SMART BUILDINGS CENTER

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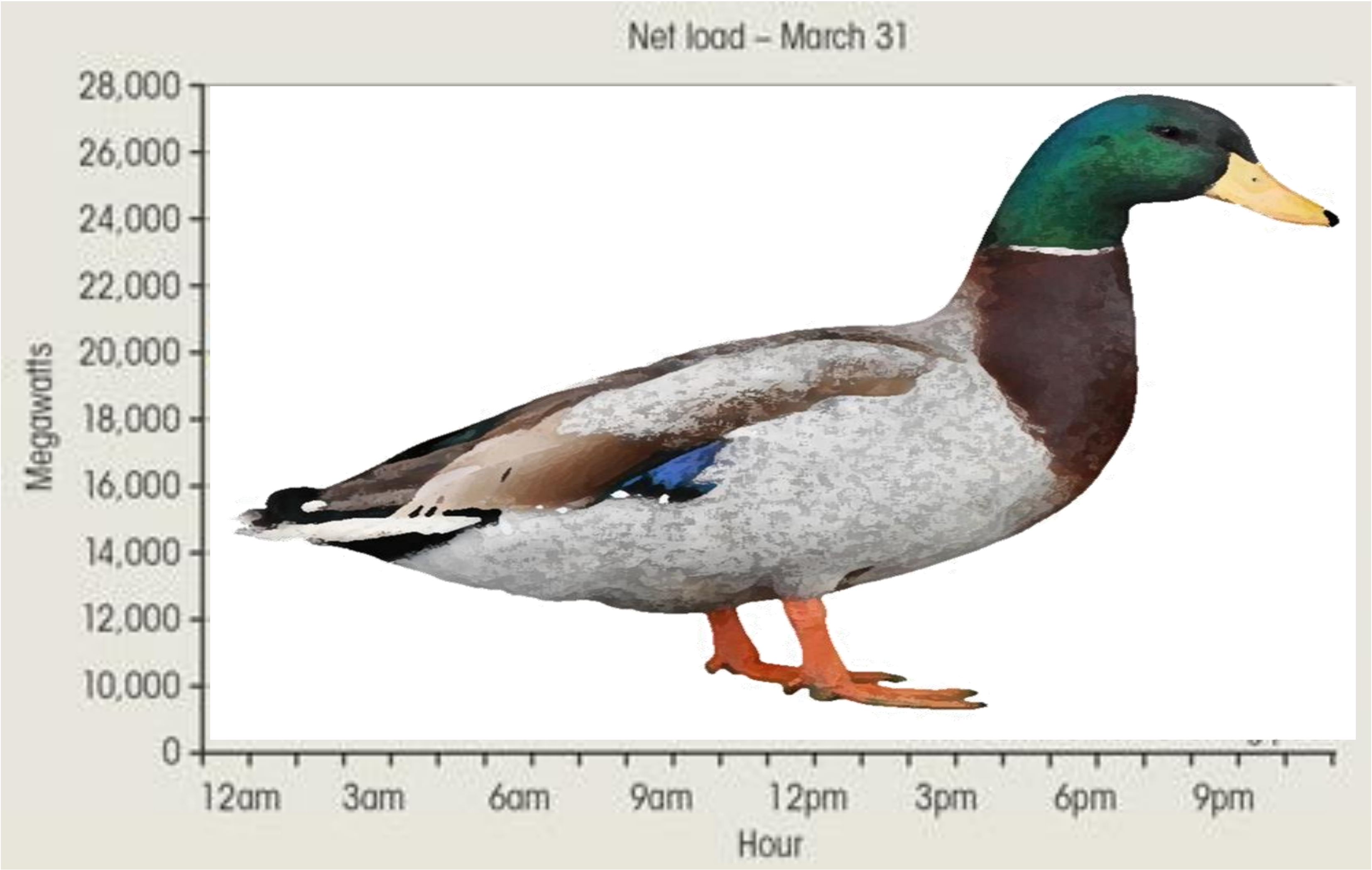
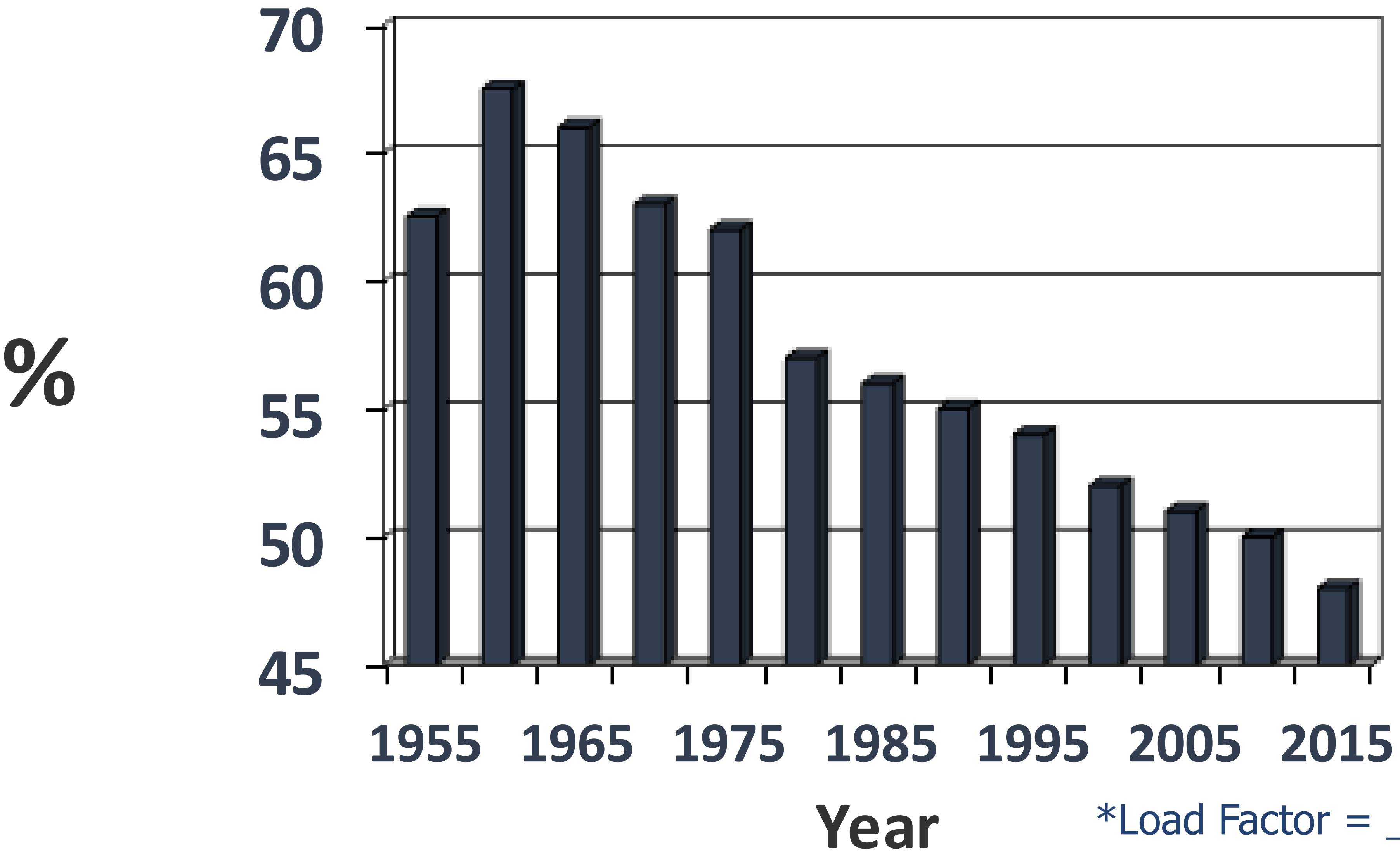
Carbon-Free Grid Goals

The Ominous “Duck Curve”

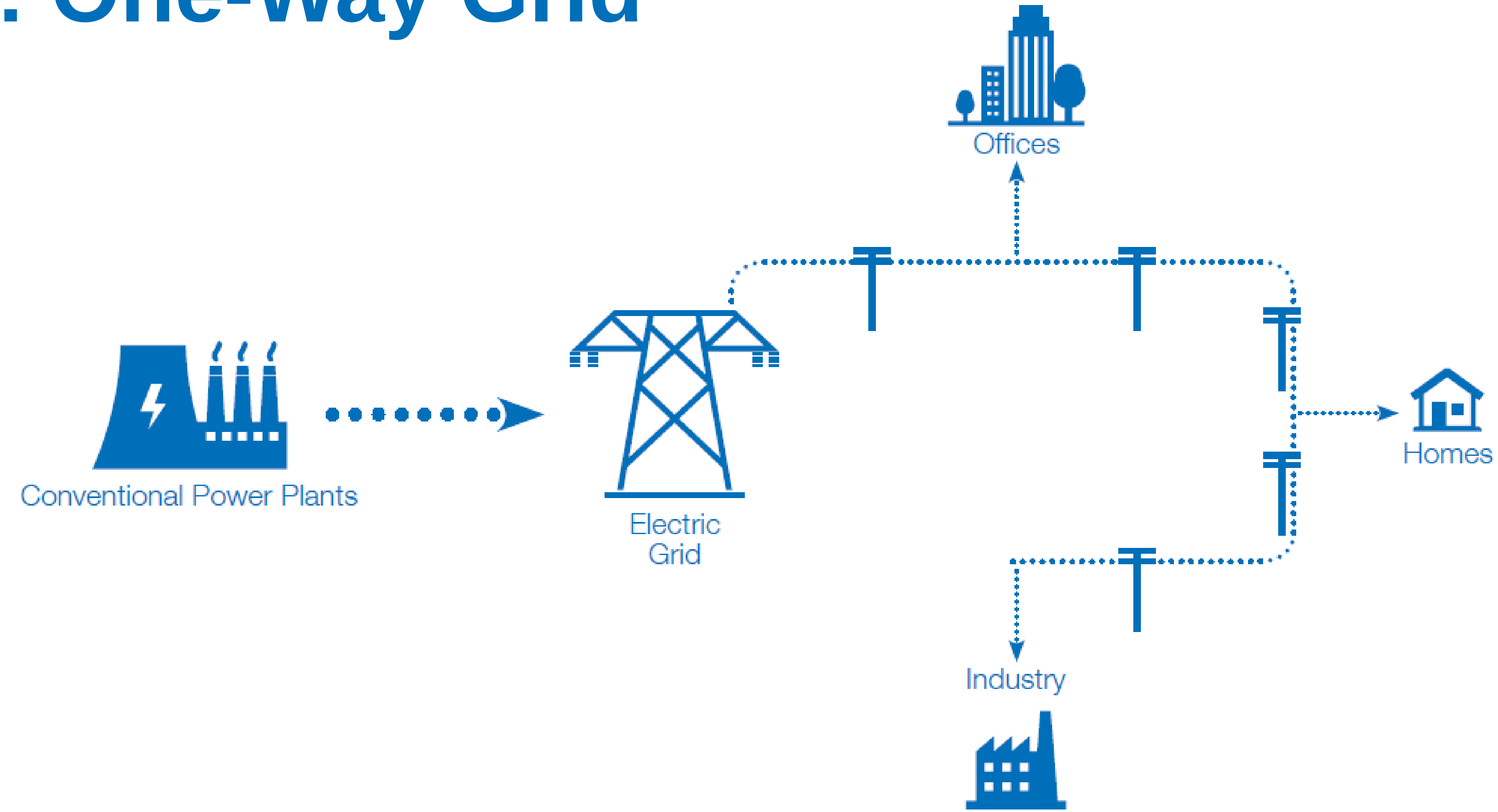


Utility Load Factors* in the USA

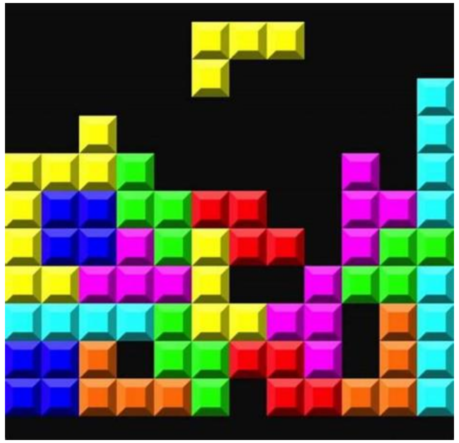


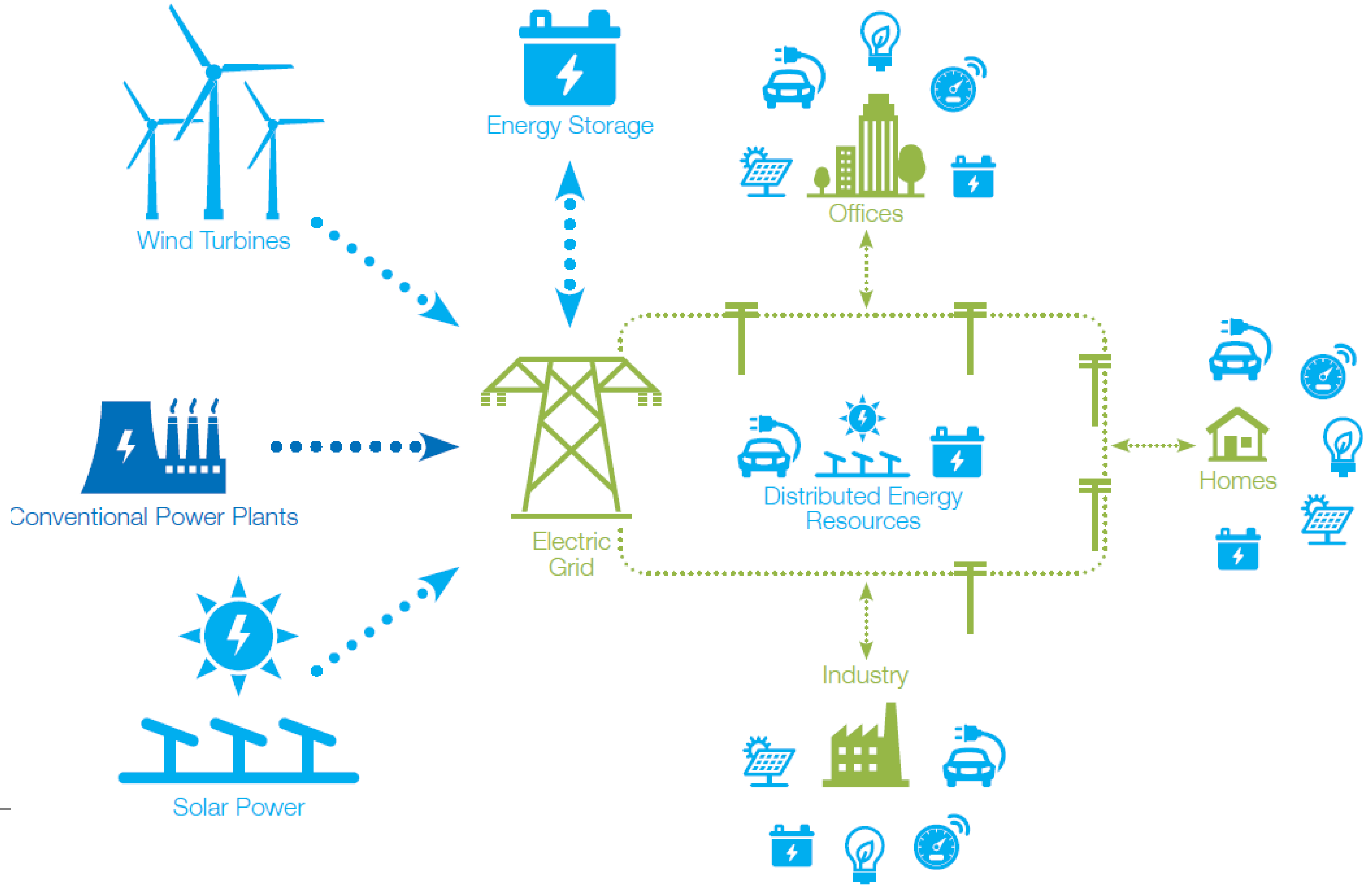
*Load Factor = Avg. Load / Peak Load

Legacy: One-Way Grid



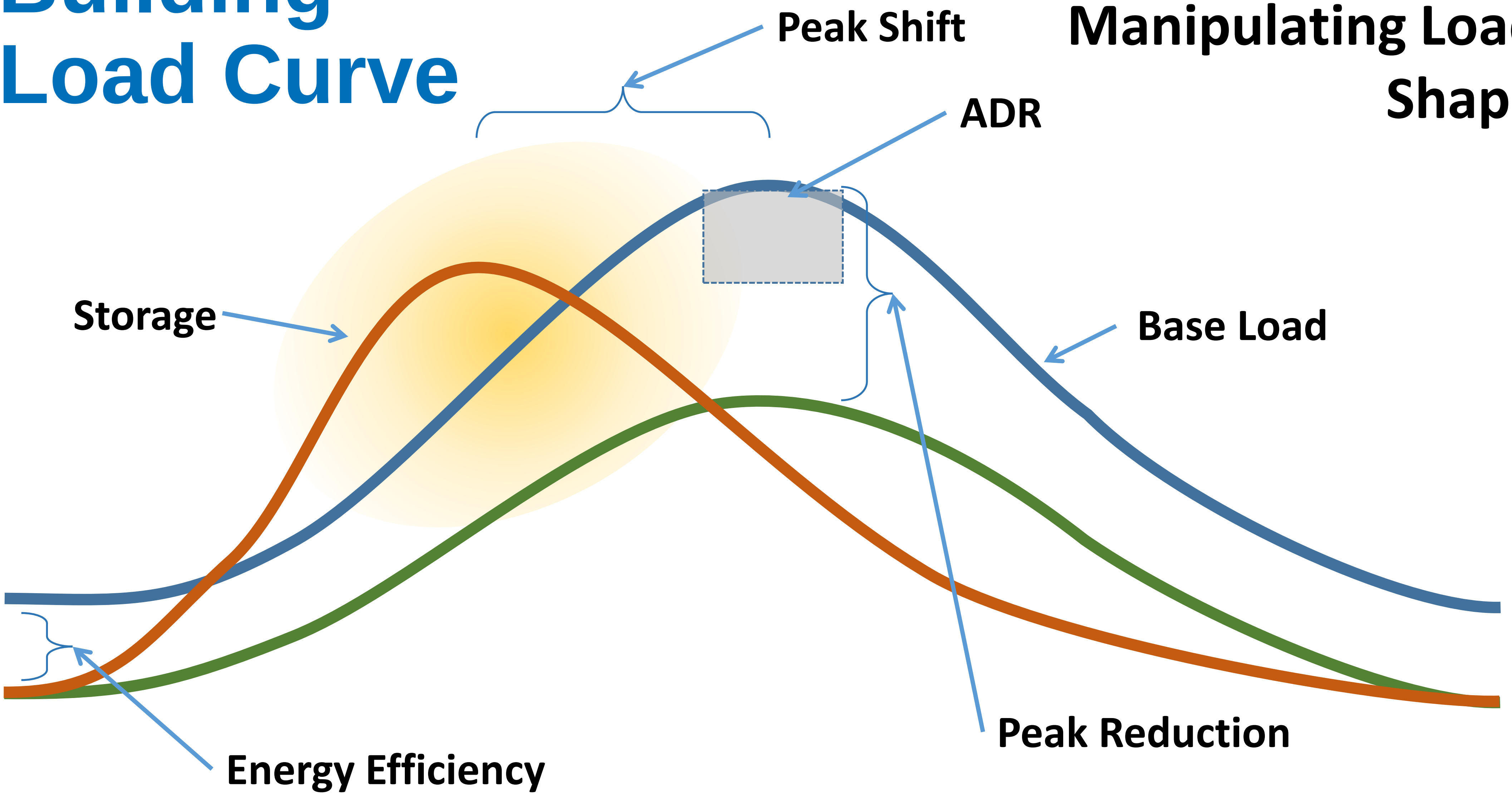
In Deployment: Interactive Grid





Building Load Curve

Manipulating Load Shape



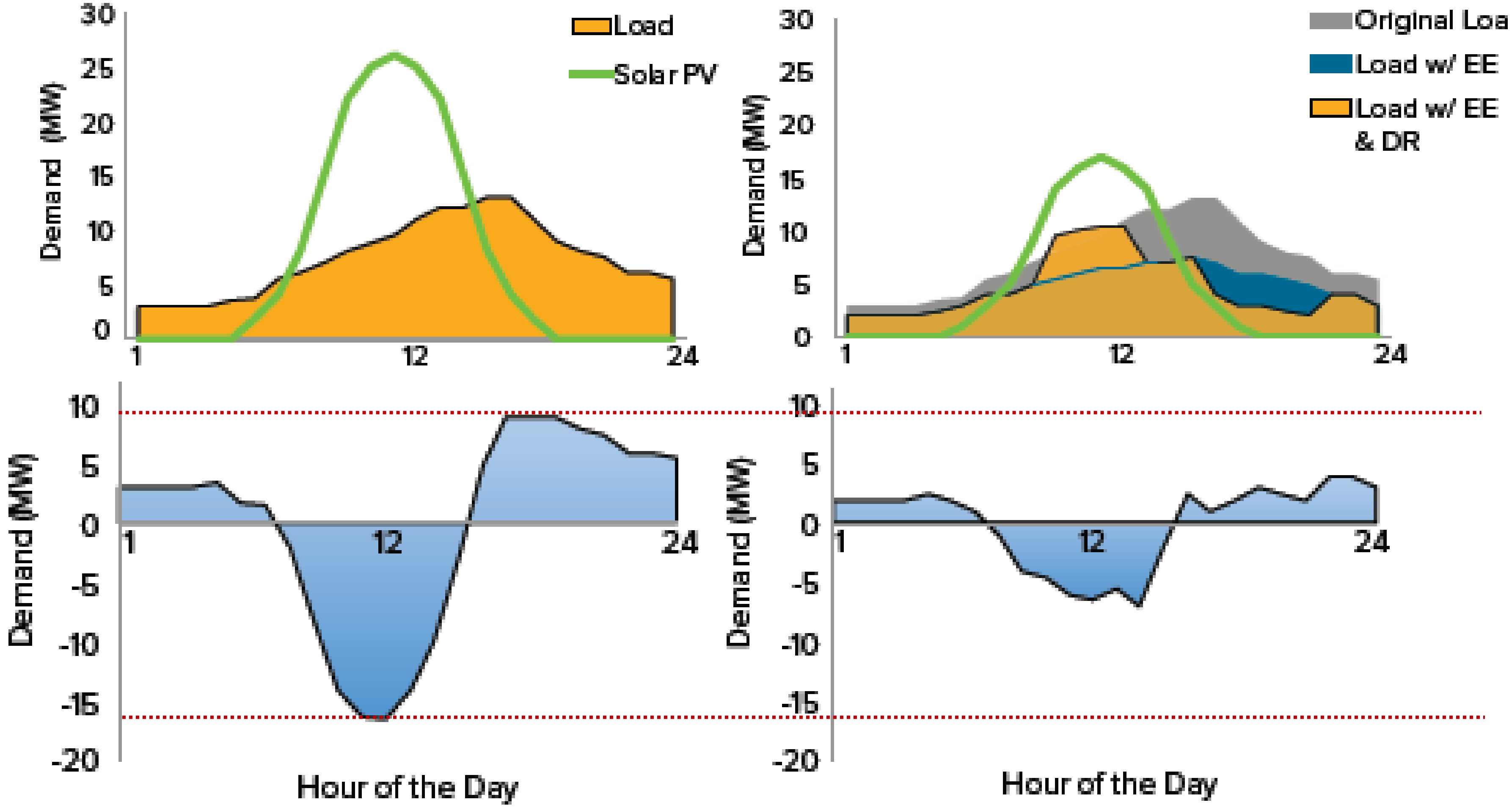
ZNE with and without Grid Integration

Solar PV only

Energy Efficiency, Demand Response + Solar PV

Load Shape

Grid Impact



Courtesy: NREL, RMI

New Industries are Becoming Engaged in the Building Sector

Mercedes-Benz Smart Home Integration Advertisement

- Car Manufacturers
- Battery Manufacturers
- Smart Home Technology
- Renewable Systems
- Appliance Manufacturers
- Internet Service Providers
- Personal Technology
- Internet Enabled Building Controls
- Dynamic Glazing

As new industries move aggressively into the buildings space, they create expectations about design features and performance capabilities that will directly impact building design and operation.

The way buildings interact with the electric grid is evolving rapidly:

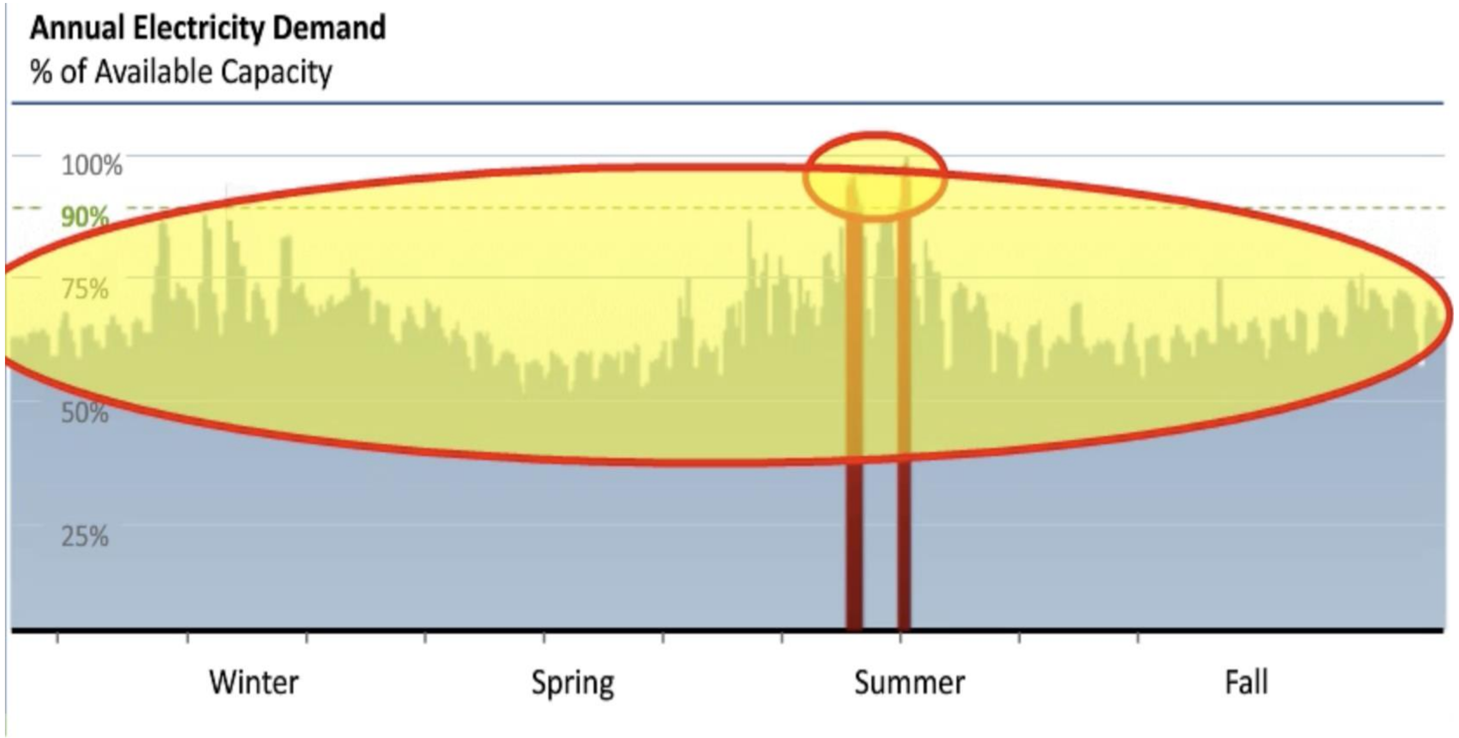
- Buildings will face increasing regulatory and economic pressure to be able to ***respond in real time*** to changing utility price and delivery structures.
- Designers will need to understand and incorporate strategies that allow buildings to ***directly interact with the utility grid***.
- Adapting to the *Interactive Grid* will be critical to maintaining ***building services*** and ***comfort***, and to grid ***reliability***.

Key differentiators of grid interactive buildings (similar to DR today and in the future)

Attribute	Today	Future
1. Interoperability and intelligence from building to grid	• DR programs, often manual, fairly static	• Ability to receive and respond to utility price signals • Ability to send load flex potential
2. Interoperability and intelligence across building systems	• BMS system for major loads (HVAC) • Individual system controls (Lighting, storage)	• Single, overarching integrator to monitor and control all loads, inc. plug loads and storage • Ability to optimize for cost, carbon, reliability, etc.
3. Load flexibility and demand-focused optimization	• Thermal energy storage • Battery storage	• Intelligence to track and map demand, shift or shed rapidly based on inputs such as price, weather, carbon, events, etc.

Building peaks drive grid peaks

- 80% of grid peak demand is driven by buildings
- >10% of grid infrastructure costs are spent to meet the peak demand that occurs <1% of the time – making those peak times the most expensive, and likely carbon intensive power.

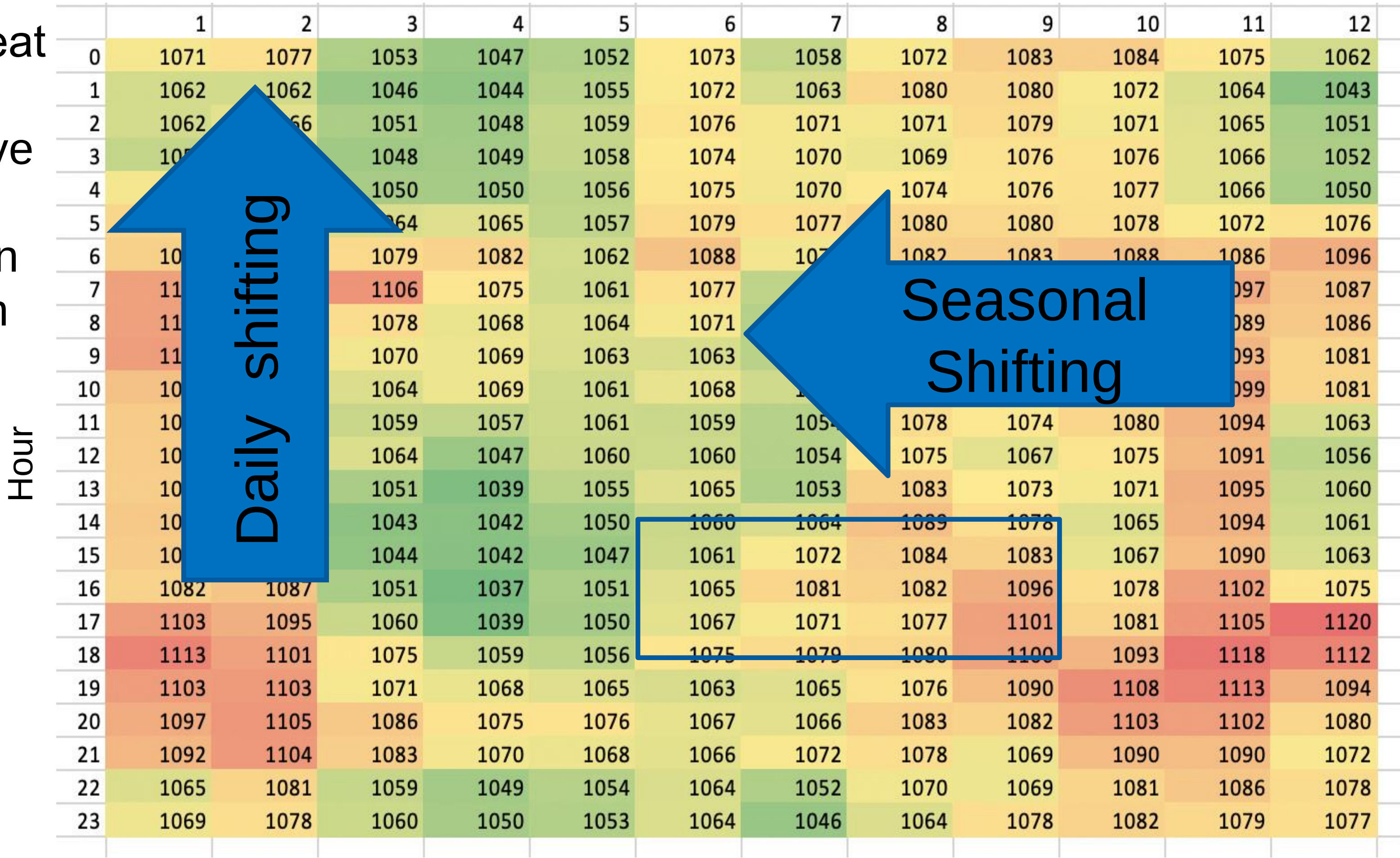


Source: DOE,

Optimizing for cost vs carbon requires different approaches

- Load flexibility is paramount (and something we're not great at today)
- Carbon optimization may have longer shifting periods
- Cost optimization depends on time based rate structures (in box)

NY ISO Carbon Intensity of Power - 2017



Hour	1	2	3	4	5	6	7	8	9	10	11	12
0	1071	1077	1053	1047	1052	1073	1058	1072	1083	1084	1075	1062
1	1062	1062	1046	1044	1055	1072	1063	1080	1080	1072	1064	1043
2	1062	[illegible]	1051	1048	1059	1076	1071	1071	1079	1071	1065	1051
3	[illegible]	[illegible]	1048	1049	1058	1074	1070	1069	1076	1076	1066	1052
4	[illegible]	[illegible]	1050	1050	1056	1075	1070	1074	1076	1077	1066	1050
5	[illegible]	[illegible]	[illegible]	1065	1057	1079	1077	1080	1080	1078	1072	1076
6	[illegible]	[illegible]	1079	1082	1062	1088	[illegible]	1082	1083	1088	1086	1096
7	[illegible]	[illegible]	1106	1075	1061	1077	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1087
8	[illegible]	[illegible]	1078	1068	1064	1071	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1086
9	[illegible]	[illegible]	1070	1069	1063	1063	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1081
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11	[illegible]	[illegible]	1059	1057	1061	1059	[illegible]	1078	1074	1080	1094	1063
12	[illegible]	[illegible]	1064	1047	1060	1060	1054	1075	1067	1075	1091	1056
13	[illegible]	[illegible]	1051	1039	1055	1065	1053	1083	1073	1071	1095	1060
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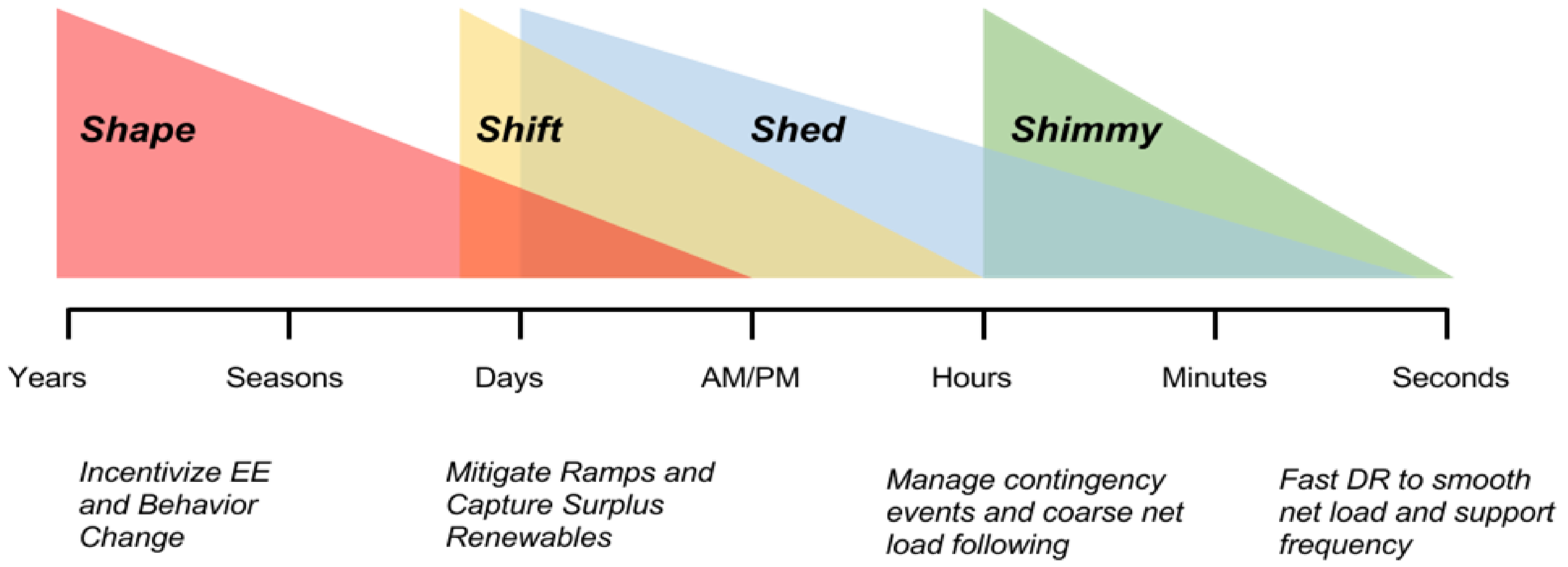
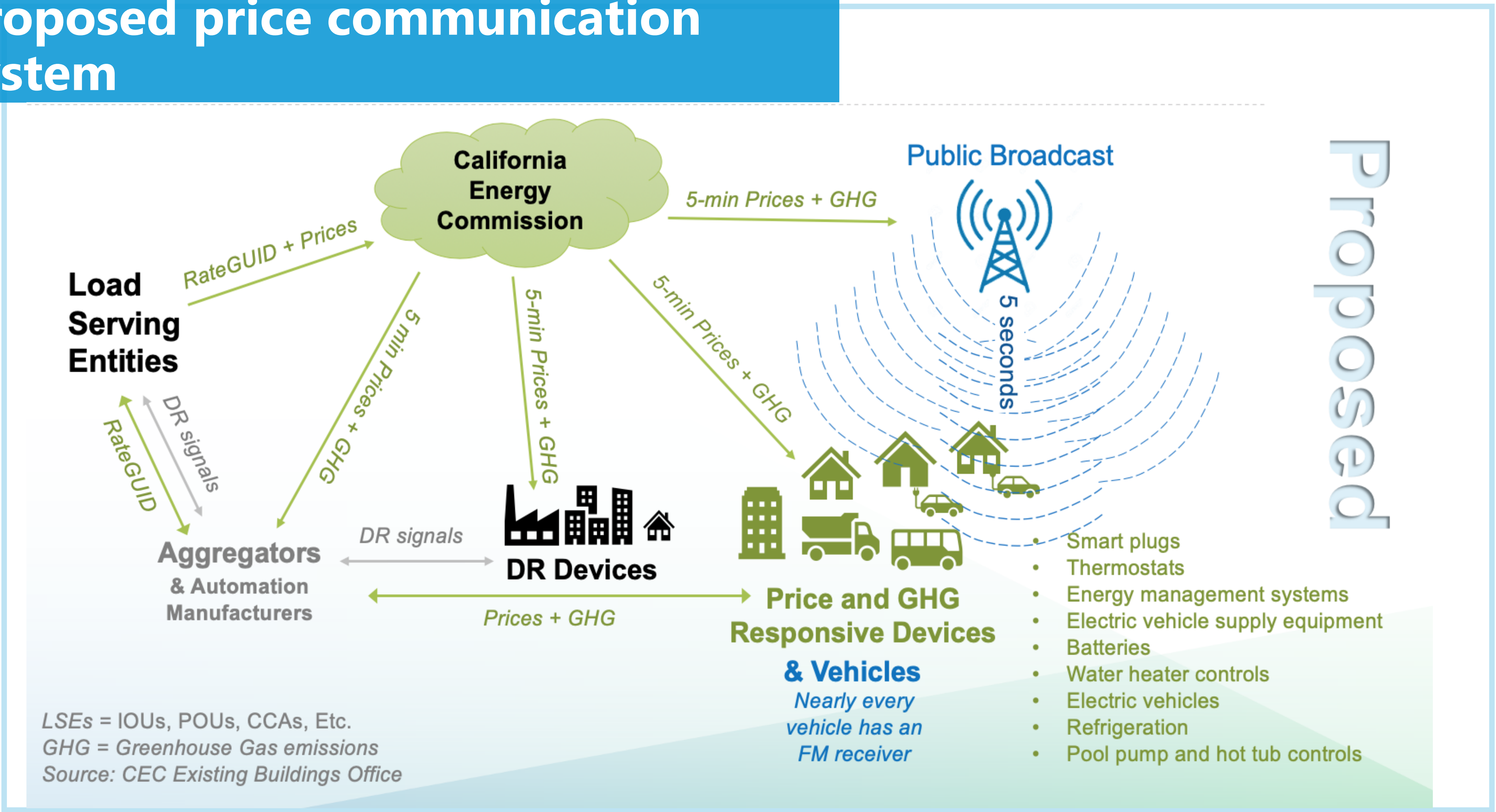
17	1103	1095	1060	1039	1050	1067	1071	1077	1101	1081	1105	1120
18	1113	1101	1075	1059	1056	1075	1079	1080	1100	1093	1118	1112
19	1103	1103	1071	1068	1065	1063	1065	1076	1090	1108	1113	1094
20	1097	1105	1086	1075	1076	1067	1066	1083	1082	1103	1102	1080
21	1092	1104	1083	1070	1068	1066	1072	1078	1069	1090	1090	1072
22	1065	1081	1059	1049	1054	1064	1052	1070	1069	1081	1086	1078
23	1069	1078	1060	1050	1053	1064	1046	1064	1078	1082	1079	1077

Buildings can provide virtual storage and grid services



- **Shape:** load change from pric
- **Shift:** virtual storage
- **Shed:** virtual generation
- **Shimmy:** virtual ancillary services

Proposed price communication system



- From the CEC Existing Buildings Office
- Support from CPUC in data model development

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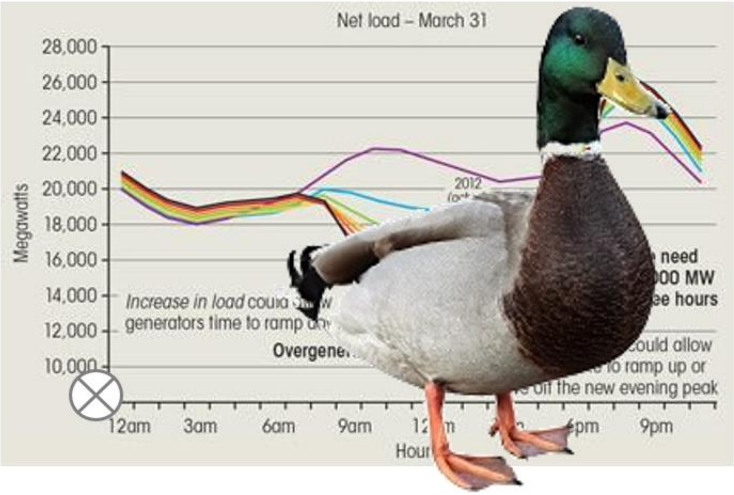
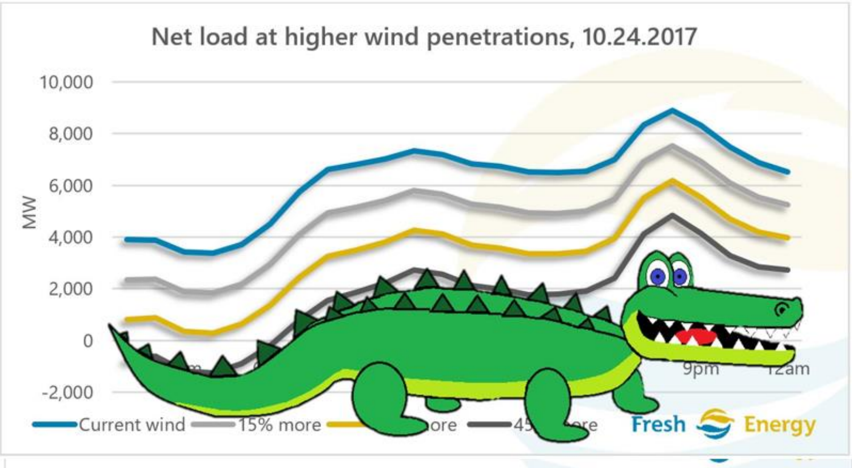
https://newbuildings.org/gridoptimal/

The Grid Menagerie

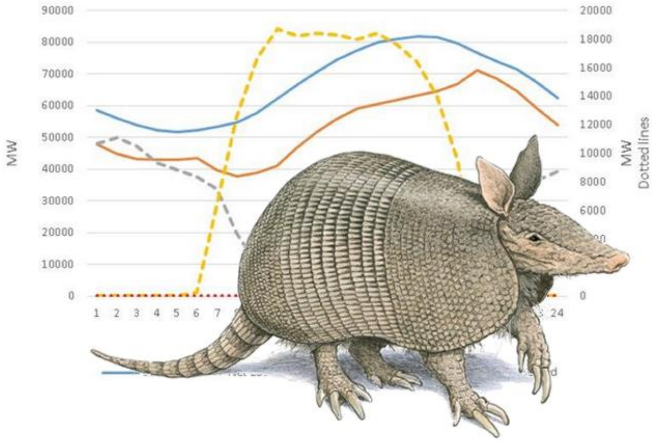
California: The Duck Curve



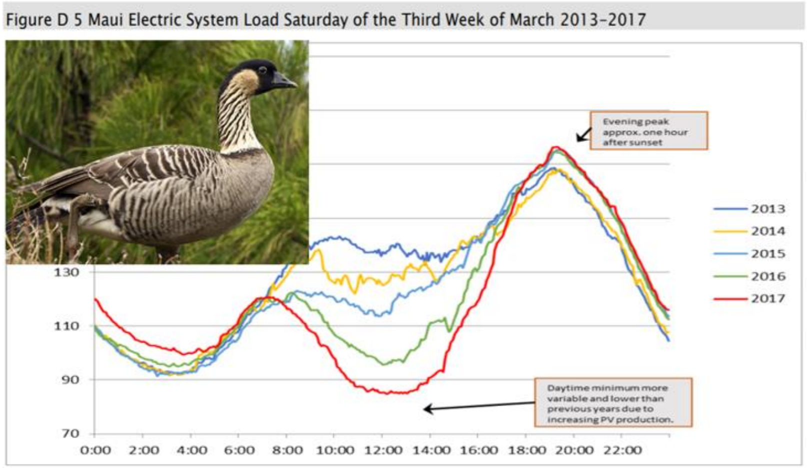
Midwest: The Gator Curve



Texas: The Armadillo Curve



Hawaii: The Nene Curve



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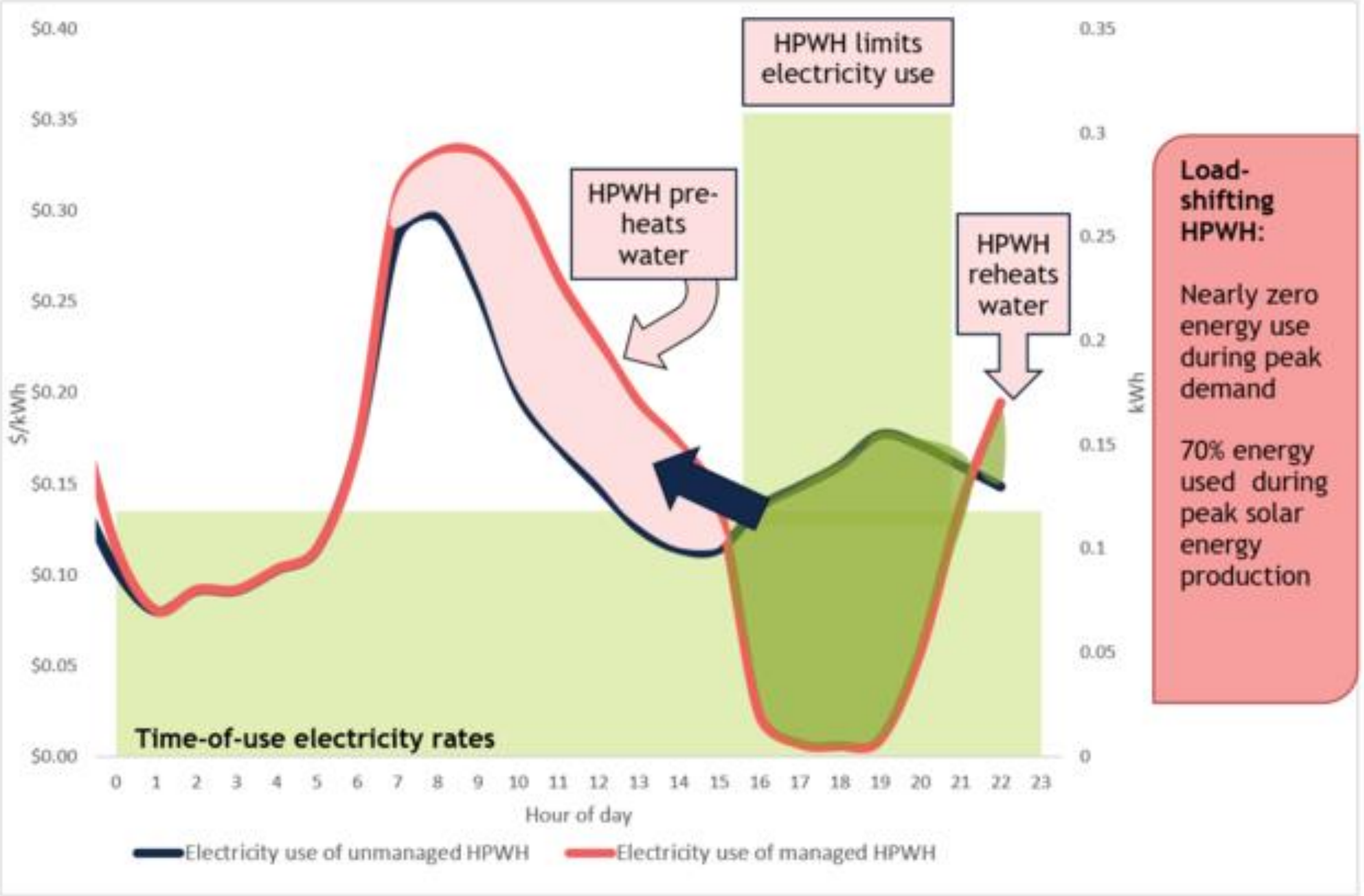
Heat Pump Water Heaters: Clean-Energy Batteries



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Source: Pierre Delforge. 2020. "[Heat Pump Water Heaters as Clean-Energy Batteries](#)." Natural Resources Defense Council.

Selected Building-Grid Integration Metrics

GridOptimal Metric	What it Measures
Grid Peak Contribution	Degree to which building demand contributes to load on the grid during system peak hours
Onsite Renewable Utilization Efficiency	Building's consumption of renewable energy generated onsite (not exporting to grid) over a year
Grid Carbon Alignment	Degree to which the building demand contributes to upstream (grid) carbon emissions over a year
Energy Efficiency vs. Baseline	Percent better than code (annual total energy use)
Short-Term Demand Flexibility	Building's ability to reduce demand (shed) for 1 hour
Long-Term Demand Flexibility	Building's ability to reduce demand (shed) for 4 hours
Dispatchable Flexibility	Building's ability to automatically reduce demand (shed) for 15 minutes, controlled by utility/ third party
Resiliency	Building ability to island from grid and/or provide energy for critical loads for 4-24 hours; motor soft start capability to help grid restart after outage

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Demand Flexibility Metrics For Shed and Shift

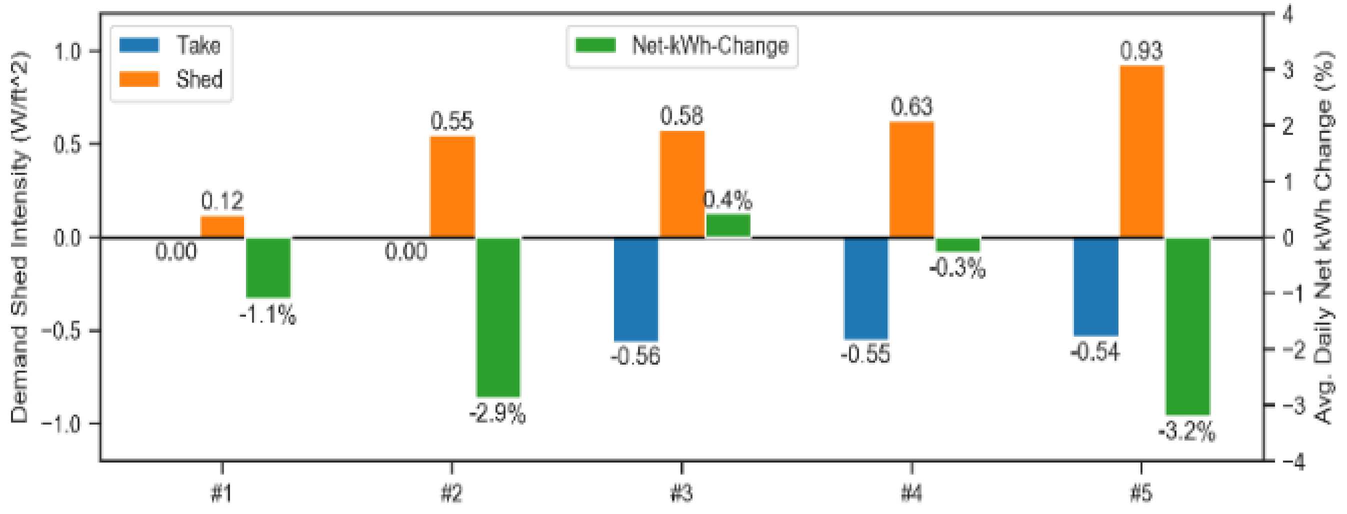
Key Metrics for Load Shed and Shift :

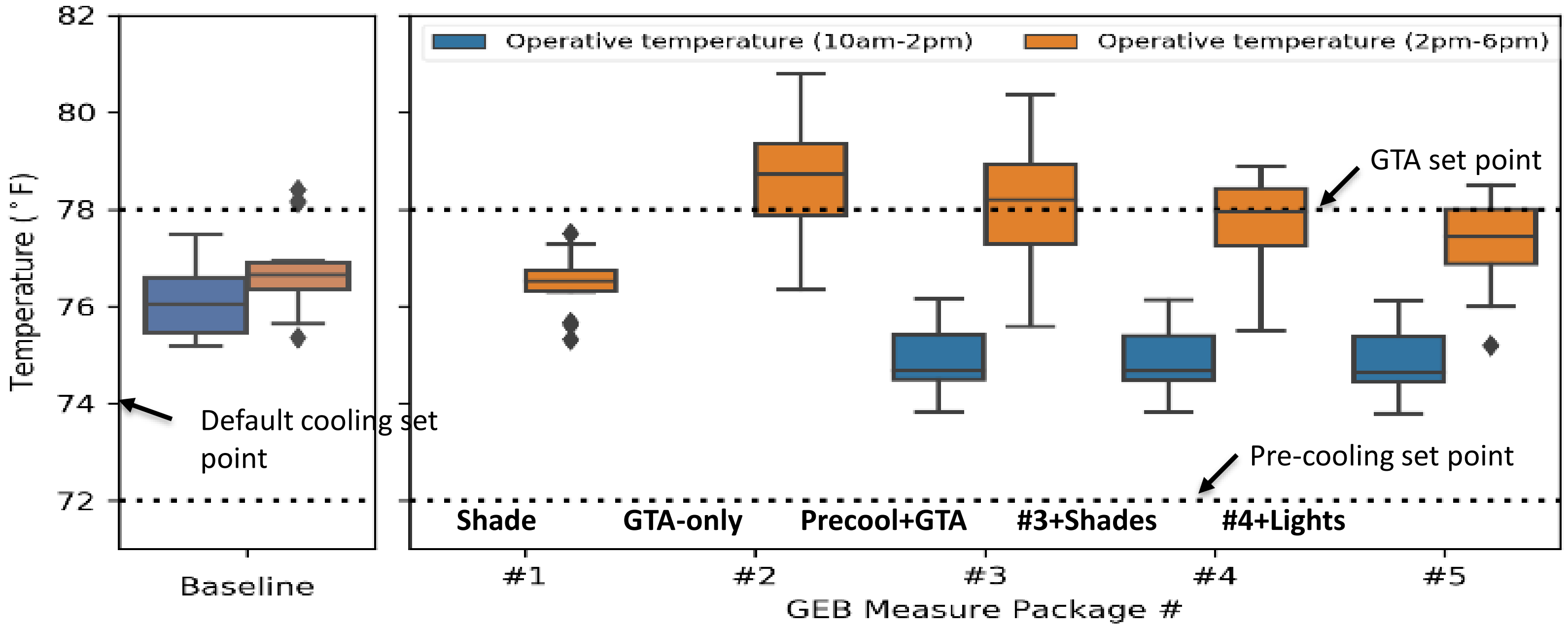
- Demand Shed Benchmark (W/ft²)
- Demand Shift Benchmarks – Increase (Take) and Shed Intensity (W/ft²)
- Net Change in Energy Consumption Percentage (24 hours) (%)
- Operative Temperature (°F)

Comparing Shed and Shift Strategies

Baseline: zone T_{op} range >3°F
#1: Shading reduces hot spots but does not shed much
#2: Global Temp Adjustment (GTA) large shed but increases T_{op} range >4°F
#3 vs #2: Precooling can increase shed (energy penalty is small) and improve comfort (by 0.5°F)
#4 vs #3: Shades increases shed, and improves comfort
#5 vs #4: Dimming lights increases shed

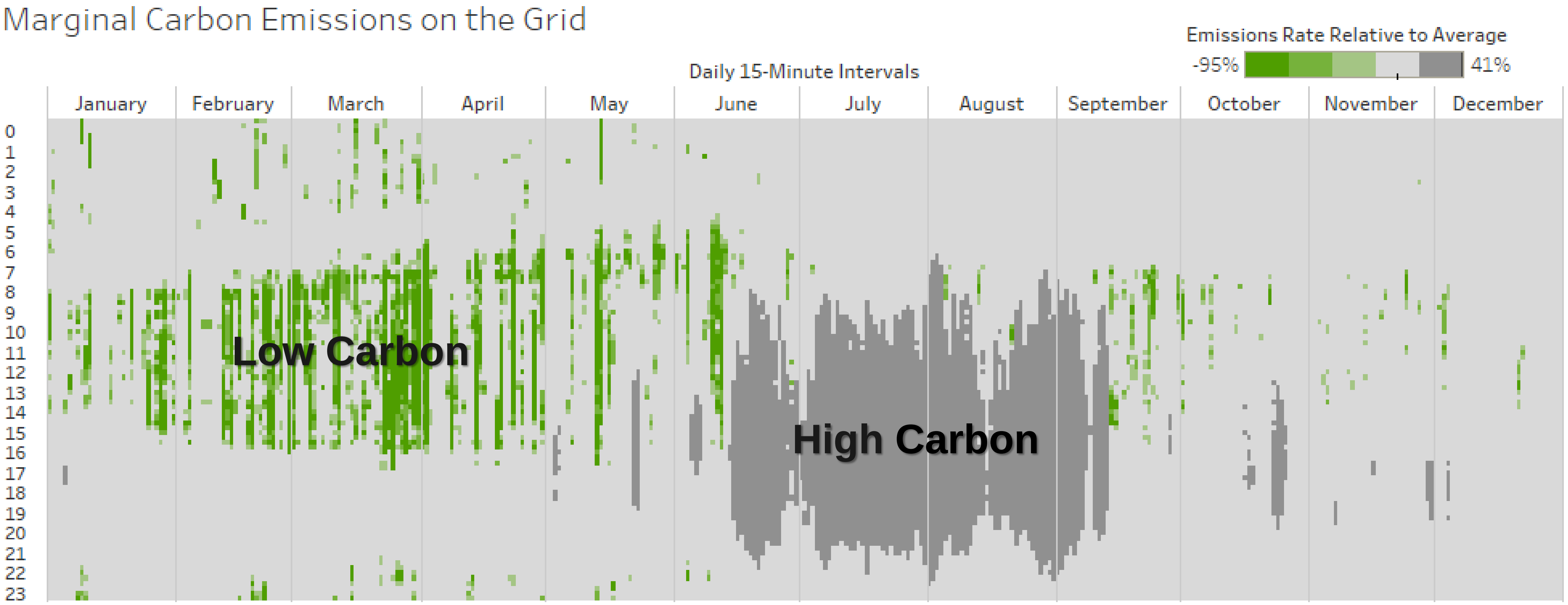
<u>Using Key Metrics To Compare 5 GEB Packages for Medium Office (2004) in El Paso, TX</u>





Backup slides

Carbon Intensity of the Grid Varies Over Time



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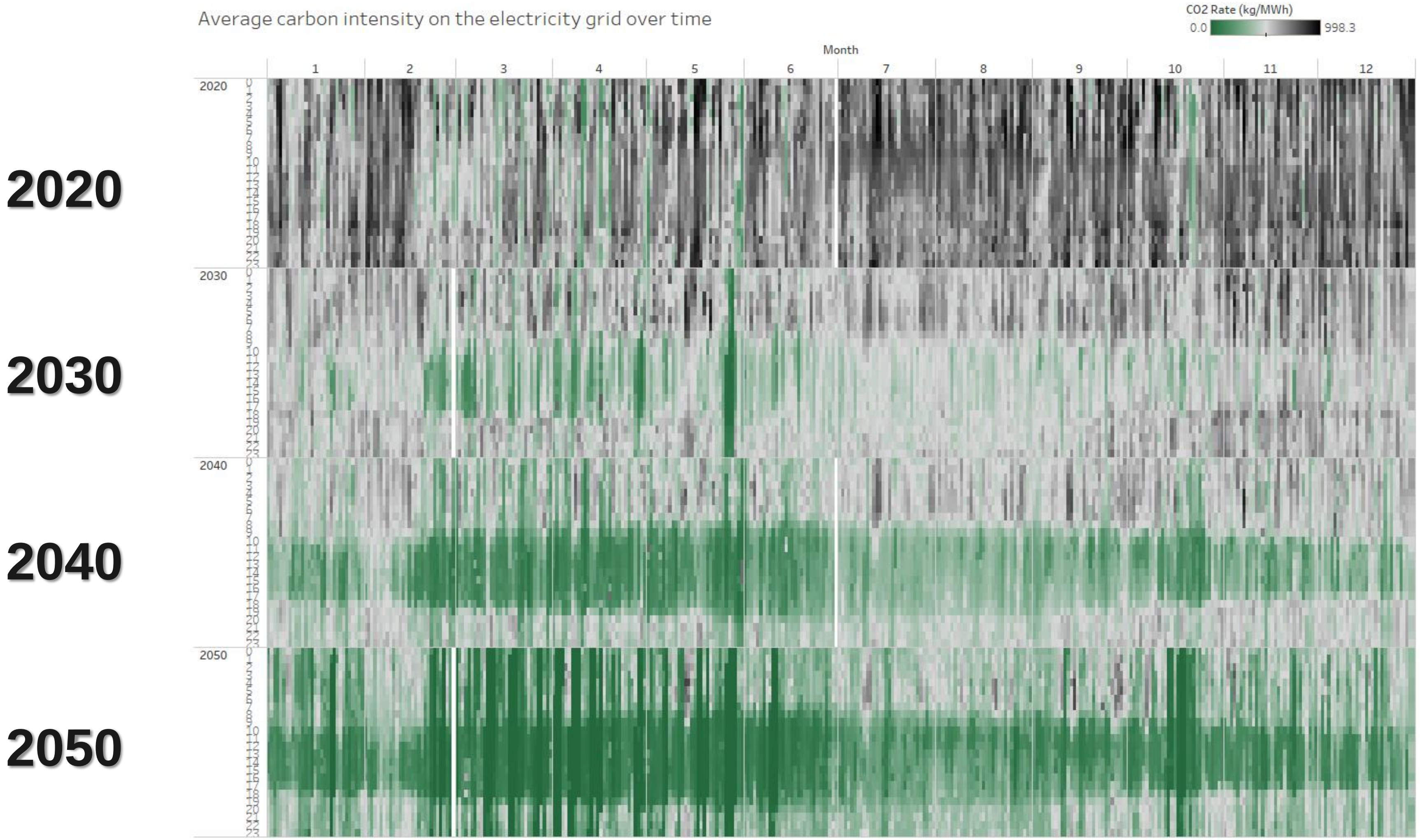
… And this Trend Will Grow in the Future!



Data Source: NREL Cambium (alpha release)
Graphics: New Buildings Institute