Authors
Dunn, Laurel N.
Berger, Michael A.
Sohn, Michael D.

Publication Date
2015-05-01

BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

Demand Response Forecasting Methodology

Laurel N. Dunn, Michael A. Berger, Michael D. Sohn

Delivered: May 1, 2015

Updated: June 24, 2016

This work was supported by the U.S. Department of Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH11231.

Disclaimer

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

List of Appendices

- 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			

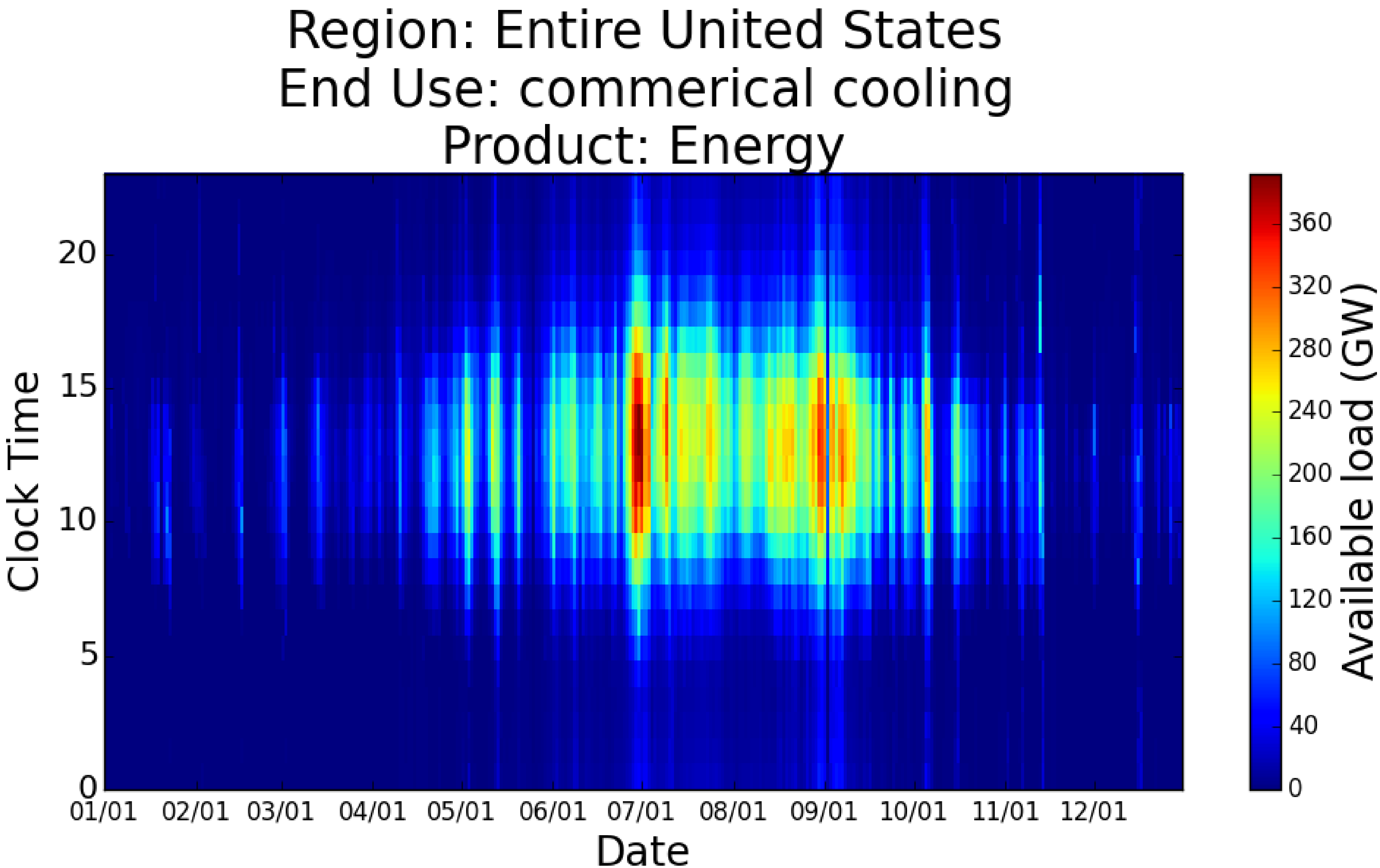
Project Overview: End Use Mapping

	Products				
Resources	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				✔	✔

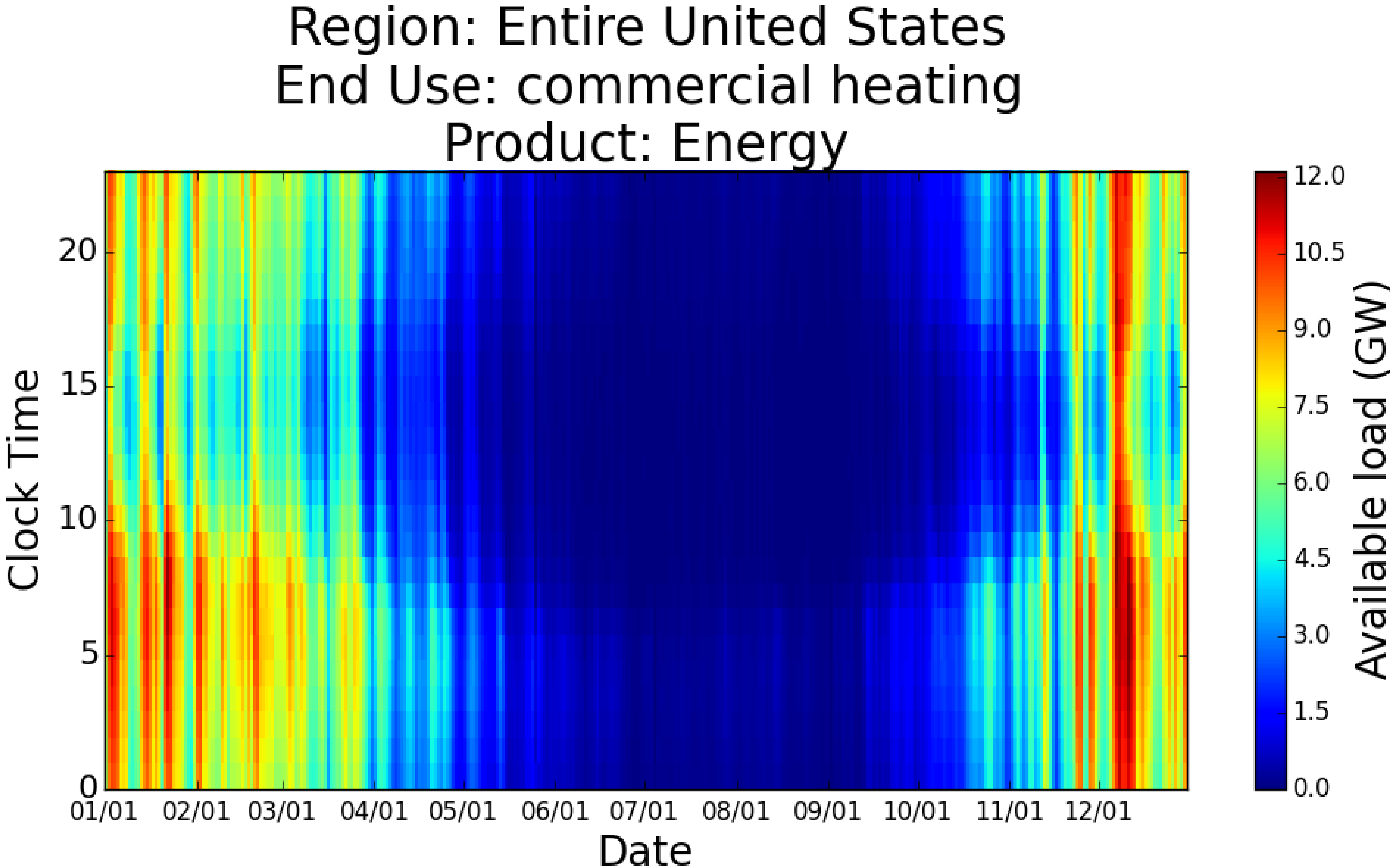
Project Overview: Weather

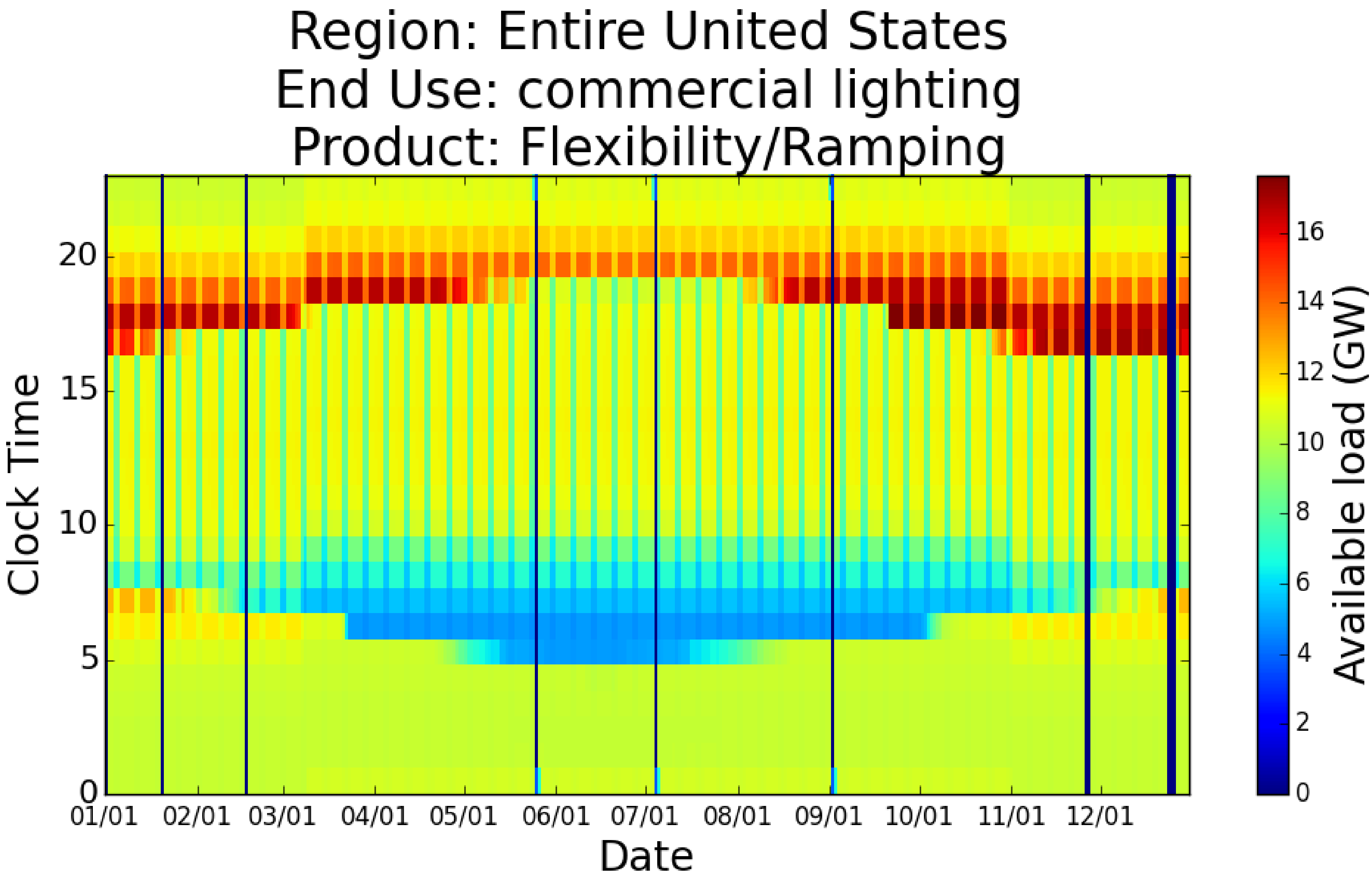
- Current results use historical 2013 weather data to represent weather in 2020
- Results are also available for a 2006 weather year

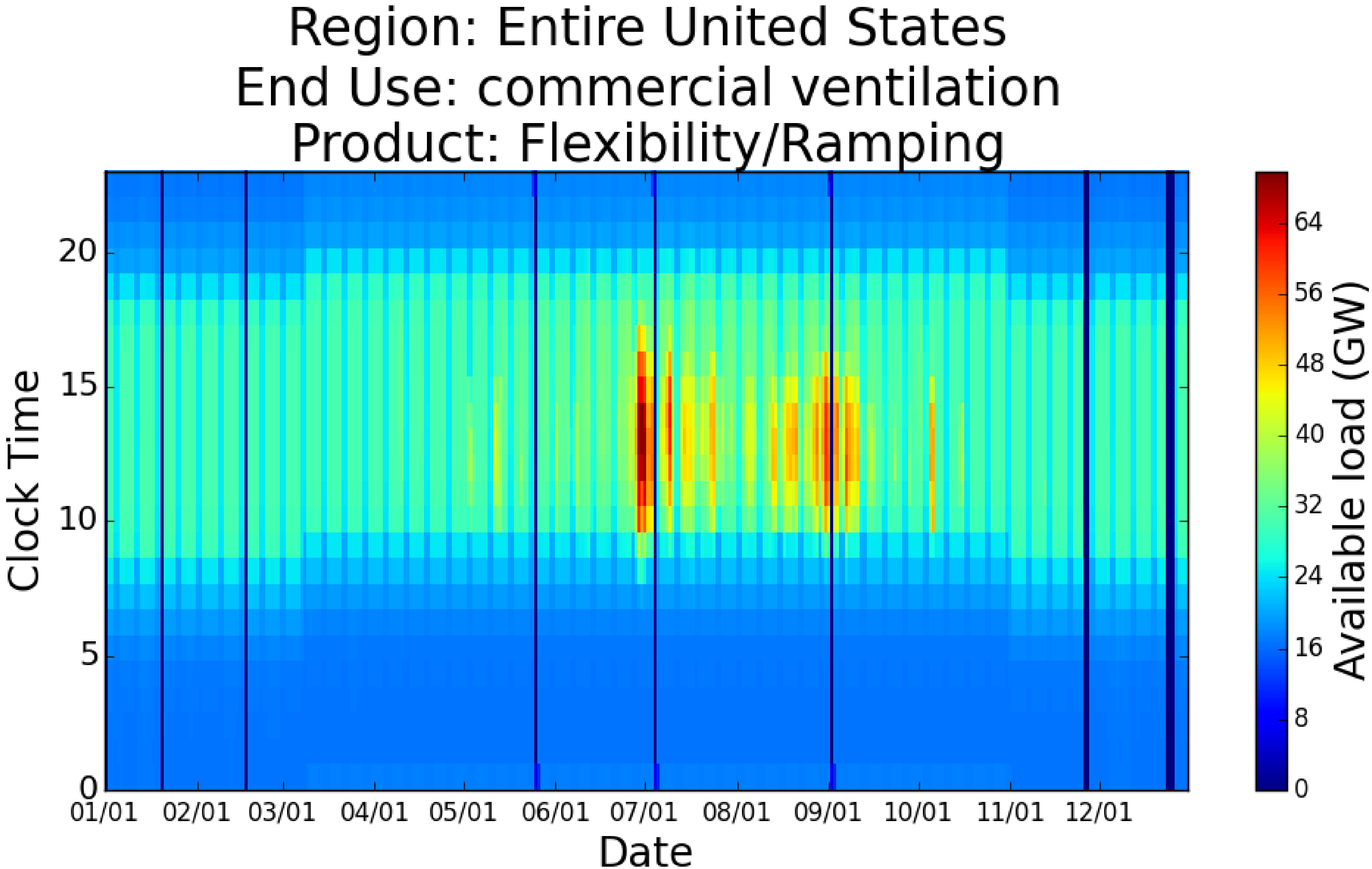
RESULTS:
Annual Demand Response Availability



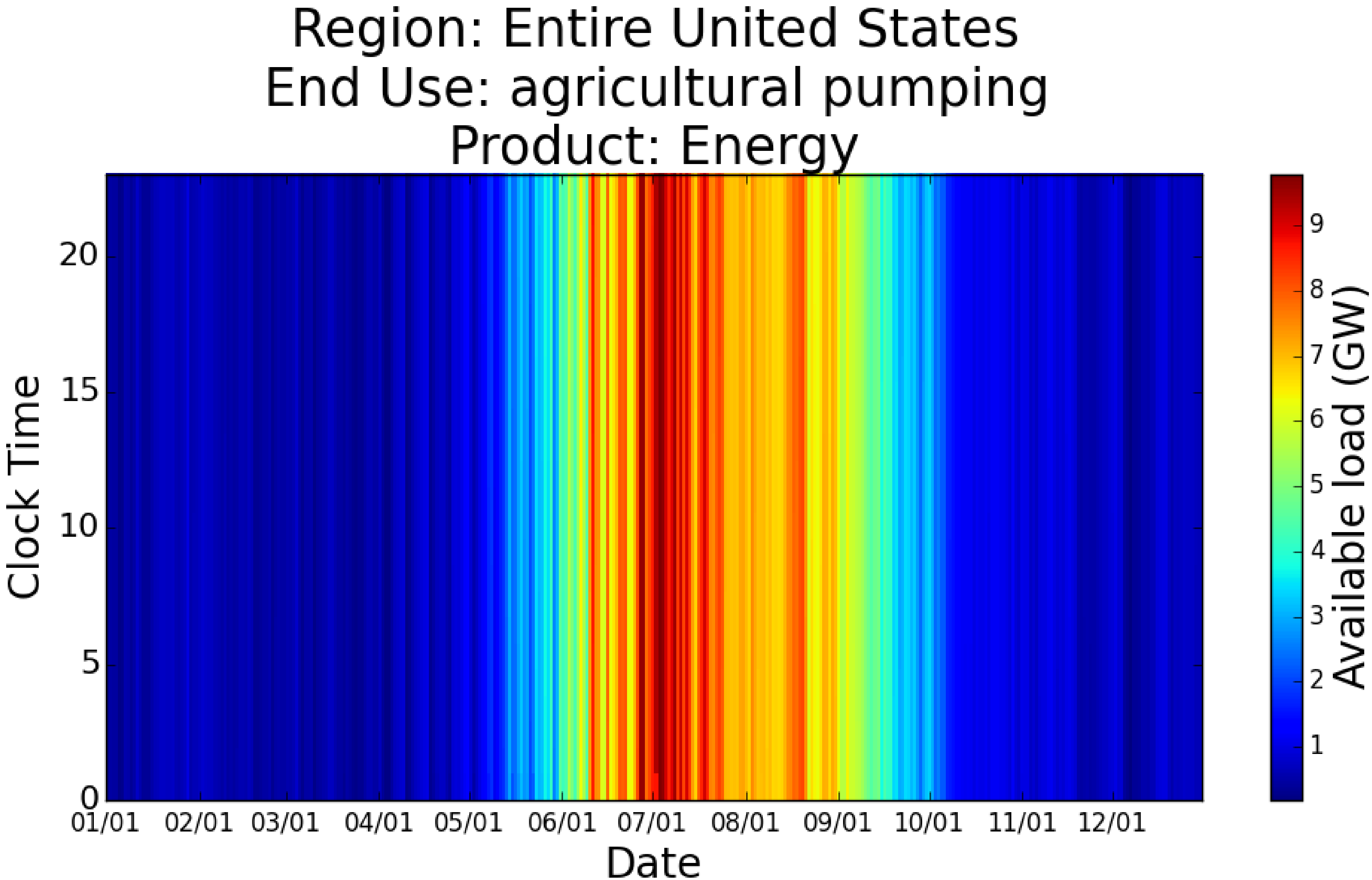
Region: Entire United States
End Use: commerical cooling
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
40
80
120
160
200
240
280
320
360

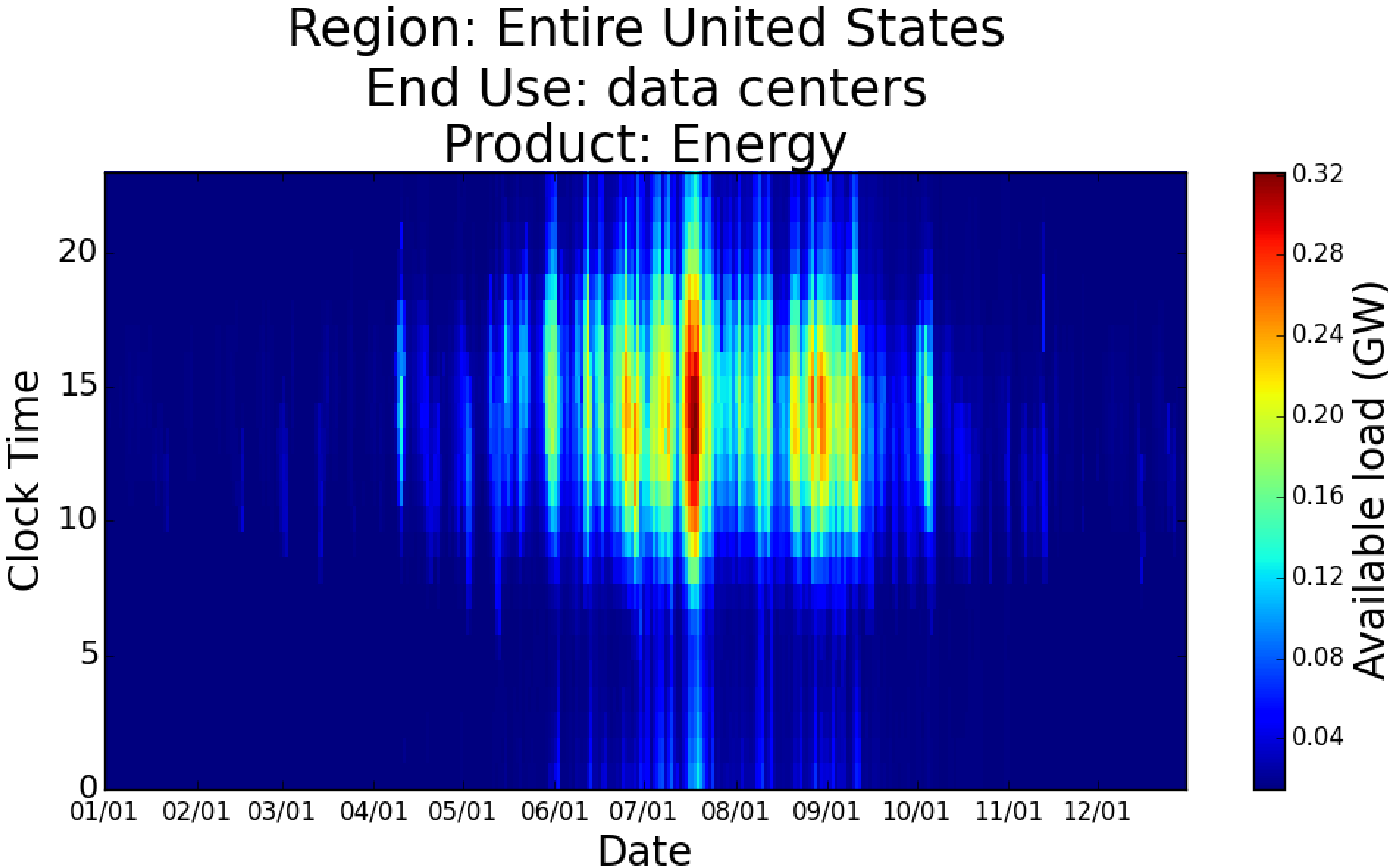

Region: Entire United States
End Use: commercial heating
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0


Region: Entire United States
End Use: commercial lighting
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
2
4
6
8
10
12
14
16

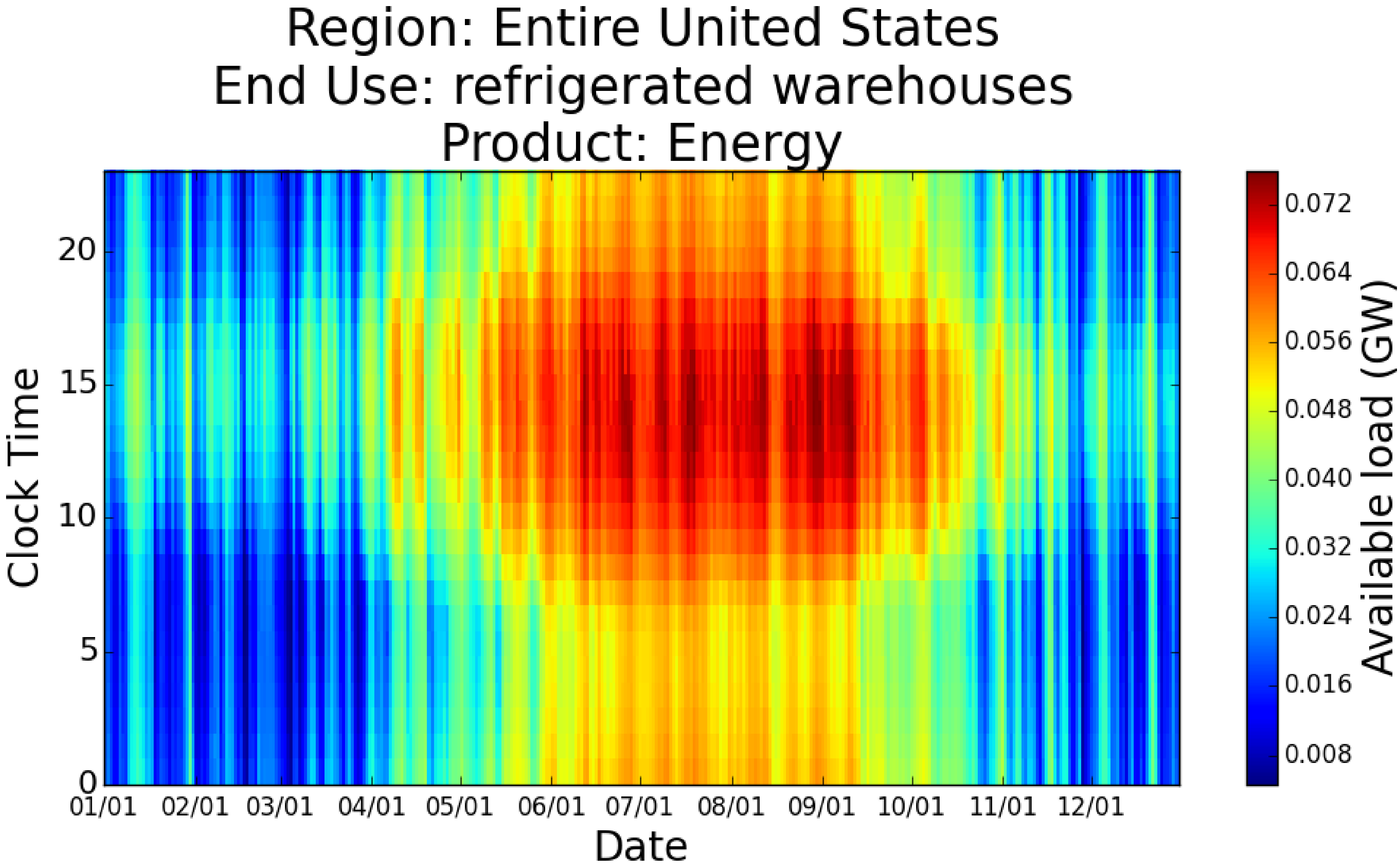


Region: Entire United States
End Use: commercial ventilation
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
0
8
16
24
32
40
48
56
64
Available load (GW)

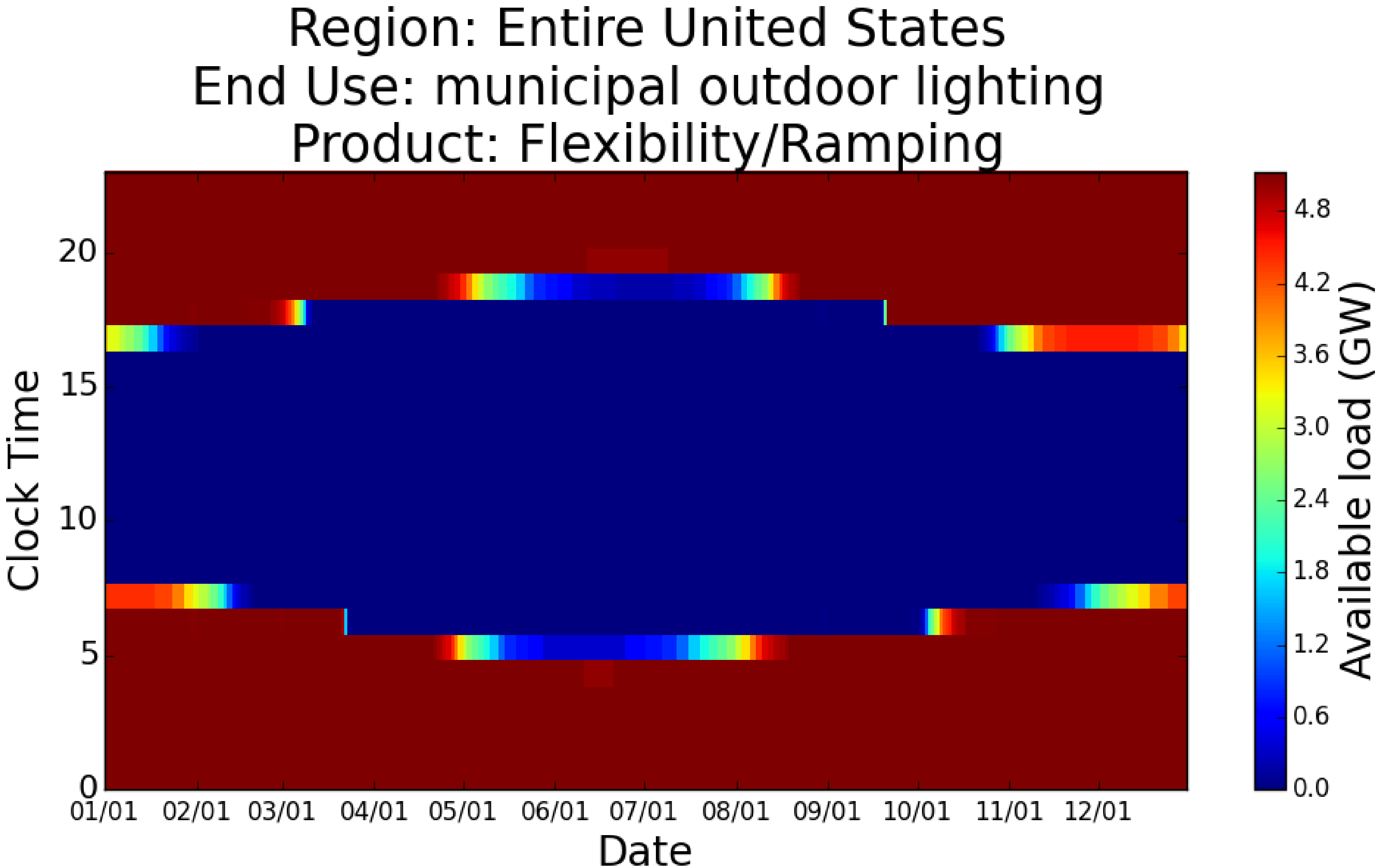

Region: Entire United States
End Use: agricultural pumping
Product: Energy
Clock Time
0
5
10
15
20
01/01 02/01 03/01 04/01 05/01 06/01 07/01 08/01 09/01 10/01 11/01 12/01
Date
Available load (GW)
1
2
3
4
5
6
7
8
9

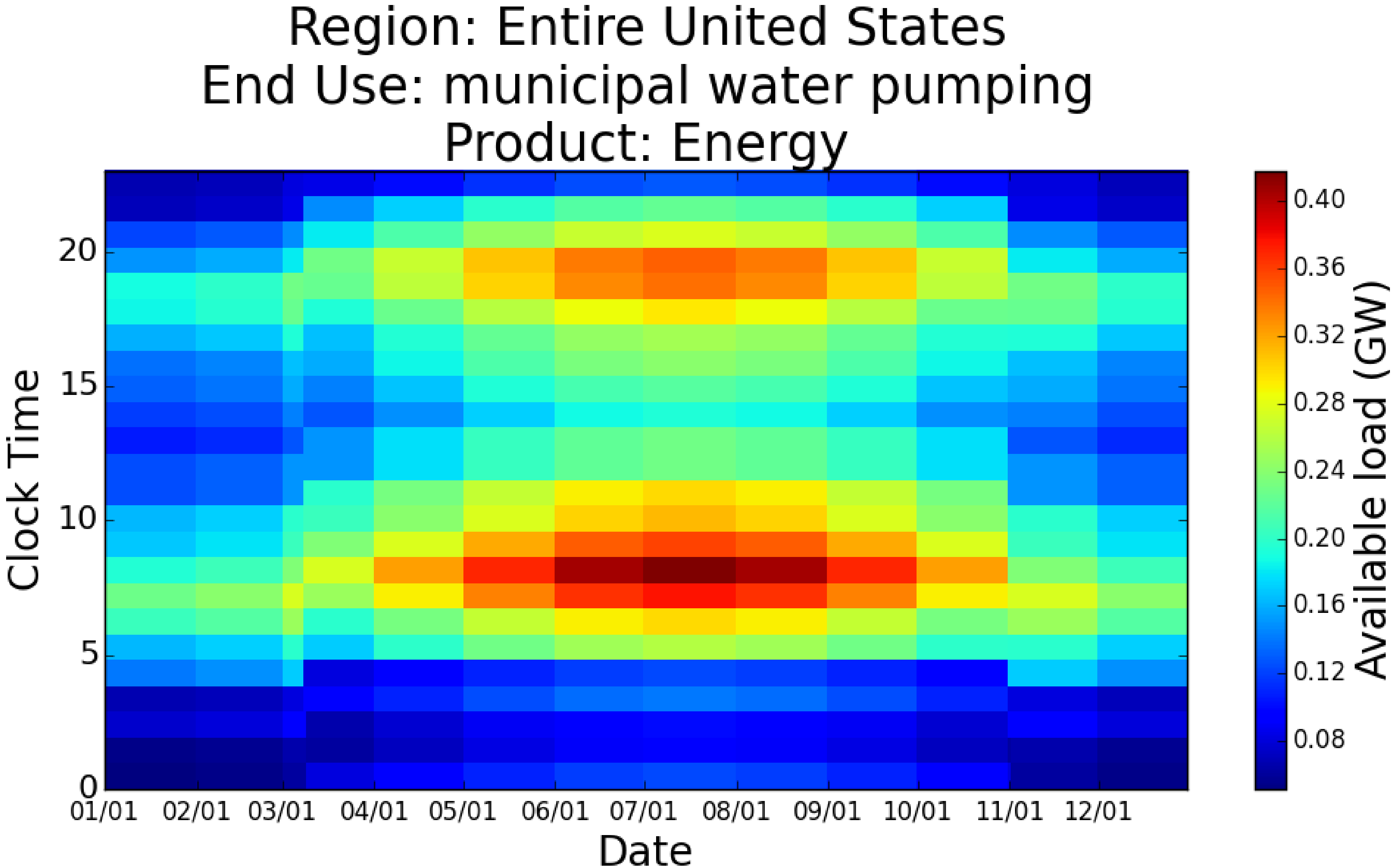


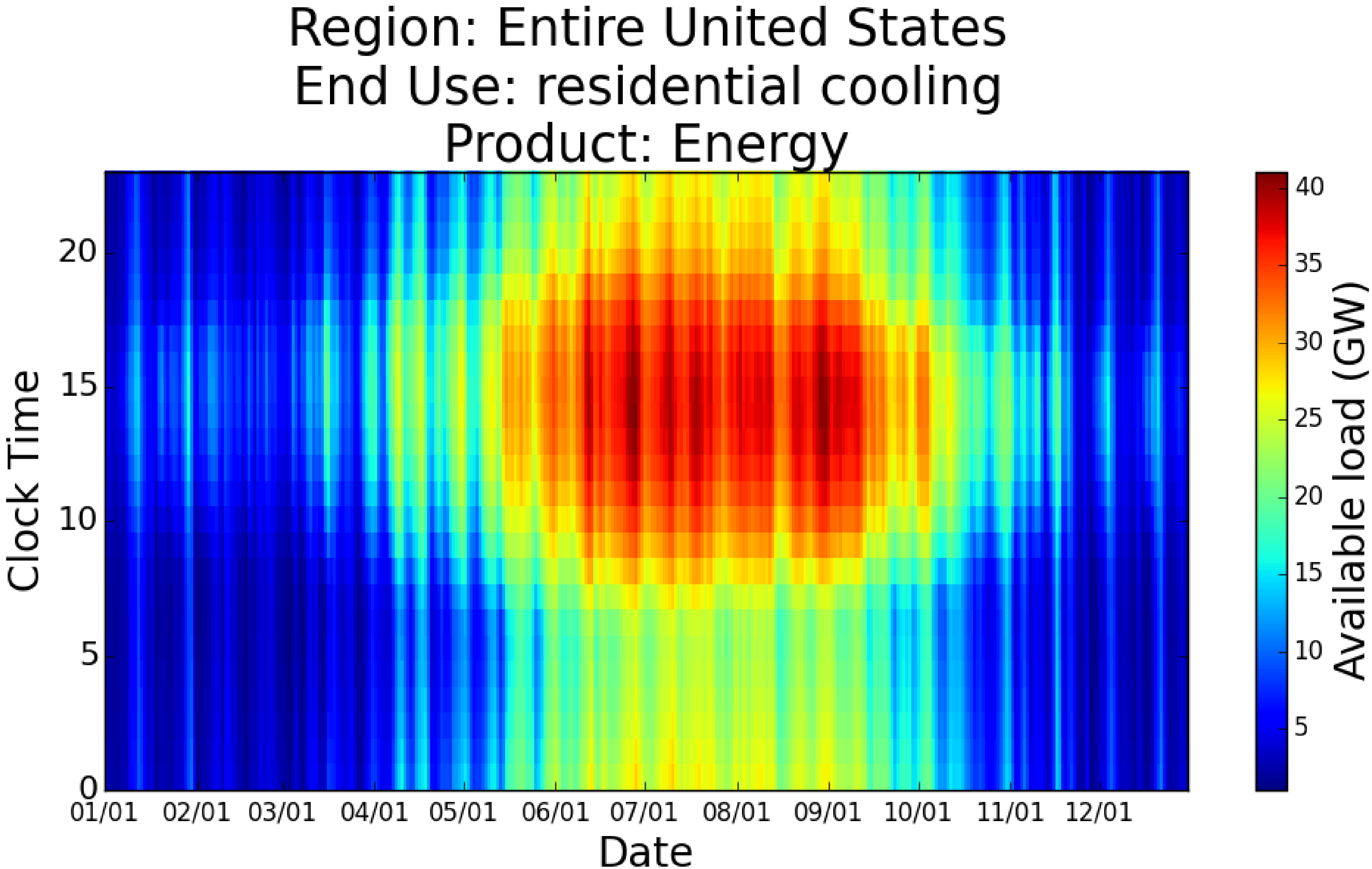
Region: Entire United States
End Use: data centers
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32

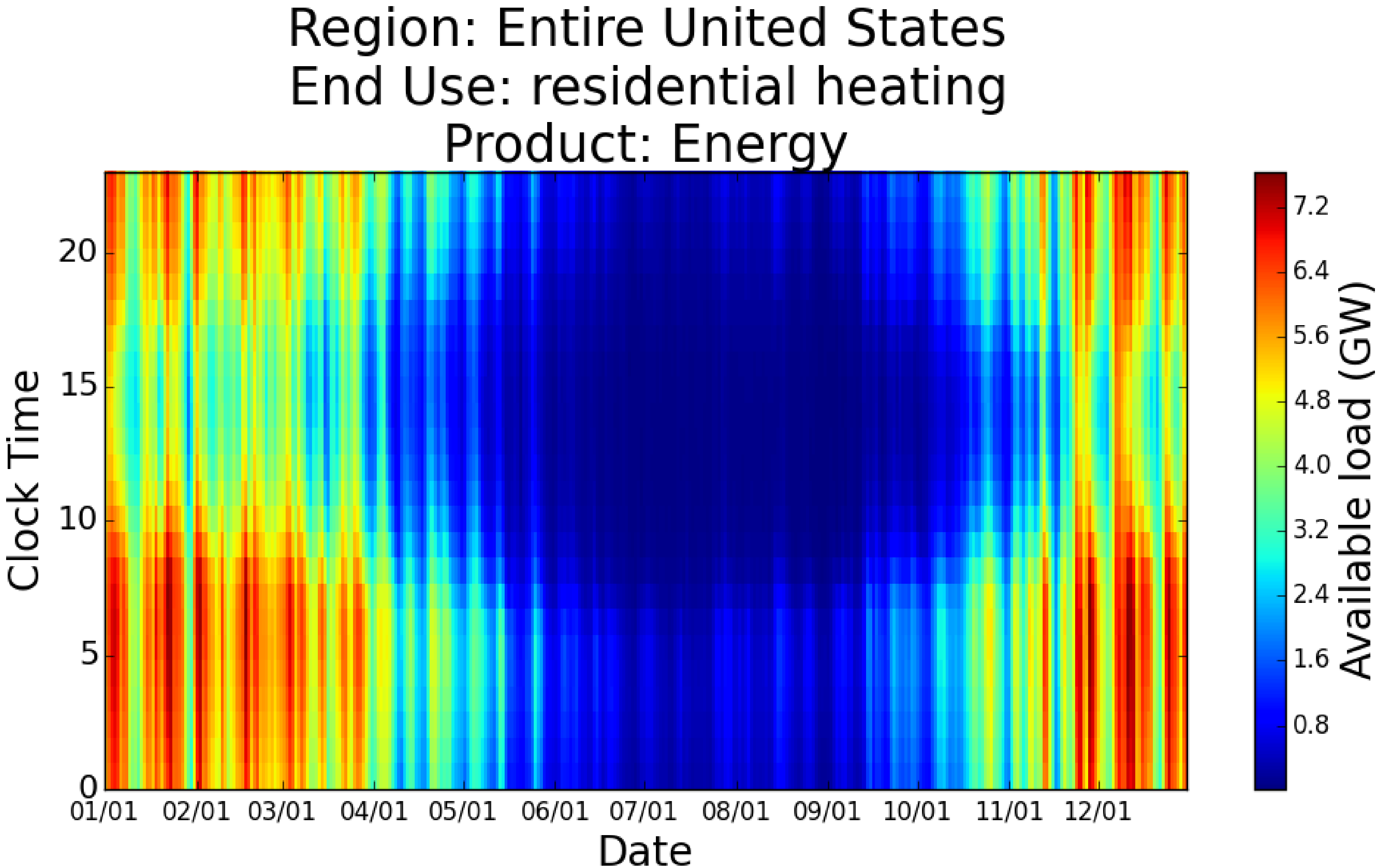


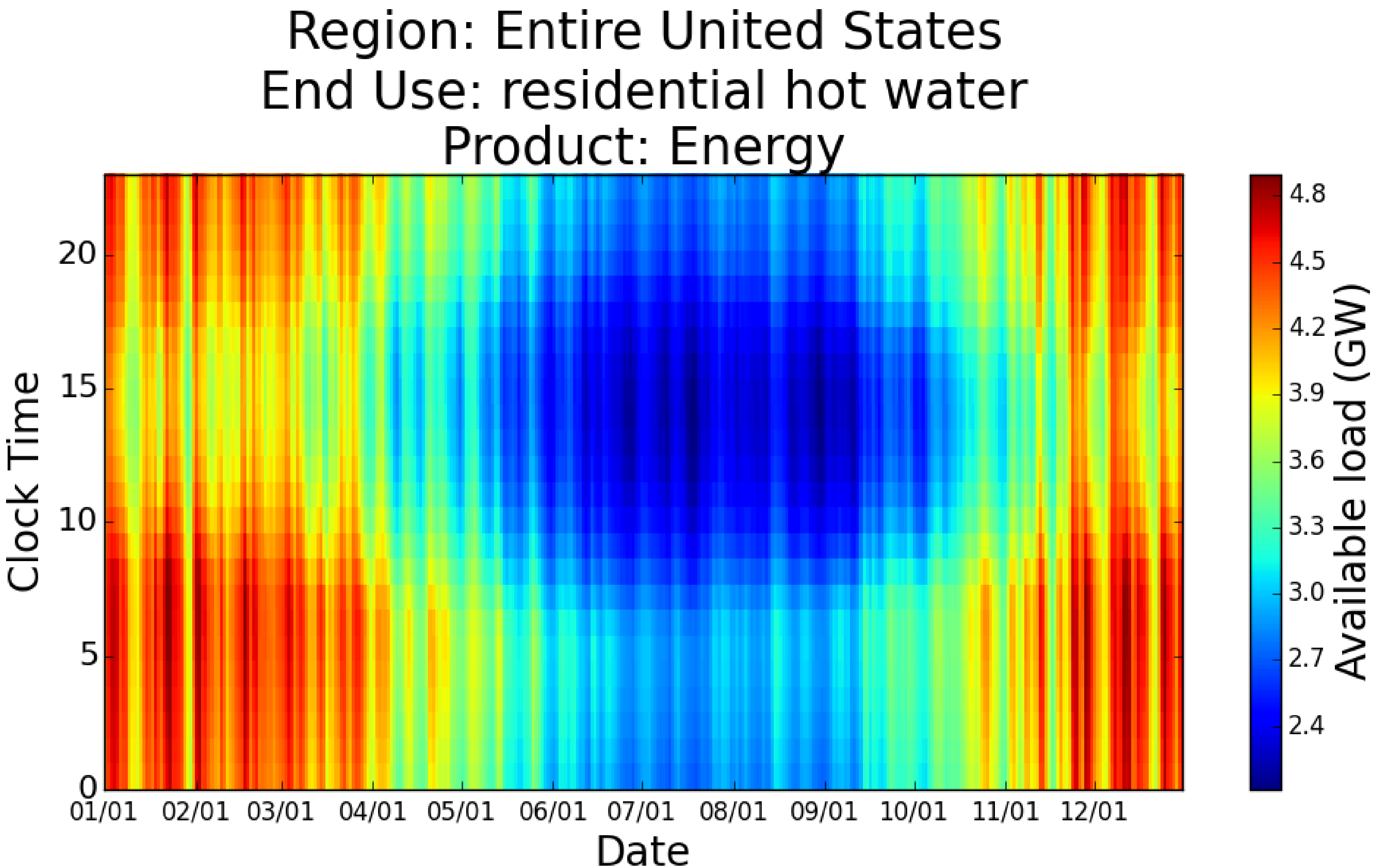
Region: Entire United States
End Use: refrigerated warehouses
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
0.072
0.064
0.056
0.048
0.040
0.032
0.024
0.016
0.008
Available load (GW)


Region: Entire United States
End Use: municipal outdoor lighting
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
Date
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Available load (GW)
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
4.8

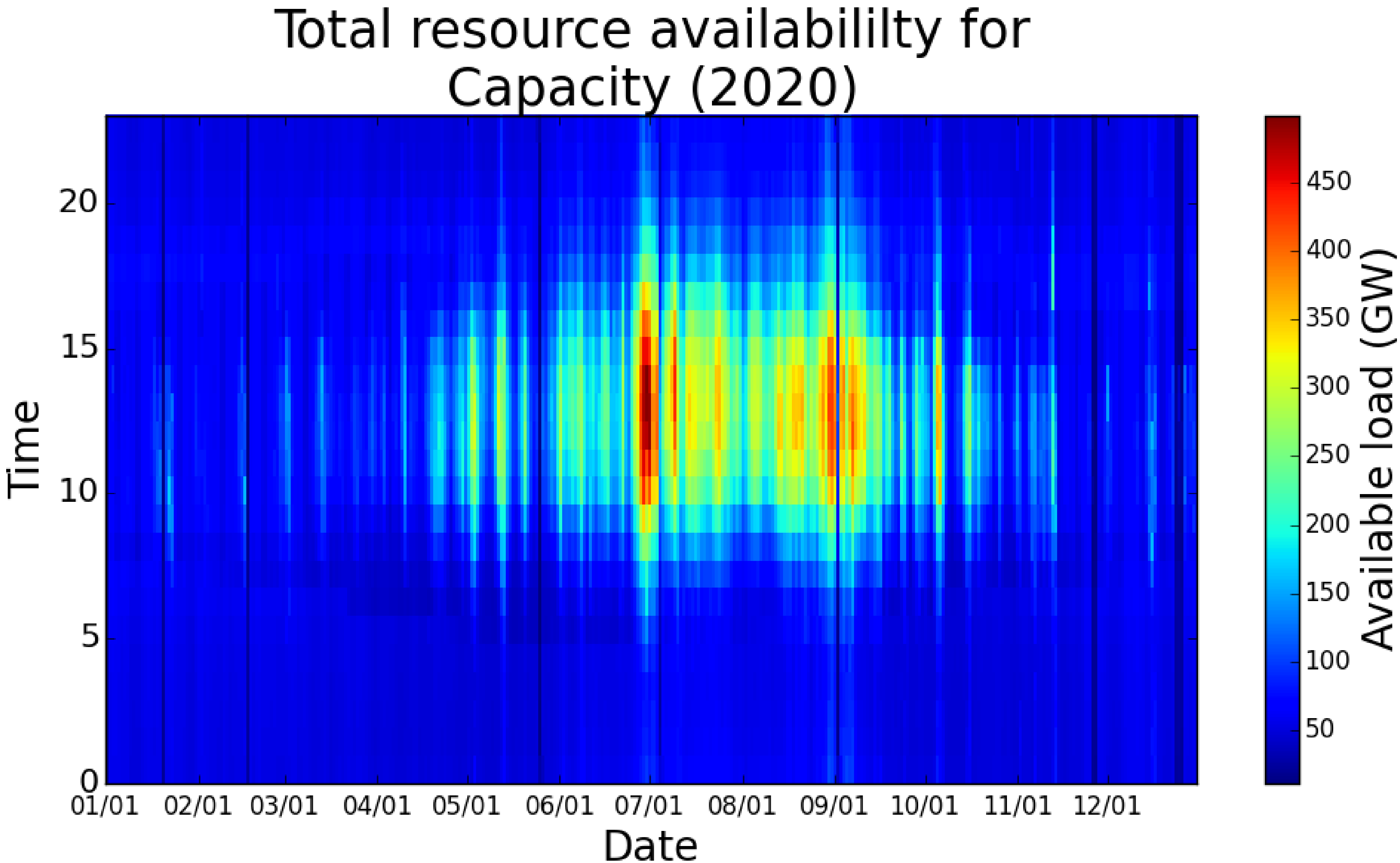

Region: Entire United States
End Use: municipal water pumping
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
Available load (GW)


Region: Entire United States
End Use: residential cooling
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
5
10
15
20
25
30
35
40

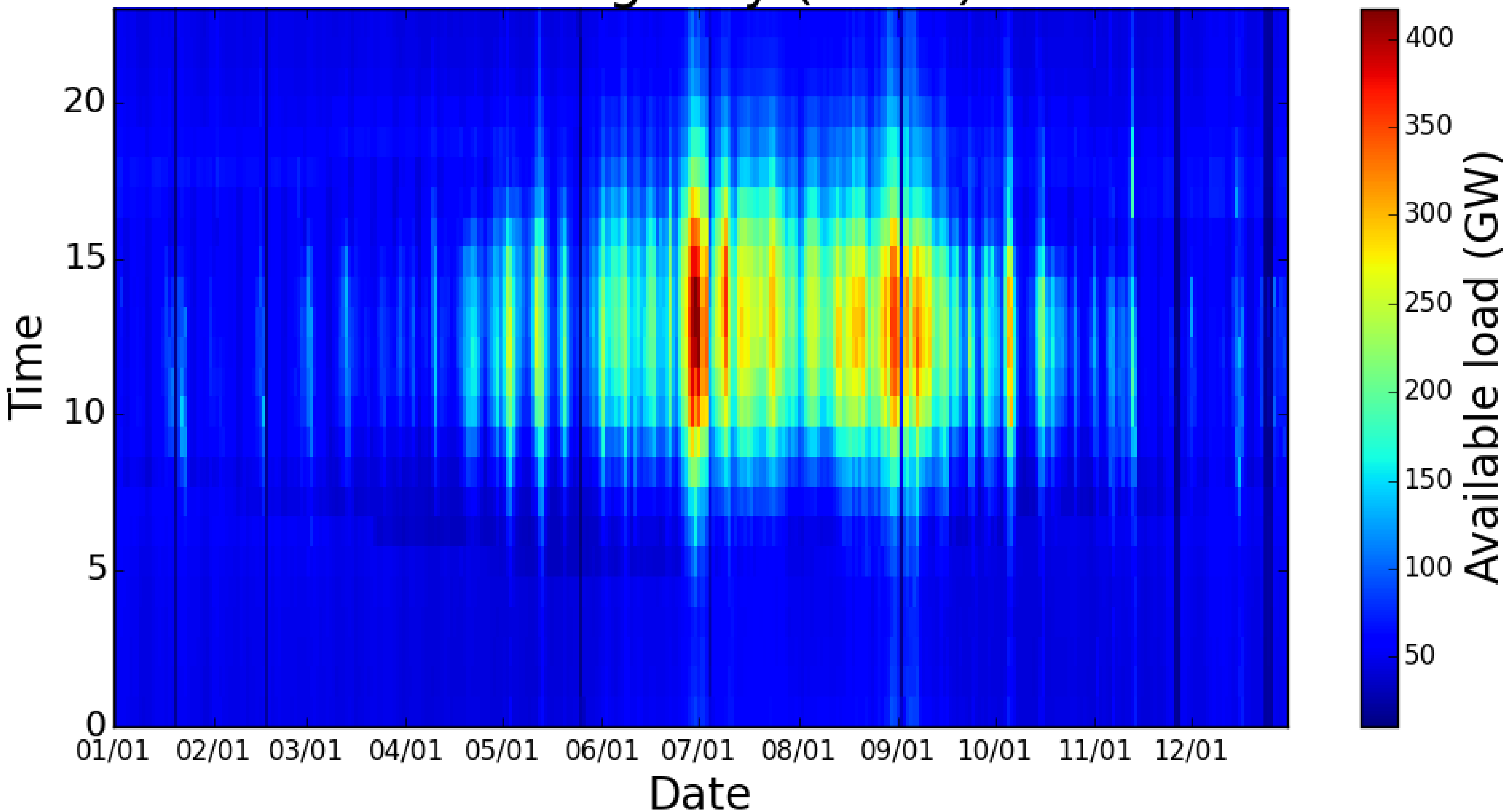

Region: Entire United States
End Use: residential heating
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2

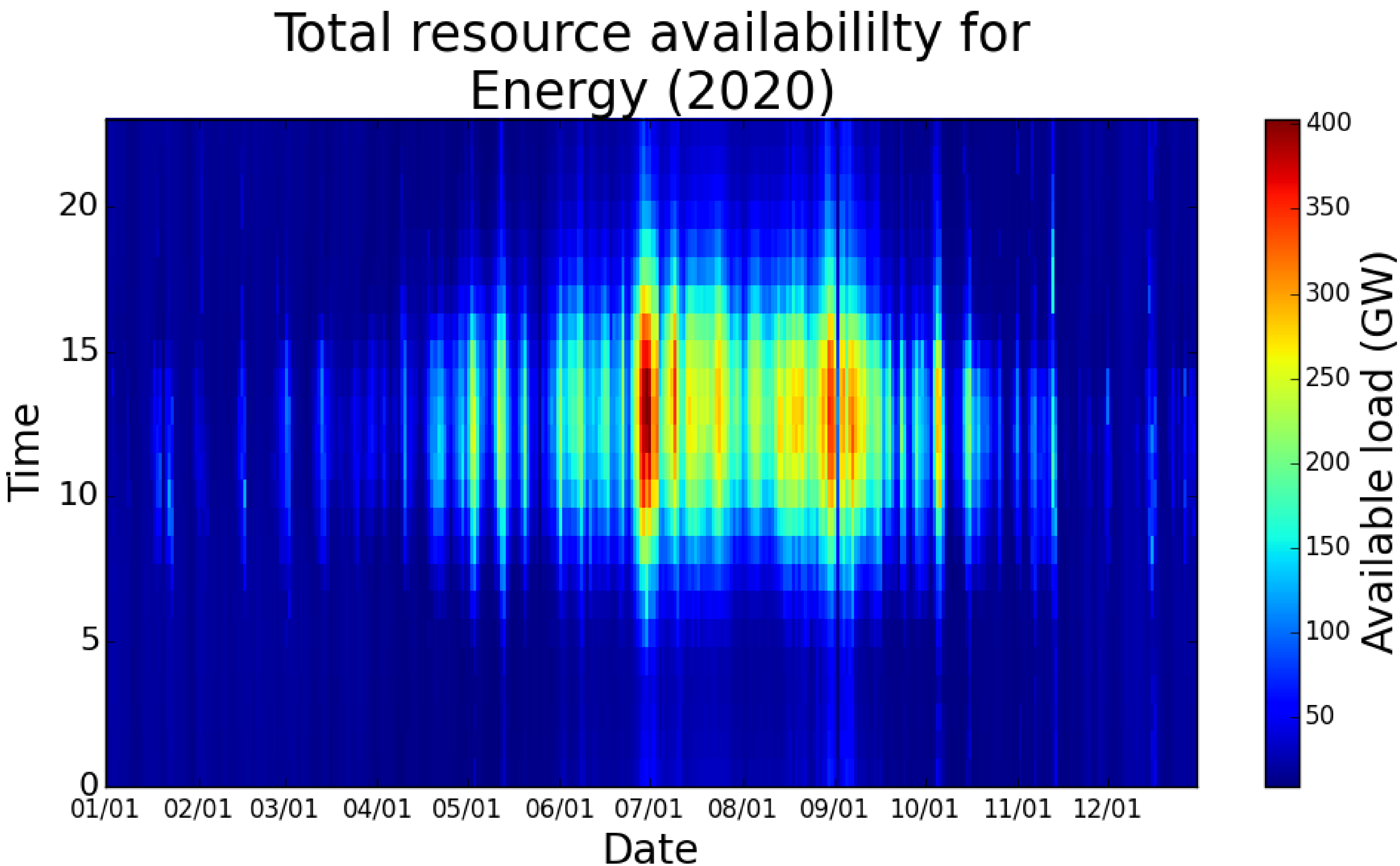

Region: Entire United States
End Use: residential hot water
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
4.8
4.5
4.2
3.9
3.6
3.3
3.0
2.7
2.4
Available load (GW)

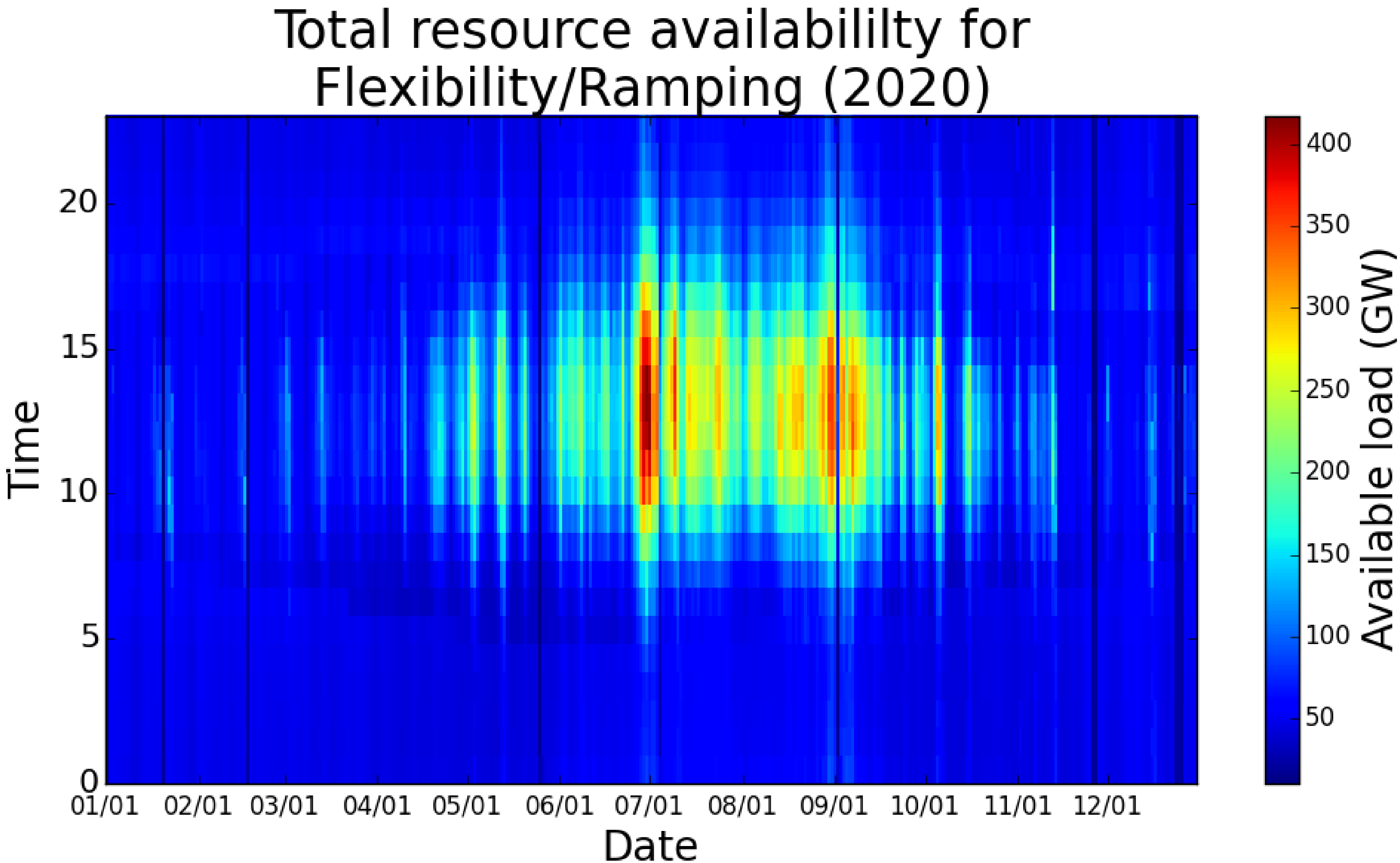
RESULTS:
Hourly Demand Response Availability by Product For All End Uses

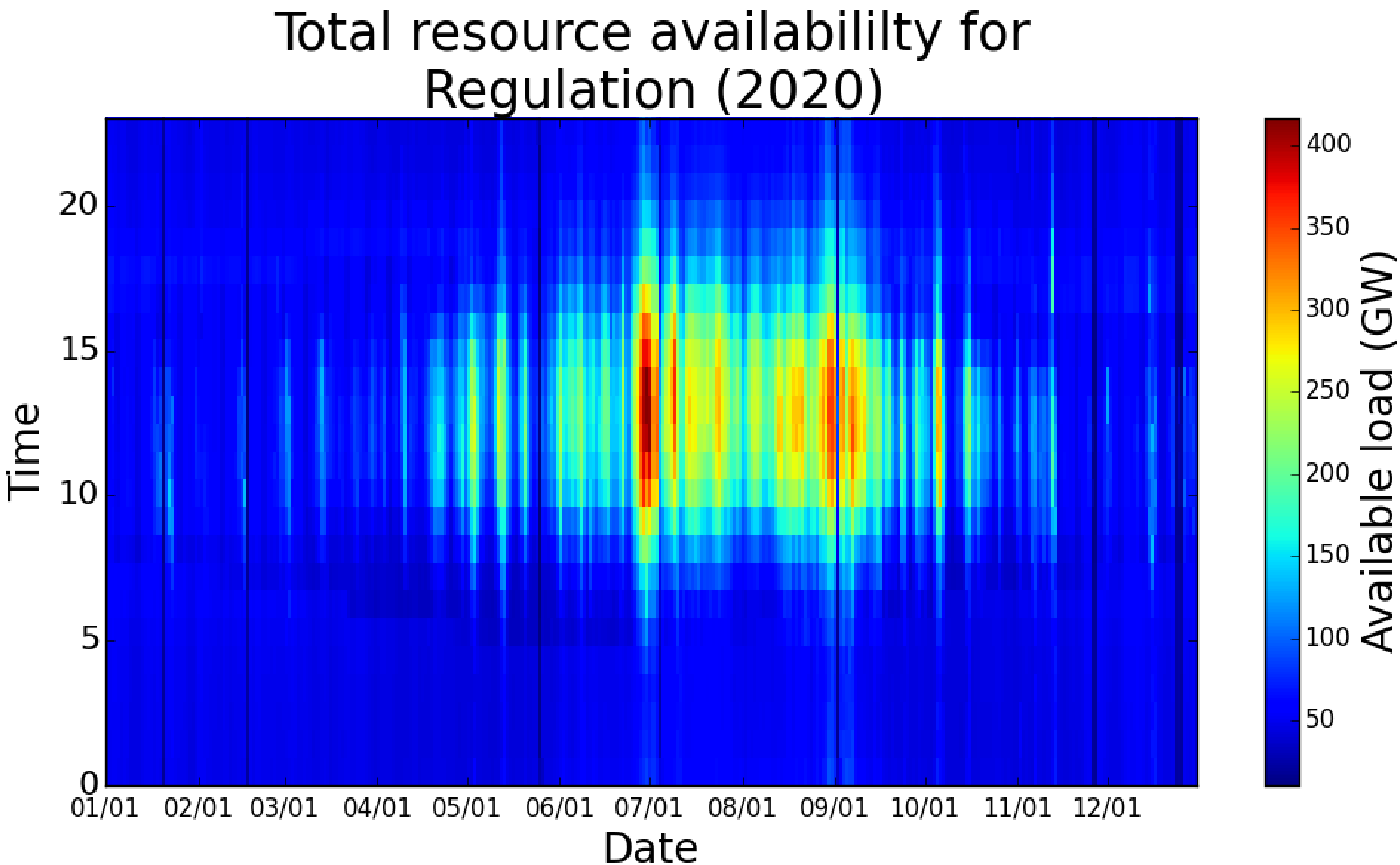

Total resource availabililty for
Capacity (2020)
Time
20
15
10
5
0
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
450
400
350
300
250
200
150
100
50

Total resource availabililty for Contingency (2020)



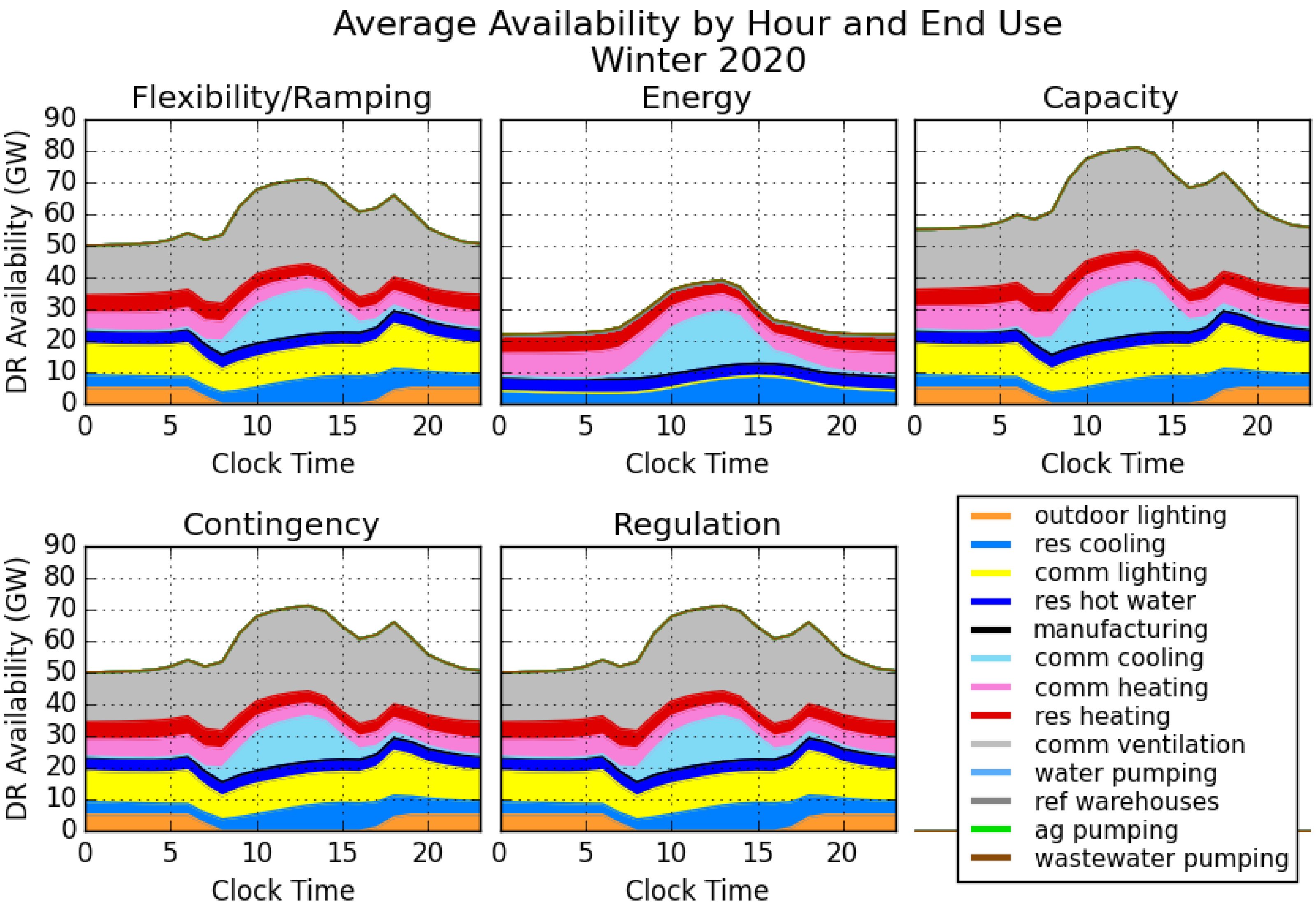

Total resource availabililty for
Energy (2020)
Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
50
100
150
200
250
300
350
400

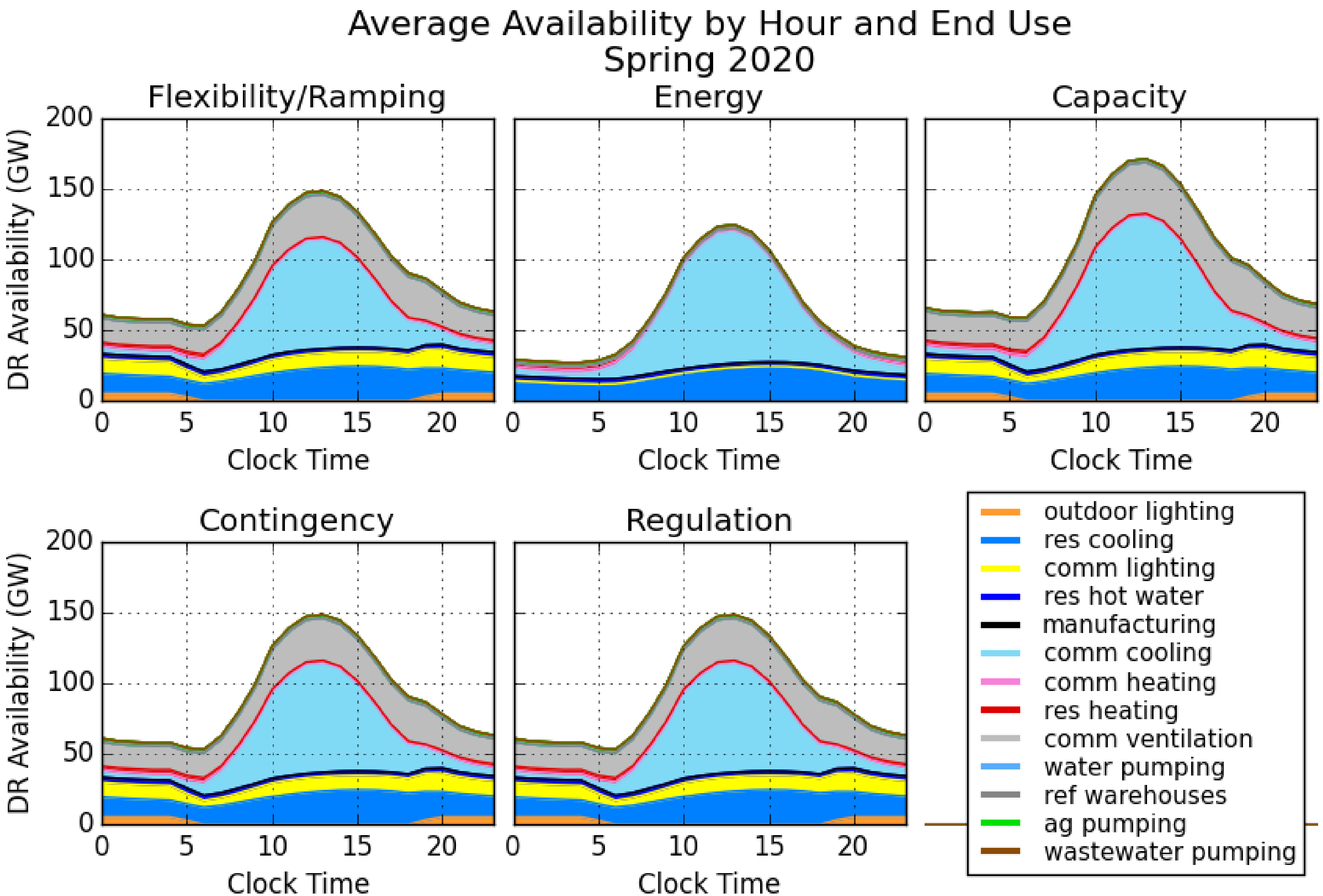

Total resource availabililty for
Flexibility/Ramping (2020)
Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
400
350
300
250
200
150
100
50
Available load (GW)

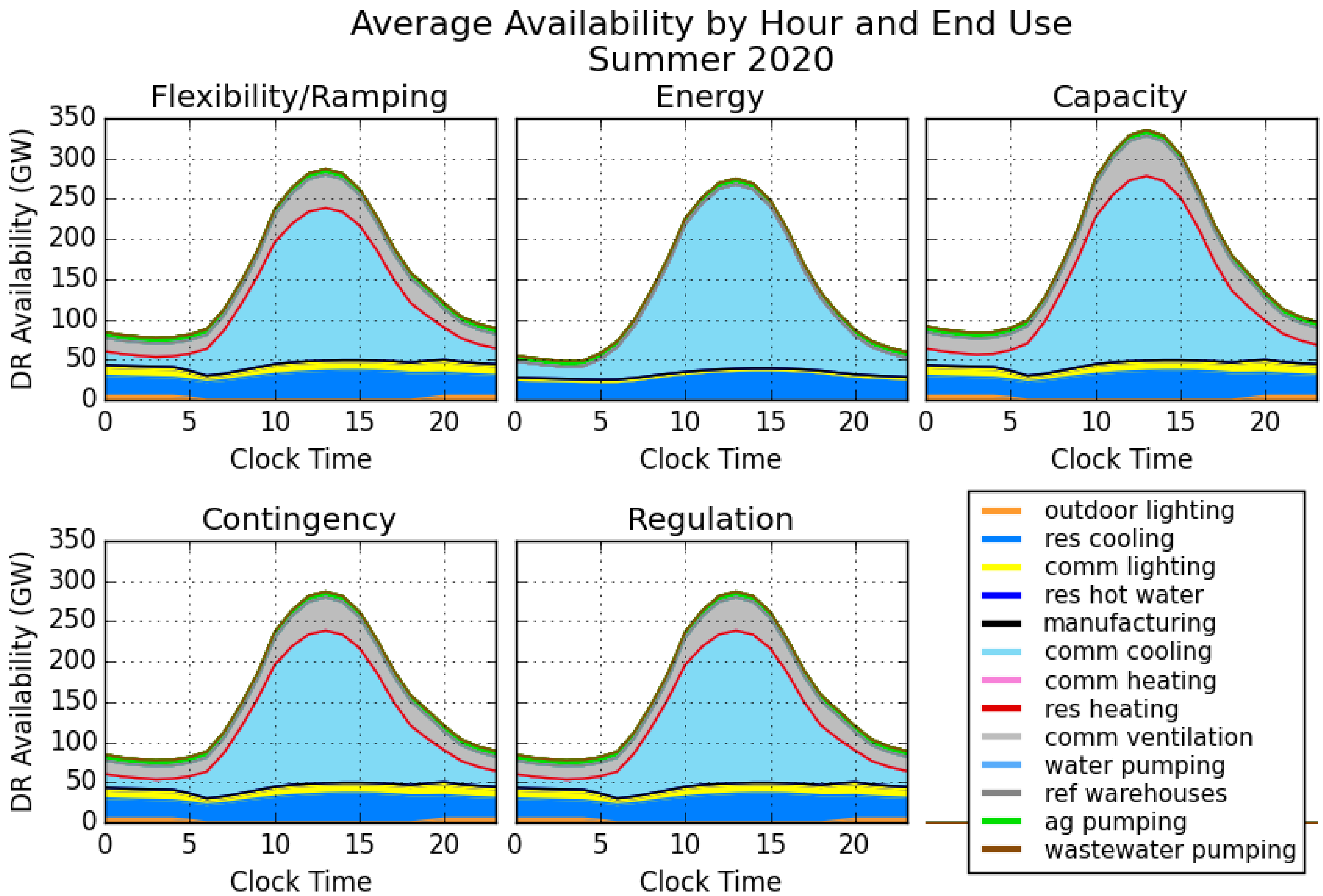


Total resource availabililty for Regulation (2020)
Time
20
15
10
5
0
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
400
350
300
250
200
150
100
50
Available load (GW)

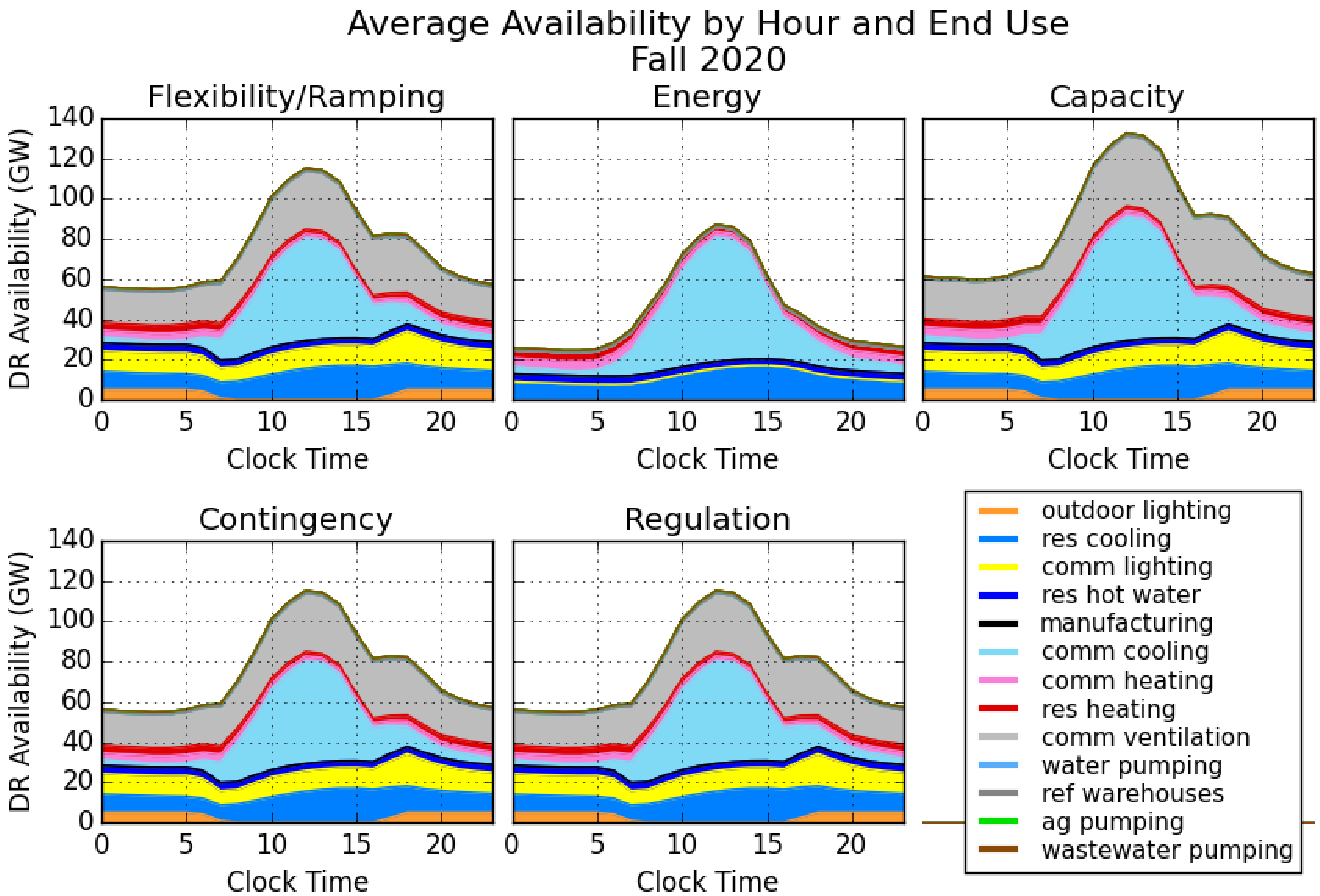
RESULTS:
Average Hourly Demand Response Availability by Season and End Use


Average Availability by Hour and End Use
Winter 2020
Flexibility/Ramping
Energy
Capacity
Contingency
Regulation
DR Availability (GW)
Clock Time
0
10
20
30
40
50
60
70
80
90
5
15
outdoor lighting
res cooling
comm lighting
res hot water
manufacturing
comm cooling
comm heating
res heating
comm ventilation
water pumping
ref warehouses
ag pumping
wastewater pumping


Average Availability by Hour and End Use
Spring 2020
Flexibility/Ramping
Energy
Capacity
Contingency
Regulation
DR Availability (GW)
Clock Time
200
150
100
50
0
0
5
10
15
20
outdoor lighting
res cooling
comm lighting
res hot water
manufacturing
comm cooling
comm heating
res heating
comm ventilation
water pumping
ref warehouses
ag pumping
wastewater pumping



Average Availability by Hour and End Use
Summer 2020
Flexibility/Ramping
Energy
Capacity
Contingency
Regulation
DR Availability (GW)
Clock Time
0
50
100
150
200
250
300
350
0
5
10
15
20
outdoor lighting
res cooling
comm lighting
res hot water
manufacturing
comm cooling
comm heating
res heating
comm ventilation
water pumping
ref warehouses
ag pumping
wastewater pumping


Average Availability by Hour and End Use
Fall 2020
Flexibility/Ramping
Energy
Capacity
Contingency
Regulation
DR Availability (GW)
Clock Time
0
20
40
60
80
100
120
140
0
5
10
15
20
outdoor lighting
res cooling
comm lighting
res hot water
manufacturing
comm cooling
comm heating
res heating
comm ventilation
water pumping
ref warehouses
ag pumping
wastewater pumping

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

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

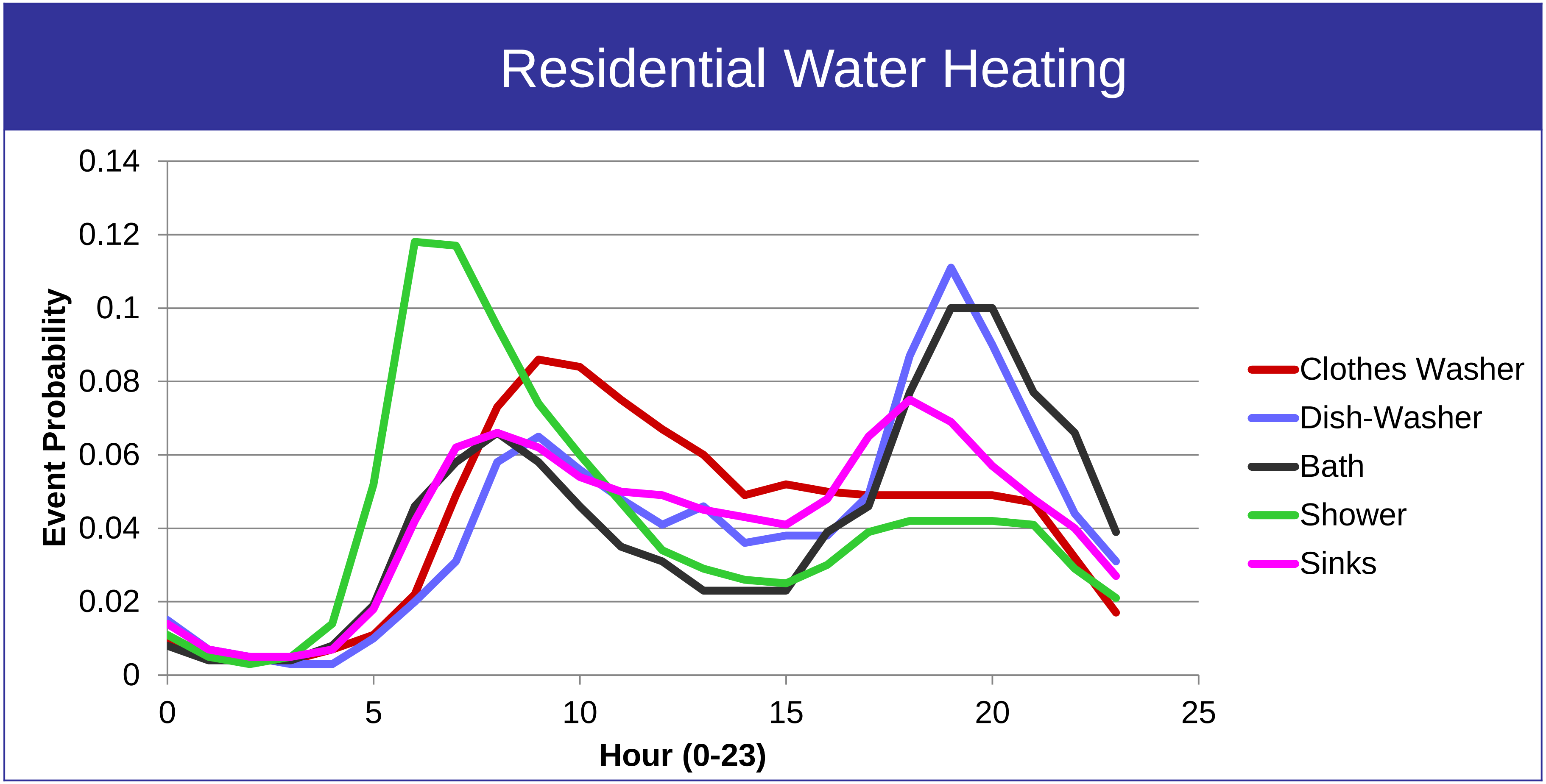
PROCEDURE
Calculating Load Shape

	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



PROCEDURE
Calculating Load Shape

	Residential Water Heating	Data Sources
1	Derive hourly event probability profiles for each hot water use	Hendron and Burch 2007, Hendron and Burch 2010
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: $N = Num_{events} \times Num_{households}$	
4	Load shape = $Volume_{water,i} \times (Temp_{water,i} - Temp_{air,i})$	

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
2	Assign fraction of national load to each BAA based on local data and tech employment. NAICS codes used include:		US Census Bureau
	518	Data processing, Hosting and Related Services	
	5415	Computer Systems Design and Related Services	

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^{o}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 expenditures[1] by average industrial electricity rates in the BAA[2] Pumping load (MWh) = Expense ($) ÷ Cost ($/MWh)	[1] USDA 2013, [2] EIA 2012
2	Weight state pumping load by BAA employment for the following NAICS codes: 11511 Support Activities for Crop Production	US Census Bureau

PROCEDURE
Agricultural Water Pumping

	Load Shape Calculation	Data Sources
1	Determine acreage for each major crop in the state. Assume acreage ranges from: • 0 to 100% planted between start and end planting dates • 100% to 0% between start and end harvesting dates	USDA 1997
2	Calculate irrigation needs per day using the Blaney-Criddle Formula[1]: $Water_{day} = .01 \times T_{air.day} \times p_{day} \times k_{t,day} \times k_{c,day} - rain_{day}$ T_{air} = outdoor air temperature[2] p = percent of annual daylight hours in time period[3] $k_t = 0.0173 \times T_{air} - 0.314$ k_c = crop watering coefficient[4] rain = rainfall in inches[2]	[1] USDA 1993, [2] NOAA 2015, [3] US Naval Observatory, [4] FAO
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

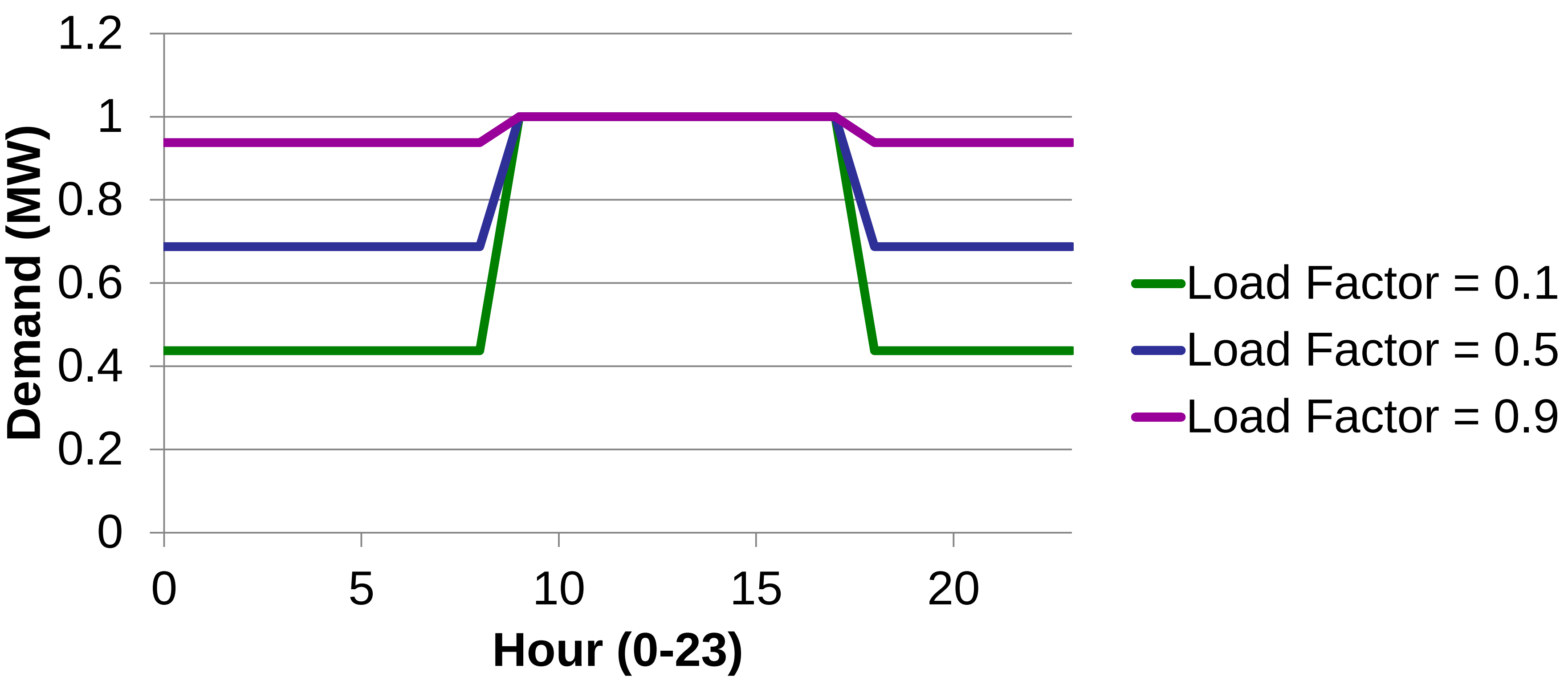
	Load Magnitude Calculation	Data Sources
1	Calculate the fraction of national industrial load attributable to the end-use	MECS 2010
2	Multiply by annual industrial demand in the BAA	EIA 861

PROCEDURE
Industrial Manufacturing

	Load Shape Calculation	Data Sources
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



BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

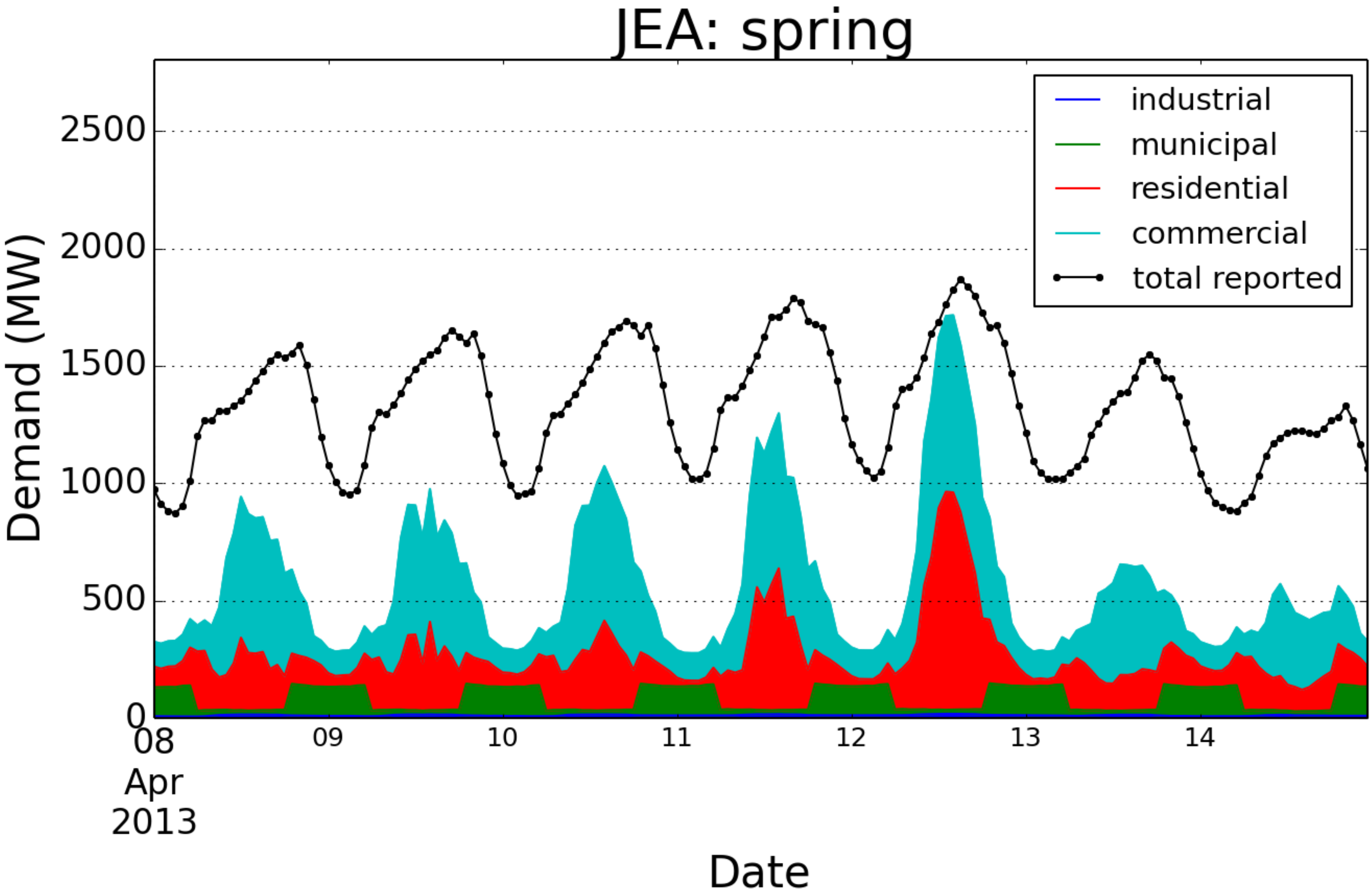
U.S. DEPARTMENT OF ENERGY

Appendix 2: Verification of End Use Load Profiles for FRCC

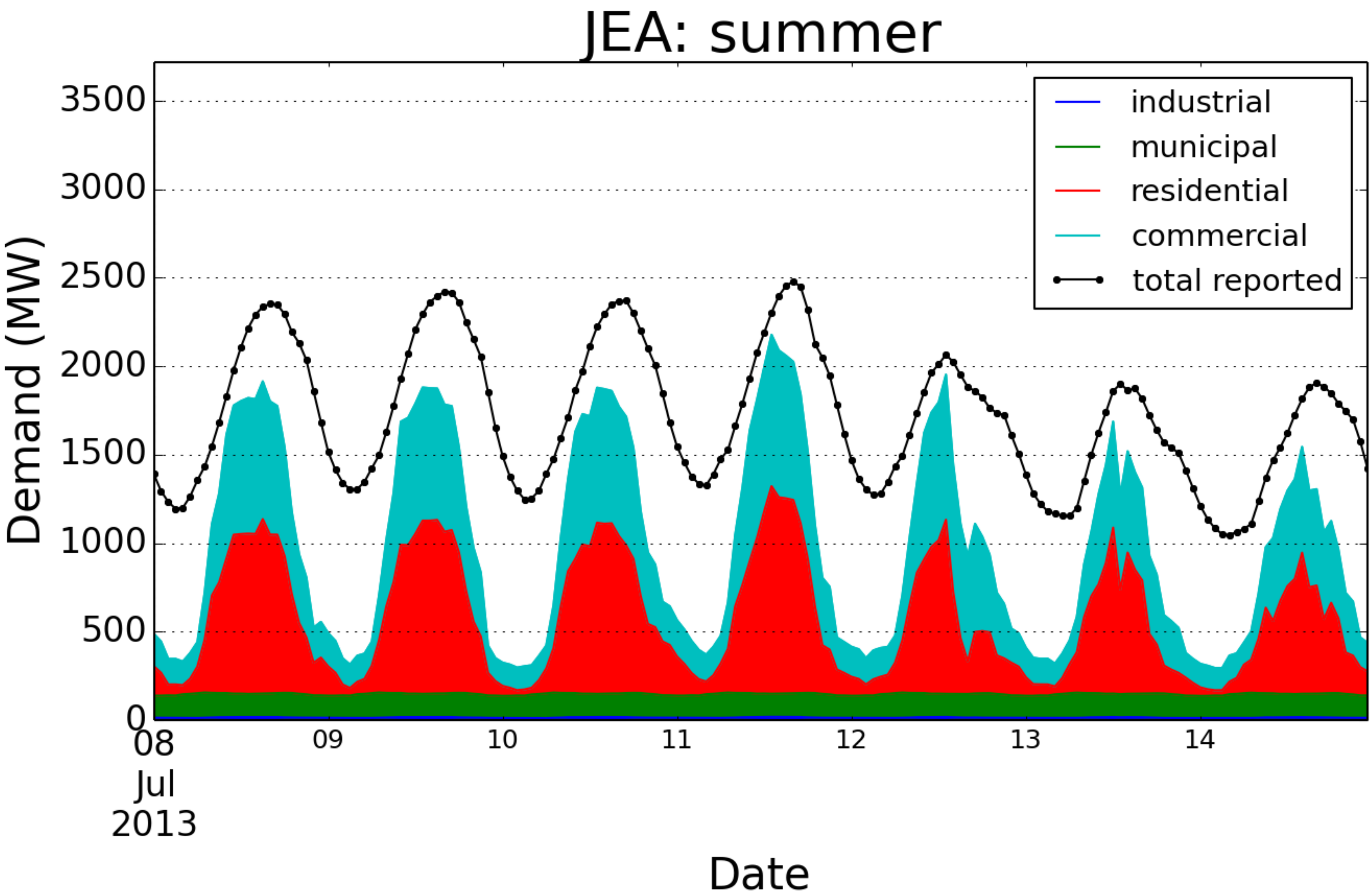
Verification of End Use Load Profiles for FRCC: Methodology

- 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.

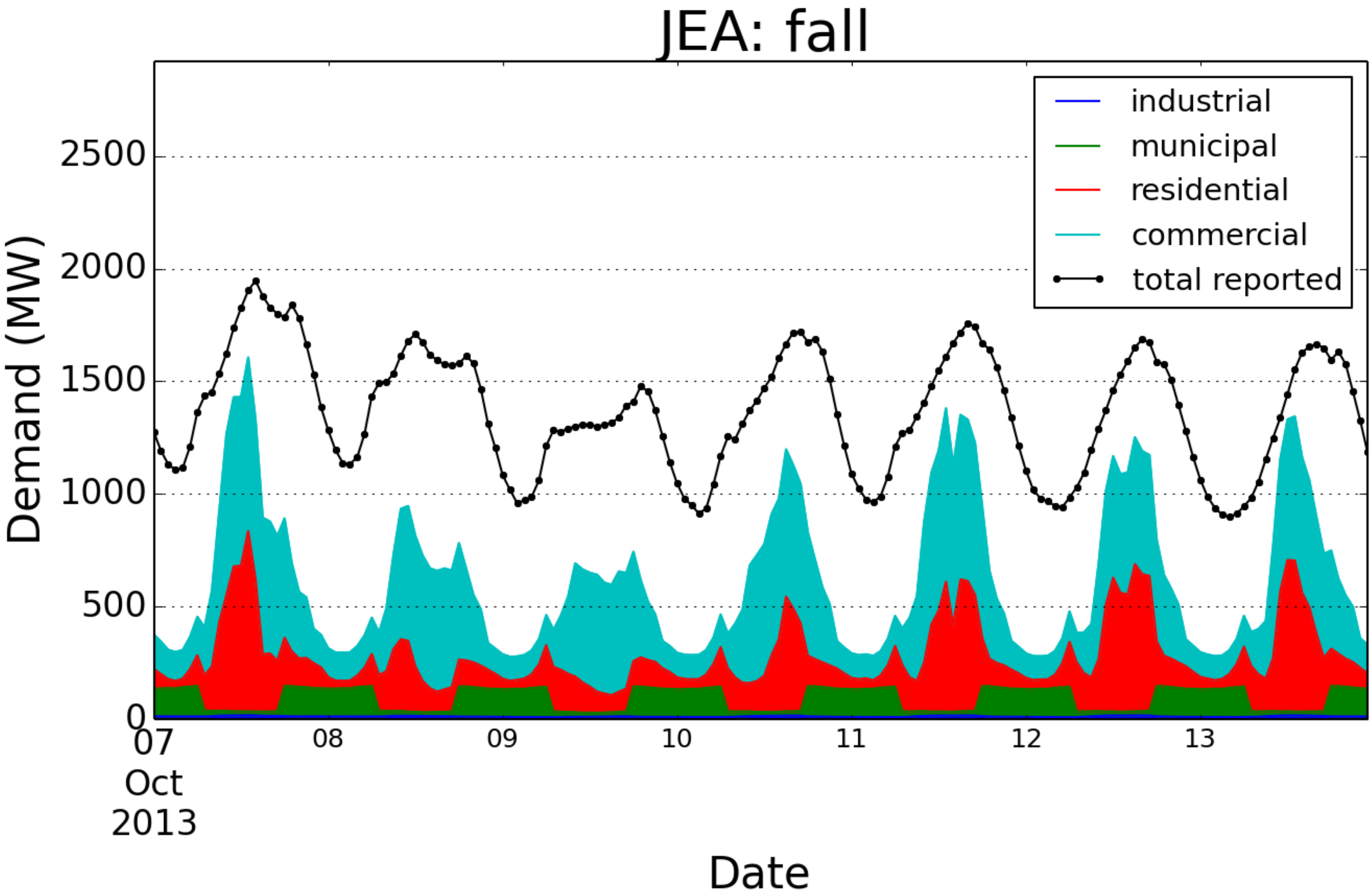
LOAD PROFILE VERIFICATION
Region: FRCC
BAA: JEA



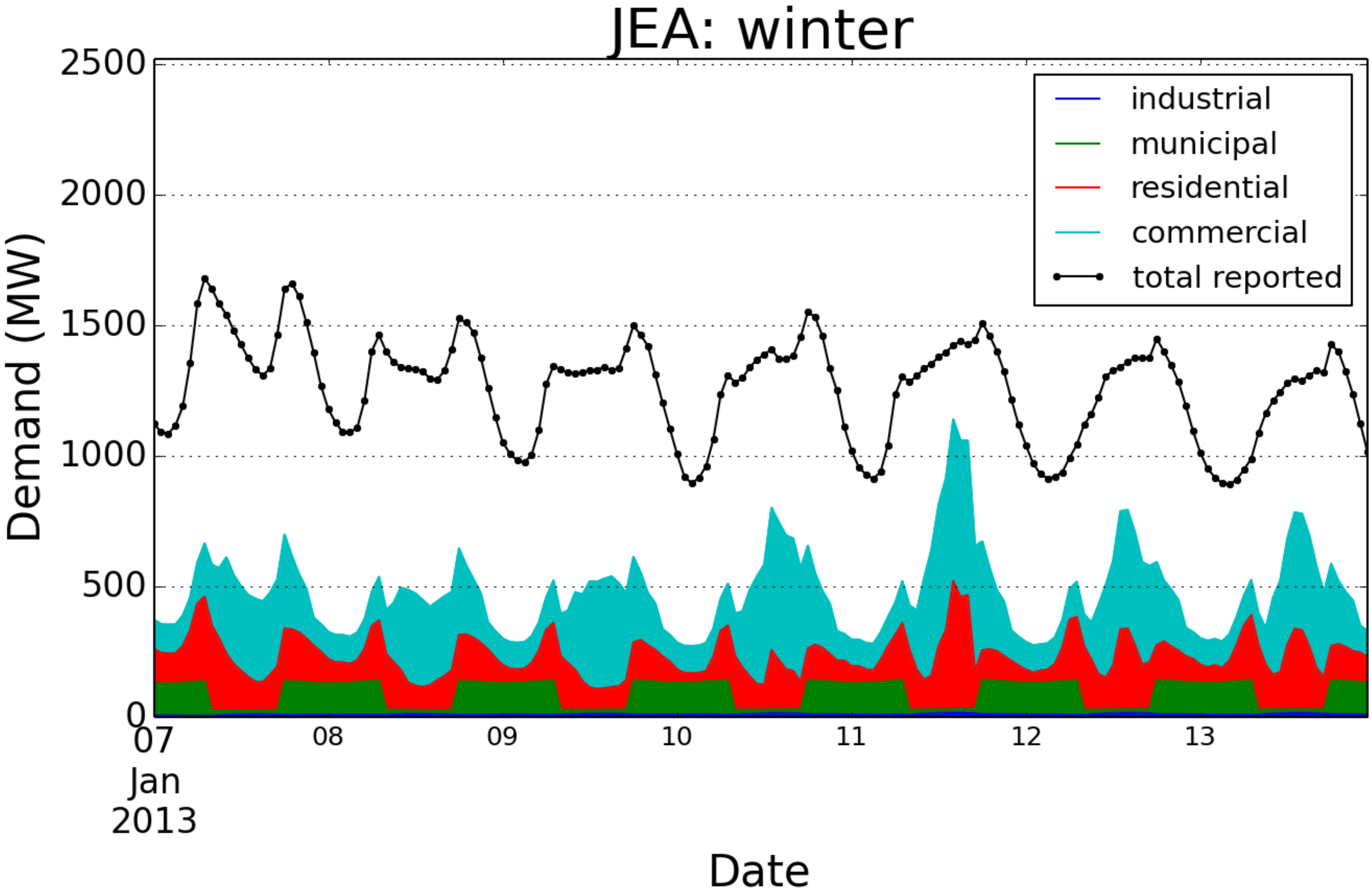
JEA: spring
industrial
municipal
residential
commercial
total reported
Demand (MW)
2500
2000
1500
1000
500
0
08
Apr
2013
09
10
11
12
13
14
Date



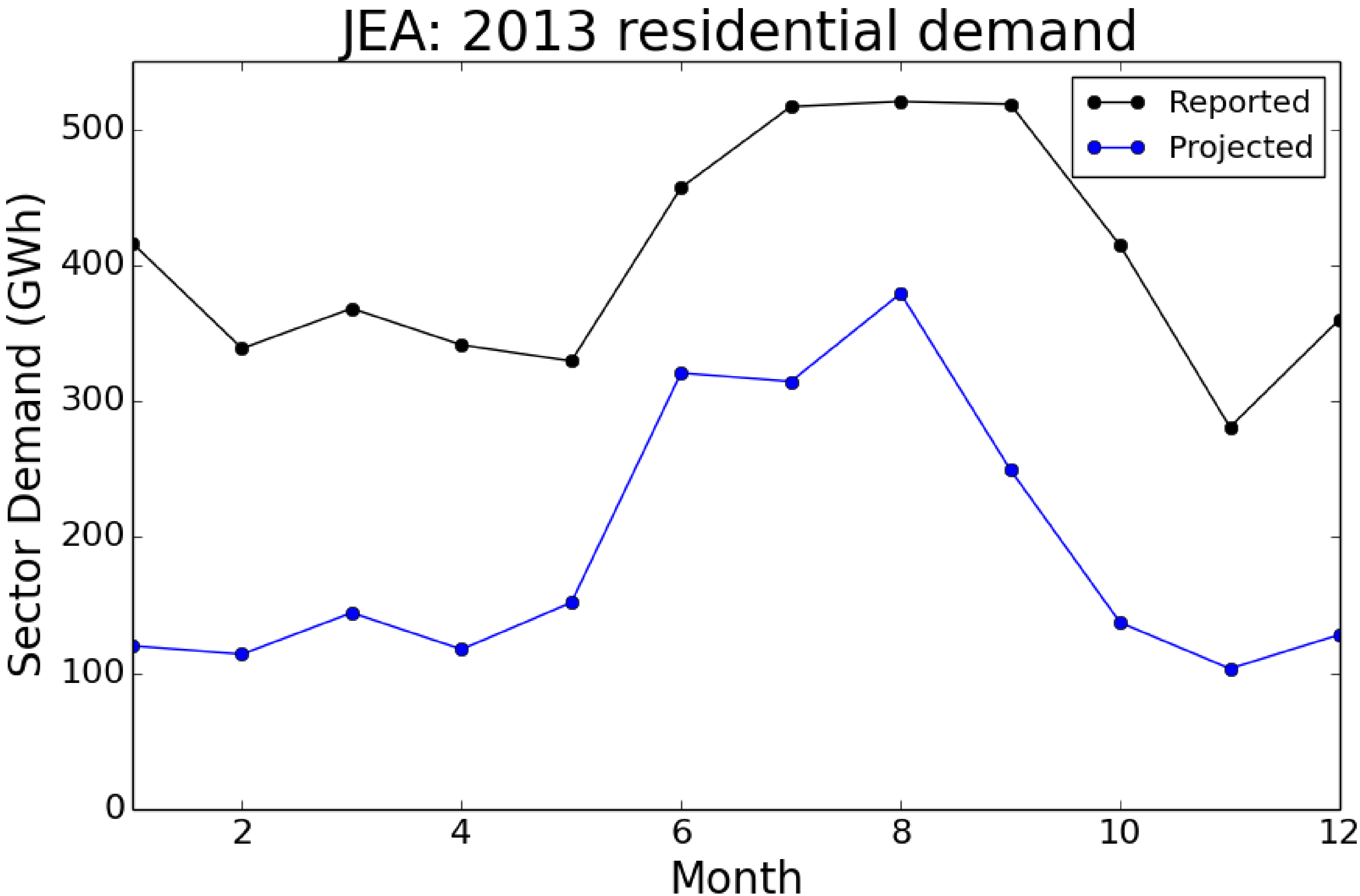
JEA: summer
Demand (MW)
3500
3000
2500
2000
1500
1000
500
0
industrial
municipal
residential
commercial
total reported
08
Jul
2013
09
10
11
12
13
14
Date

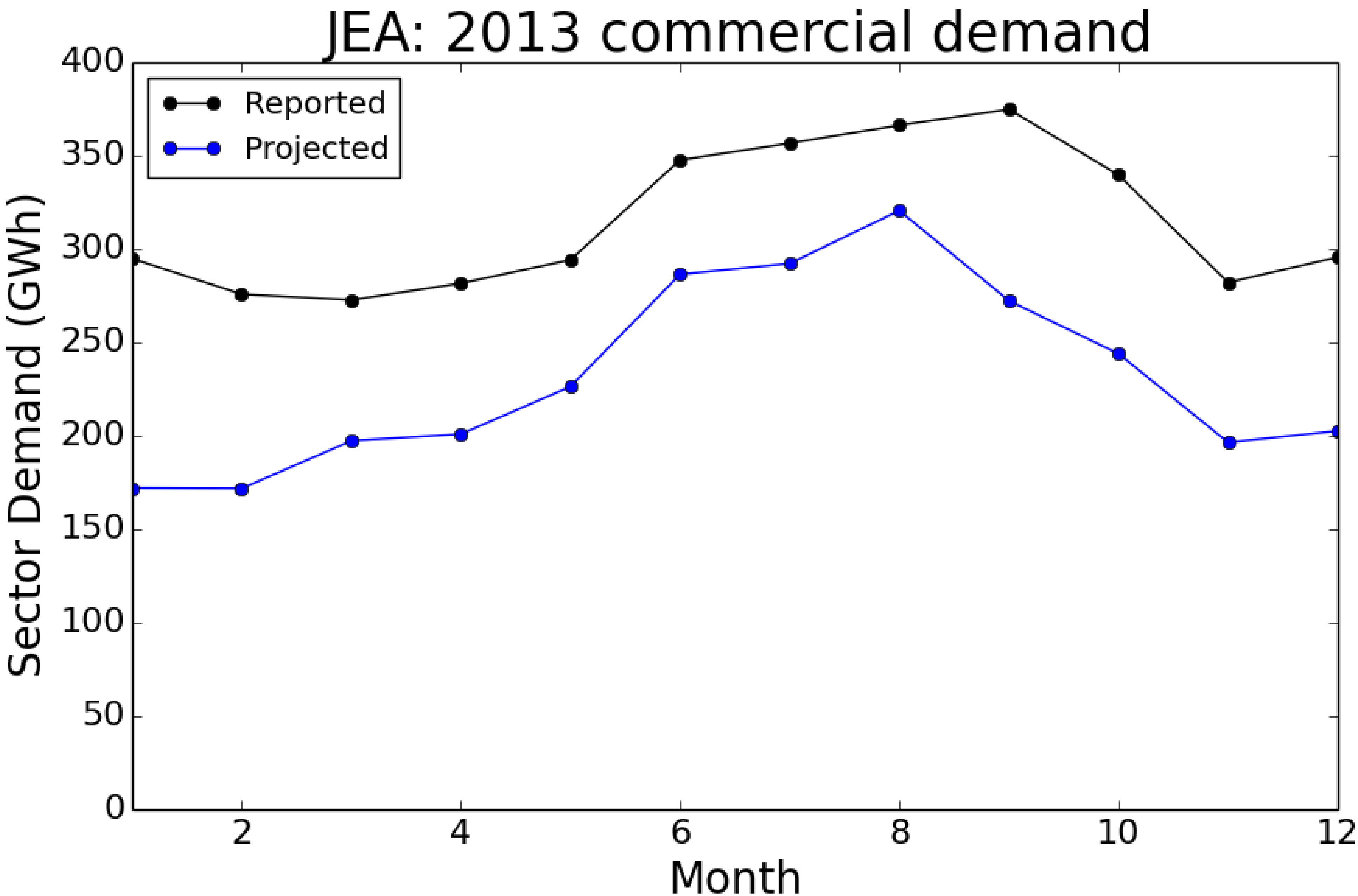


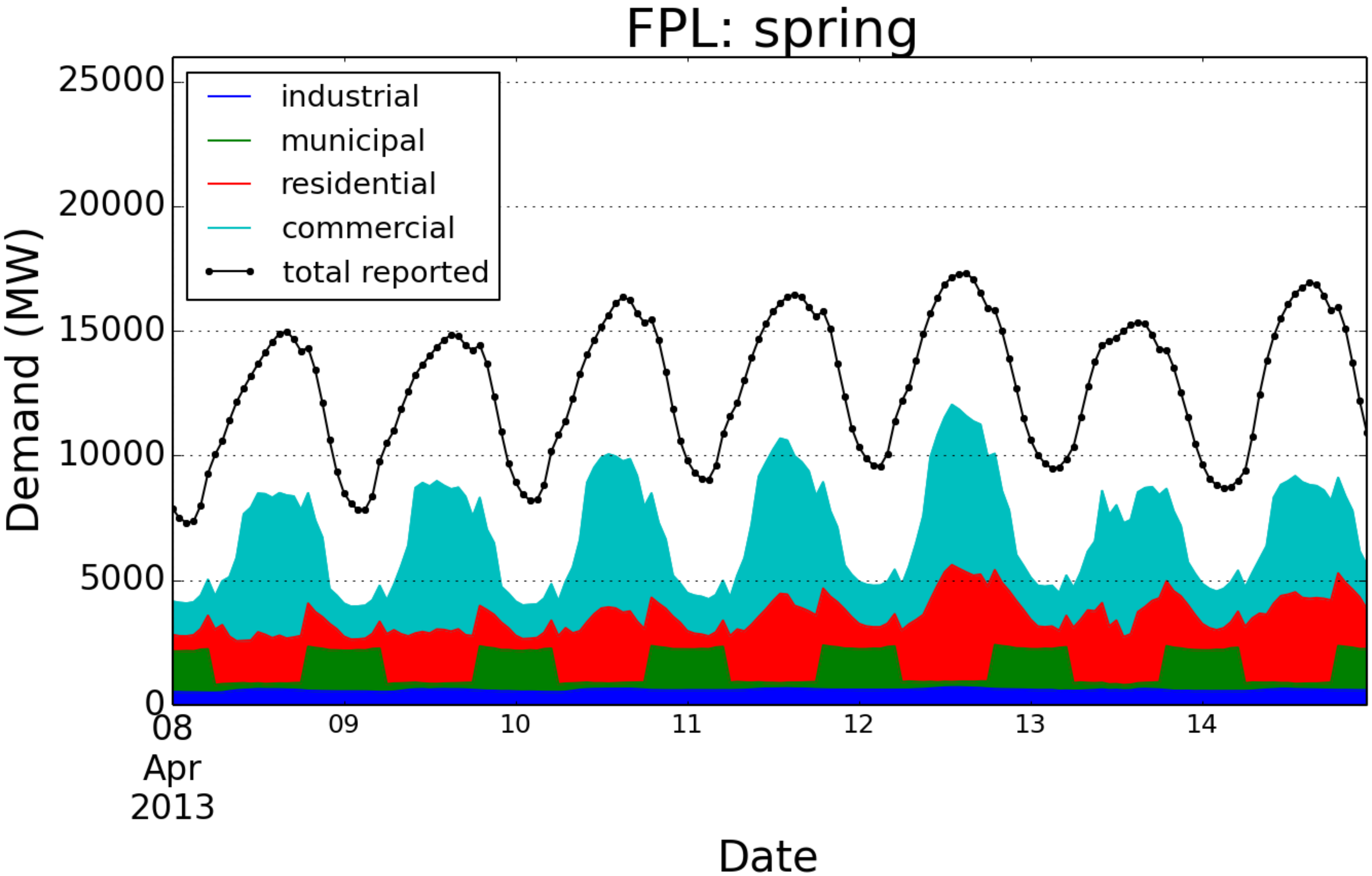
JEA: fall
Demand (MW)
2500
2000
1500
1000
500
0
07
Oct
2013
08
09
10
11
12
13
Date
industrial
municipal
residential
commercial
total reported



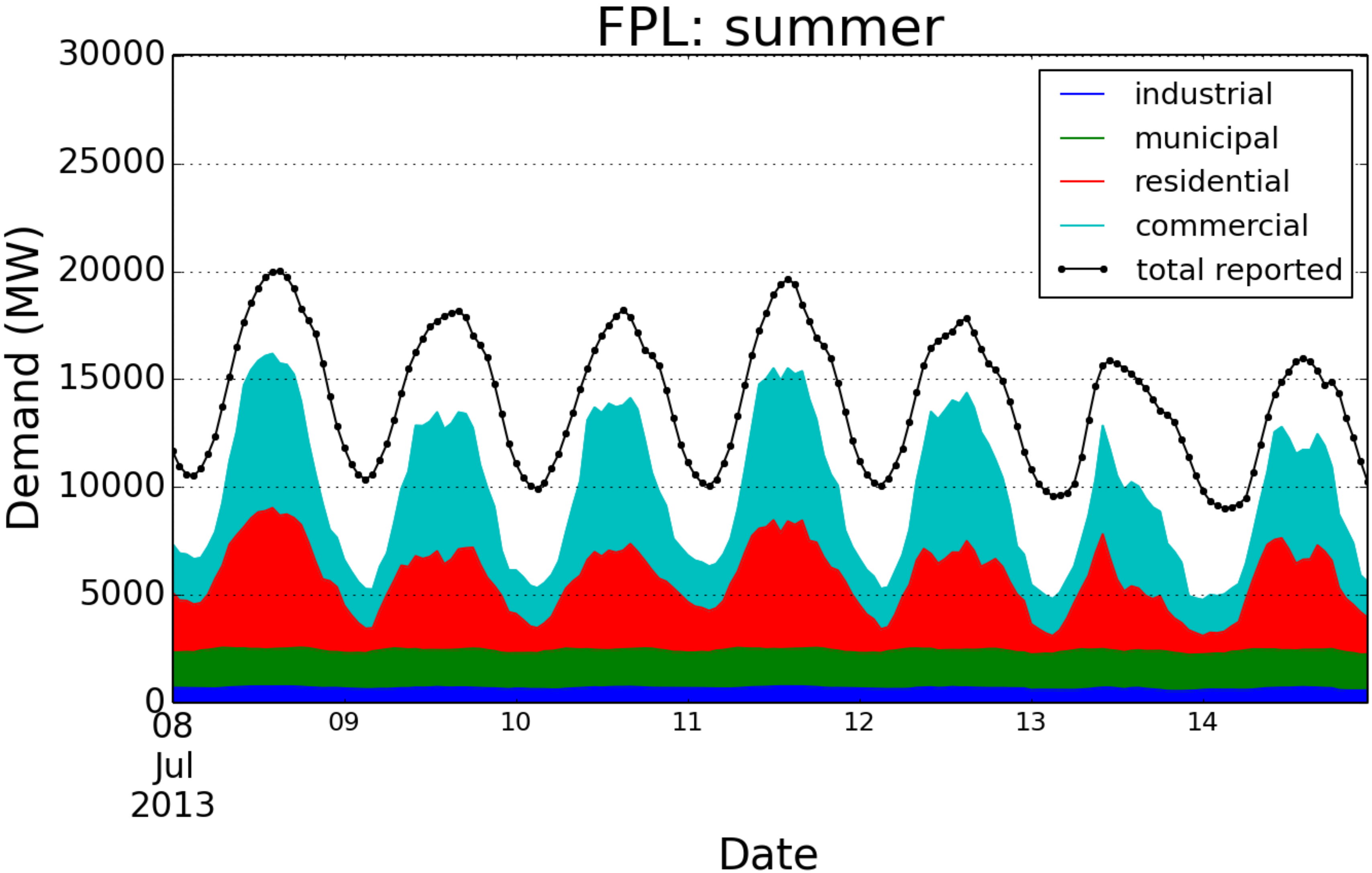
JEA: winter
Demand (MW)
2500
2000
1500
1000
500
0
industrial
municipal
residential
commercial
total reported
07
Jan
2013
08
09
10
11
12
13
Date


JEA: 2013 residential demand
Reported
Projected
Sector Demand (GWh)
0
100
200
300
400
500
Month
2
4
6
8
10
12

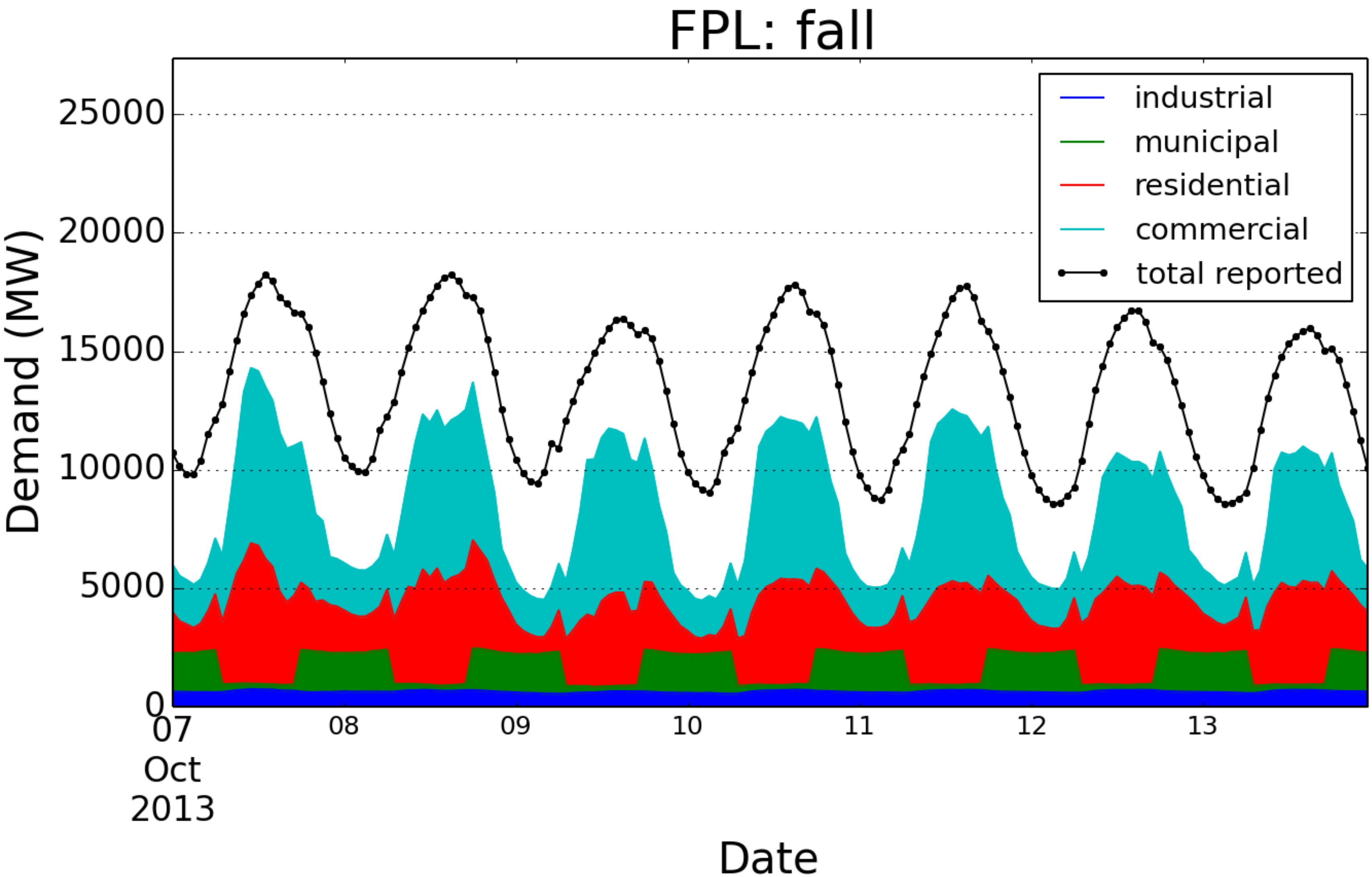

JEA: 2013 commercial demand
Reported
Projected
Sector Demand (GWh)
0
50
100
150
200
250
300
350
400
2
4
6
8
10
12
Month

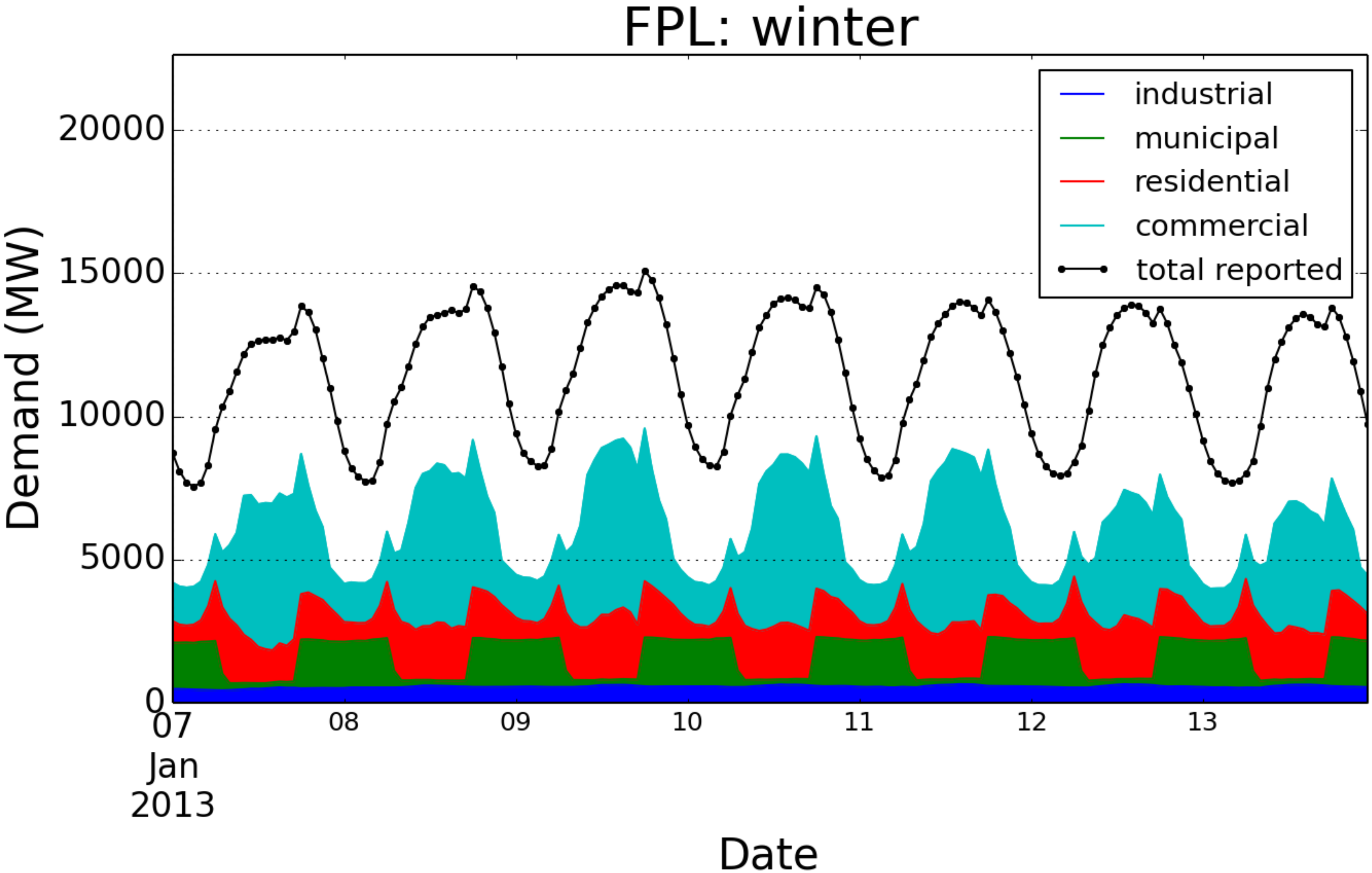

FPL: spring
industrial
municipal
residential
commercial
total reported
Demand (MW)
25000
20000
15000
10000
5000
0
08
Apr
2013
09
10
11
12
13
14
Date

LOAD PROFILE VERIFICATION
Region: FRCC
BAA: FPL

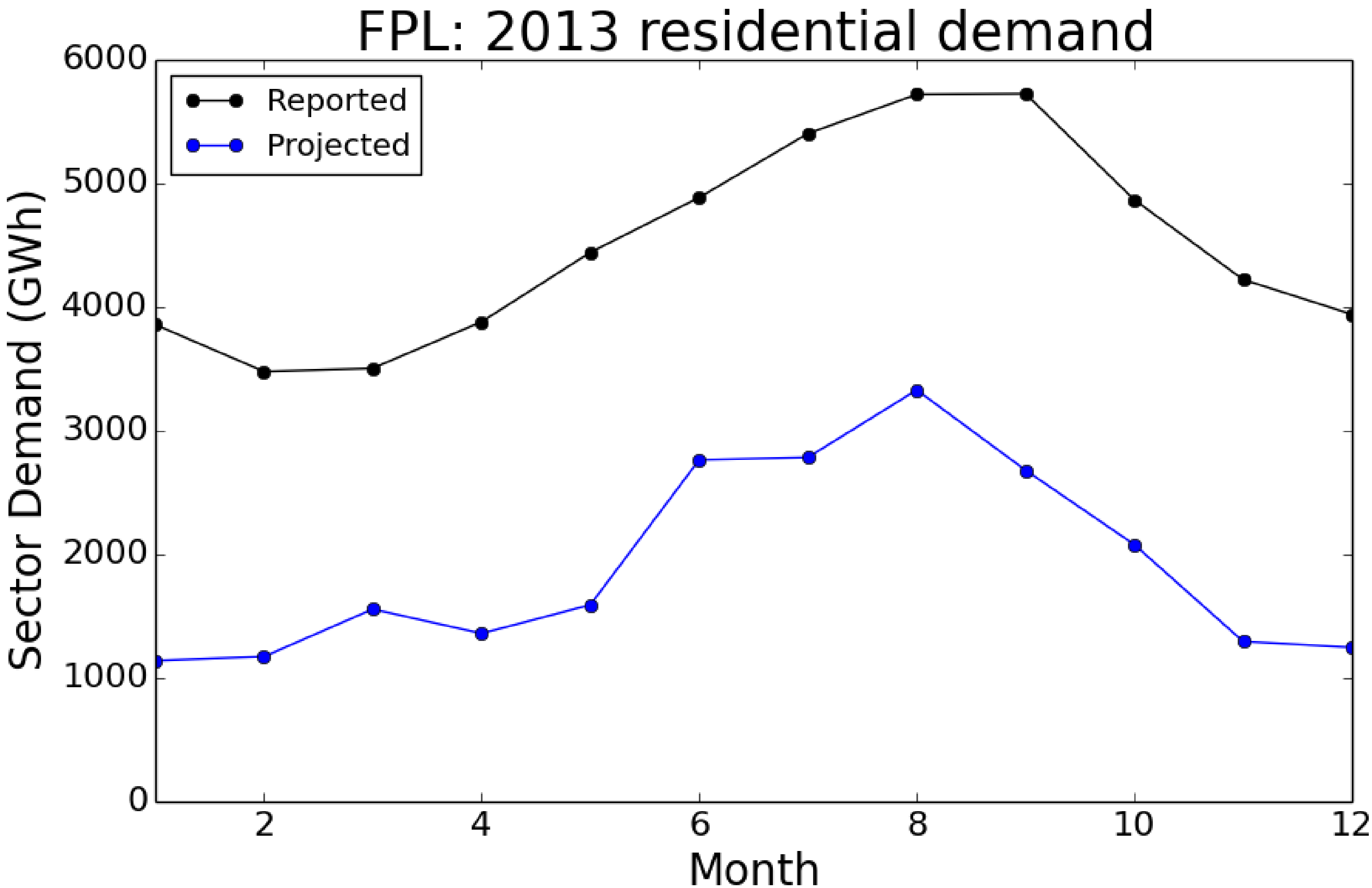


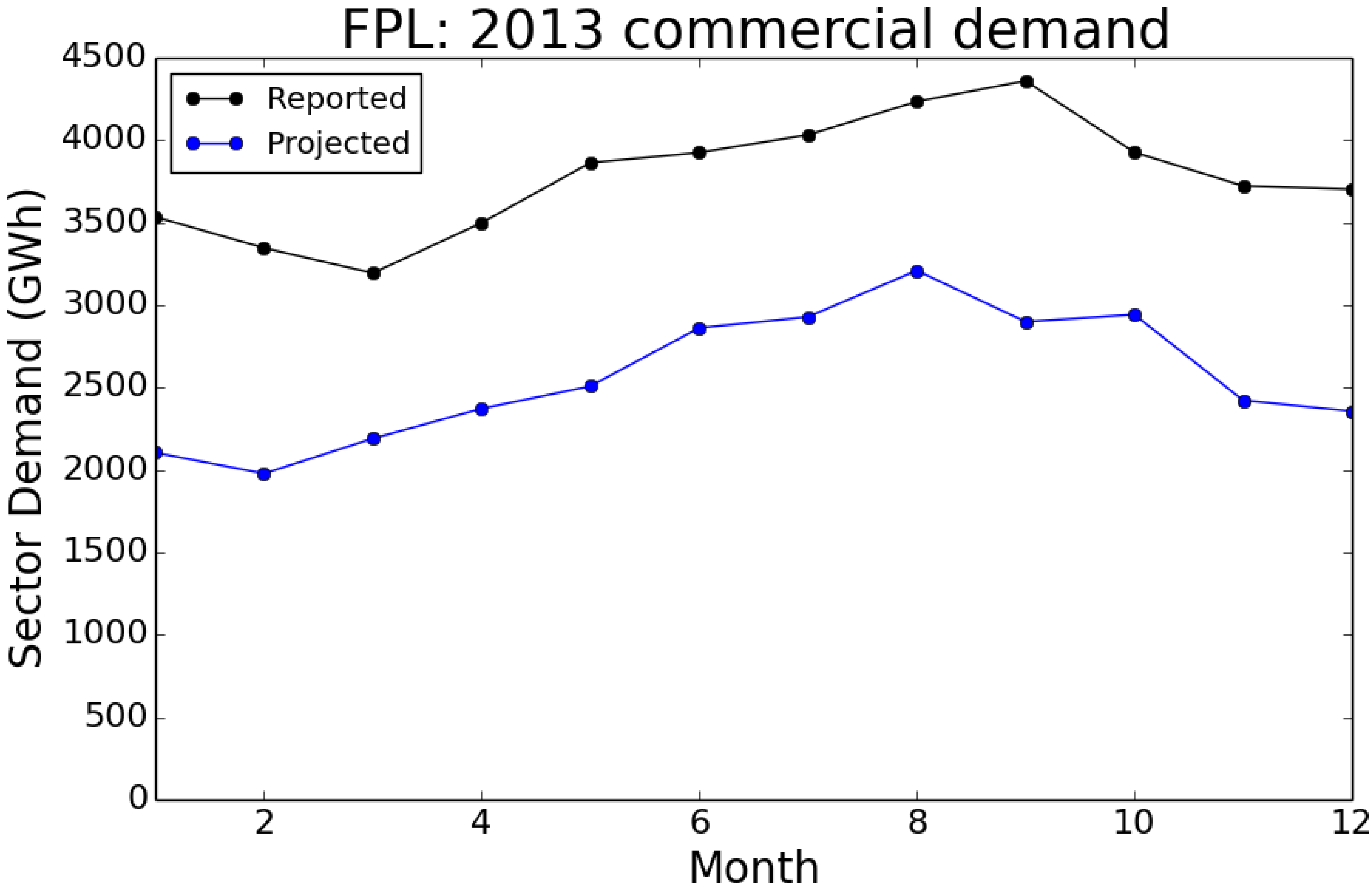
FPL: summer
Demand (MW)
30000
25000
20000
15000
10000
5000
0
08
Jul
2013
09
10
11
12
13
14
Date
industrial
municipal
residential
commercial
total reported


FPL: fall
Demand (MW)
25000
20000
15000
10000
5000
0
07
Oct
2013
08
09
10
11
12
13
Date
industrial
municipal
residential
commercial
total reported

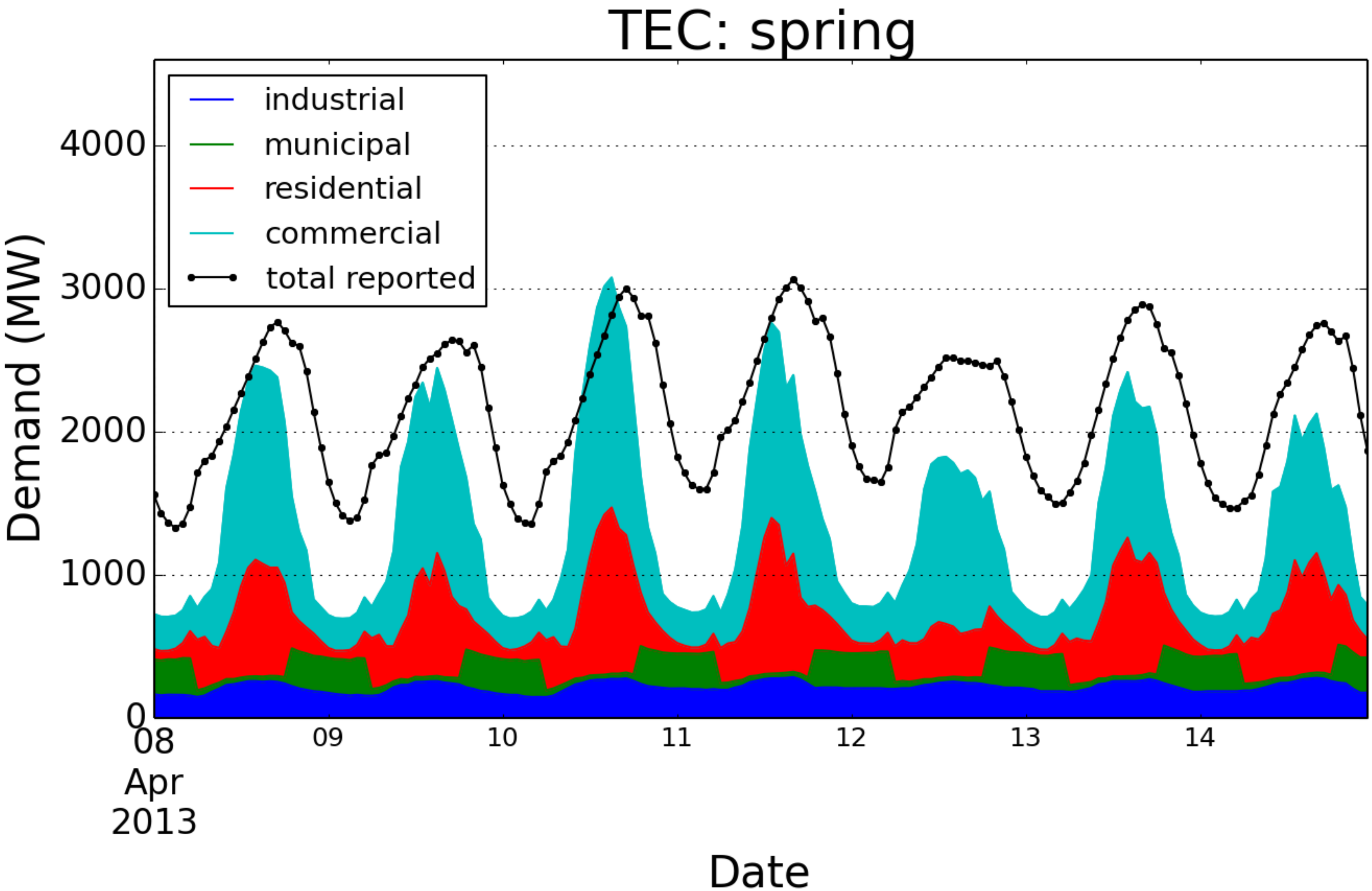


FPL: winter
Demand (MW)
20000
15000
10000
5000
0
07
Jan
2013
08
09
10
11
12
13
Date
industrial
municipal
residential
commercial
total reported

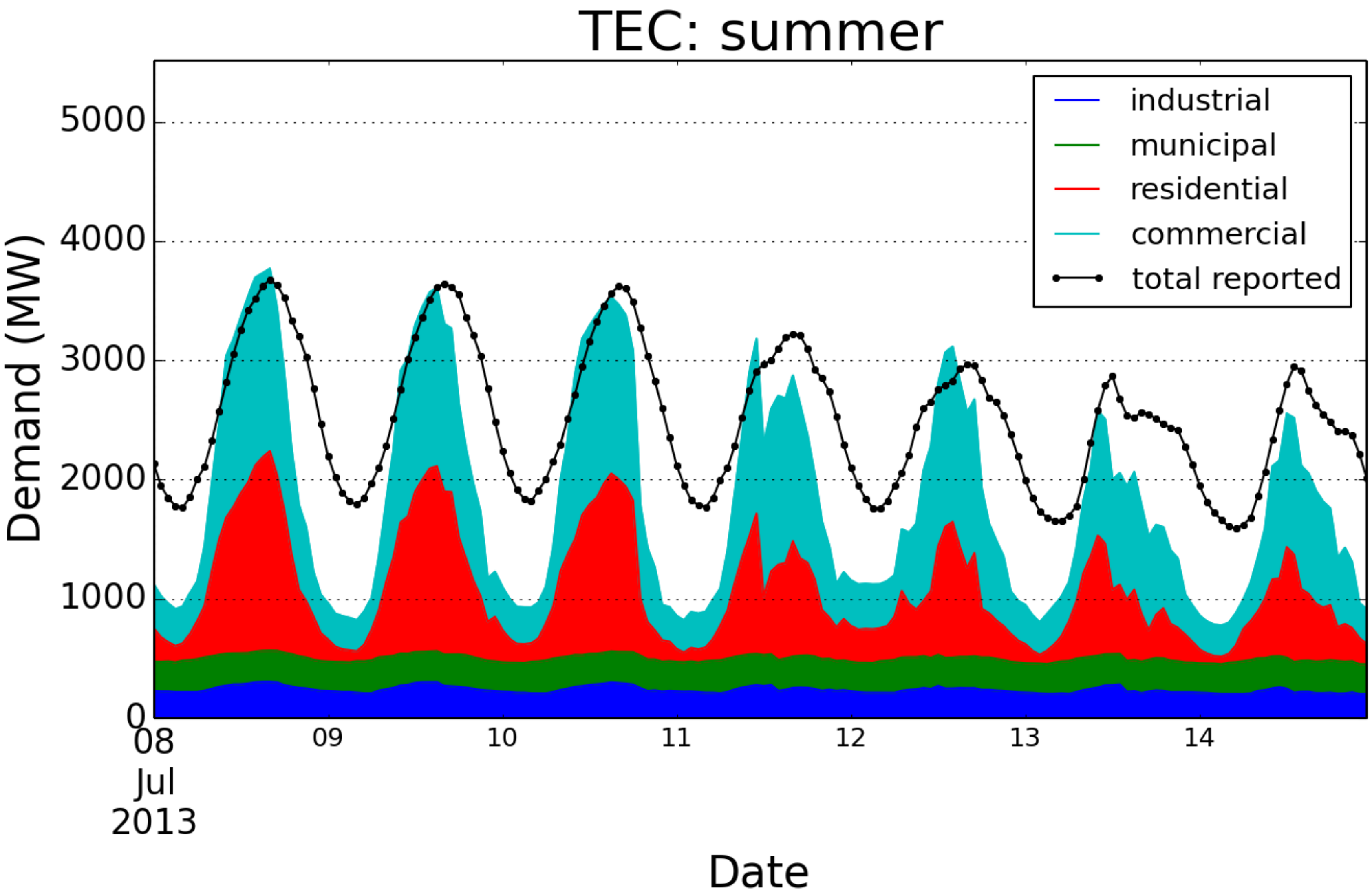

FPL: 2013 residential demand
Reported
Projected
Sector Demand (GWh)
6000
5000
4000
3000
2000
1000
0
2
4
6
8
10
12
Month

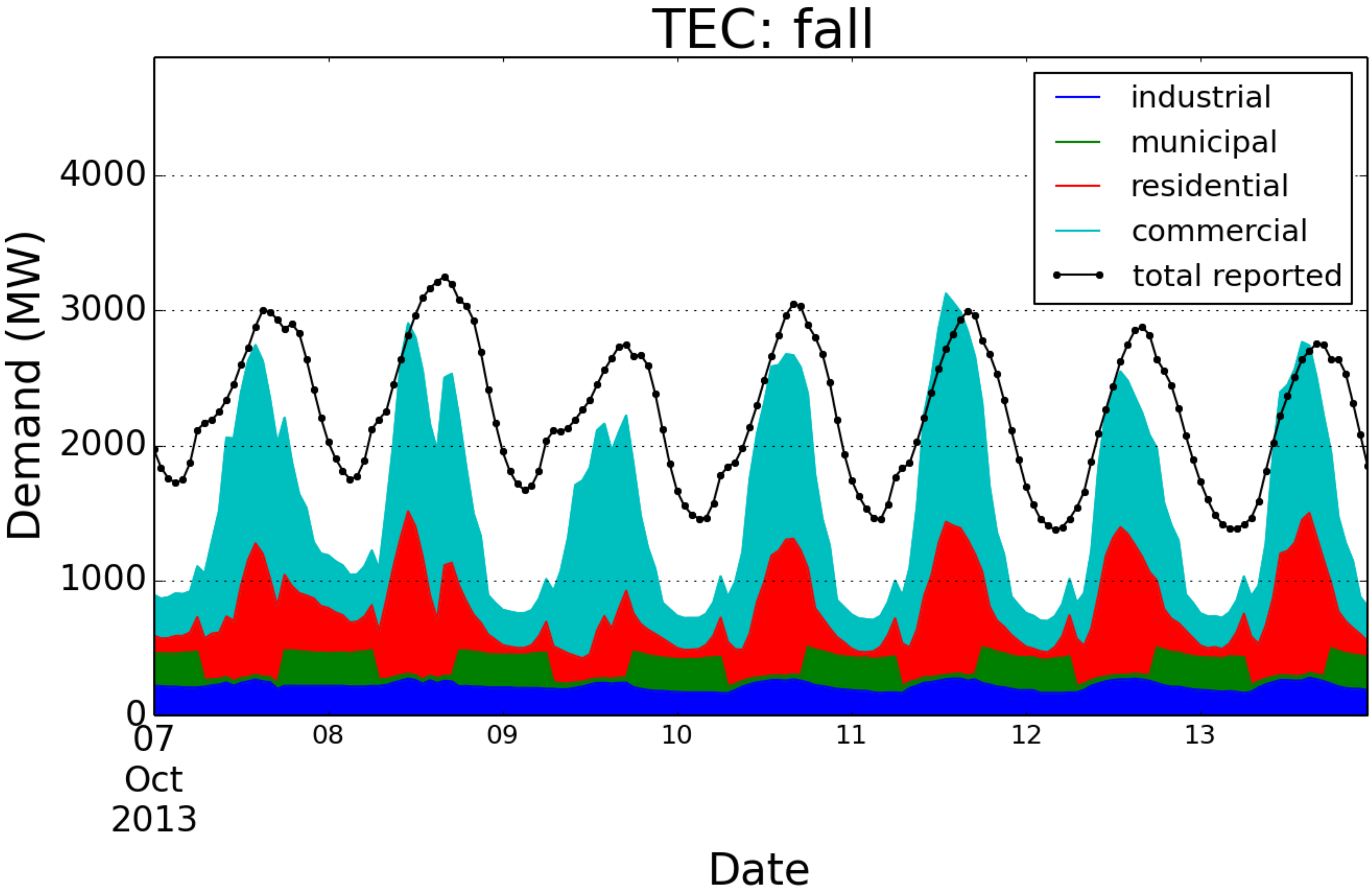

FPL: 2013 commercial demand
Reported
Projected
Sector Demand (GWh)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Month
2
4
6
8
10
12

LOAD PROFILE VERIFICATION
Region: FRCC
BAA: TEC

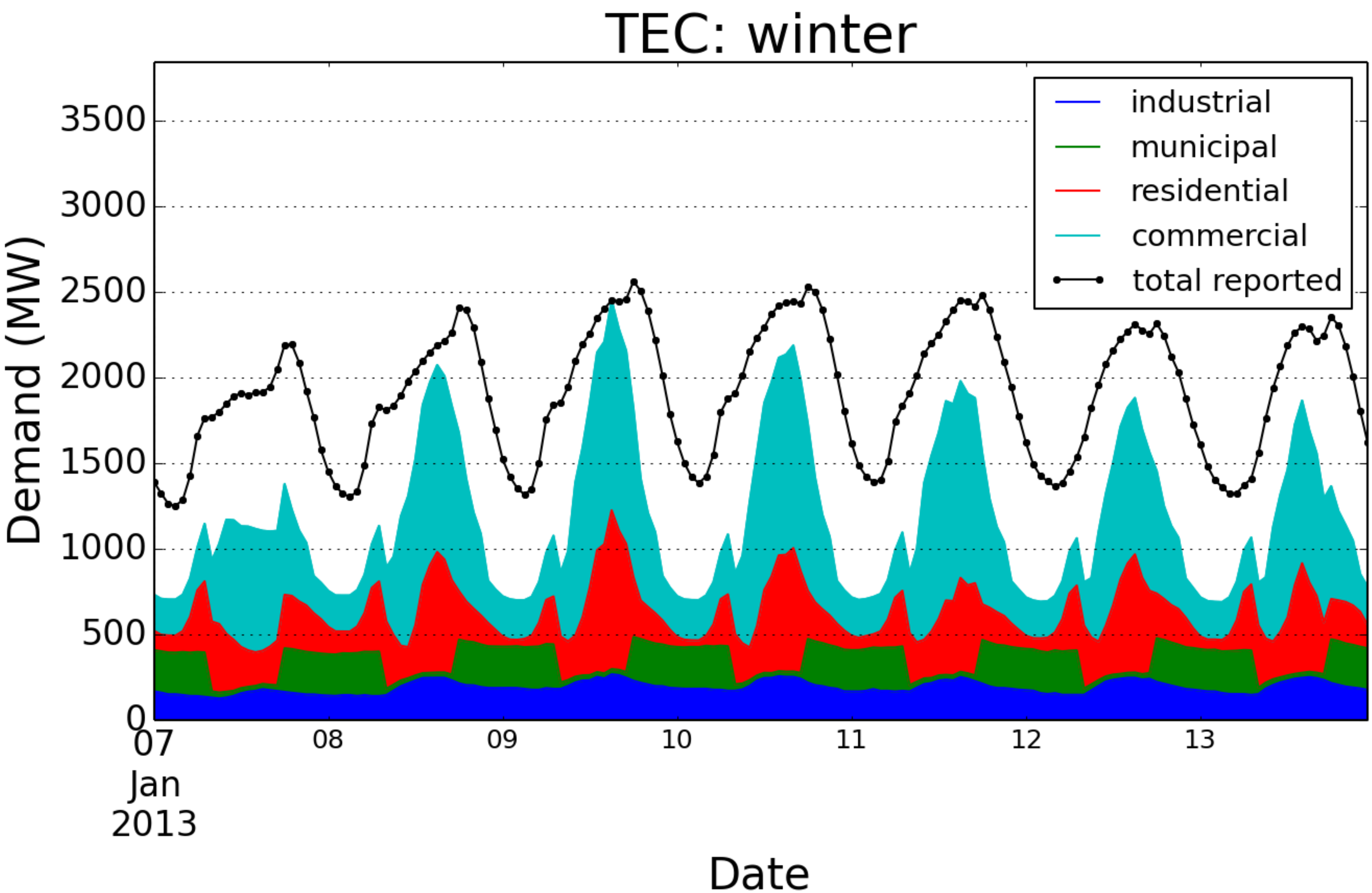


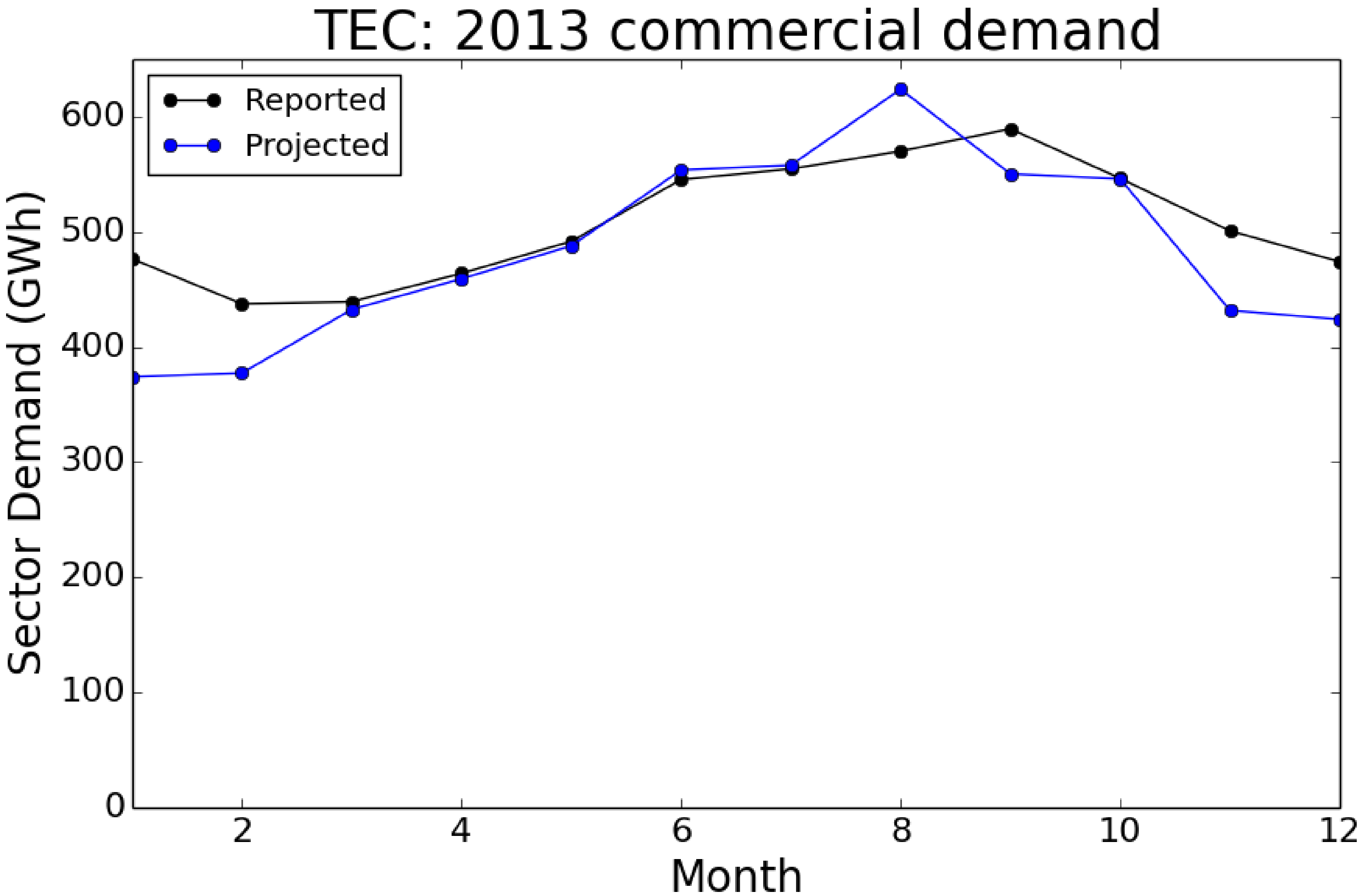
TEC: spring
industrial
municipal
residential
commercial
total reported
Demand (MW)
4000
3000
2000
1000
0
08
Apr
2013
09
10
11
12
13
14
Date

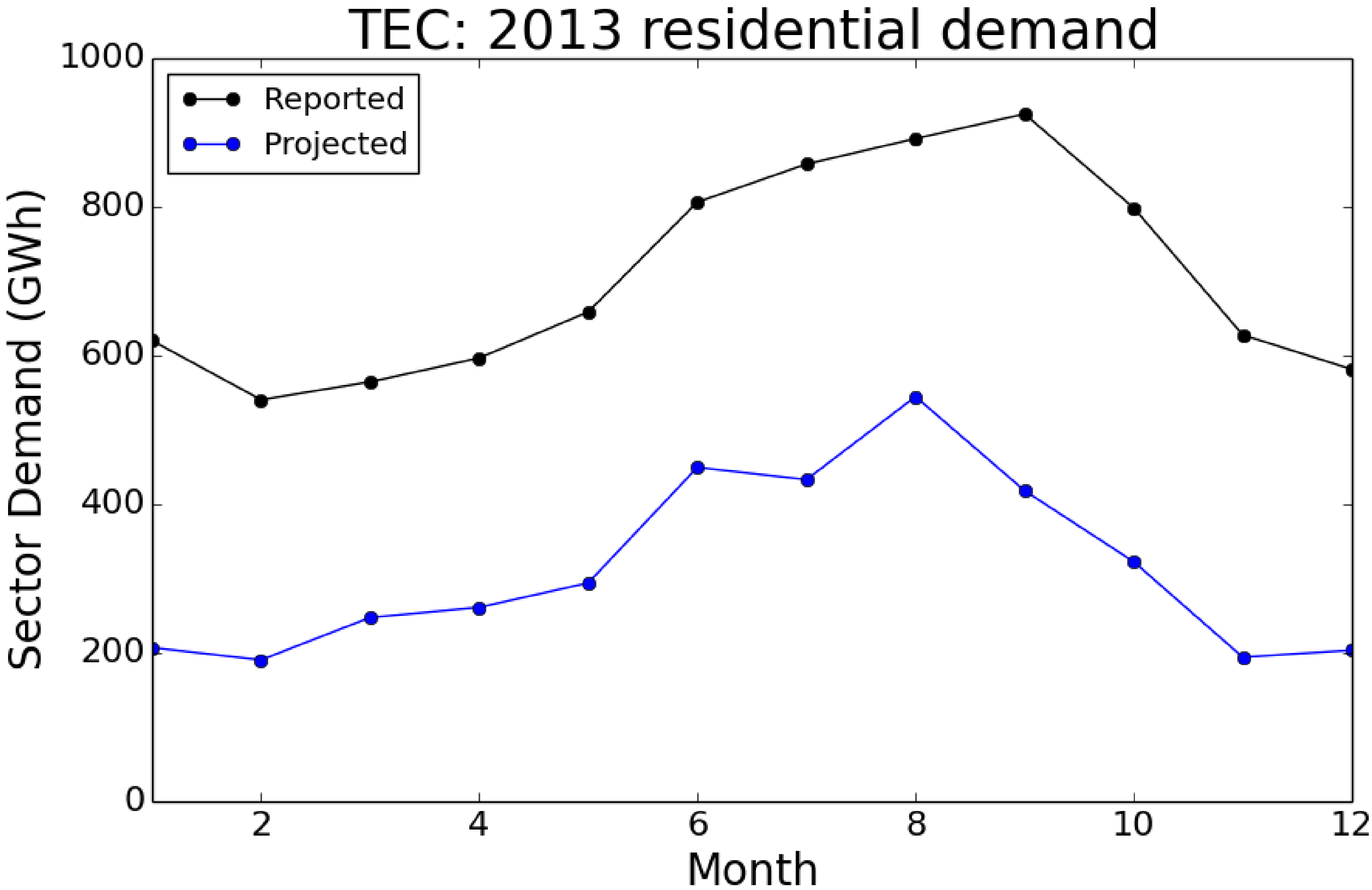

TEC: summer
Demand (MW)
5000
4000
3000
2000
1000
0
08
Jul
2013
09
10
11
12
13
14
Date
industrial
municipal
residential
commercial
total reported



TEC: fall
industrial
municipal
residential
commercial
total reported
Demand (MW)
4000
3000
2000
1000
0
07
Oct
2013
08
09
10
11
12
13
Date


TEC: winter
Demand (MW)
0
500
1000
1500
2000
2500
3000
3500
07
Jan
2013
08
09
10
11
12
13
Date
industrial
municipal
residential
commercial
total reported


TEC: 2013 commercial demand
Reported
Projected
Sector Demand (GWh)
0
100
200
300
400
500
600
2
4
6
8
10
12
Month


TEC: 2013 residential demand
Reported
Projected
Sector Demand (GWh)
Month
0
200
400
600
800
1000
2
4
6
8
10
12

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	-

BERKELEY LAB

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	Max acceptability calculated using current DR response rates: Accept = Peak Reduction $_{Actual}$ / Peak Reduction $_{Potential}$ Minimum acceptability is zero	EIA, 2012
2	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.	-
3	Assume 100% acceptability at all time for DLC end-uses, including: • 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
2	Assume 100% acceptability at all time for DLC end-uses, including: • Residential cooling • Residential water heating • Agricultural water pumping • Municipal water pumping • Municipal waste water pumping • Outdoor lighting • Refrigerated warehouses • Data centers	-

PROCEDURE
Acceptability Filter

	Acceptability Filter Shape	Data Sources
1	For commercial end-uses, acceptability is: • time variable • inversely correlated with building occupancy We use the commercial lighting load shape as a proxy for occupancy.	Olsen et al, 2013
2	For non-DLC residential end-uses (e.g., electric heating), acceptability is: • time variable • inversely correlated with lighting load (occupants' willingness to respond is a function of both building occupancy and outdoor air temperature)	-
3	For residential DLC end-uses (cooling and water heating), and industrial manufacturing and non-manufacturing end-uses, acceptability is assumed to be flat	-

BERKELEY LAB

LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

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

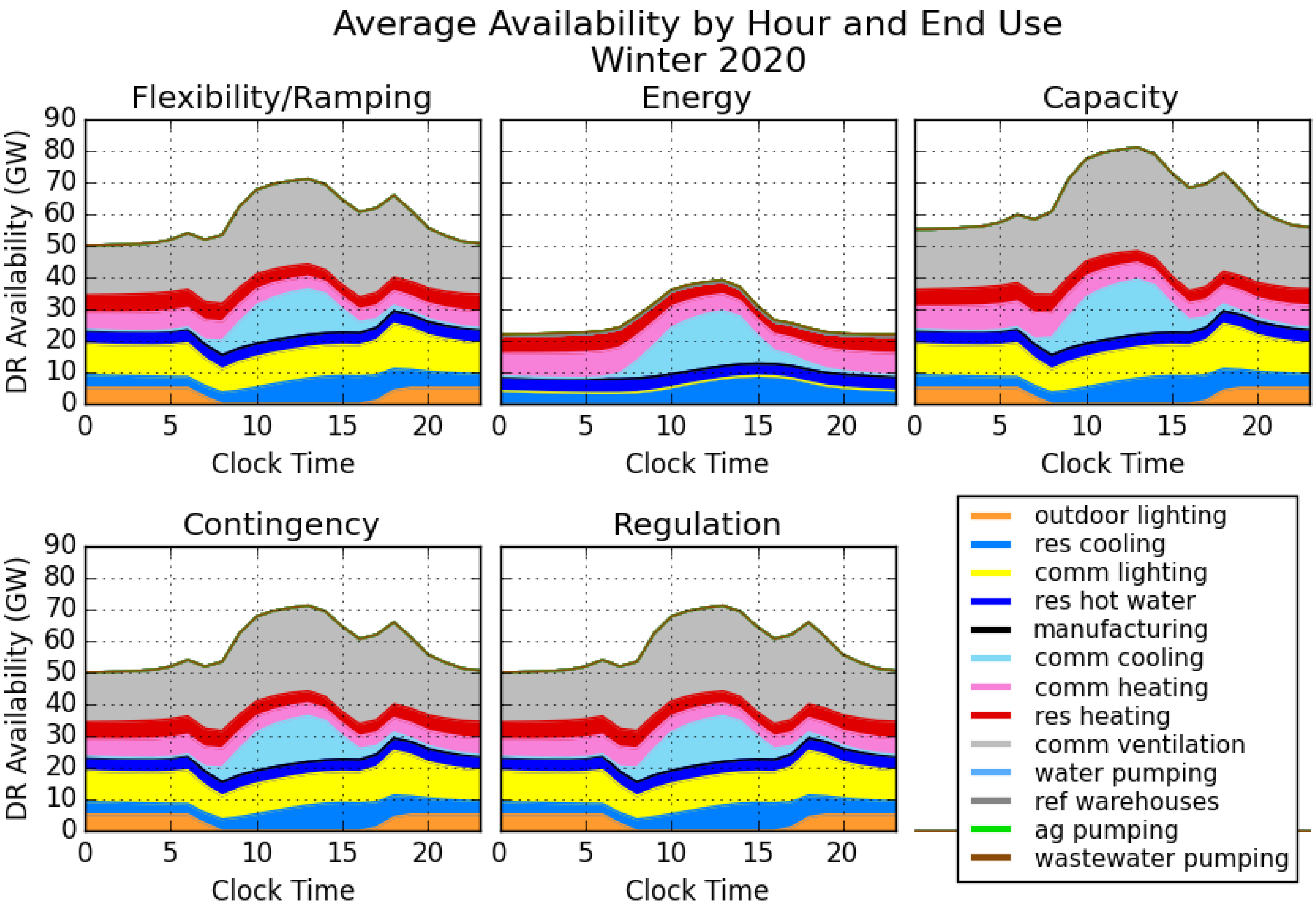
Municipal Water Pumping				
Product	Sheddable	Controllable	Acceptable	Combined Filter
Contingency	5%	1% - 98%	100%	0% - 5%
Flexibility	5%	1% - 98%	100%	0% - 5%
Energy	5%	1% - 98%	100%	0% - 5%
Capacity	5%	1% - 98%	100%	0% - 5%
Regulation	0%	1% - 98%	100%	0%

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%

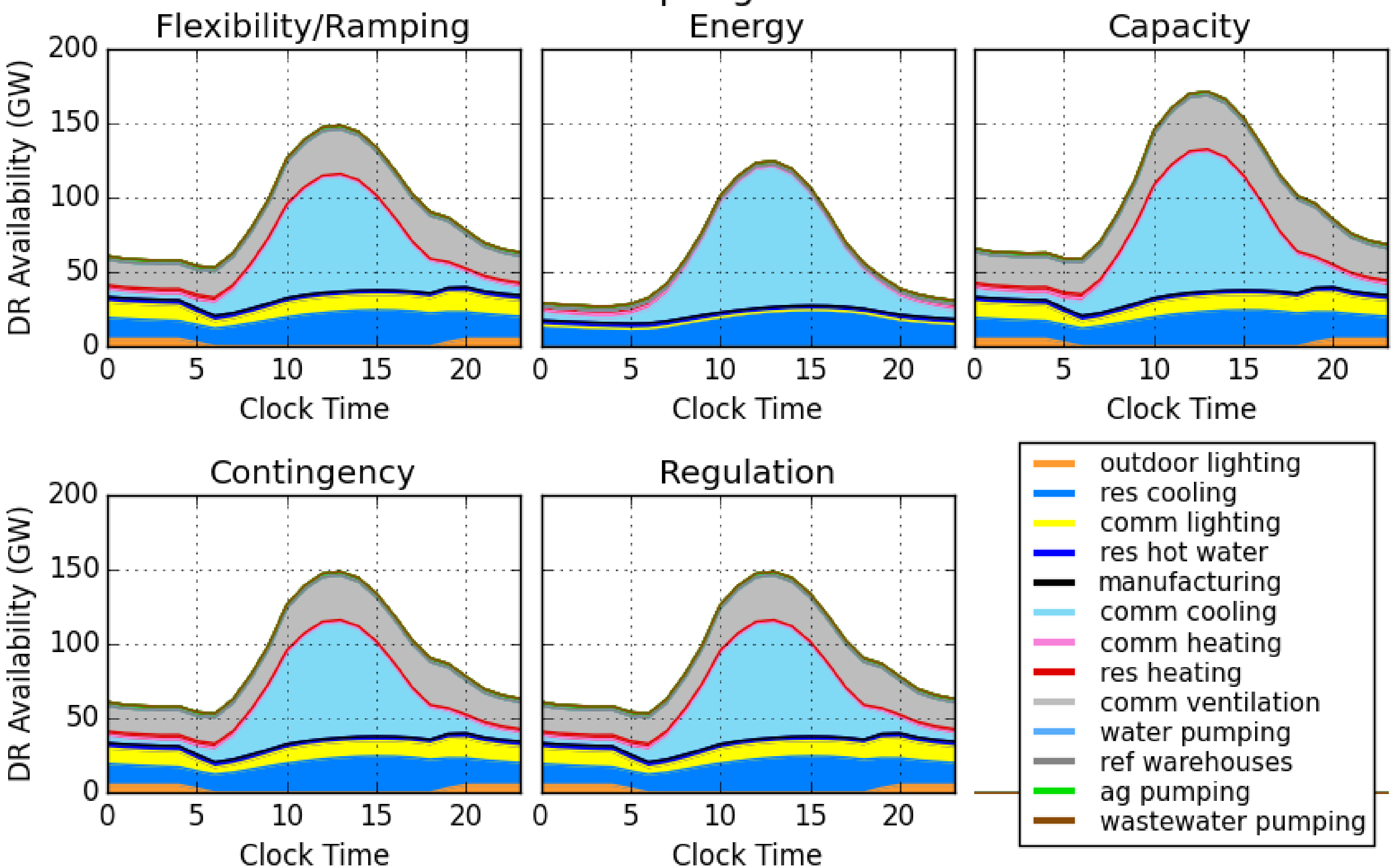
Appendix 5: Visualization of Demand Response Availability Results

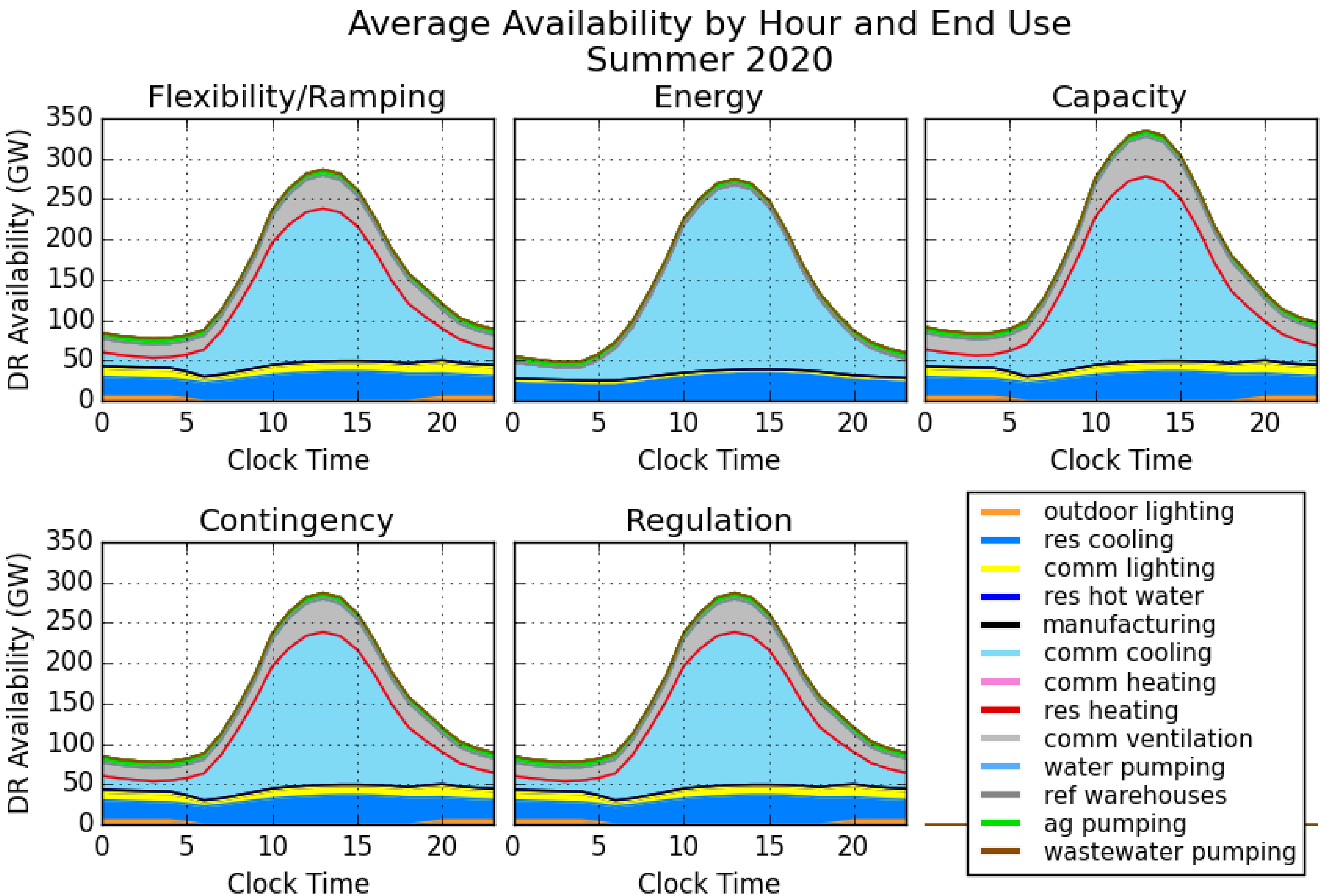
VISUALIZATION OF RESULTS:
Average Hourly Demand Response Availability by Season and End Use



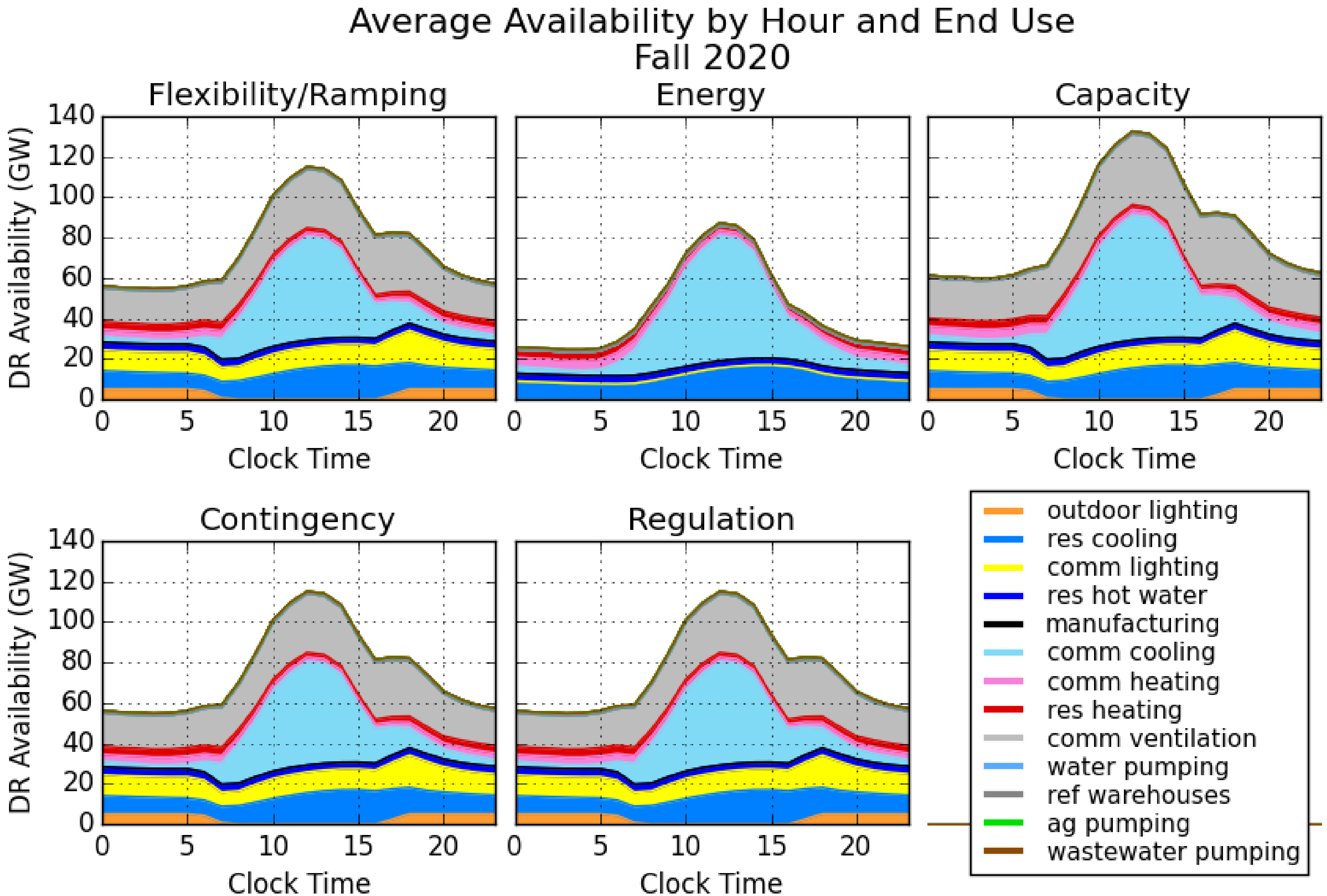
Average Availability by Hour and End Use
Winter 2020
Flexibility/Ramping
Energy
Capacity
Contingency
Regulation
DR Availability (GW)
Clock Time
0
10
20
30
40
50
60
70
80
90
5
15
outdoor lighting
res cooling
comm lighting
res hot water
manufacturing
comm cooling
comm heating
res heating
comm ventilation
water pumping
ref warehouses
ag pumping
wastewater pumping

Average Availability by Hour and End Use
Spring 2020



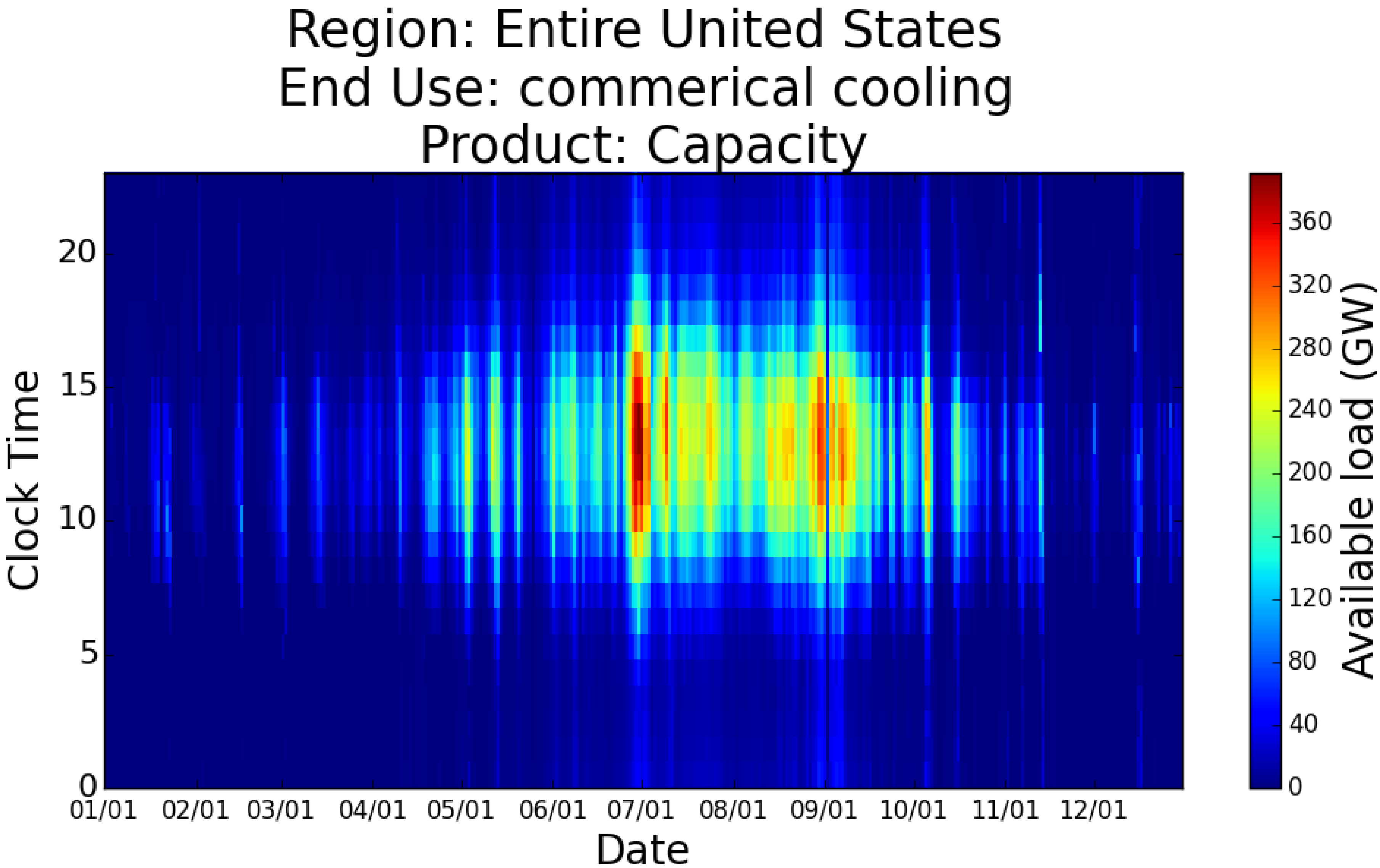


Average Availability by Hour and End Use
Summer 2020
Flexibility/Ramping
Energy
Capacity
Contingency
Regulation
DR Availability (GW)
Clock Time
0
50
100
150
200
250
300
350
0
5
10
15
20
outdoor lighting
res cooling
comm lighting
res hot water
manufacturing
comm cooling
comm heating
res heating
comm ventilation
water pumping
ref warehouses
ag pumping
wastewater pumping

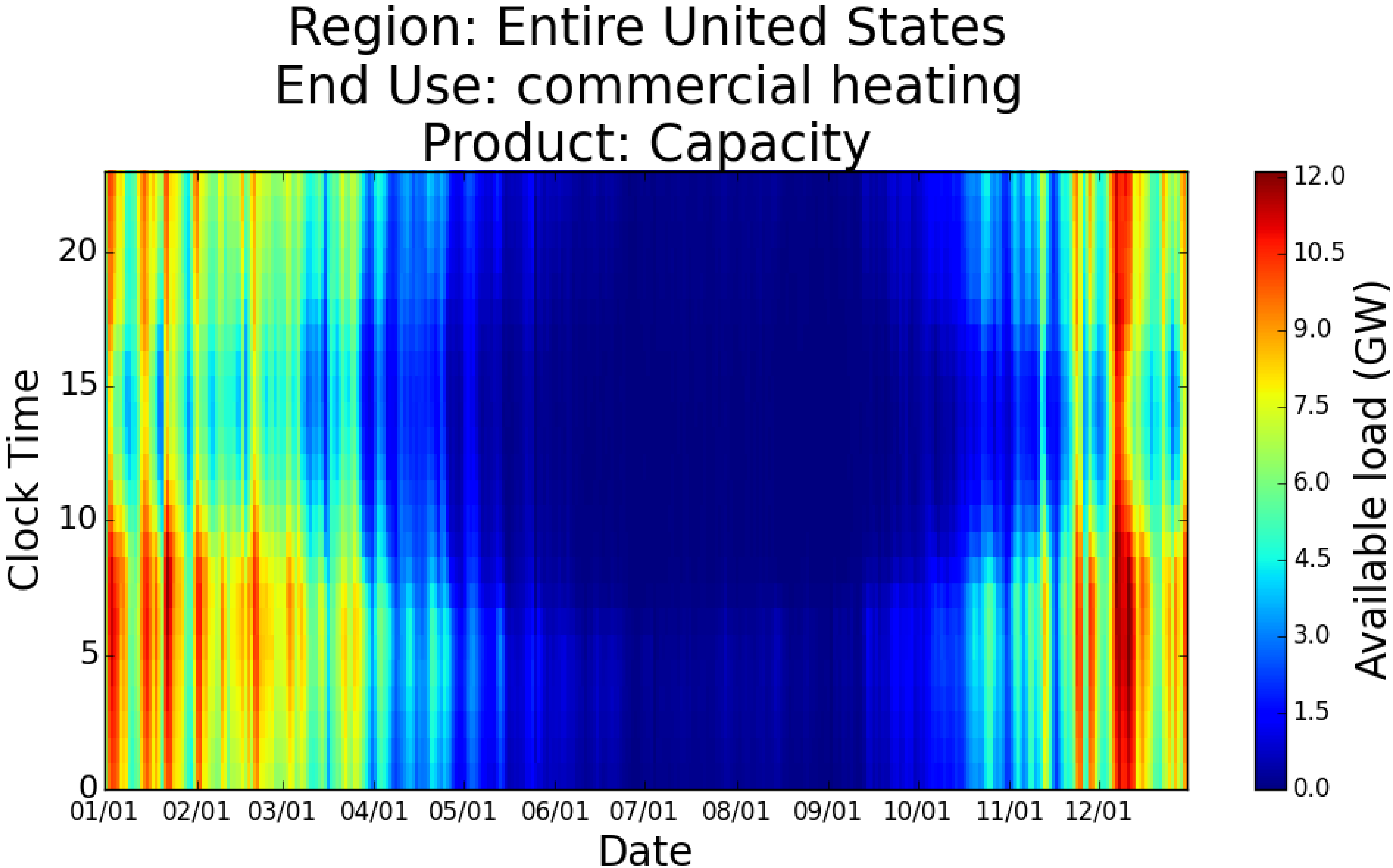


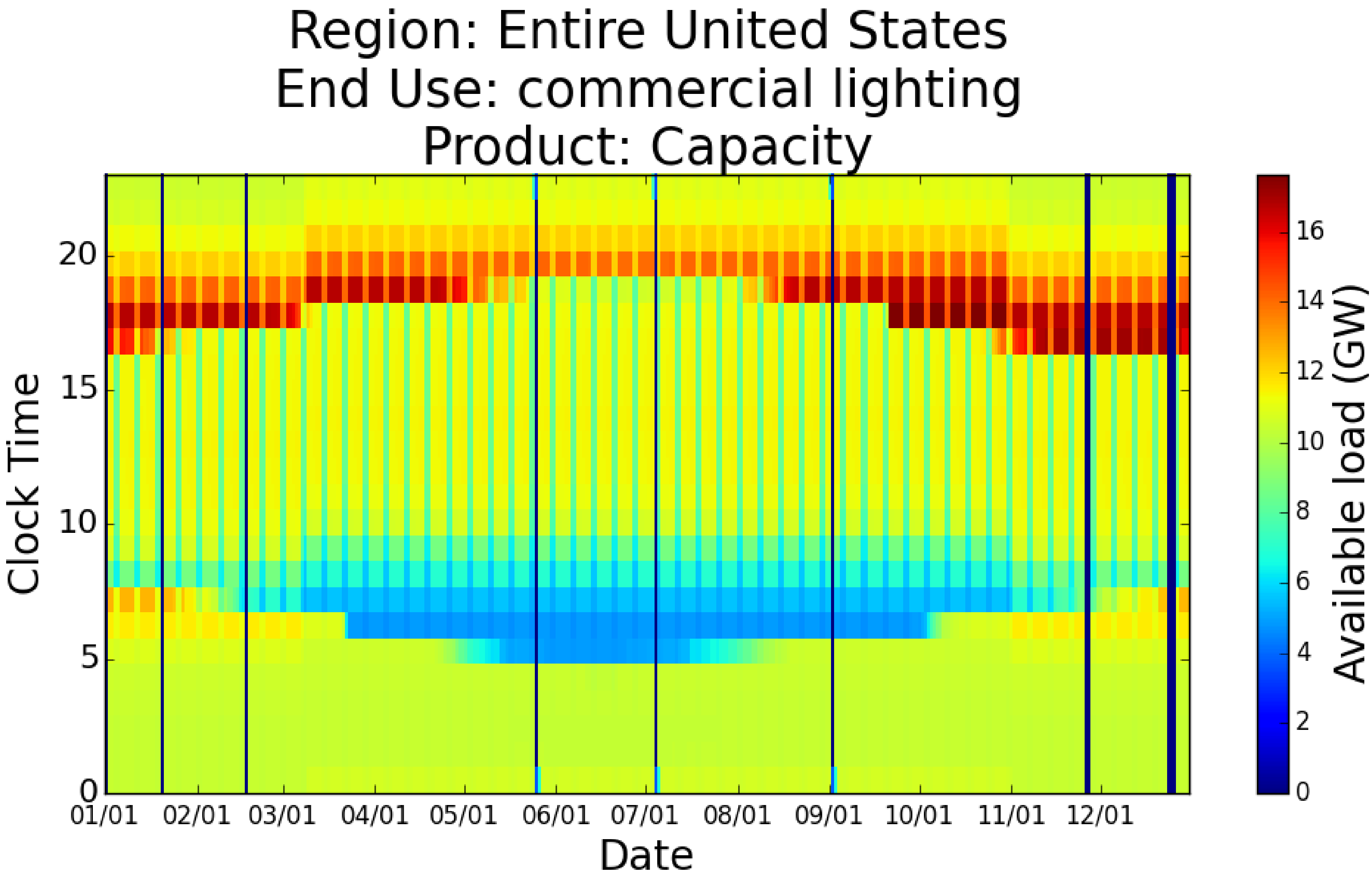
BERKELEY LAB

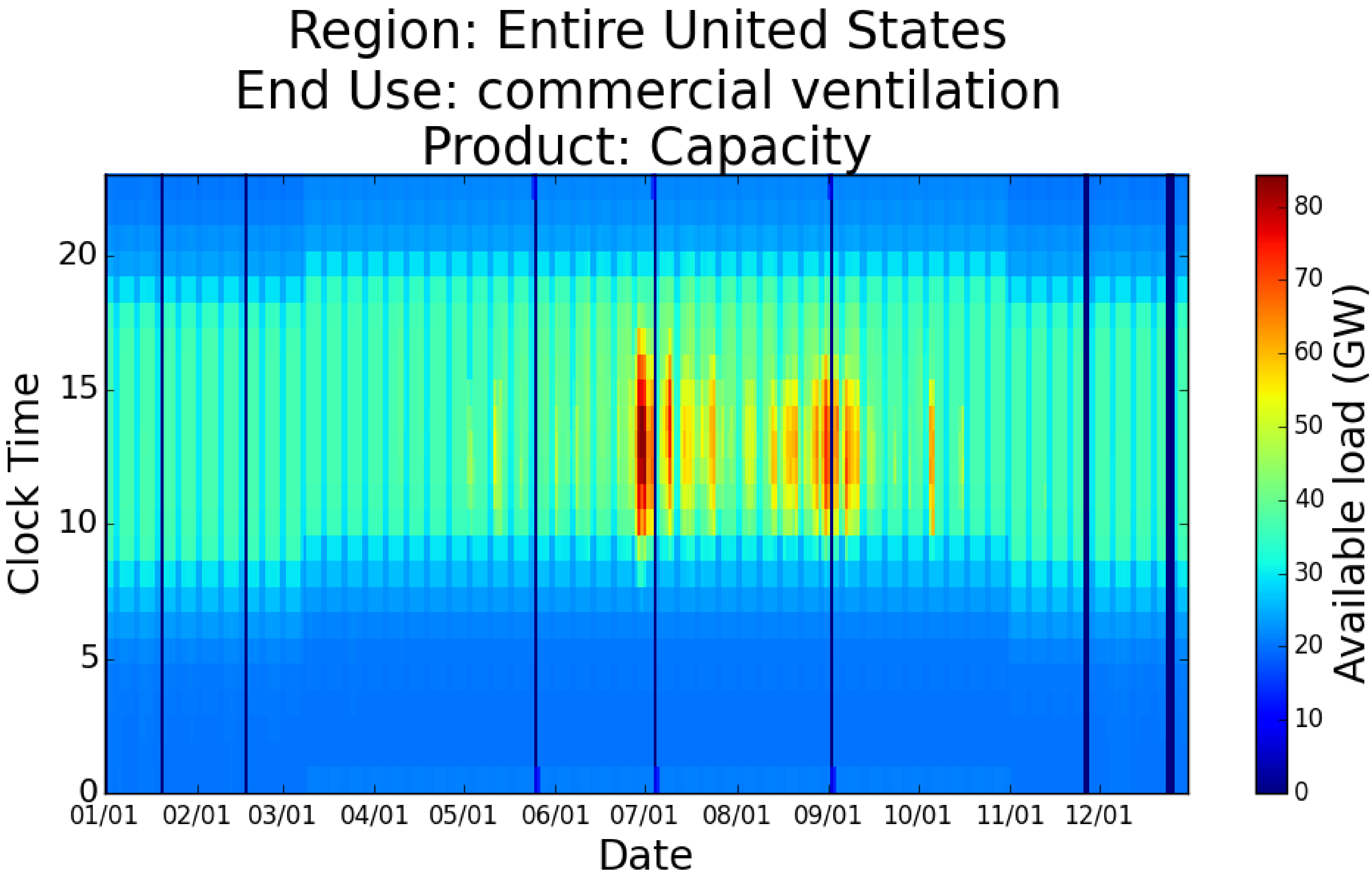
VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Capacity

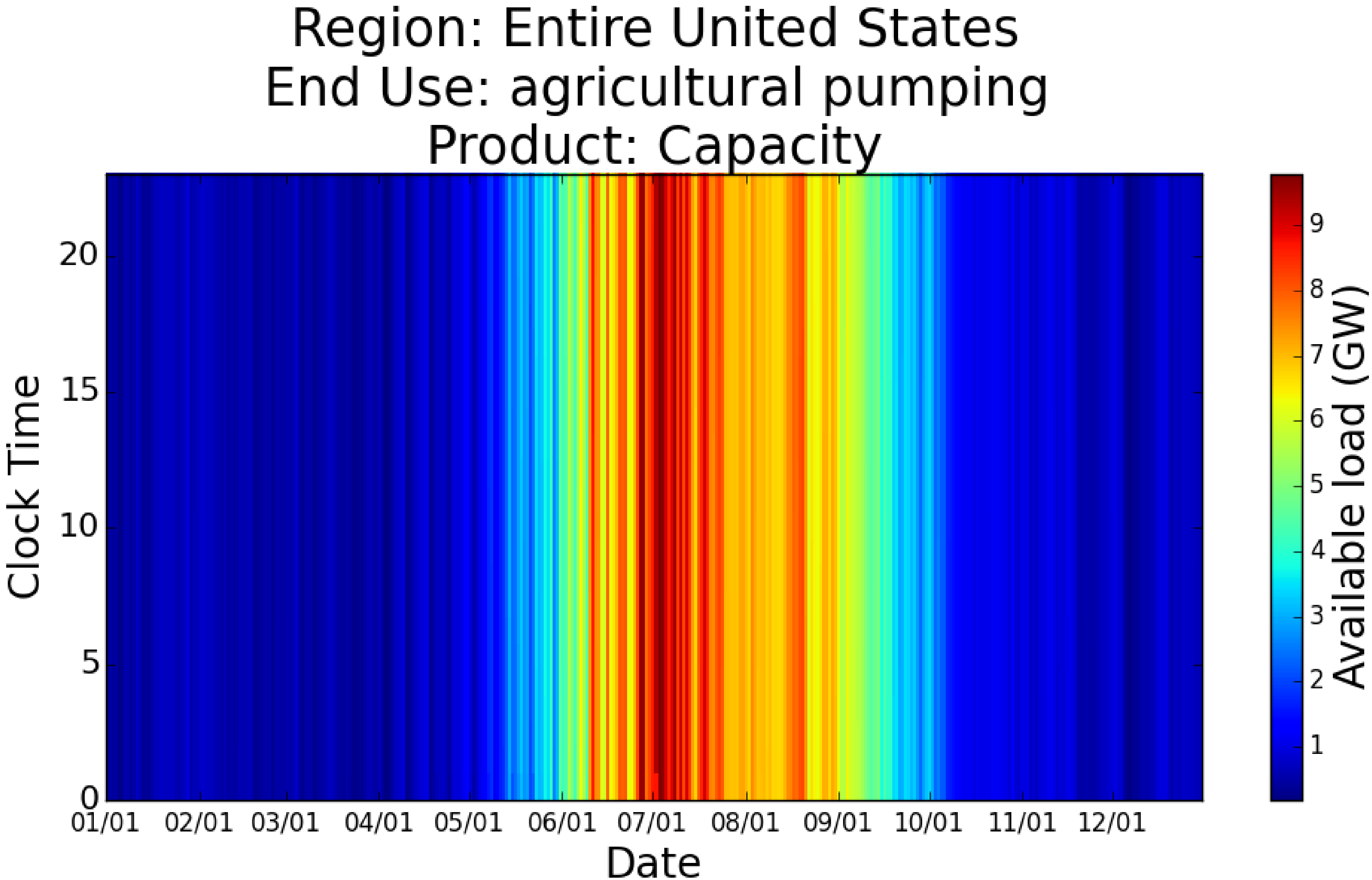


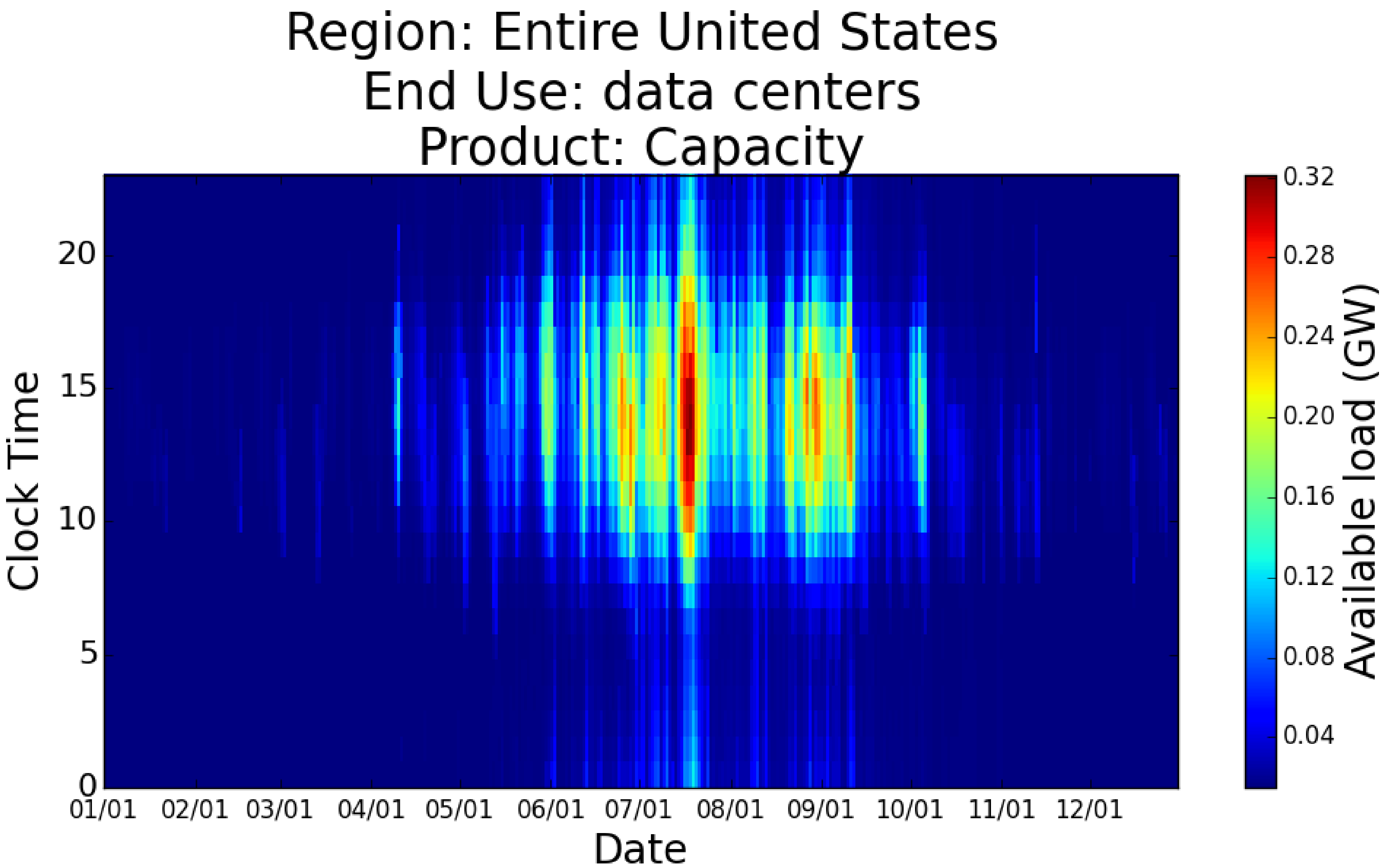
Region: Entire United States
End Use: commerical cooling
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
40
80
120
160
200
240
280
320
360

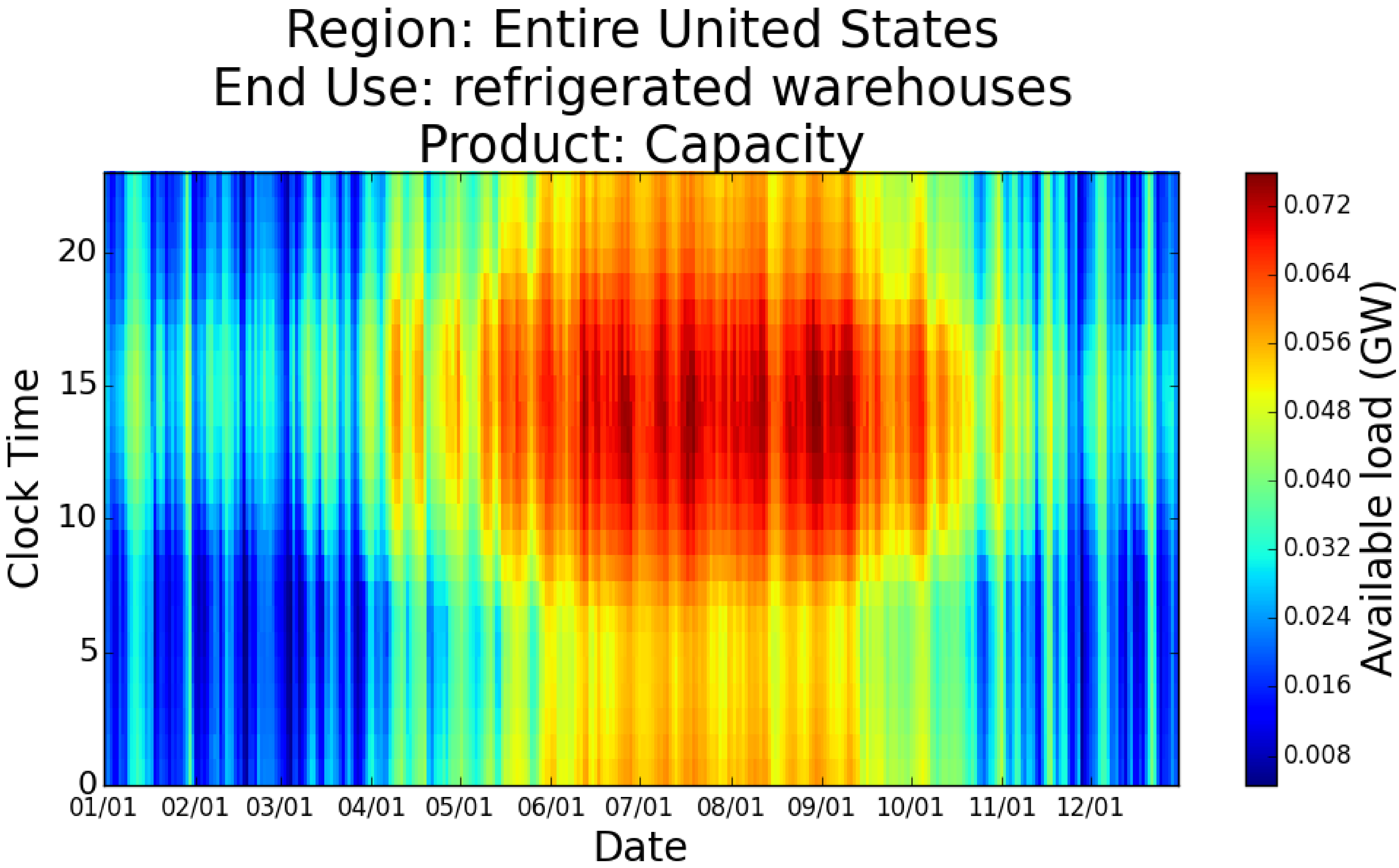

Region: Entire United States
End Use: commercial heating
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0


Region: Entire United States
End Use: commercial lighting
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
2
4
6
8
10
12
14
16

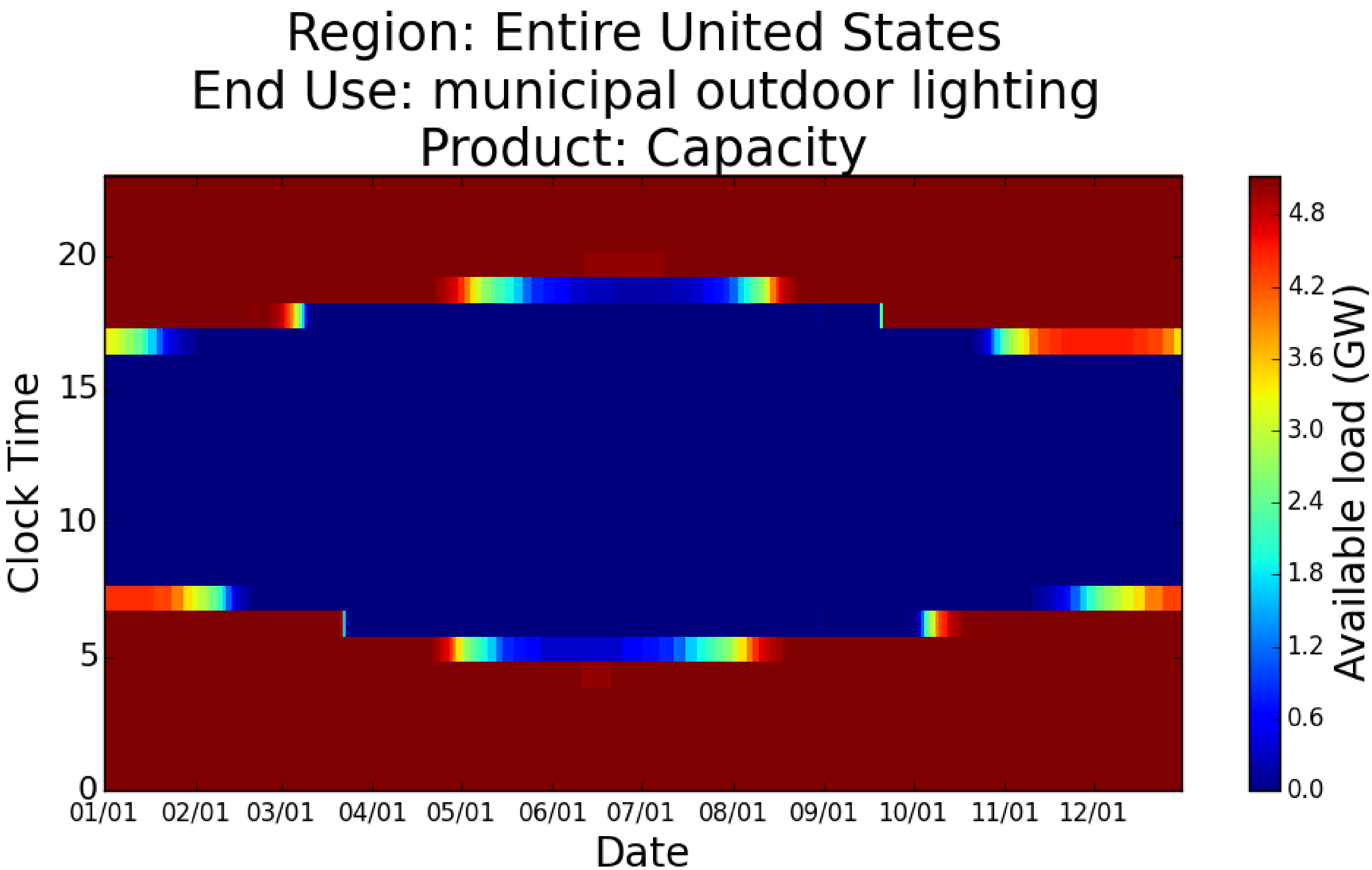

Region: Entire United States
End Use: commercial ventilation
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
10
20
30
40
50
60
70
80


Region: Entire United States
End Use: agricultural pumping
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
1
2
3
4
5
6
7
8
9

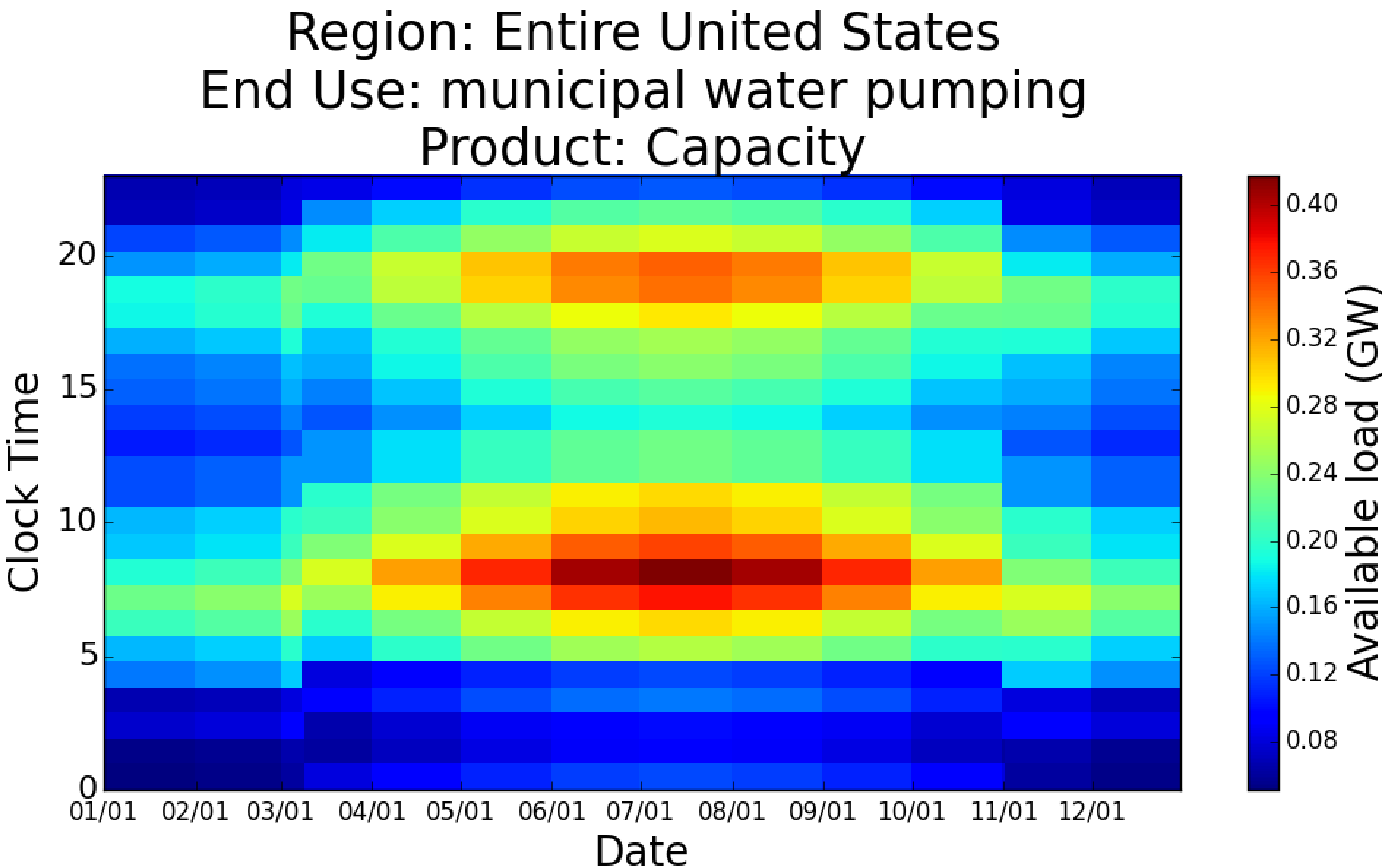

Region: Entire United States
End Use: data centers
Product: Capacity
Clock Time
0
5
10
15
20
Date
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Available load (GW)
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32

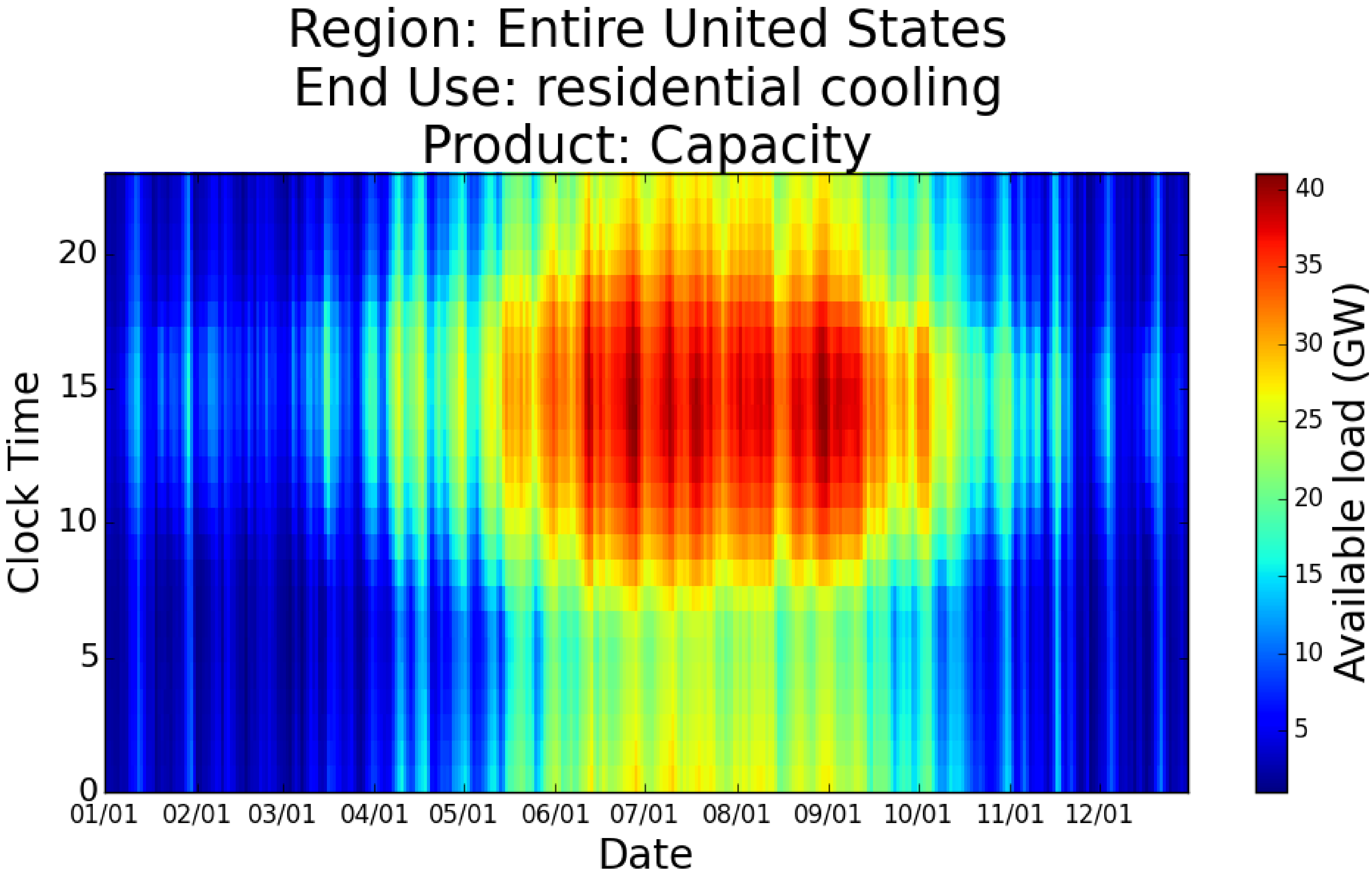


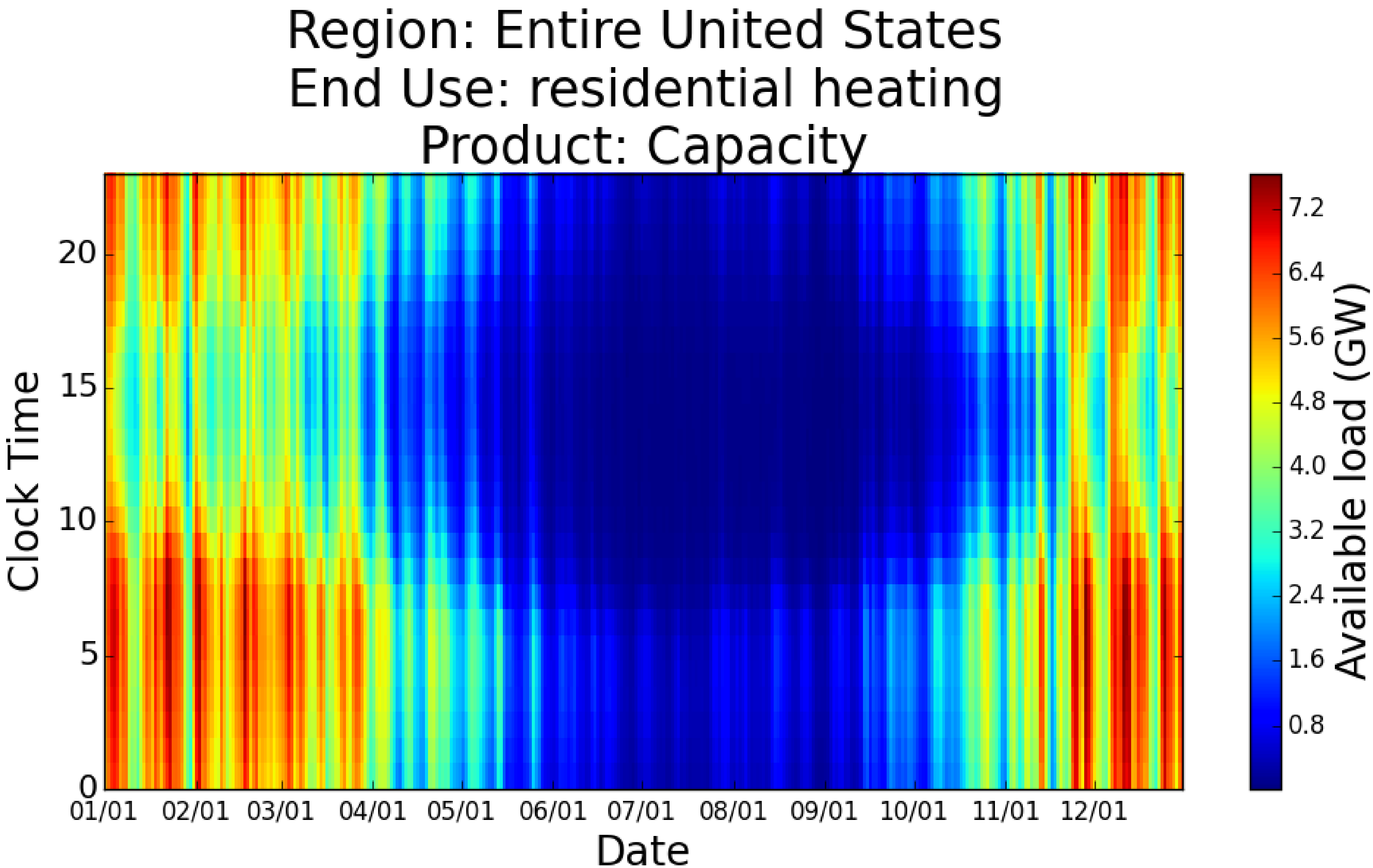
Region: Entire United States
End Use: refrigerated warehouses
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.072
0.064
0.056
0.048
0.040
0.032
0.024
0.016
0.008

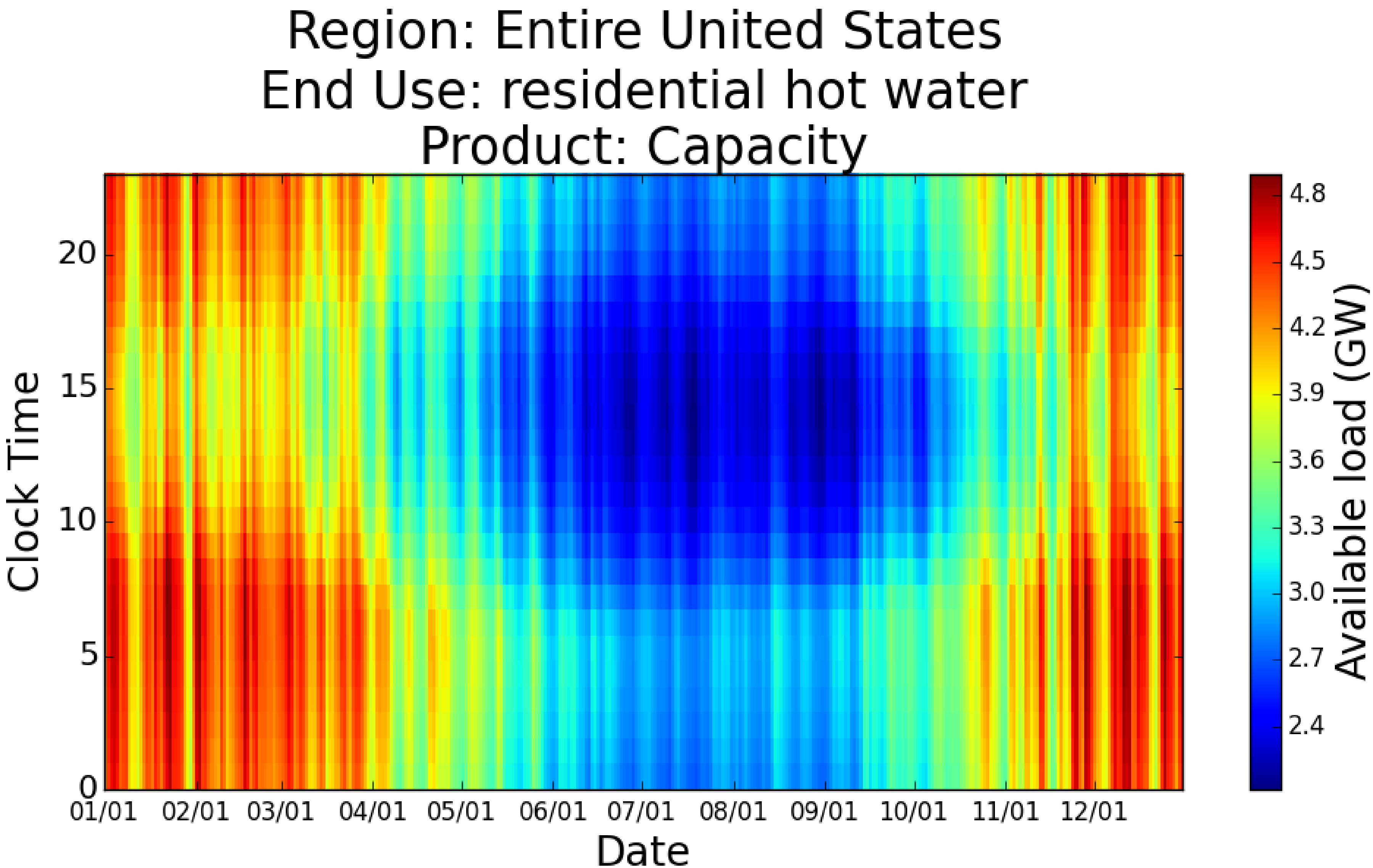


Region: Entire United States
End Use: municipal outdoor lighting
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
4.8

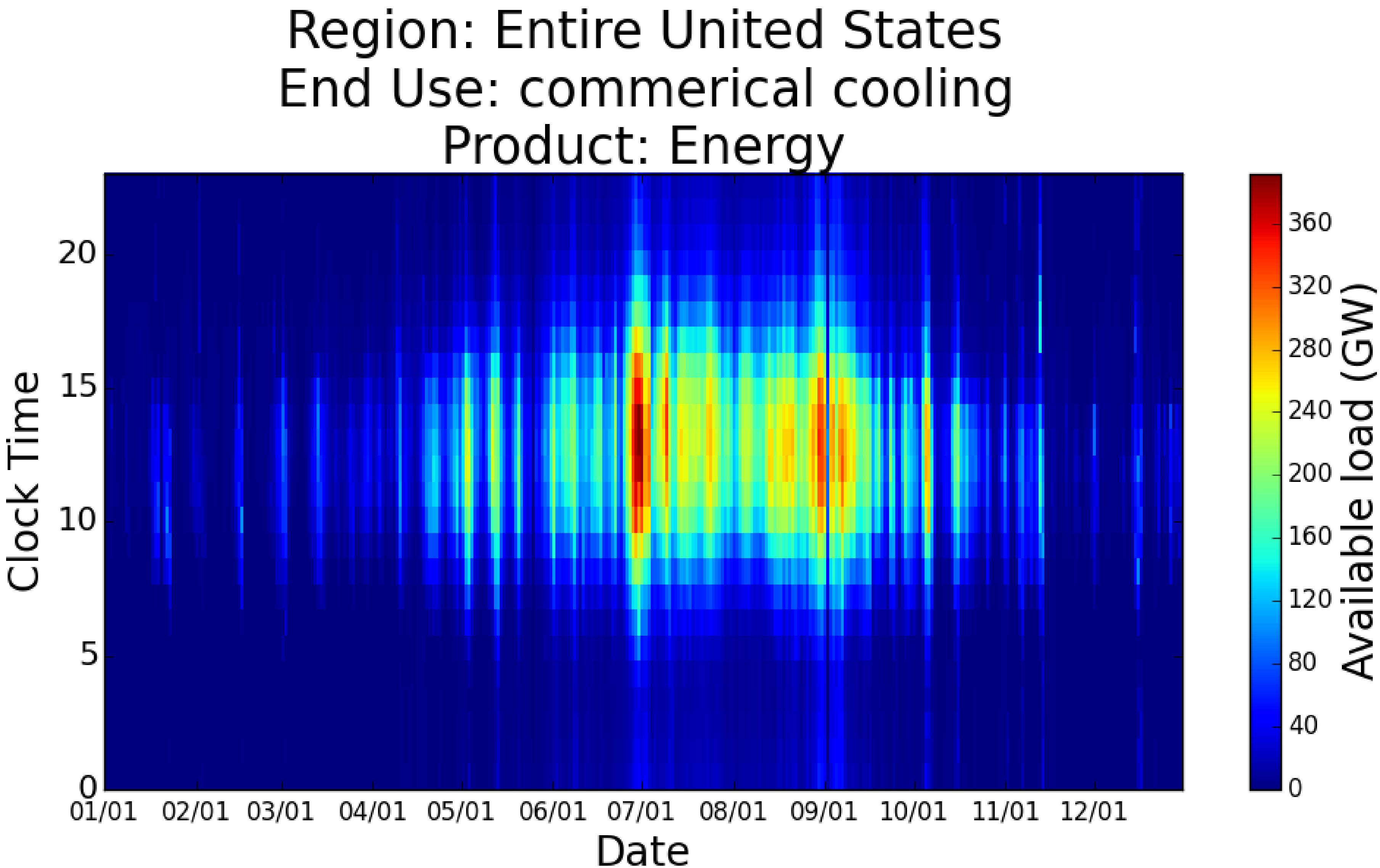

Region: Entire United States
End Use: municipal water pumping
Product: Capacity
Clock Time
0
5
10
15
20
01/01 02/01 03/01 04/01 05/01 06/01 07/01 08/01 09/01 10/01 11/01 12/01
Date
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40
Available load (GW)

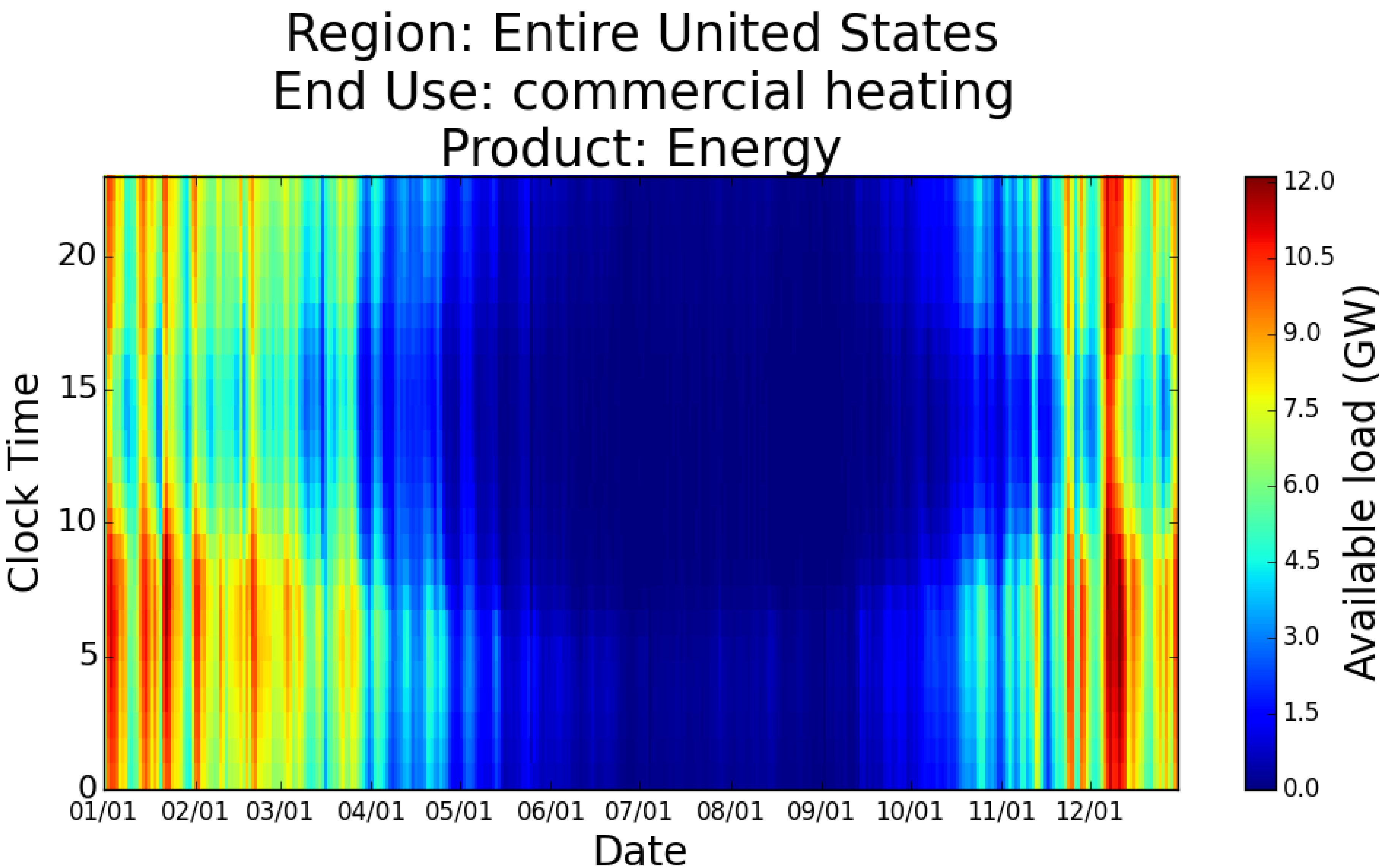

Region: Entire United States
End Use: residential cooling
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
5
10
15
20
25
30
35
40


Region: Entire United States
End Use: residential heating
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2

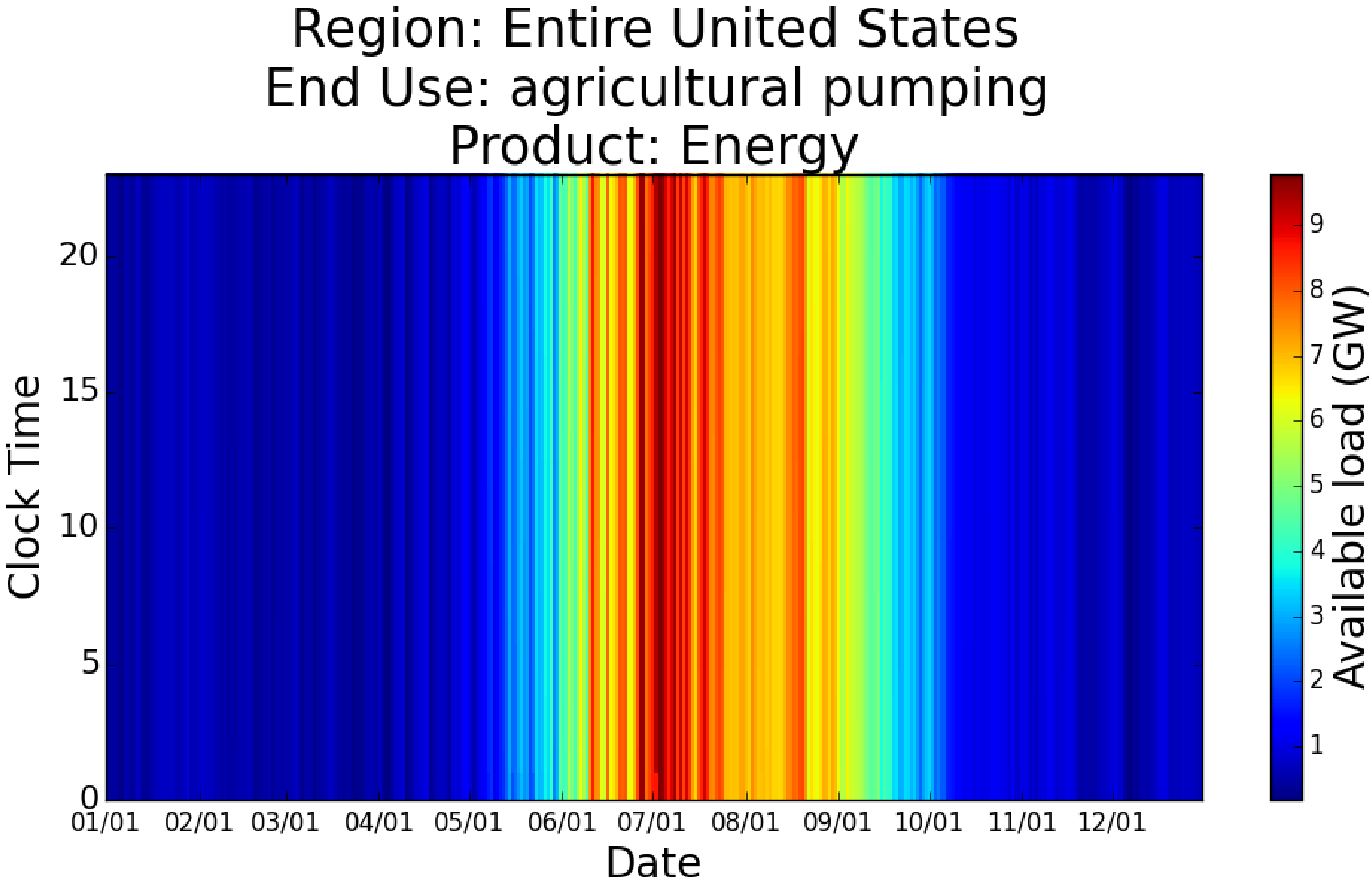

Region: Entire United States
End Use: residential hot water
Product: Capacity
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
4.8
4.5
4.2
3.9
3.6
3.3
3.0
2.7
2.4
Available load (GW)

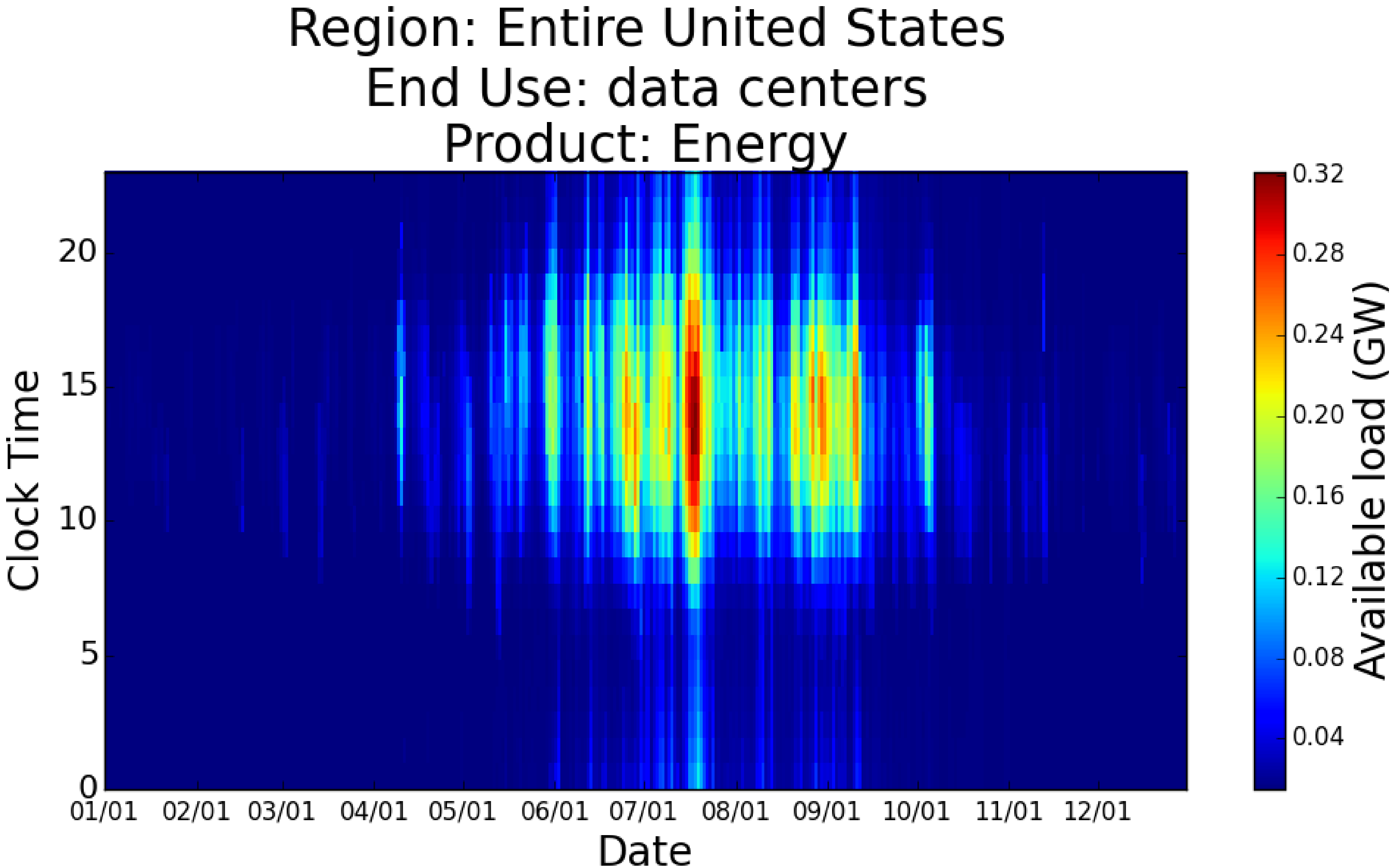
VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Energy

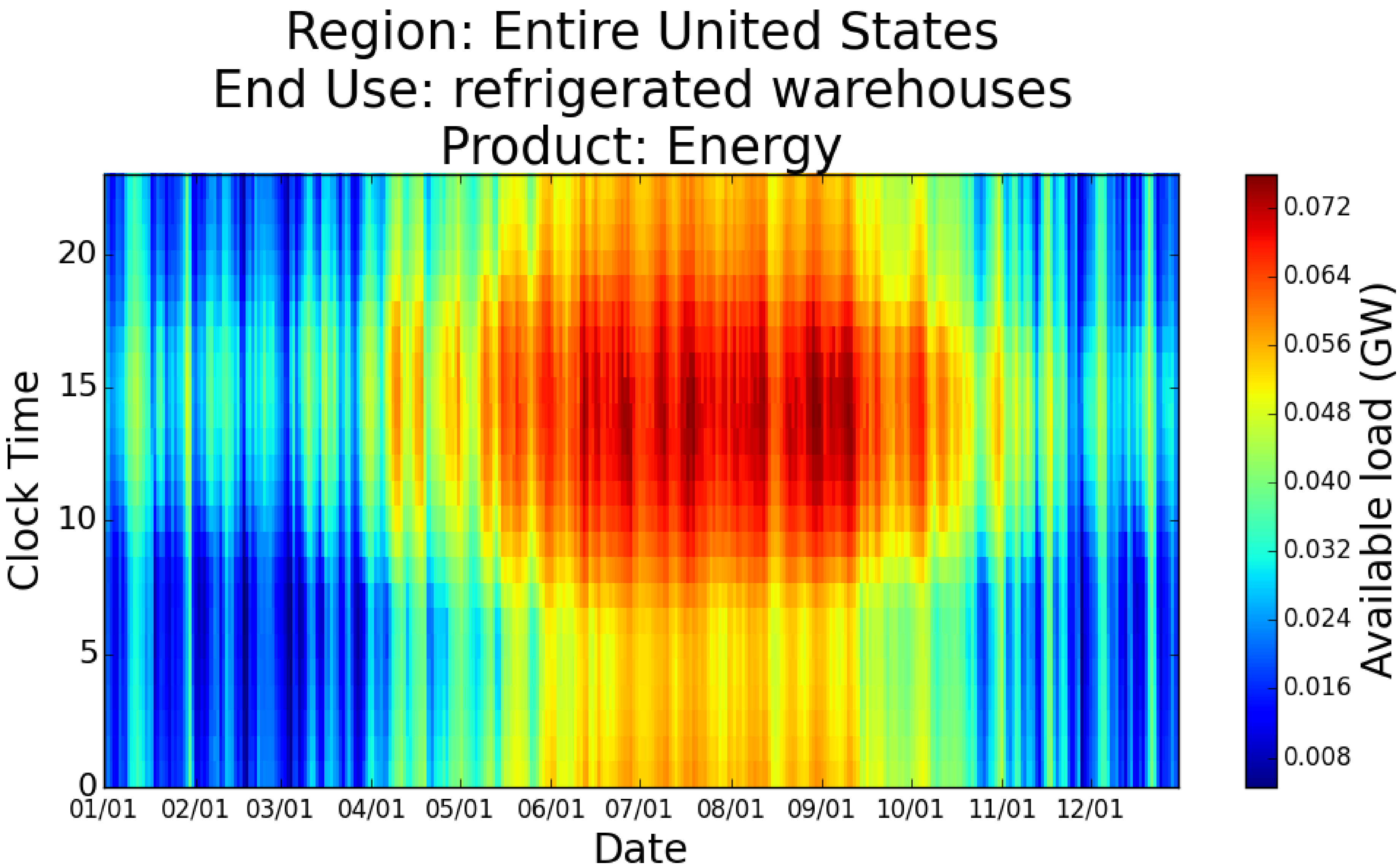

Region: Entire United States
End Use: commerical cooling
Product: Energy
Clock Time
0
5
10
15
20
Date
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Available load (GW)
0
40
80
120
160
200
240
280
320
360

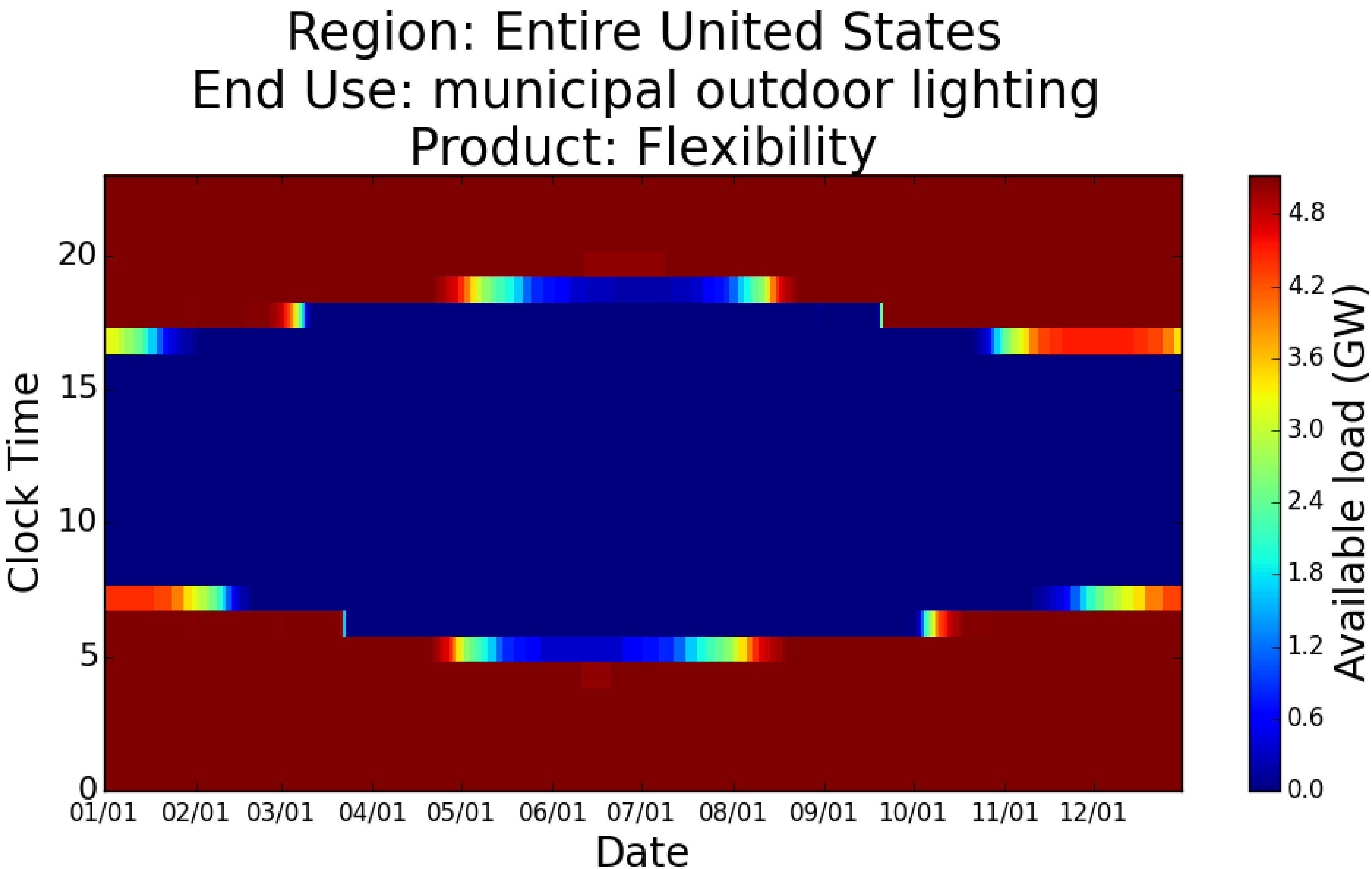


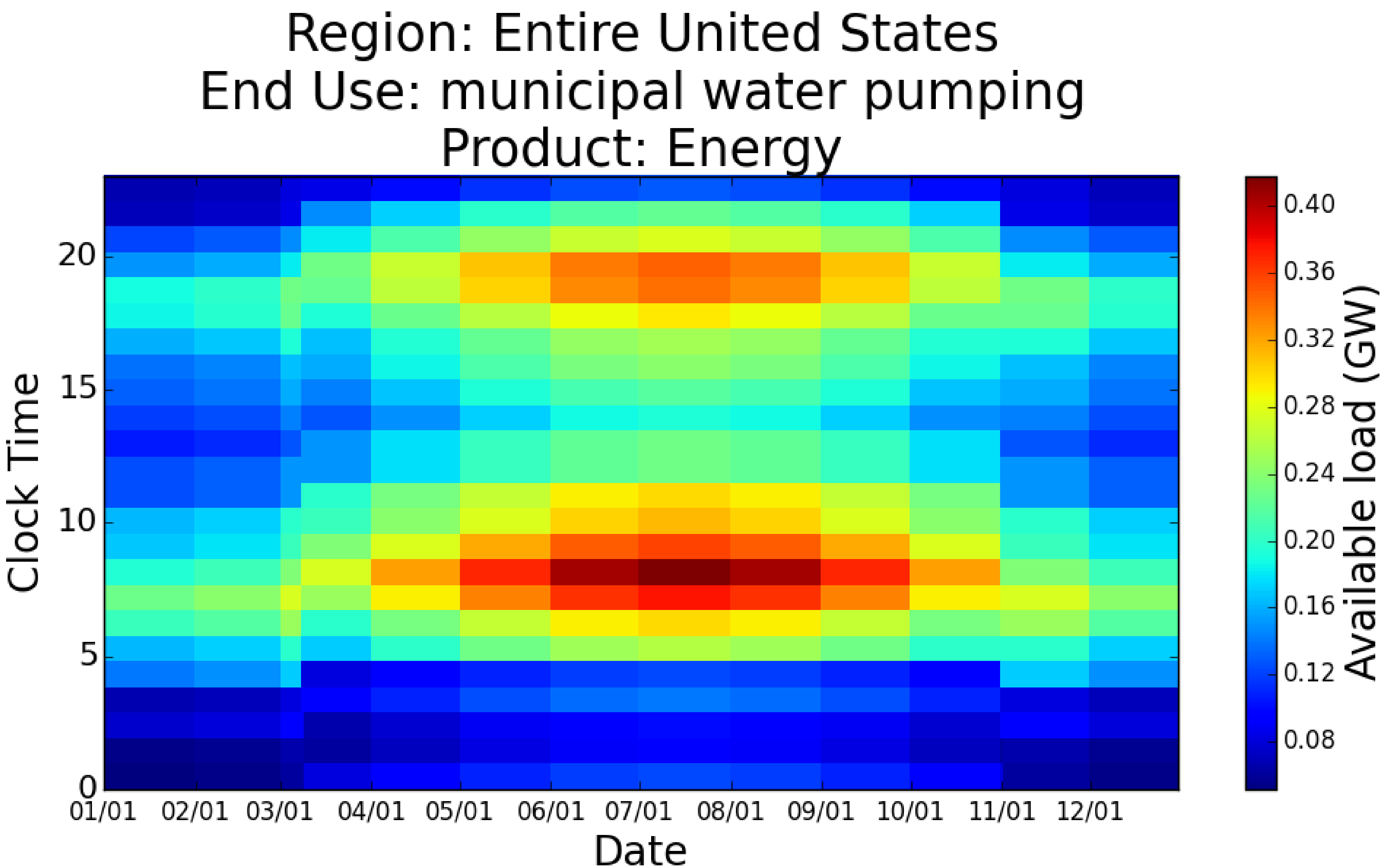
Region: Entire United States
End Use: commercial heating
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.0
1.5
3.0
4.5
6.0
7.5
9.0
10.5
12.0

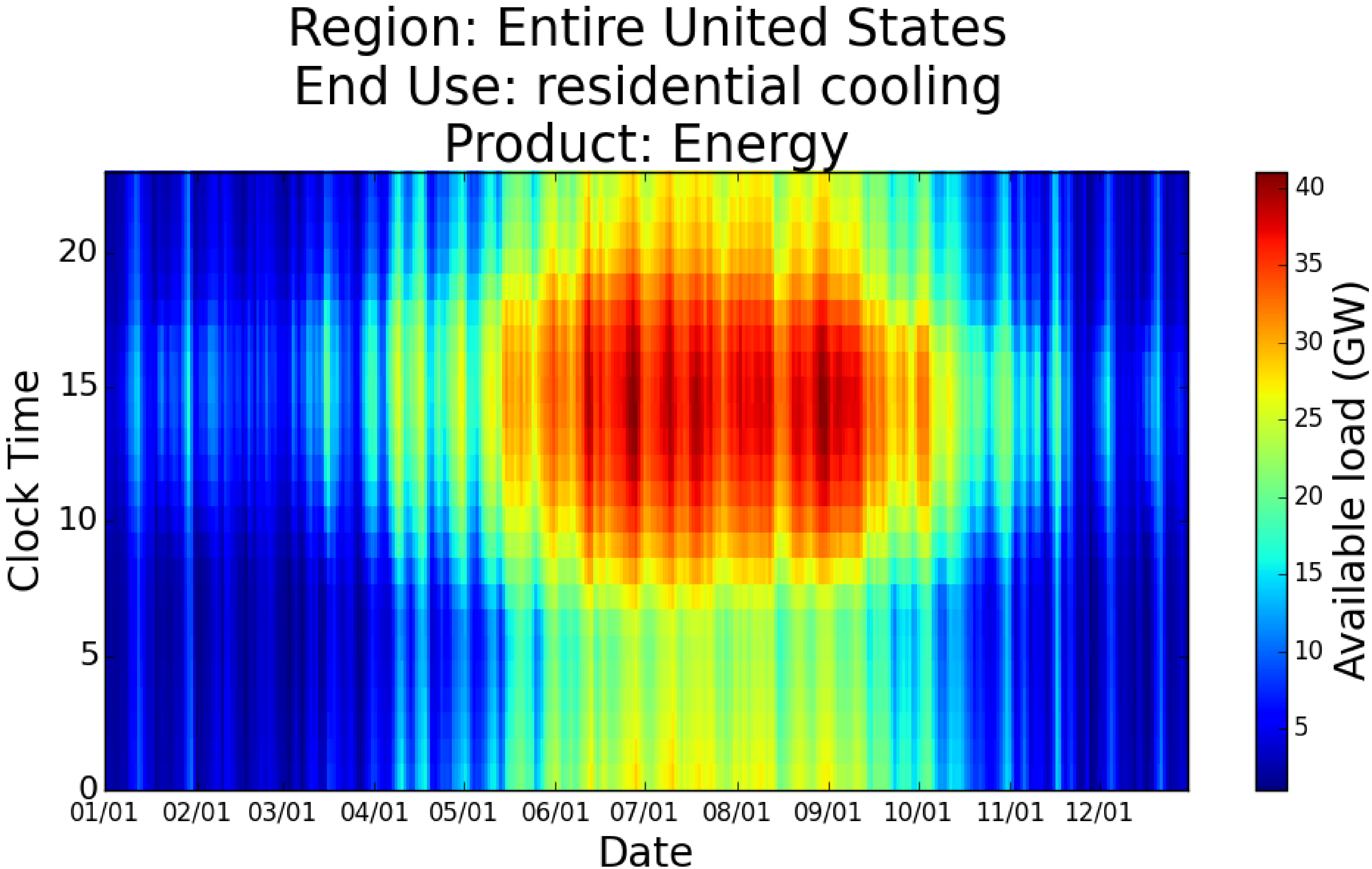

Region: Entire United States
End Use: agricultural pumping
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
1
2
3
4
5
6
7
8
9

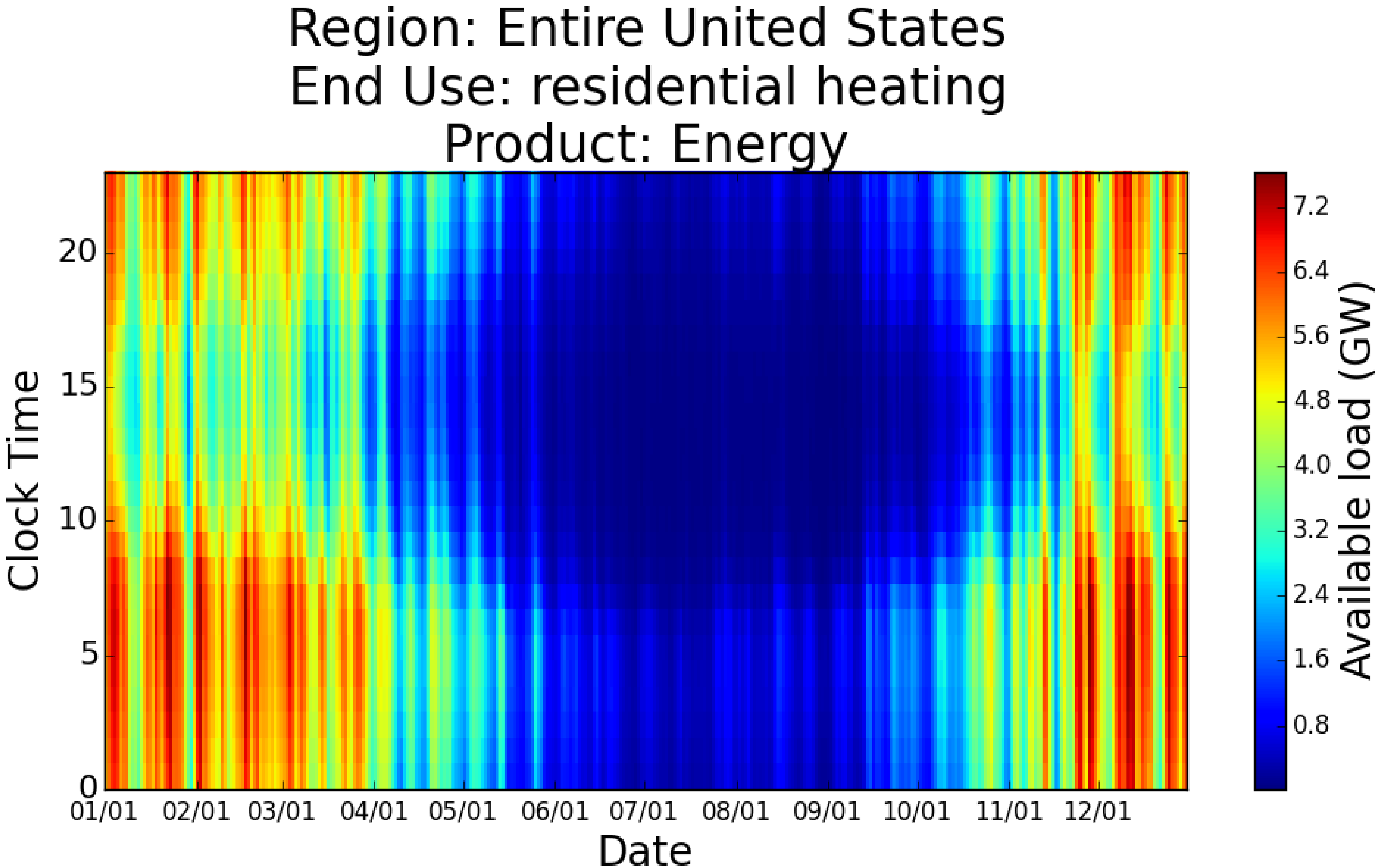

Region: Entire United States
End Use: data centers
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32


Region: Entire United States
End Use: refrigerated warehouses
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
0.072
0.064
0.056
0.048
0.040
0.032
0.024
0.016
0.008
Available load (GW)

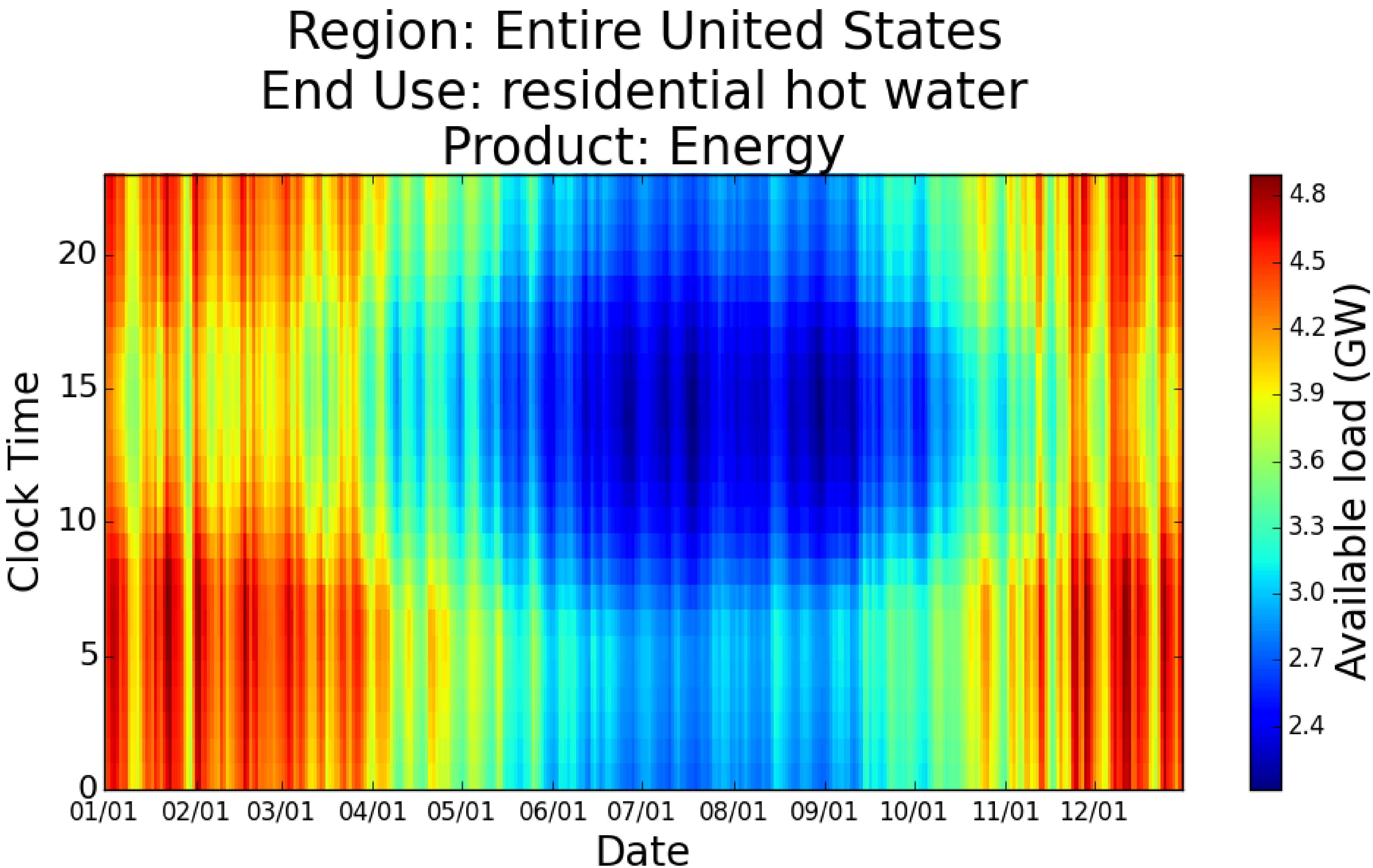

Region: Entire United States
End Use: municipal outdoor lighting
Product: Flexibility
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
4.8


Region: Entire United States
End Use: municipal water pumping
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
0.08
0.12
0.16
0.20
0.24
0.28
0.32
0.36
0.40
Available load (GW)

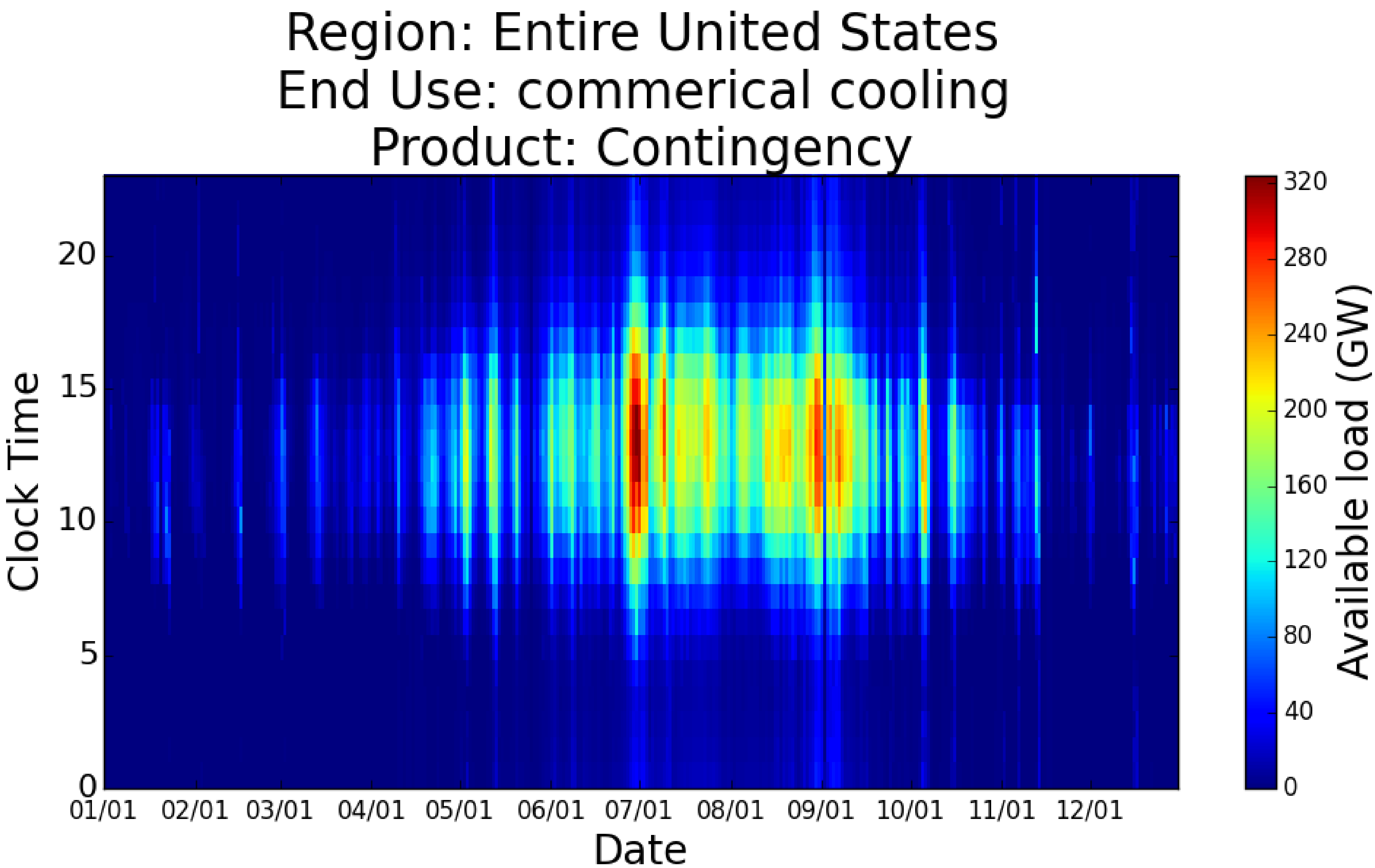

Region: Entire United States
End Use: residential cooling
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
5
10
15
20
25
30
35
40

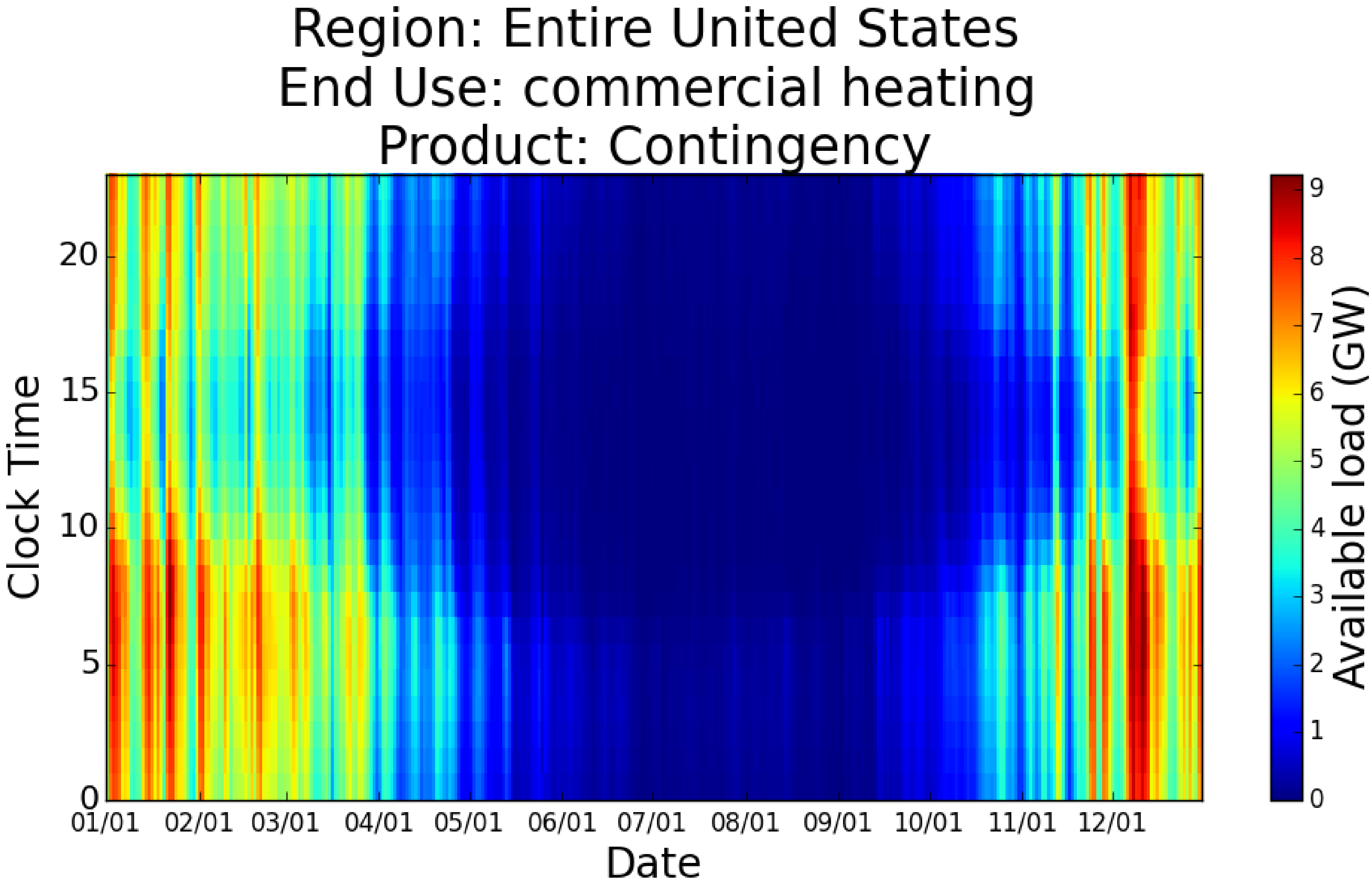


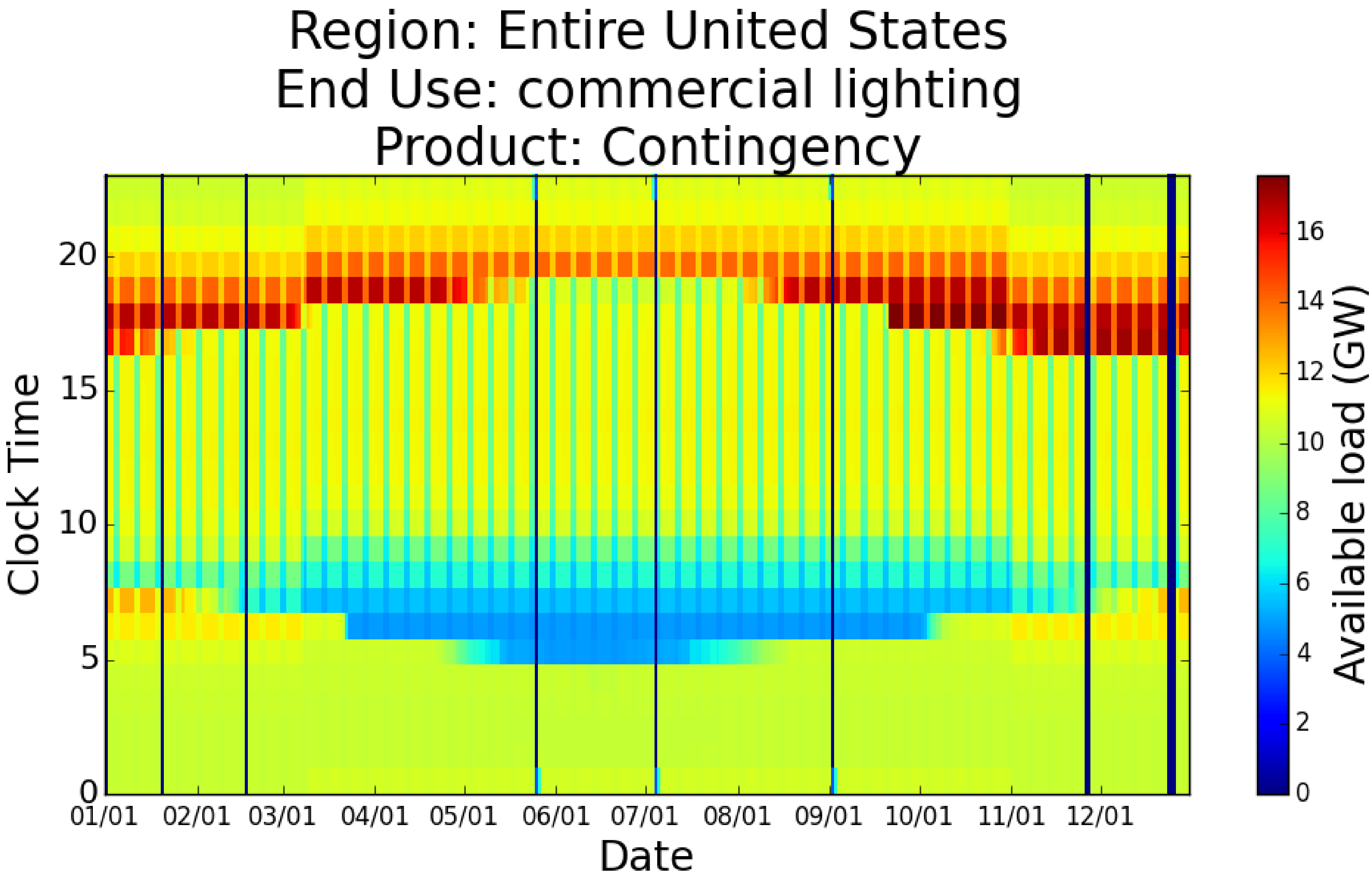
Region: Entire United States
End Use: residential heating
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2


Region: Entire United States
End Use: residential hot water
Product: Energy
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
4.8
4.5
4.2
3.9
3.6
3.3
3.0
2.7
2.4
Available load (GW)

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

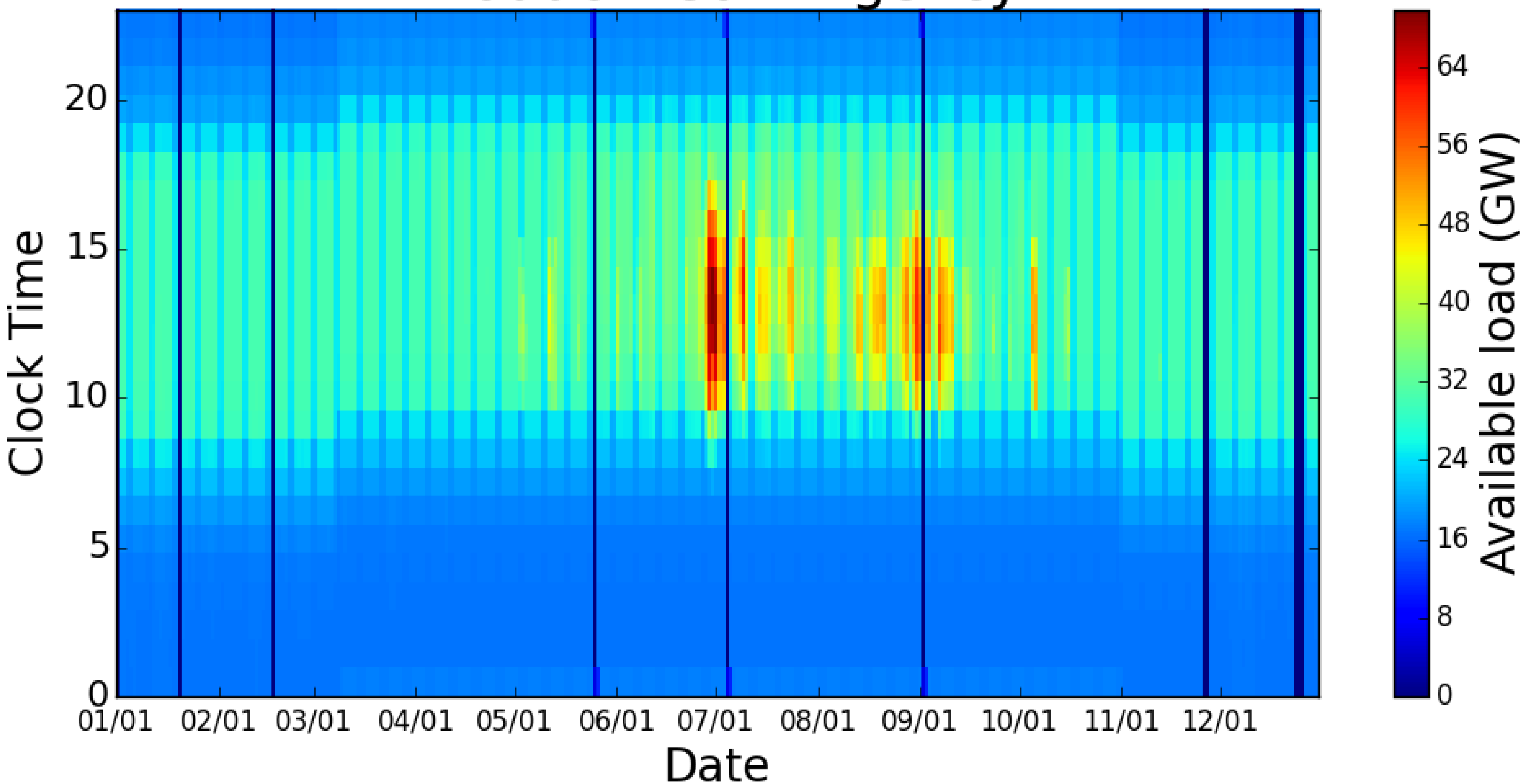

Region: Entire United States
End Use: commerical cooling
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
40
80
120
160
200
240
280
320

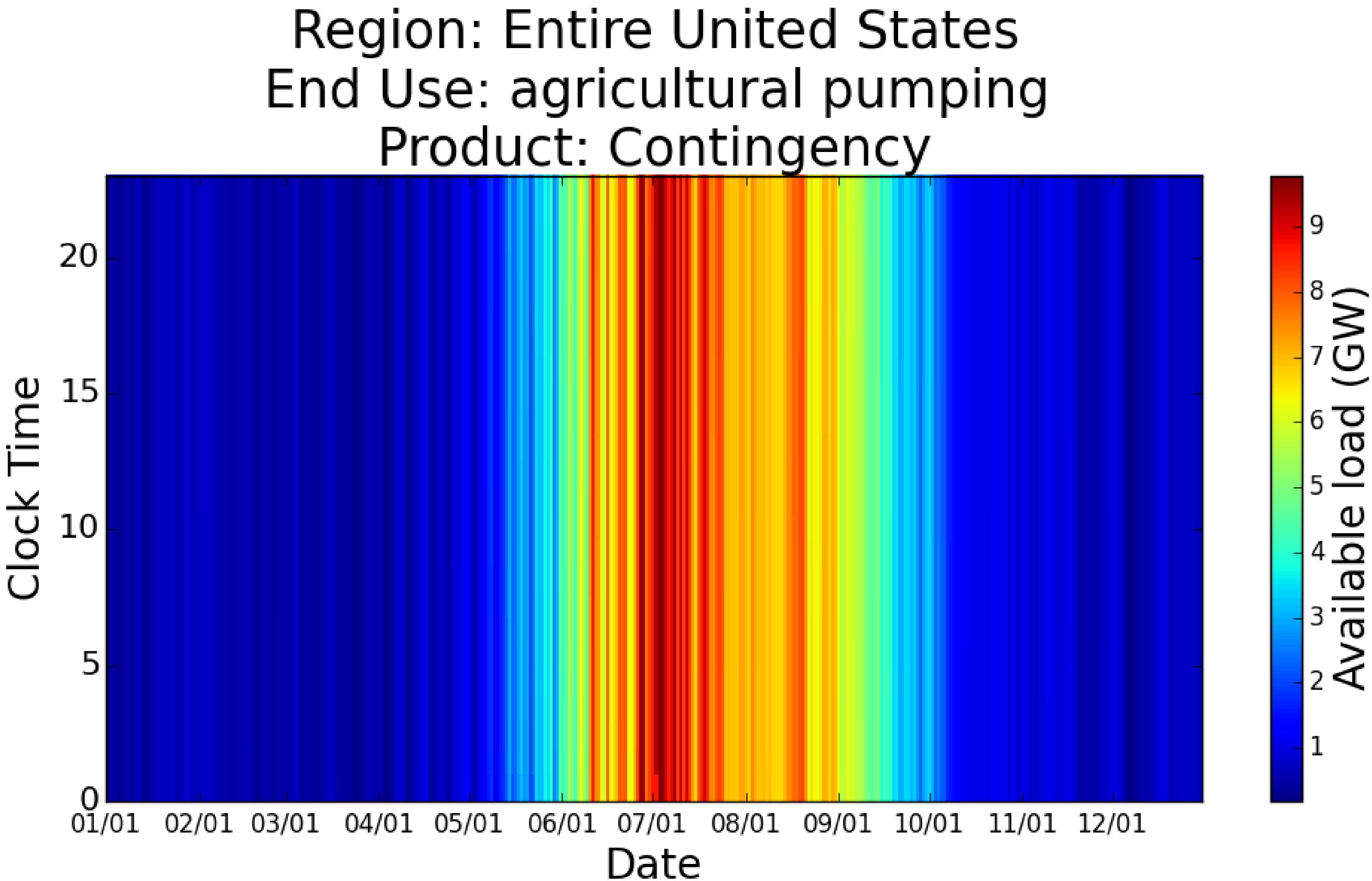

Region: Entire United States
End Use: commercial heating
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
1
2
3
4
5
6
7
8
9



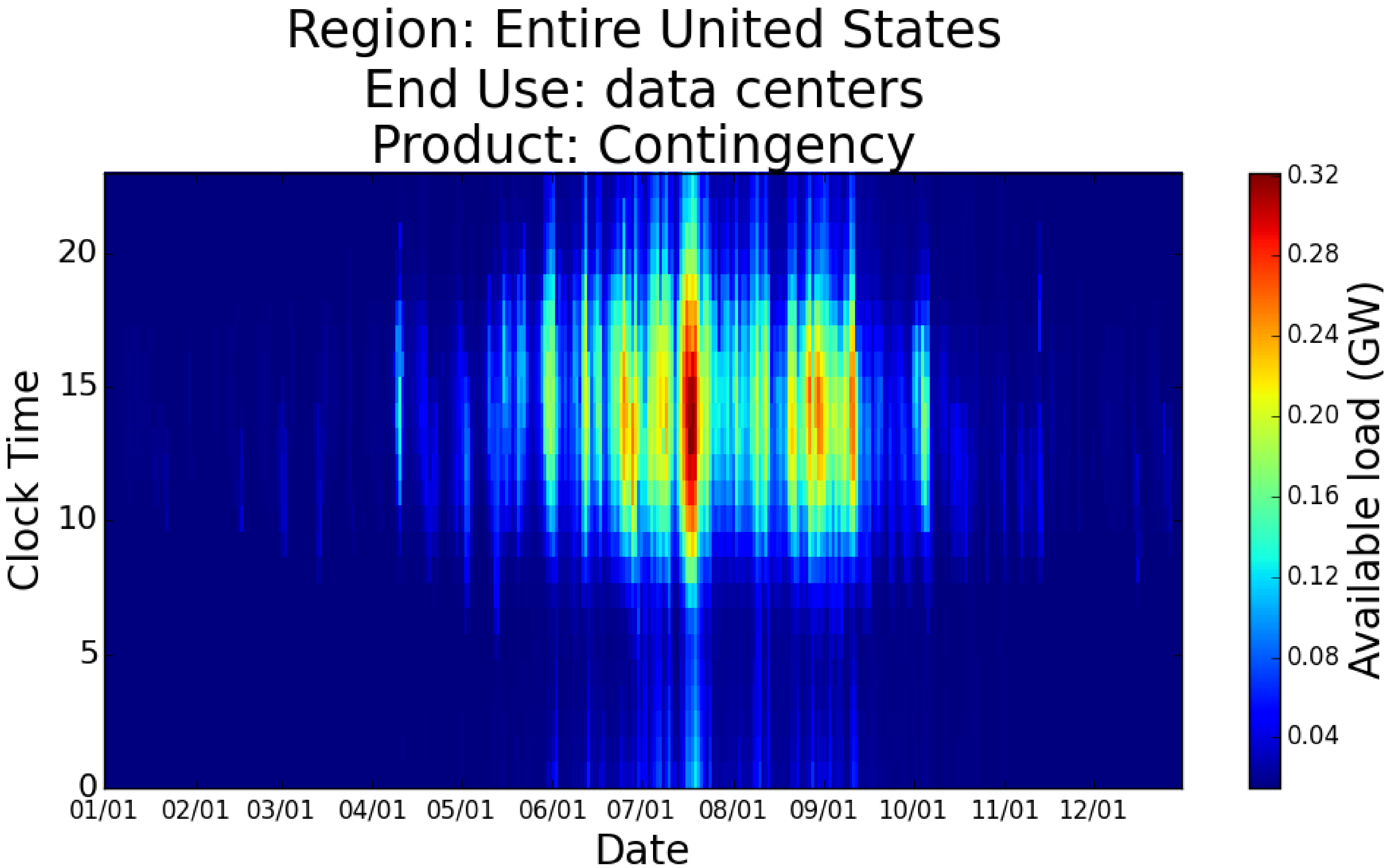
Region: Entire United States
End Use: commercial lighting
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
2
4
6
8
10
12
14
16

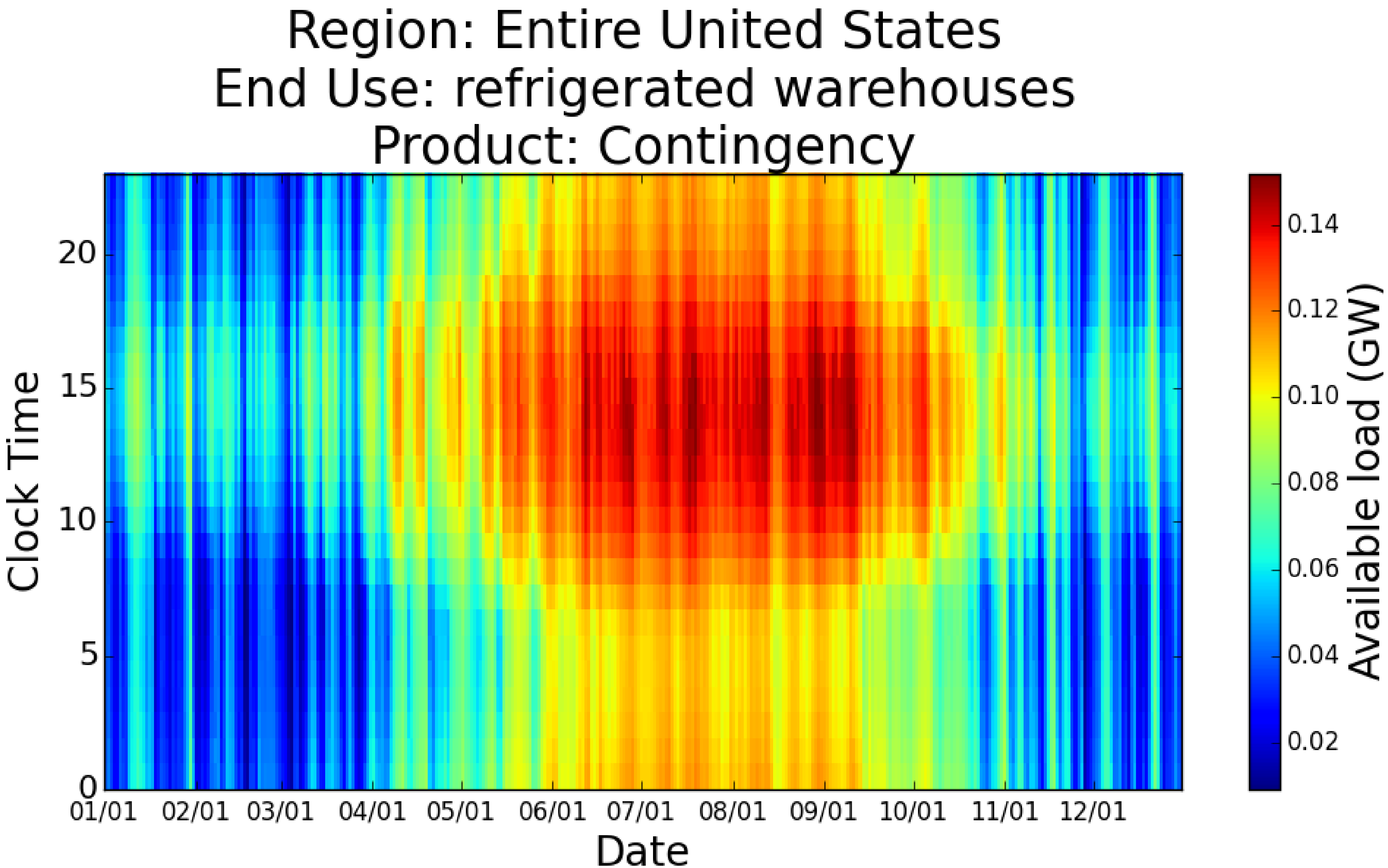
Region: Entire United States
End Use: commercial ventilation
Product: Contingency



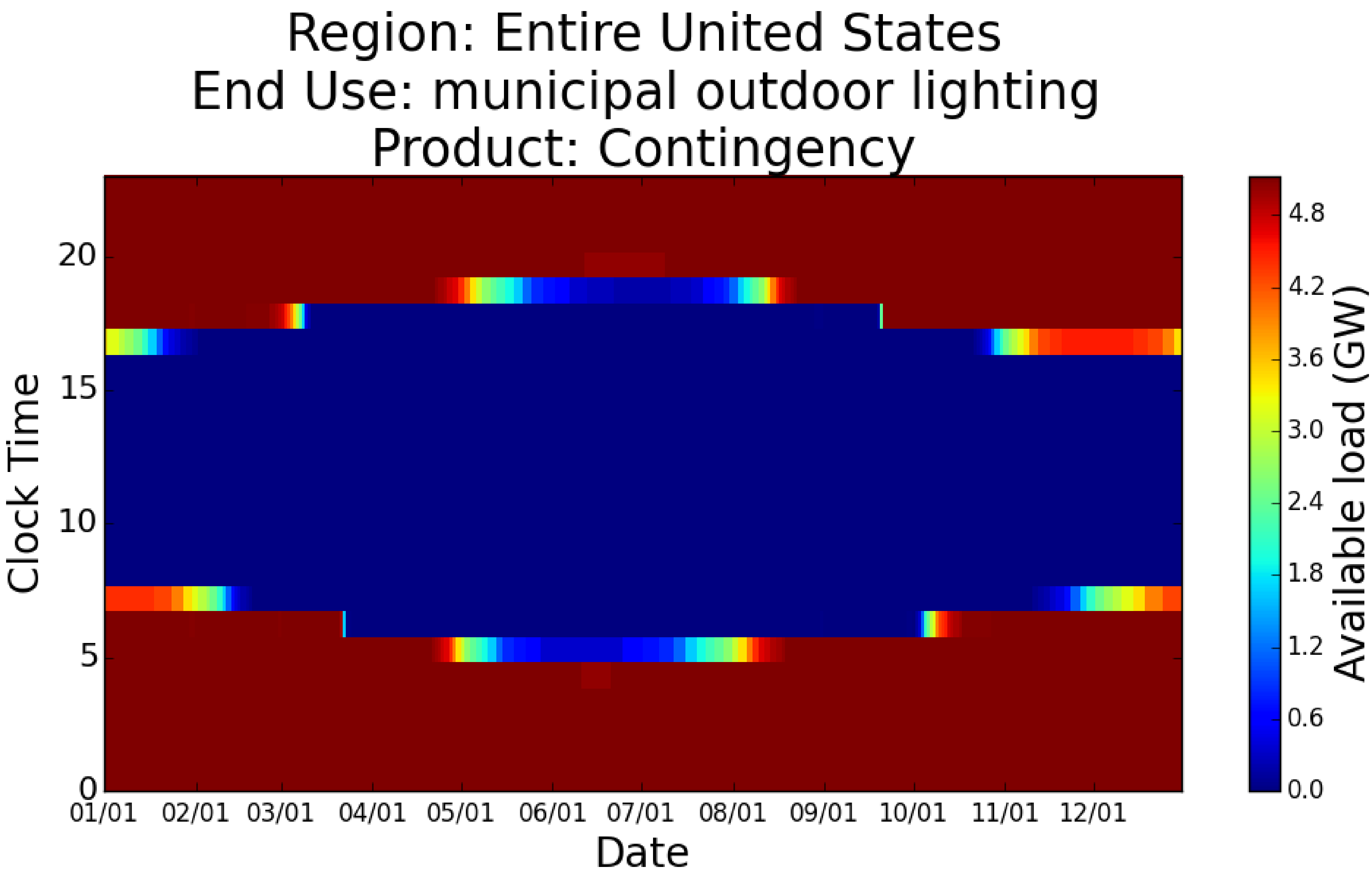


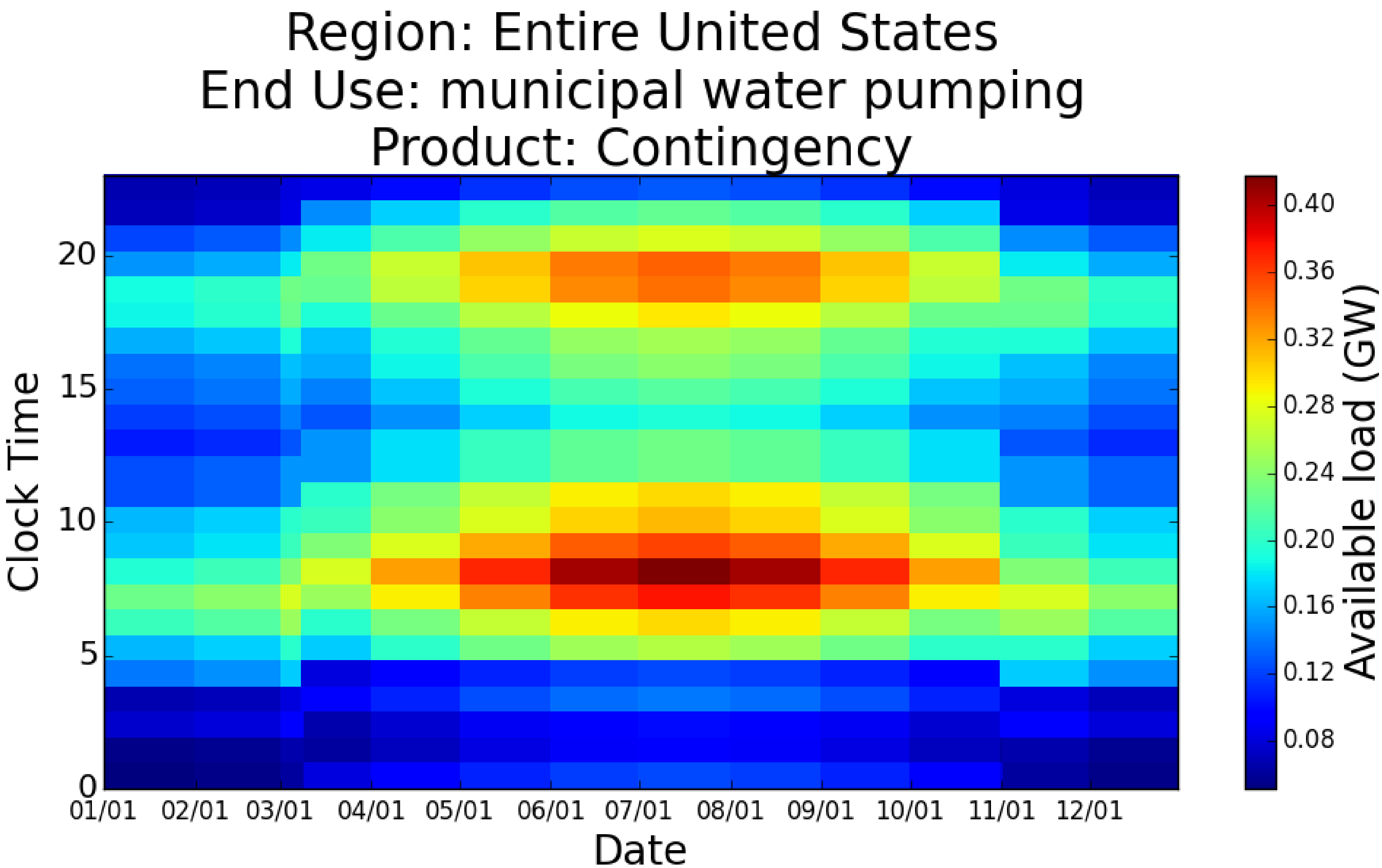
Region: Entire United States
End Use: agricultural pumping
Product: Contingency
Clock Time
0
5
10
15
20
01/01 02/01 03/01 04/01 05/01 06/01 07/01 08/01 09/01 10/01 11/01 12/01
Date
Available load (GW)
1
2
3
4
5
6
7
8
9


Region: Entire United States
End Use: data centers
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
0.04
0.08
0.12
0.16
0.20
0.24
0.28
0.32
Available load (GW)

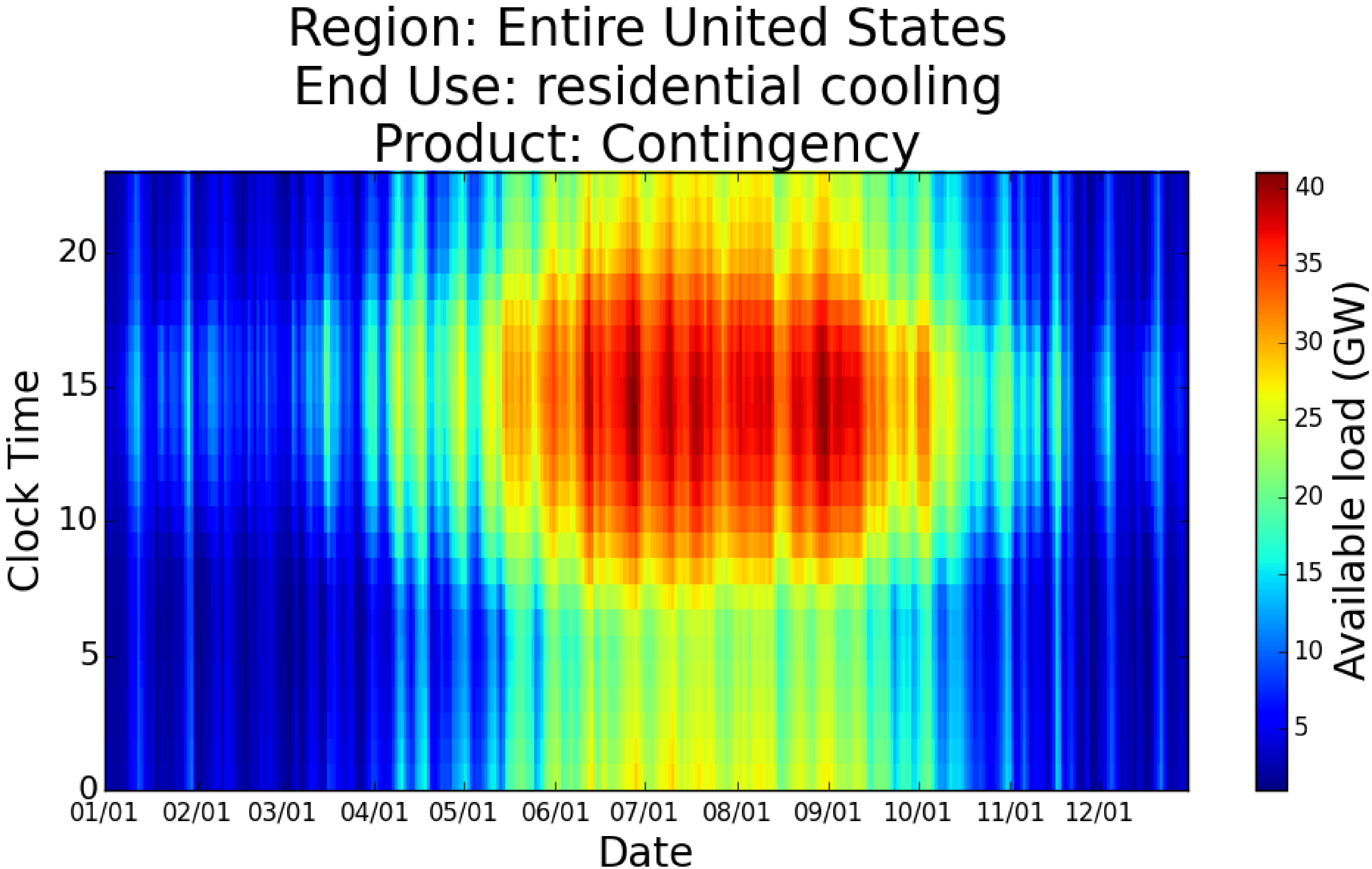


Region: Entire United States
End Use: refrigerated warehouses
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.02
0.04
0.06
0.08
0.10
0.12
0.14

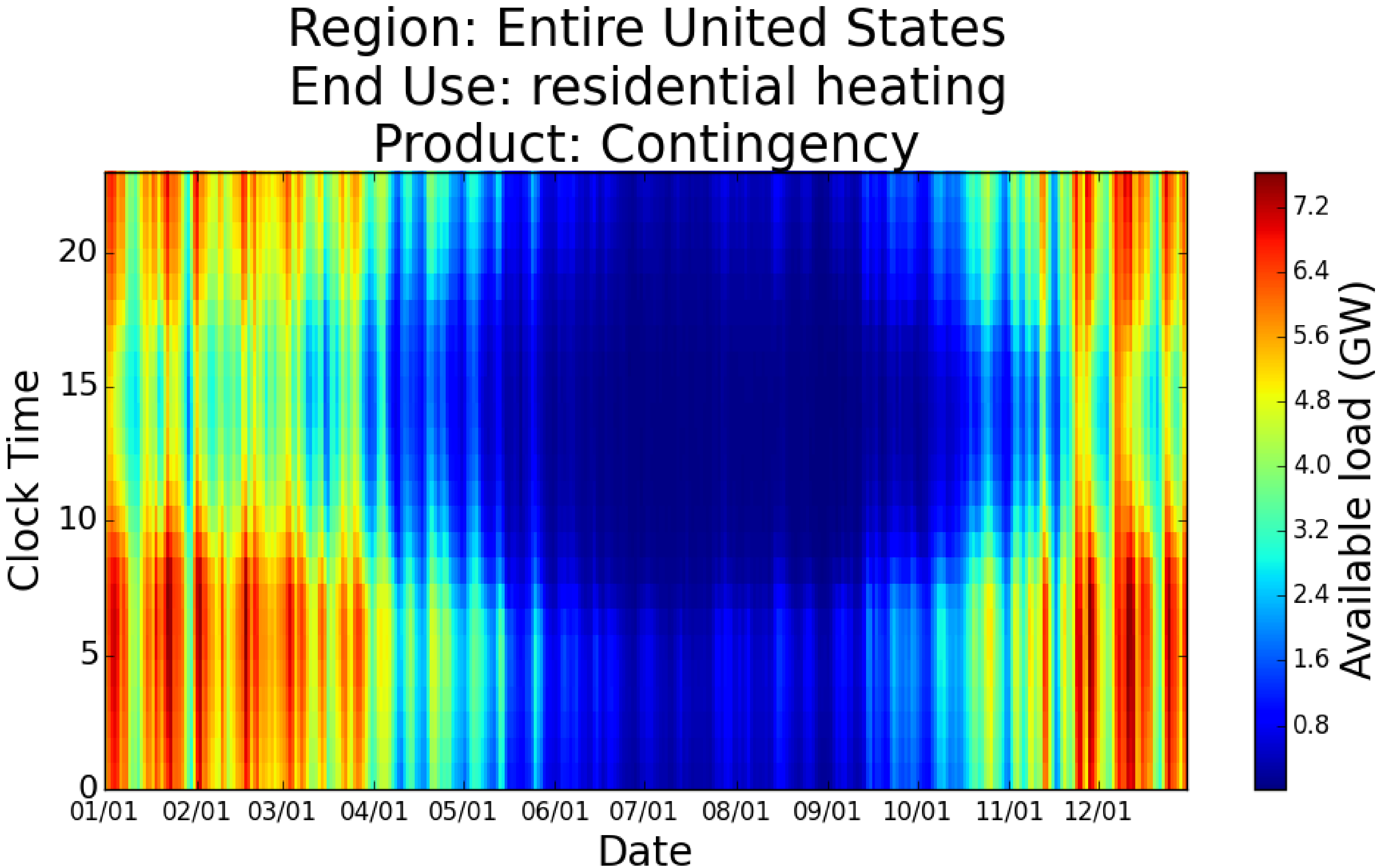

Region: Entire United States
End Use: municipal outdoor lighting
Product: Contingency
Clock Time
0
5
10
15
20
Date
01/01 02/01 03/01 04/01 05/01 06/01 07/01 08/01 09/01 10/01 11/01 12/01
Available load (GW)
0.0 0.6 1.2 1.8 2.4 3.0 3.6 4.2 4.8

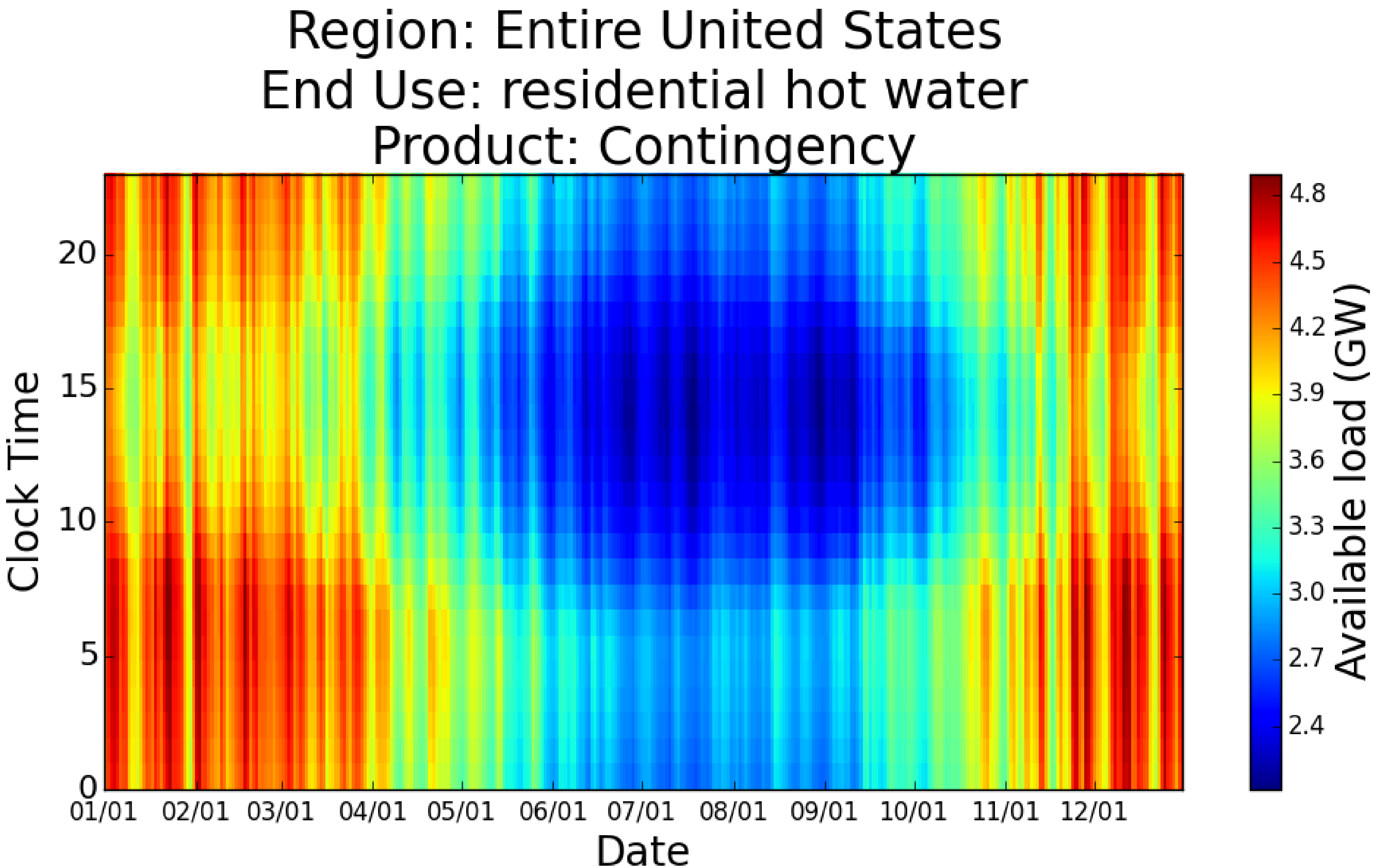


Region: Entire United States
End Use: municipal water pumping
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08

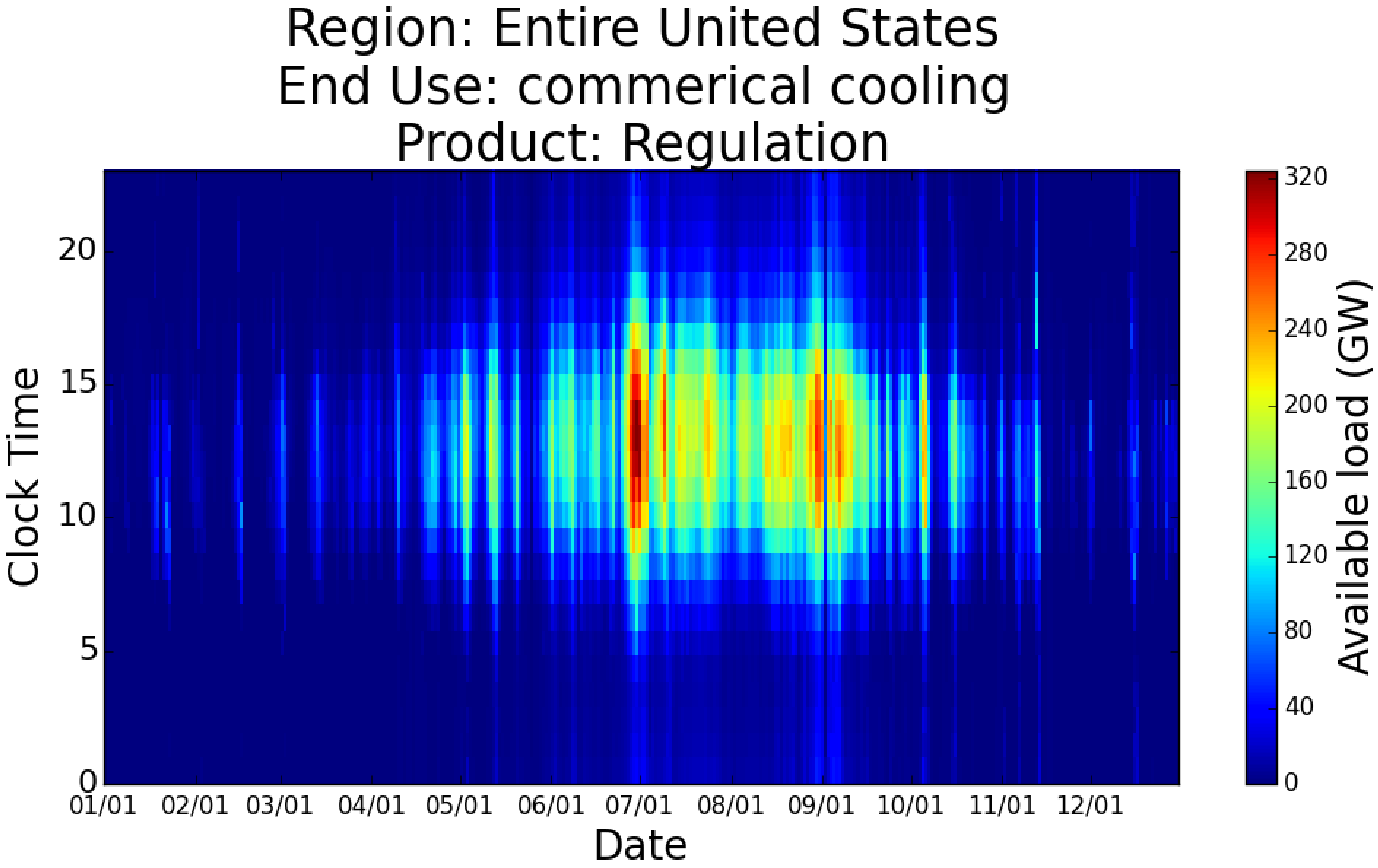


Region: Entire United States
End Use: residential cooling
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
5
10
15
20
25
30
35
40
Available load (GW)

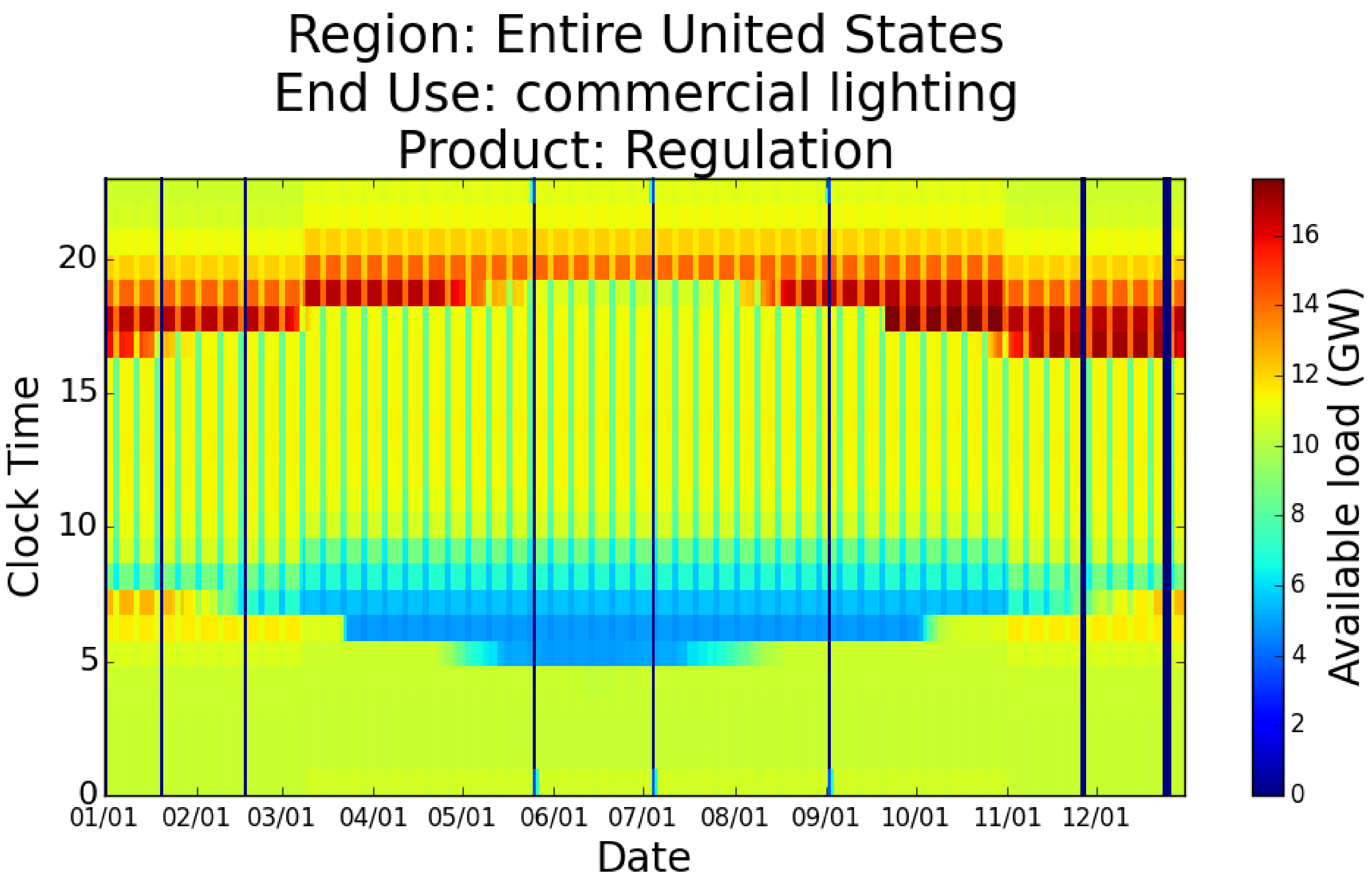

Region: Entire United States
End Use: residential heating
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2
Available load (GW)

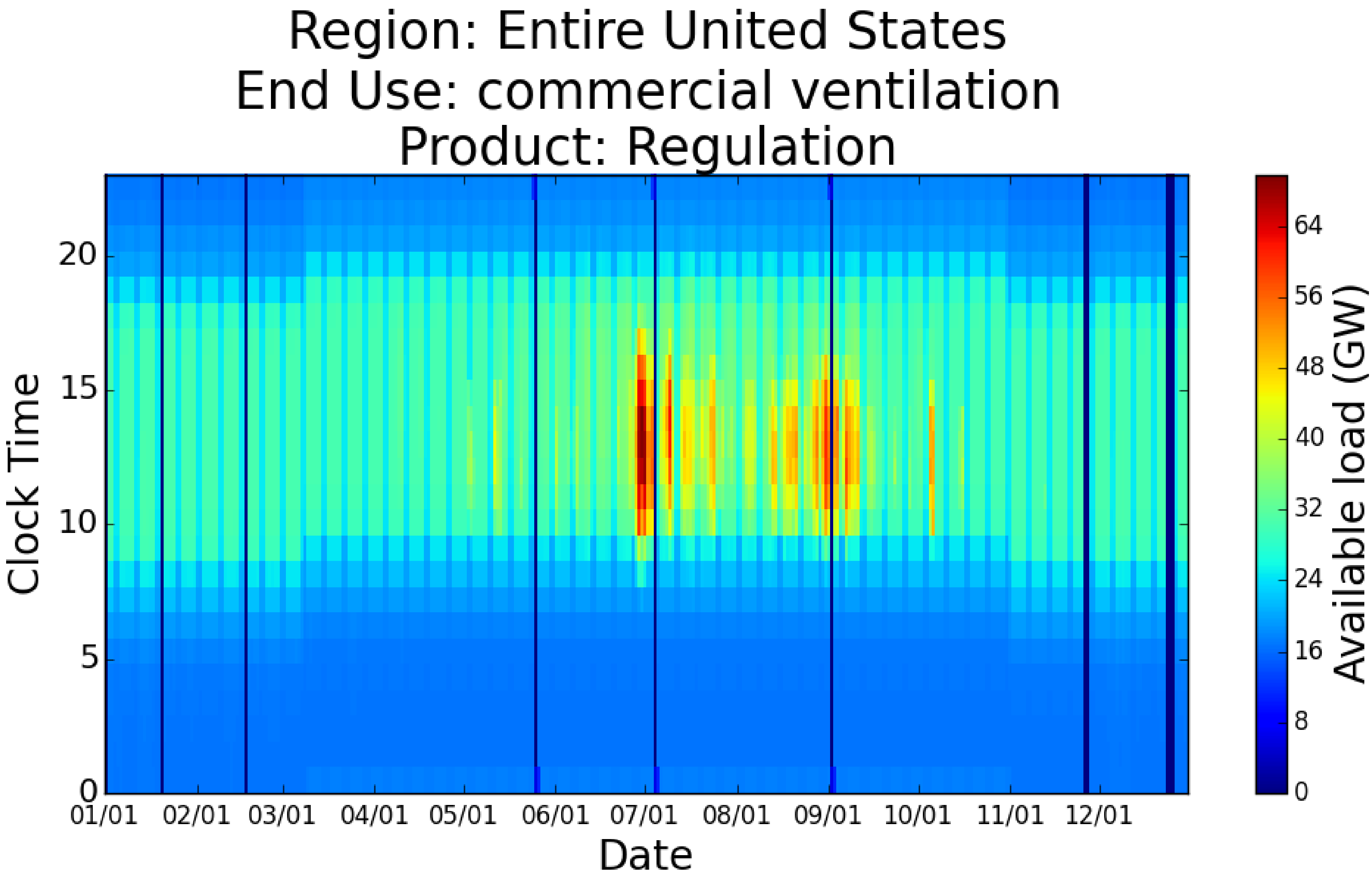

Region: Entire United States
End Use: residential hot water
Product: Contingency
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
4.8
4.5
4.2
3.9
3.6
3.3
3.0
2.7
2.4
Available load (GW)

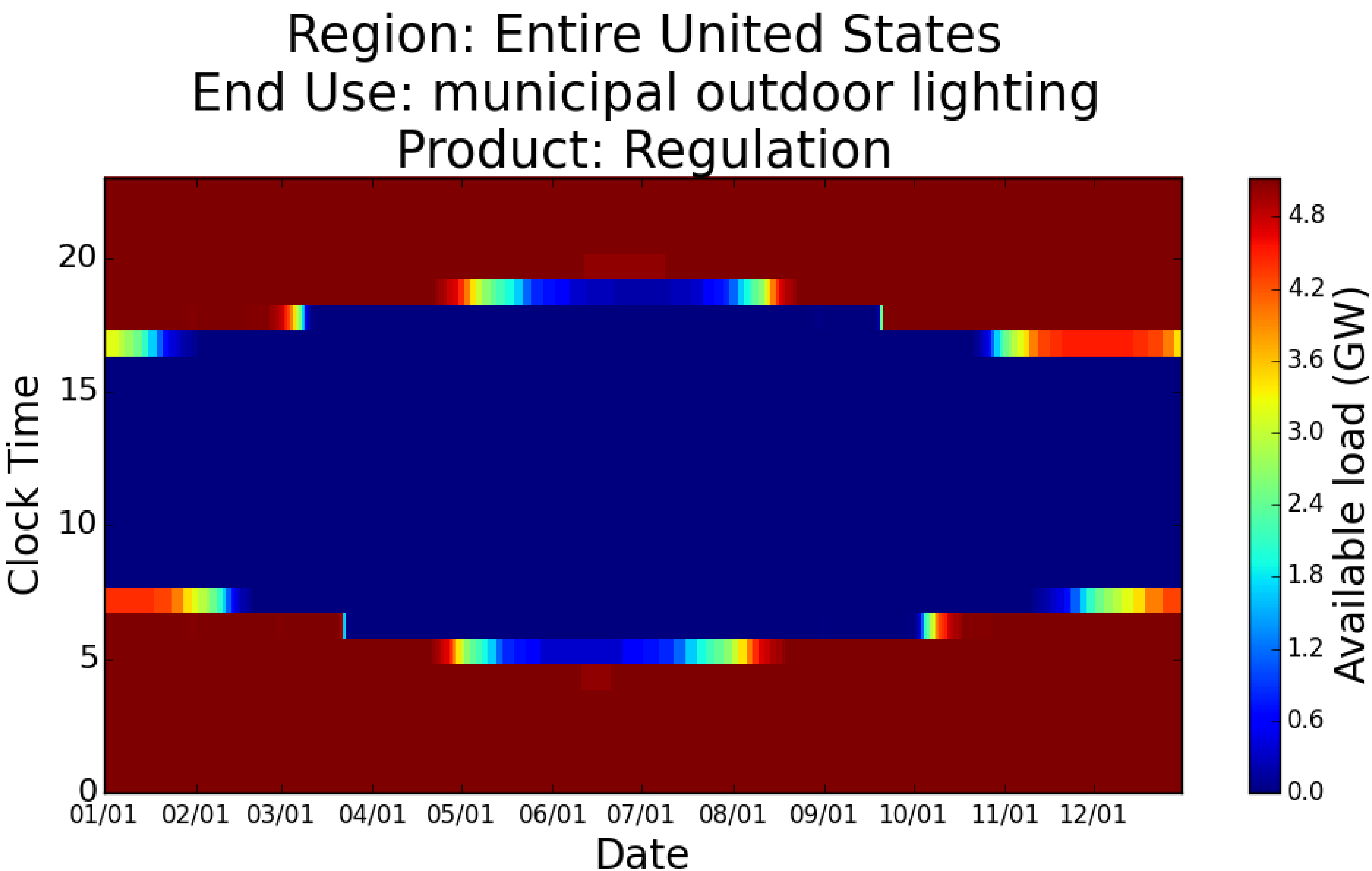
VISUALIZATION OF RESULTS: Hourly Demand Response Availability by End Use Product: Regulation

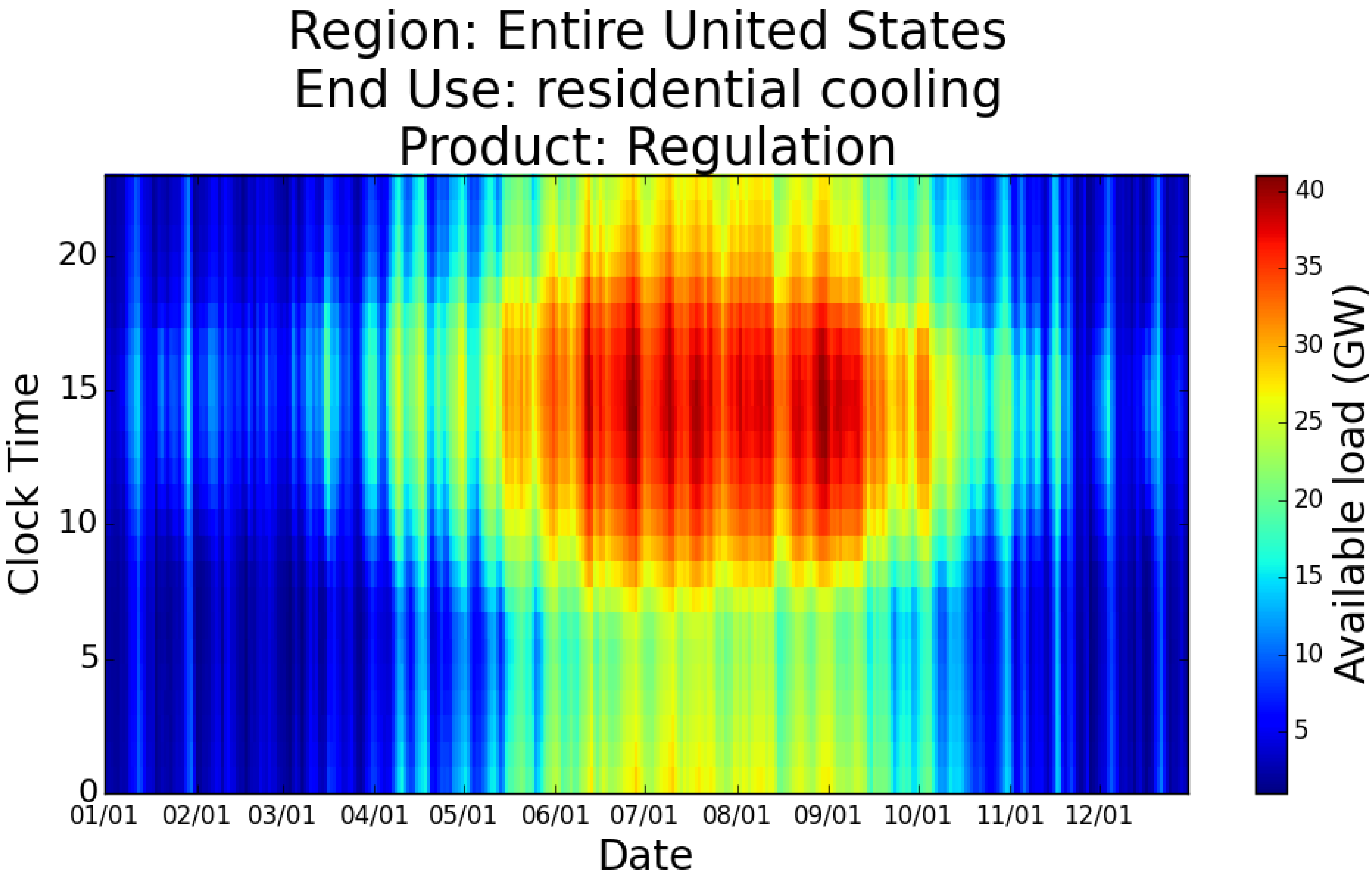


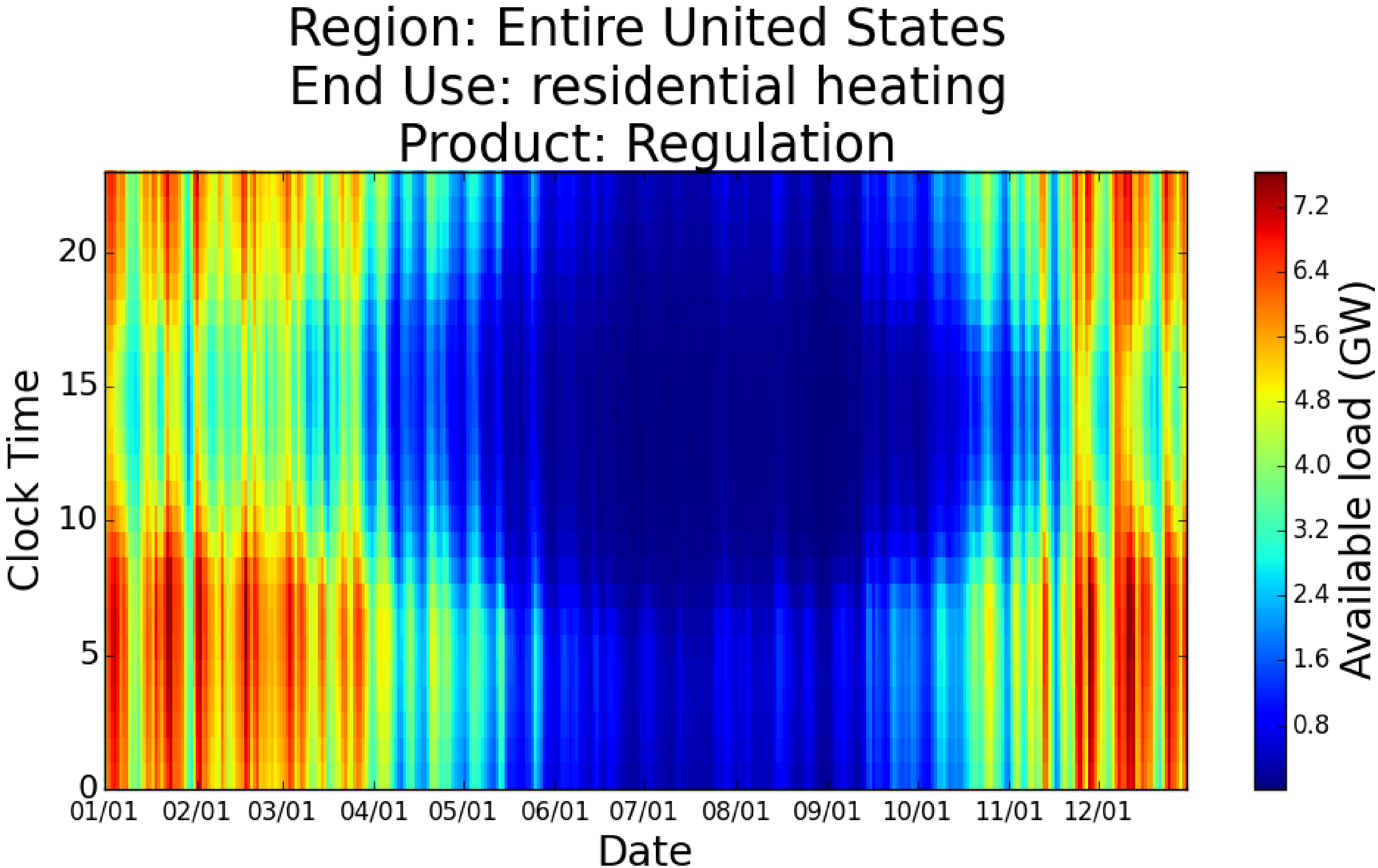
Region: Entire United States
End Use: commerical cooling
Product: Regulation
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
40
80
120
160
200
240
280
320

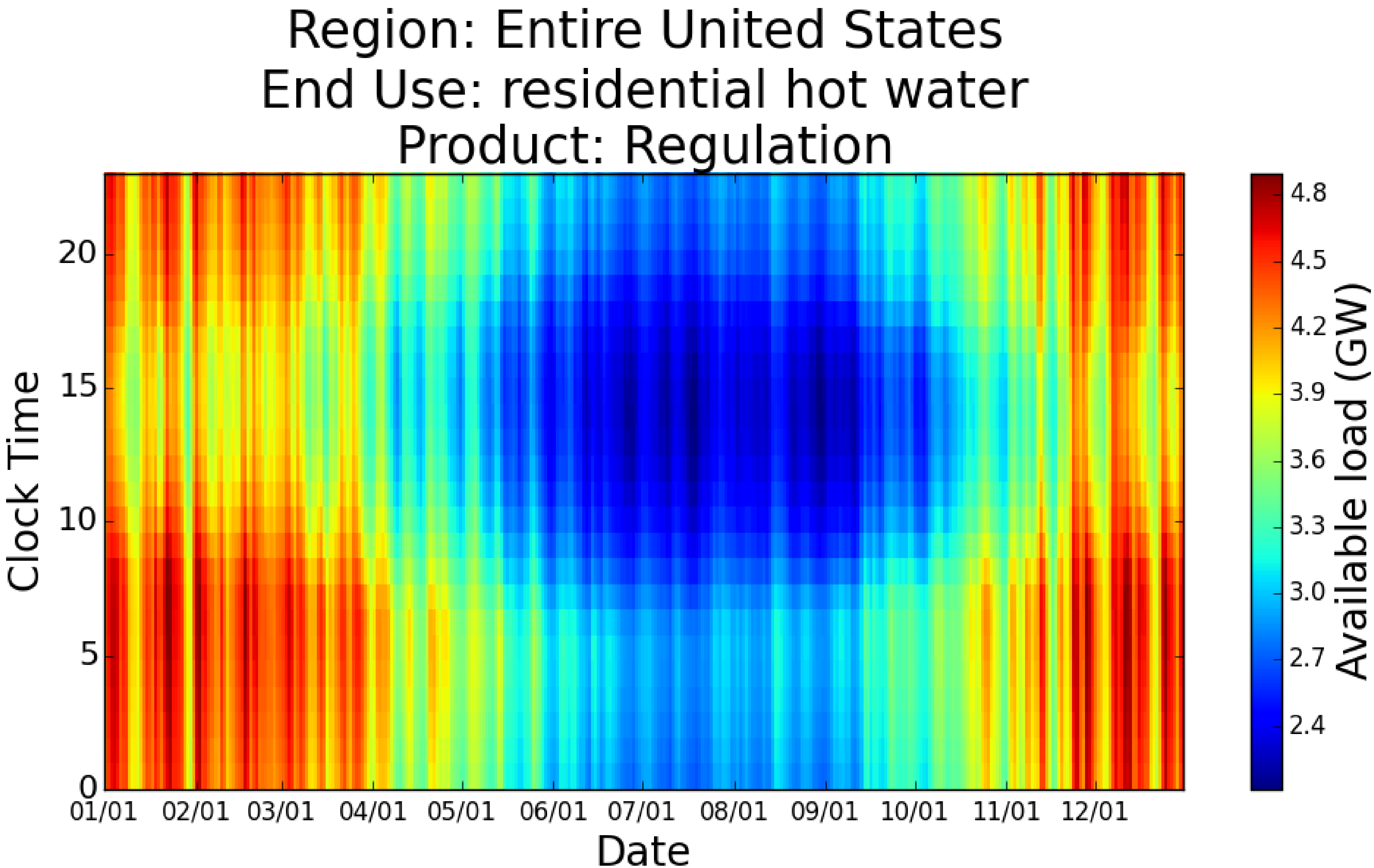

Region: Entire United States
End Use: commercial lighting
Product: Regulation
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
2
4
6
8
10
12
14
16


Region: Entire United States
End Use: commercial ventilation
Product: Regulation
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
8
16
24
32
40
48
56
64

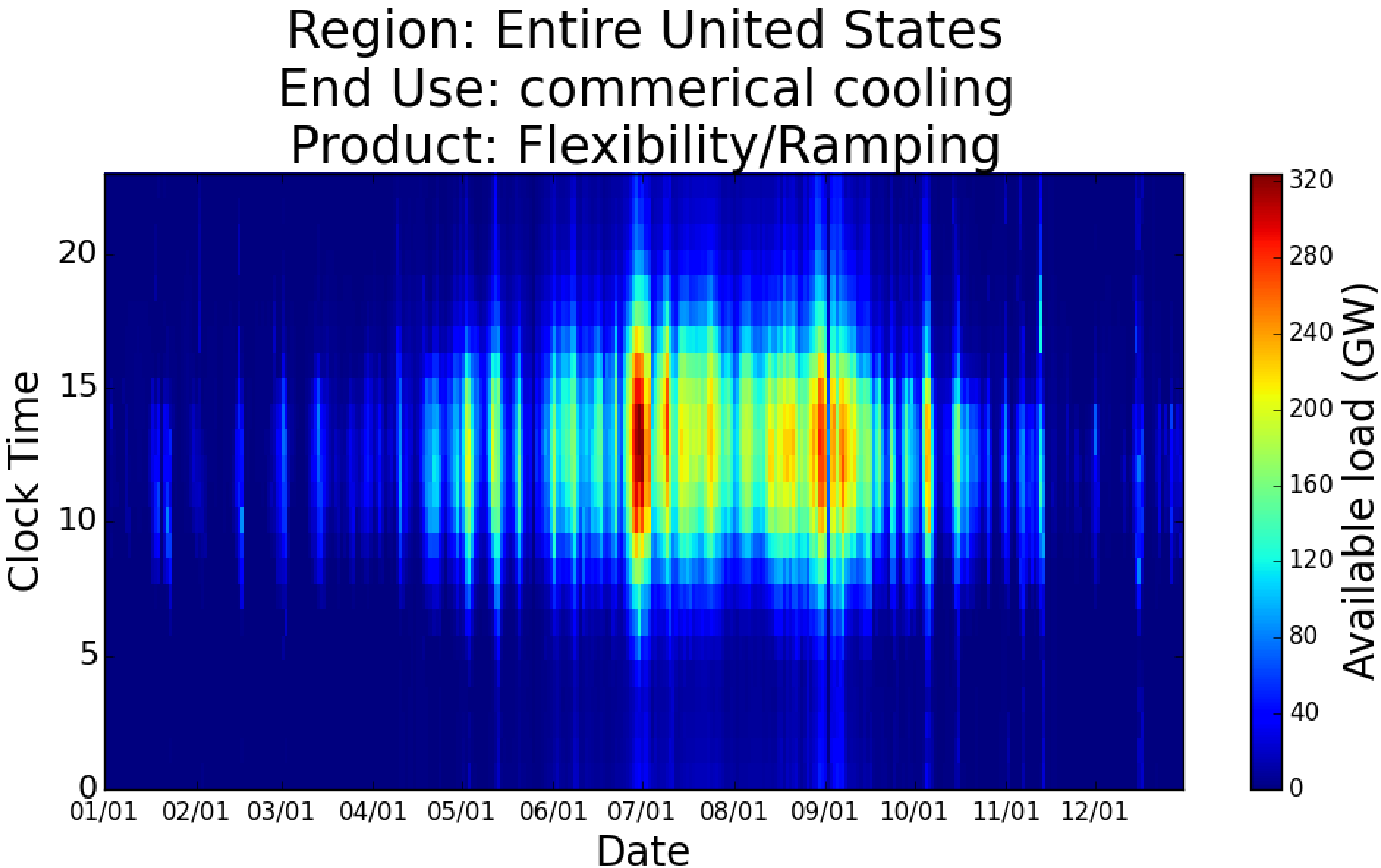

Region: Entire United States
End Use: municipal outdoor lighting
Product: Regulation
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.0
0.6
1.2
1.8
2.4
3.0
3.6
4.2
4.8

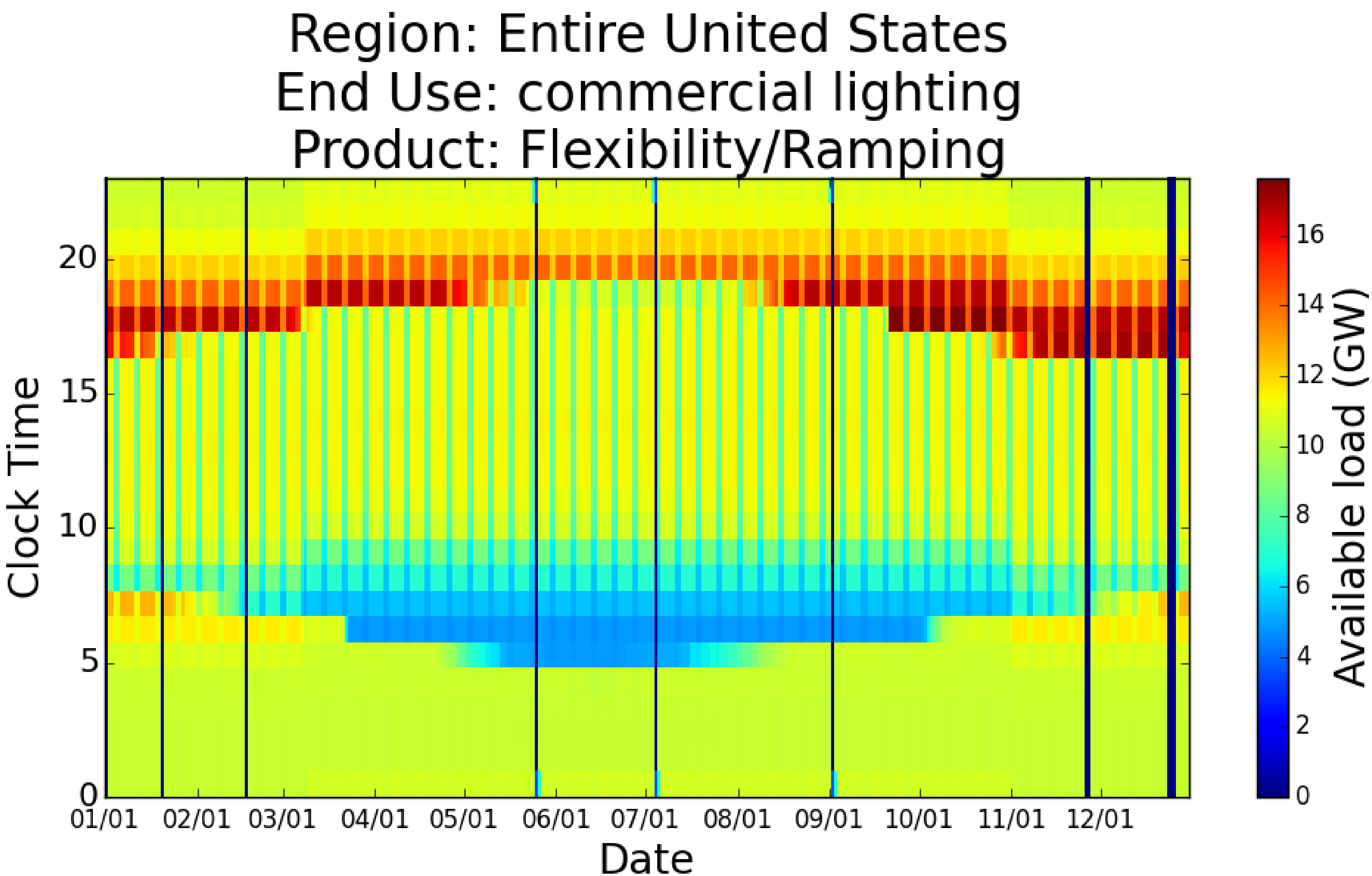

Region: Entire United States
End Use: residential cooling
Product: Regulation
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
5
10
15
20
25
30
35
40

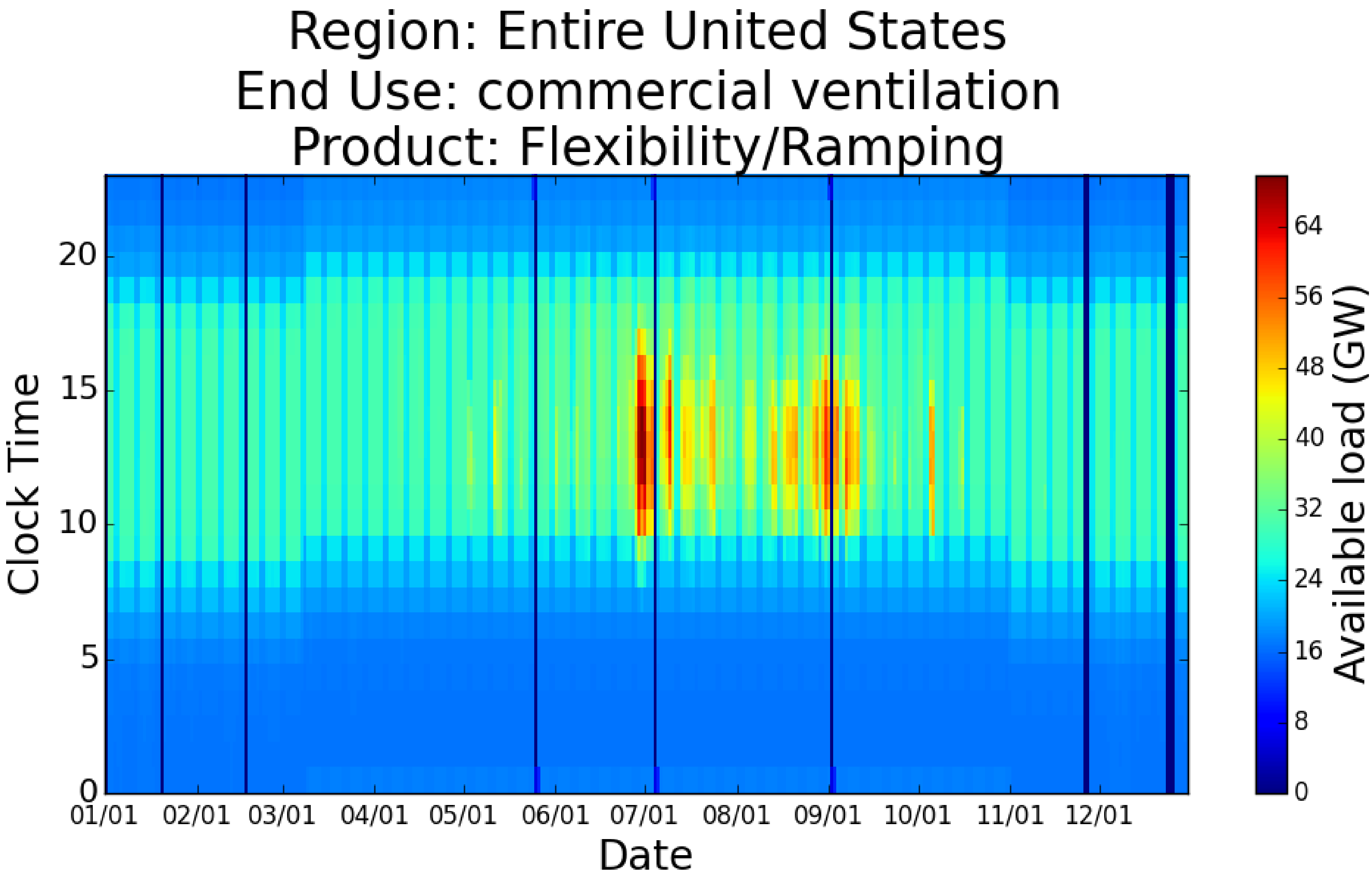

Region: Entire United States
End Use: residential heating
Product: Regulation
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2


Region: Entire United States
End Use: residential hot water
Product: Regulation
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
4.8
4.5
4.2
3.9
3.6
3.3
3.0
2.7
2.4

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

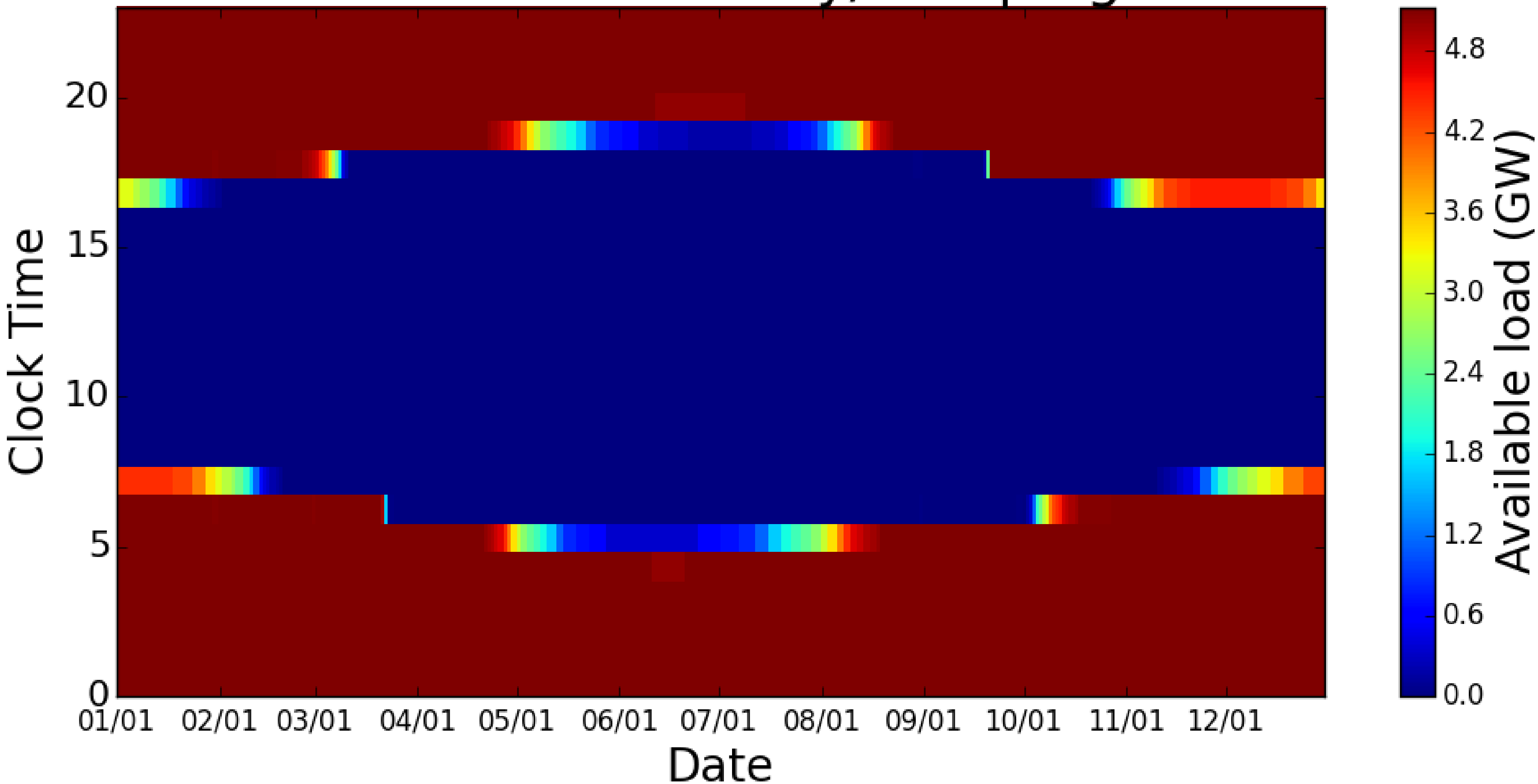

Region: Entire United States
End Use: commerical cooling
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
40
80
120
160
200
240
280
320

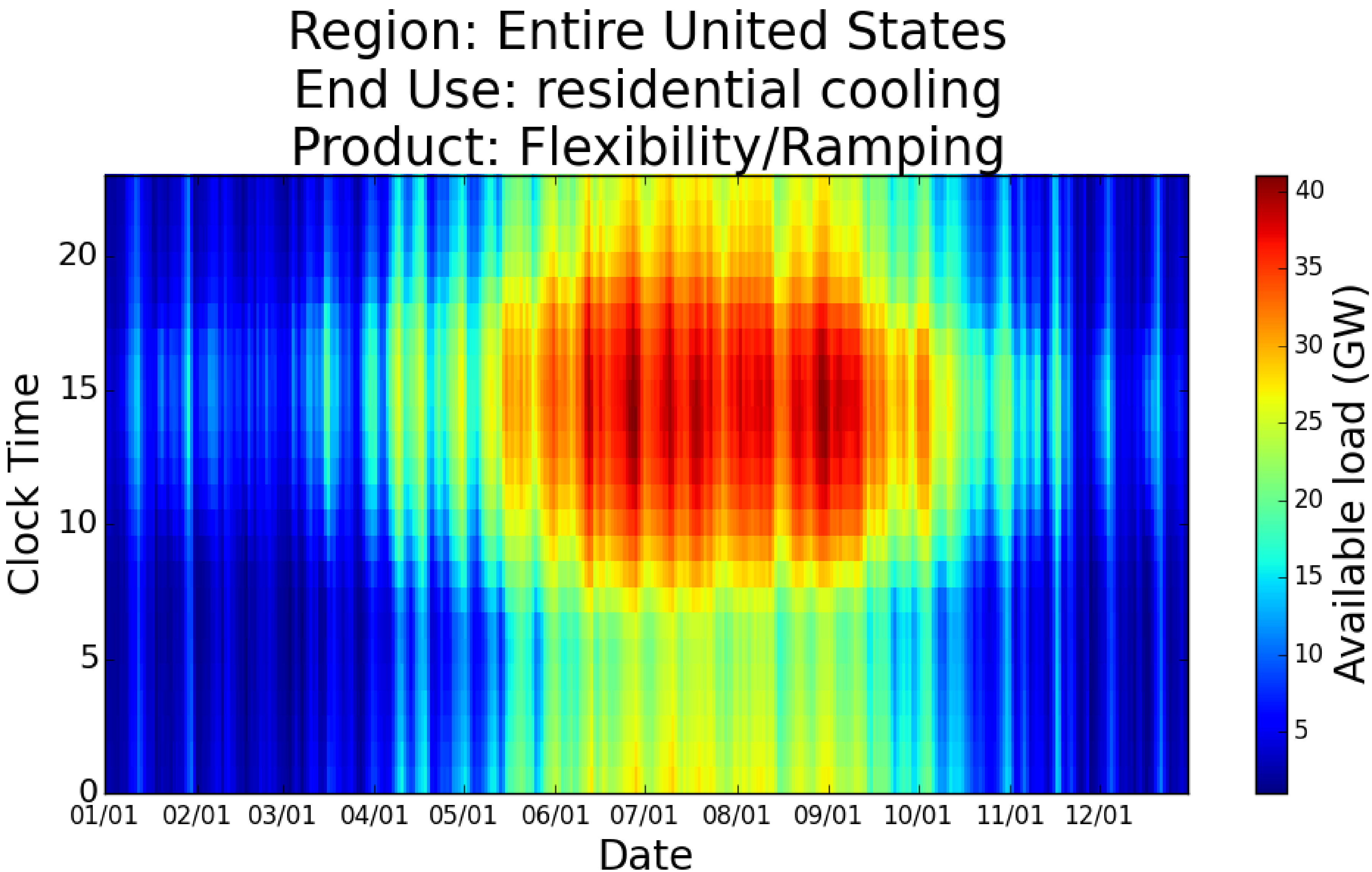

Region: Entire United States
End Use: commercial lighting
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
2
4
6
8
10
12
14
16

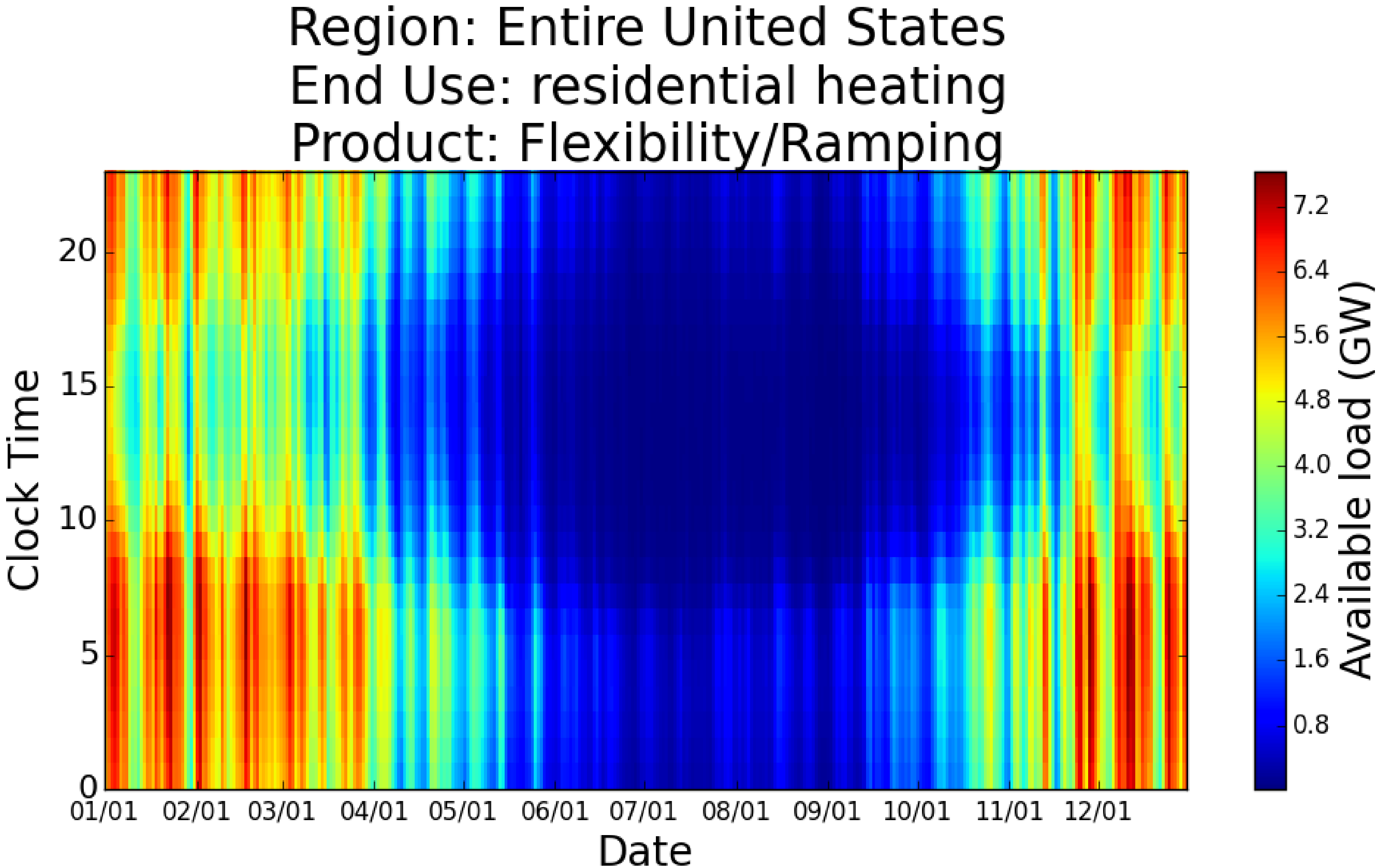


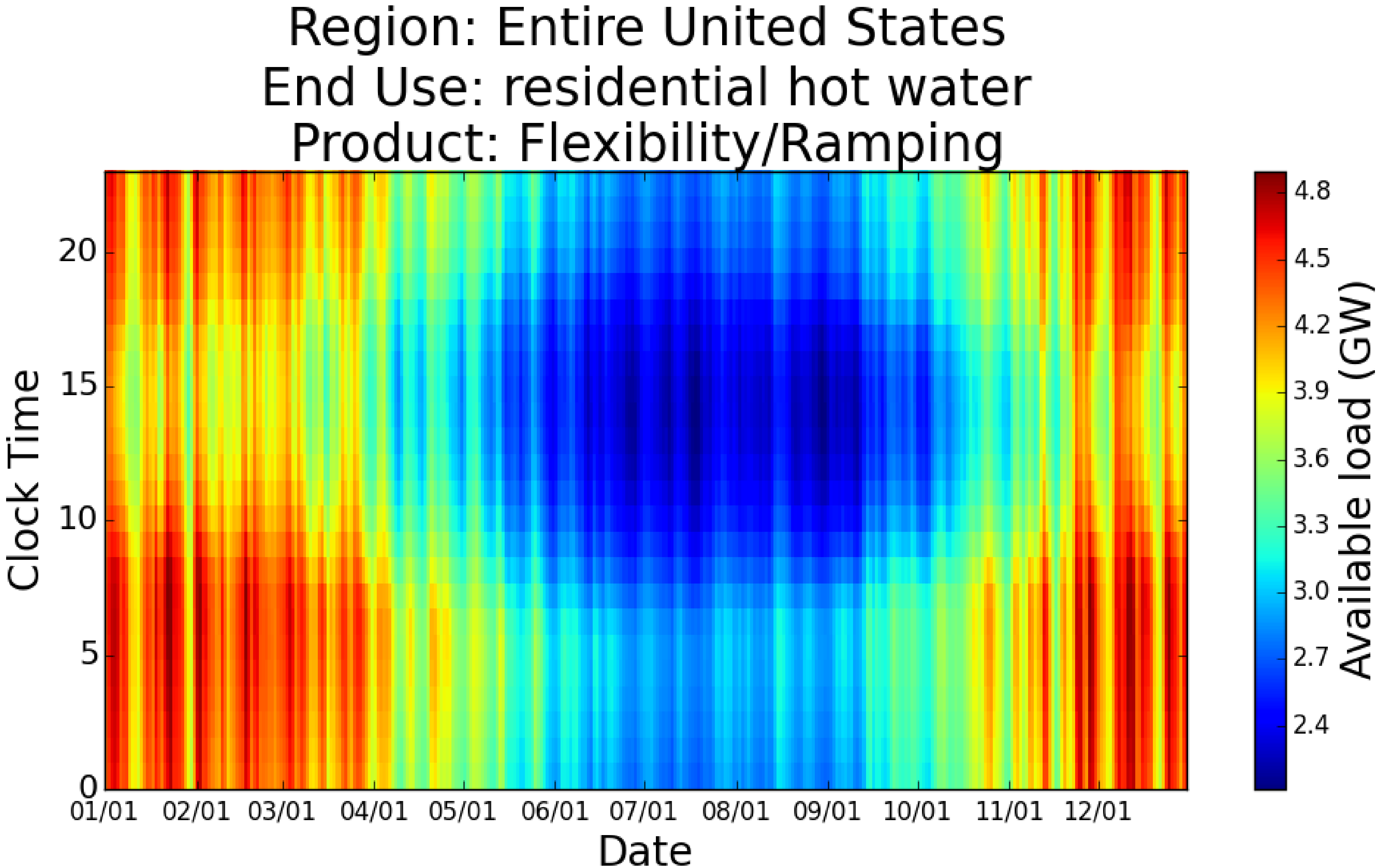
Region: Entire United States
End Use: commercial ventilation
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
0
8
16
24
32
40
48
56
64

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




Region: Entire United States
End Use: residential cooling
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
Available load (GW)
5
10
15
20
25
30
35
40


Region: Entire United States
End Use: residential heating
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01 02/01 03/01 04/01 05/01 06/01 07/01 08/01 09/01 10/01 11/01 12/01
Date
Available load (GW)
0.8
1.6
2.4
3.2
4.0
4.8
5.6
6.4
7.2


Region: Entire United States
End Use: residential hot water
Product: Flexibility/Ramping
Clock Time
0
5
10
15
20
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date
4.8
4.5
4.2
3.9
3.6
3.3
3.0
2.7
2.4
Available load (GW)