415	43,315
	Highest	Battery Storage	167,002	74,837

Source: Franconi, E, J Lerond, C Nambiar, M Rosenberg, R Hart, D Kim. 2021. *Realizing Demand Flexibility with Commercial Building Energy Codes*. PNNL-29604. Pacific Northwest National Laboratory, Richland, Washington. [Publication Pending]



Utilize New Code Mechanisms

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Incorporate GEB-related requirements into new code mechanisms, such as the Additional Energy Efficiency Credits

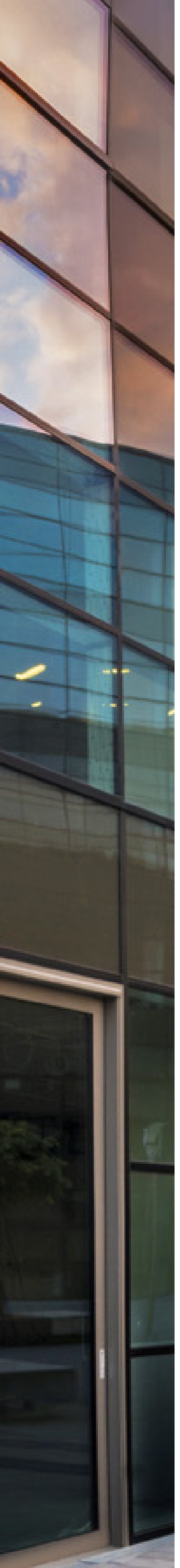
Office example

Additional Energy Efficiency Credits for Group B Occupancies

Climate Zone:	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
C406.2.1: 5% Heating	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	1	1	NA	1
C406.2.2: 5% Cooling	6	6	5	5	4	4	3	3	3	2	2	2	1	2	2	2	1
C406.2.3: 10% Heating	NA	NA	NA	NA	NA	NA	NA	1	NA	NA	2	1	1	2	2	NA	1
C406.2.4: 10% Cooling	11	12	10	9	7	7	6	5	6	4	4	5	3	4	3	3	3
C406.3.1: 10% LPA	9	8	9	9	9	9	10	8	9	9	7	8	8	6	7	7	6
C406.4:Digital Lt Ctrl	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	1
C406.5: Renewable	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
C406.6: DOAS	4	4	4	4	4	3	2	5	3	2	5	3	2	7	4	5	3
C406.7.1: SWH HR	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C406.7.2: SWH NG eff	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C406.7.3: SWH HP	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
C406.8: 85% UA	1	4	2	4	4	3	NA	7	4	5	10	7	6	11	10	14	16
C406.9: Low Leak	2	1	1	2	4	1	NA	8	2	3	11	4	1	15	8	11	6

Additional Energy Efficiency Credits

- Establish a peak load management credit category for GEB technology
  - Lighting and HVAC demand flexibility and demand response
  - Automated shading
  - Electric & ice storage
  - SHW storage
  - Building mass & night flush
- Include the section as a requirement for performance-based compliance



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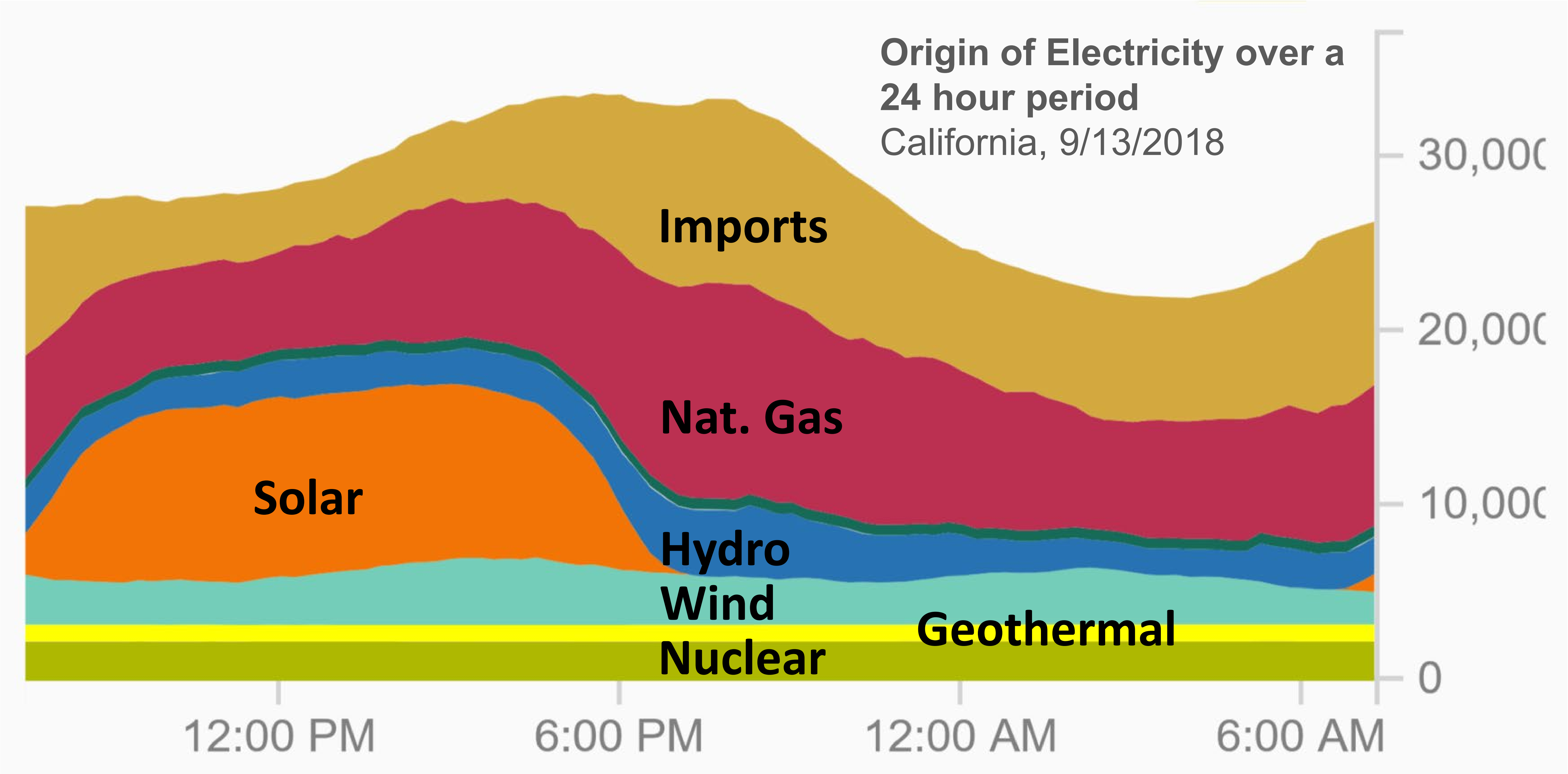
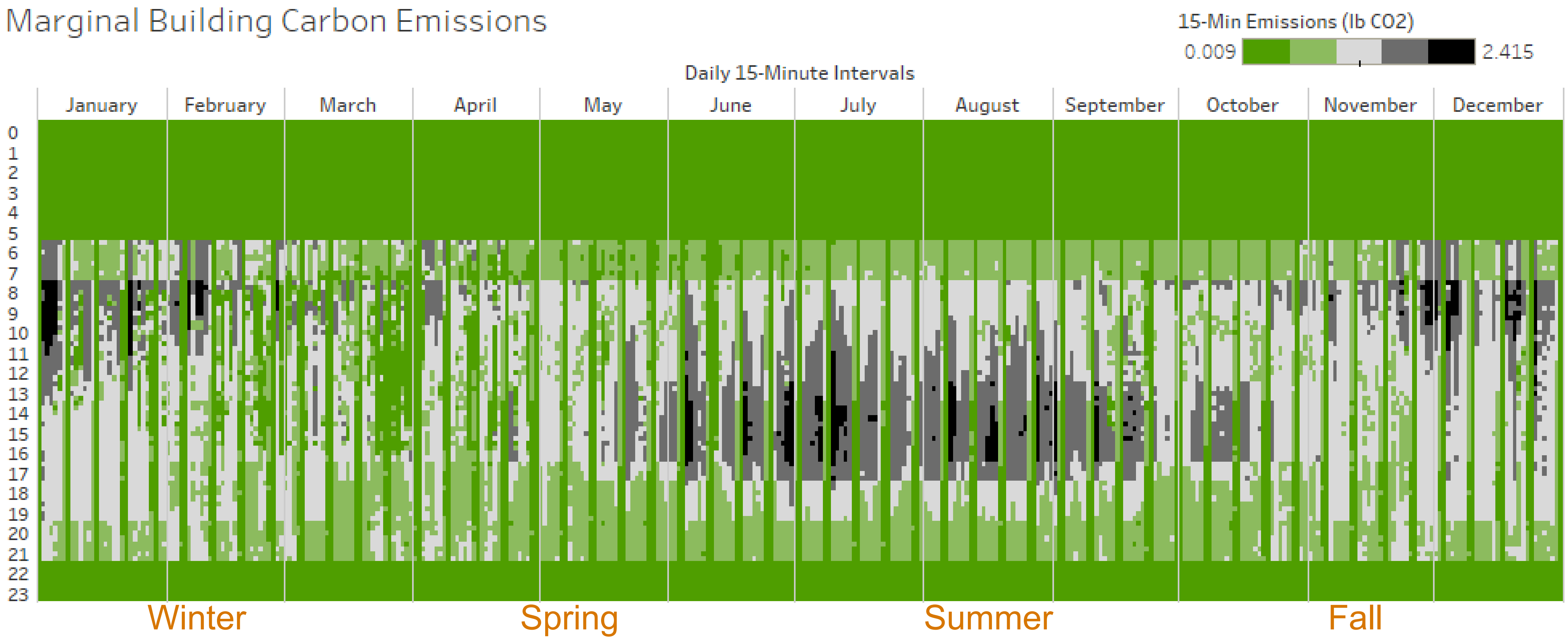
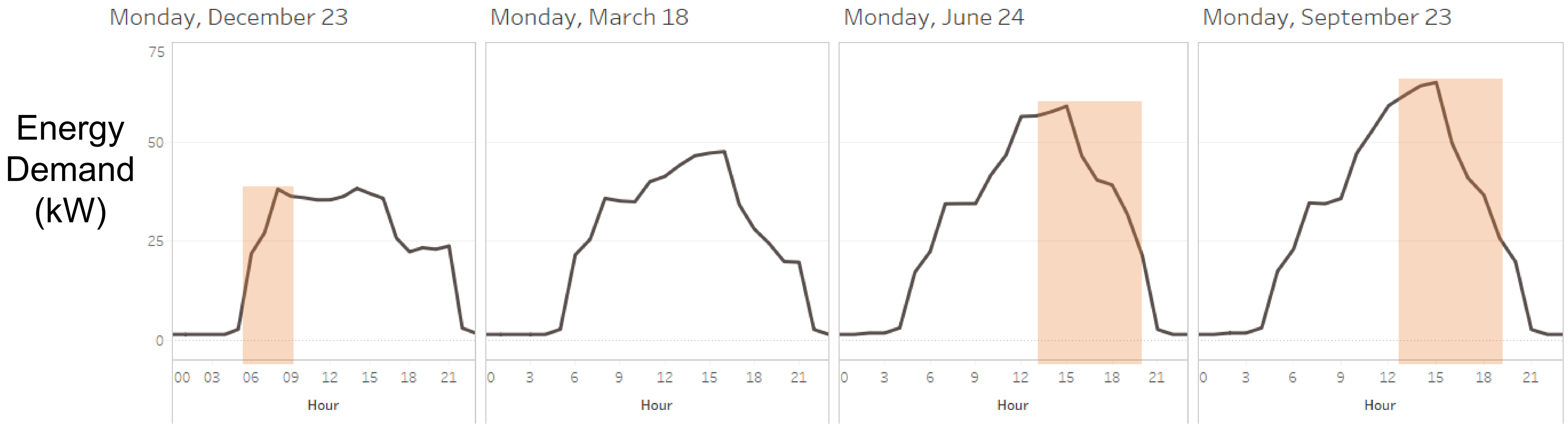
Carbon Content of Grid Varies in sub-Hour Increments



Carbon Impacts not Aligned with Current Grid Signals

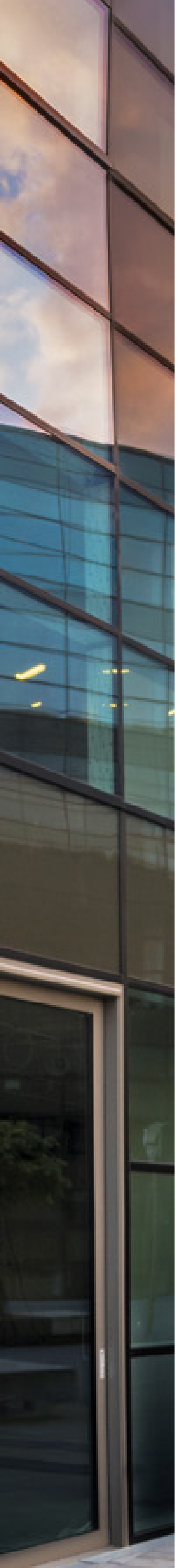


Building Energy Load Shape Priorities Vary Seasonally; Requires Performance Analysis to Address



Reduce energy use in the

Winter mornings and **Summer evenings**



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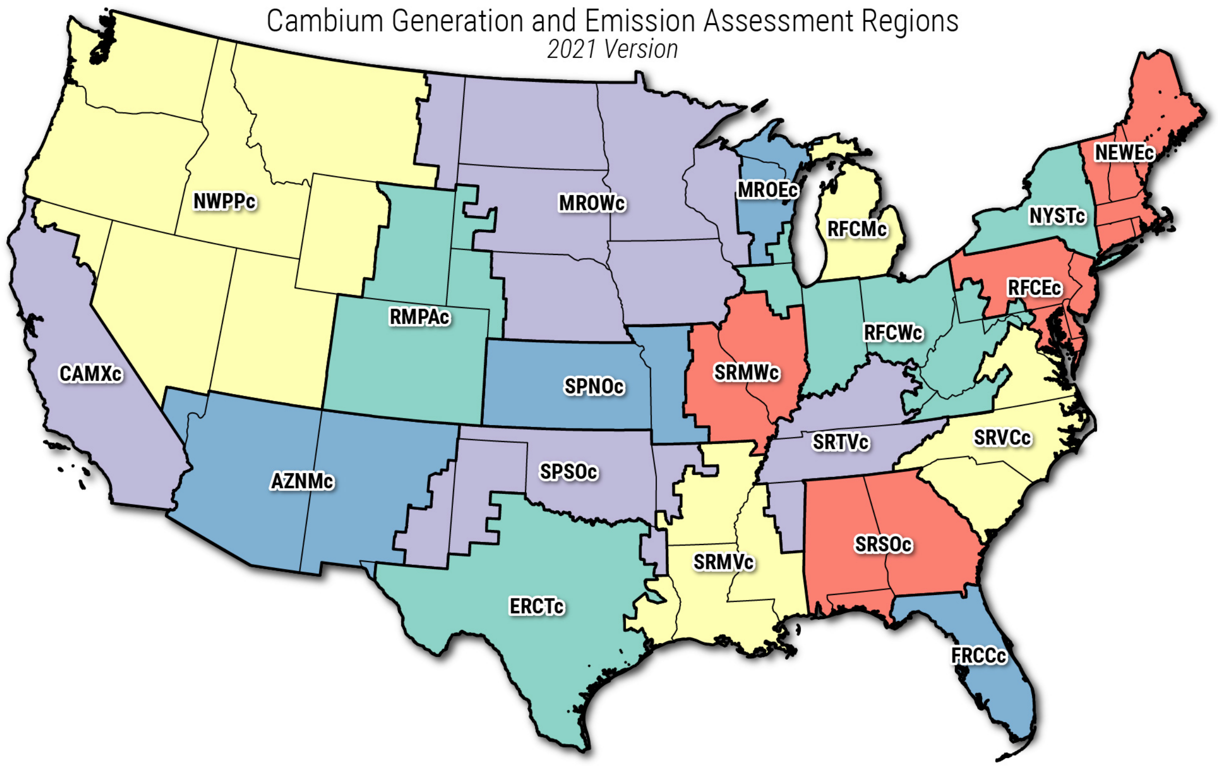
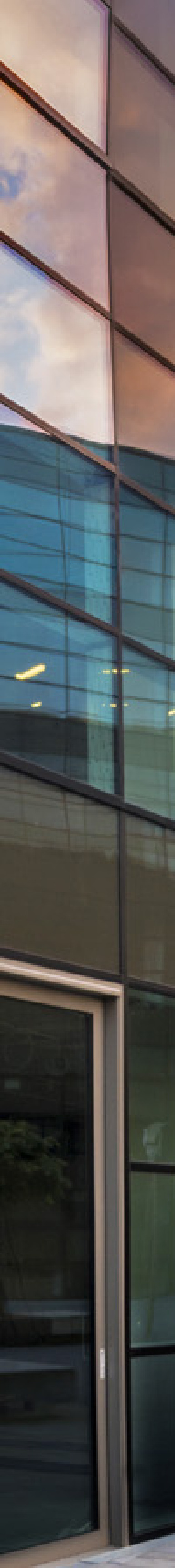
Future-Proofing Building Efficiency Investments with Energy Codes

Long-run marginal CO_2e emissions eGrid hourly data trends
20-year levelized values, mid-case scenario

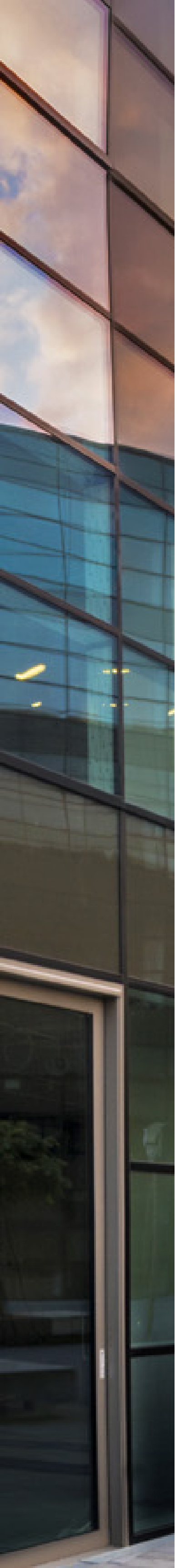
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
NWPP	342	334	328	328	329	327	324	325	325	307	264	228	218	216	214	216	215	217	225	265	310	332	345	349
CAMX	229	216	222	232	241	244	247	241	231	170	111	64	57	56	56	57	60	60	64	105	171	209	239	235
AZNM	330	334	339	346	348	350	350	346	320	262	203	182	181	182	181	180	178	180	188	236	284	313	323	323
RMPA	443	440	436	438	439	435	428	413	377	322	272	248	245	243	244	250	248	258	298	381	422	440	439	440
MROW	382	390	394	394	386	368	349	306	263	216	186	177	176	177	177	181	186	215	273	314	336	340	351	366
SPSO	453	452	449	450	458	454	445	410	346	258	205	193	194	197	197	198	205	239	332	413	452	449	446	452
SPNO	493	499	500	495	495	482	467	422	367	299	274	265	266	266	269	266	272	299	366	417	446	454	465	479
SRMV	432	422	417	417	418	423	415	383	327	275	254	251	251	254	258	260	266	299	357	413	437	431	435	444
ERCT	438	433	429	431	440	428	411	368	283	199	162	159	160	161	161	164	166	178	241	324	381	383	401	431
SRMW	494	507	505	507	507	496	460	397	324	258	224	215	217	218	219	218	238	286	356	414	446	449	461	476
MROE	535	535	535	537	535	528	489	443	391	329	302	297	298	300	302	303	319	365	433	483	517	519	518	529
RFCW	531	535	534	535	528	511	465	395	326	268	253	251	250	254	256	261	277	345	401	451	471	481	507	522
SRTV	553	564	566	566	557	536	492	427	349	288	273	271	269	271	273	277	294	354	428	479	492	483	502	527
SRSO	510	514	512	514	520	519	468	383	306	266	252	249	252	254	260	267	289	357	416	465	466	451	469	497
SRVC	397	401	401	402	399	379	321	256	190	152	143	141	145	149	152	158	178	252	302	332	327	326	354	382
FRCC	557	549	546	546	555	562	457	281	171	143	136	135	138	146	153	166	196	297	389	439	433	428	482	537
RFCM	463	460	461	459	461	459	440	412	373	340	331	330	332	336	340	341	355	398	439	473	478	464	461	468
RFCE	358	358	358	361	365	357	330	297	259	239	234	236	238	243	244	252	277	323	348	363	357	359	363	363
NYUP	170	169	169	169	171	168	156	142	124	117	113	112	112	114	115	120	133	157	178	191	184	178	179	179
NYLI	188	187	184	186	187	188	176	160	138	131	129	129	129	133	134	140	155	183	200	213	208	206	204	196
NEWE	178	174	173	173	174	174	165	150	135	127	125	124	123	129	130	136	156	185	202	209	202	193	193	185



Note: Data based on preliminary results from NREL's Cambium tool. Scenarios can be viewed and downloaded at https://cambium.nrel.gov.



Summary and Discussion



GEBs in Energy Codes Summary

Opportunities

Prescriptive:

- Flexible Load Capabilities
  - Heating
  - Cooling
  - DHW
  - Vehicle Charging
- Smart Appliances
- Expanded Cx Requirements
- Distributed Generation
  - On-Site Solar
  - On-Site Storage
  - Self Utilization

Performance:

- Consideration of Demand and Carbon Metrics (TOU)
- Load Shape Modeling

Challenges

Prescriptive:

- Flexible Load Capabilities
  - Heating
  - Cooling
  - DHW
  - Vehicle Charging
- Smart Appliances
- Expanded Cx Requirements
- Distributed Generation
  - On-Site Solar
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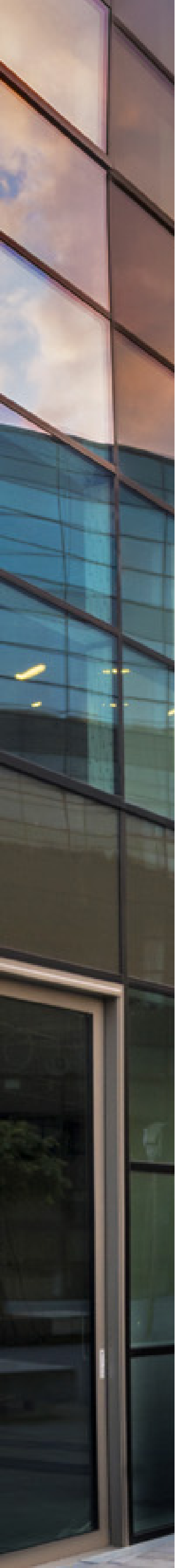
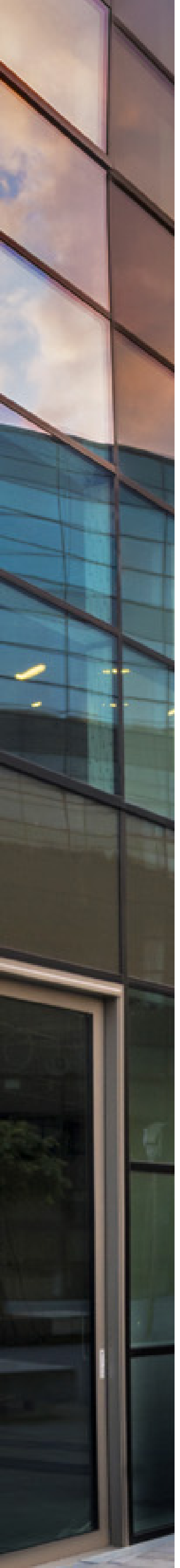
Performance:

- Consideration of Demand and Carbon Metrics (TOU)
- Load Shape Modeling



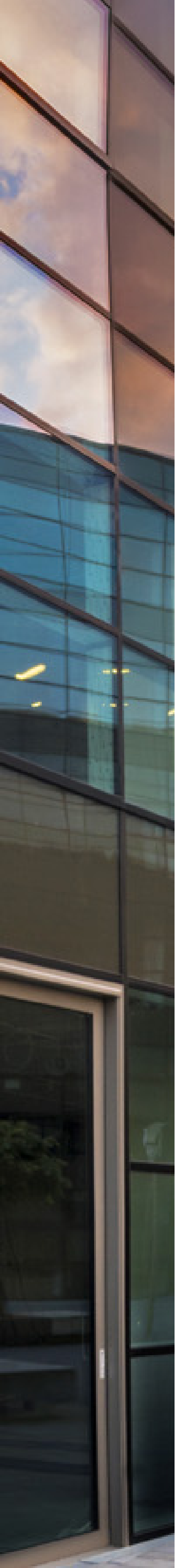
GEB in Energy Codes Summary

- Trends and Drivers
  - Buildings play an important role in decarbonization, which requires increased efficiency and demand flexibility to shed and shift load
  - Building energy codes are an effective policy mechanism for achieving GEBs
- Challenges
  - Large variations in utility rates
  - Utility rates don’t reflect electricity carbon emissions
  - Prescriptive path doesn’t account for variability in rates or carbon
- Near-term opportunities
  - Lower cost GEB technologies
  - New energy code compliance mechanisms
  - Targeted analysis to inform GEB advancement in code



GEB in Energy Codes Discussion

- Addressing GEBs with performance-based compliance
- Future proofing building investments with energy codes
- What are the benefits of adopting a standardized communication protocol for GEB technologies? What are the disadvantages?



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Thank you