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Demand Response Forecasting Methodology

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Presentation Outline

Project Overview

Summary of Results

- Annual Demand Response Availability
- Hourly Availability for All End Uses
- Average Hourly Availability by Season and End Use

Considerations and Next Steps

Appendices

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- Appendix 1: Load Profile Generation Methods
- Appendix 2: Verification of End Use Load Profiles for FRCC
- Appendix 3: Demand Response Filter Generation Methods
- Appendix 4: Demand Response Filter Values
- Appendix 5: Visualization of Demand Response Availability Results

Abbreviations

DR: Demand Response

BAA: Balancing Authority Area

FRCC: Florida Reliability Coordinating Council

FPL: Florida Power & Light Company

TEC: Tampa Electric Company

JEA: Jacksonville Electric Authority

PROJECT OVERVIEW

Project Overview: Research Tasks

To estimate regional hourly DR availability by end use for the Eastern, Western and Texas Interconnections

Project Overview: Disaggregation of Outputs

Desired Outputs

1. Load Profiles
2. Demand Response Filters
 - Sheddability
 - Controllability
 - Acceptability
3. Demand Response Resource Potential

Disaggregated By:

1. End-use
2. Hour
3. Region
4. Grid Product

Project Overview: Demand Response Filter Definitions

Sheddability: The technical potential for load reduction.

Controllability: The fraction of load enabled to provide DR.

Acceptability: The fraction of load likely to respond when called on provide DR at a given time.

Project Overview: End-Uses

Residential	Commercial	Industrial	Municipal
Space cooling Space heating Water heating	Space cooling Space Heating Indoor lighting Ventilation	Agricultural water pumping Data centers Refrigerated warehouses Manufacturing	Freshwater distribution pumping Road & garage lighting Wastewater pumping

Project Overview: Product Definitions

Products		Physical Requirements			
Product Type	General Description	How fast to respond	Length of response	Time to fully respond	How often called
Regulation	Response to random unscheduled deviations in scheduled net load (bidirectional)	30 seconds	Energy neutral in 15 minutes	5 minutes	Continuous within specified bid period
Flexibility	Additional load-following reserve for large un-forecasted wind/solar ramps (bidirectional)	5 minutes	1 hour	20 minutes	Continuous within specified bid period
Contingency	Rapid and immediate response to a loss in supply	1 minute	≤ 30 minutes	≤ 10 minutes	≤ Once per day
Energy	Shed or shift energy consumption over time	5 minutes	≥ 1 hour	10 minutes	1-2 times per day with 4-8 hour notification
Capacity	Ability to serve as an alternative to generation	Top 20 hours coincident with balancing authority area system peak			

Project Overview: End Use Mapping

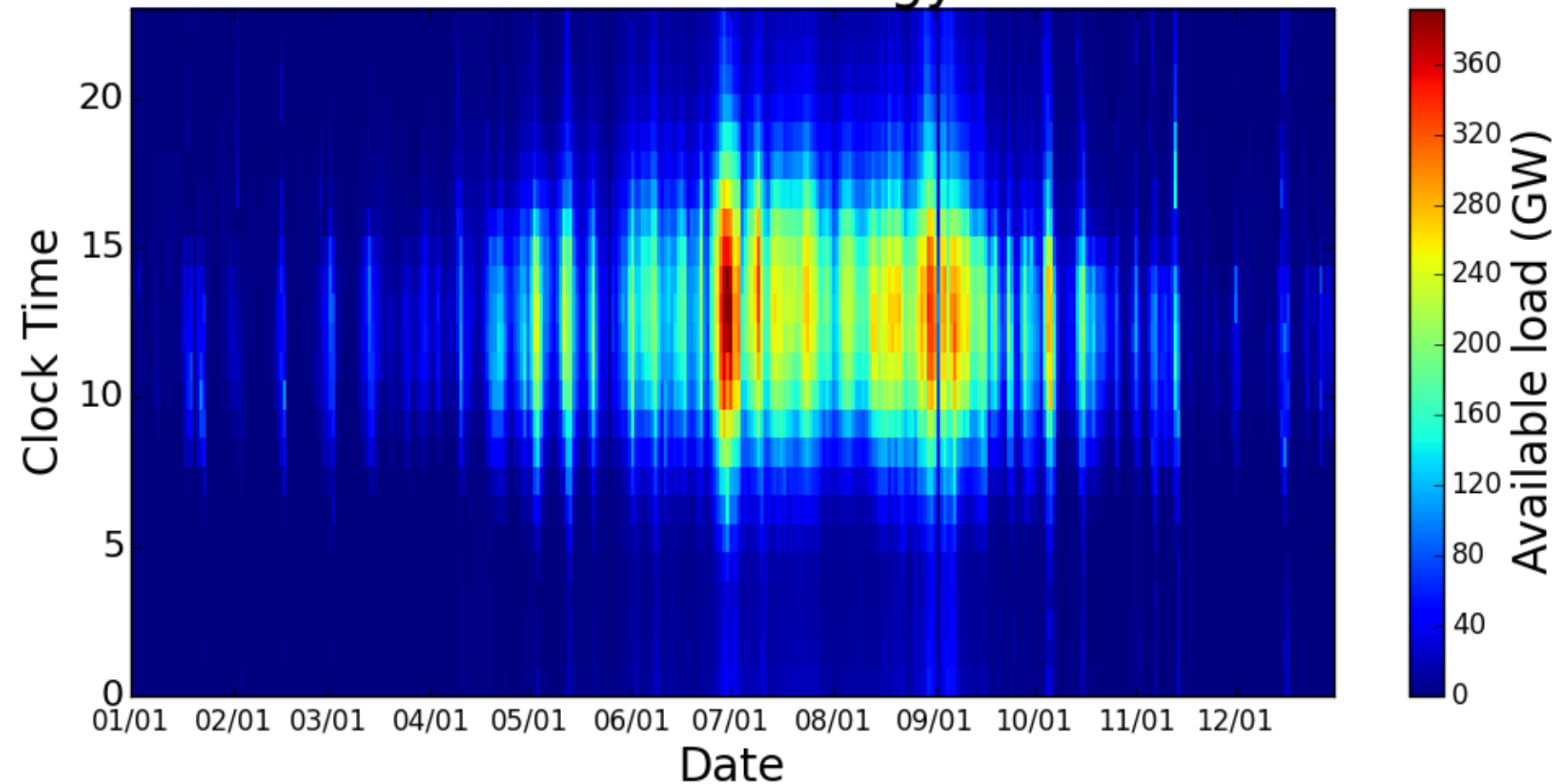
Resources	Products				
	Regulation	Flexibility	Contingency	Energy	Capacity
Agricultural Pumping			✓	✓	✓
Commercial Cooling	✓	✓	✓	✓	✓
Commercial Heating				✓	✓
Commercial Lighting	✓	✓	✓		✓
Commercial Ventilation	✓	✓	✓		✓
Data Centers			✓	✓	✓
Municipal Lighting	✓	✓	✓		✓
Municipal Pumping				✓	✓
Refrigerated Warehouses				✓	✓
Residential Cooling	✓	✓	✓	✓	✓
Residential Heating	✓	✓	✓	✓	✓
Res. Water Heating	✓	✓	✓	✓	✓
Wastewater Pumping				✓	✓

Project Overview: Weather

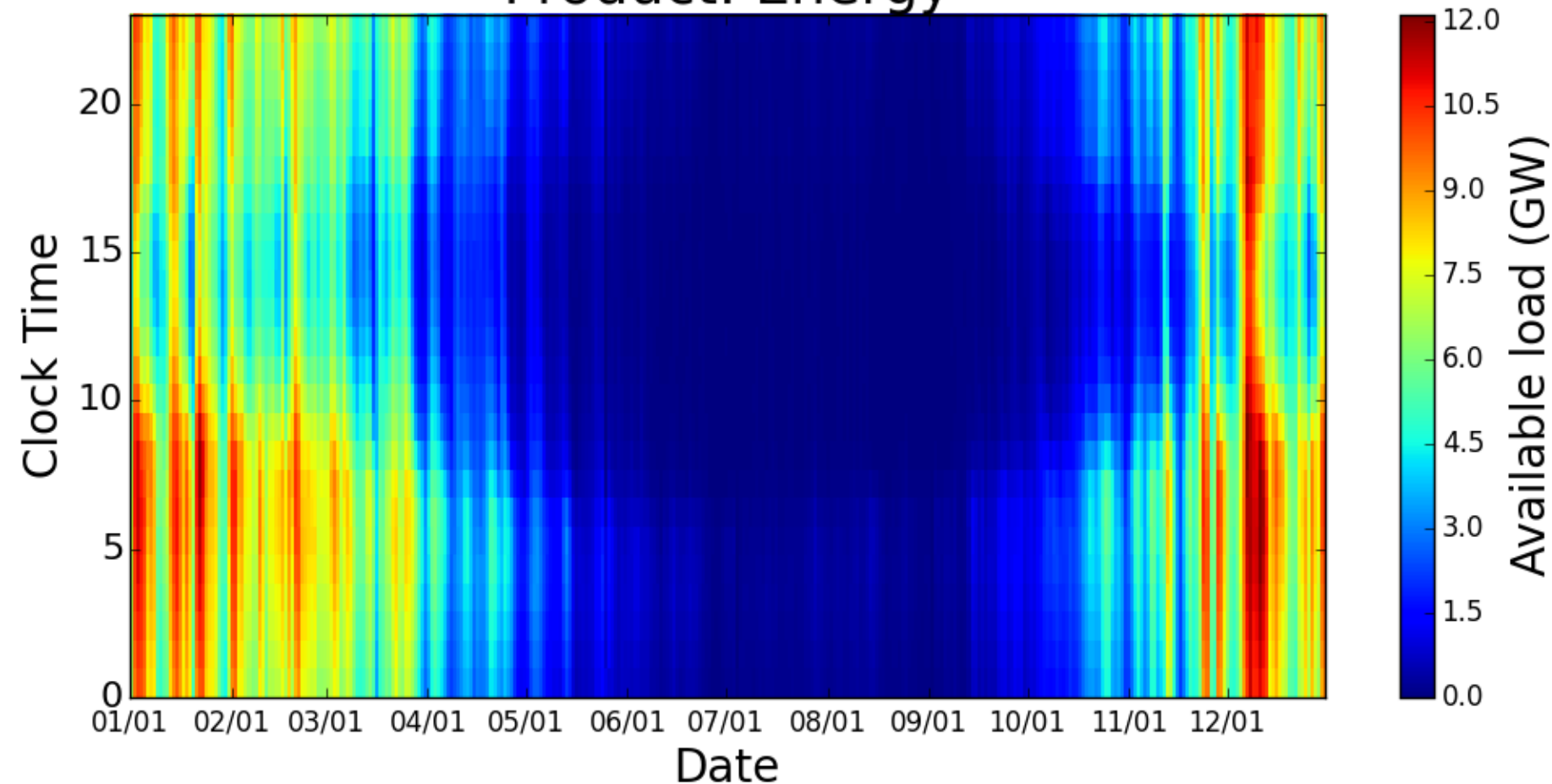
- Current results use historical 2013 weather data to represent weather in 2020
- Results are also available for a 2006 weather year

RESULTS: Annual Demand Response Availability

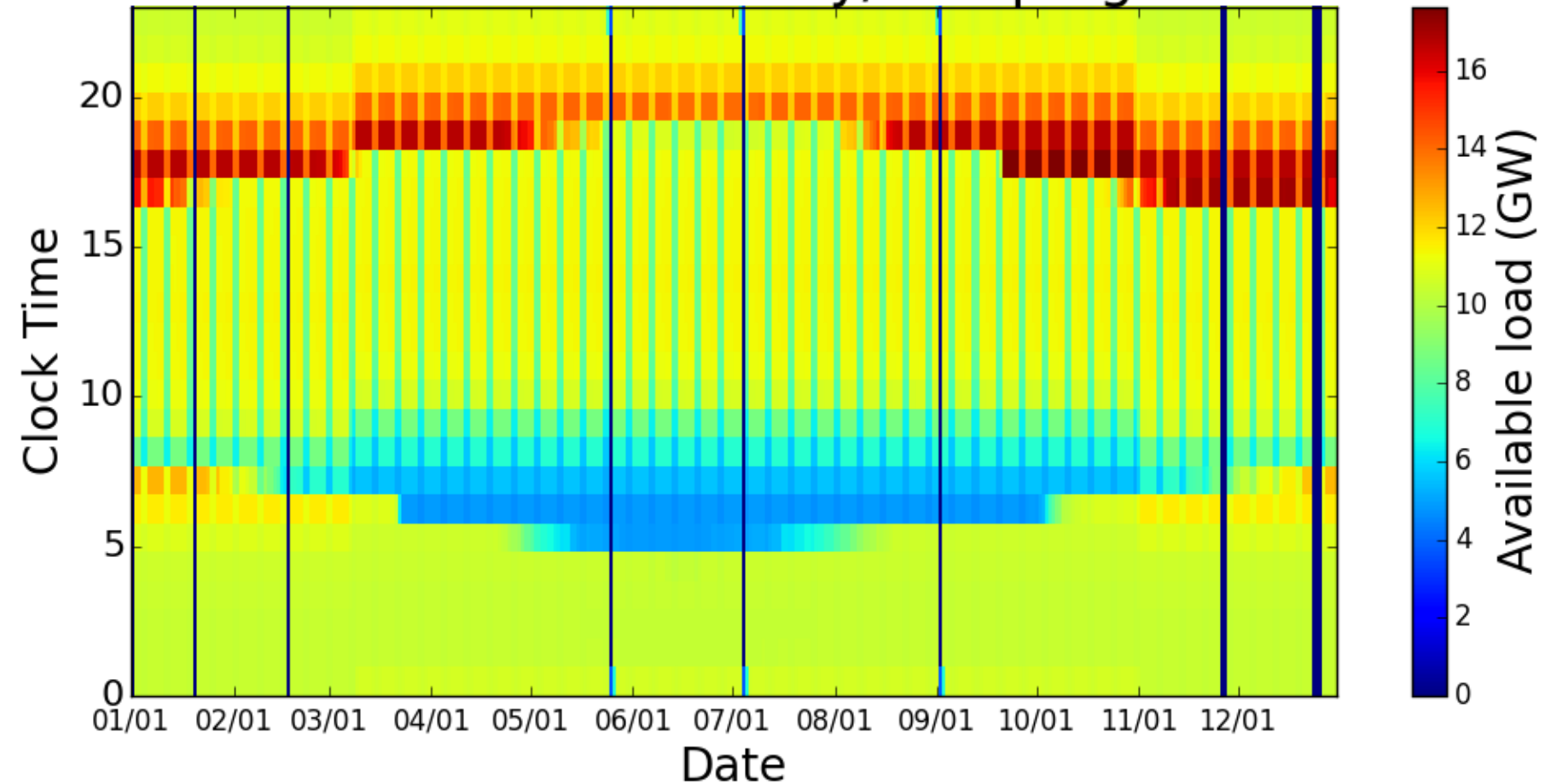
Region: Entire United States
End Use: commercial cooling
Product: Energy



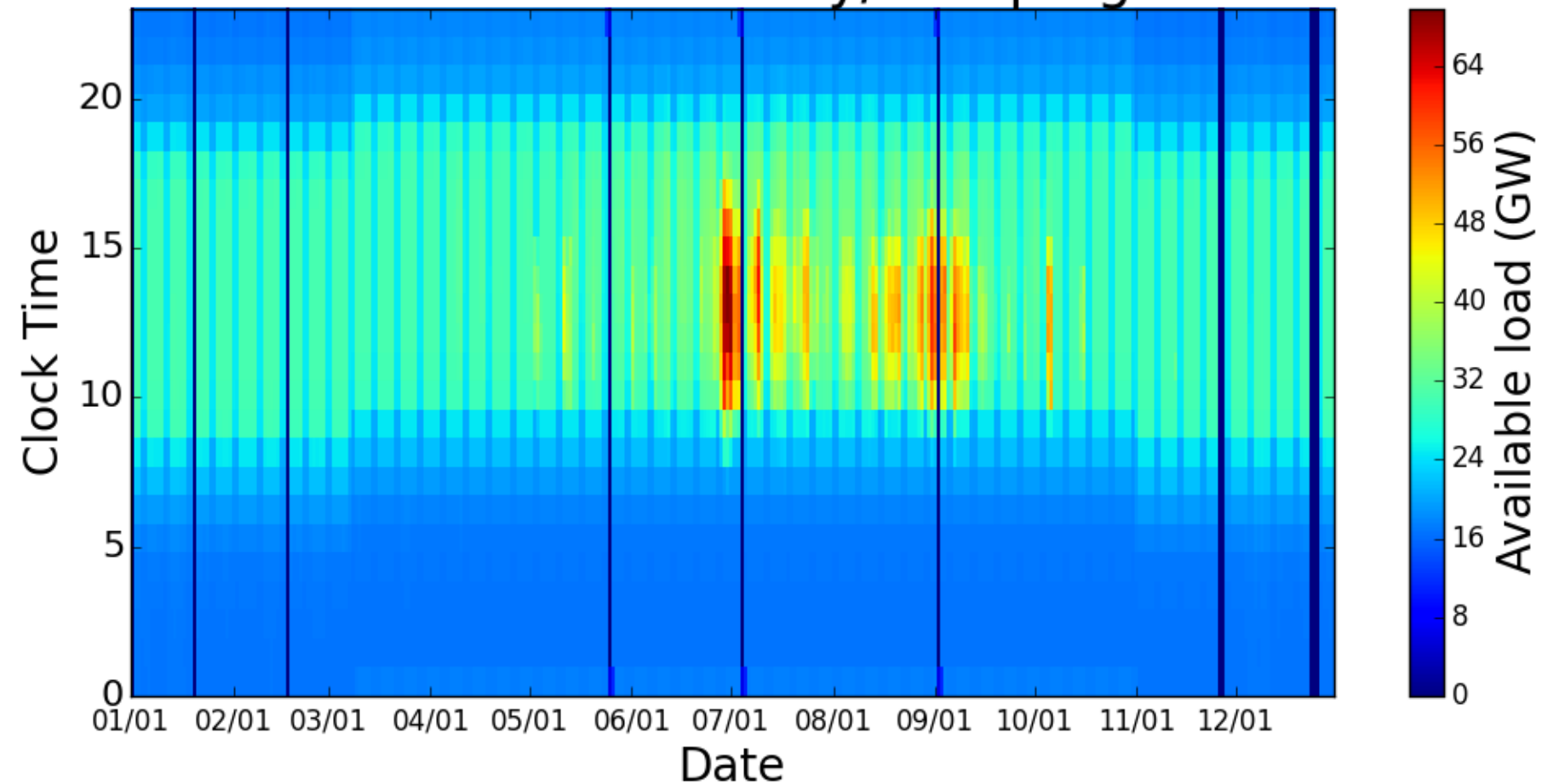
Region: Entire United States
End Use: commercial heating
Product: Energy



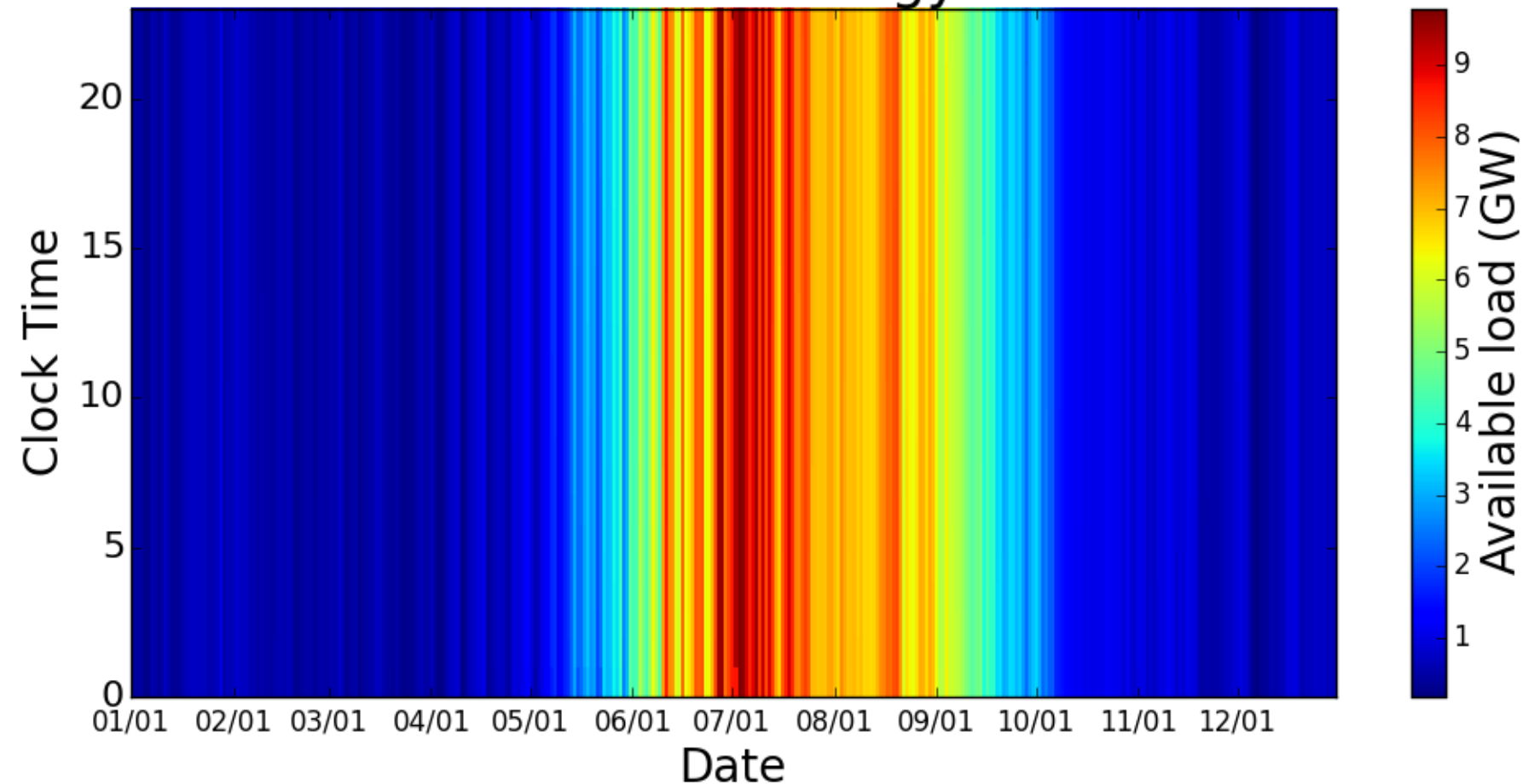
Region: Entire United States
End Use: commercial lighting
Product: Flexibility/Ramping



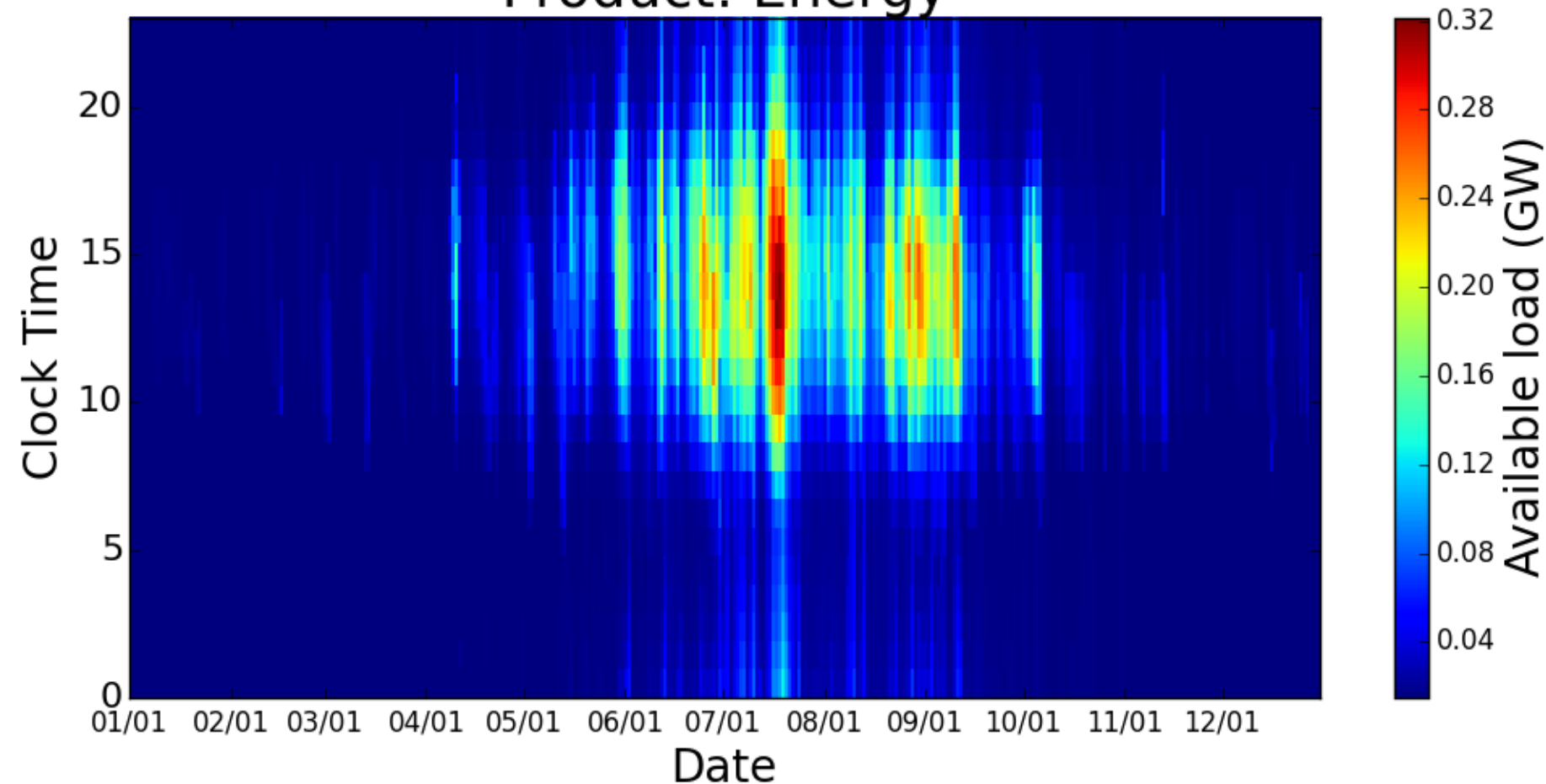
Region: Entire United States
End Use: commercial ventilation
Product: Flexibility/Ramping



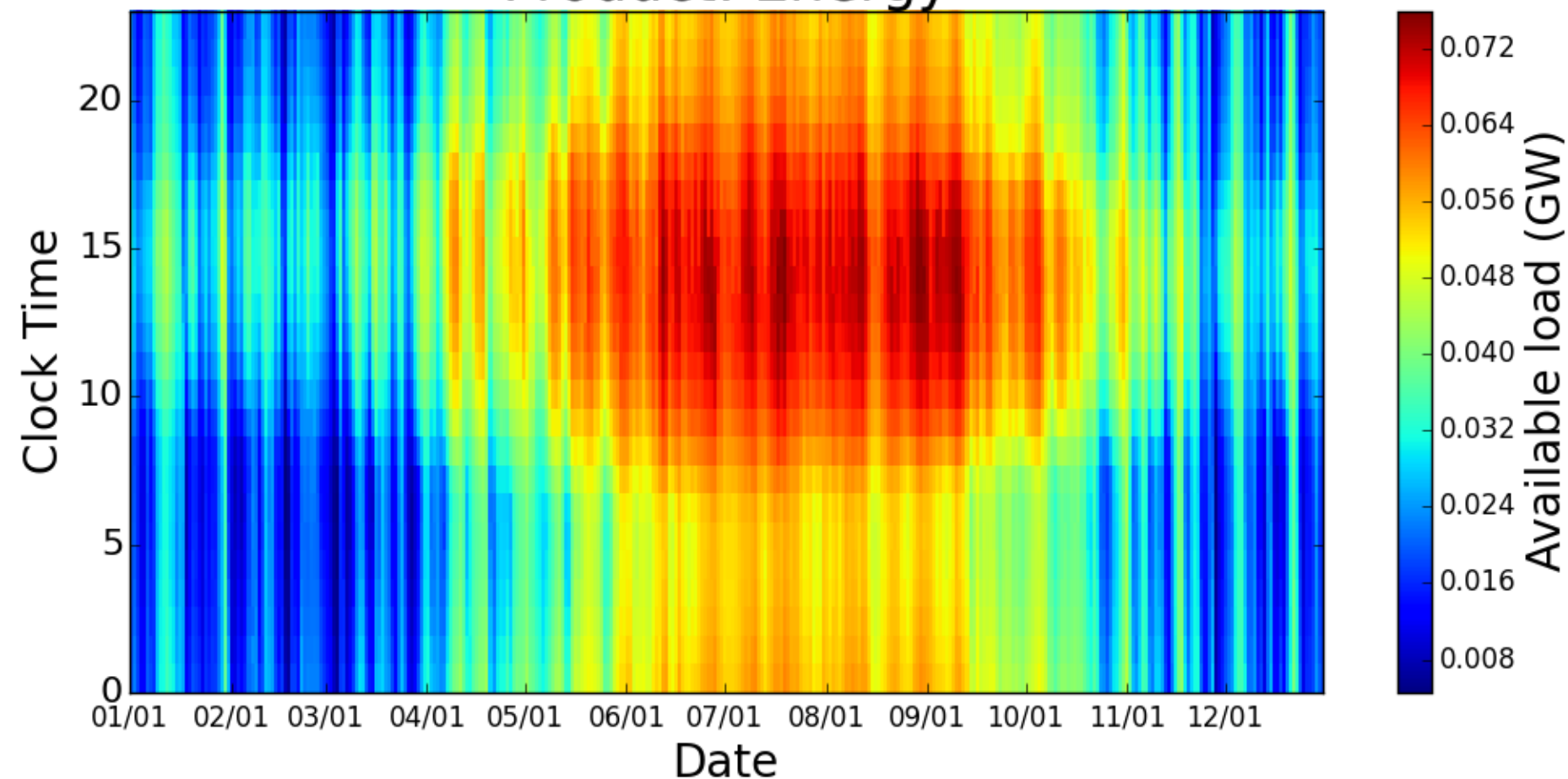
Region: Entire United States
End Use: agricultural pumping
Product: Energy



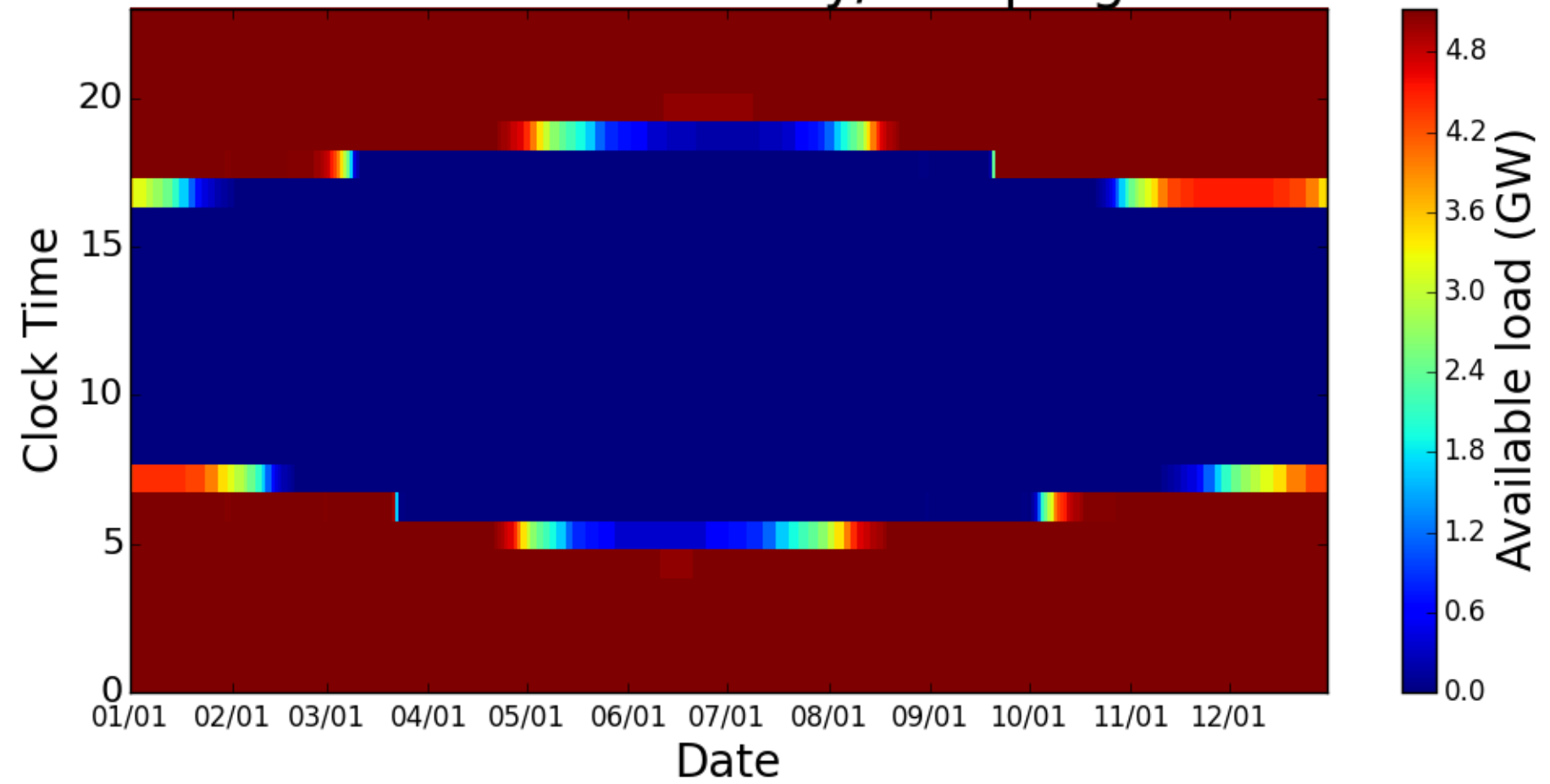
Region: Entire United States
End Use: data centers
Product: Energy



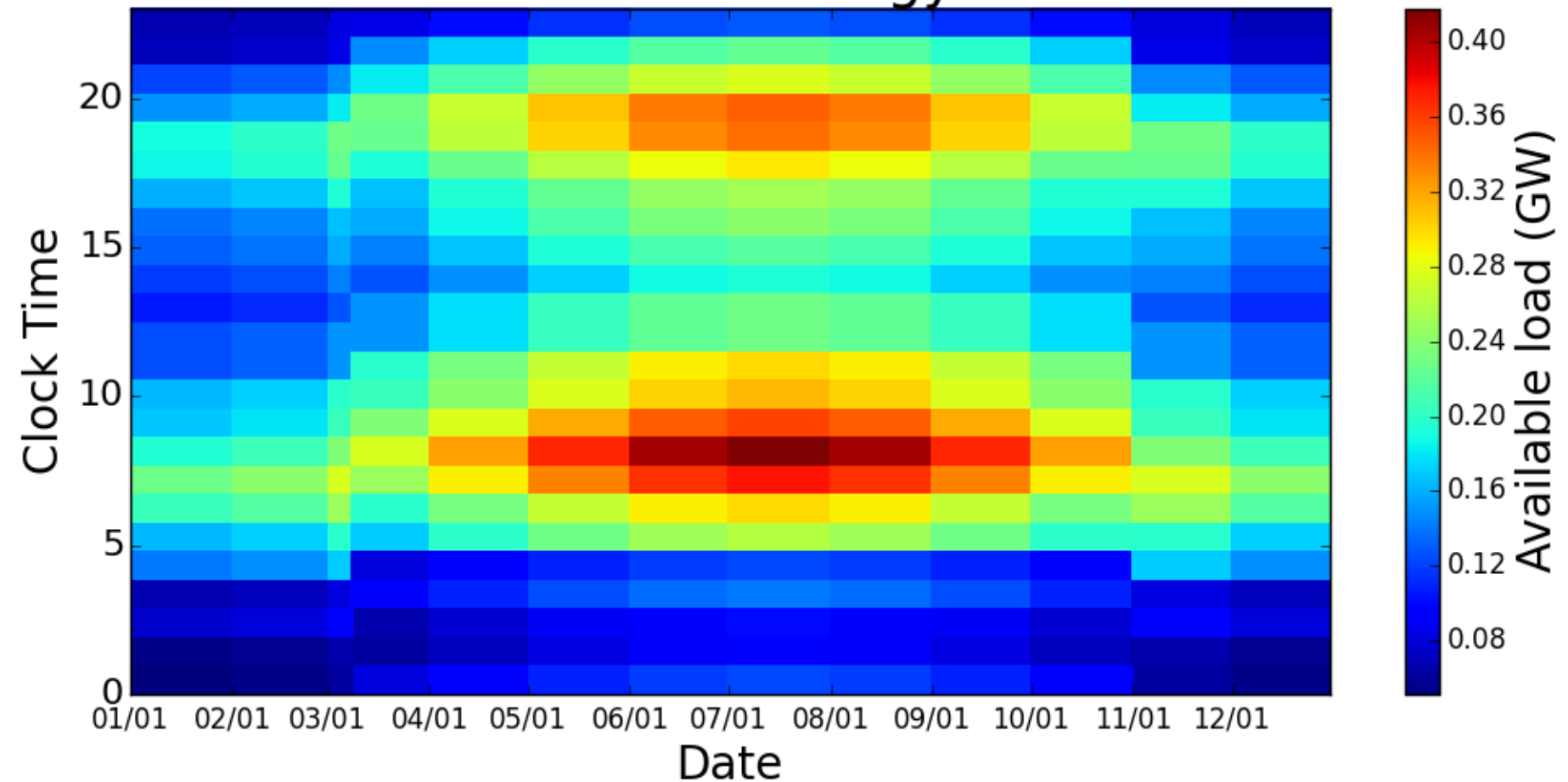
Region: Entire United States
End Use: refrigerated warehouses
Product: Energy



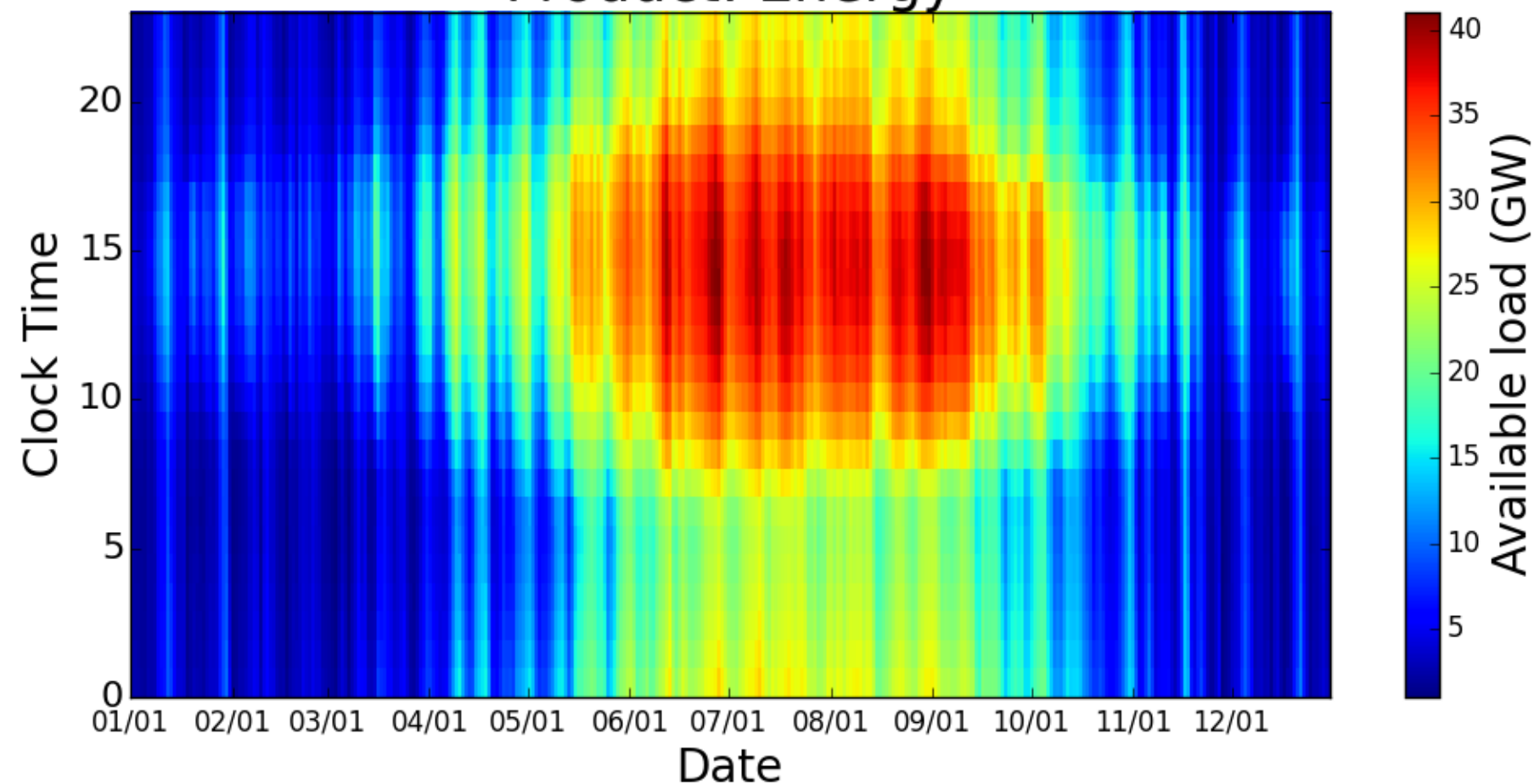
Region: Entire United States
End Use: municipal outdoor lighting
Product: Flexibility/Ramping



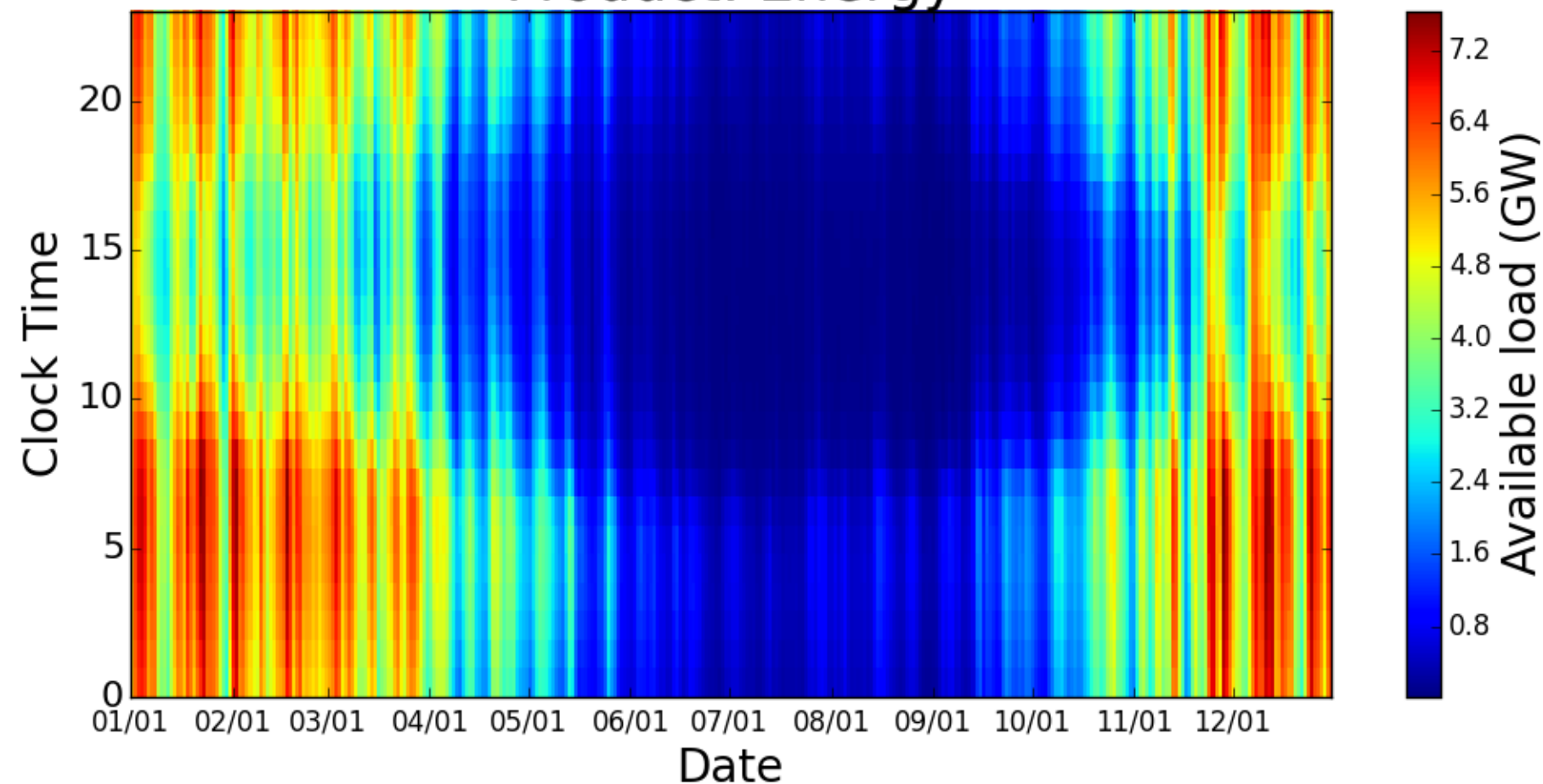
Region: Entire United States
End Use: municipal water pumping
Product: Energy



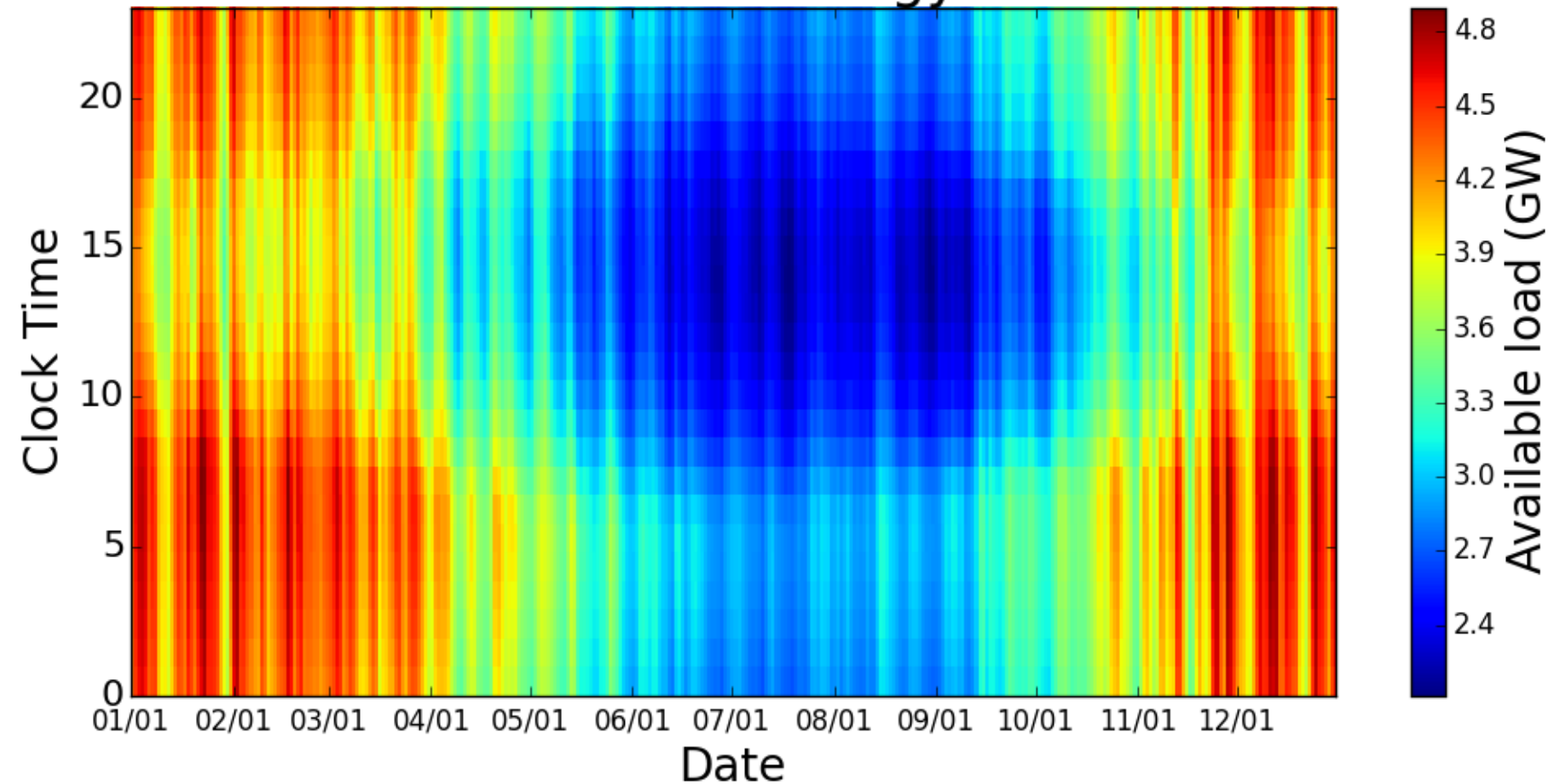
Region: Entire United States
End Use: residential cooling
Product: Energy



Region: Entire United States
End Use: residential heating
Product: Energy

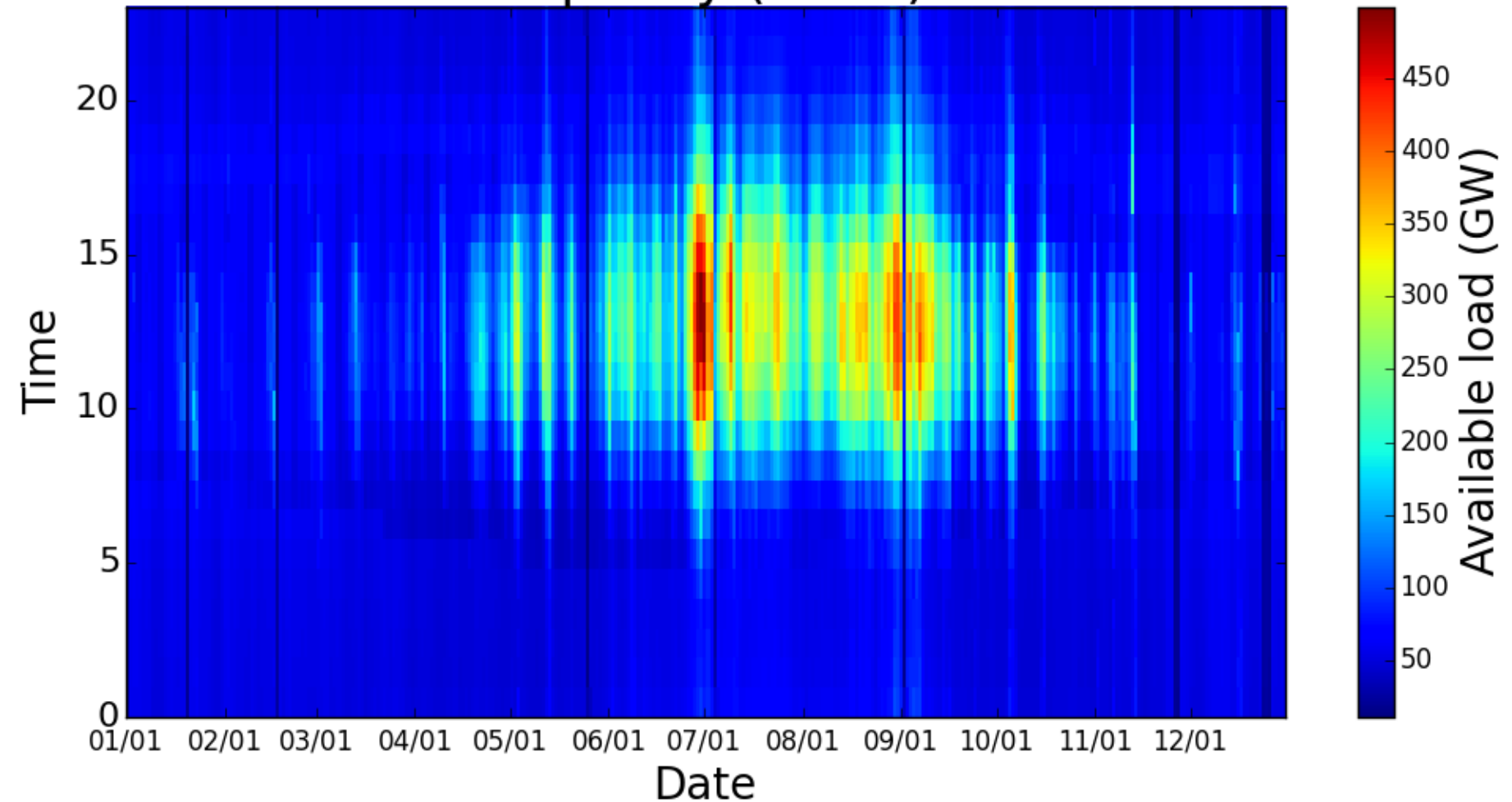


Region: Entire United States
End Use: residential hot water
Product: Energy

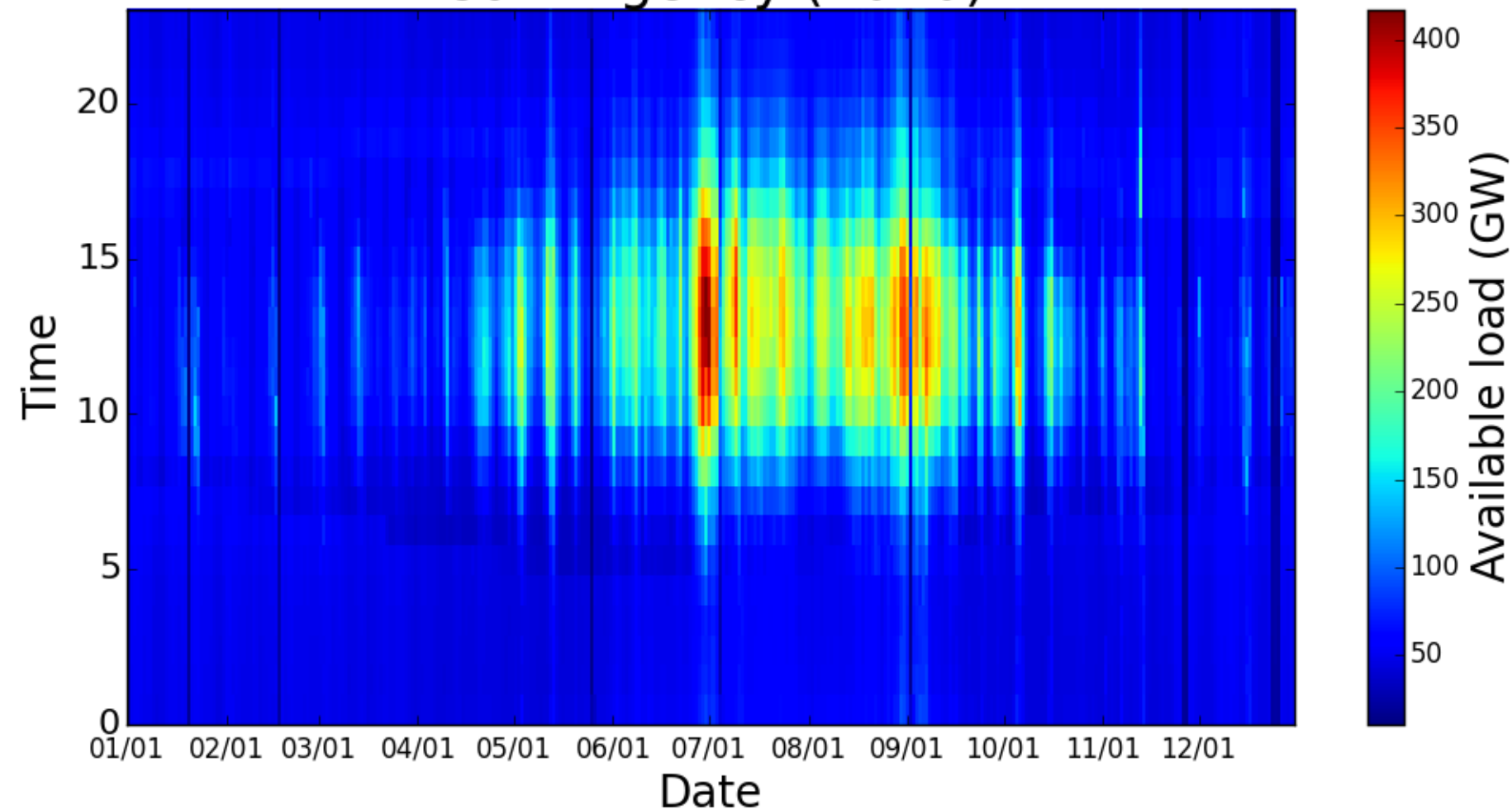


RESULTS: Hourly Demand Response Availability by Product For All End Uses

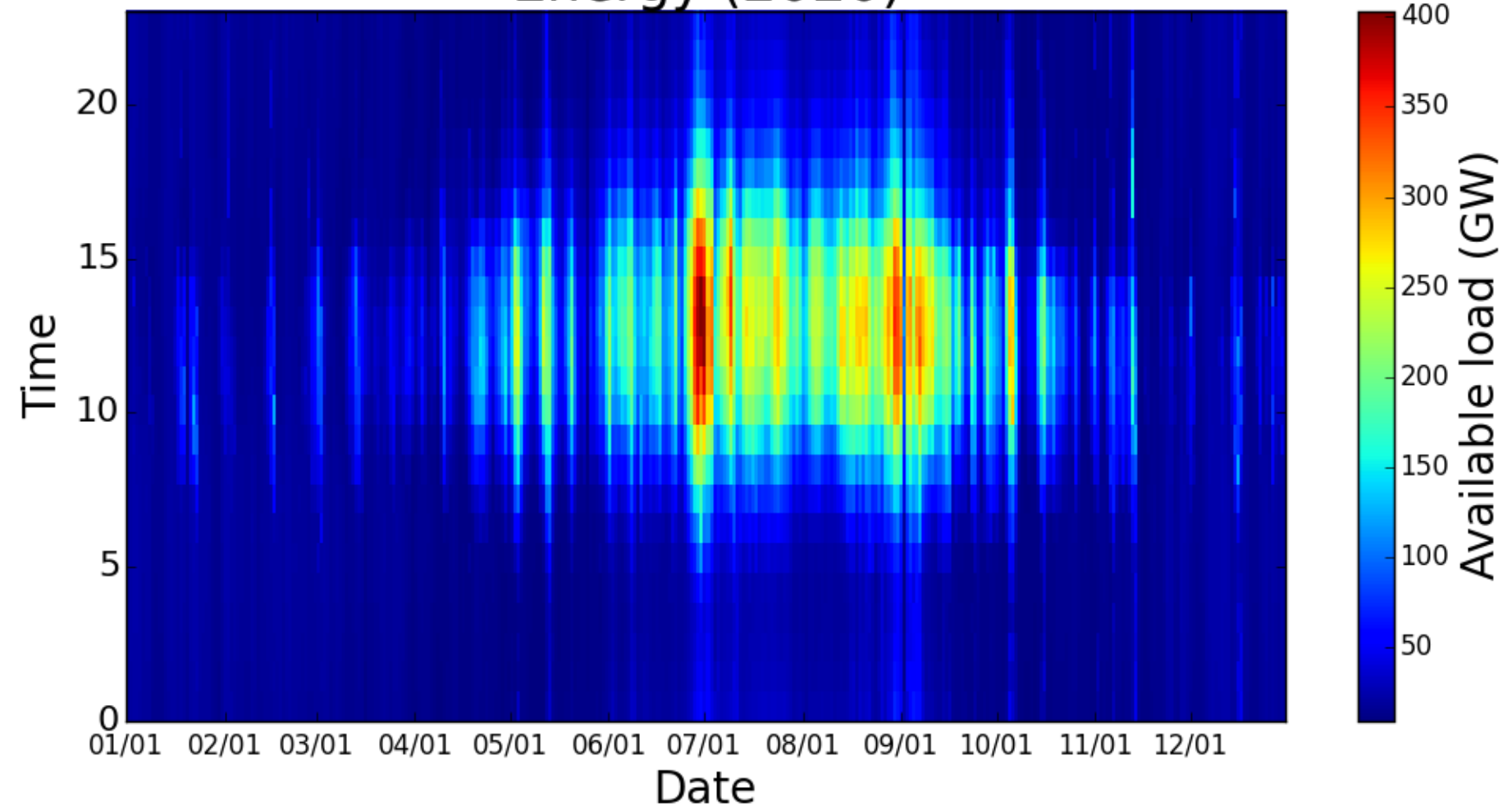
Total resource availability for Capacity (2020)



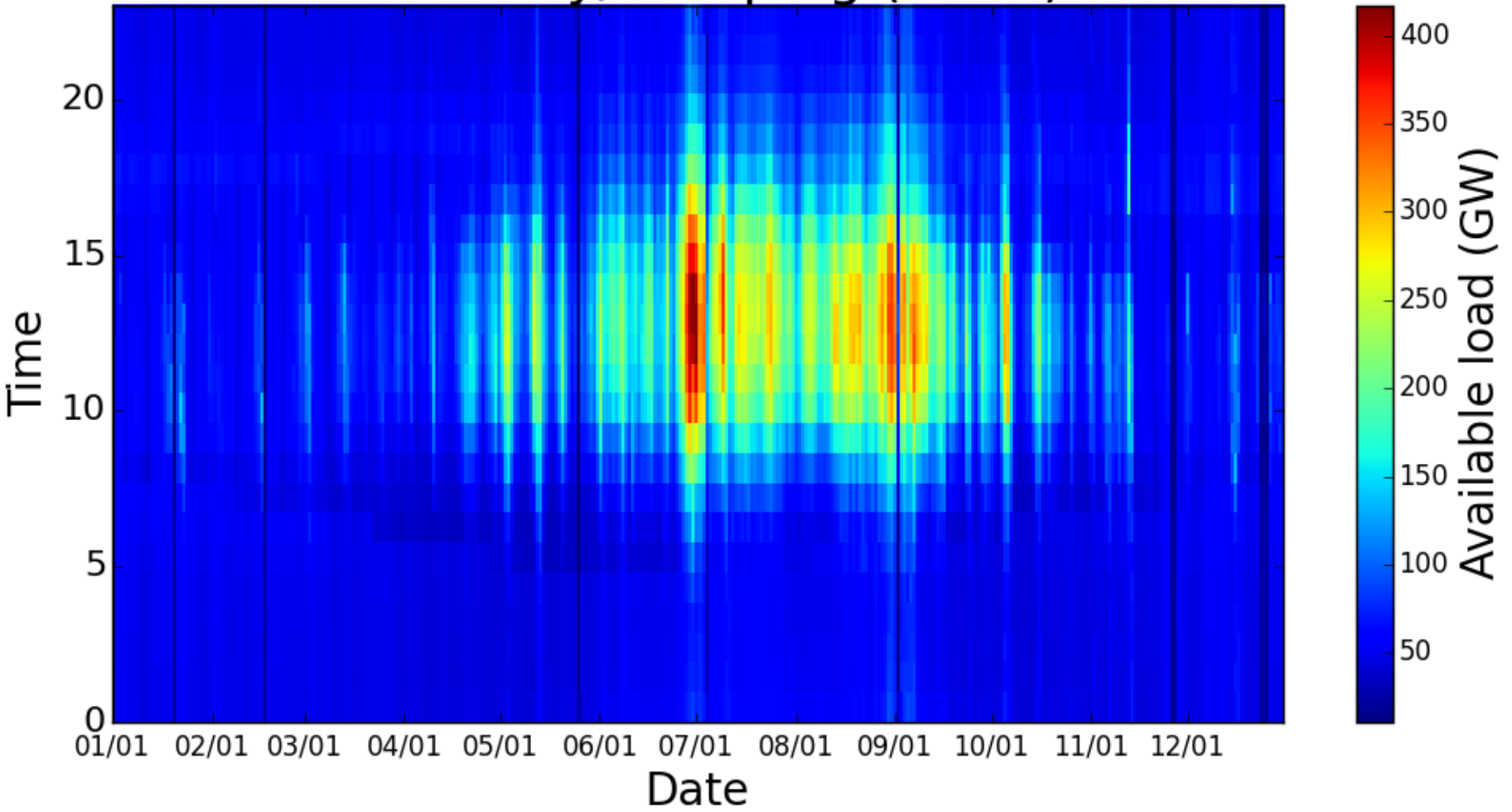
Total resource availability for Contingency (2020)



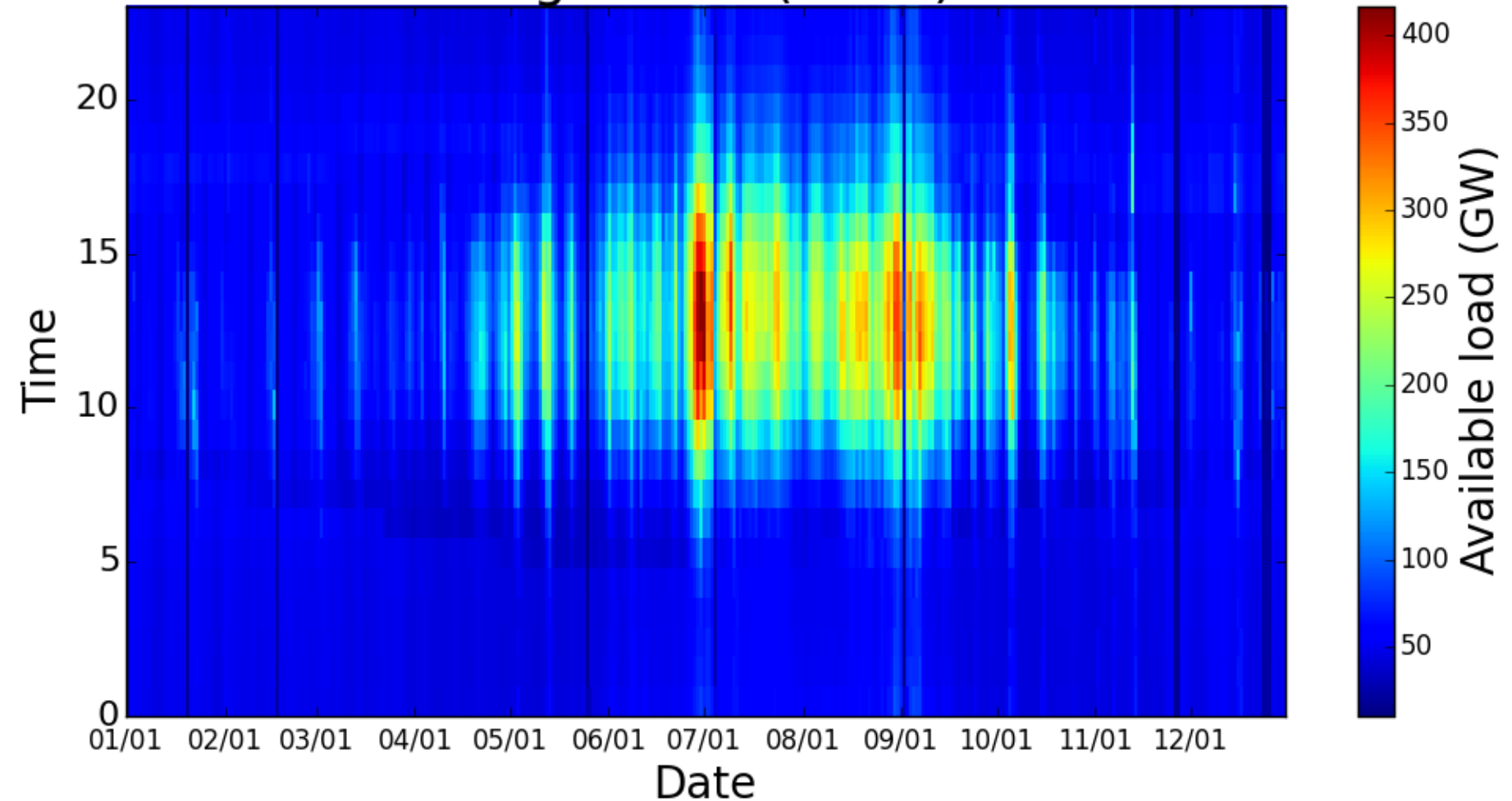
Total resource availability for Energy (2020)



Total resource availability for Flexibility/Ramping (2020)

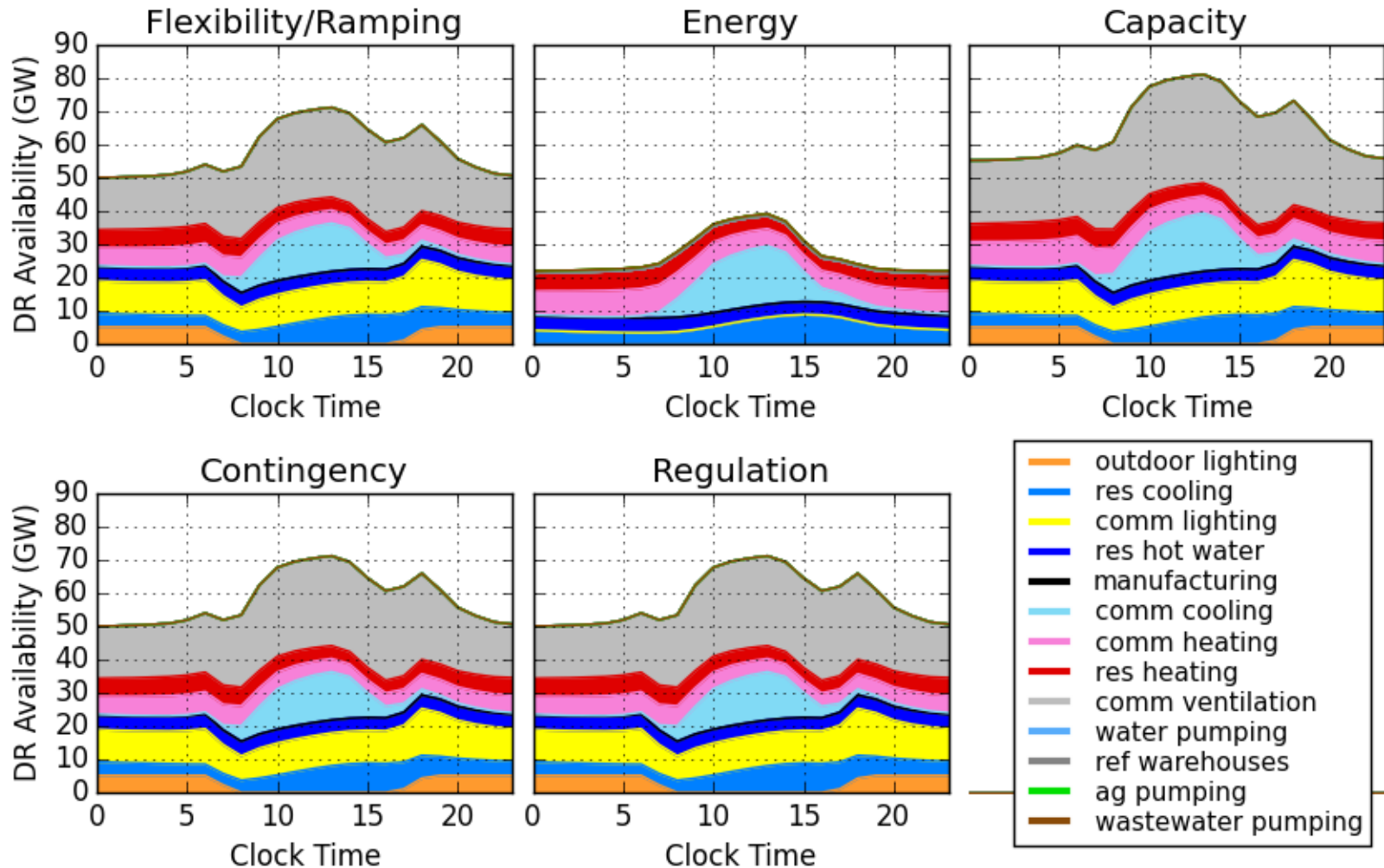


Total resource availability for Regulation (2020)

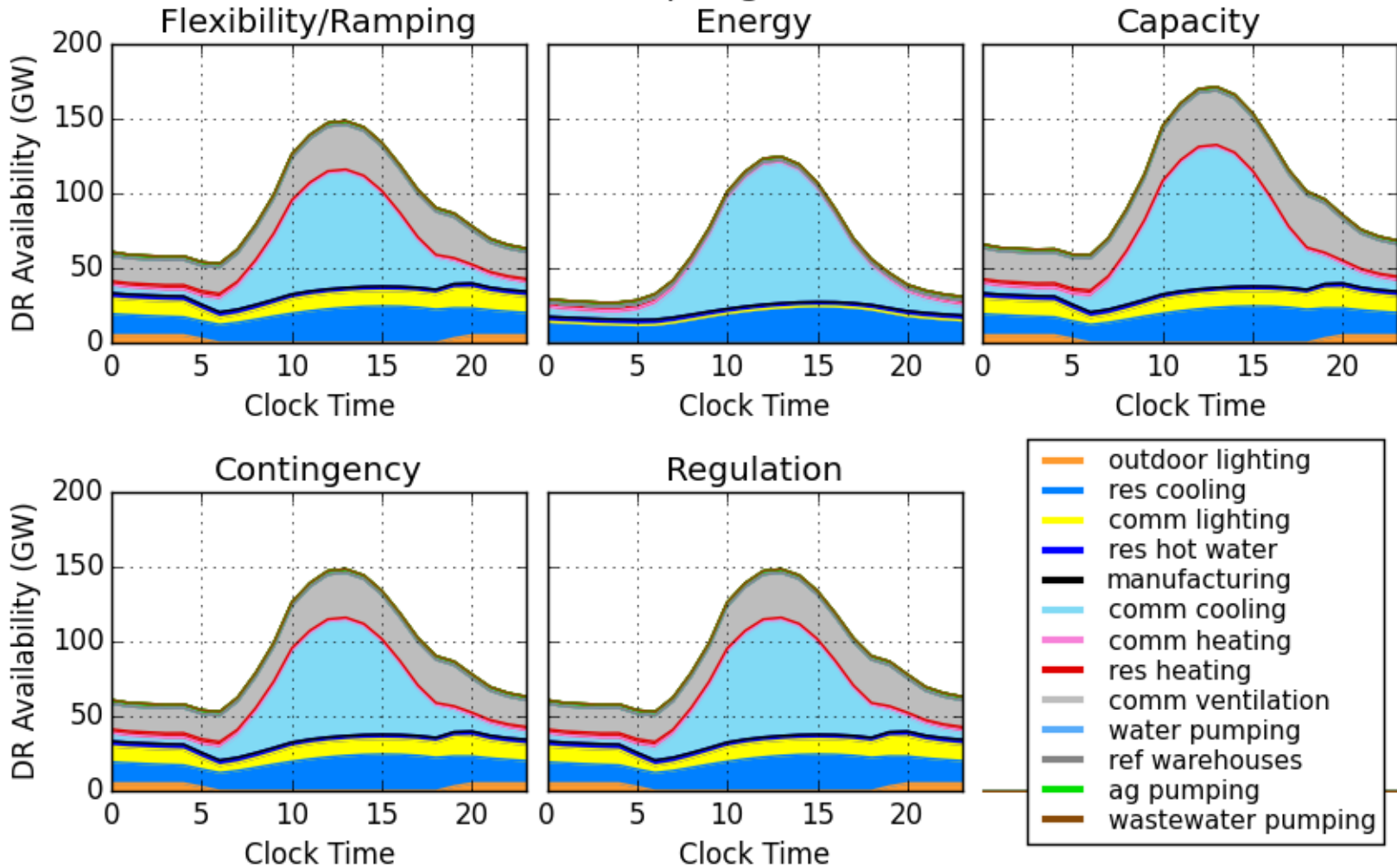


RESULTS: Average Hourly Demand Response Availability by Season and End Use

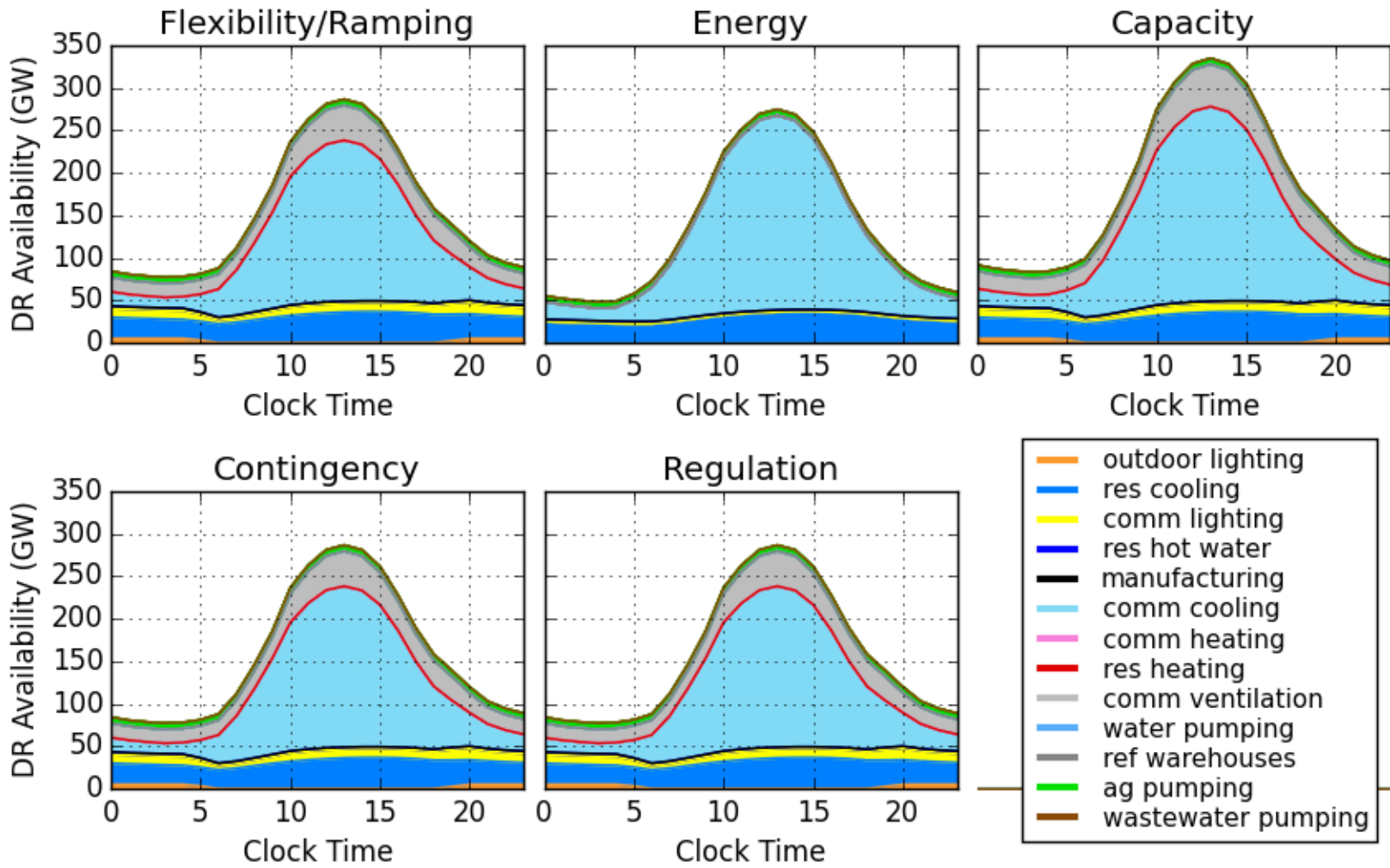
Average Availability by Hour and End Use Winter 2020



Average Availability by Hour and End Use Spring 2020

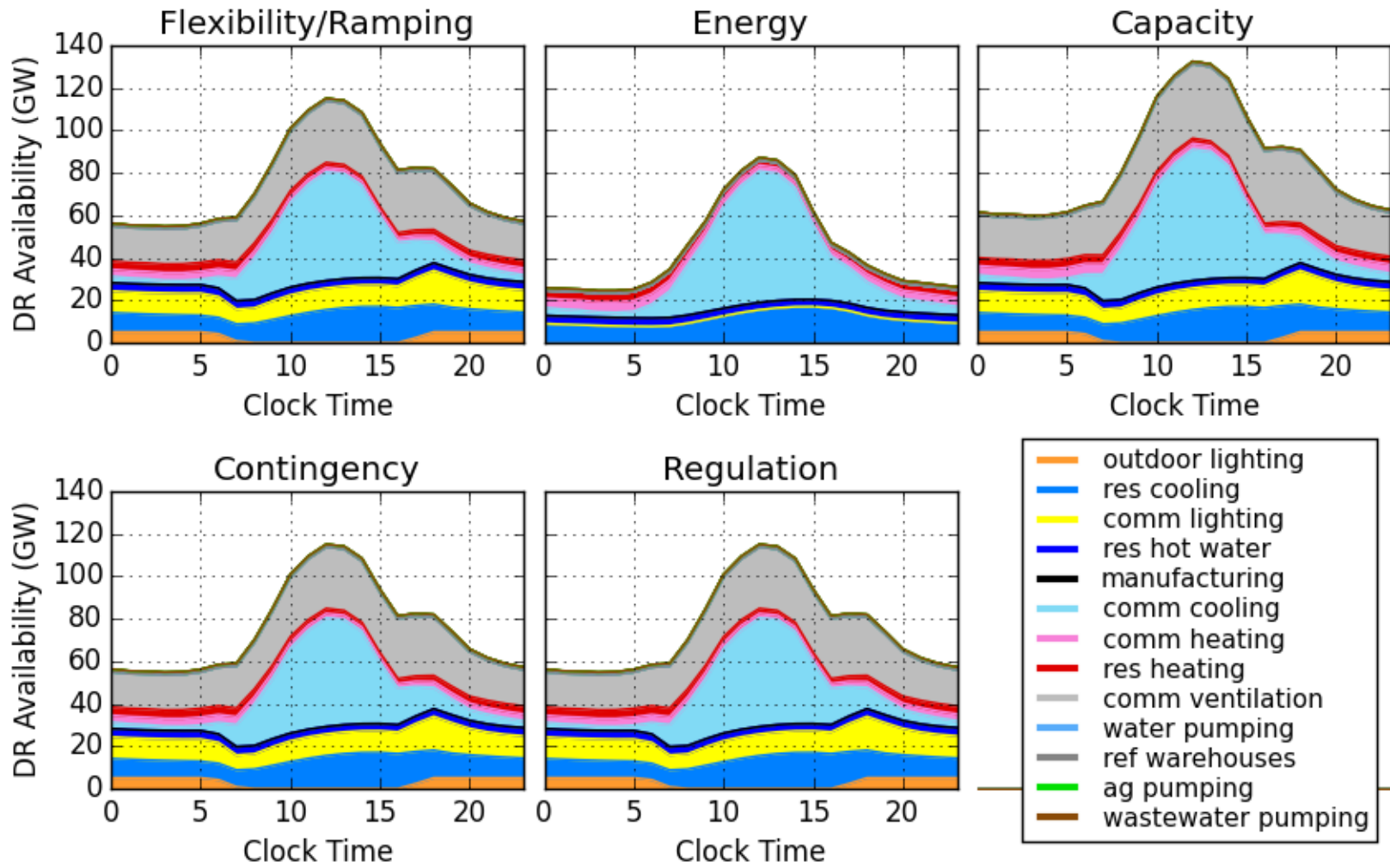


Average Availability by Hour and End Use Summer 2020



Average Availability by Hour and End Use

Fall 2020



Considerations Moving Forward

- Results represent forecasted hourly DR potential in 2020 across the entire United States
- DR resources may saturate ancillary services markets during, particularly during high cooling load hours
 - To be confirmed in production cost model results
- Any future marginal benefit analyses will require scenarios where markets are not saturated



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Appendix 1: Load Profile Generation Methods

LOAD PROFILE GENERATION

Residential & Commercial End-Uses

PROCEDURE

Calculating Load Magnitude

All residential & commercial end-uses		Data Sources
1	Sum residential electricity sales across utilities in region	EIA form 861
2	Calculate share of residential load attributable to each end-use in the corresponding census divisions	CBECS / RECS
3	Compute load magnitude in corresponding data measurement year (2009 for RECS, 2003 for CBECS)	-
4	Apply growth factor based on change in HDD, CDD, or daylight hours between measurement year and weather year (2013 or 2006)	NOAA ISD-Lite, US Naval Observatory

PROCEDURE

Calculating Load Shape

Residential and Commercial Heating and Cooling		Data Sources
1	Estimate occupancy schedules for each building in RECS/CBECS based on reported information	CBECS / RECS
2	Link schedule with reported (or default) setpoint temperatures to generate hourly setpoint temperatures	CBECS / RECS
3	Calculate hourly CDD/HDD	NOAA ISD-Lite
4	For each hour, take the population (or employment) weighted average CDD/HDD across all weather stations in the service territory	US Census Bureau

PROCEDURE

Calculating Load Shape

Commercial Ventilation		Data Sources
1	For buildings with CAV systems, ventilation is either “ON” or “OFF”, and follows building occupancy schedule	-
2	For buildings with VAV systems, ventilation for heating and cooling is assumed to follow heating and cooling load shapes	CBECS / RECS
3	Minimum ventilation rate for VAV systems (in occupied mode) is set at 40% of the peak ventilation	Zhang, et. al.
4	For both CAV and VAV systems, ventilation is assumed to be zero during unoccupied hours	-

PROCEDURE

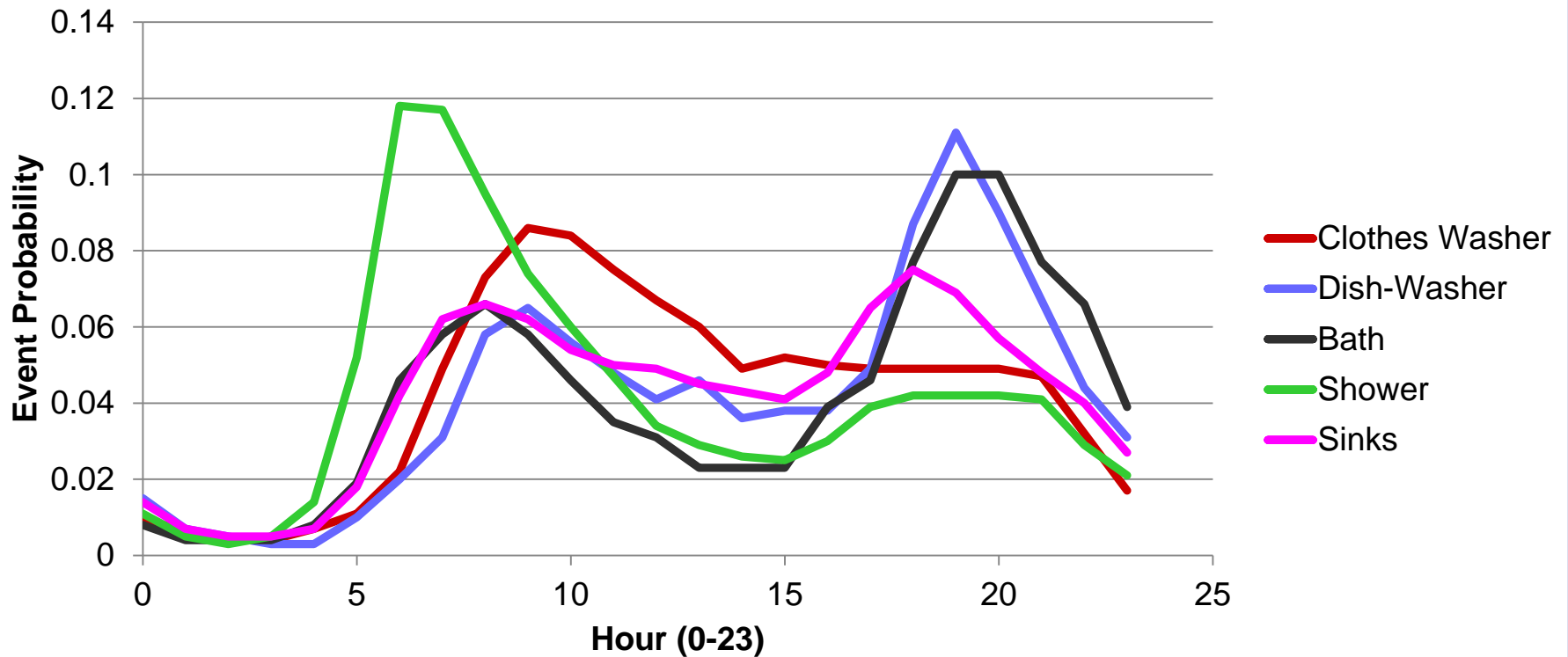
Calculating Load Shape

Commercial Lighting		Data Sources
1	Estimate occupancy schedules for each building in RECS/CBECS based on reported information	CBECS / RECS
2	Obtain percentage lit from CBECS. Includes: Percent lit open, percent lit closed, percent lit by daylighting	CBECS / RECS
3	Link occupancy schedule with sunrise and sunset times to determine percent lit in each hour	US Naval Observatory

PROCEDURE

Calculating Load Shape

Residential Water Heating



PROCEDURE

Calculating Load Shape

Residential Water Heating

Data Sources

1 Derive hourly event probability profiles for each hot water use

2 Determine the number and volume of hot water events per household per year

3 Randomly sample N events annually for each water use, where: $N = \text{Num}_{\text{events}} \times \text{Num}_{\text{households}}$

4 Load shape = $\text{Volume}_{\text{water},i} \times (\text{Temp}_{\text{water},i} - \text{Temp}_{\text{air},i})$

Hendron and Burch 2007,
Hendron and Burch 2010

LOAD PROFILE GENERATION

Municipal End-Uses

PROCEDURE

Municipal Water Pumping

Load Magnitude Calculation		Data Sources
1	0.115 MWh pumping load per person per year	EPRI 2000
2	Multiply by local population	US Census Bureau

PROCEDURE

Municipal Water Pumping

Load Shape Calculation

Data Sources

- | | | |
|---|--|----------------------------------|
| 1 | Assign hourly diurnal load shape | House 2007 |
| 2 | Apply monthly scaling factors to each day | CA Dept. of Water Resources 1994 |
| 3 | Assume wastewater pumping load profiles to be flat | Olsen, et. al. 2013 |

PROCEDURE

Municipal Lighting

Load Magnitude Calculation

Data Sources

- | | | |
|---|---|-----------------------|
| 1 | Use national load magnitudes for municipal lighting from DOE 2008 (for flood and area lighting) and DOE 2012 (for street and parking lighting). | DOE 2008,
DOE 2012 |
| 2 | Disaggregate by BAA based on local population | US Census
Bureau |

PROCEDURE

Municipal Lighting

Load Shape Calculation

Data Sources

- 1 Assume lighting is ON or OFF, based on local sunrise and sunset times

US Naval Observatory

LOAD PROFILE GENERATION

Industrial Non-Manufacturing End-Uses

PROCEDURE

Data Centers

Load Magnitude Calculation

Data Sources

1 US EPA estimates that data centers account for 3% of national electricity sales

EPA 2007

Assign fraction of national load to each BAA based on local data and tech employment. NAICS codes used include:

2

518	Data processing, Hosting and Related Services
5415	Computer Systems Design and Related Services

US Census Bureau

PROCEDURE

Data Centers

Load Shape Calculation		Data Sources
1	Cooling load accounts for 40% of total data center load	Ghatikar et al. 2012
2	Assume 60% of data center load is flat (non-cooling)	Sheppy et al. 2011
3	For the remaining 40%, load shape is proportional to CDD, calculated using 75°F setpoint temperature	ASHRAE 2008

PROCEDURE

Refrigerated Warehouses

	Load Magnitude Calculation	Data Sources
1	Sum refrigeration load for refrigerated warehouses in CBECS	CBECS
2	Weight census division load magnitude by the number of people employed in the corresponding NAICS codes: 493120 Refrigerated Warehousing and Storage	US Census Bureau

PROCEDURE

Refrigerated Warehouses

Load Shape Calculation

Data Sources

- 1 Calculate “CDD” with a setpoint temperature 34 F (mid-range for cold storage)

CBECS

PROCEDURE

Agricultural Water Pumping

Load Magnitude Calculation

Data Sources

- 1 Multiply agricultural pumping expenditures¹ by average industrial electricity rates in the BAA²

¹ USDA 2013,
² EIA 2012

$$\text{Pumping load (MWh)} = \text{Expense (\$)} \div \text{Cost (\$/MWh)}$$

- 2 Weight state pumping load by BAA employment for the following NAICS codes:

US Census
Bureau

11511 Support Activities for Crop Production

PROCEDURE

Agricultural Water Pumping

Load Shape Calculation		Data Sources
1	<p>Determine acreage for each major crop in the state.</p> <p>Assume acreage ranges from:</p> <ul style="list-style-type: none"> • 0 to 100% planted between start and end planting dates • 100% to 0% between start and end harvesting dates 	USDA 1997
2	<p>Calculate irrigation needs per day using the Blaney-Criddle Formula¹:</p> $\text{Water}_{\text{day}} = .01 \times T_{\text{air,day}} \times p_{\text{day}} \times k_{t,\text{day}} \times k_{c,\text{day}} - \text{rain}_{\text{day}}$ <p>T_{air} = outdoor air temperature²</p> <p>p = percent of annual daylight hours in time period³</p> $k_t = 0.0173 \times T_{\text{air}} - 0.314$ <p>k_c = crop watering coefficient⁴</p> <p>rain = rainfall in inches²</p>	<p>¹ USDA 1993,</p> <p>² NOAA 2015,</p> <p>³ US Naval Observatory,</p> <p>⁴ FAO</p>
3	Daily load shapes are assumed to be flat	Olsen, et al, 2013

LOAD PROFILE GENERATION

Industrial Manufacturing End-Uses

PROCEDURE

Industrial Manufacturing

End-Use Selection		Data Sources
1	Choose the 5 NAICS codes with the highest employment in each BAA	US Census Bureau
2	Use MECS to identify the two most energy intensive end-uses for the chosen manufacturing industries	MECS 2010

PROCEDURE

Industrial Manufacturing

Load Magnitude Calculation

Data Sources

- | | Load Magnitude Calculation | Data Sources |
|---|--|--------------|
| 1 | Calculate the fraction of national industrial load attributable to the end-use | MECS 2010 |
| 2 | Multiply by annual industrial demand in the BAA | EIA 861 |

PROCEDURE

Industrial Manufacturing

Load Shape Calculation

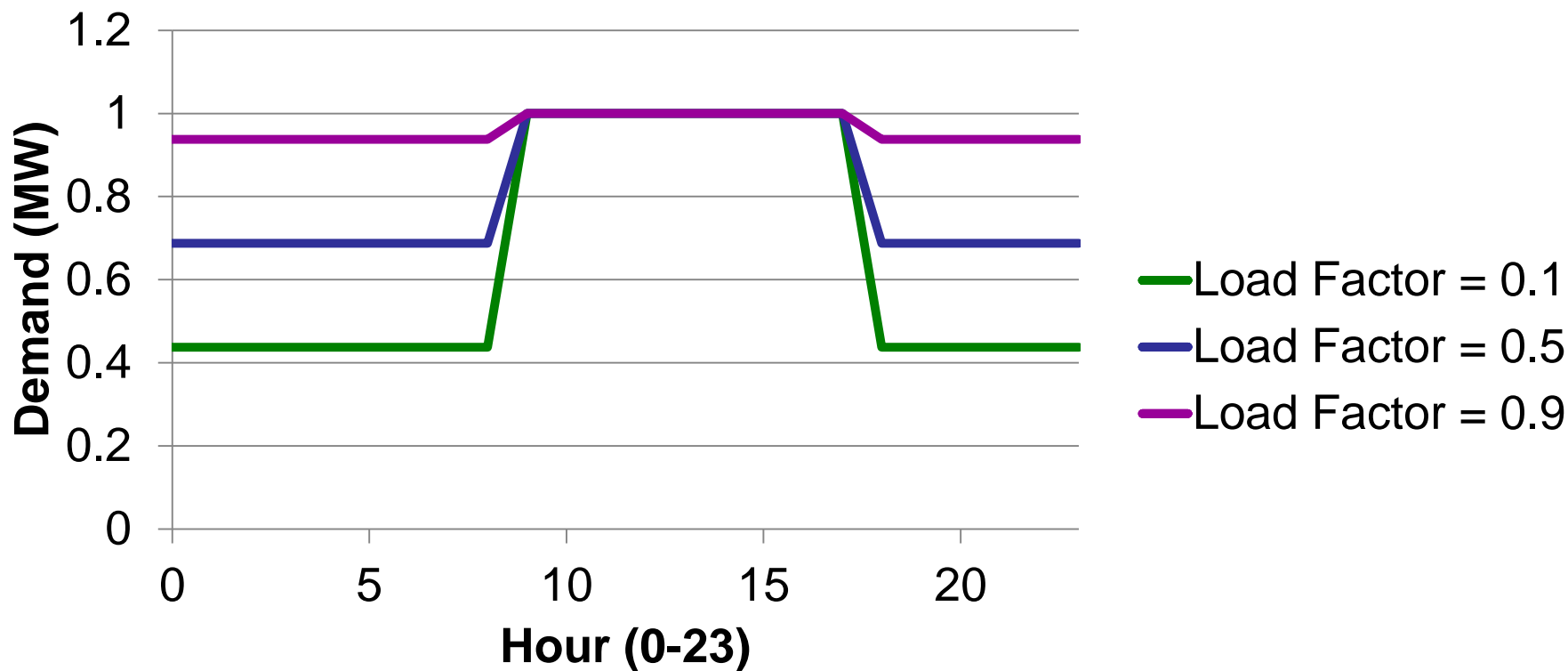
Data Sources

- | | Load Shape Calculation | Data Sources |
|---|---|--------------|
| 1 | Calculate annual load factor
Load factor = annual load (kWh) × peak load (kW) / 8760 (h) | IAC 2015 |
| 2 | Assume facilities operate daily between 9 am and 5 pm, except holidays | |
| 3 | Assume the daily load factor is the same as the annual load factor | |
| 4 | Assume peak load occurs throughout operating hours | |

PROCEDURE

Industrial Manufacturing

Load Shape Calculation





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Appendix 2: Verification of End Use Load Profiles for FRCC

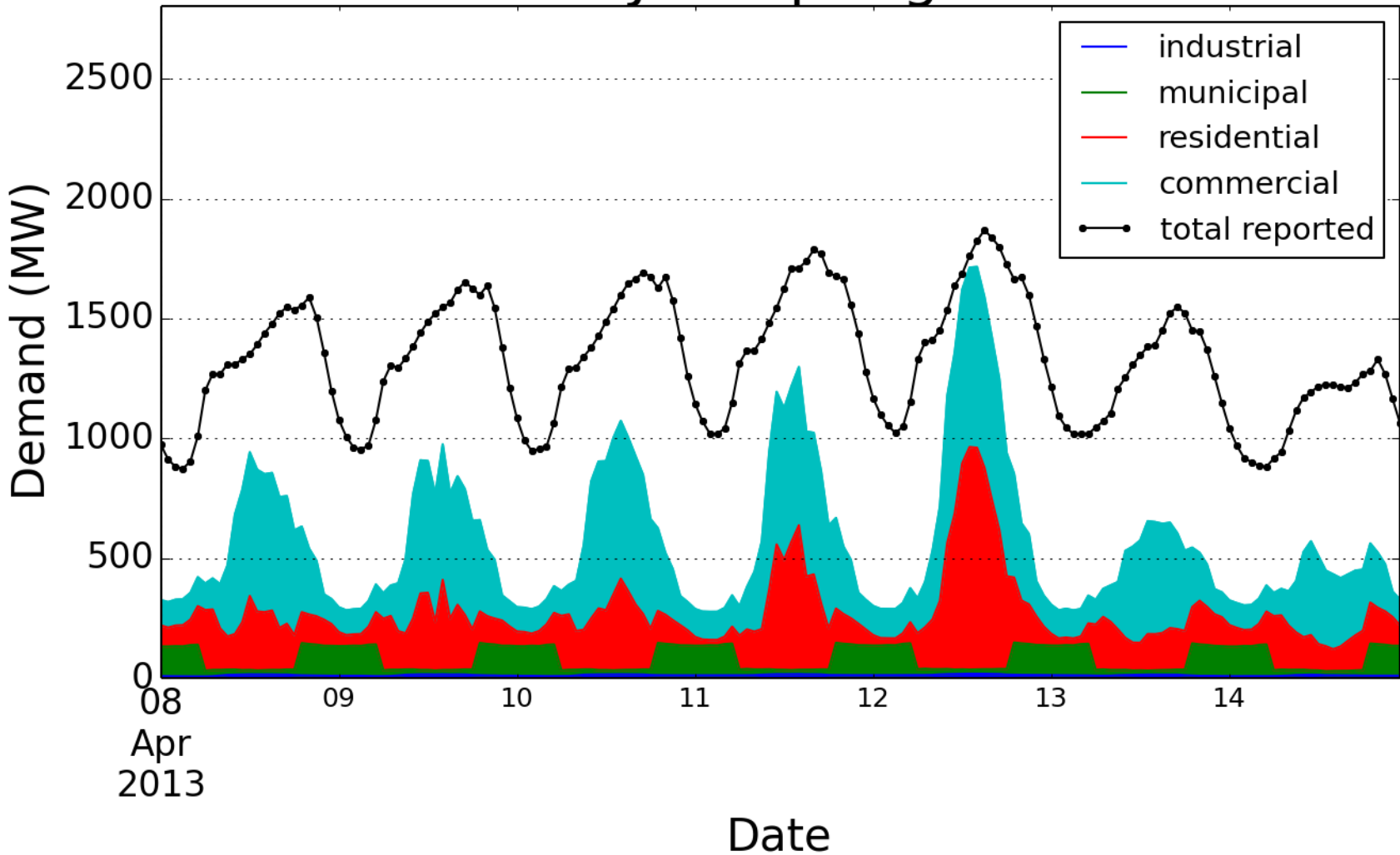
Verification of End Use Load Profiles for FRCC: Methodology

- We use the model to project hourly load profiles for 2013, and compare results with hourly system-level load and monthly sector-level load for BAAs in FRCC.
- Because our model only estimates load for select end uses well-suited to provide DR, we expect projections to be less than (or equal to) reported values.

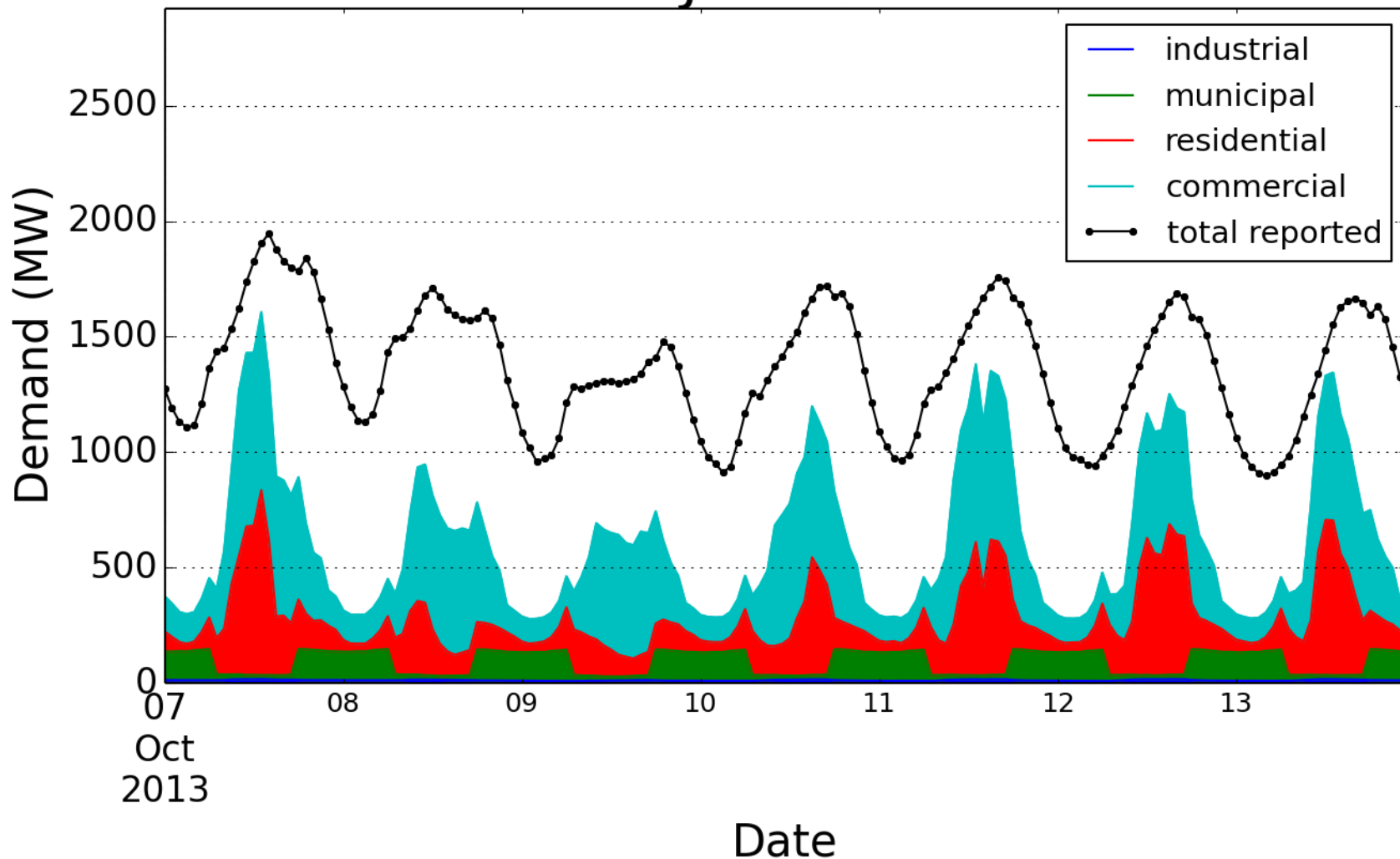
LOAD PROFILE VERIFICATION

Region: FRCC
BAA: JEA

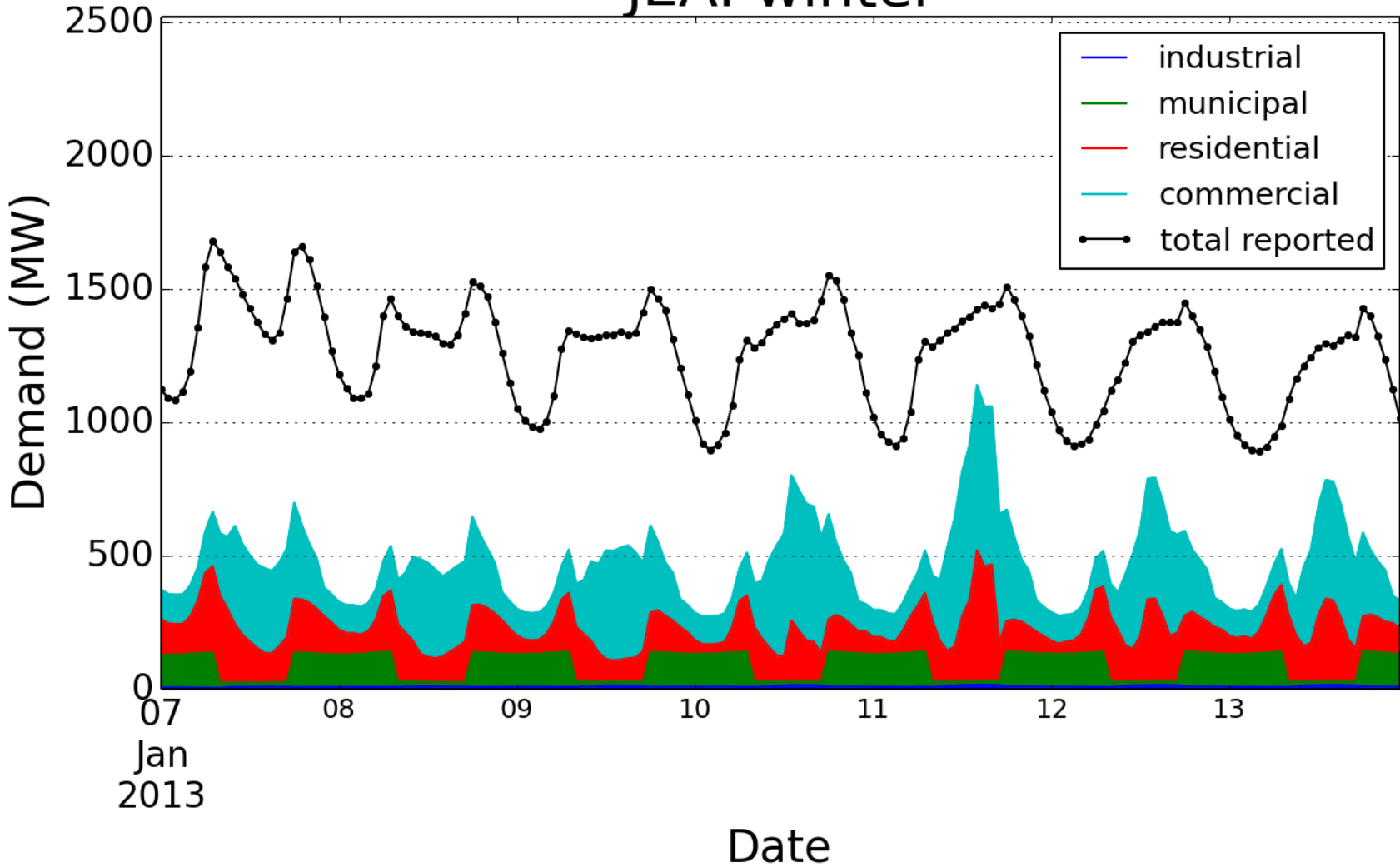
JEA: spring



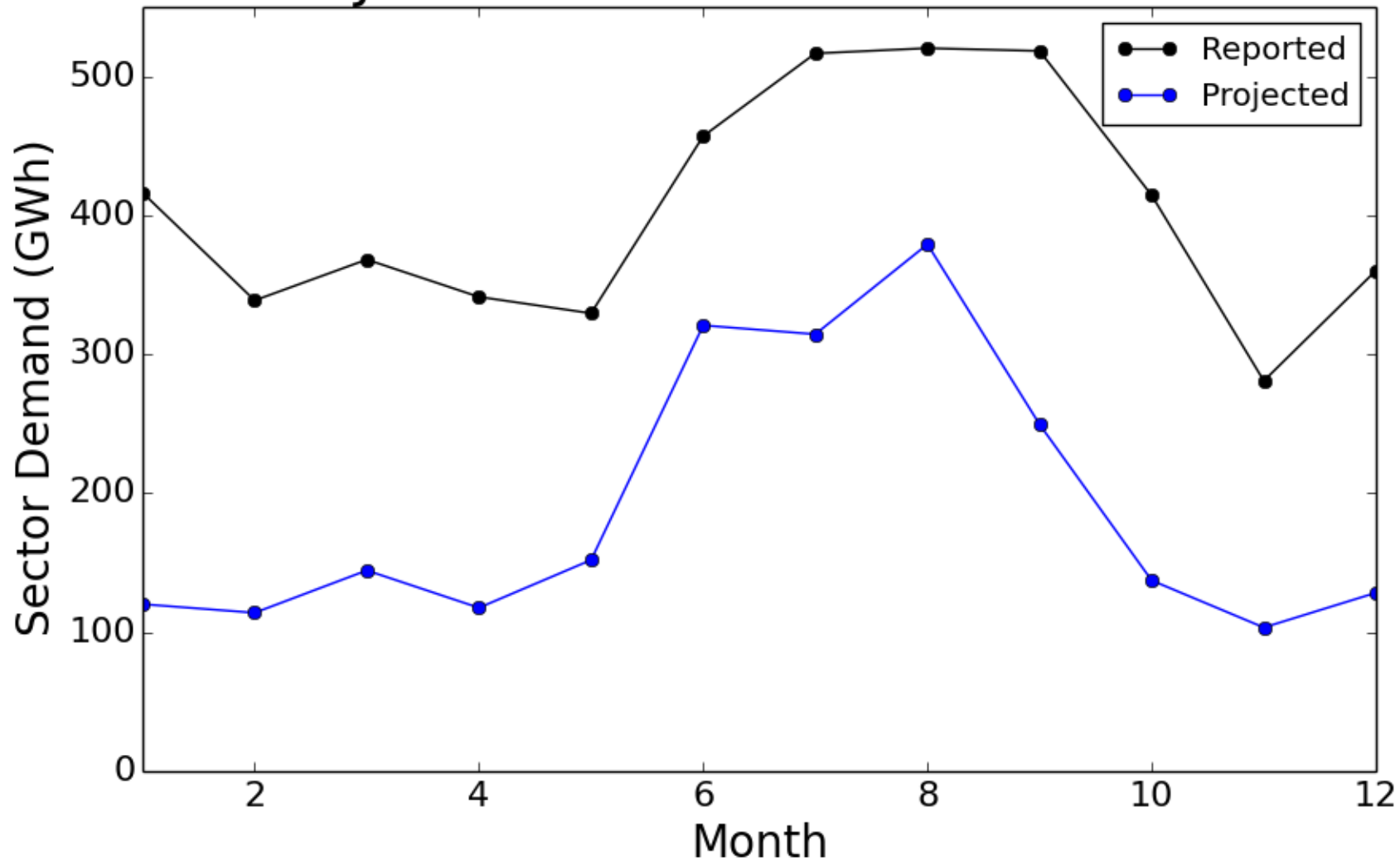
JEA: fall



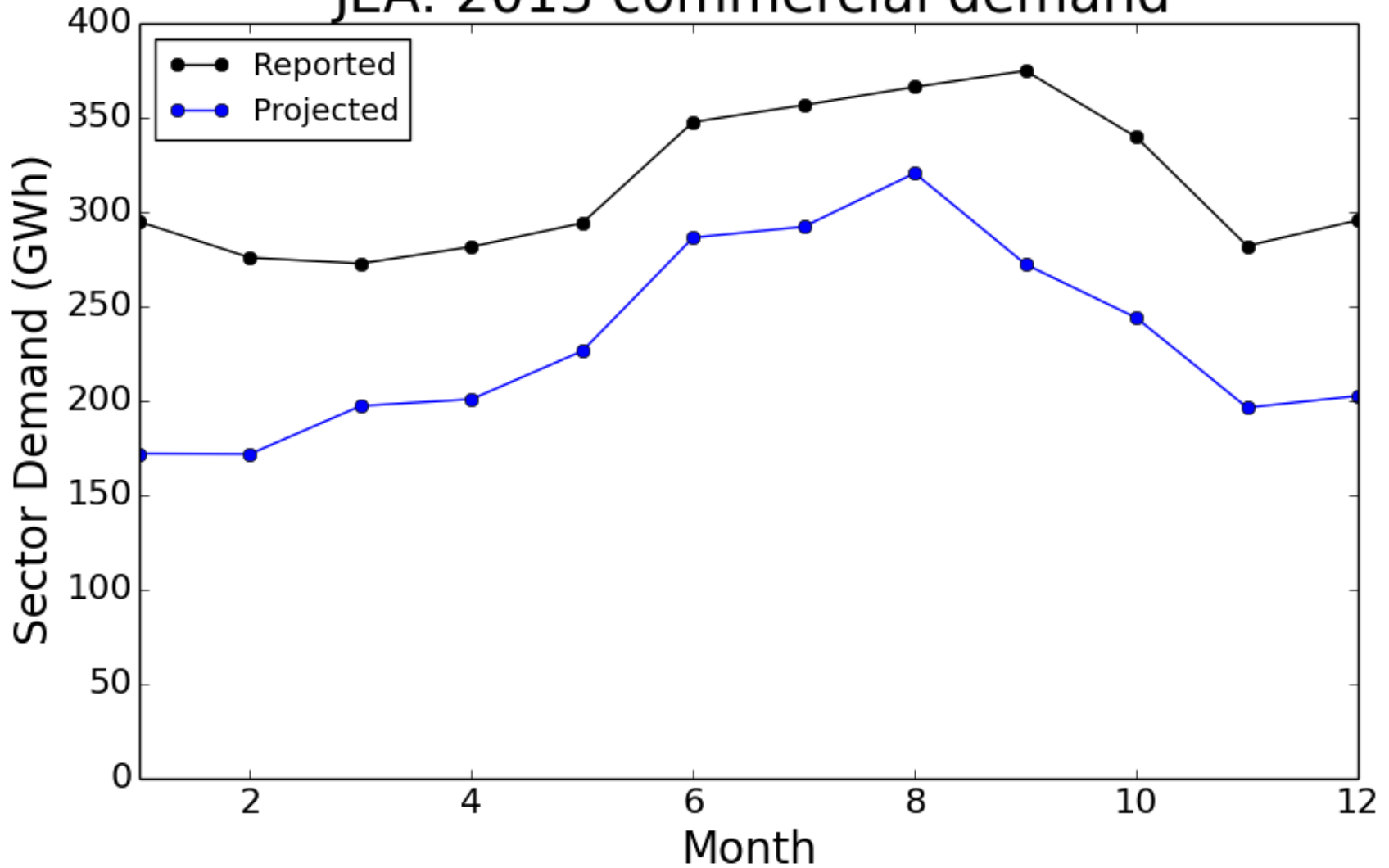
JEA: winter



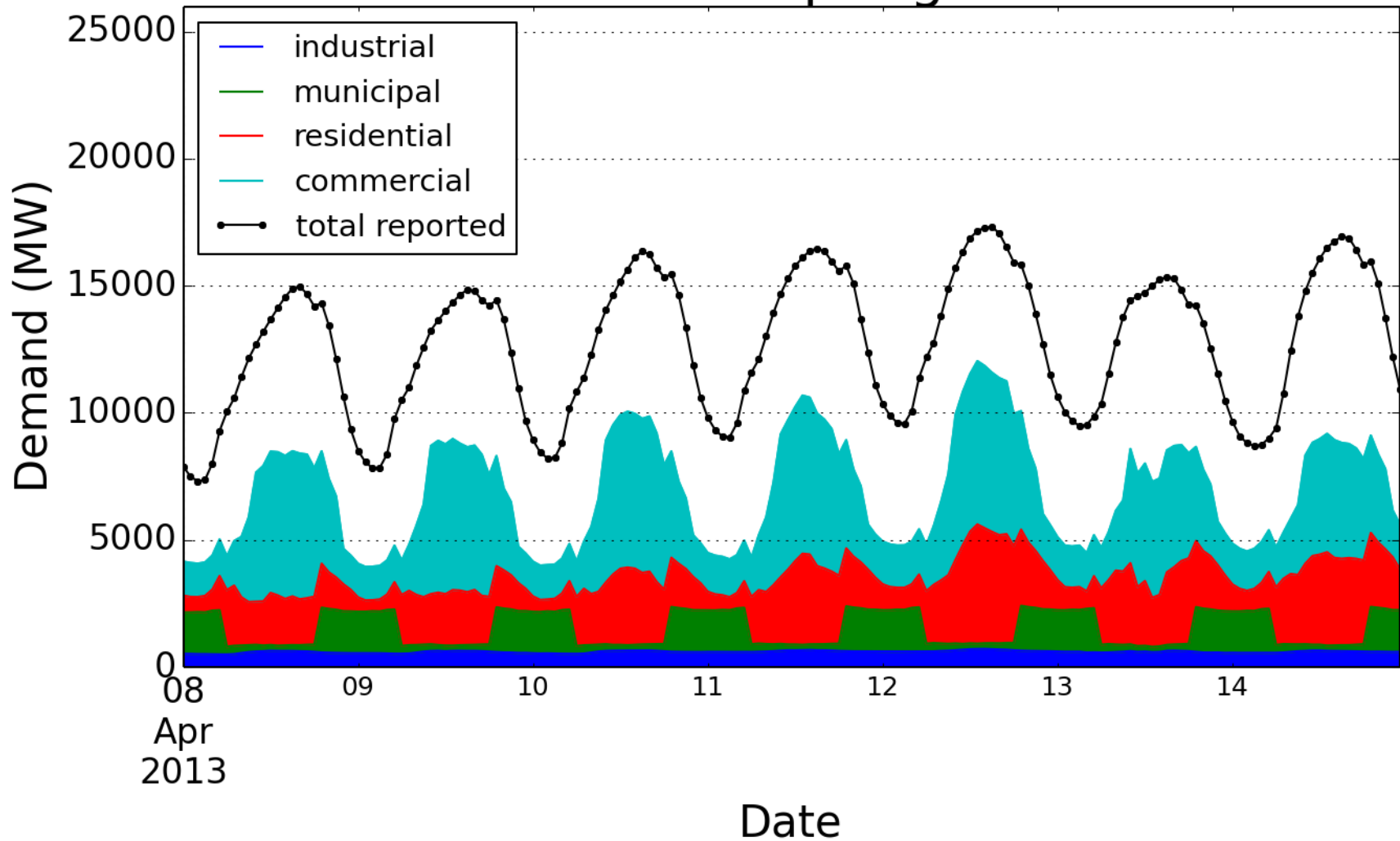
JEA: 2013 residential demand



JEA: 2013 commercial demand



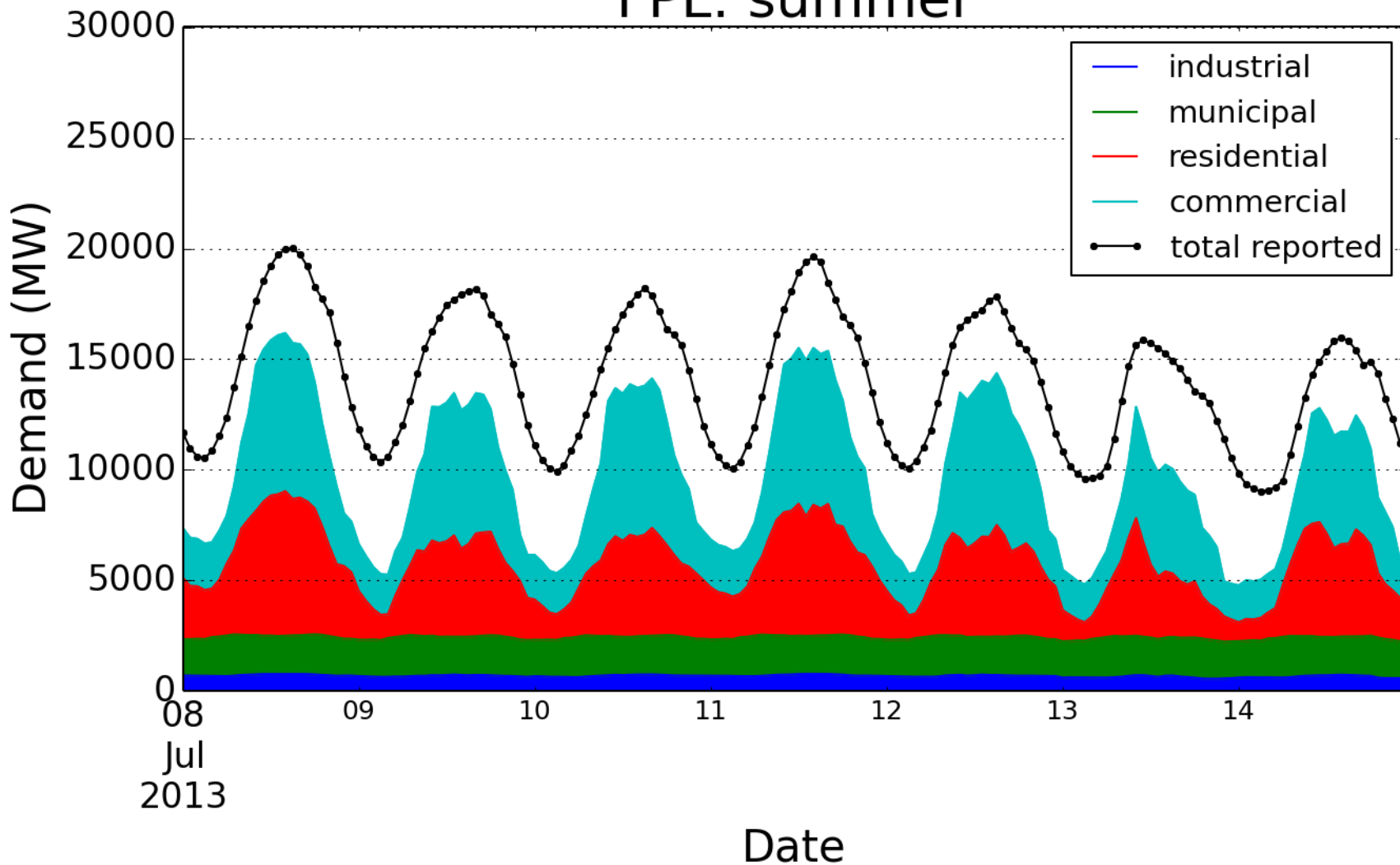
FPL: spring



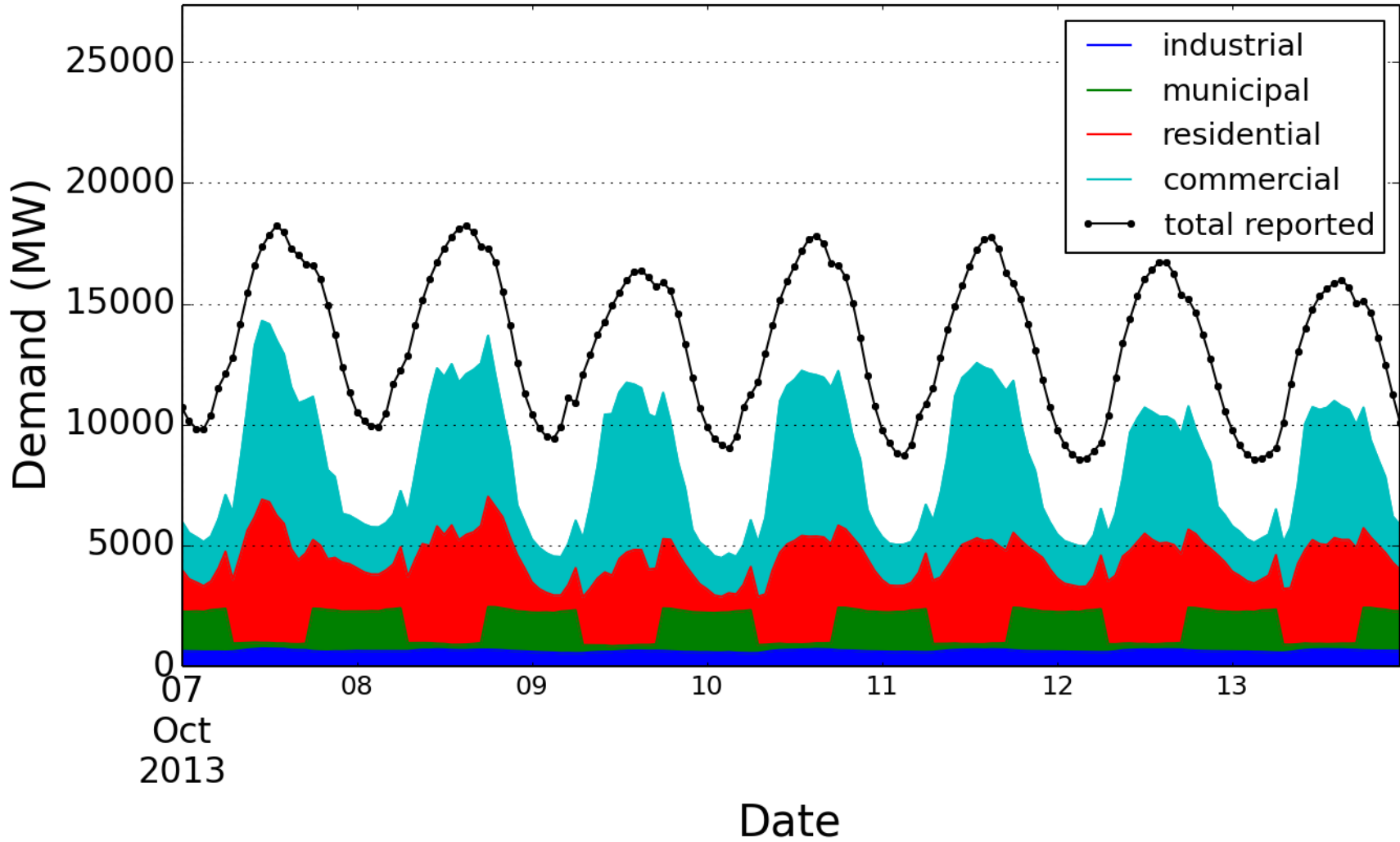
LOAD PROFILE VERIFICATION

Region: FRCC
BAA: FPL

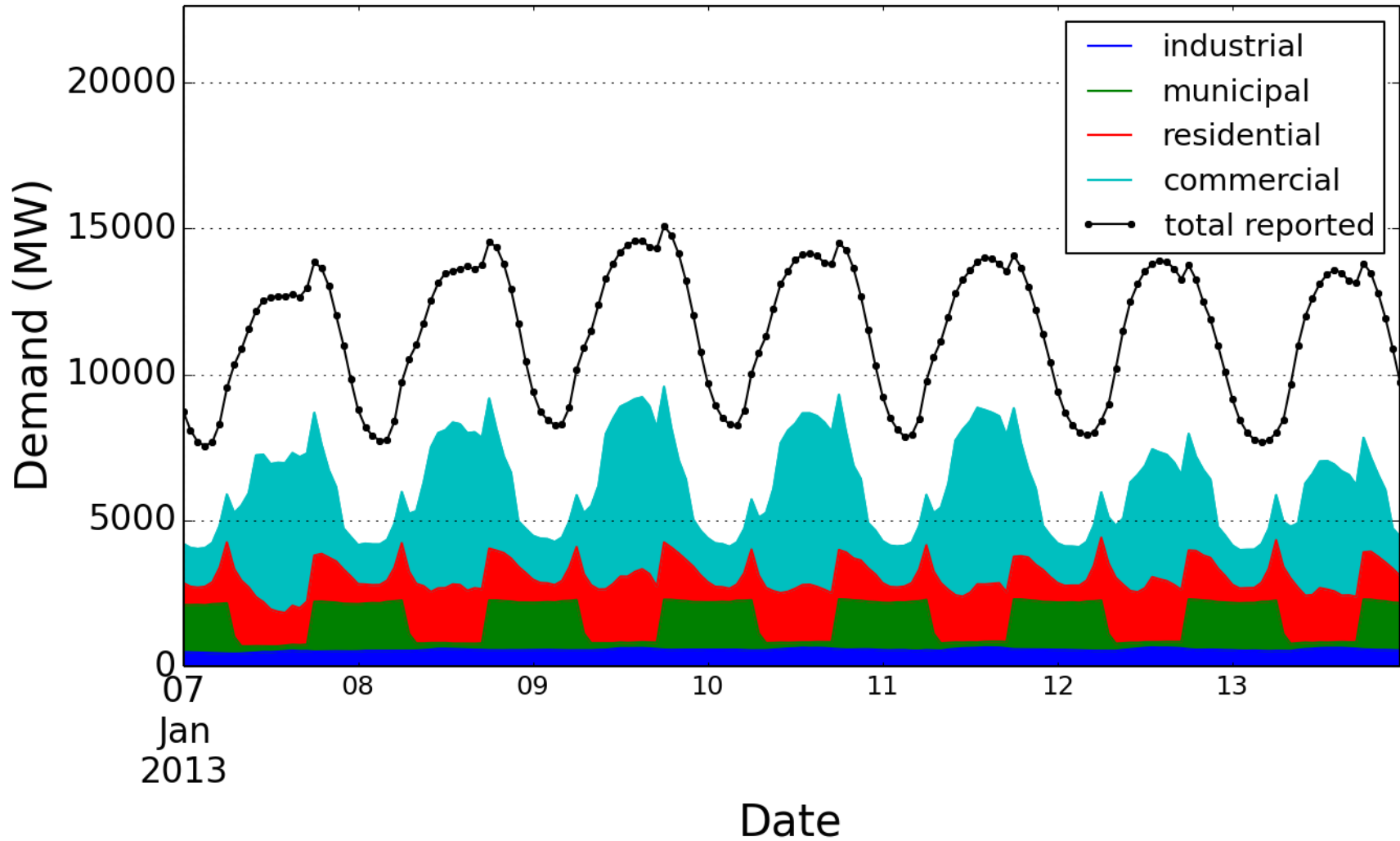
FPL: summer



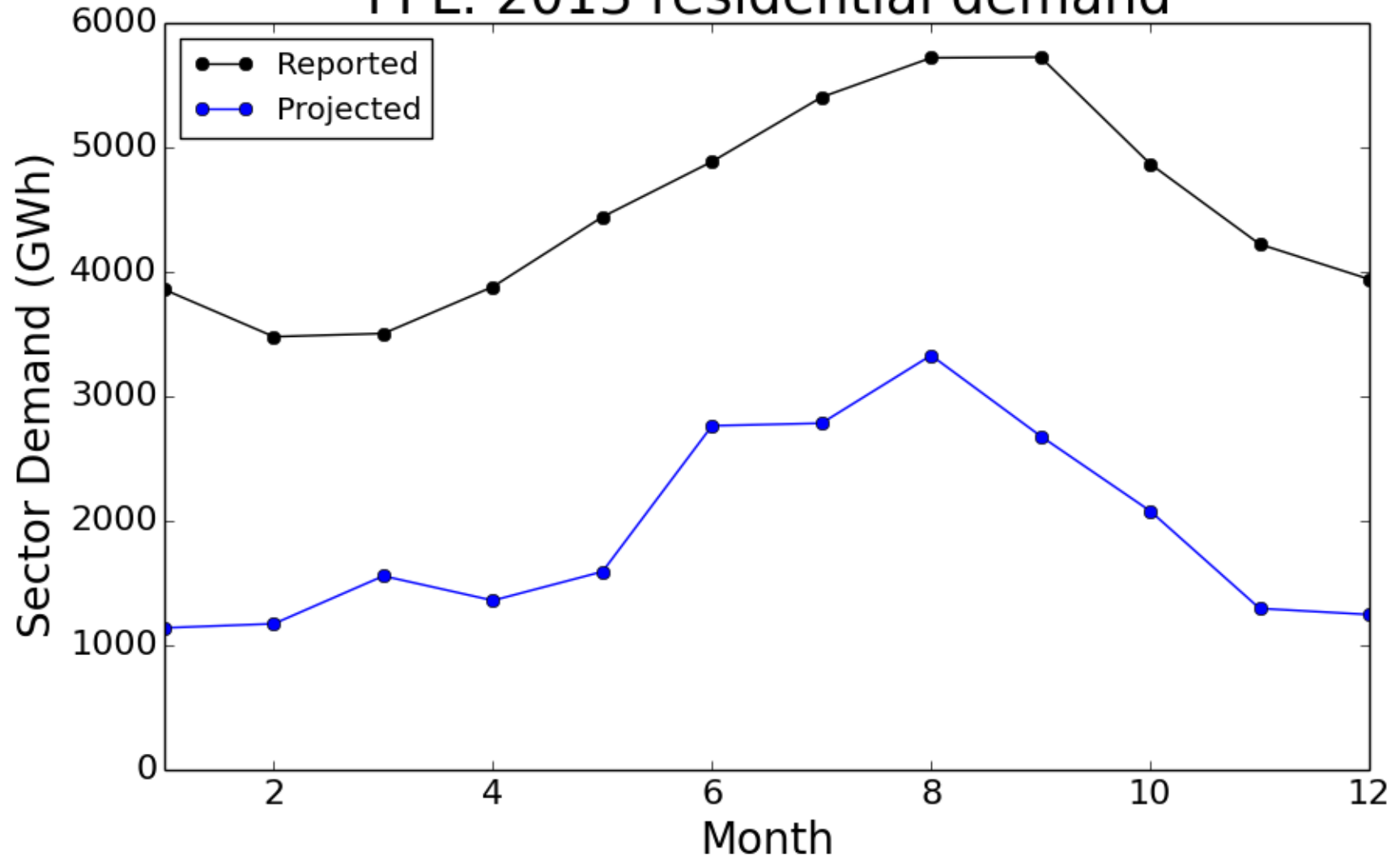
FPL: fall



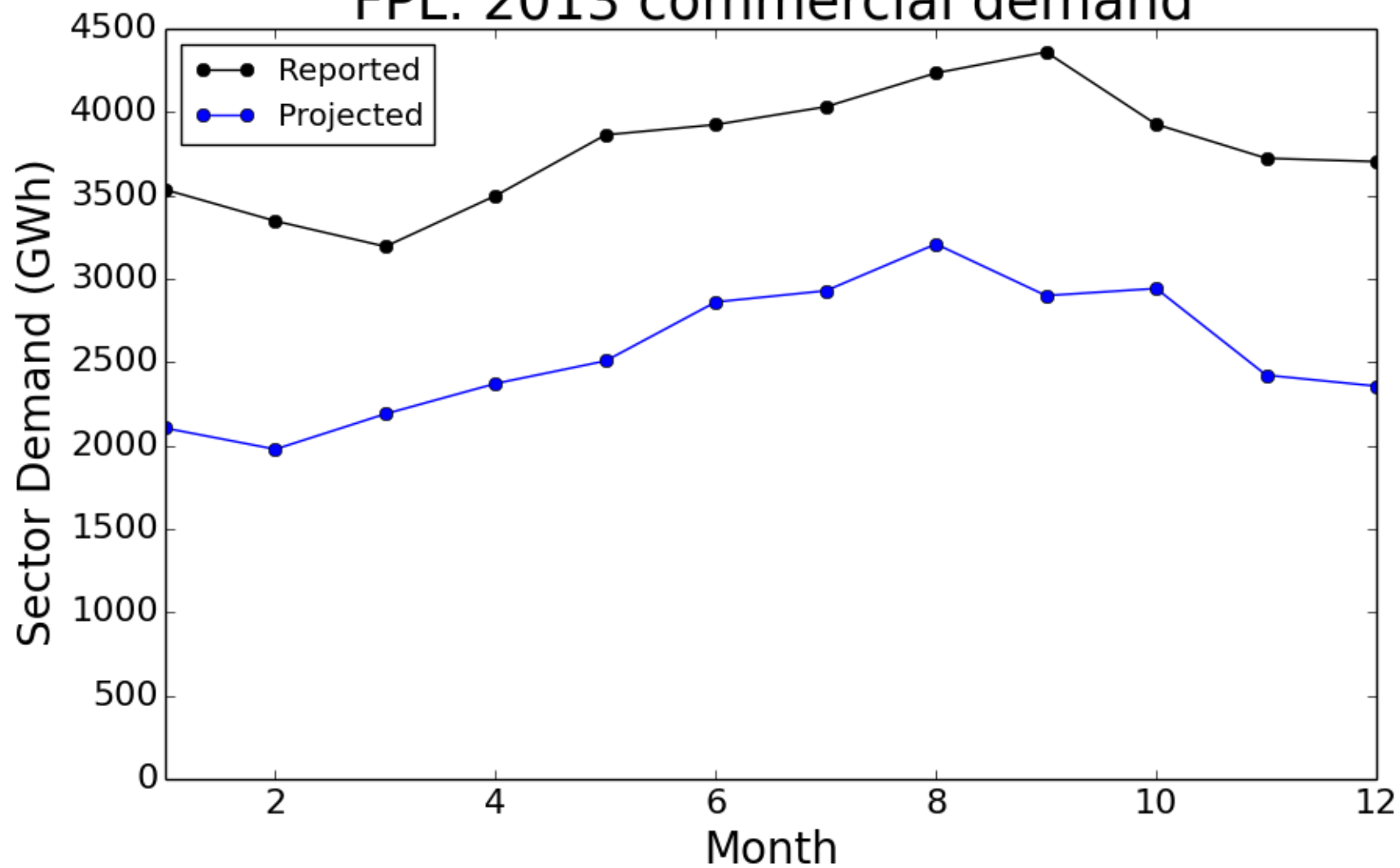
FPL: winter



FPL: 2013 residential demand



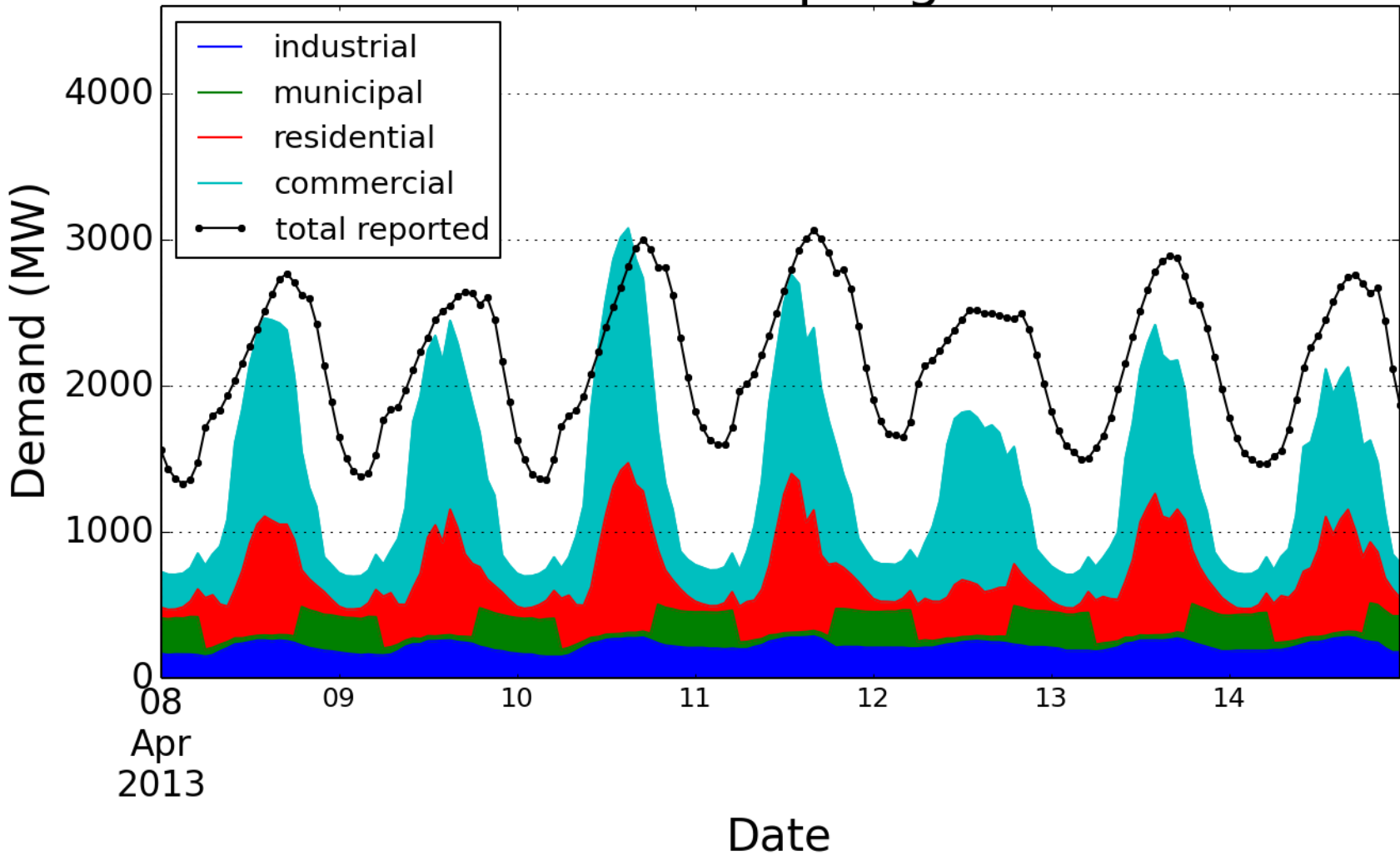
FPL: 2013 commercial demand



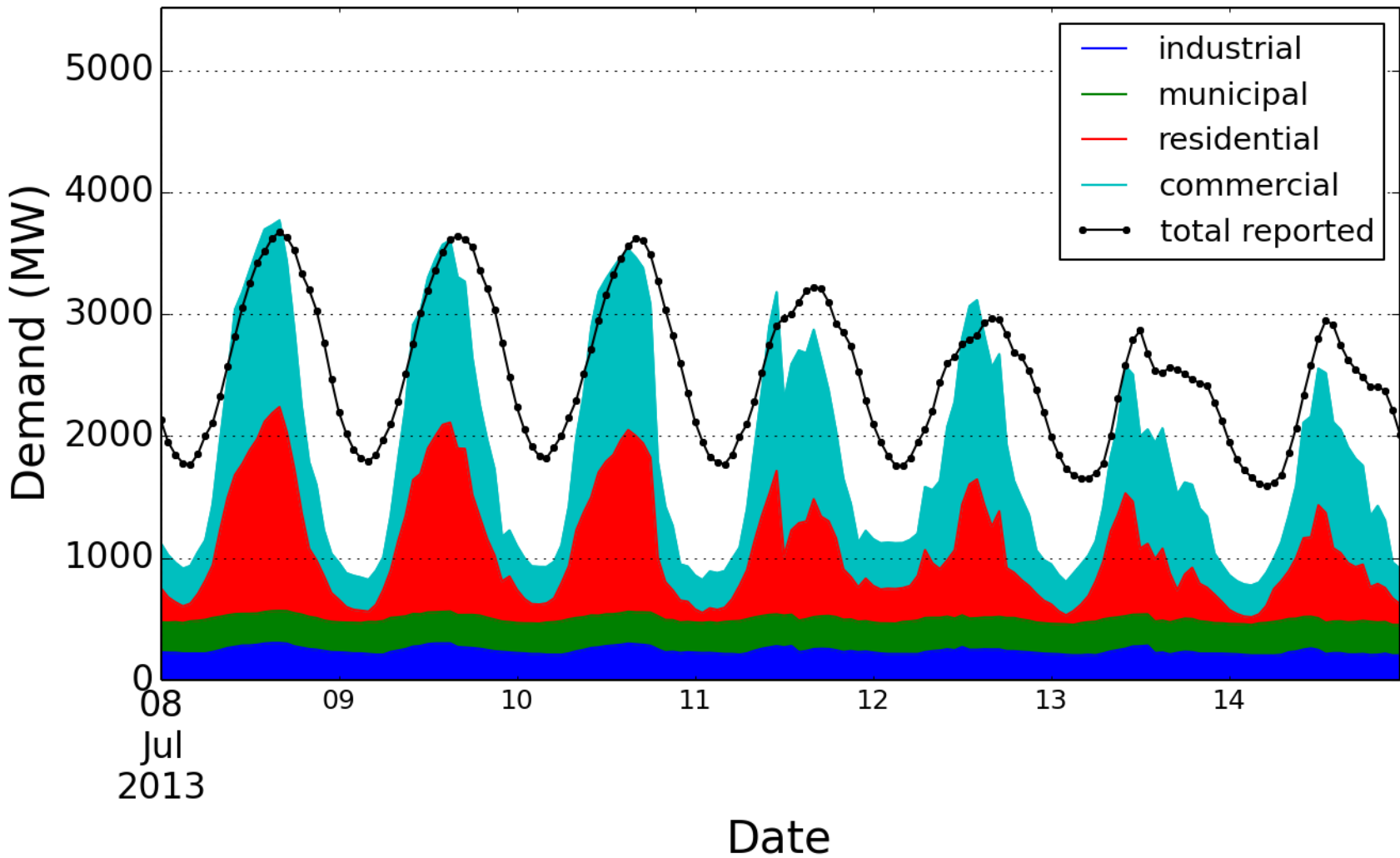
LOAD PROFILE VERIFICATION

Region: FRCC
BAA: TEC

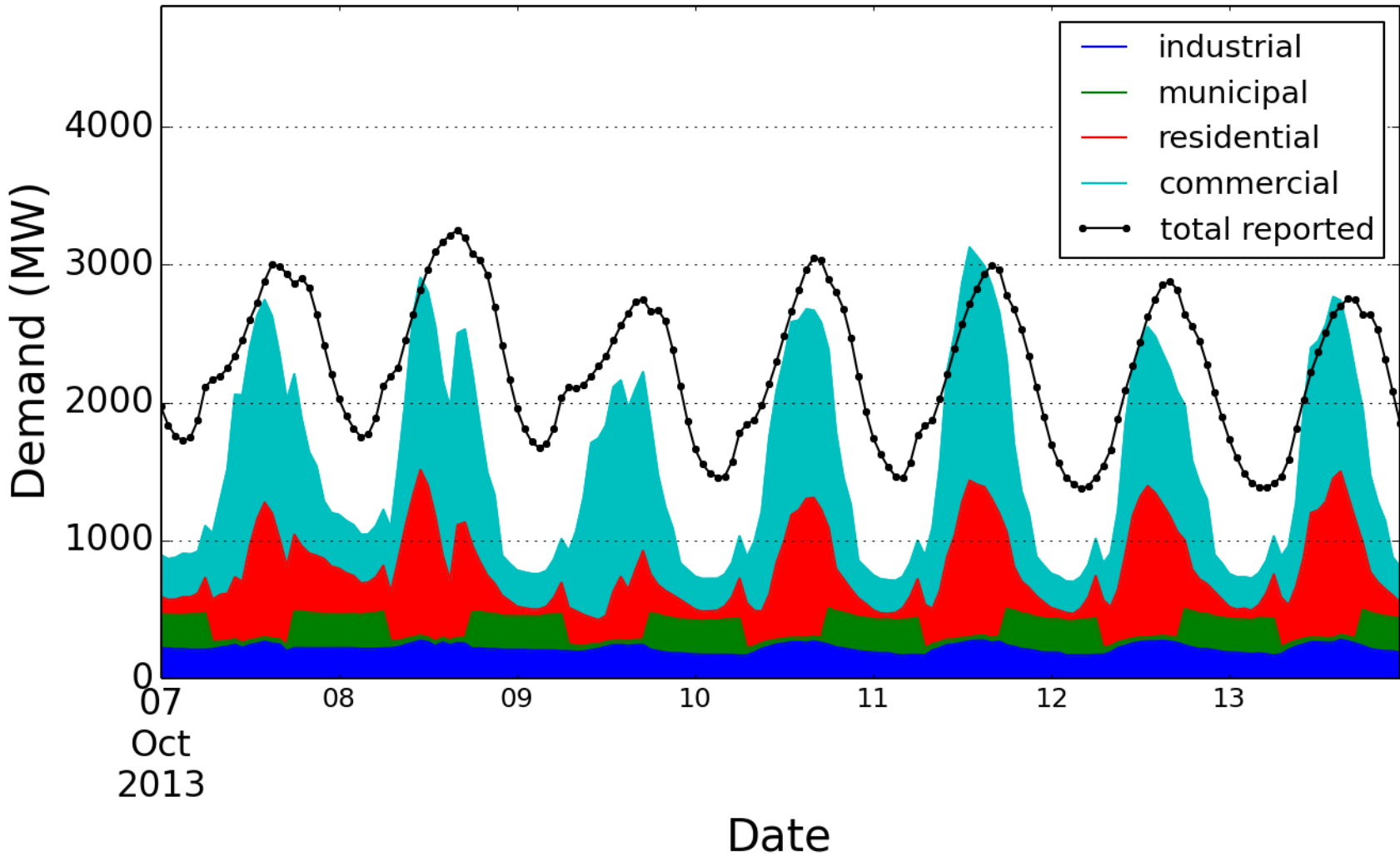
TEC: spring



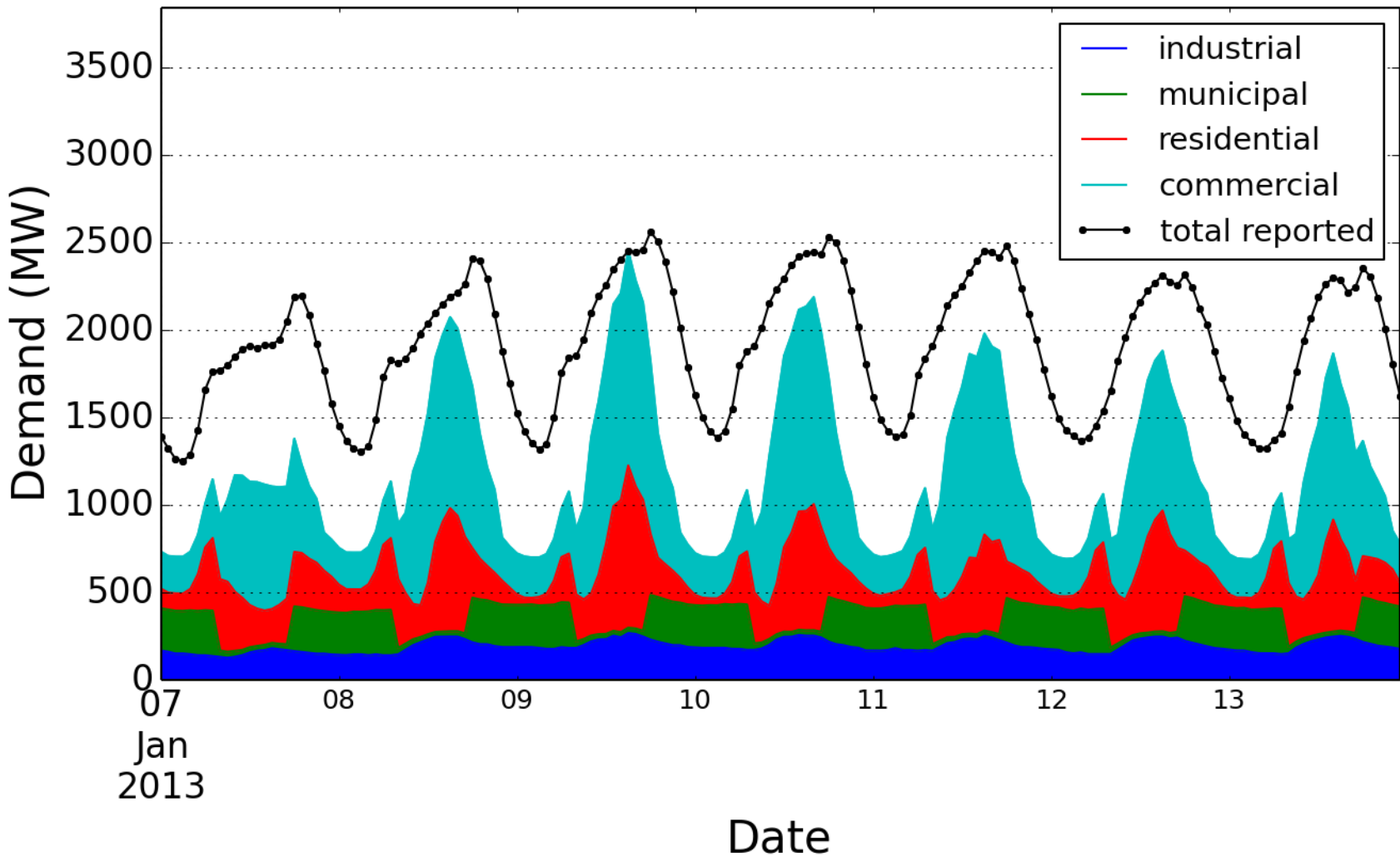
TEC: summer



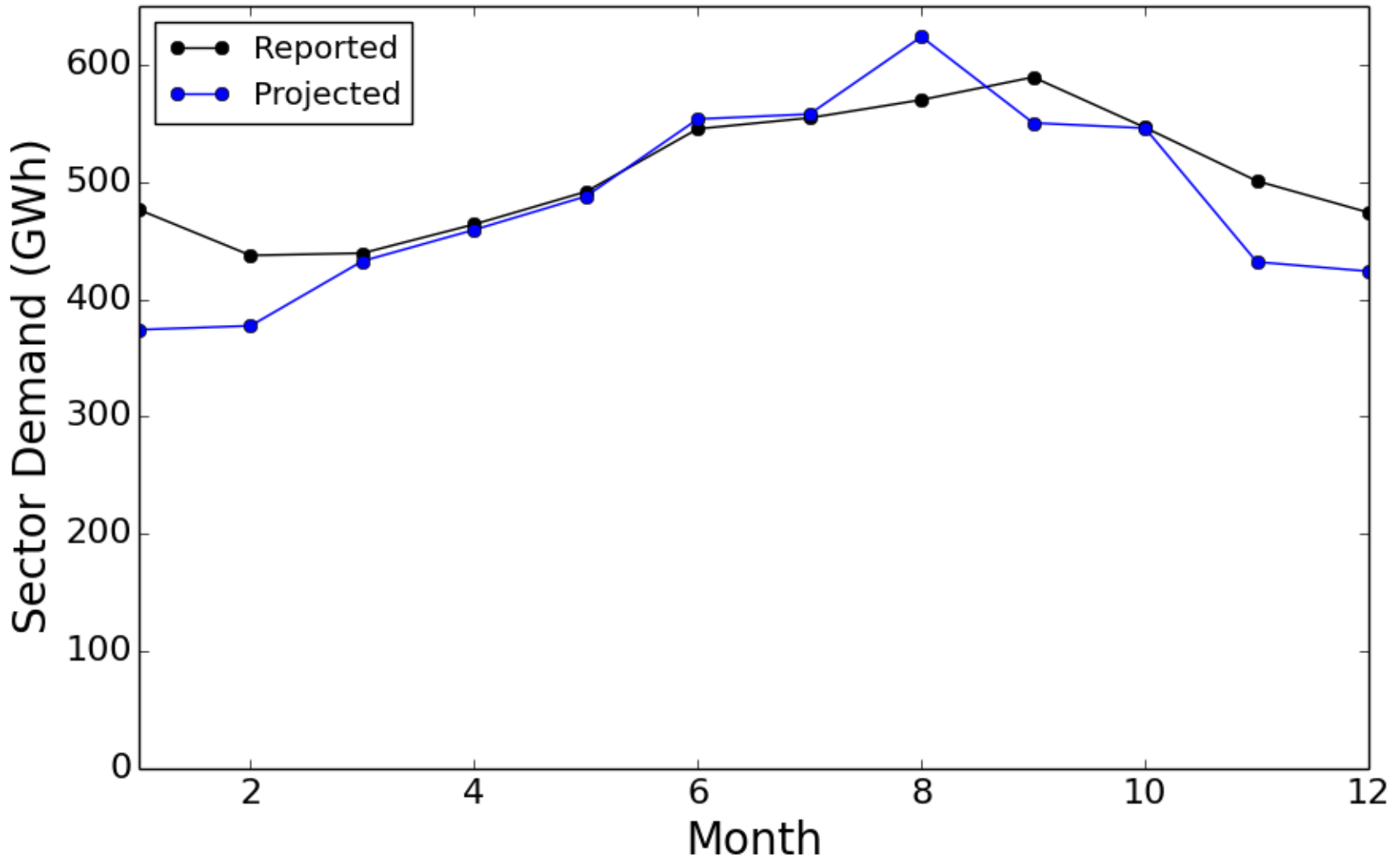
TEC: fall



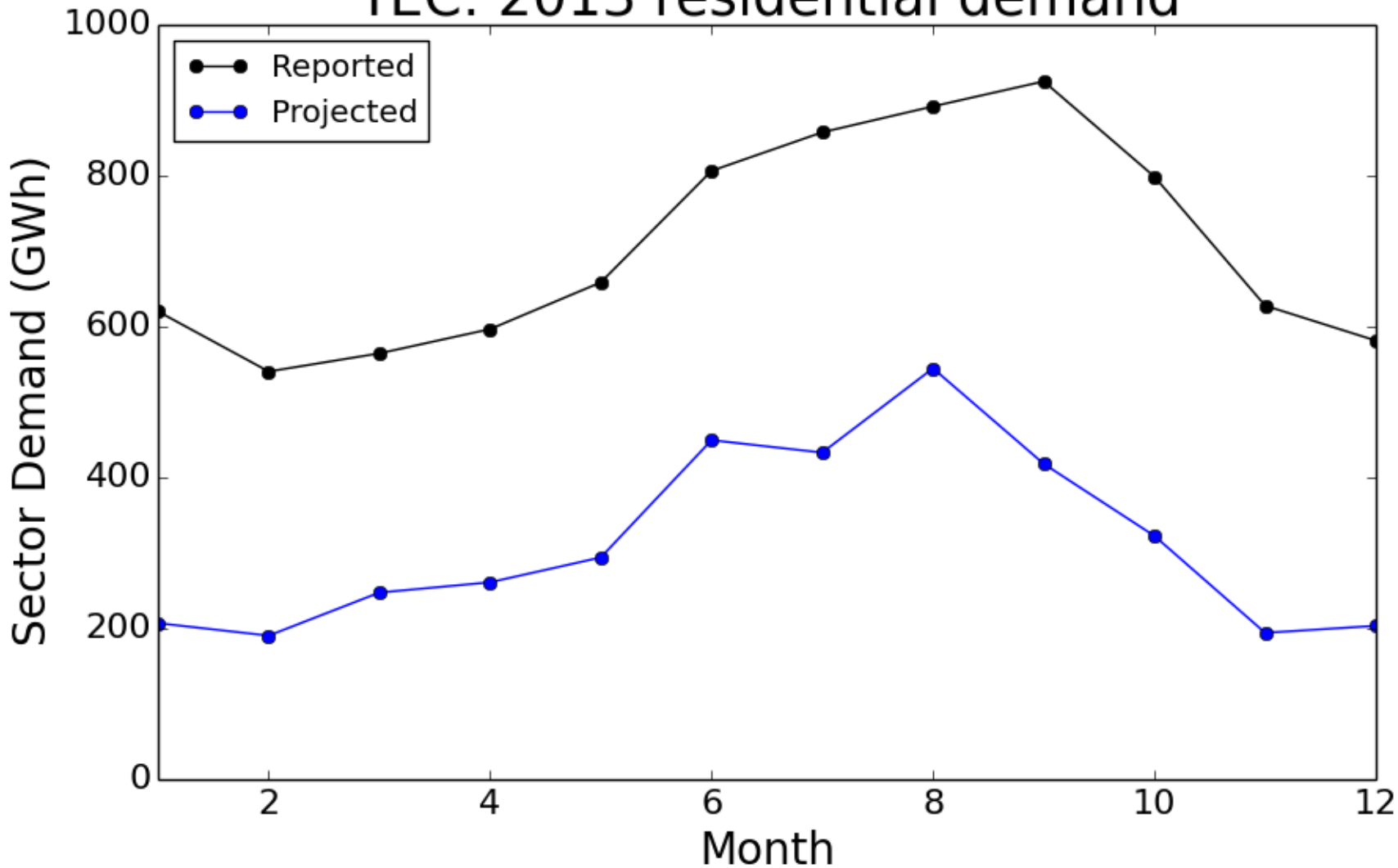
TEC: winter



TEC: 2013 commercial demand



TEC: 2013 residential demand





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Appendix 3: Demand Response Filter Generation Methods

Demand Response Filter Definitions

Sheddability: The technical potential for load reduction.

Controllability: The fraction of load enabled to provide DR.

Acceptability: The fraction of load likely to respond when called on provide DR.

PROCEDURE

Sheddability Filter

	Filter Calculation	Data Sources
1	For all non-manufacturing end-uses, use the same shed filters as the WECC study. Derived from Watson et. al	Olsen, et al 2013
2	For manufacturing end-uses, assume 100% shed for thermal processes, 50% shed for mechanical processes, and 0% shed for other processes.	-
3	Sheddability filter is flat throughout the year	-

PROCEDURE

Controllability Filter

Filter Calculation		Data Sources
1	For non manufacturing end-uses, controllability is derived from the percent participation in DR programs	EIA, 2012
2	Assume that in 2020, each utility/region will achieve participation rates on par with the average participation in DR programs in the same NERC region in 2013.	-
3	For residential & commercial end-uses, assume that enablement rates are proportional to the magnitude of each resource relative to other candidate resources.	-
4	Controllability filter is flat throughout the year	-

PROCEDURE

Controllability Filter

	Filter Calculation	Data Sources
1	For manufacturing end uses, calculate the average percent peak load reduction achievable through demand management measures by NAICS code from among recommendations in the IAC database	IAC 2015
2	Assume controllability is equal to percent peak load reduction computed in step 1	-
3	Controllability filter is flat throughout the year	-

PROCEDURE

Acceptability Filter

Energy and Capacity Calculation		Data Sources
1	<p>Max acceptability calculated using current DR response rates:</p> $\text{Accept} = \text{Peak Reduction}_{\text{Actual}} / \text{Peak Reduction}_{\text{Potential}}$ <p>Minimum acceptability is zero</p>	EIA, 2012
2	<p>Assume that in 2020, each region will achieve response rates on par with the average response rate in DR programs in the same NERC region in 2013.</p>	-
3	<p>Assume 100% acceptability at all time for DLC end-uses, including:</p> <hr/> <ul style="list-style-type: none"> • Residential cooling • Residential water heating • Agricultural water pumping • Municipal water pumping • Municipal waste water pumping • Outdoor lighting • Refrigerated warehouses • Data centers 	-

PROCEDURE

Acceptability Filter

Flexibility, Regulation & Contingency Calculation		Data Sources
1	Minimum acceptability is 0%, maximum is 2%	Olsen, et al., 2013
Assume 100% acceptability at all time for DLC end-uses, including:		
2	<ul style="list-style-type: none">Residential coolingResidential water heatingAgricultural water pumpingMunicipal water pumpingMunicipal waste water pumpingOutdoor lightingRefrigerated warehousesData centers	-

PROCEDURE

Acceptability Filter

Acceptability Filter Shape	Data Sources
<p>1 For commercial end-uses, acceptability is:</p> <ul style="list-style-type: none"> • time variable • inversely correlated with building occupancy <p>We use the commercial lighting load shape as a proxy for occupancy.</p>	<p>Olsen et al, 2013</p>
<p>2 For non-DLC residential end-uses (e.g., electric heating), acceptability is:</p> <ul style="list-style-type: none"> • time variable • inversely correlated with lighting load (occupants' willingness to respond is a function of both building occupancy and outdoor air temperature) 	<p>-</p>
<p>3 For residential DLC end-uses (cooling and water heating), and industrial manufacturing and non-manufacturing end-uses, acceptability is assumed to be flat</p>	<p>-</p>



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Appendix 4: Demand Response Filter Values

DR Filter Values

Commercial Cooling				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	40% - 45%	0% - 37%	0% - 2%	0% - 1%
Flexibility	40% - 45%	0% - 37%	0% - 2%	0% - 1%
Energy	47% - 55%	0% - 37%	0% - 97%	0% - 20%
Capacity	47% - 55%	0% - 37%	0% - 97%	0% - 20%
Regulation	40% - 45%	0% - 37%	0% - 2%	0% - 1%

DR Filter Values

Commercial Heating				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	0%	0% - 14%	0% - 2%	0%
Flexibility	0%	0% - 14%	0% - 2%	0%
Energy	51% - 59%	0% - 14%	0% - 97%	0% - 8%
Capacity	51% - 59%	0% - 14%	0% - 97%	0% - 8%
Regulation	0%	0% - 14%	0% - 2%	0%

DR Filter Values

Commercial Lighting				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	21% - 27%	0% - 99%	0% - 2%	0% - 1%
Flexibility	21% - 27%	0% - 99%	0% - 2%	0% - 1%
Energy	0%	0% - 99%	0% - 97%	0%
Capacity	21% - 27%	0% - 99%	0% - 97%	0% - 25%
Regulation	21% - 27%	0% - 99%	0% - 2%	0% - 1%

DR Filter Values

Commercial Ventilation				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	40% - 45%	0% - 34%	0% - 2%	0% - 1%
Flexibility	40% - 45%	0% - 34%	0% - 2%	0% - 1%
Energy	0%	0% - 34%	0% - 97%	0%
Capacity	47% - 55%	0% - 34%	0% - 97%	0% - 18%
Regulation	40% - 45%	0% - 34%	0% - 2%	0% - 1%

DR Filter Values

Residential Cooling				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	70%	2% - 91%	50% - 99%	1% - 63%
Flexibility	70%	2% - 91%	50% - 99%	1% - 63%
Energy	70%	2% - 91%	50% - 99%	1% - 63%
Capacity	70%	2% - 91%	50% - 99%	1% - 63%
Regulation	70%	2% - 91%	50% - 99%	1% - 63%

DR Filter Values

Residential Heating				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	20%	1% - 87%	0% - 2%	0% - 0.4%
Flexibility	20%	1% - 87%	0% - 2%	0% - 0.4%
Energy	0%	1% - 87%	0% - 99%	0%
Capacity	0%	1% - 87%	0% - 99%	0%
Regulation	20%	1% - 87%	0% - 2%	0% - 0.4%

DR Filter Values

Residential Hot Water				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	25% - 25%	1% - 68%	50% - 99%	0% - 16%
Flexibility	25% - 25%	1% - 68%	50% - 99%	0% - 16%
Energy	25% - 25%	1% - 68%	50% - 99%	0% - 16%
Capacity	25% - 25%	1% - 68%	50% - 99%	0% - 16%
Regulation	25% - 25%	1% - 68%	50% - 99%	0% - 16%

DR Filter Values

Agricultural Water Pumping				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	100%	1% - 98%	100%	1% - 98%
Flexibility	0%	1% - 98%	100%	0%
Energy	100%	1% - 98%	100%	1% - 98%
Capacity	100%	1% - 98%	100%	1% - 98%
Regulation	0%	1% - 98%	100%	0%

DR Filter Values

Data Centers				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	3%	1% - 98%	100%	0% - 3%
Flexibility	3%	1% - 98%	100%	0% - 3%
Energy	3%	1% - 98%	100%	0% - 3%
Capacity	3%	1% - 98%	100%	0% - 3%
Regulation	3%	1% - 98%	100%	0% - 3%

DR Filter Values

Refrigerated Warehouses				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	10%	1% - 98%	100%	0% - 10%
Flexibility	0%	1% - 98%	100%	0%
Energy	5%	1% - 98%	100%	0% - 5%
Capacity	5%	1% - 98%	100%	0% - 5%
Regulation	0%	1% - 98%	100%	0%

DR Filter Values

Manufacturing				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	0% - 100%	1% - 98%	100%	0% - 31%
Flexibility	0% - 100%	1% - 98%	100%	0% - 31%
Energy	0% - 50%	1% - 98%	100%	0% - 15%
Capacity	0% - 50%	1% - 98%	100%	0% - 15%
Regulation	0% - 100%	1% - 98%	100%	0% - 31%

DR Filter Values

Outdoor Lighting				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	5%	1% - 98%	100%	0% - 5%
Flexibility	5%	1% - 98%	100%	0% - 5%
Energy	0%	1% - 98%	100%	0%
Capacity	5%	1% - 98%	100%	0% - 5%
Regulation	5%	1% - 98%	100%	0% - 5%

DR Filter Values

Municipal Water Pumping				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	5%	1% - 98%	100%	0% - 5%
Flexibility	5%	1% - 98%	100%	0% - 5%
Energy	5%	1% - 98%	100%	0% - 5%
Capacity	5%	1% - 98%	100%	0% - 5%
Regulation	0%	1% - 98%	100%	0%

DR Filter Values

Municipal Waste Water Pumping				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	5%	1% - 98%	100%	0% - 5%
Flexibility	5%	1% - 98%	100%	0% - 5%
Energy	5%	1% - 98%	100%	0% - 5%
Capacity	5%	1% - 98%	100%	0% - 5%
Regulation	0% - 0%	1% - 98%	100%	0%



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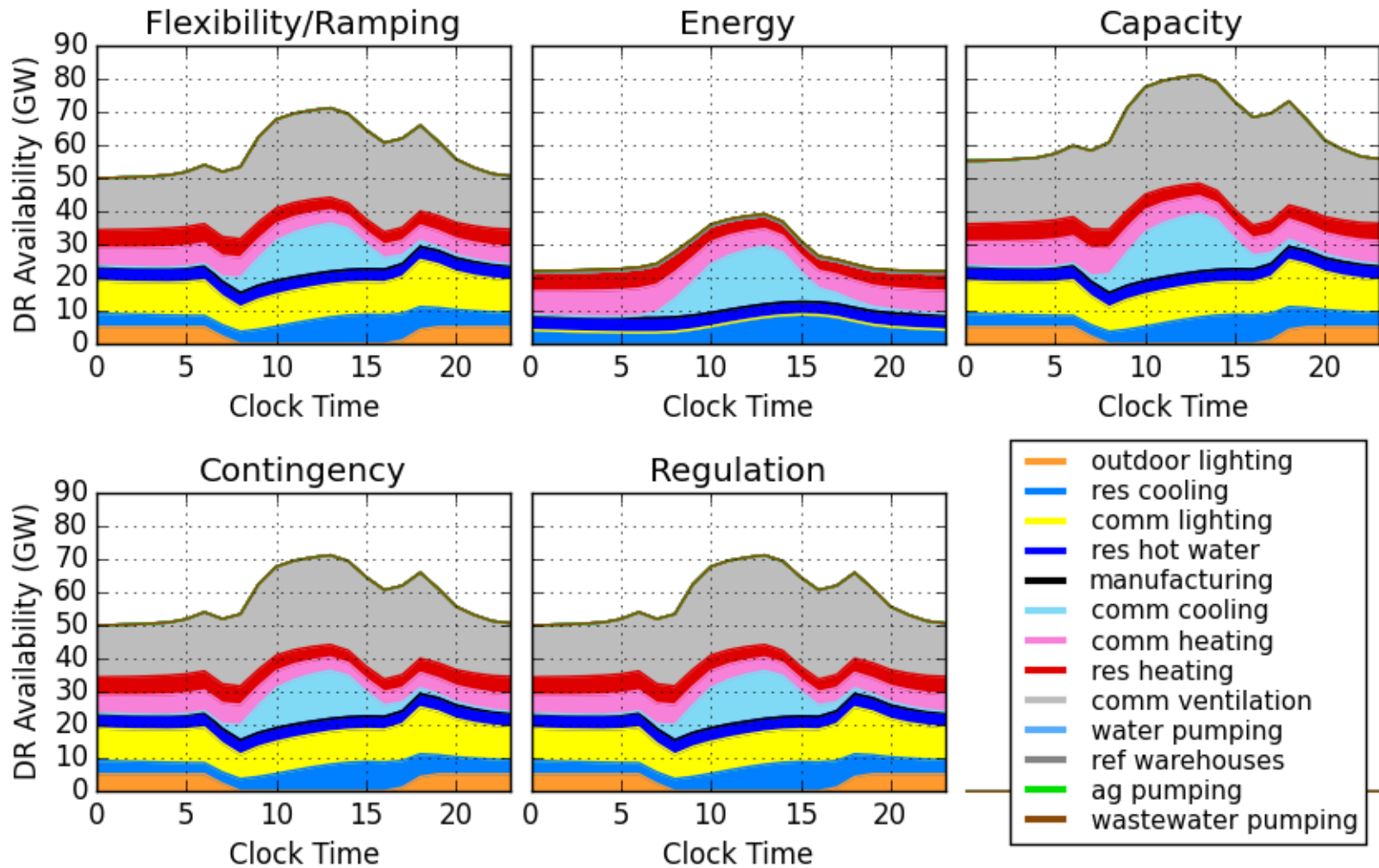


U.S. DEPARTMENT OF
ENERGY

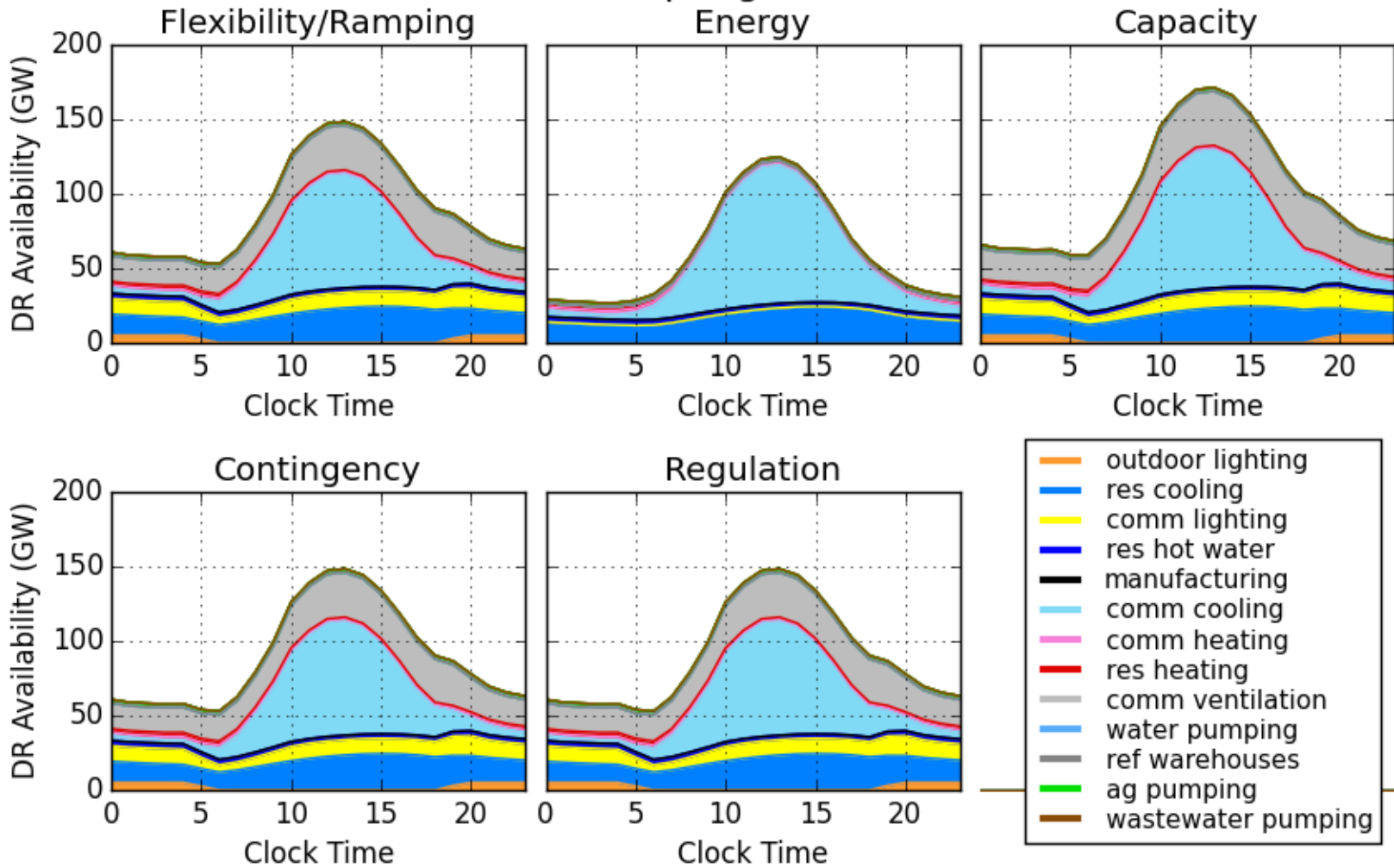
Appendix 5: Visualization of Demand Response Availability Results

VISUALIZATION OF RESULTS: Average Hourly Demand Response Availability by Season and End Use

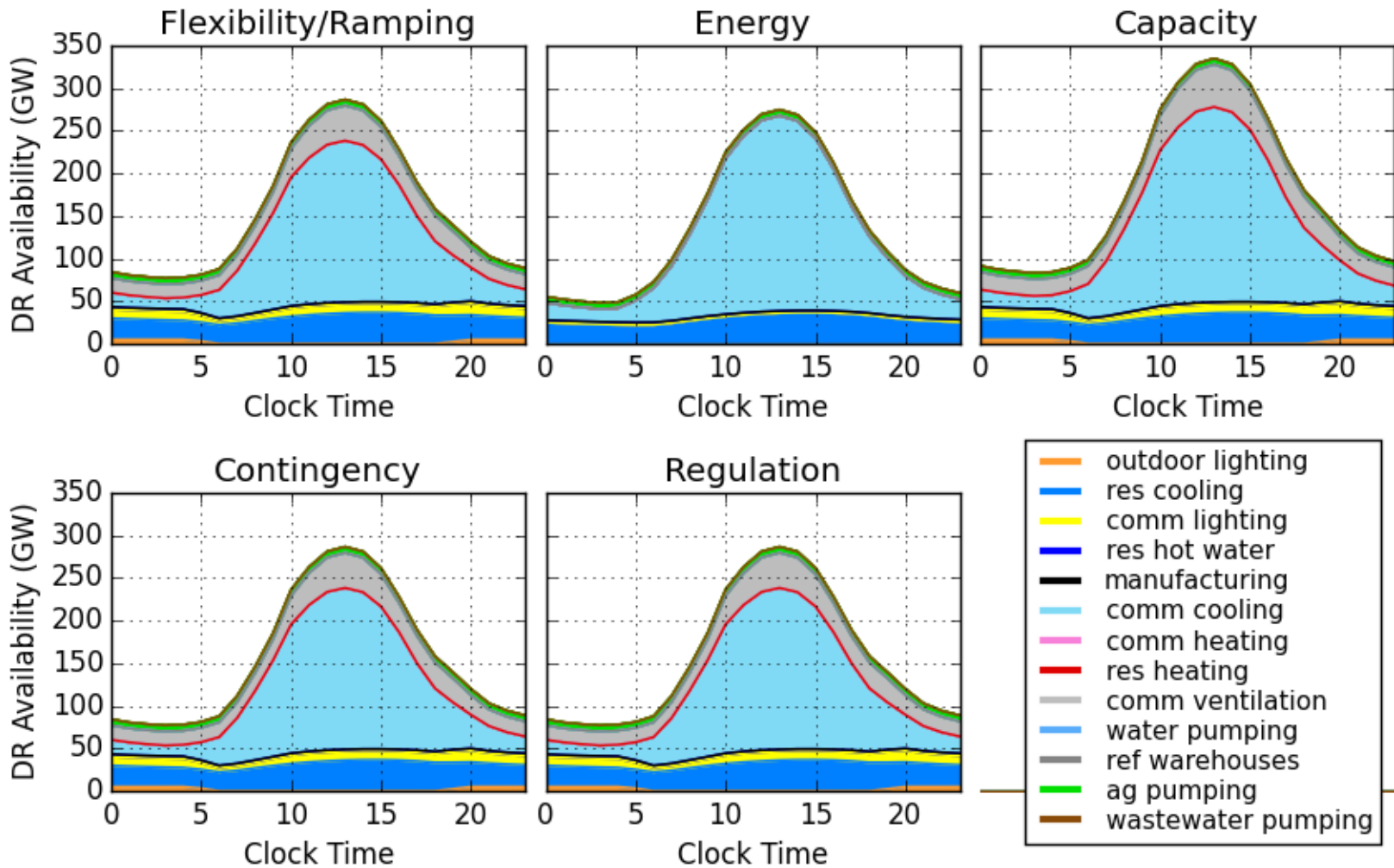
Average Availability by Hour and End Use Winter 2020



Average Availability by Hour and End Use Spring 2020

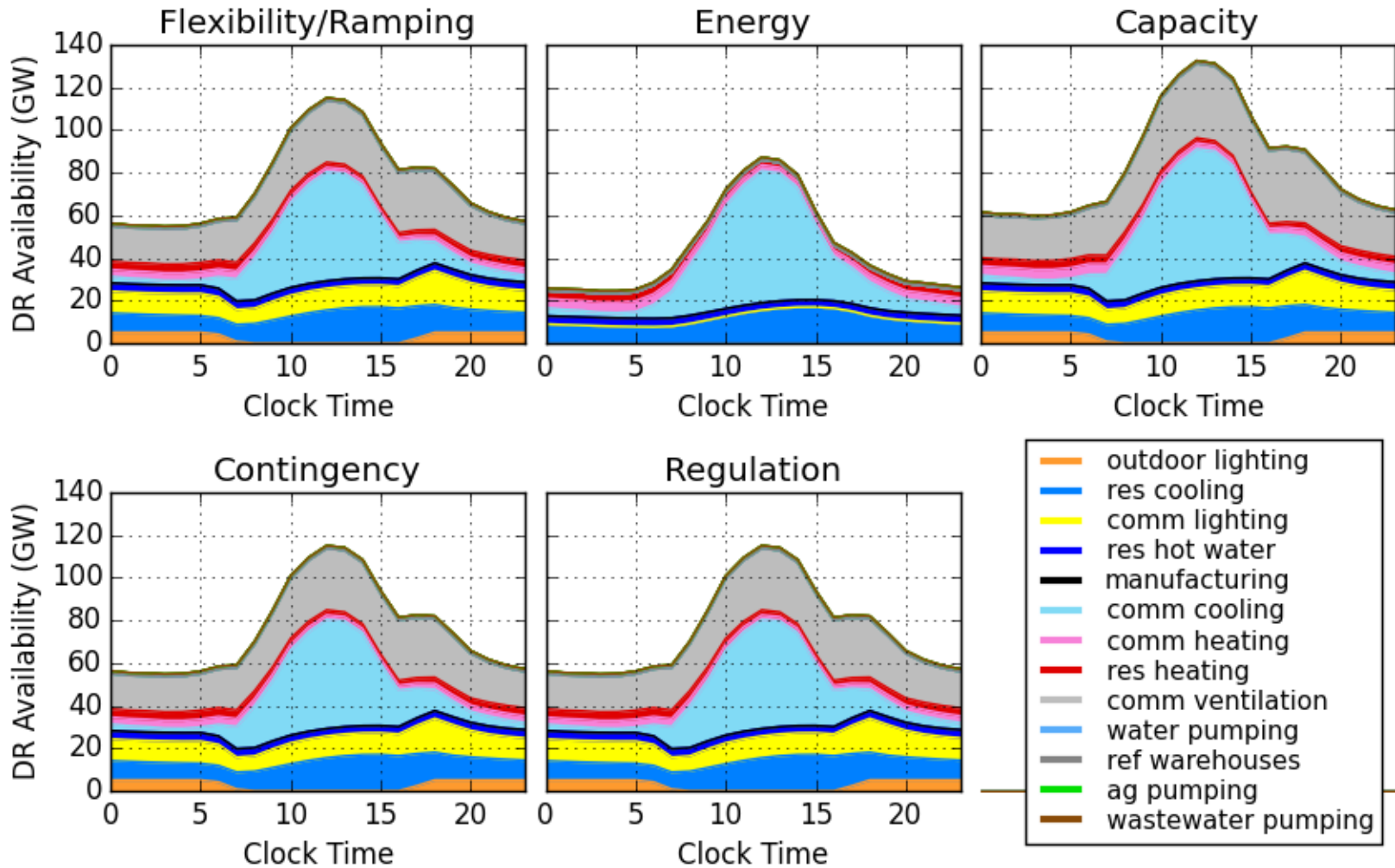


Average Availability by Hour and End Use Summer 2020



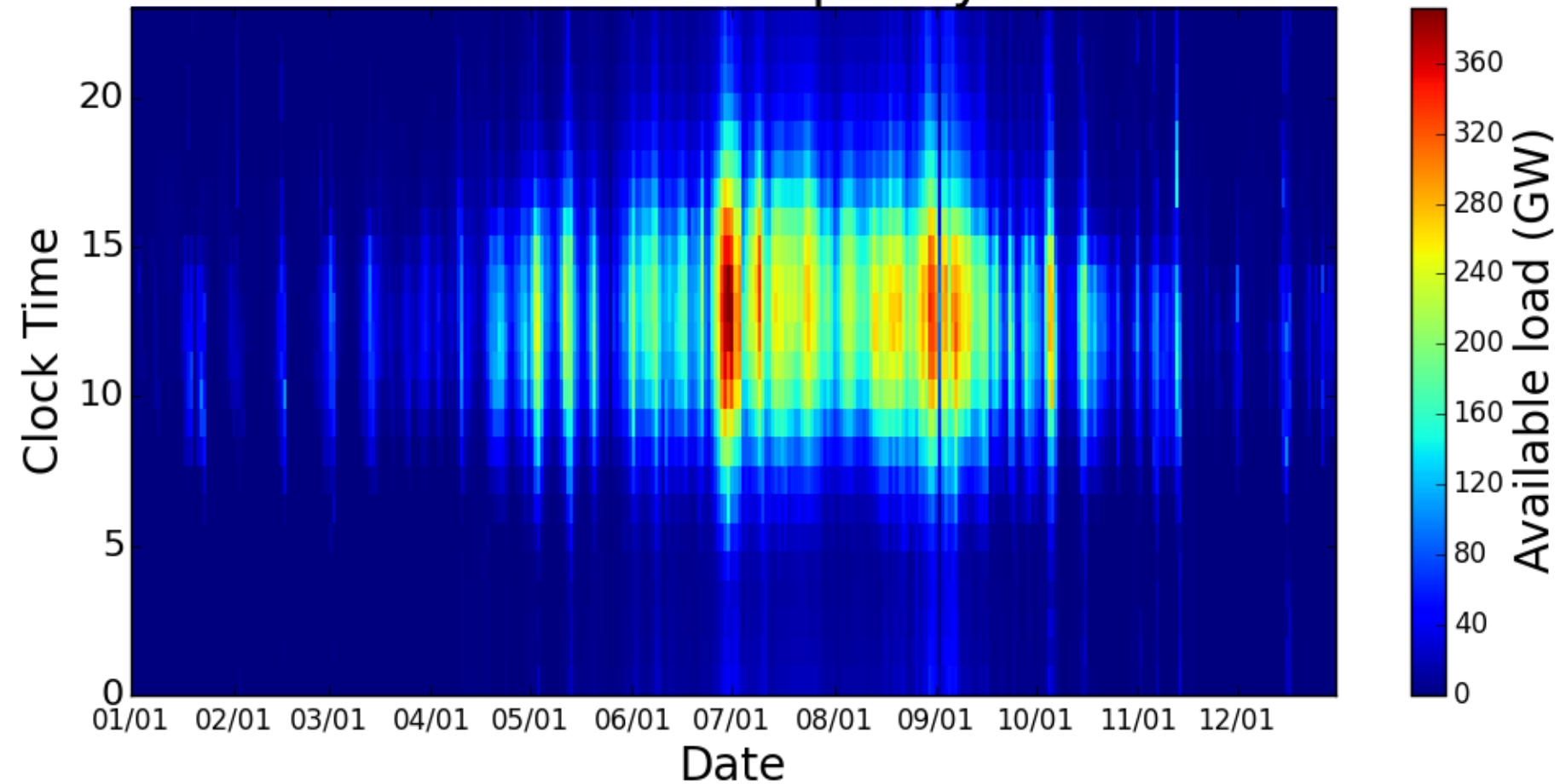
Average Availability by Hour and End Use

Fall 2020

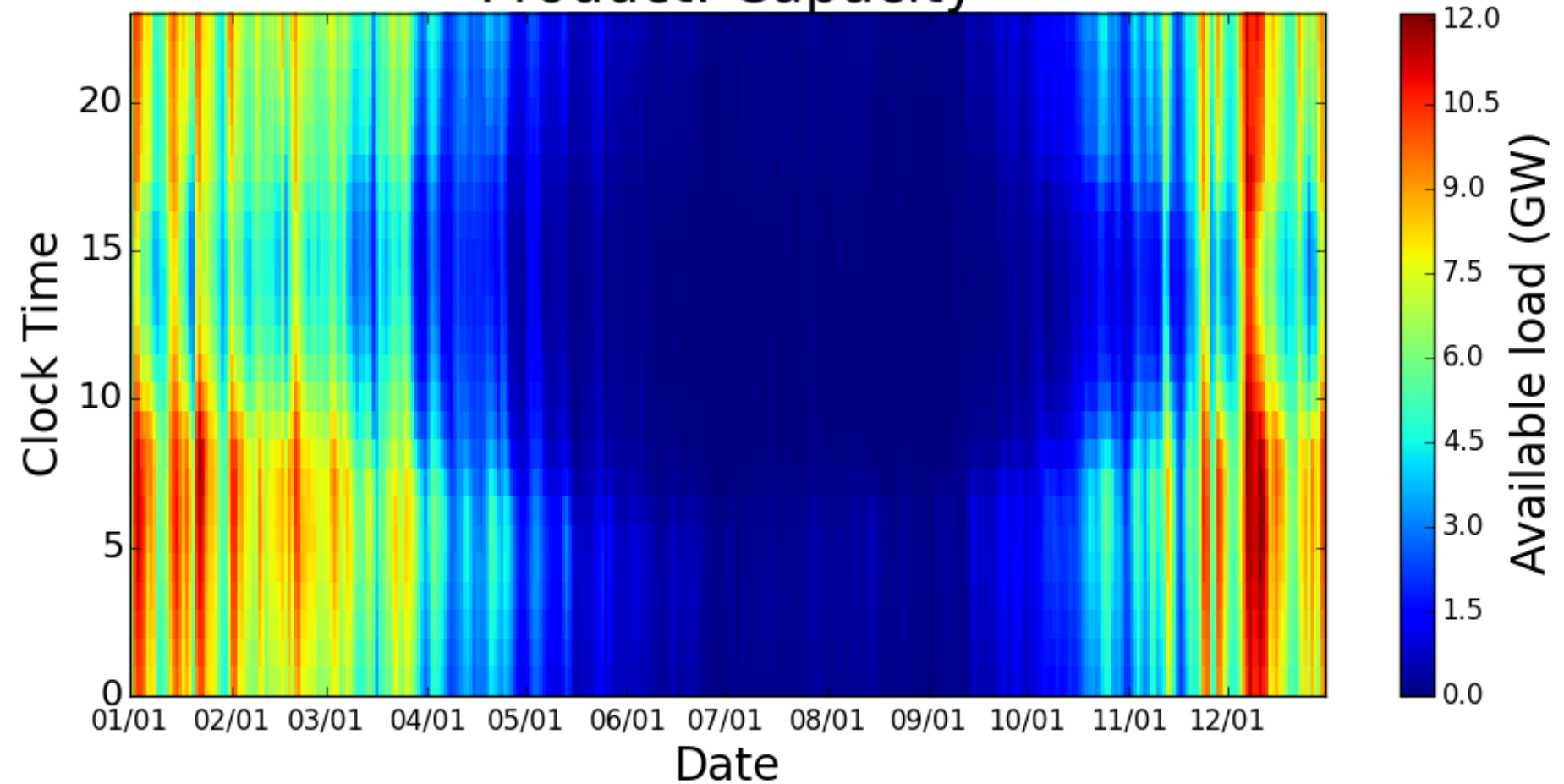


VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Capacity

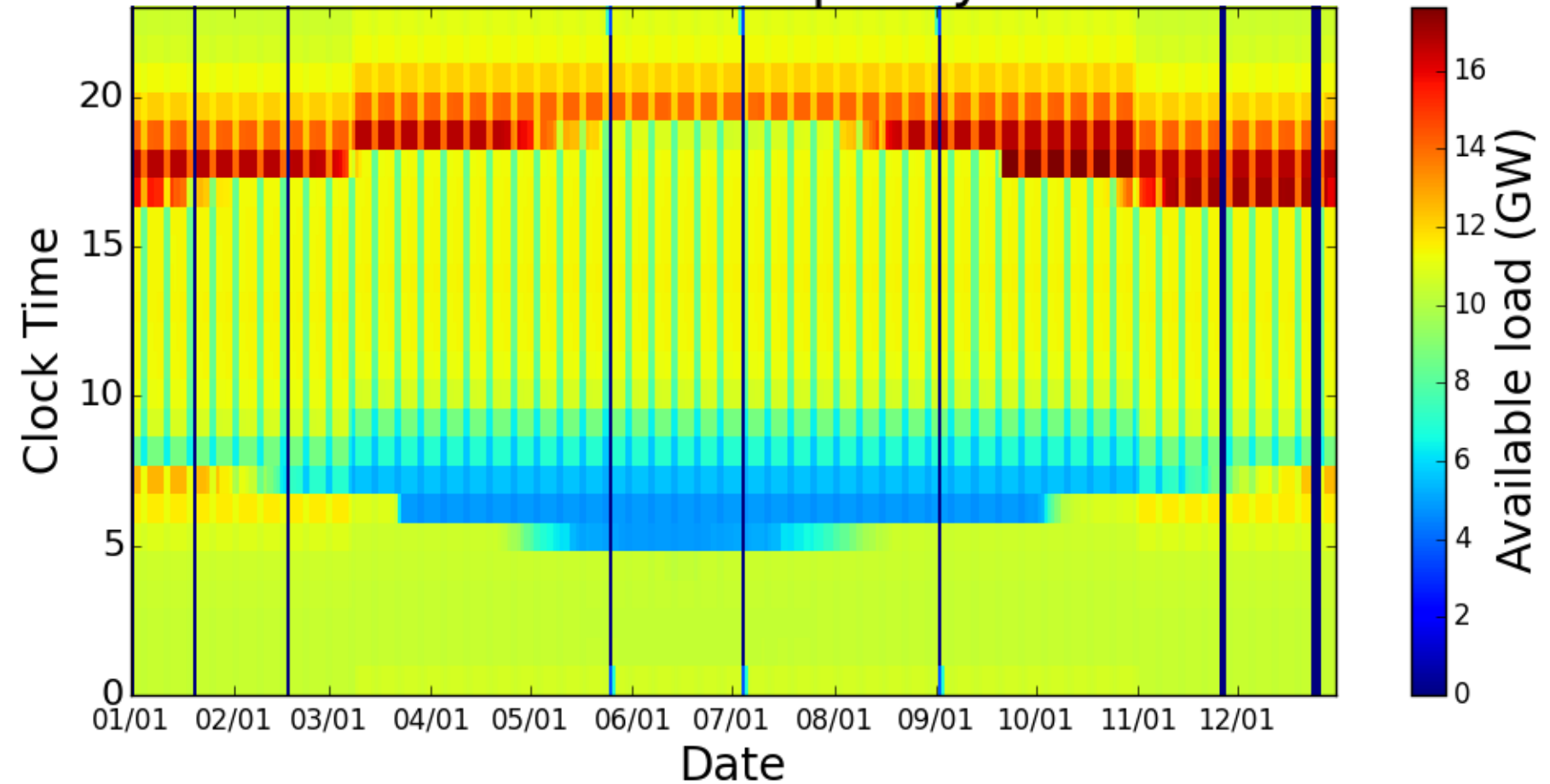
Region: Entire United States
End Use: commercial cooling
Product: Capacity



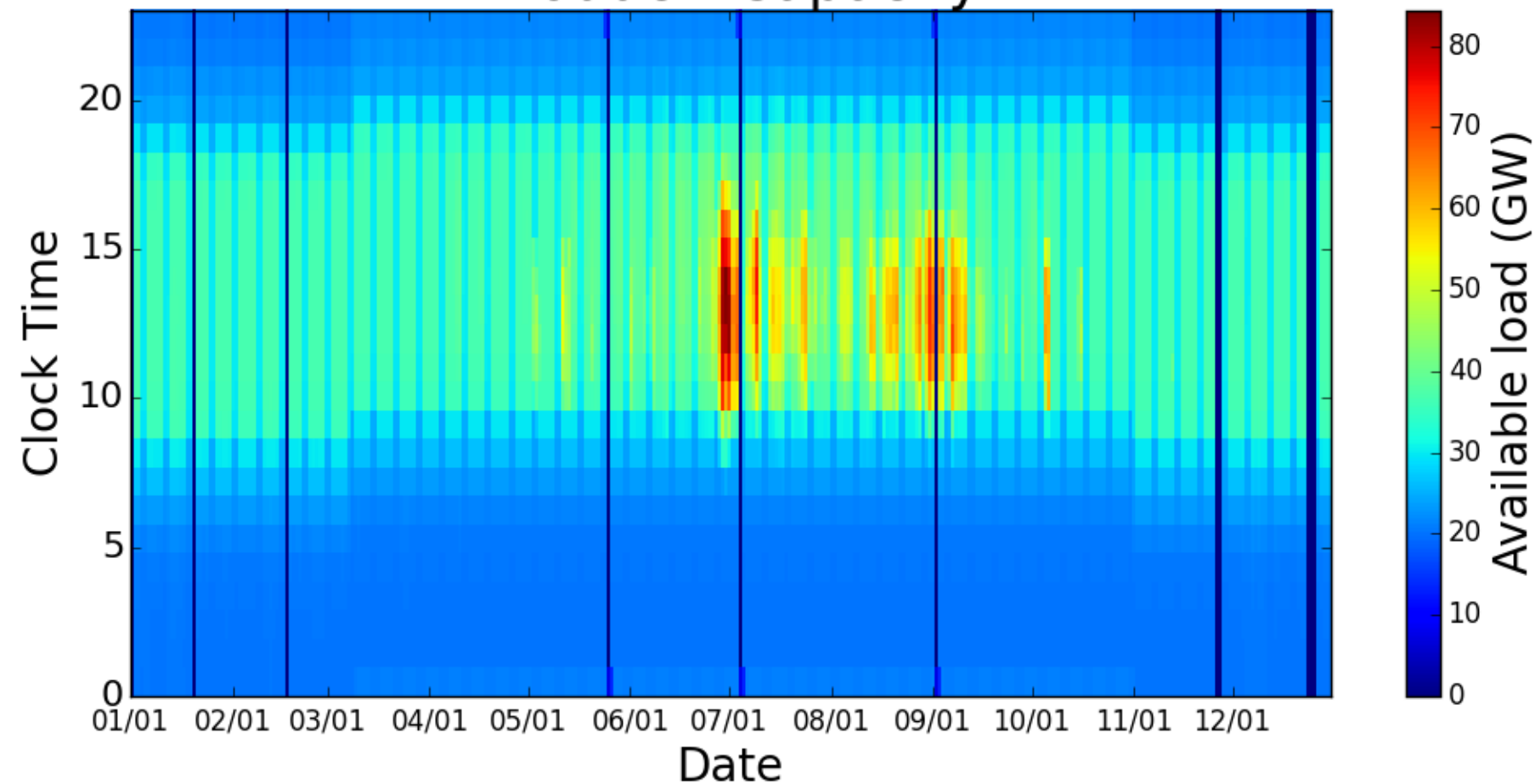
Region: Entire United States
End Use: commercial heating
Product: Capacity



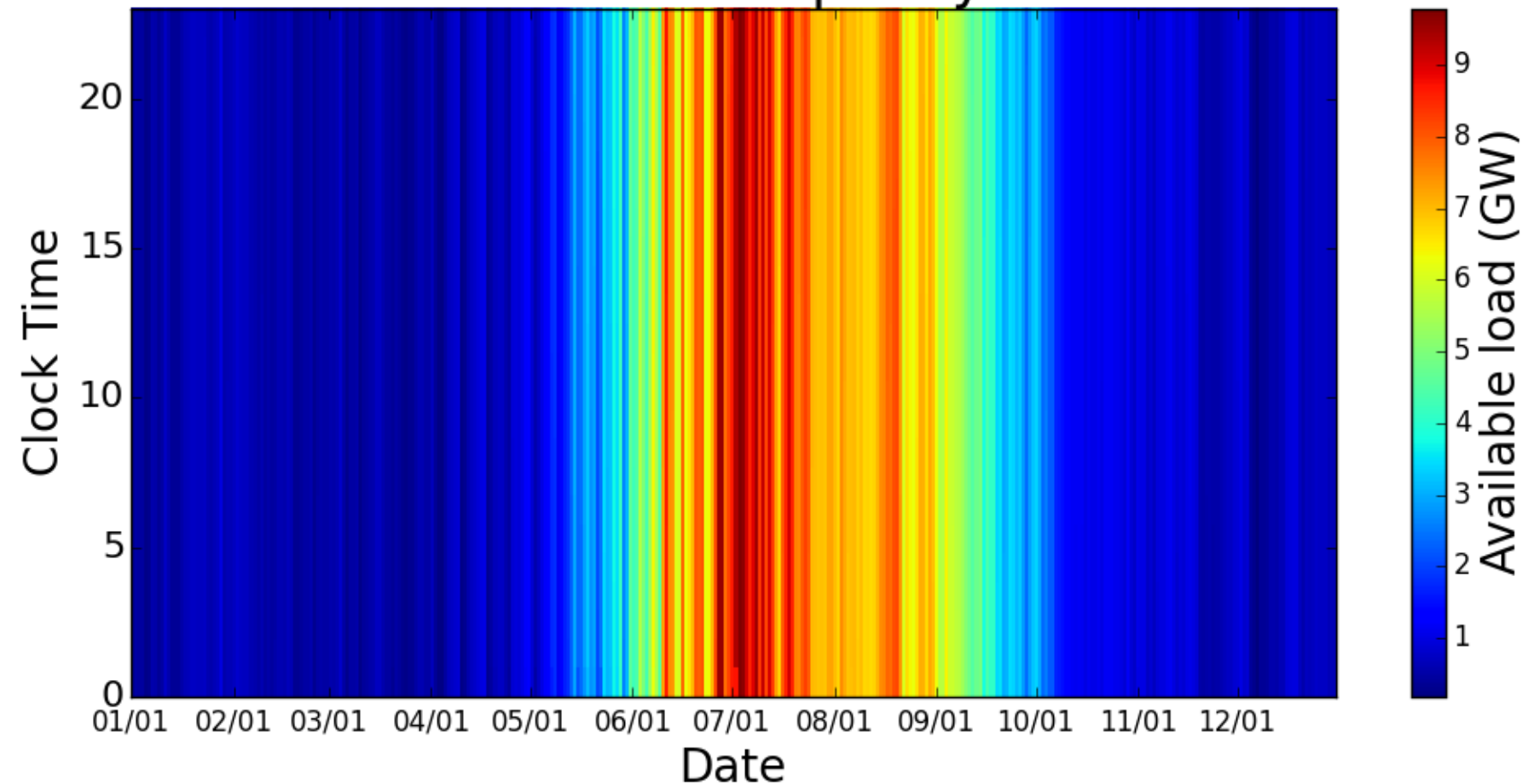
Region: Entire United States
End Use: commercial lighting
Product: Capacity



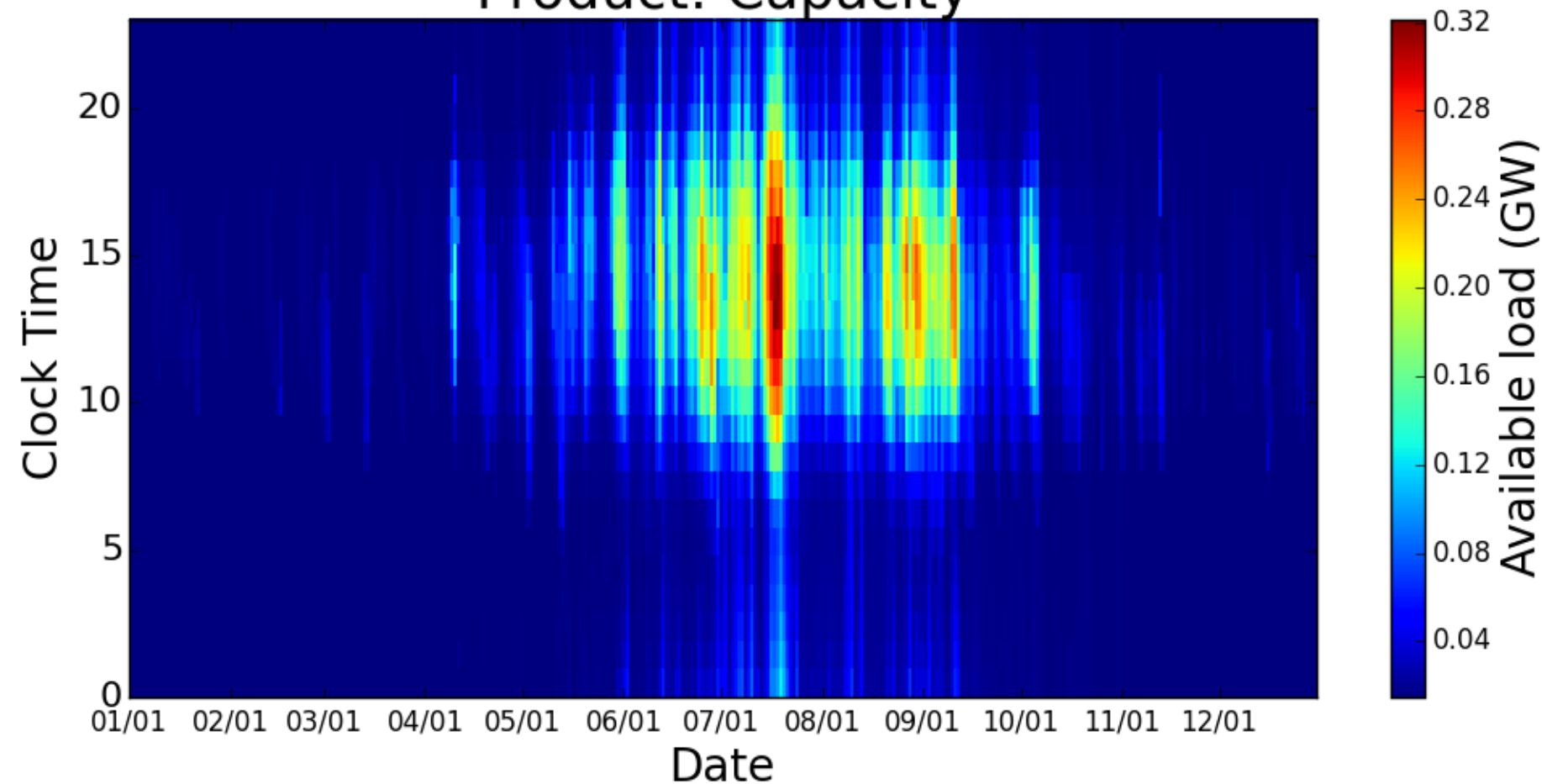
Region: Entire United States
End Use: commercial ventilation
Product: Capacity



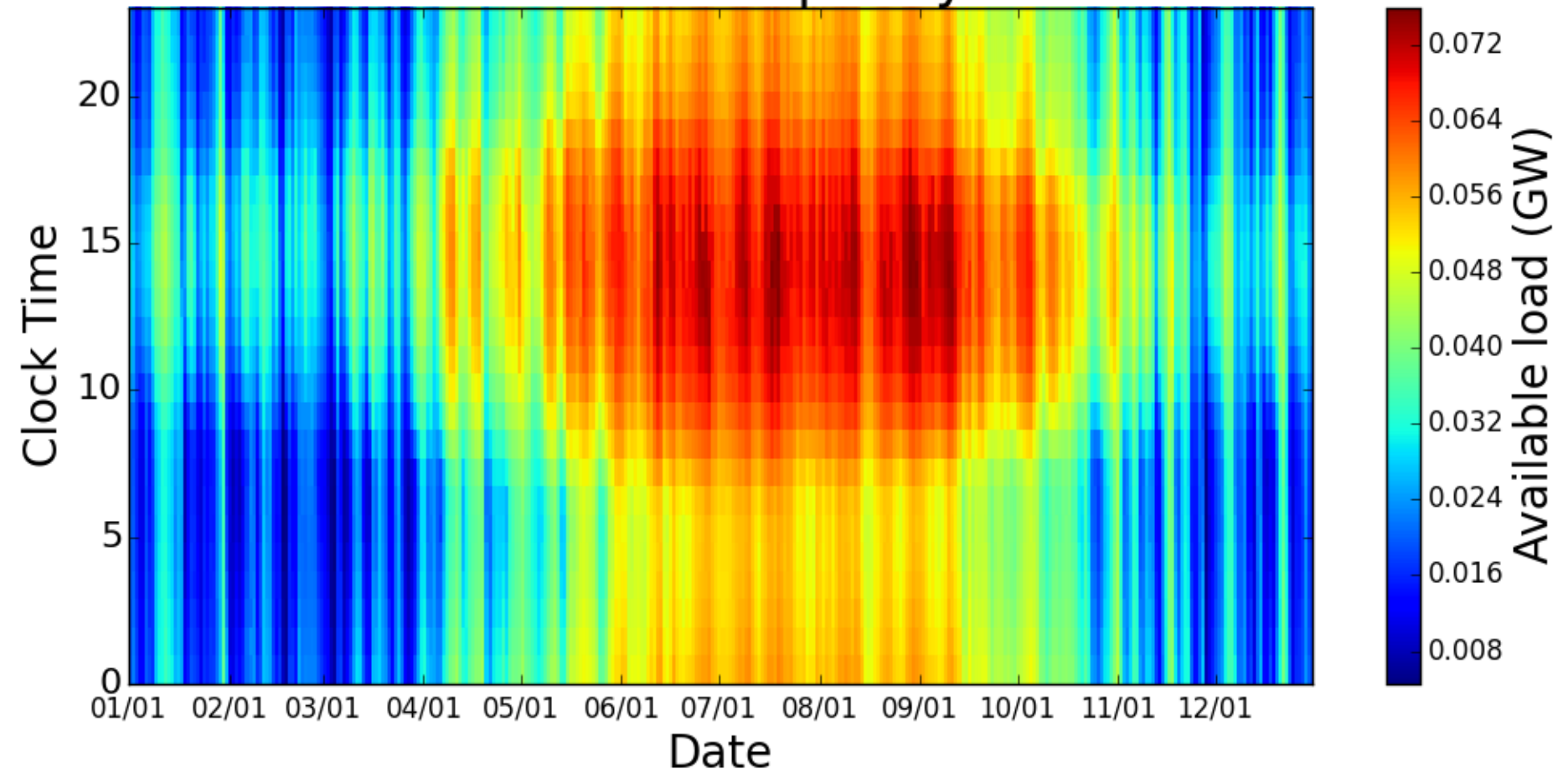
Region: Entire United States
End Use: agricultural pumping
Product: Capacity



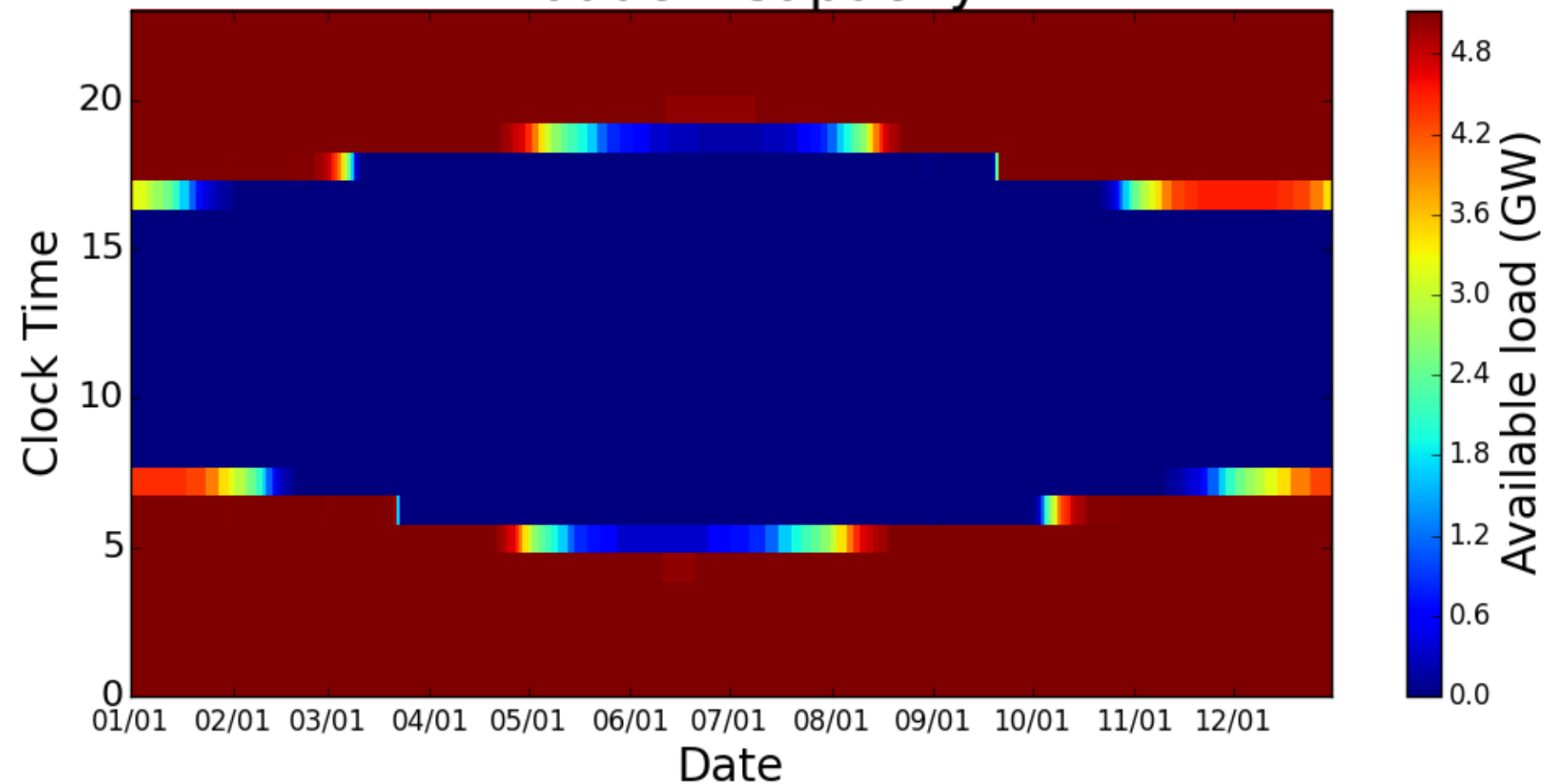
Region: Entire United States
End Use: data centers
Product: Capacity



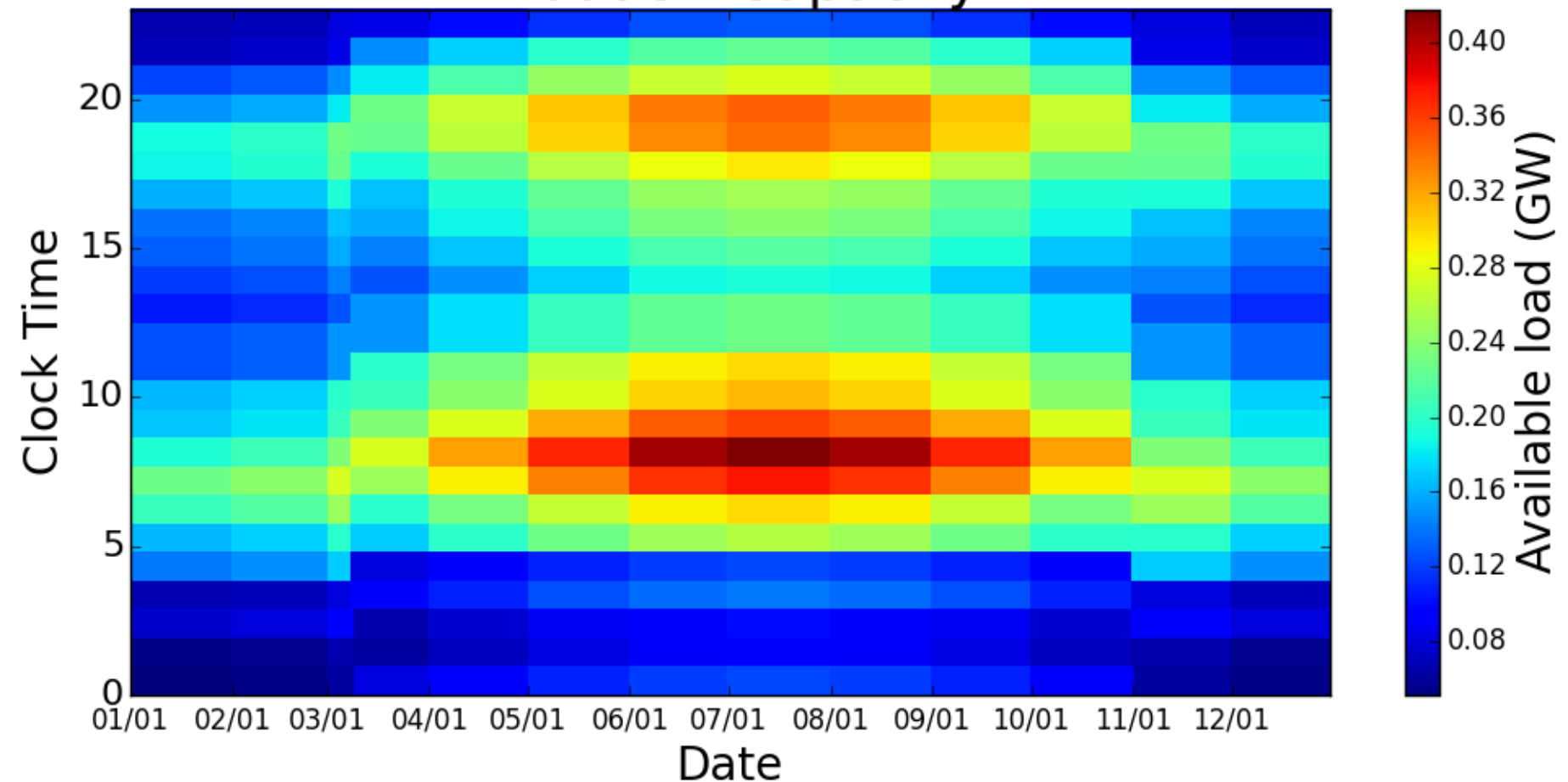
Region: Entire United States
End Use: refrigerated warehouses
Product: Capacity



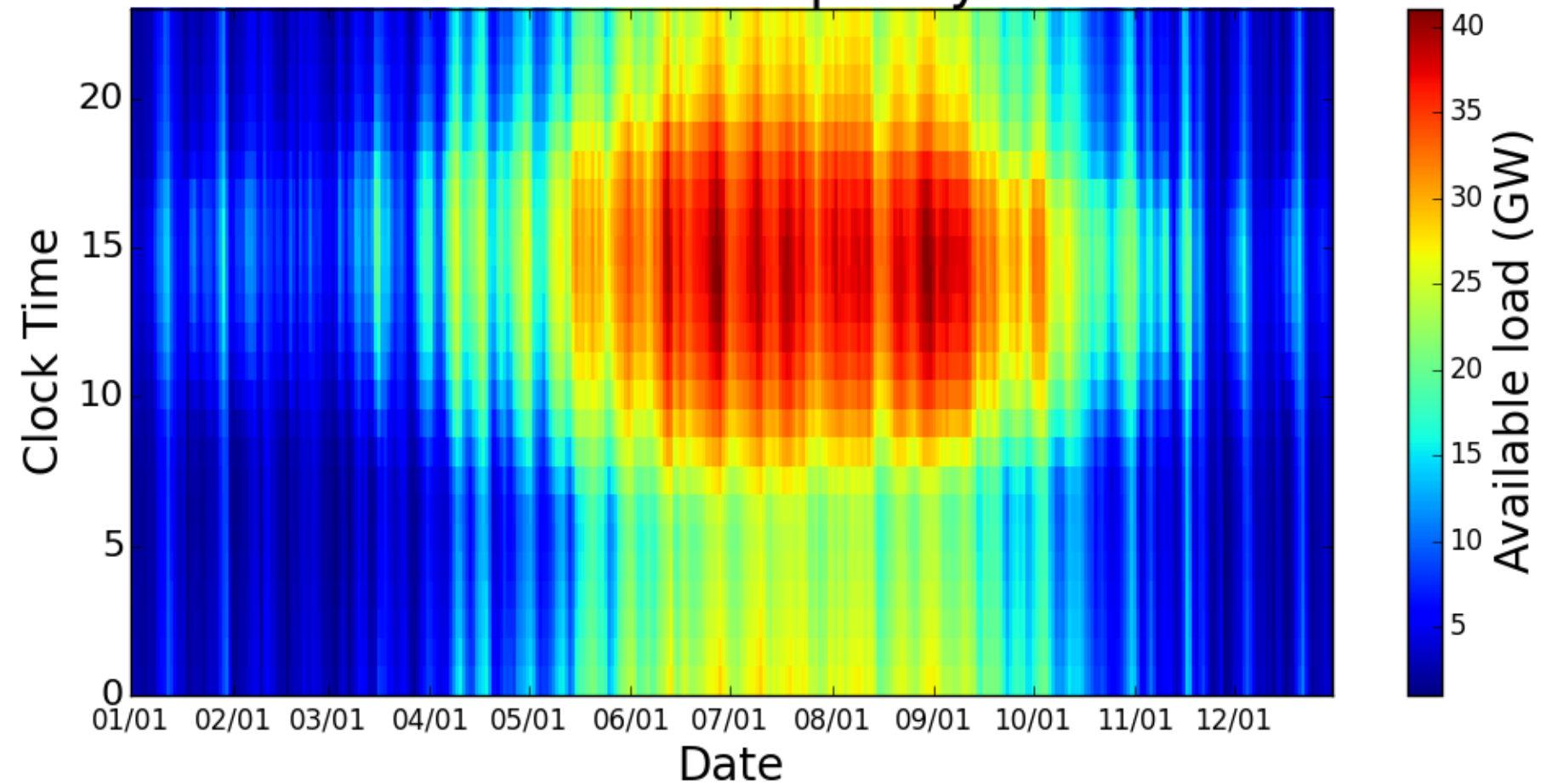
Region: Entire United States
End Use: municipal outdoor lighting
Product: Capacity



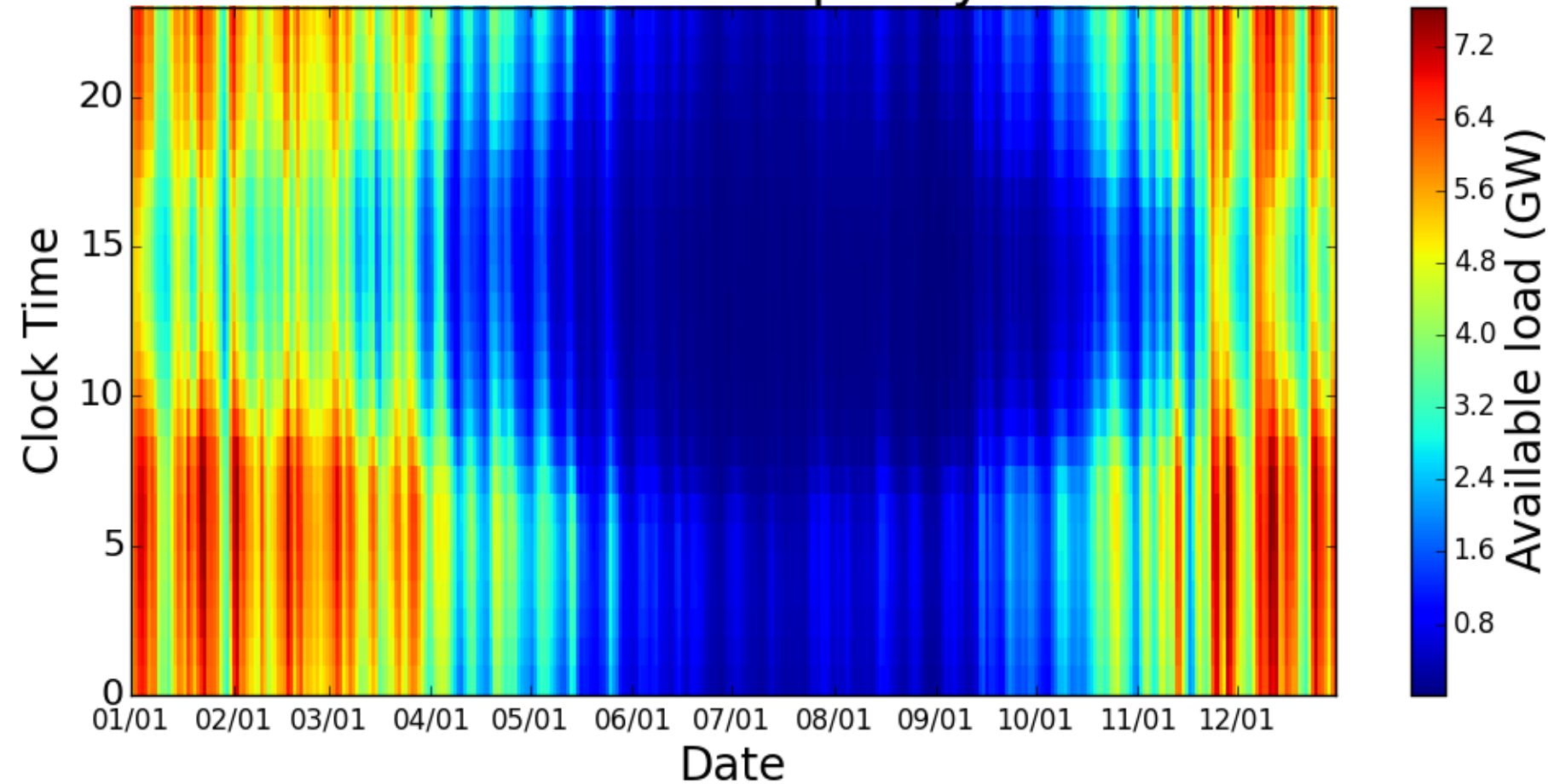
Region: Entire United States
End Use: municipal water pumping
Product: Capacity



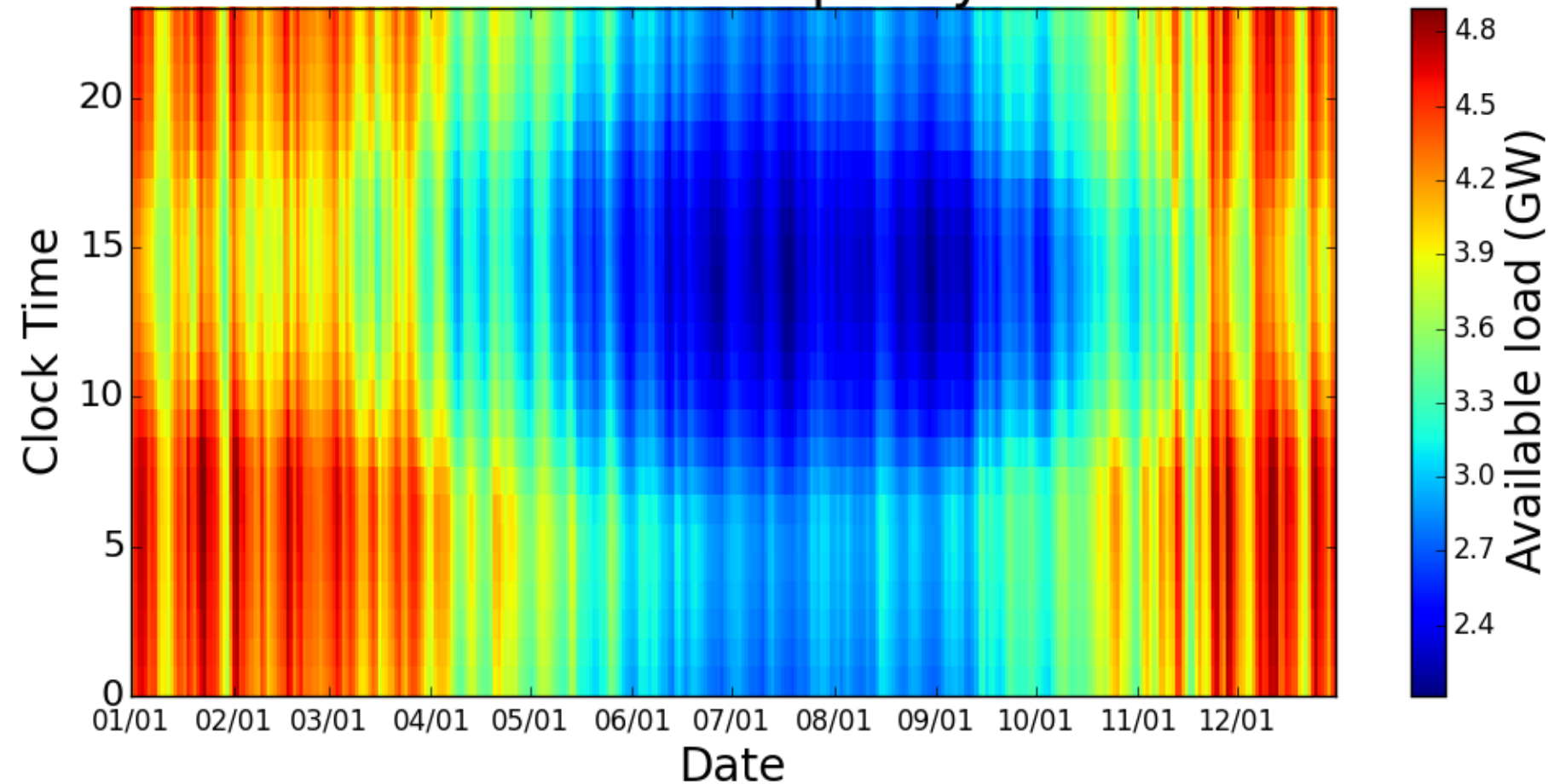
Region: Entire United States
End Use: residential cooling
Product: Capacity



Region: Entire United States
End Use: residential heating
Product: Capacity

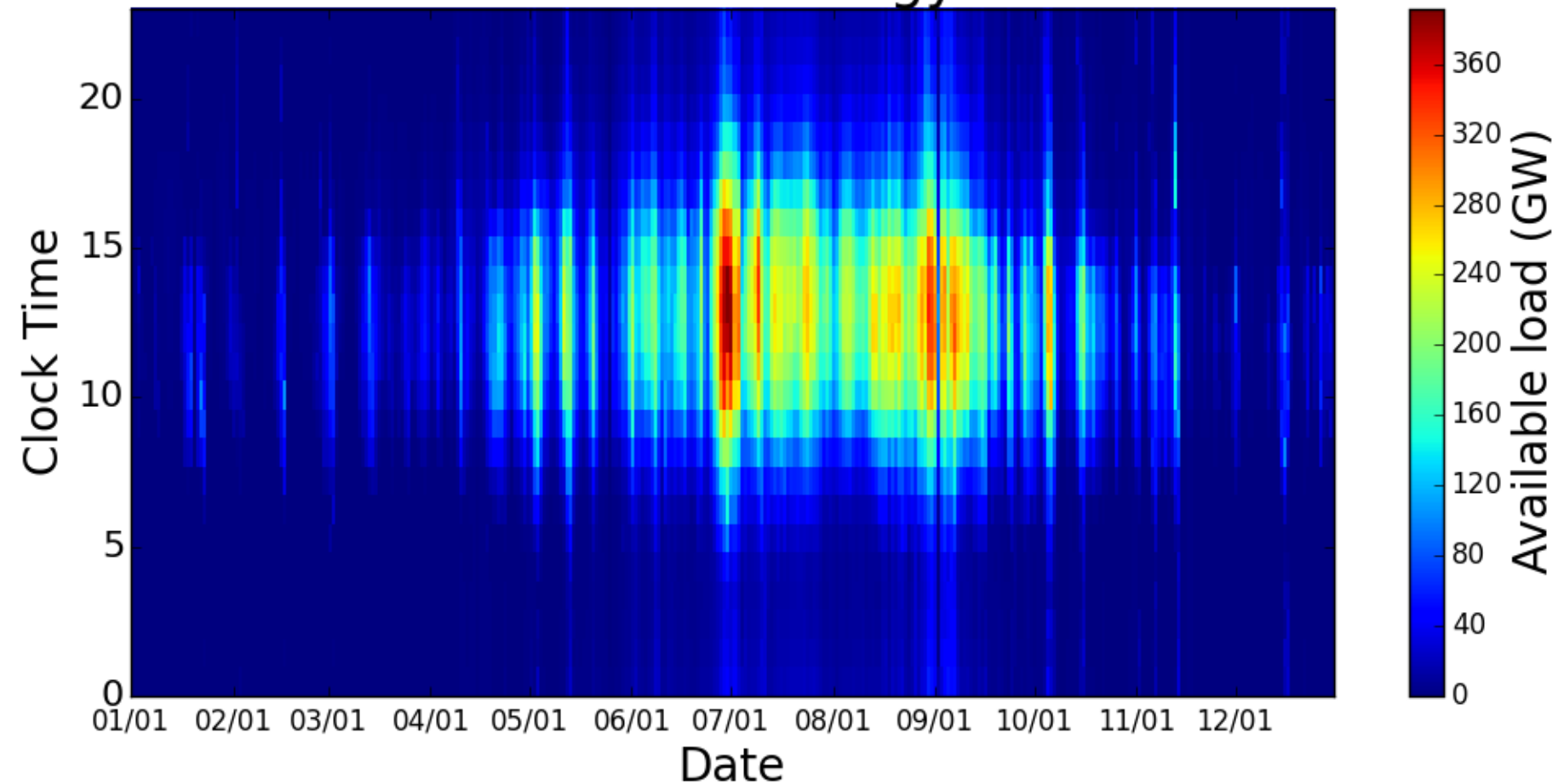


Region: Entire United States
End Use: residential hot water
Product: Capacity

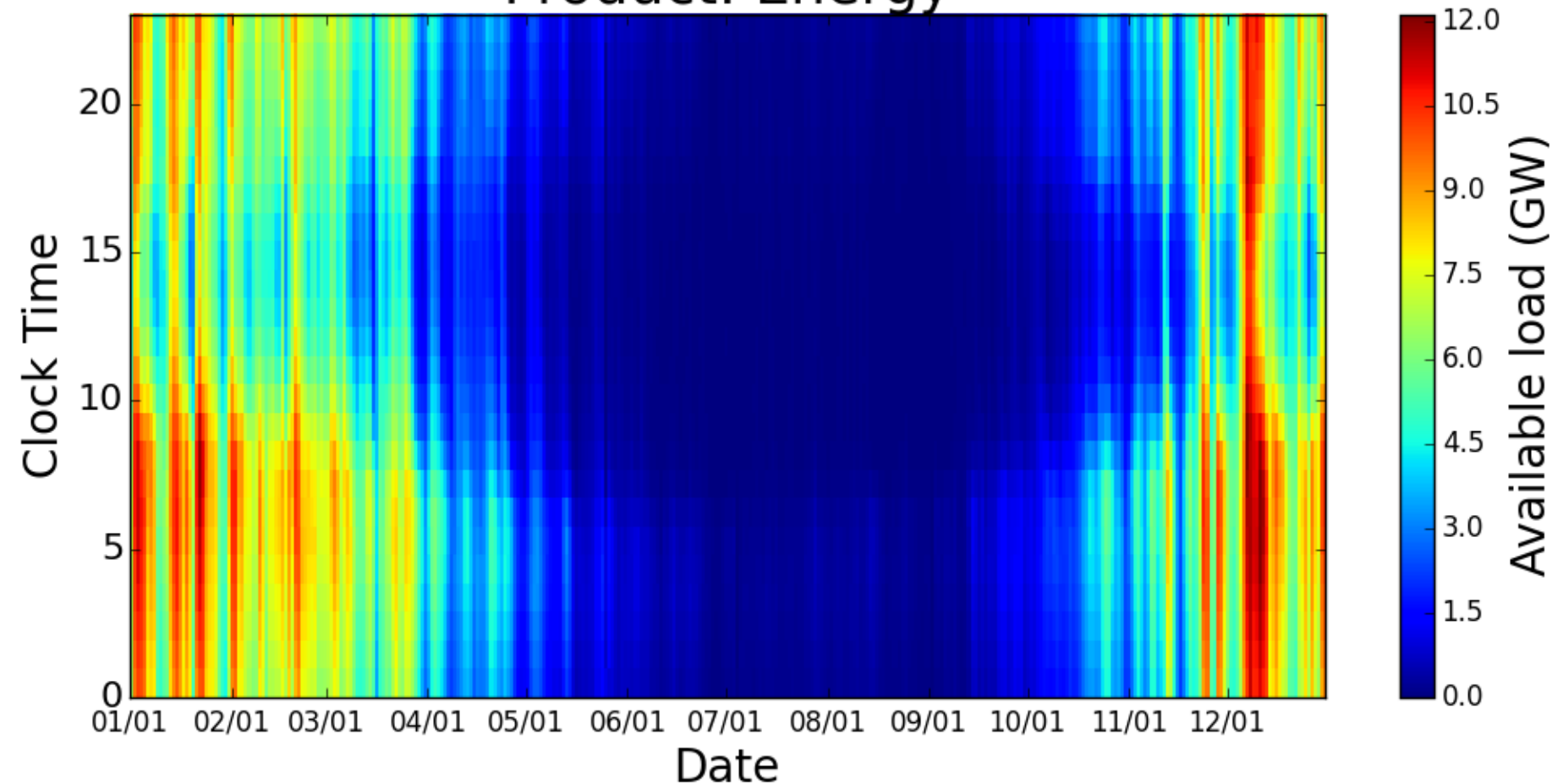


VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Energy

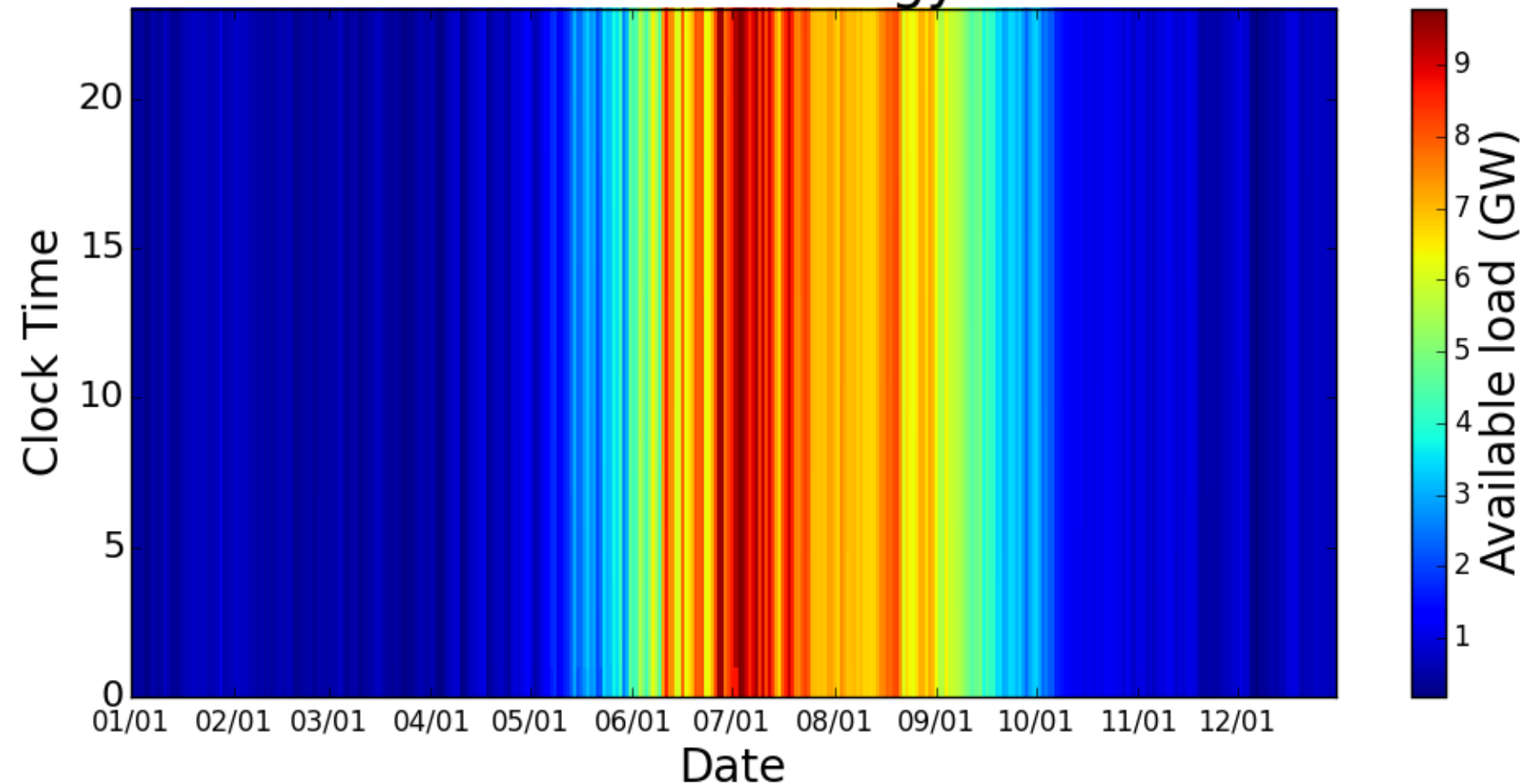
Region: Entire United States
End Use: commercial cooling
Product: Energy



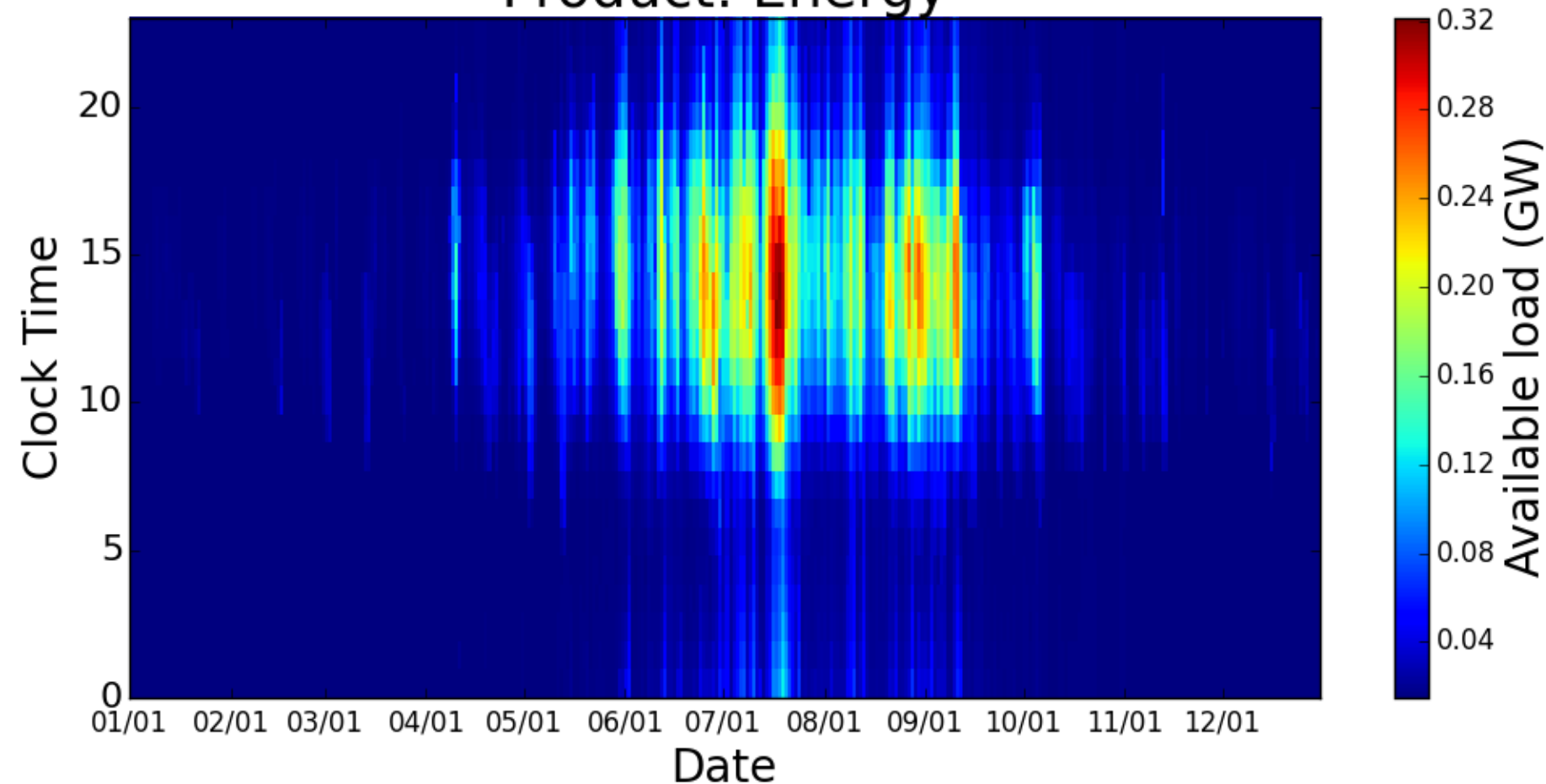
Region: Entire United States
End Use: commercial heating
Product: Energy



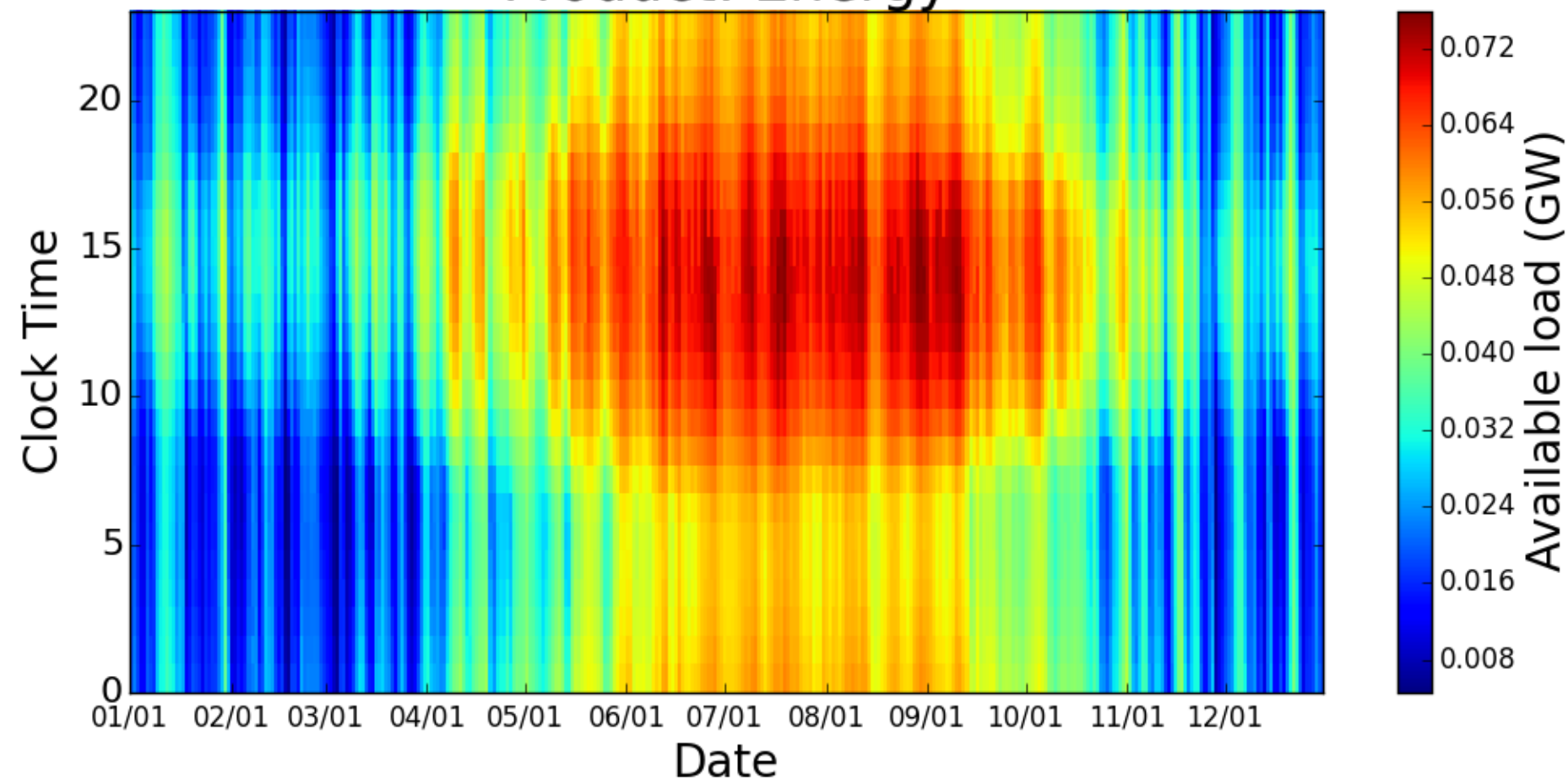
Region: Entire United States
End Use: agricultural pumping
Product: Energy



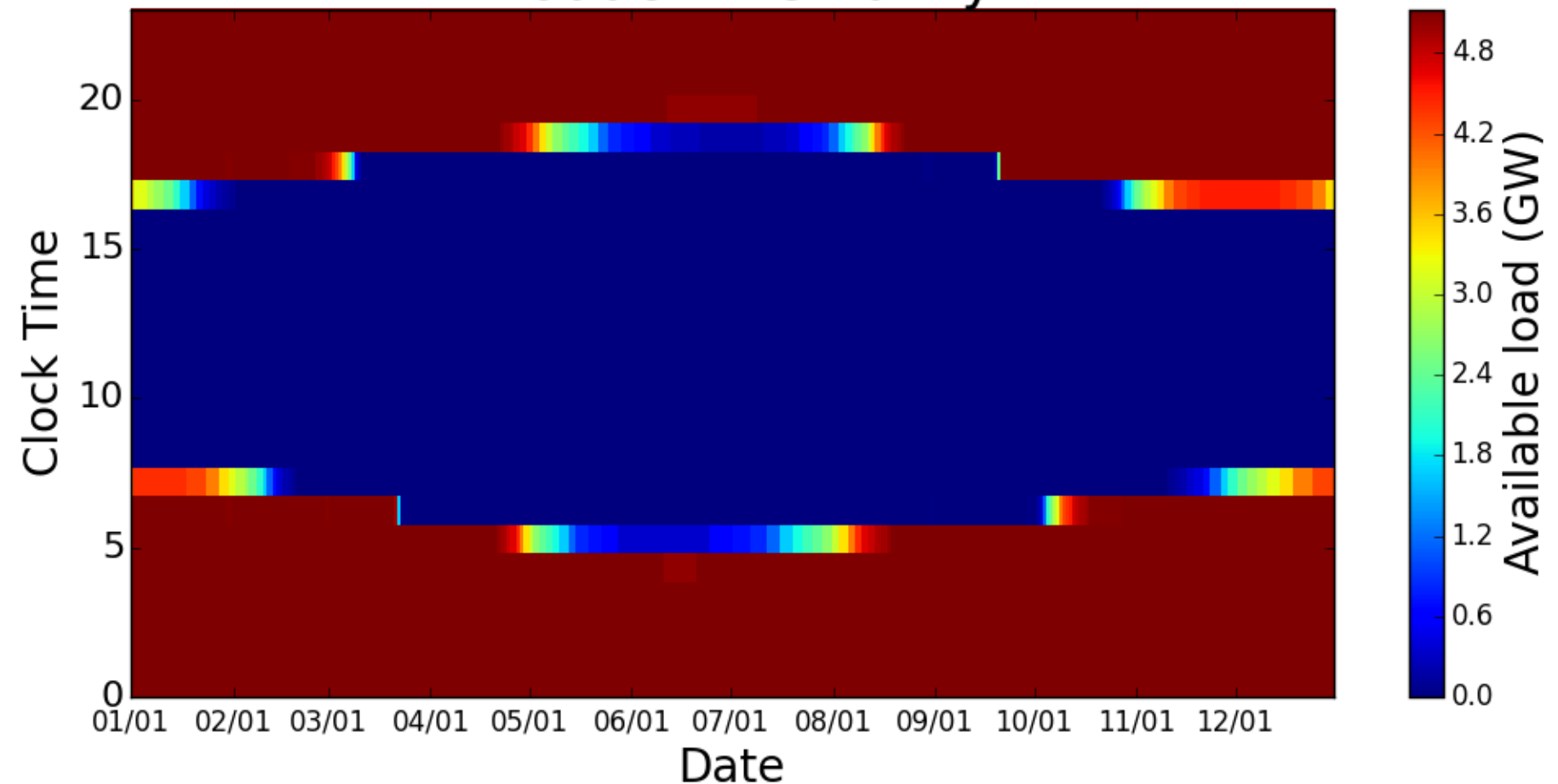
Region: Entire United States
End Use: data centers
Product: Energy



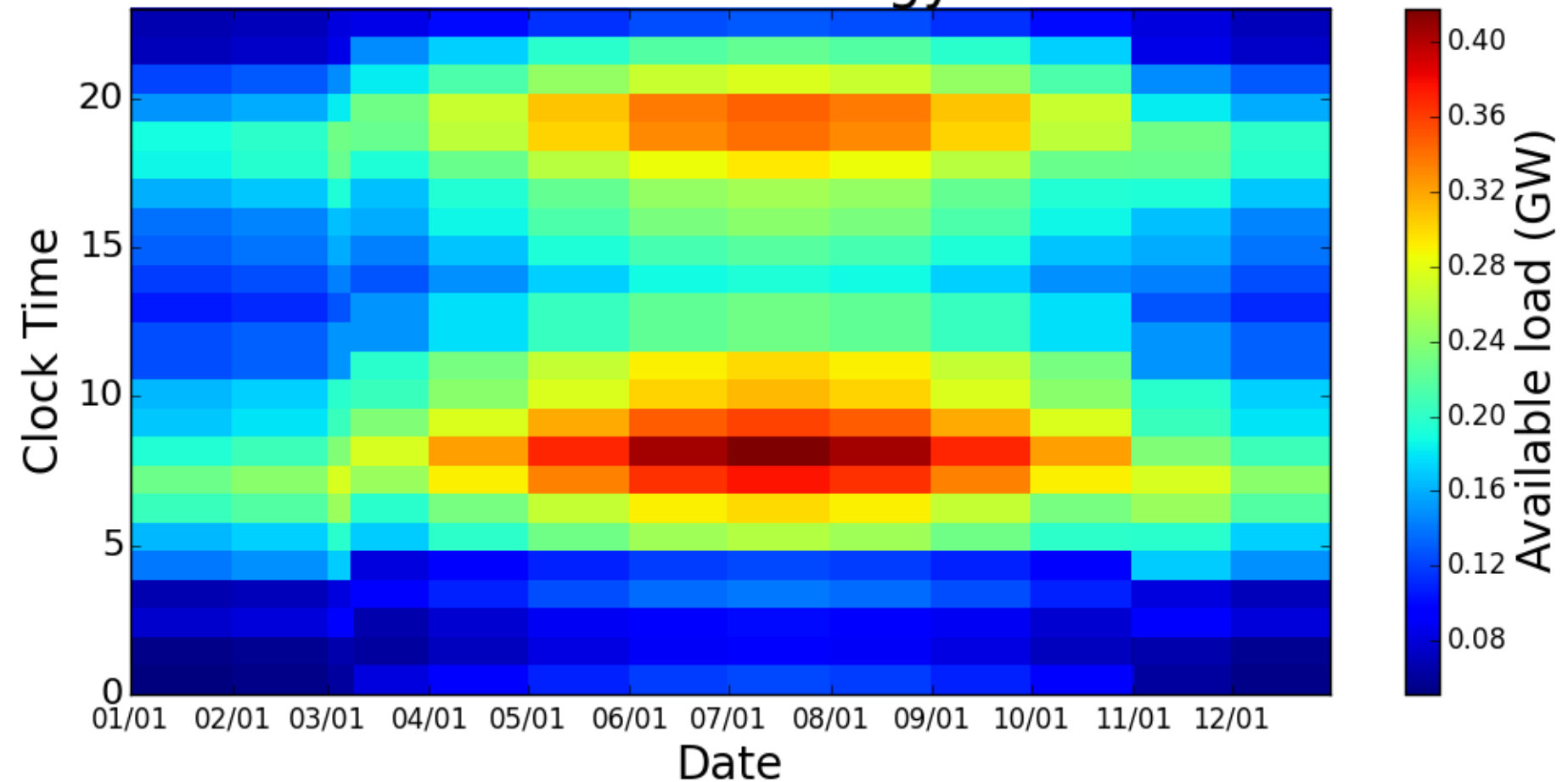
Region: Entire United States
End Use: refrigerated warehouses
Product: Energy



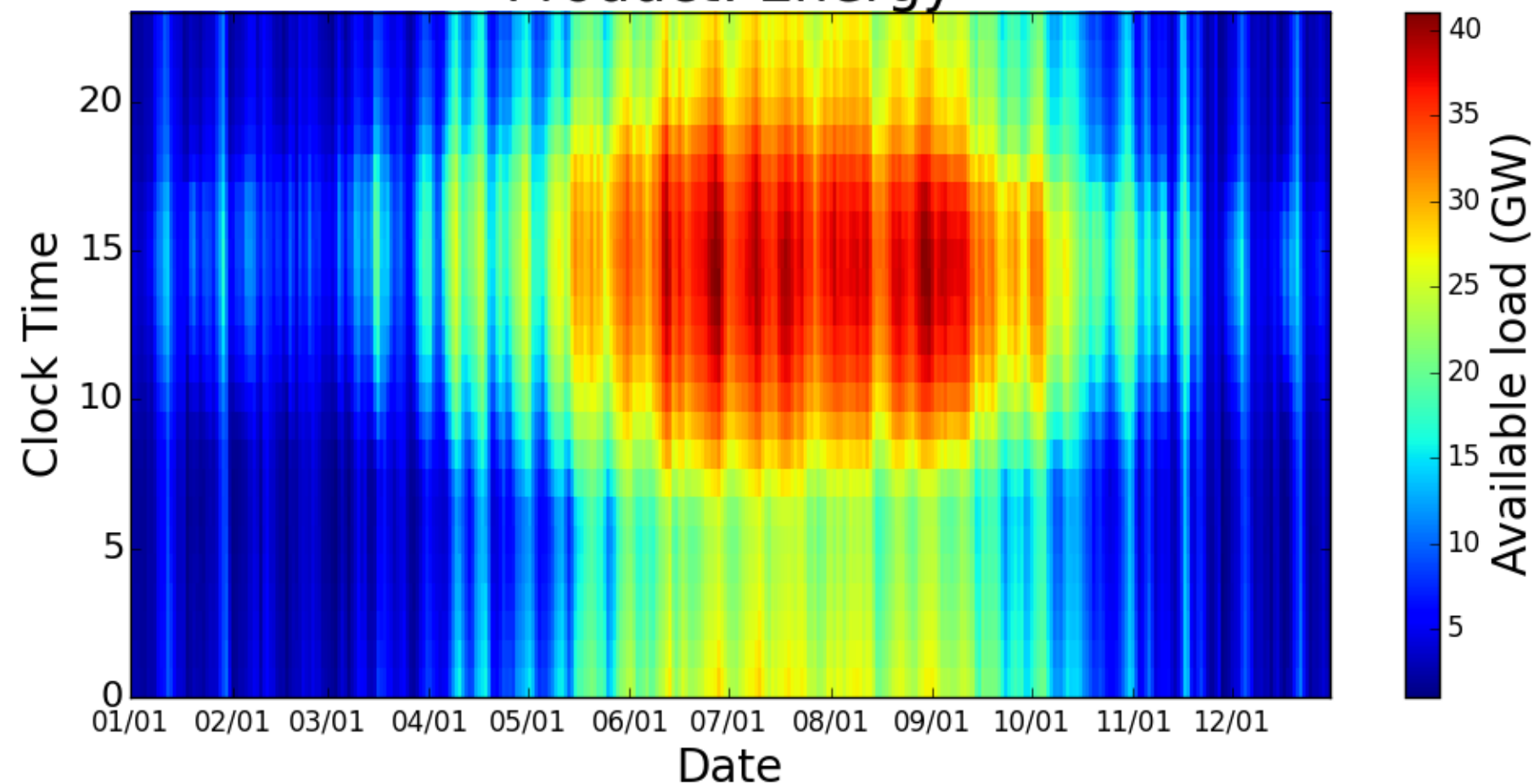
Region: Entire United States
End Use: municipal outdoor lighting
Product: Flexibility



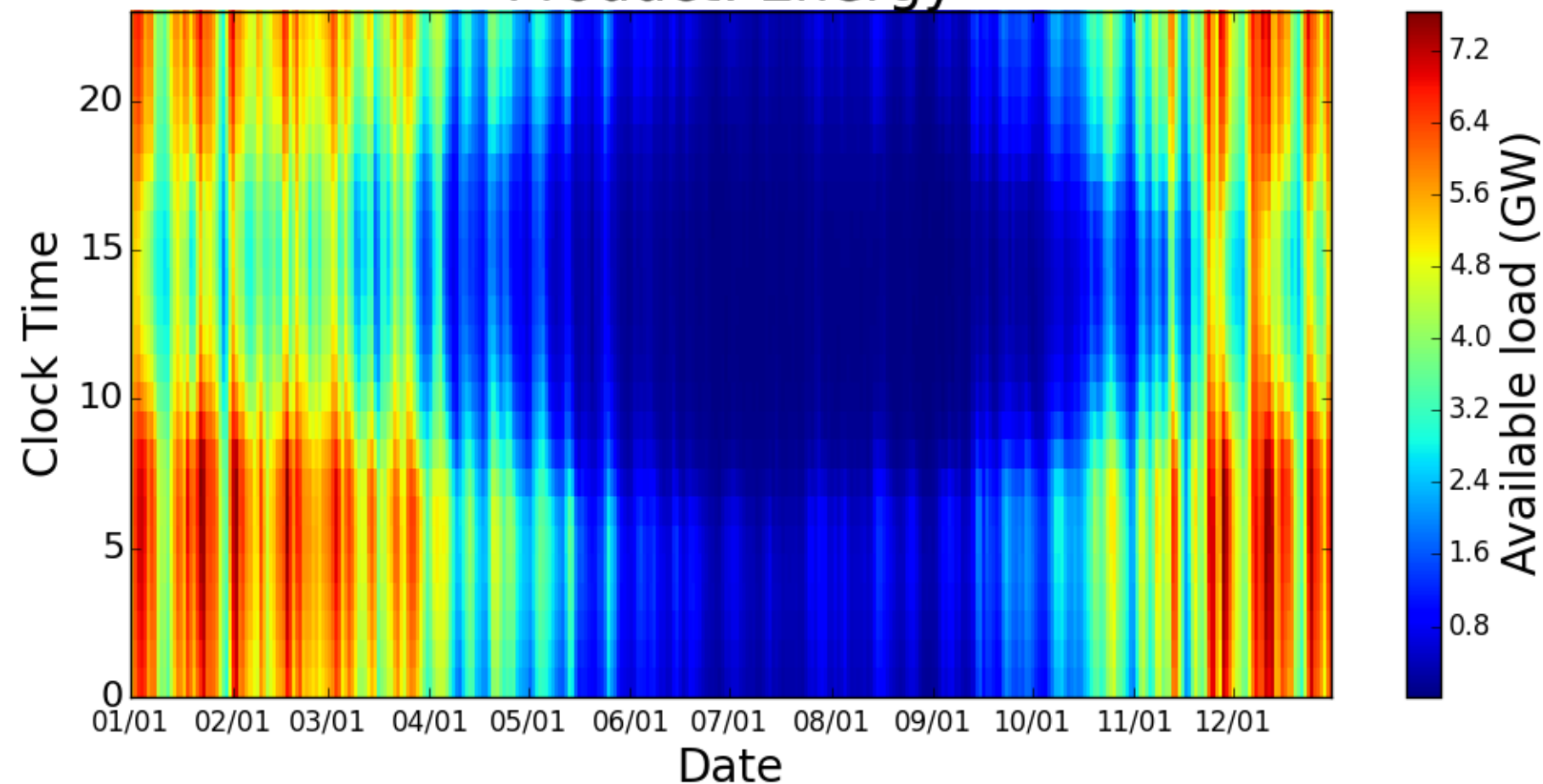
Region: Entire United States
End Use: municipal water pumping
Product: Energy



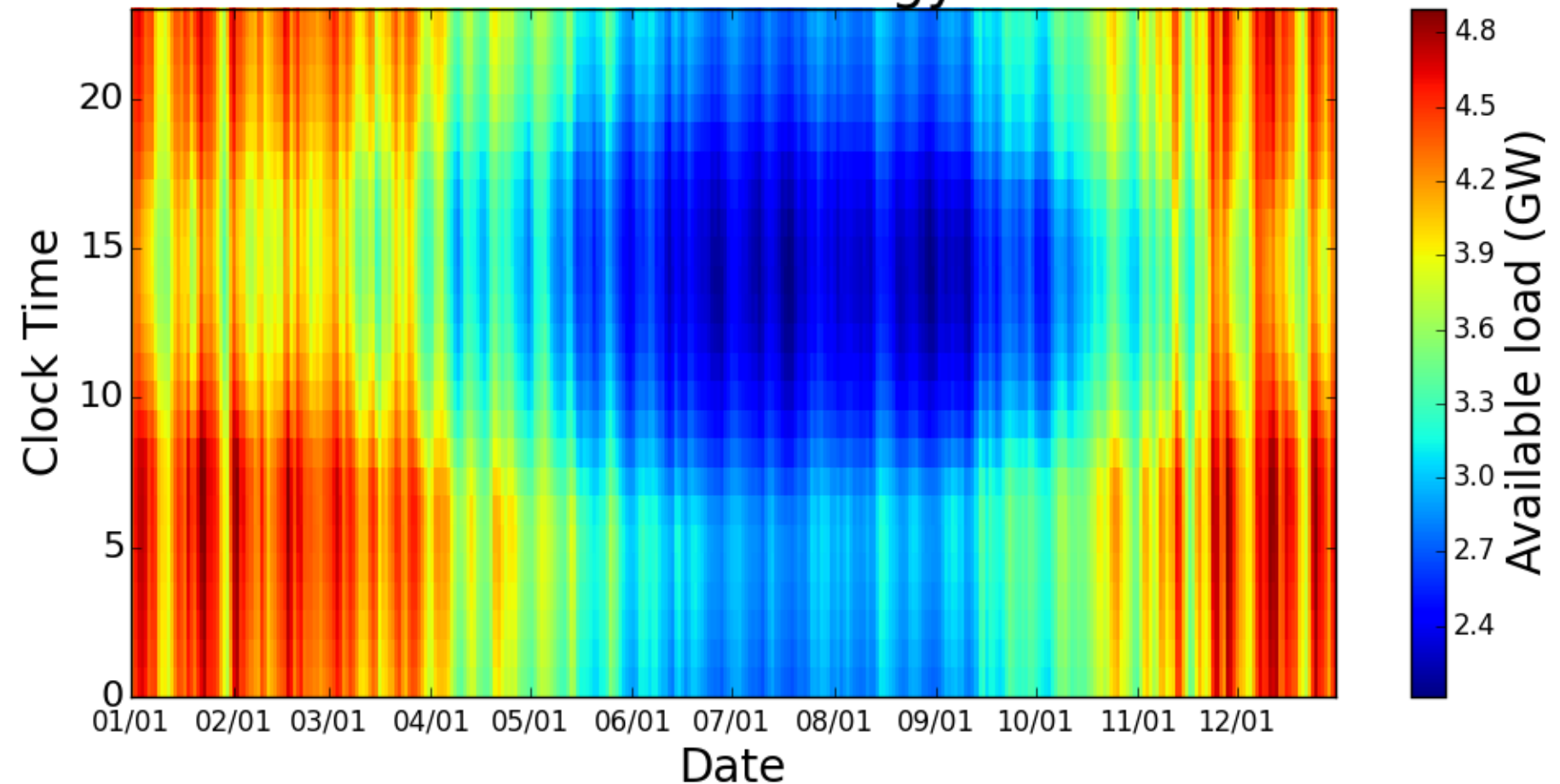
Region: Entire United States
End Use: residential cooling
Product: Energy



Region: Entire United States
End Use: residential heating
Product: Energy

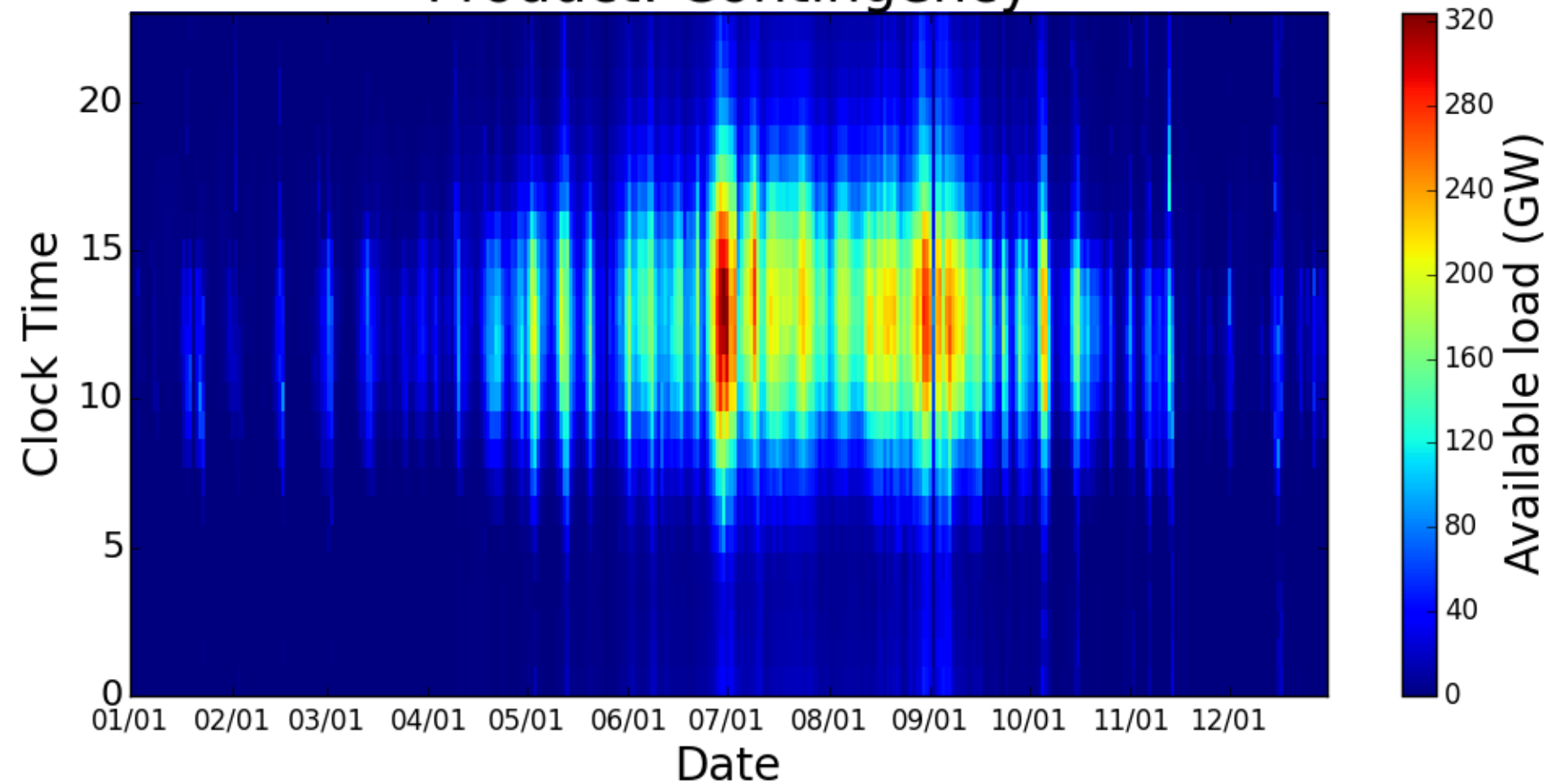


Region: Entire United States
End Use: residential hot water
Product: Energy

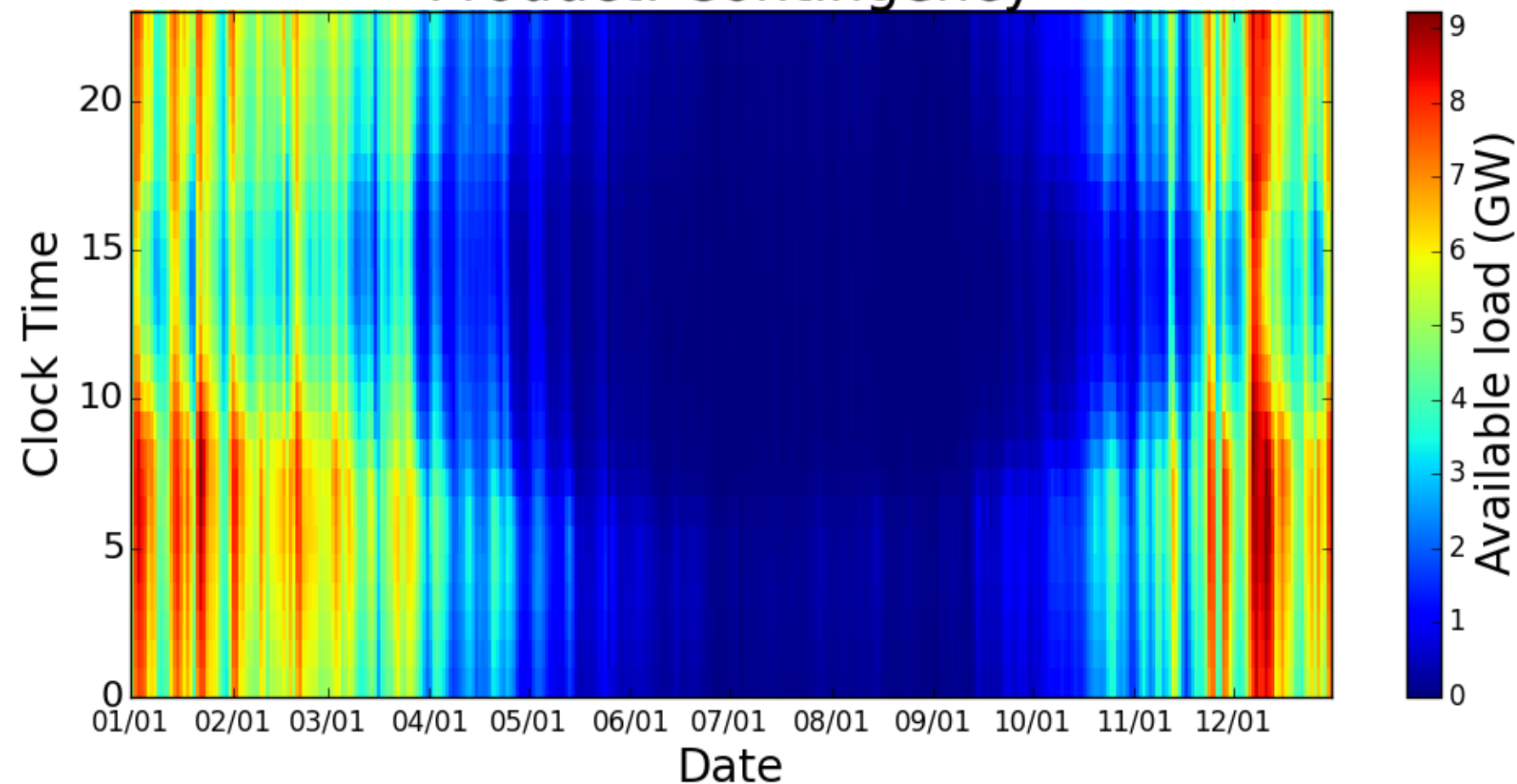


VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Contingency

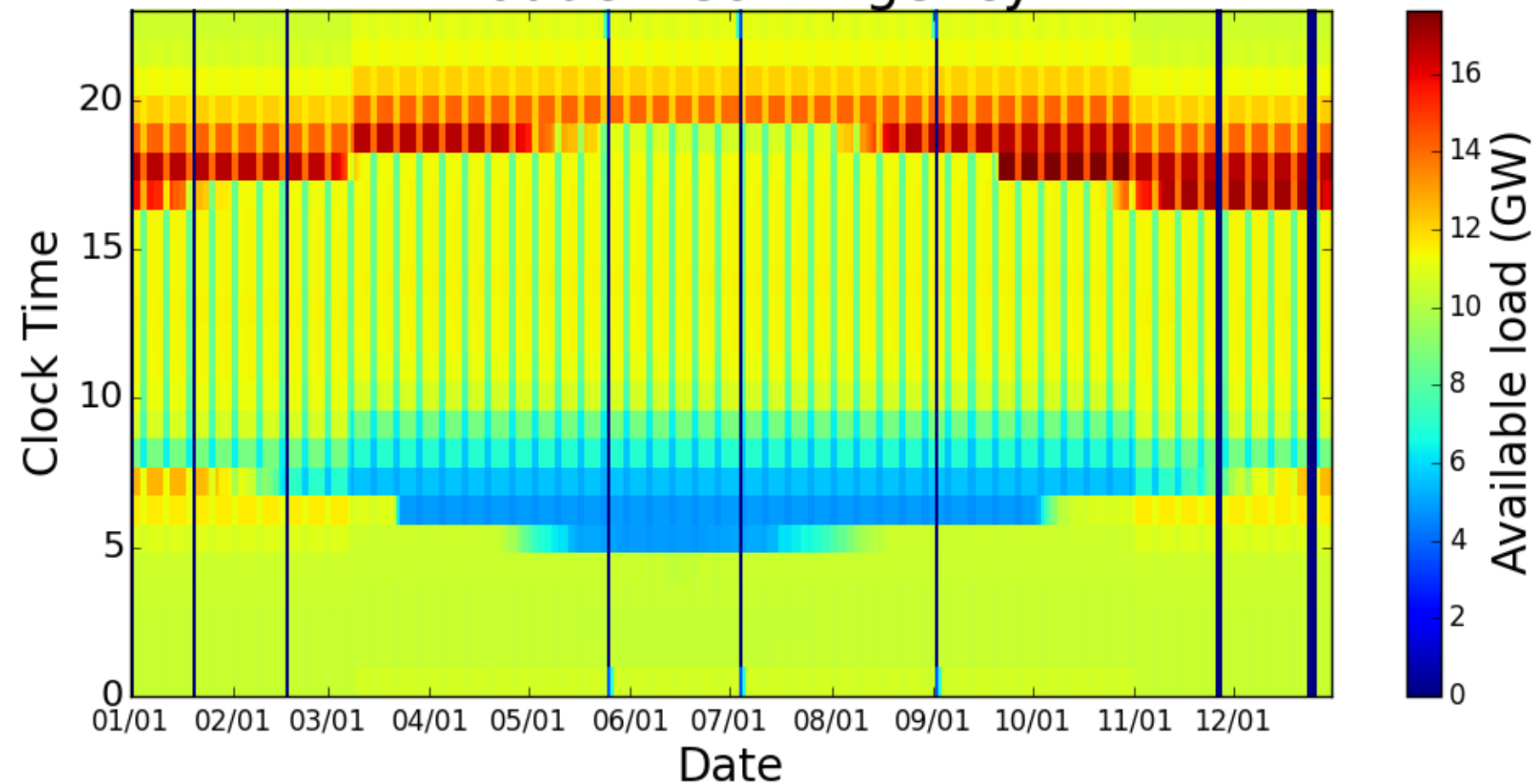
Region: Entire United States
End Use: commercial cooling
Product: Contingency



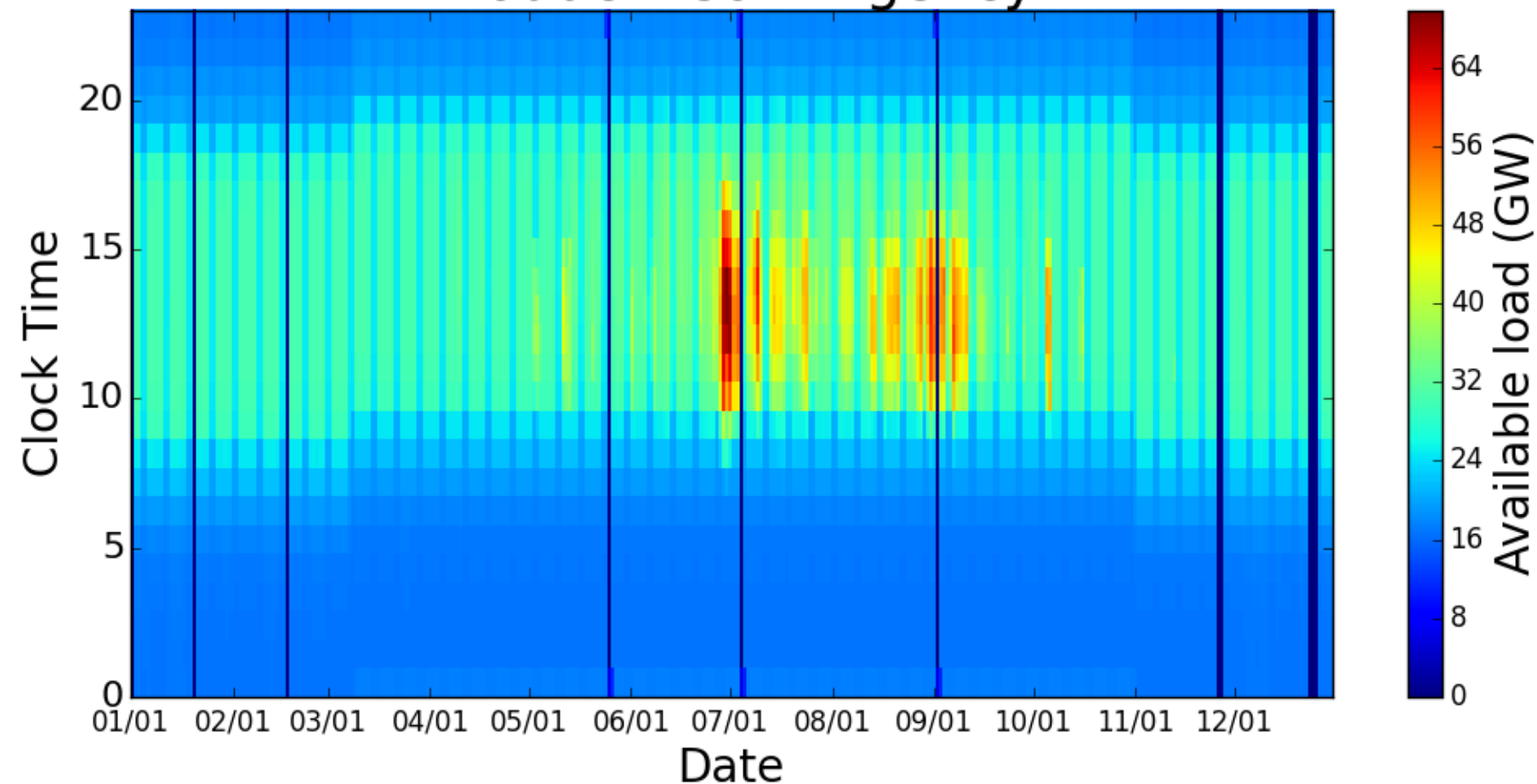
Region: Entire United States
End Use: commercial heating
Product: Contingency



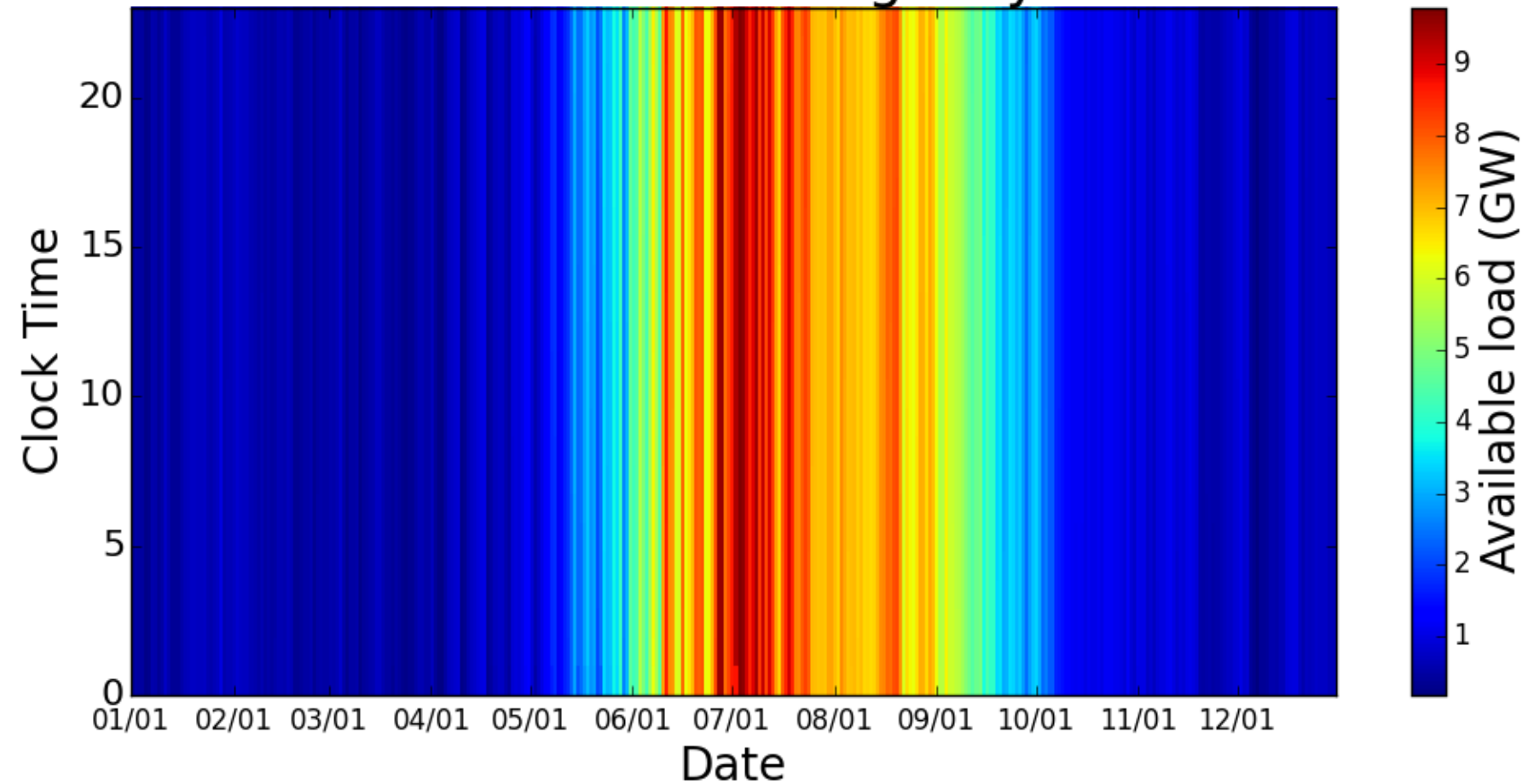
Region: Entire United States
End Use: commercial lighting
Product: Contingency



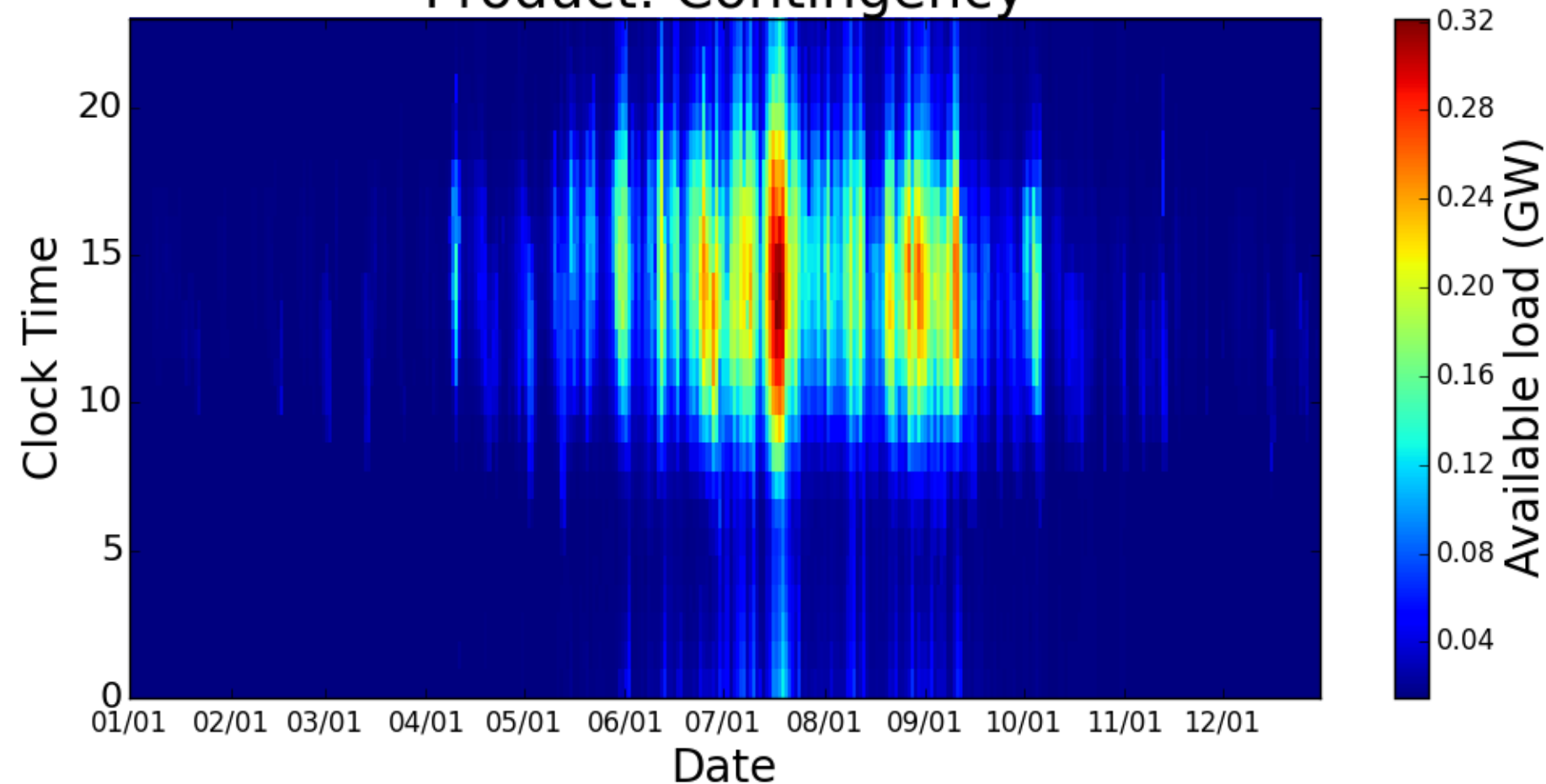
Region: Entire United States
End Use: commercial ventilation
Product: Contingency



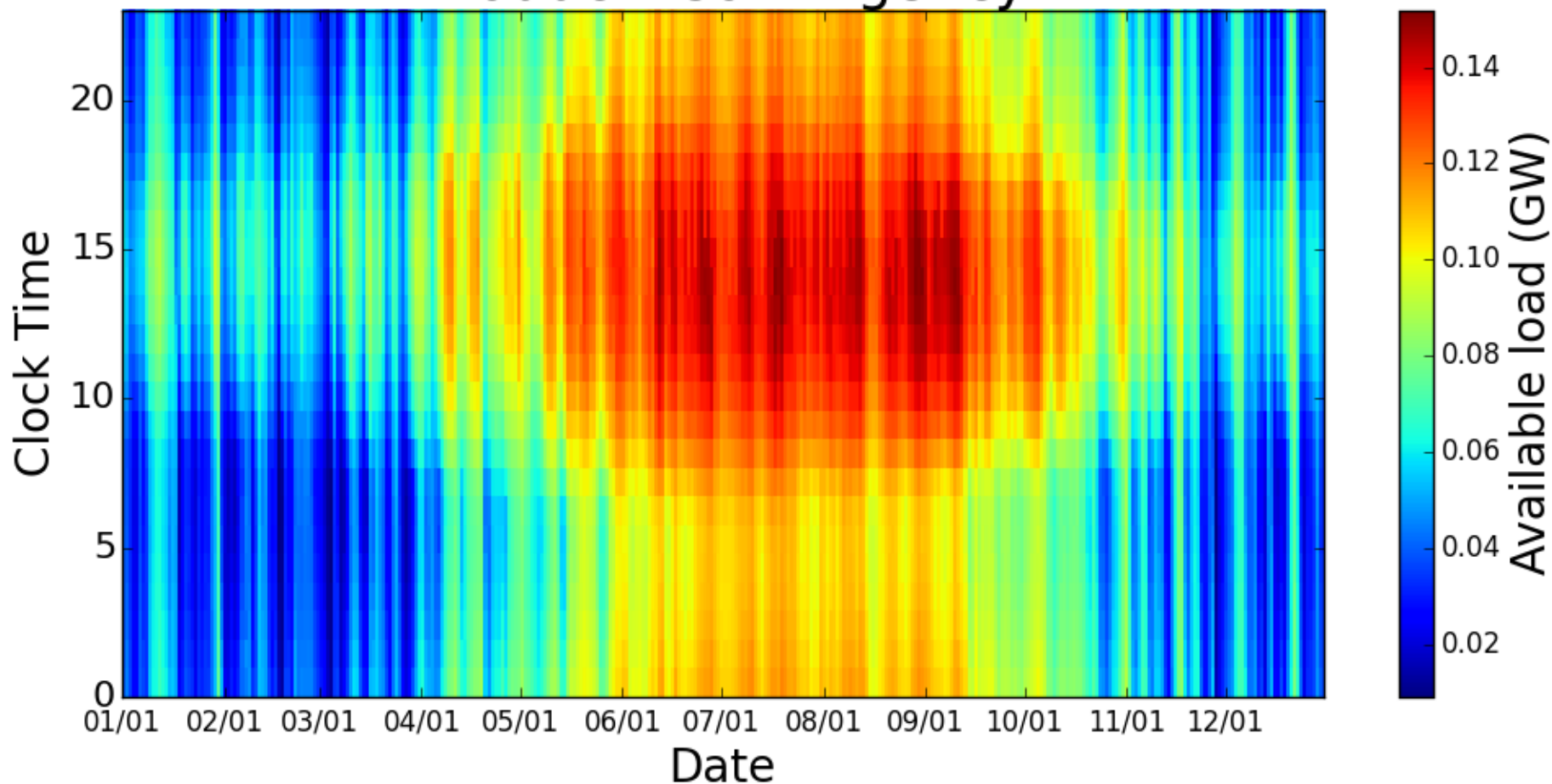
Region: Entire United States
End Use: agricultural pumping
Product: Contingency



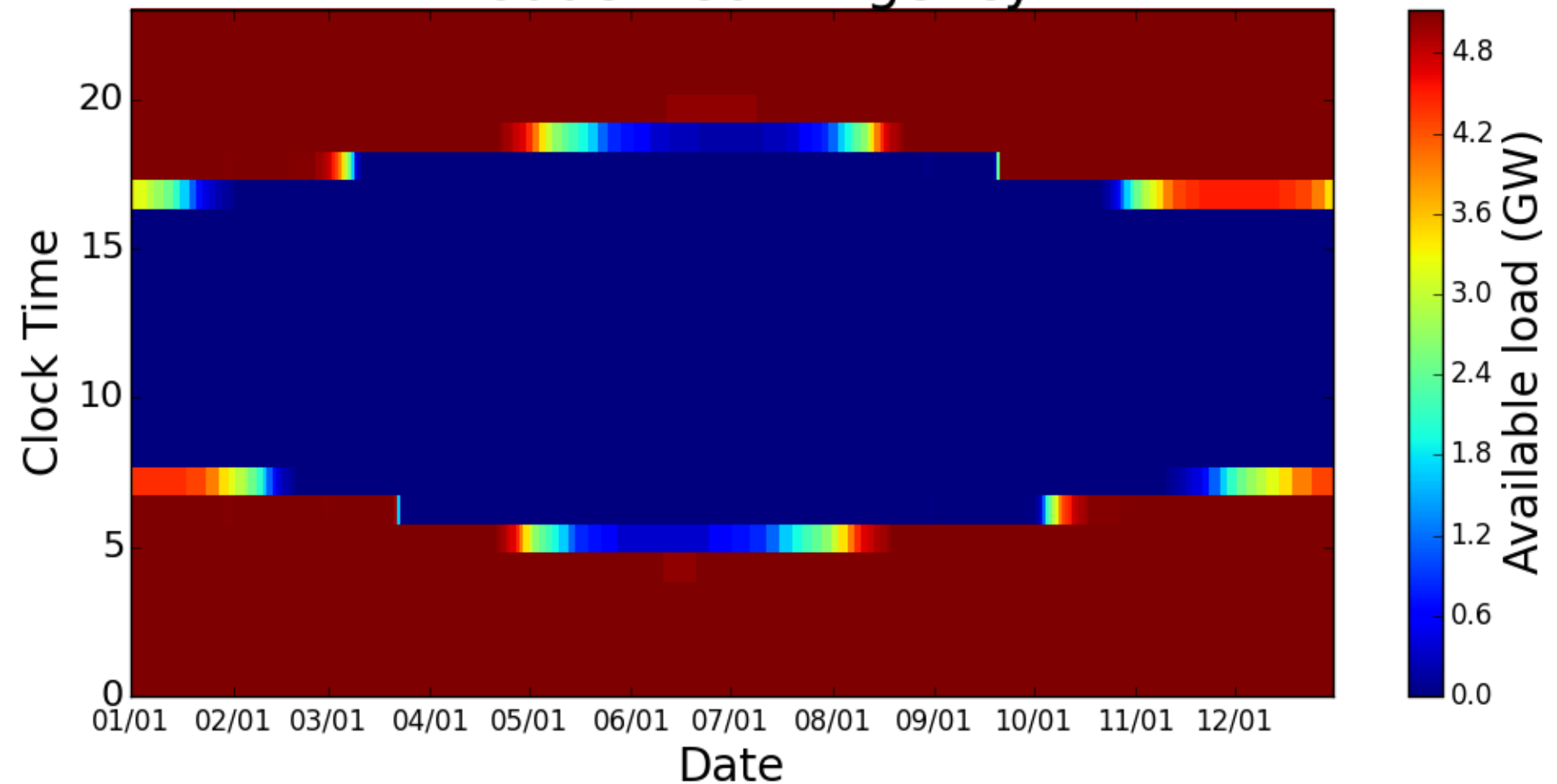
Region: Entire United States
End Use: data centers
Product: Contingency



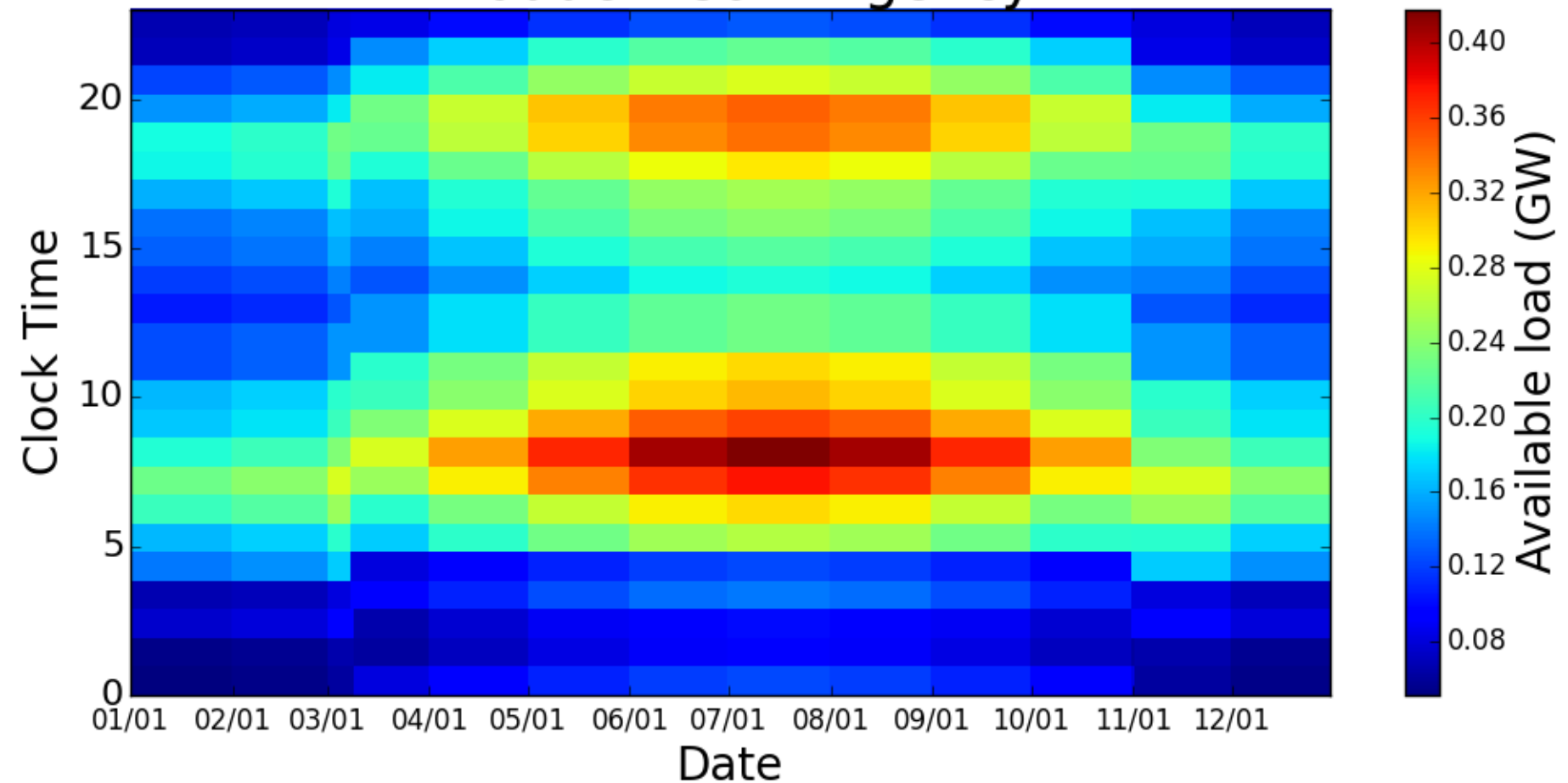
Region: Entire United States
End Use: refrigerated warehouses
Product: Contingency



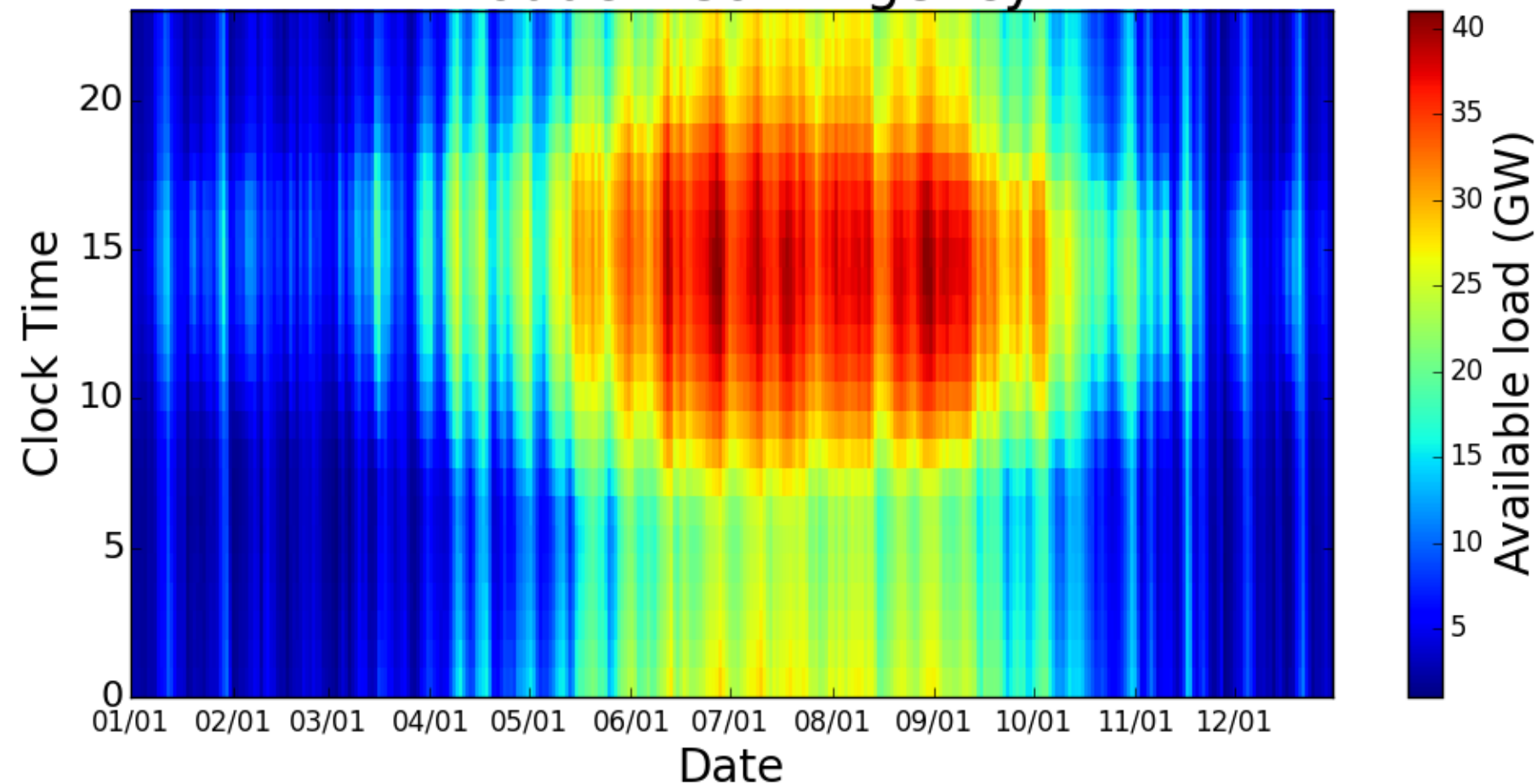
Region: Entire United States
End Use: municipal outdoor lighting
Product: Contingency



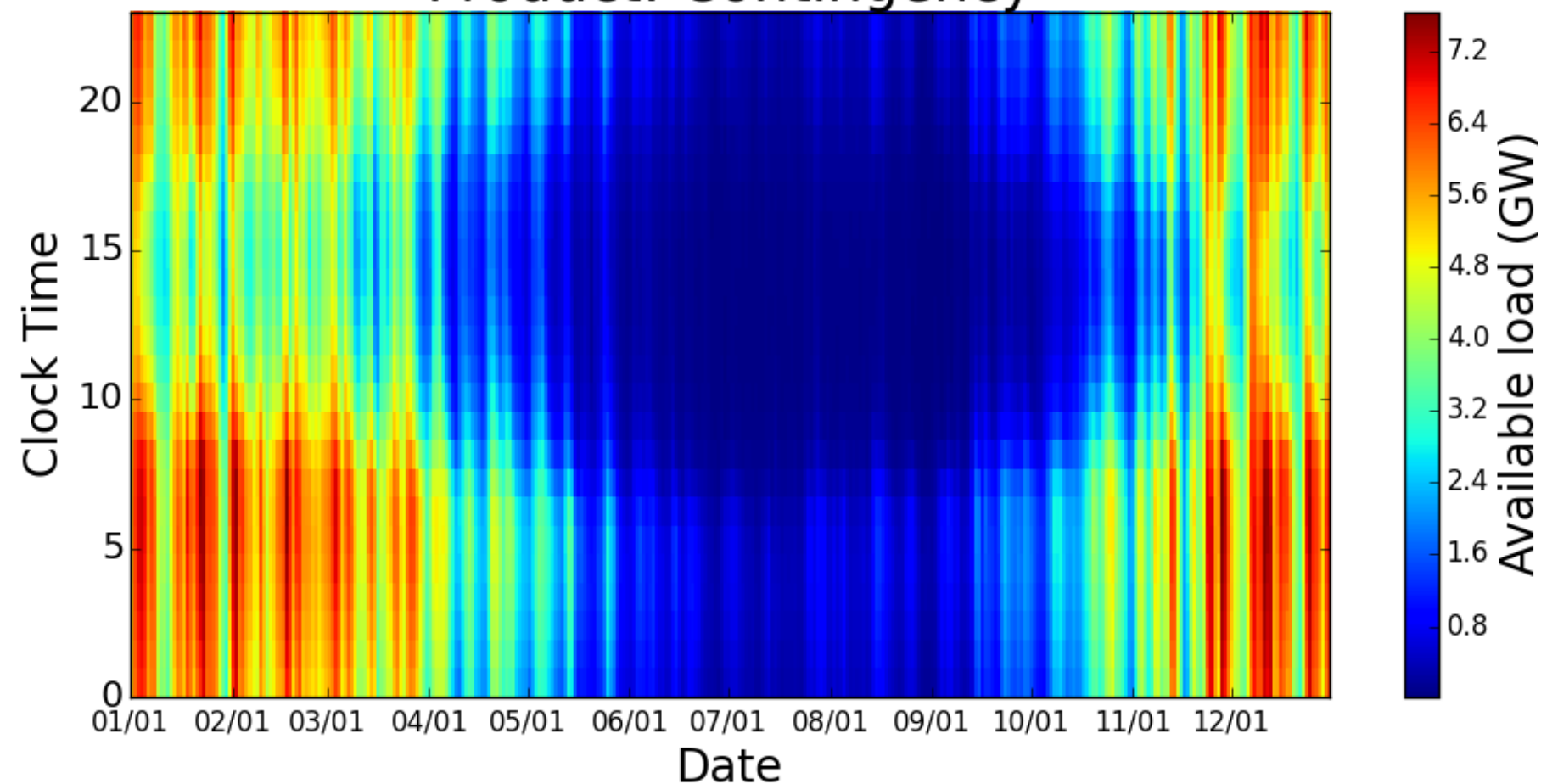
Region: Entire United States
End Use: municipal water pumping
Product: Contingency



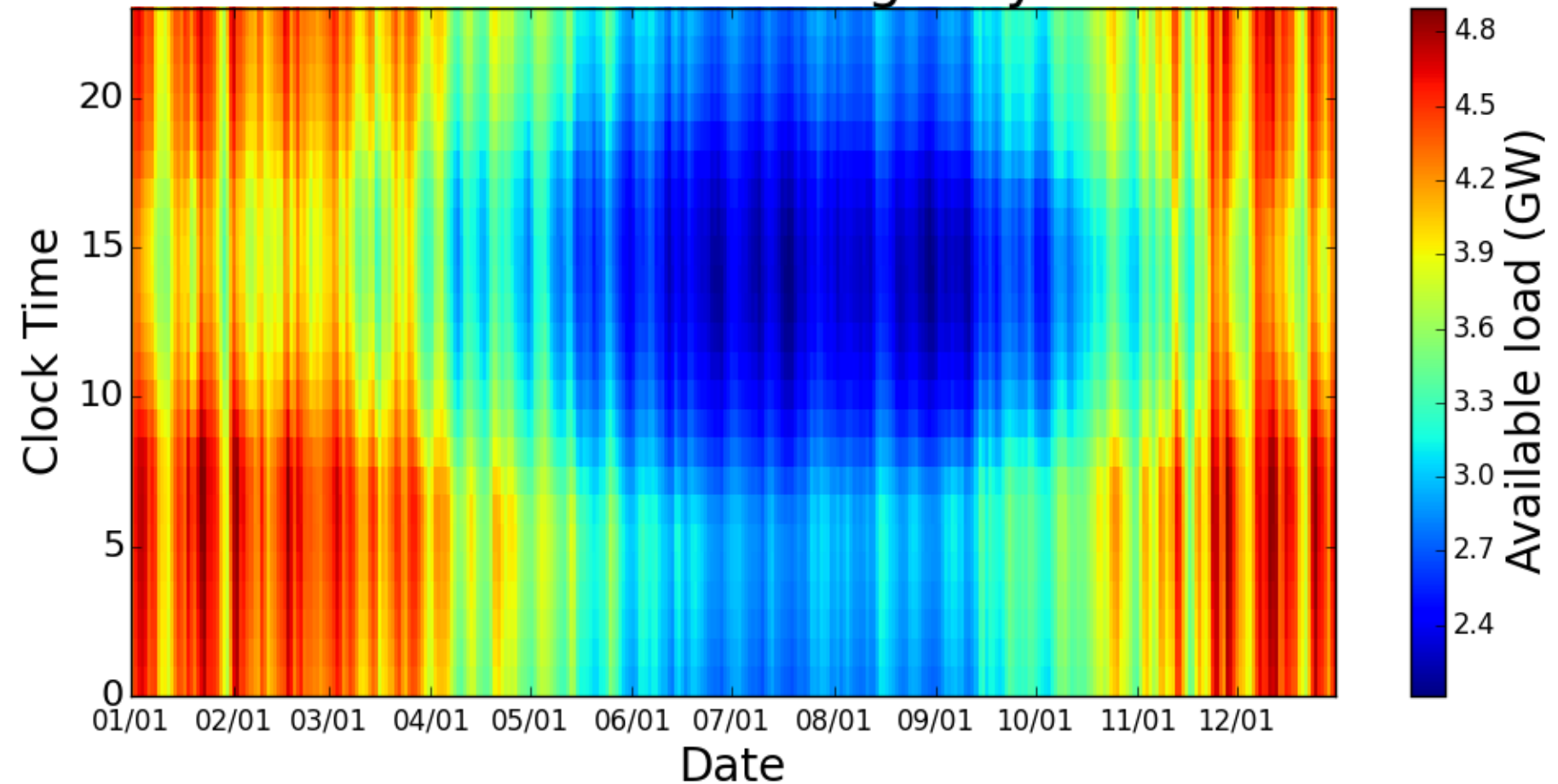
Region: Entire United States
End Use: residential cooling
Product: Contingency



Region: Entire United States
End Use: residential heating
Product: Contingency

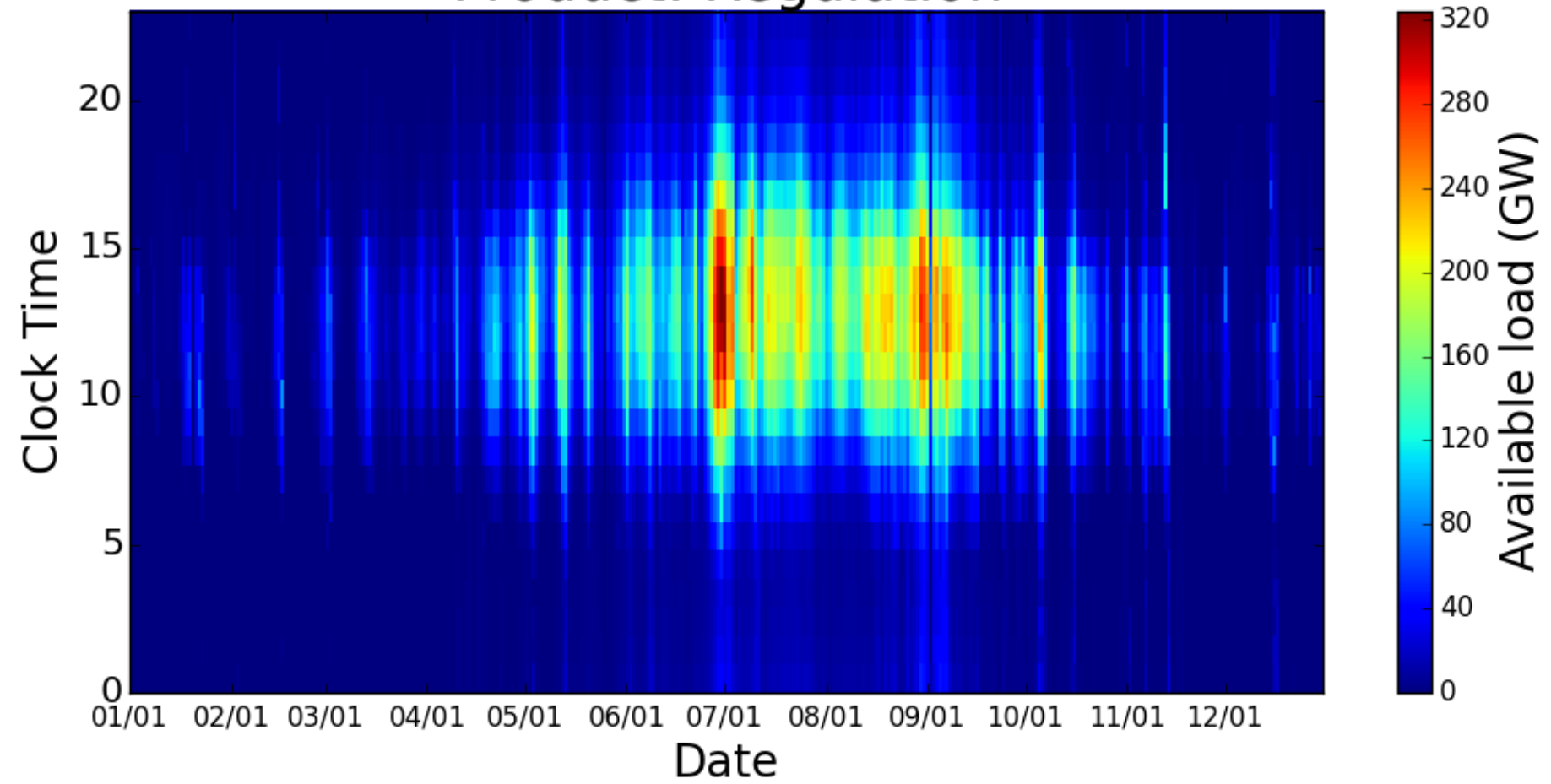


Region: Entire United States
End Use: residential hot water
Product: Contingency

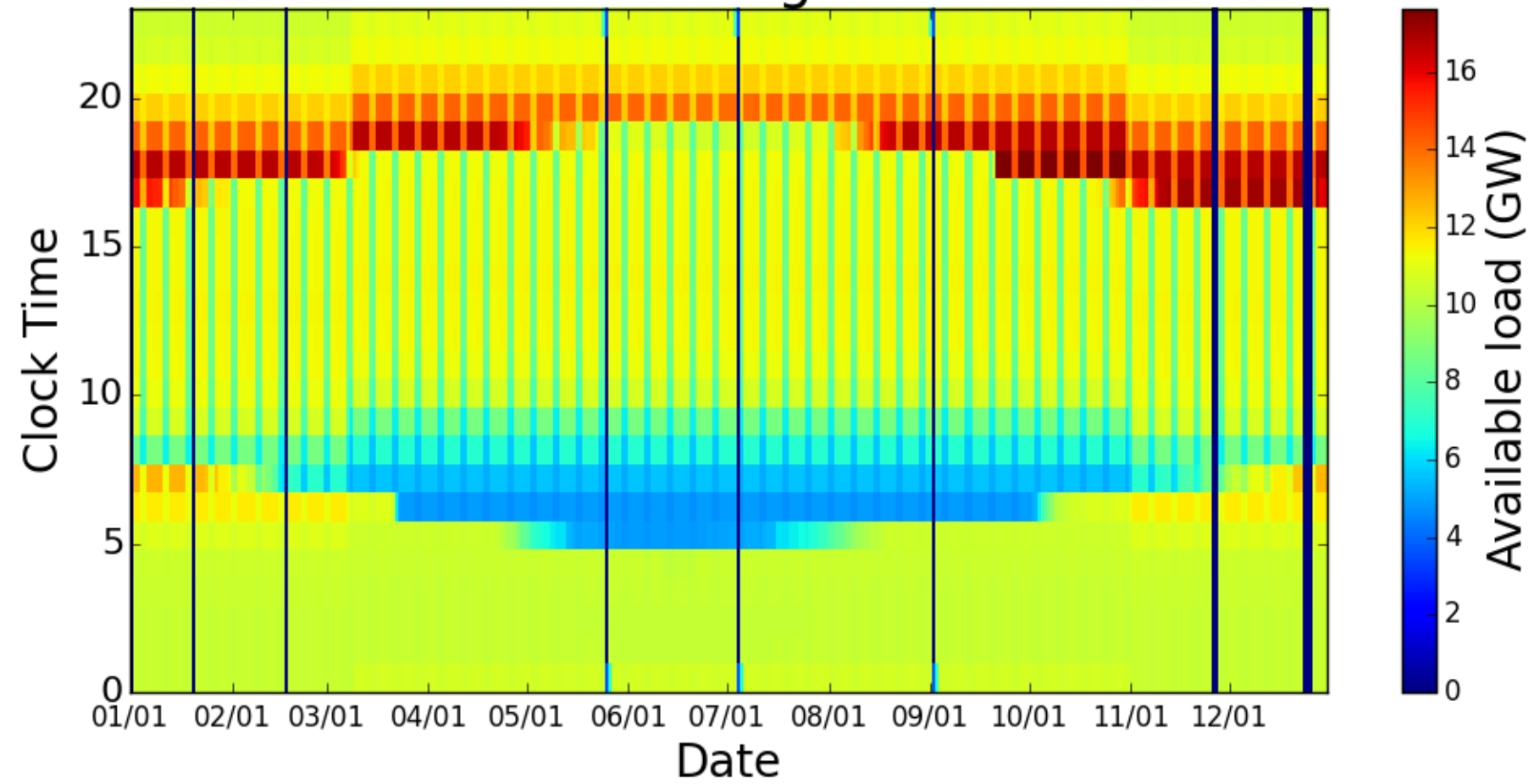


VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Regulation

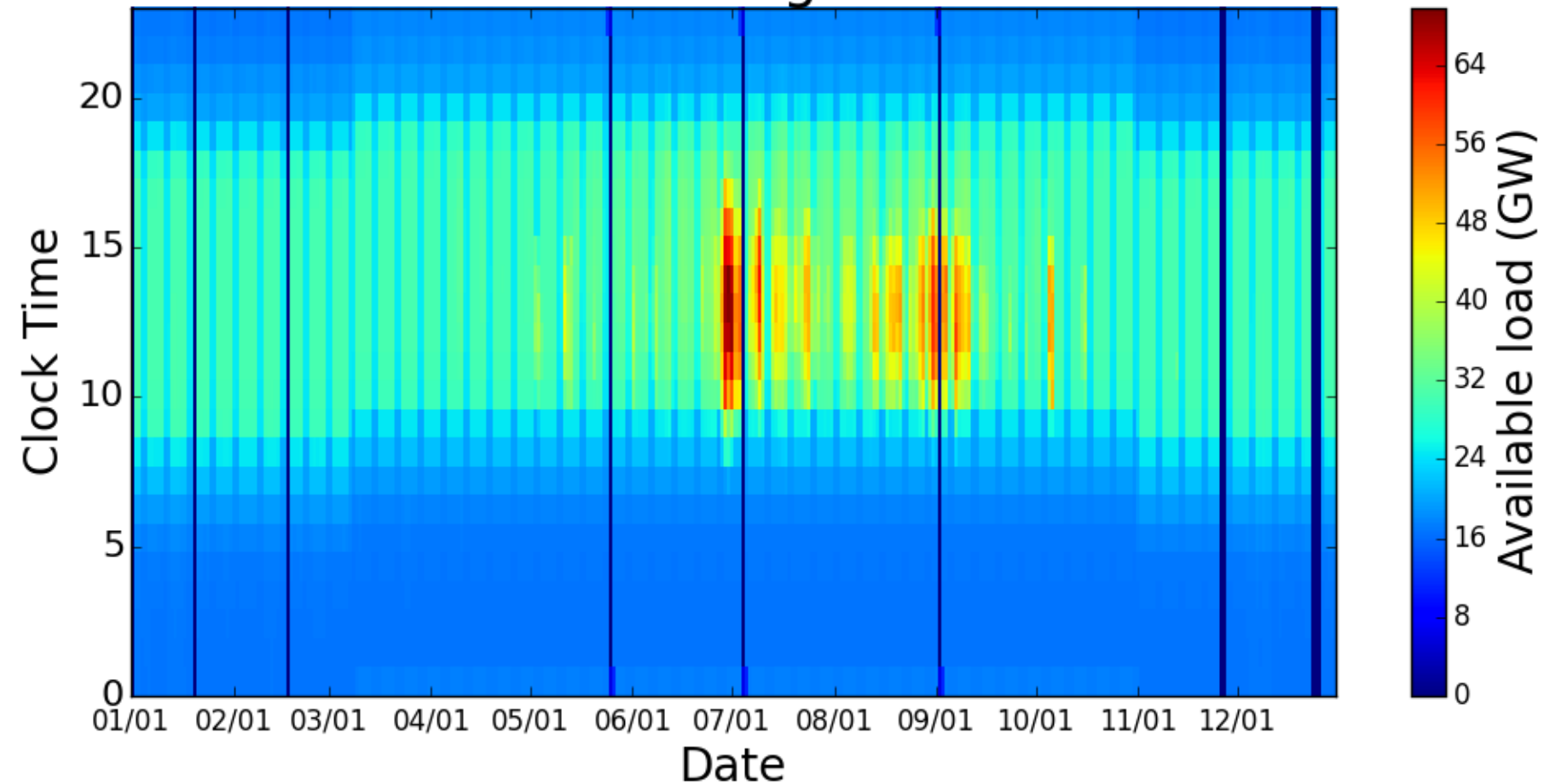
Region: Entire United States
End Use: commercial cooling
Product: Regulation



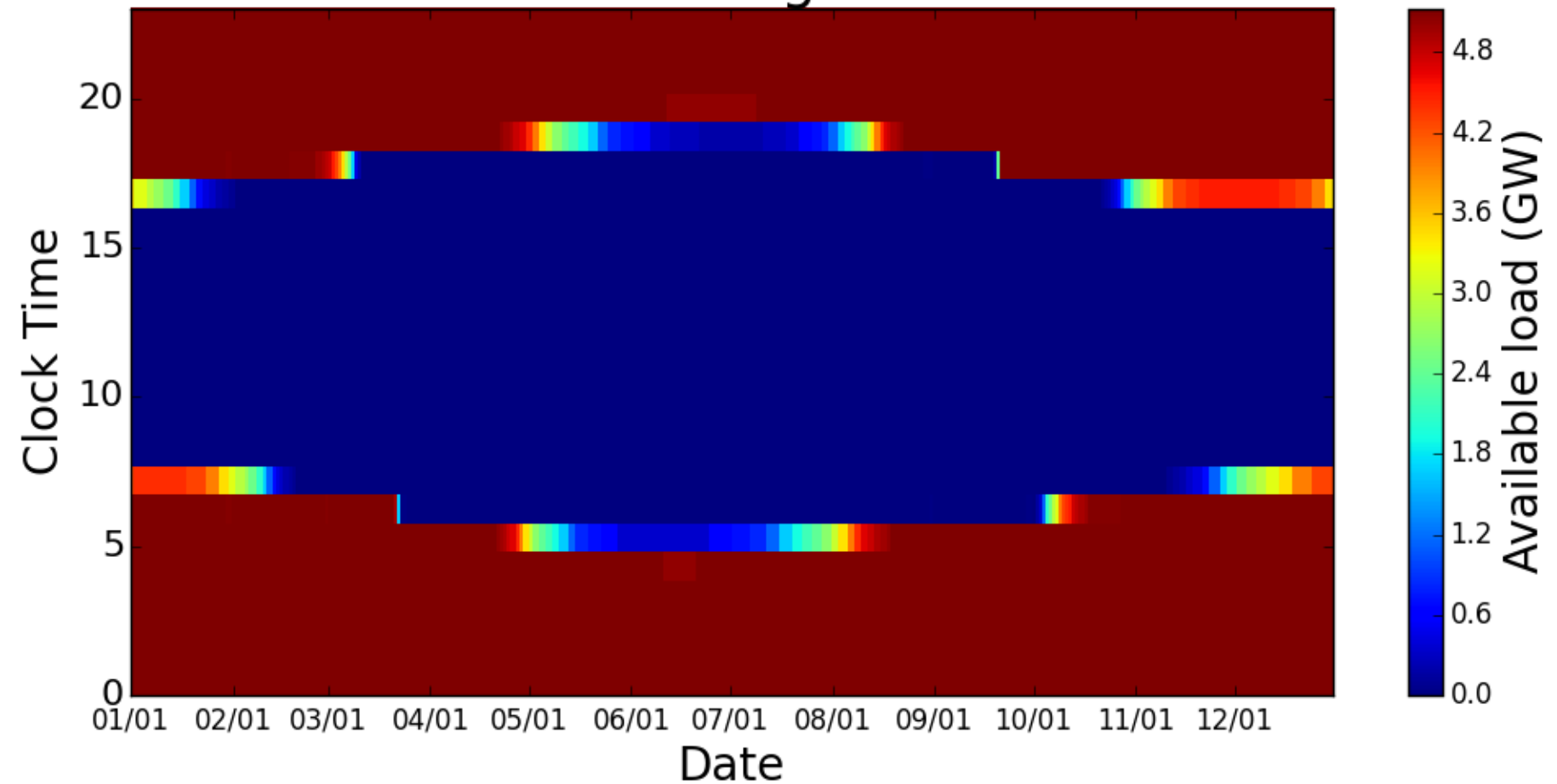
Region: Entire United States
End Use: commercial lighting
Product: Regulation



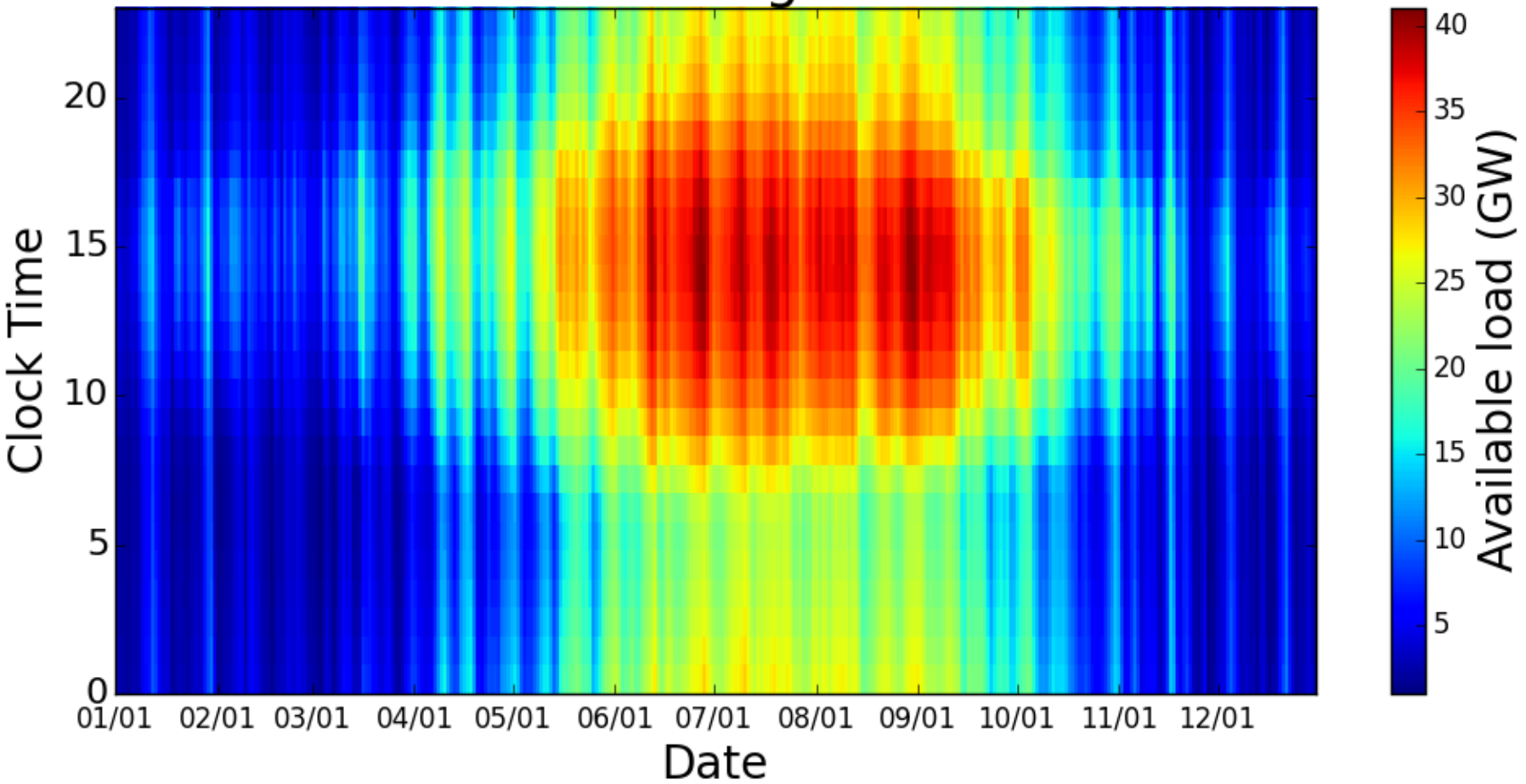
Region: Entire United States
End Use: commercial ventilation
Product: Regulation



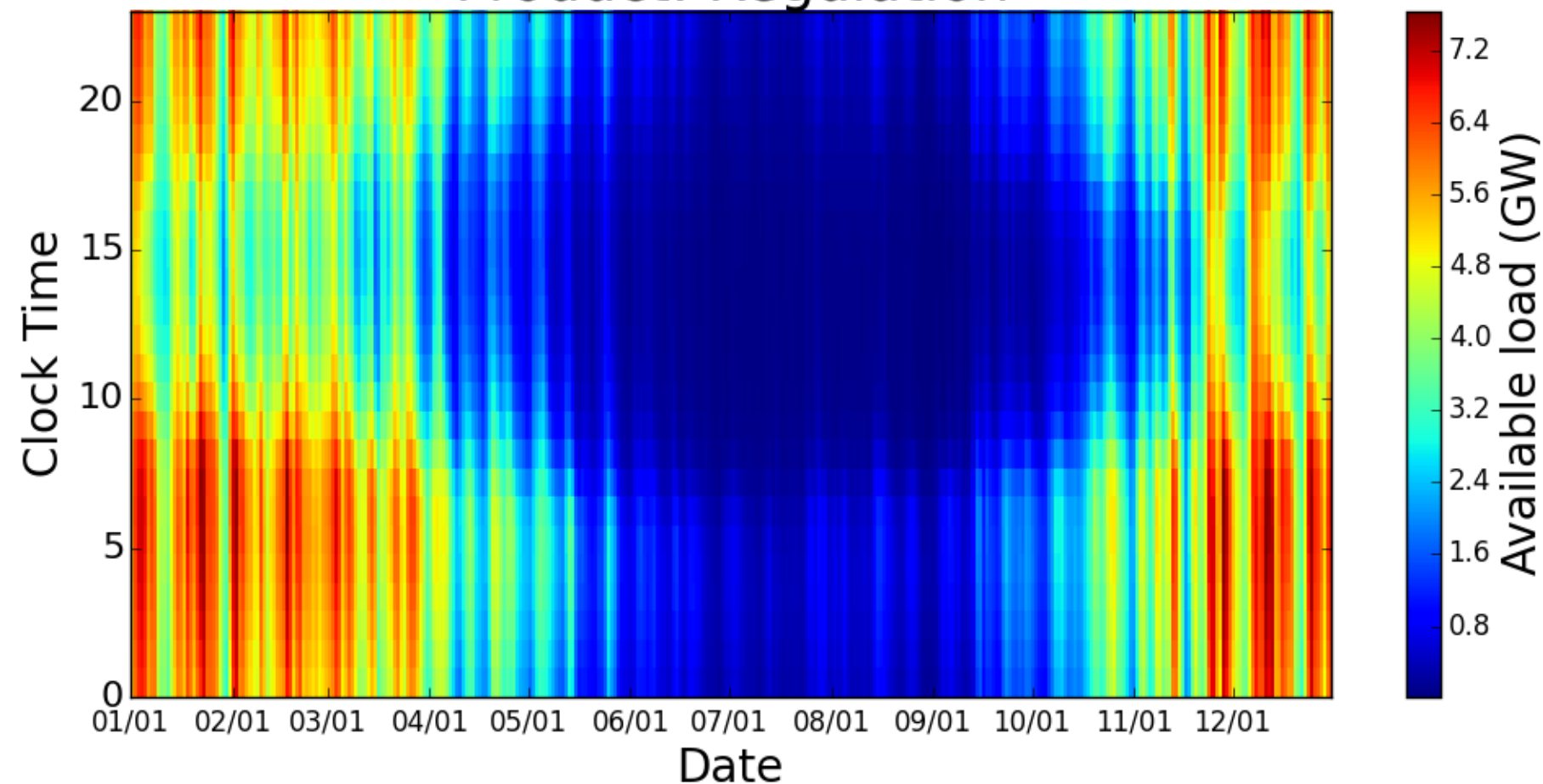
Region: Entire United States
End Use: municipal outdoor lighting
Product: Regulation



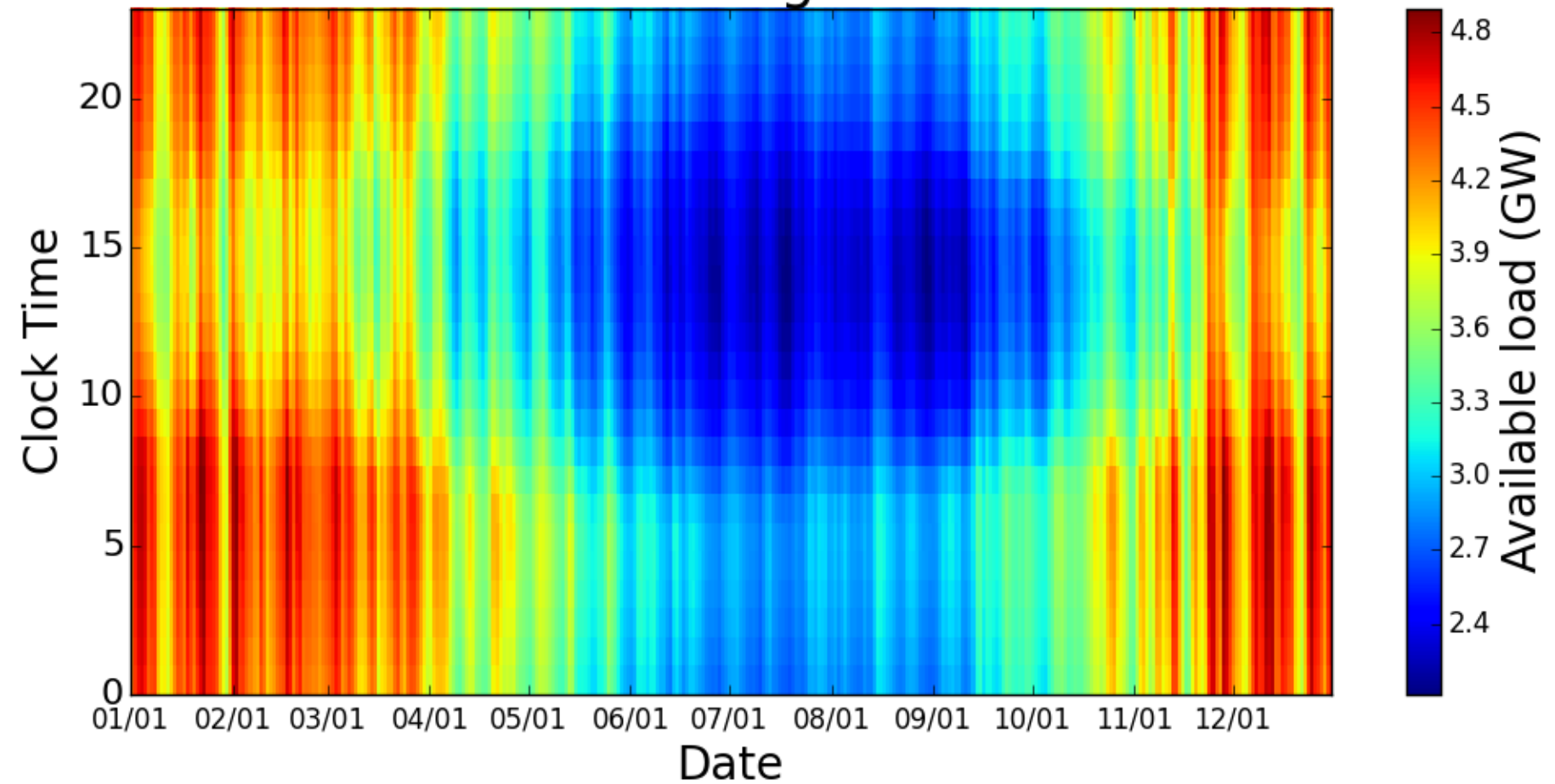
Region: Entire United States
End Use: residential cooling
Product: Regulation



Region: Entire United States
End Use: residential heating
Product: Regulation

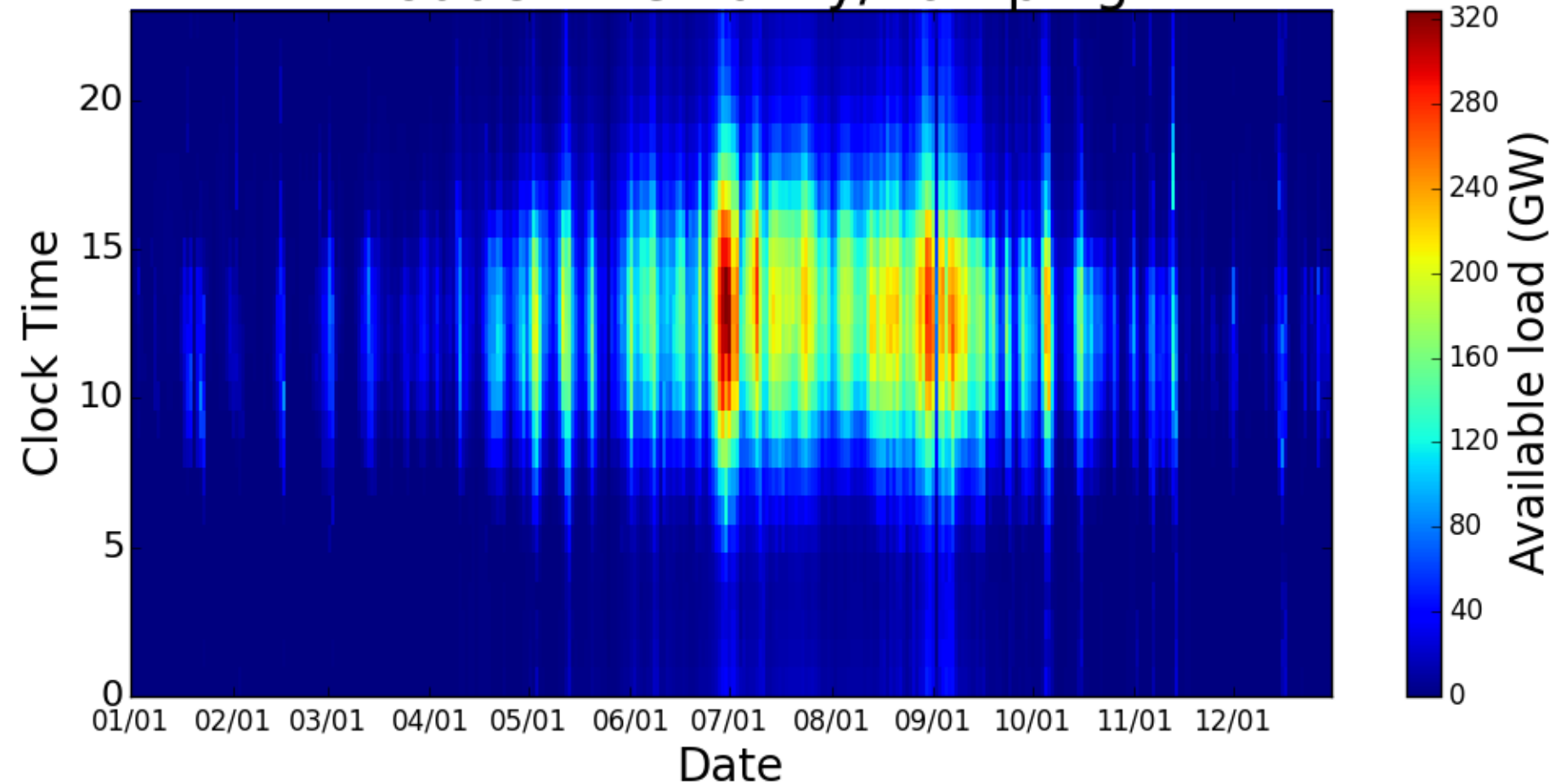


Region: Entire United States
End Use: residential hot water
Product: Regulation

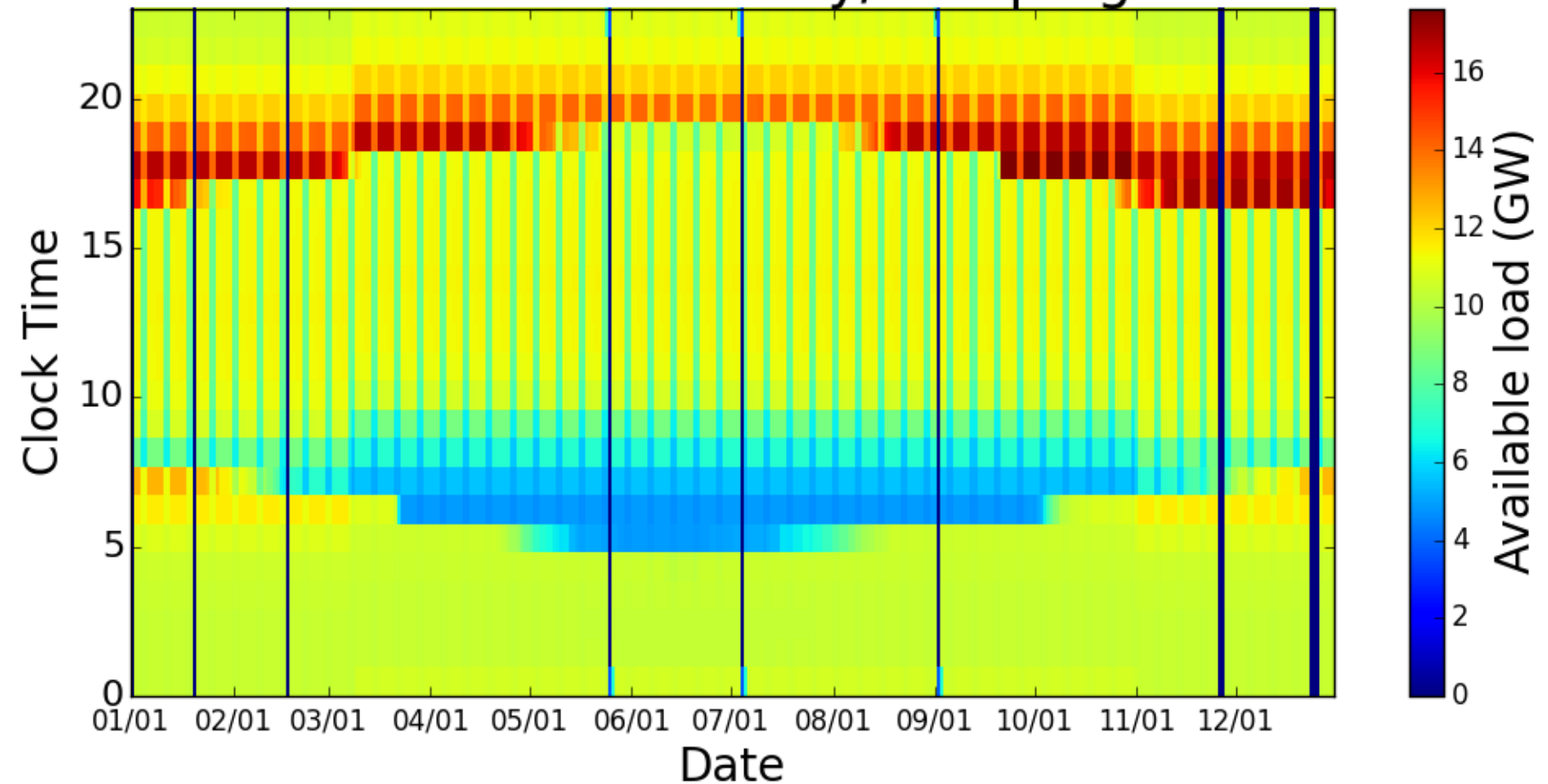


VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Flexibility

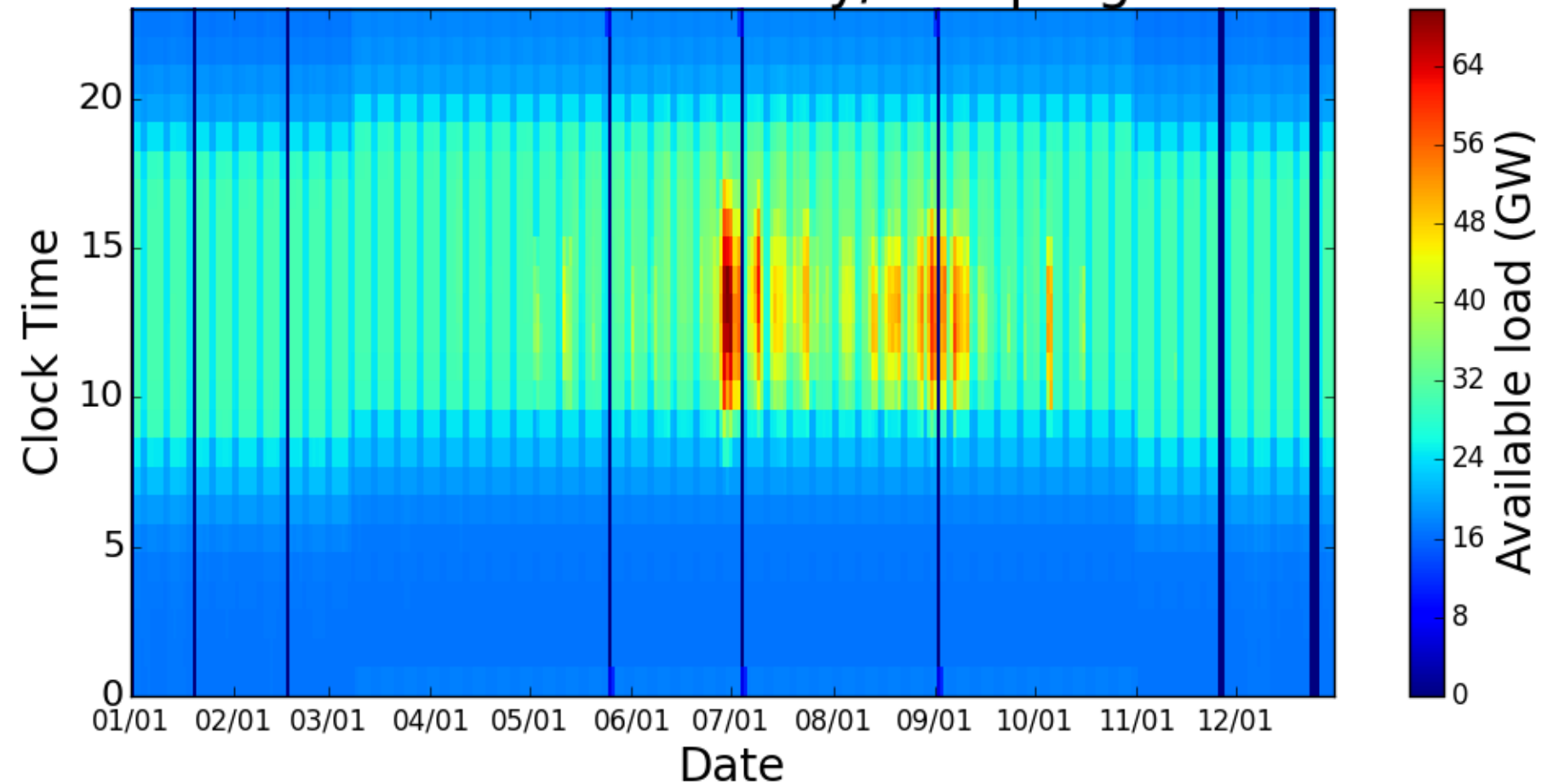
Region: Entire United States
End Use: commercial cooling
Product: Flexibility/Ramping



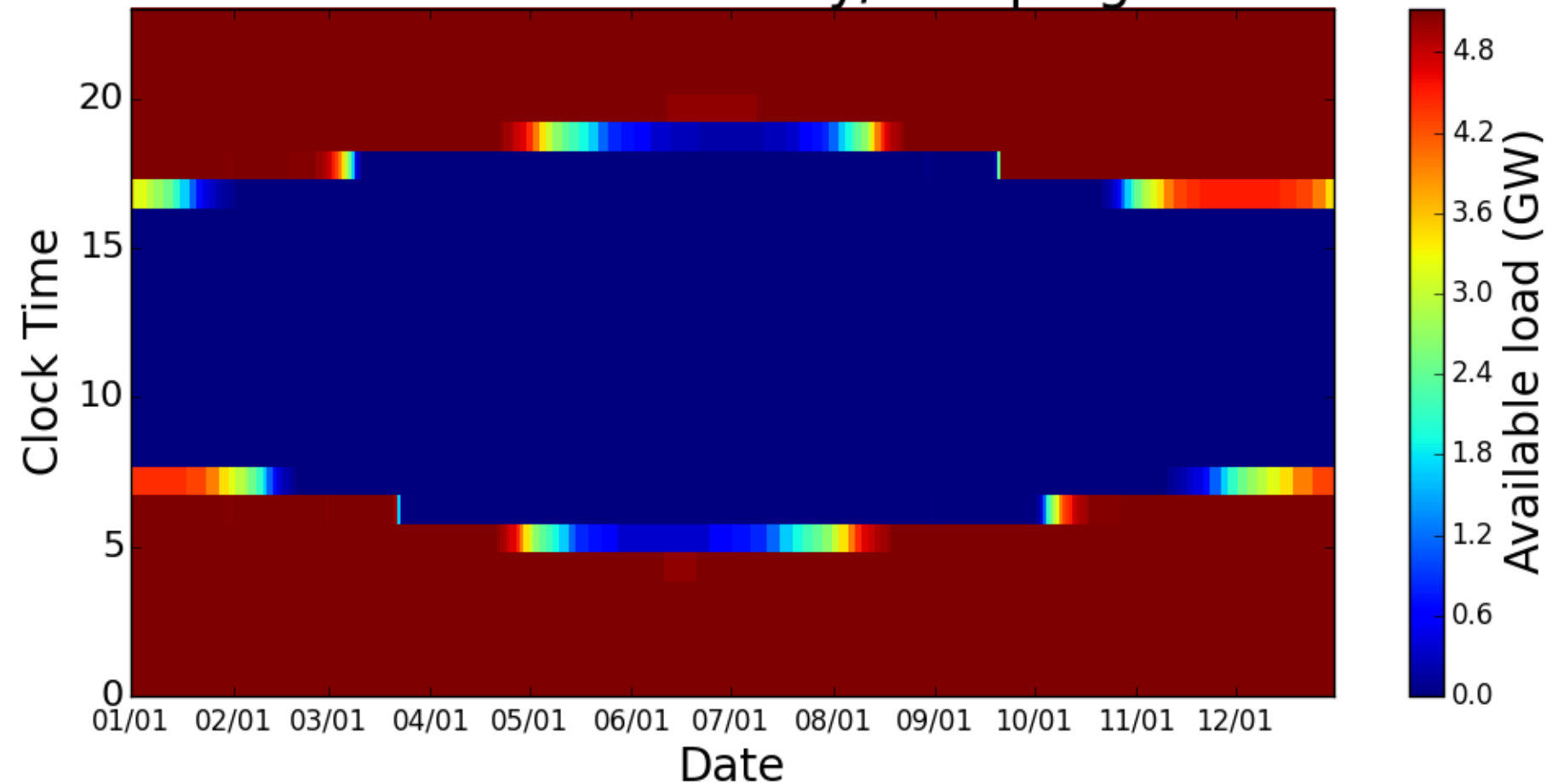
Region: Entire United States
End Use: commercial lighting
Product: Flexibility/Ramping



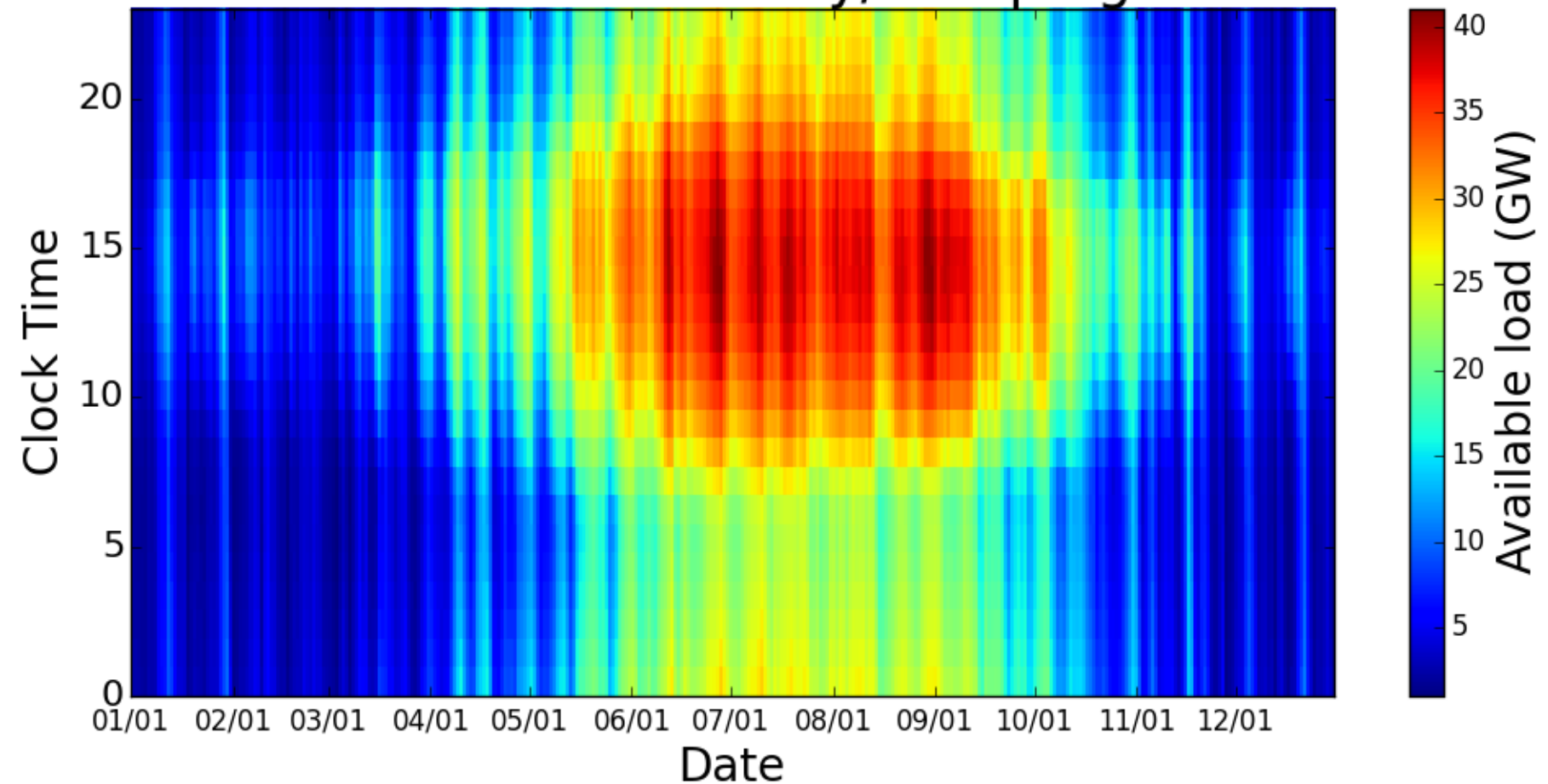
Region: Entire United States
End Use: commercial ventilation
Product: Flexibility/Ramping



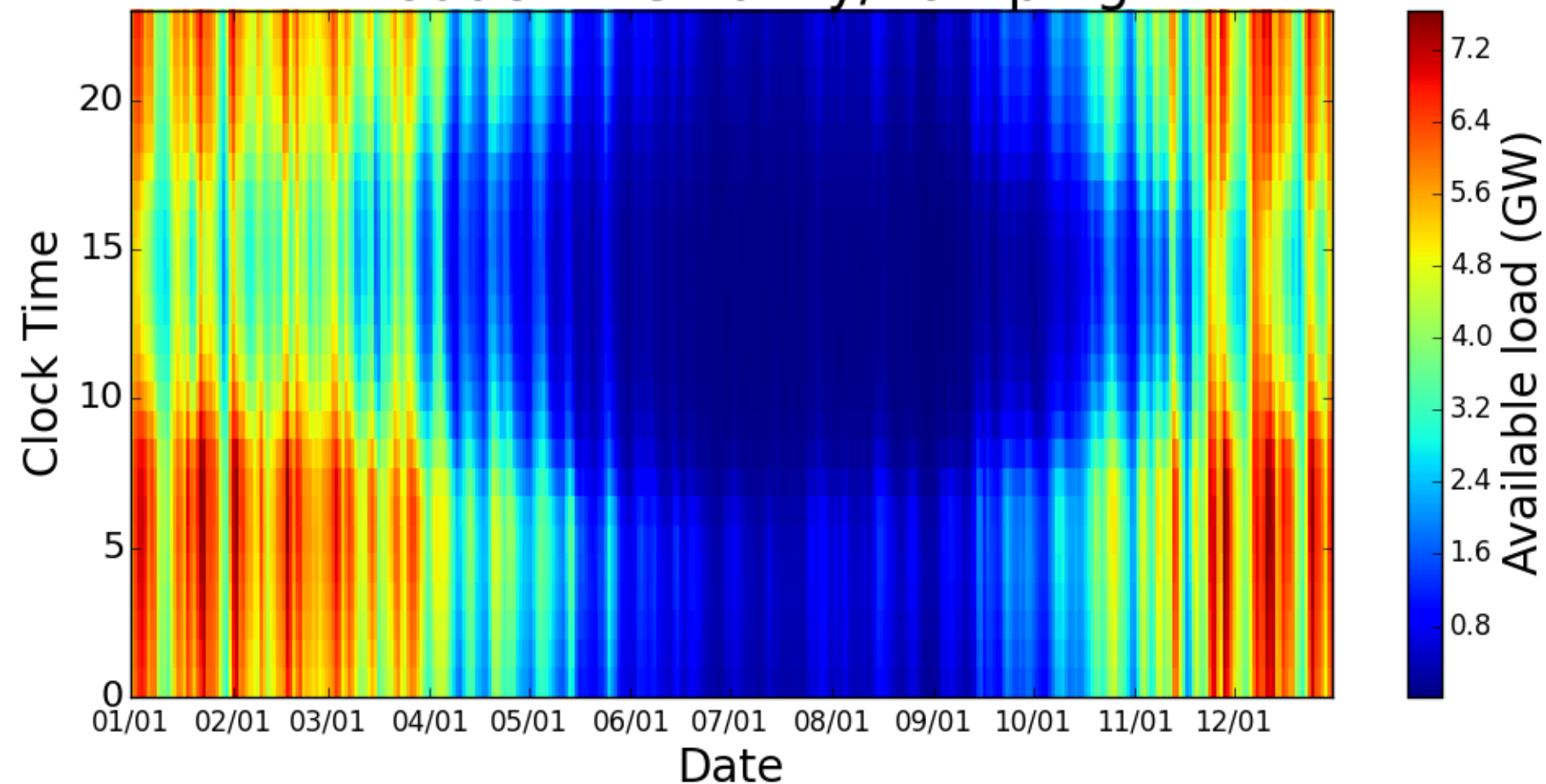
Region: Entire United States
End Use: municipal outdoor lighting
Product: Flexibility/Ramping



Region: Entire United States
End Use: residential cooling
Product: Flexibility/Ramping



Region: Entire United States
End Use: residential heating
Product: Flexibility/Ramping



Region: Entire United States
End Use: residential hot water
Product: Flexibility/Ramping

