NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Interconnection CPS1 Performance July 2024

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Background

Daniel Baker demonstrates below how to derive CPS1 for the interconnection.

From Attachment 1 BAL-001-2:

$$CPS1 = 100 * (2 - CF)$$

$$CF_{1\ minute} = \frac{ACE * \Delta F}{-10\beta}$$

$$CF = \frac{CF_{1\ minute}}{\varepsilon_1^2}$$

Combine (2) and (3):

$$CF = \frac{ACE * \Delta F}{-10\beta * \varepsilon_1^2}$$

Expand ACE:

$$CF = \frac{(NAI - NSI) - 10\beta(\Delta F) * \Delta F}{-10\beta * \varepsilon_1^2}$$

Assume NAI-NSI = 0 for interconnection level:

$$CF = \frac{(0) - 10\beta(\Delta F) * \Delta F}{-10\beta * \varepsilon_1^2}$$

Cancel and simplify:

$$CF = \frac{\Delta F^2}{\varepsilon_1^2}$$

$$CPS1_{Interconnection} = 100 * \left(2 - \frac{\Delta F^2}{\varepsilon_1^2}\right)$$

Daniel Baker can provide more information on this derivation if interested.

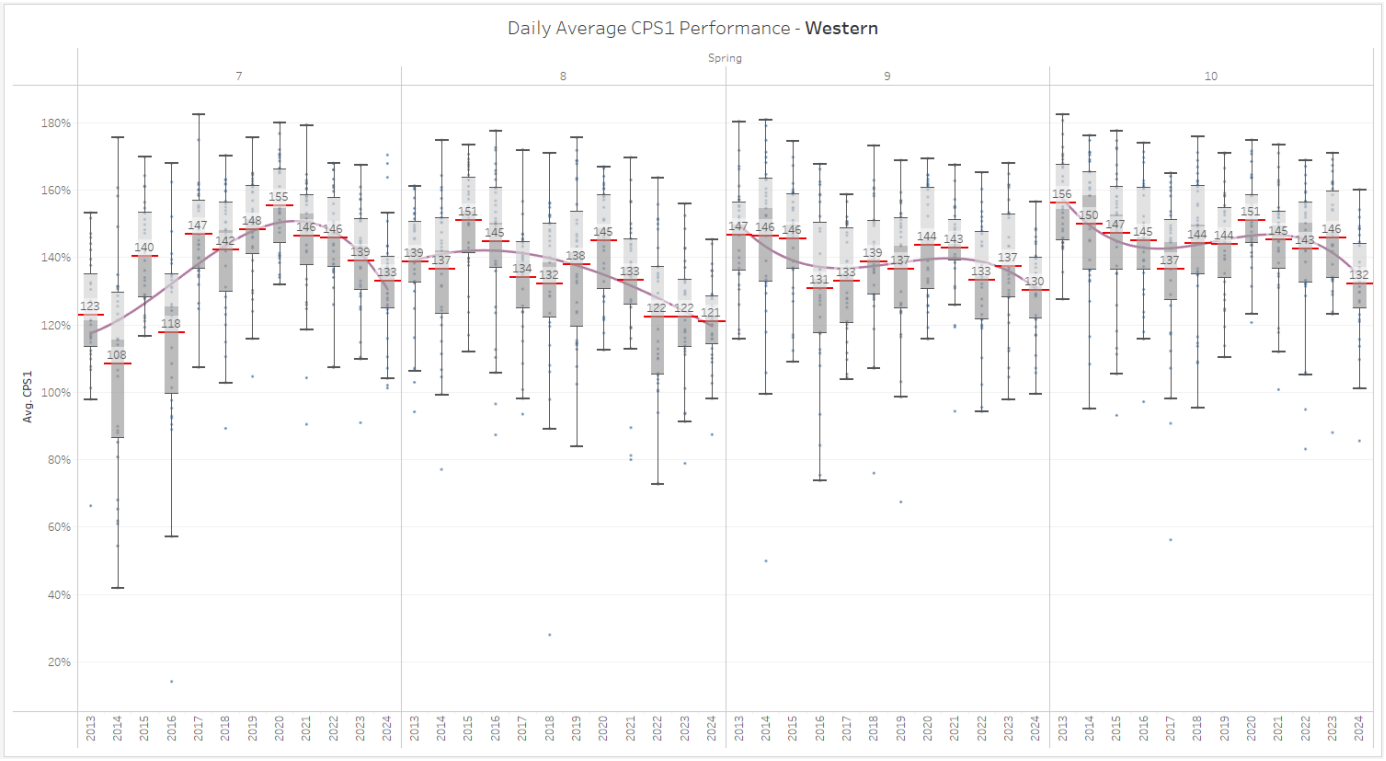
The goal of this report is to plot CPS1 performance year-over-year to determine which hours are experiencing more degradation than others, specifically solar AM/PM hours.

Solar AM Charts

These box and whisker charts provide a year-over-year look at CPS1 performance for each interconnection during solar AM hours (HE 7, HE 8, HE 9, and HE 10). The season and hours are shown across the top of the chart, and the years are shown across the bottom of the chart. Each dot represents a day in the season. The seasons are represented as Spring (March-May), Summer (June-August), Fall (September-November), and Winter (December-February). The box and whisker chart provides the distribution for each year and allows you to see the changing patterns year-over-year. Since the previous season is always the objective, we're looking to see if we improved frequency performance throughout that season.

Western Interconnect

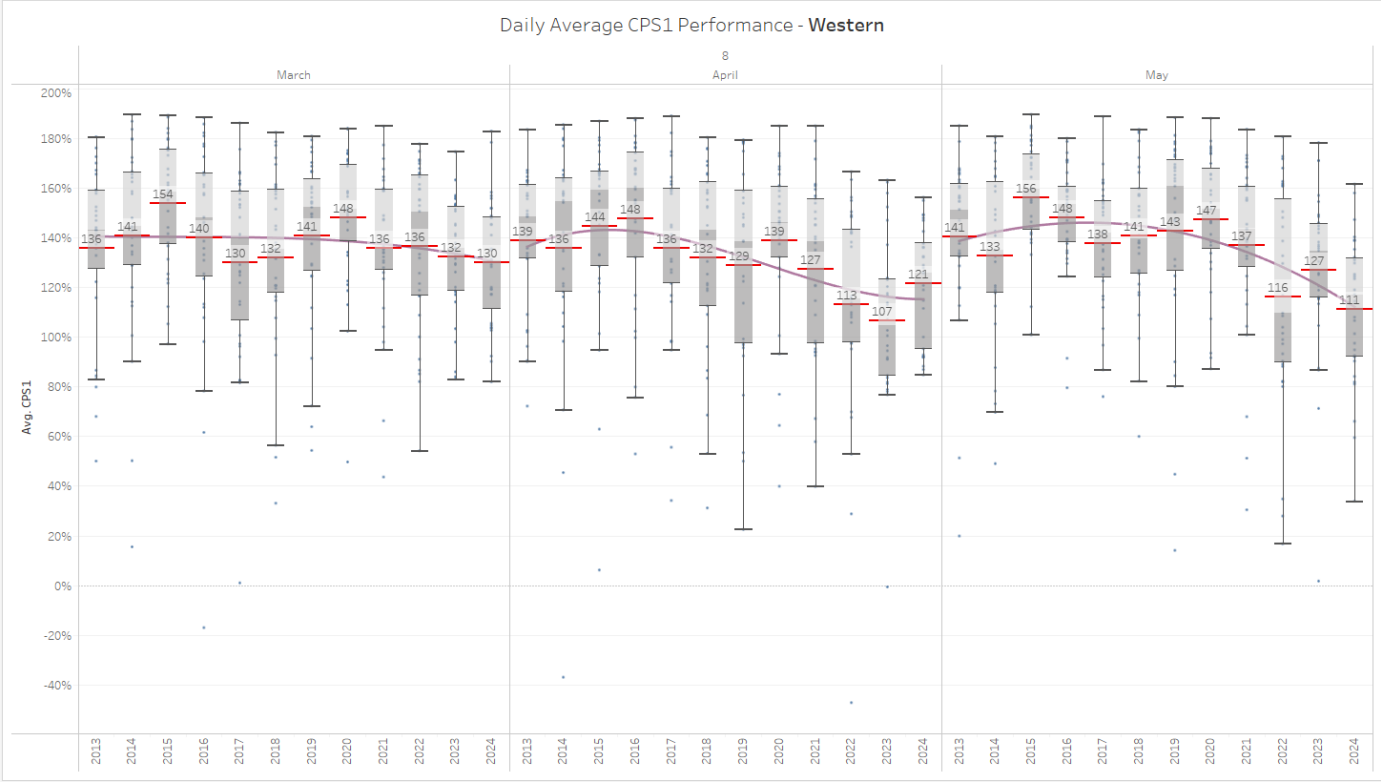
These charts represent Spring data from 2013-2024. If we focus on the purple polynomial trendline, the average CPS1 performance shows a downward trend in all HE hours year-over-year, with **HE 8** showing the greatest drop in average performance.



HE 8

Takeaways:

1. Variability has decreased significantly in April in recent years.
2. Average performance changes from 2022-2023:
    a. March decreased **2%**
    b. April increased **14%**
    c. May decreased **16%**



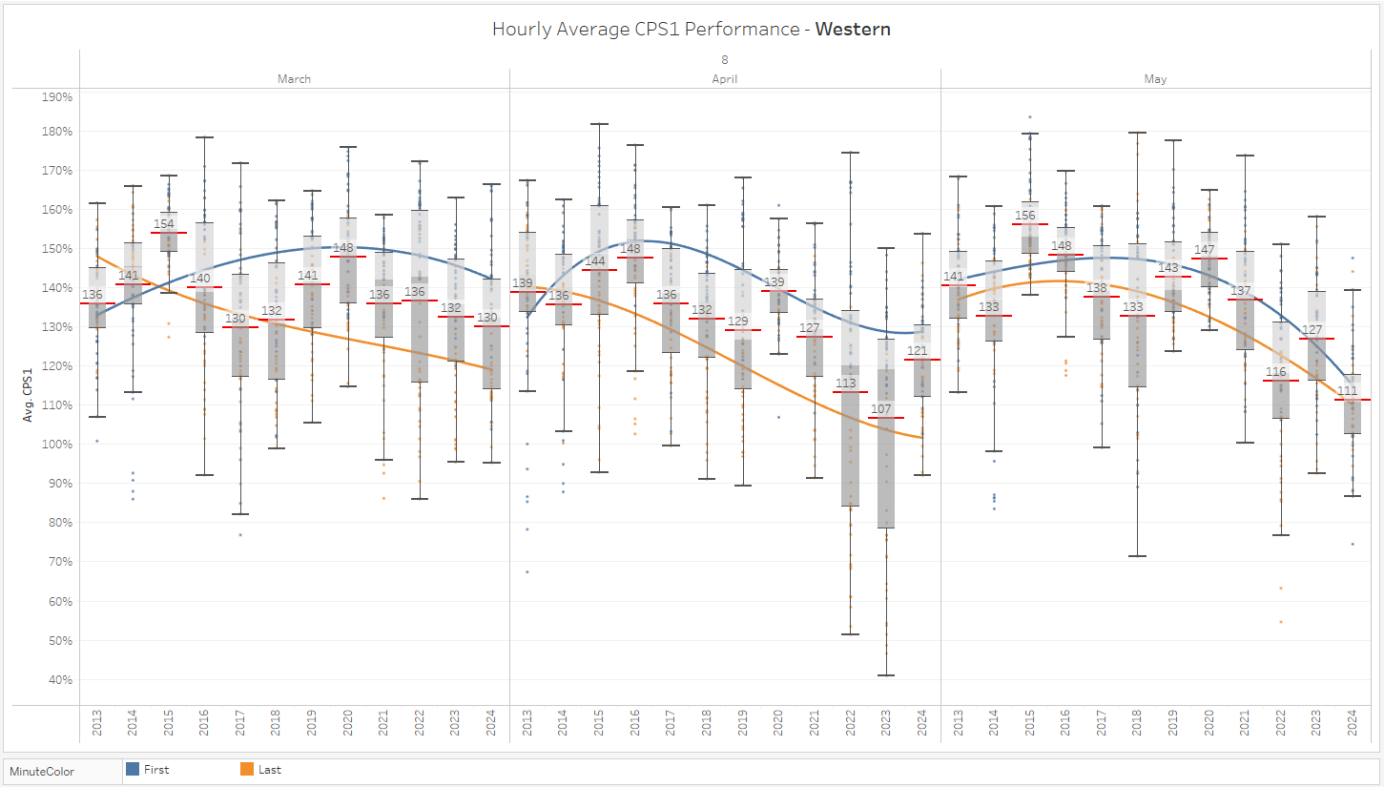
Hourly Performance

Based on the previous analysis, March and May look to be contributing to the downward trend in Spring performance during HE 8. What is the data telling me at the hourly and minute level? This chart is a look at solar AM hours during each of these months (year-over-year), for all days in the month, with HE across the top. This time, the dots represent minutes.

There are two separate polynomial trends comparing the **first half** of the hour to the **last half** of the hour. I color-coded the dots (minutes) to differentiate the minutes in the first half of the hour (blue) from the minutes in the last half of the hour (orange).

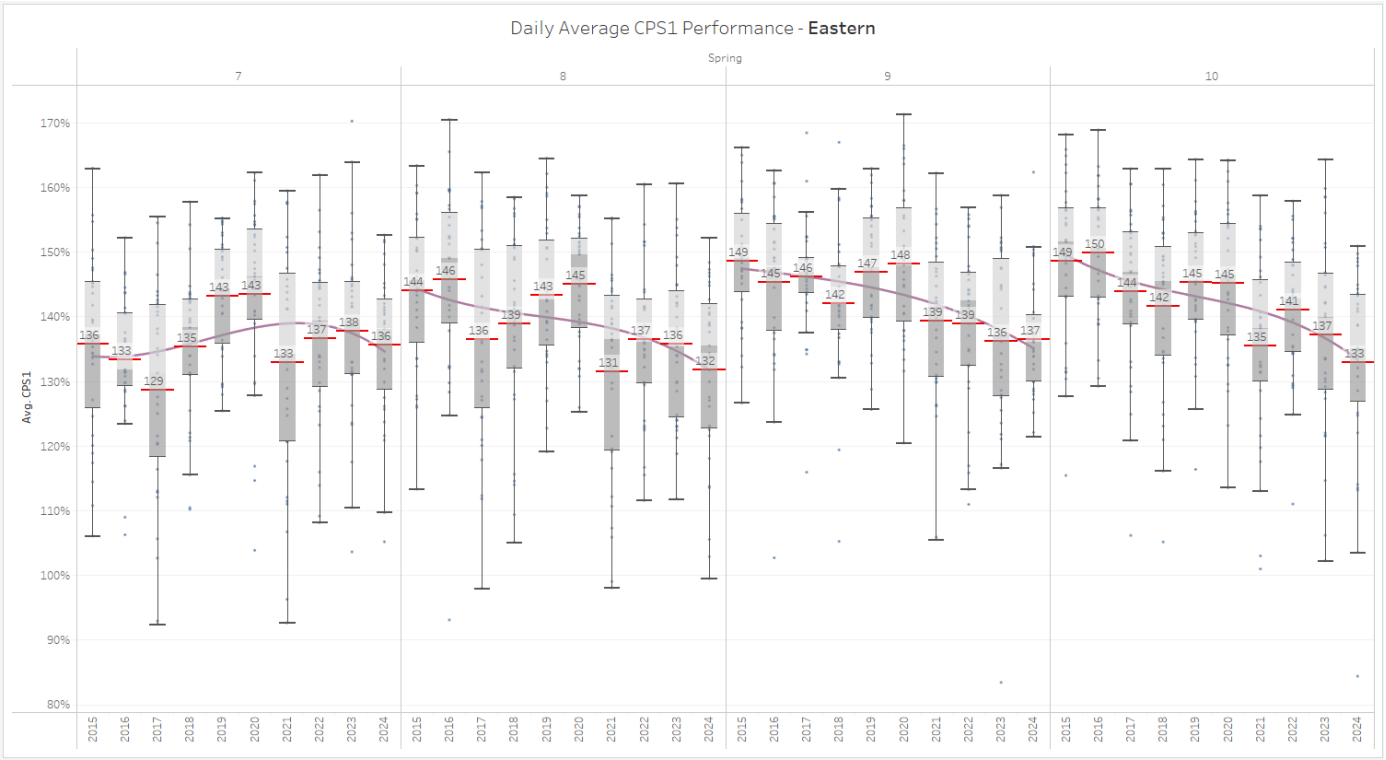
Takeaways:

1. May shows downward trends in recent years **throughout** the hour.
2. March and April show a greater struggle during the **second half** of the hour.



Eastern Interconnect

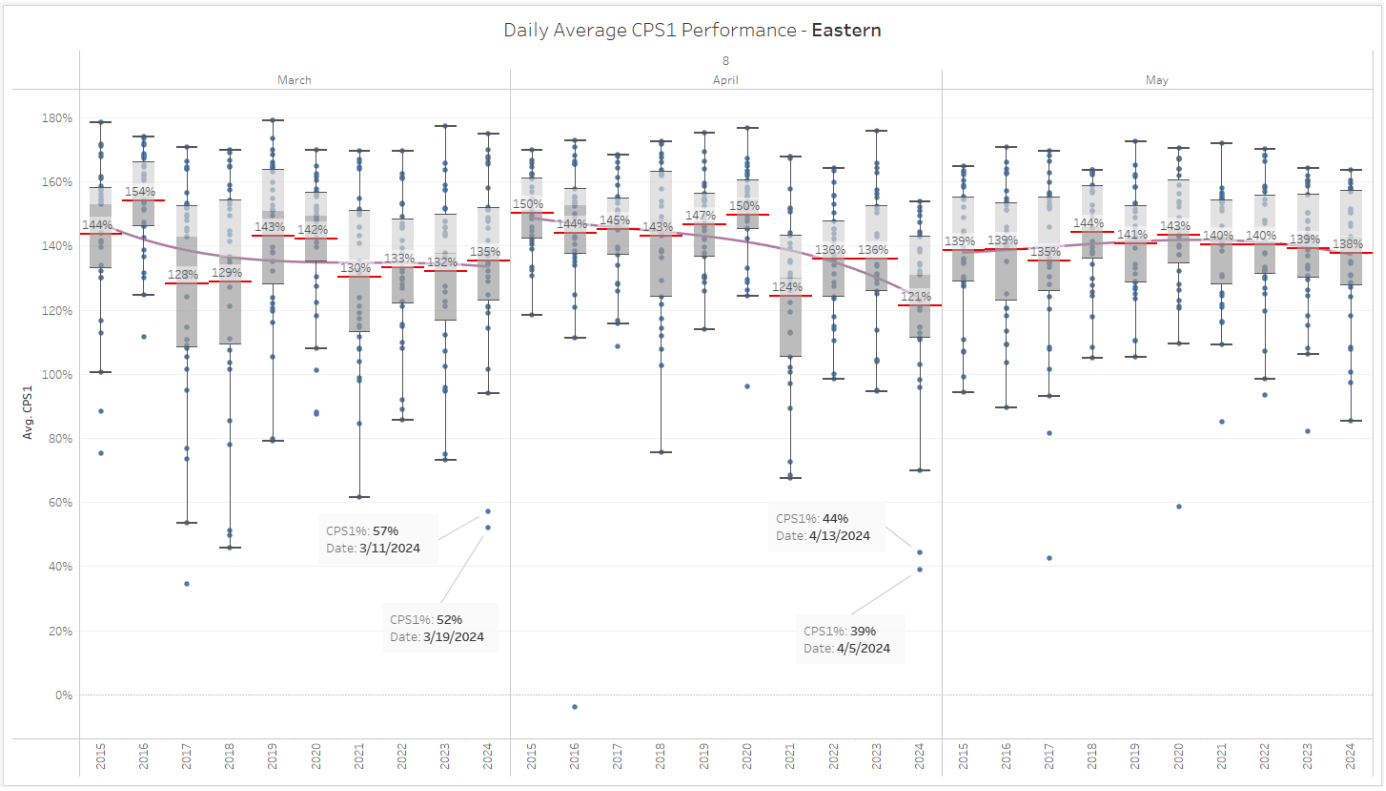
These charts represent Spring data from 2015-2024. The average performance from 2015-2020 was ~145%. Since 2021, average performance is ~135% in all HE hours year-over-year. Is this the new normal?



HE 8

Takeaways:

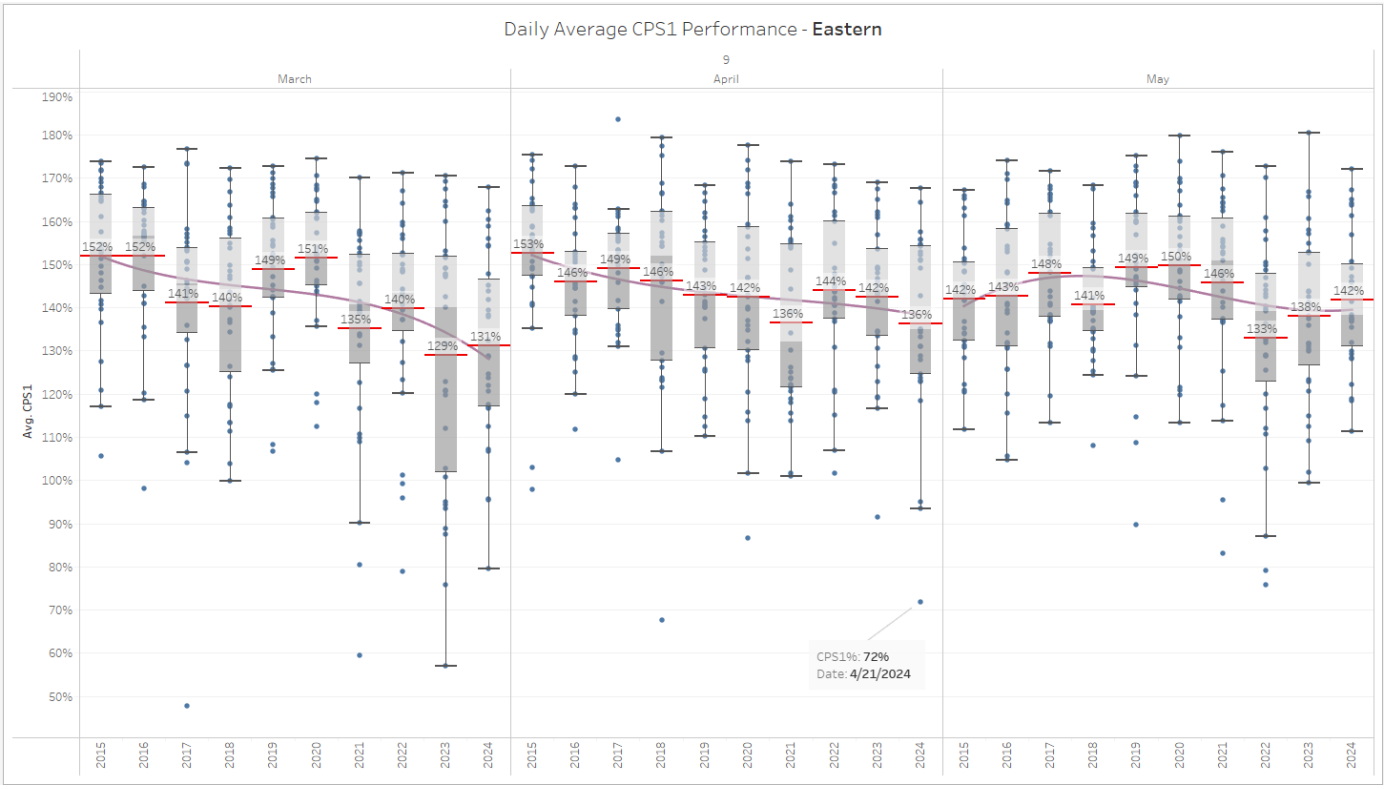
1. April experienced the most change in average performance since 2020.
2. Average performance changes from 2023-2024:
    a. March increased **3%**
    b. April decreased **15%**
    c. May decreased **1%**



HE 9

Takeaways:

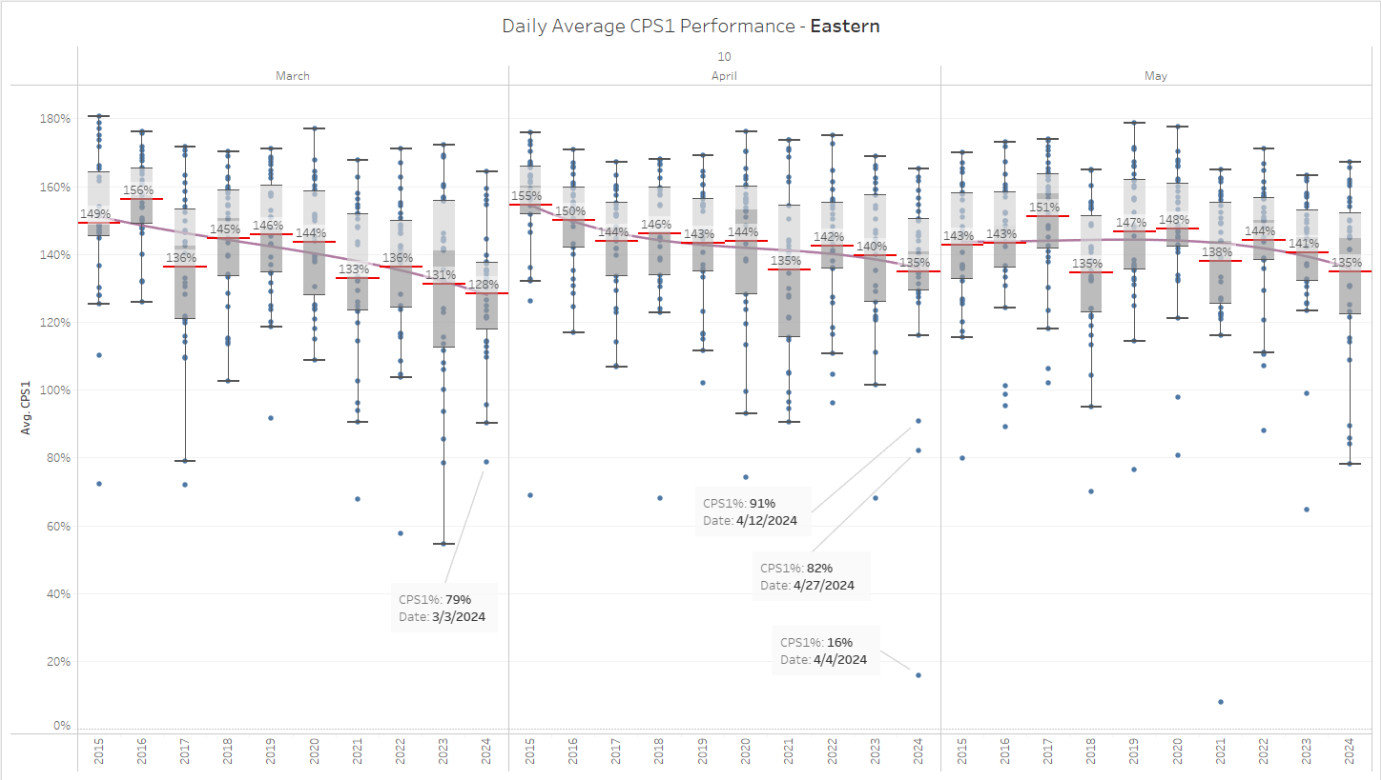
1. March has experienced considerable changes in variability in recent years.
    a. Tall boxes = wide IQR
    b. Long whiskers = wide range of performance outside IQR
2. Average performance changes from 2023-2024:
    a. March increased **2%**
    b. April decreased **6%**
    c. May increased **4%**



HE 10

Takeaways:

1. All months have experienced a steady decline in average performance in recent years.
2. **March** and **May** have experienced changes in variability in recent years.
3. Average performance changes from 2023-2024:
    a. March decreased **3%**
    b. April decreased **5%**
    c. May decreased **6%**



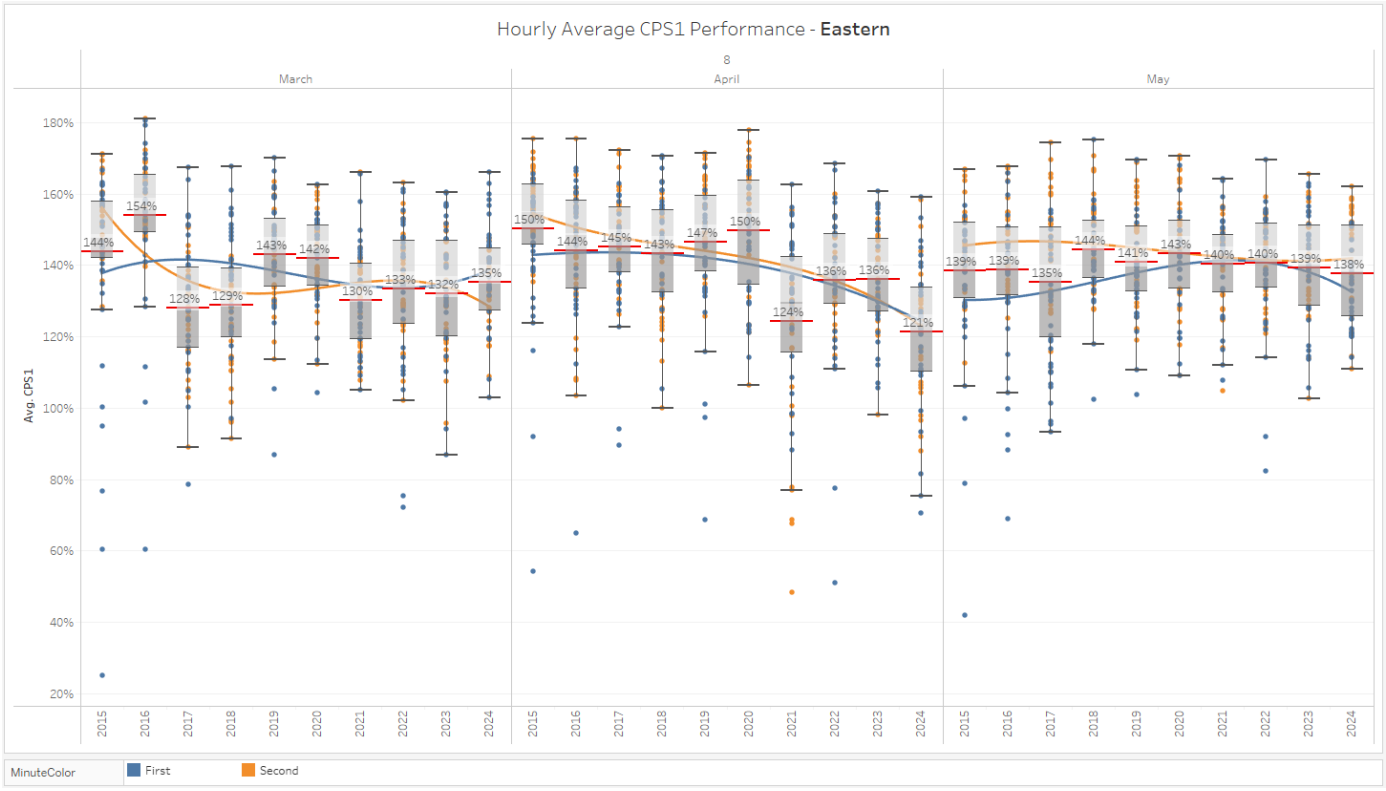
Hourly Performance

Based on the previous analysis, both **March** and **April** look to be contributing to the downward trend in Spring performance during **HE 8-10**. What is the data telling me at the hourly and minute level? These charts provide a look at solar AM hours during each of these months (year-over-year), for all days in the month, with HE across the top. This time, the dots represent minutes.

There are two separate polynomial trends comparing the **first half** of the hour to the **last half** of the hour. I color-coded the dots (minutes) to differentiate the minutes in the first half of the hour (blue) from the minutes in the last half of the hour (orange).

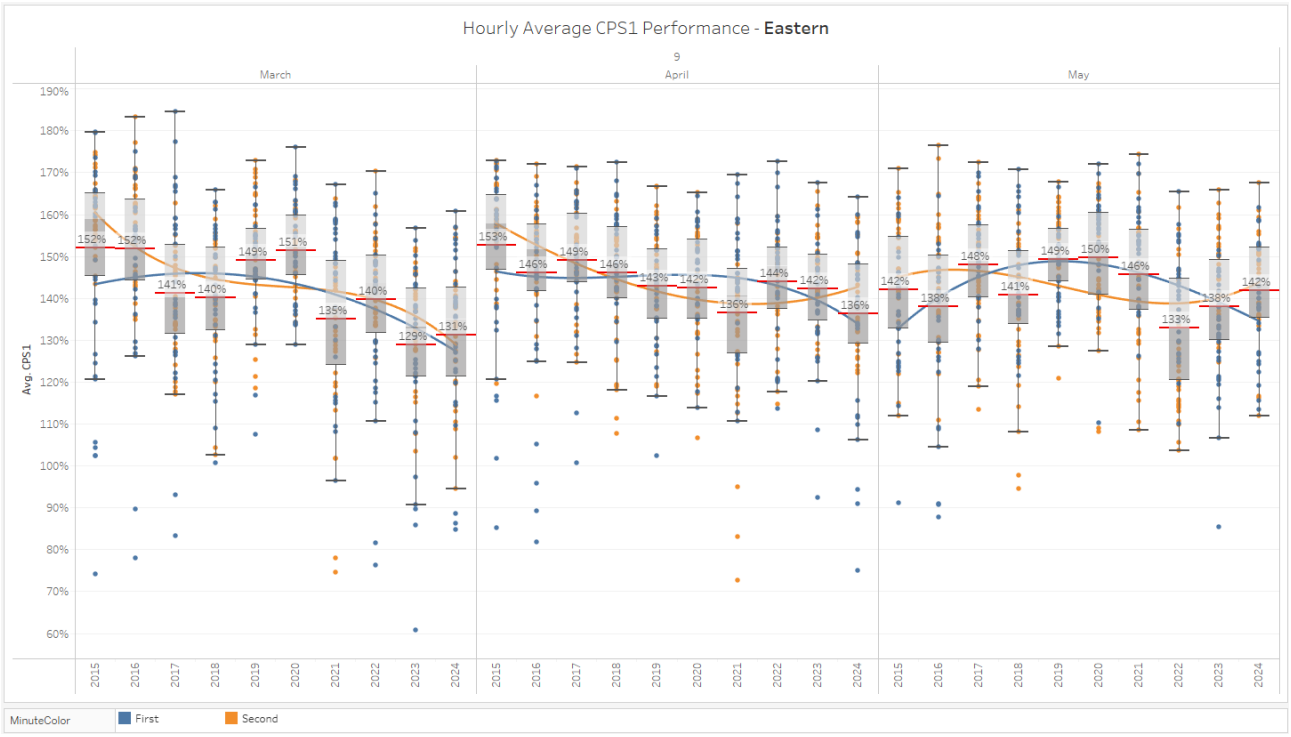
Takeaways (**HE 8**):

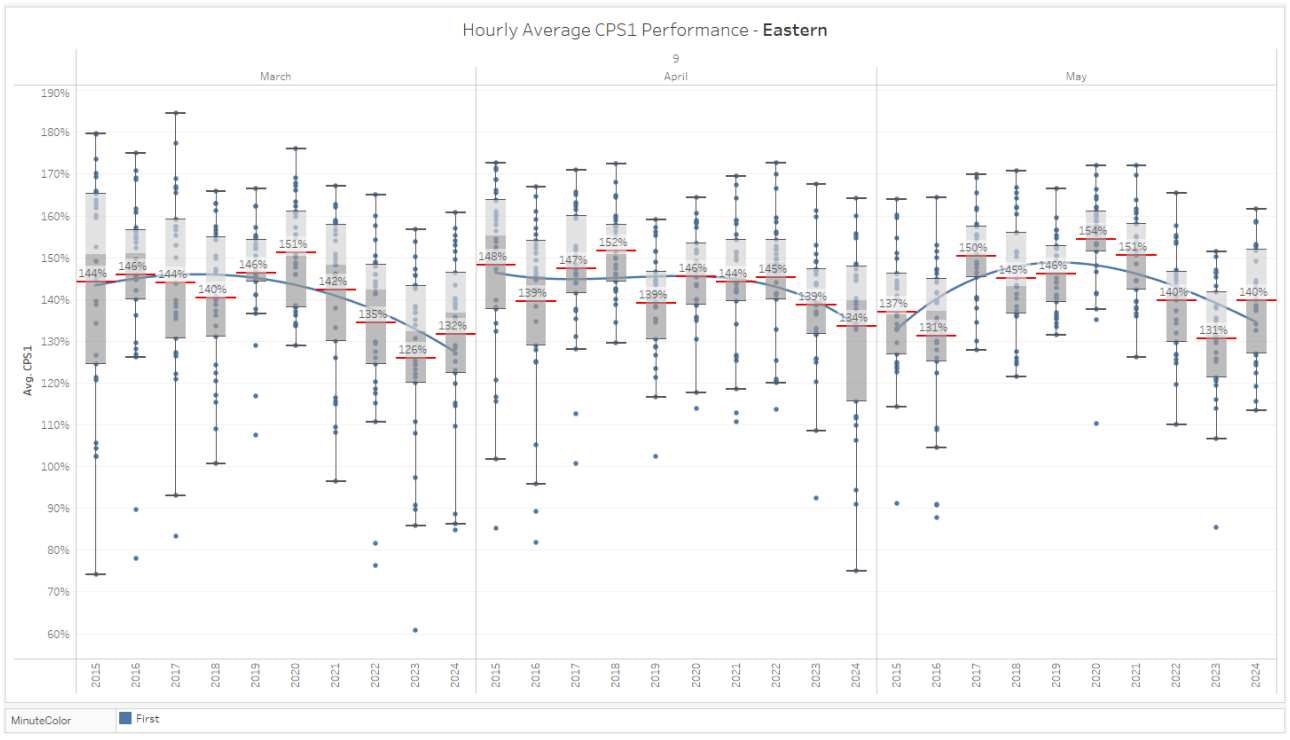
1. **April** has experienced more struggles during the second half of the hour in recent years.



Takeaways (**HE 9**):

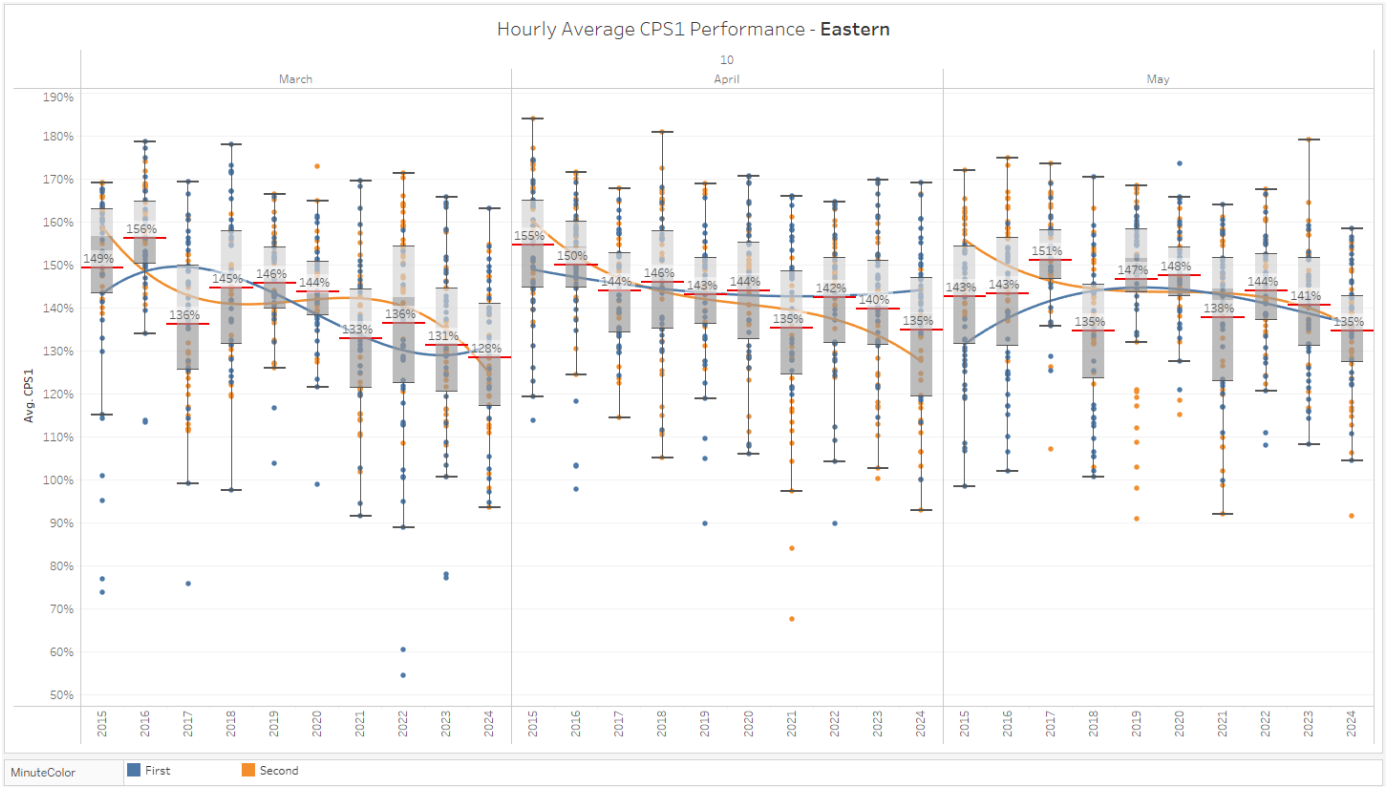
1. **March** shows downward trends **throughout** the hour since 2021.
2. **March** and **April** have experienced increased variability during the **first half** of the hour in recent years.

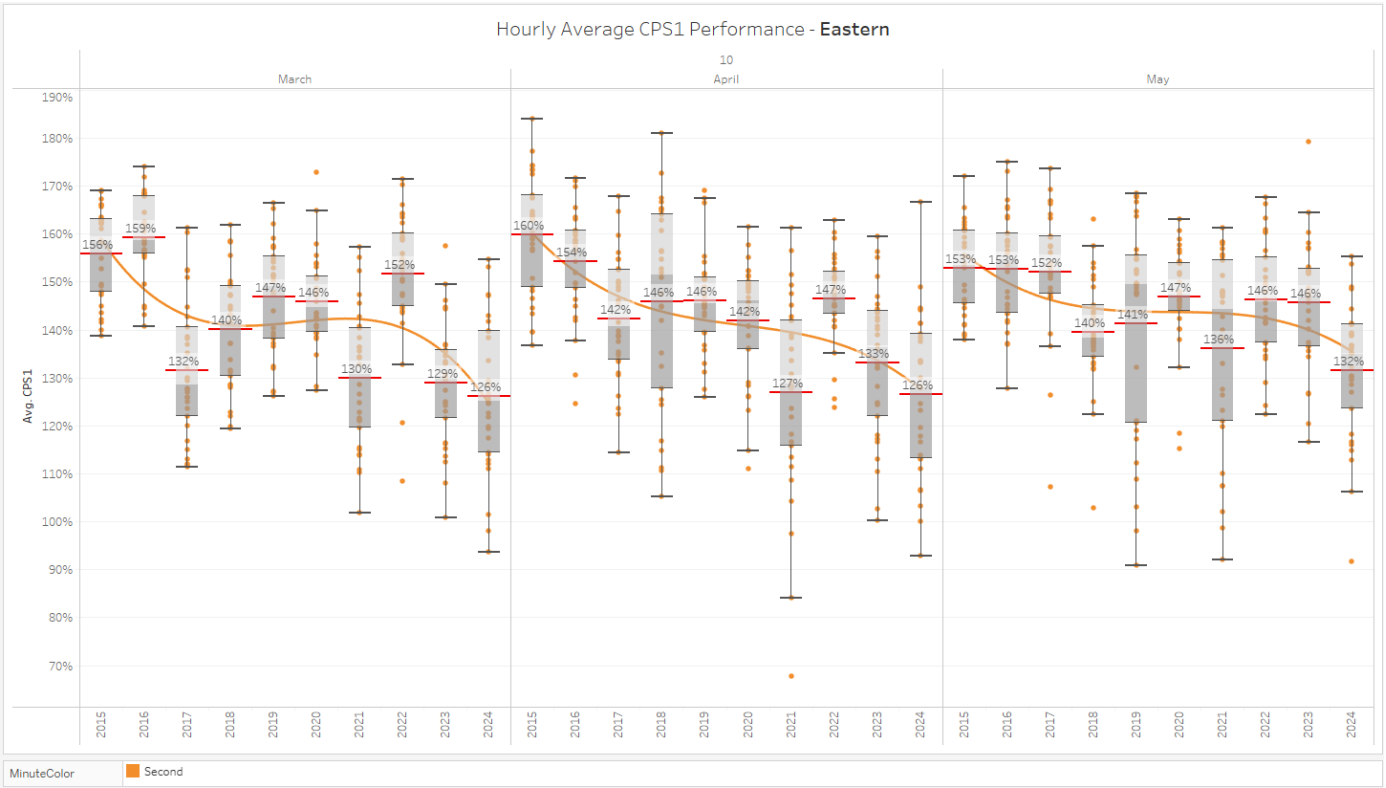




Takeaways (**HE 10**):

1. All months show a greater struggle during the **second half** of the hour in recent years.



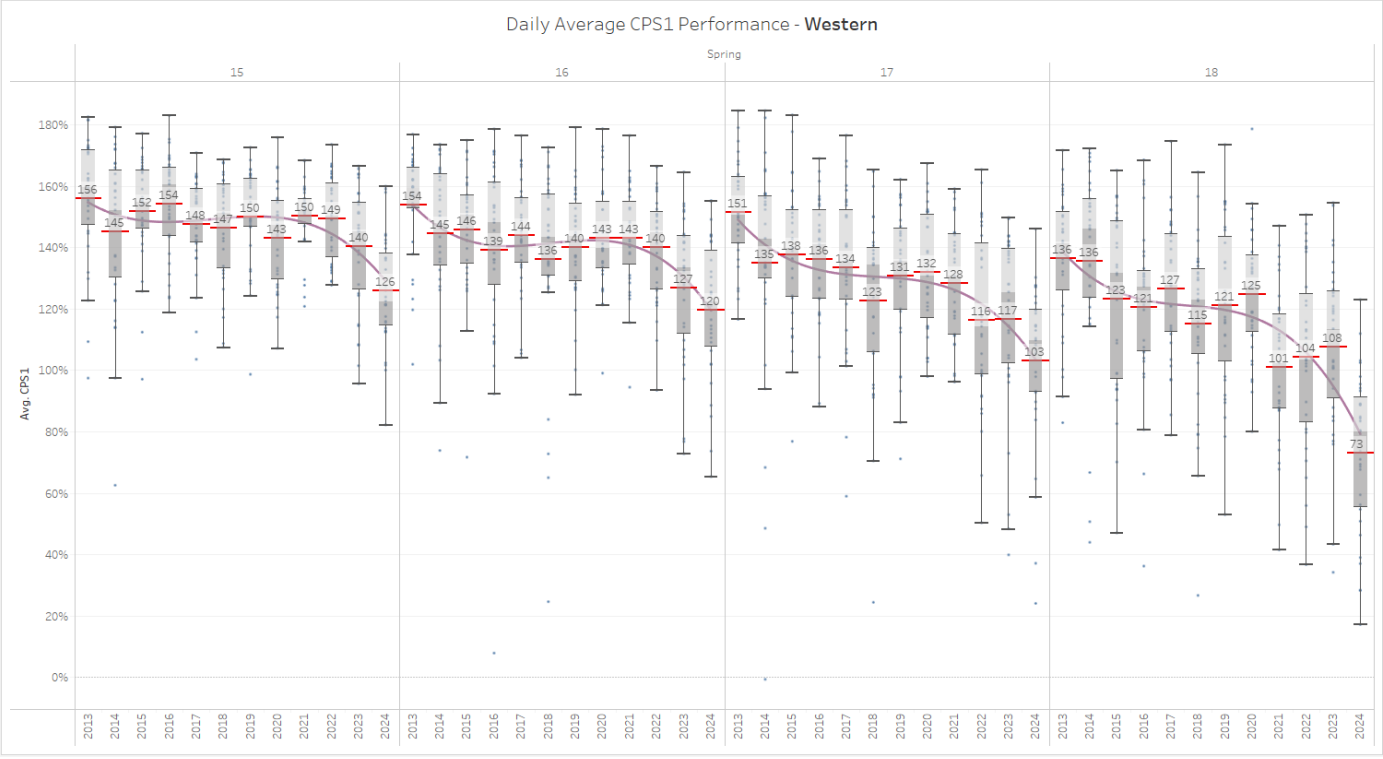


Solar PM Charts

These box and whisker charts provide a year-over-year look at CPS1 performance for each interconnection during solar PM hours (HE 15, HE 16, HE 17, and HE 18). The season and hours are shown across the top of the chart, and the years are shown across the bottom of the chart. Each dot represents a day in the season. The seasons are represented as Spring (March-May), Summer (June-August), Fall (September-November), and Winter (December-February). The box and whisker chart provides the distribution for each year and allows you to see the changing patterns year-over-year. Since the previous season is always the objective, we're looking to see if we improved frequency performance throughout that season.

Western Interconnect

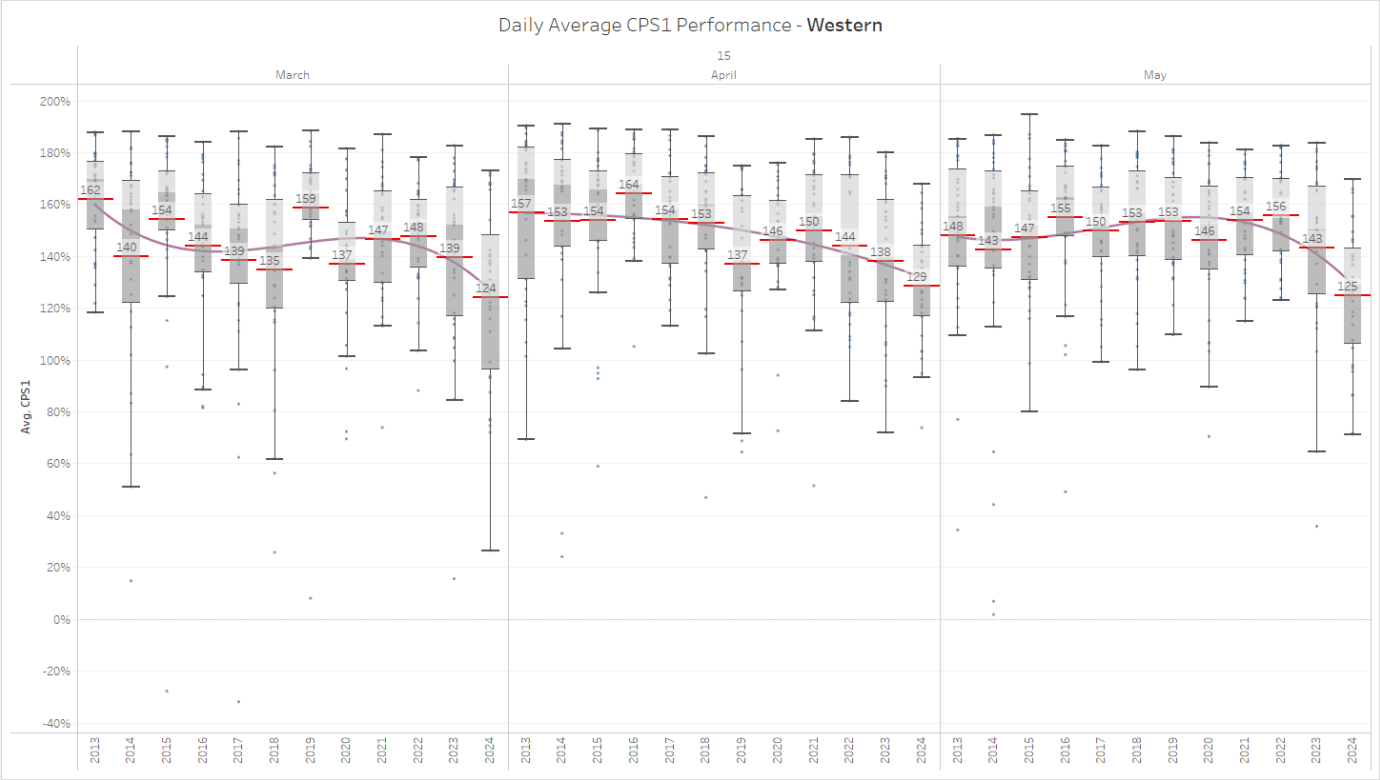
These charts represent **Spring** data from 2013-2024. If we focus on the purple polynomial trendline, the average CPS1 performance shows a downward trend in all HE hours year-over-year, with **HE 18** showing the greatest drop in performance in 2024.



HE 15

Takeaways:

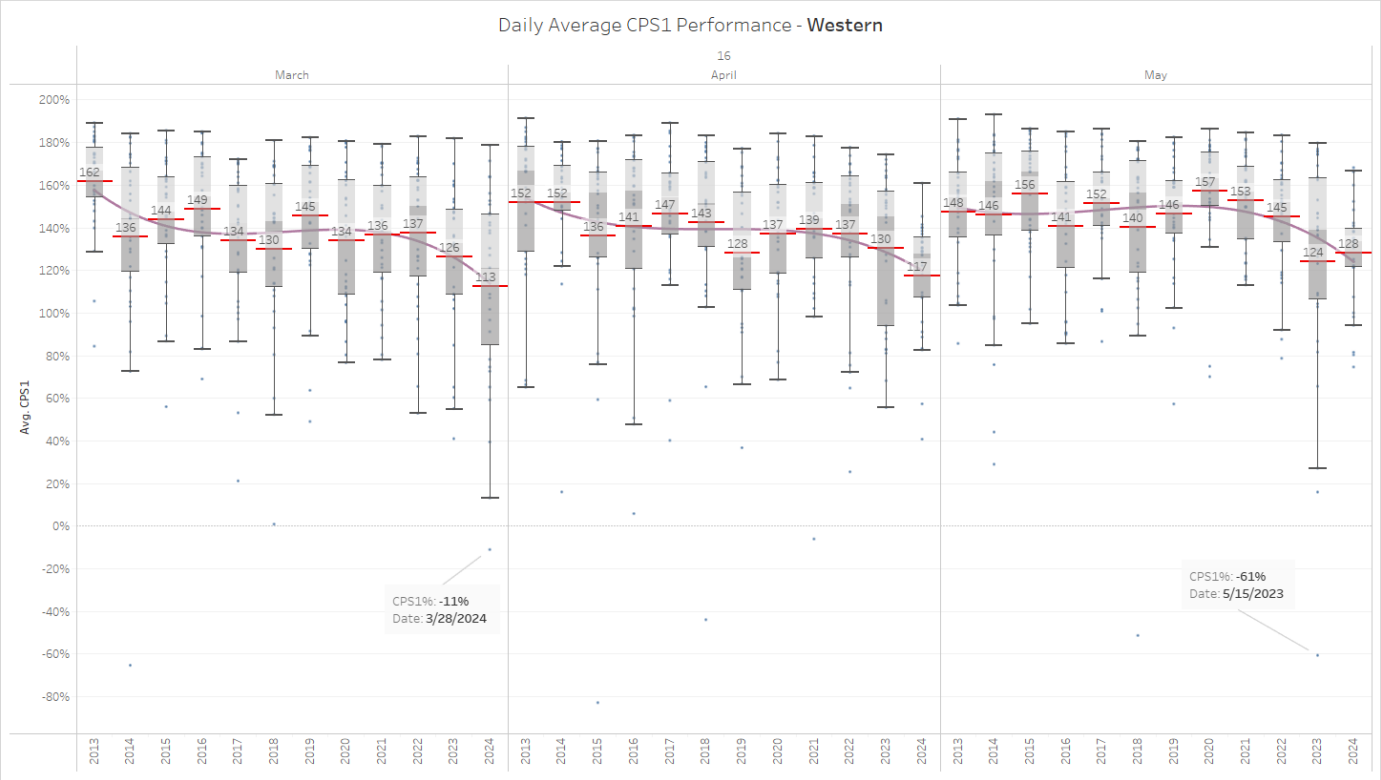
1. All months have experienced a significant decline in average performance in recent years.
2. **March** experienced an increase in variability in recent years.
3. Average performance changes from 2023-2024:
    a. March decreased **15%**
    b. April decreased **9%**
    c. May decreased **18%**



HE 16

Takeaways:

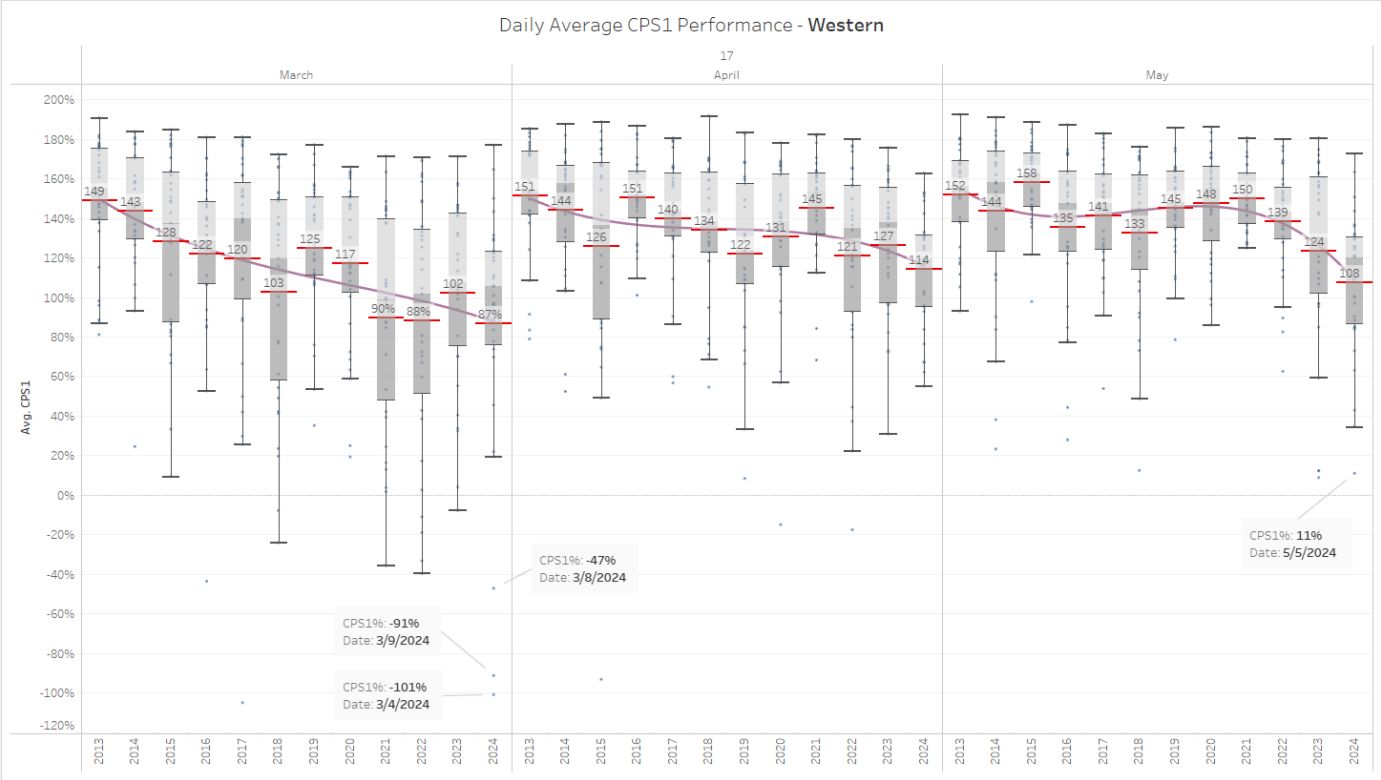
1. **March** and **April** have experienced a significant decline in average performance in recent years.
2. March experienced an increase in variability in 2024 in both the IQR and the whiskers.
3. Average performance changes from 2023-2024:
    a. March decreased **13%**
    b. April decreased **13%**
    c. May increased **4%**



HE 17

Takeaways:

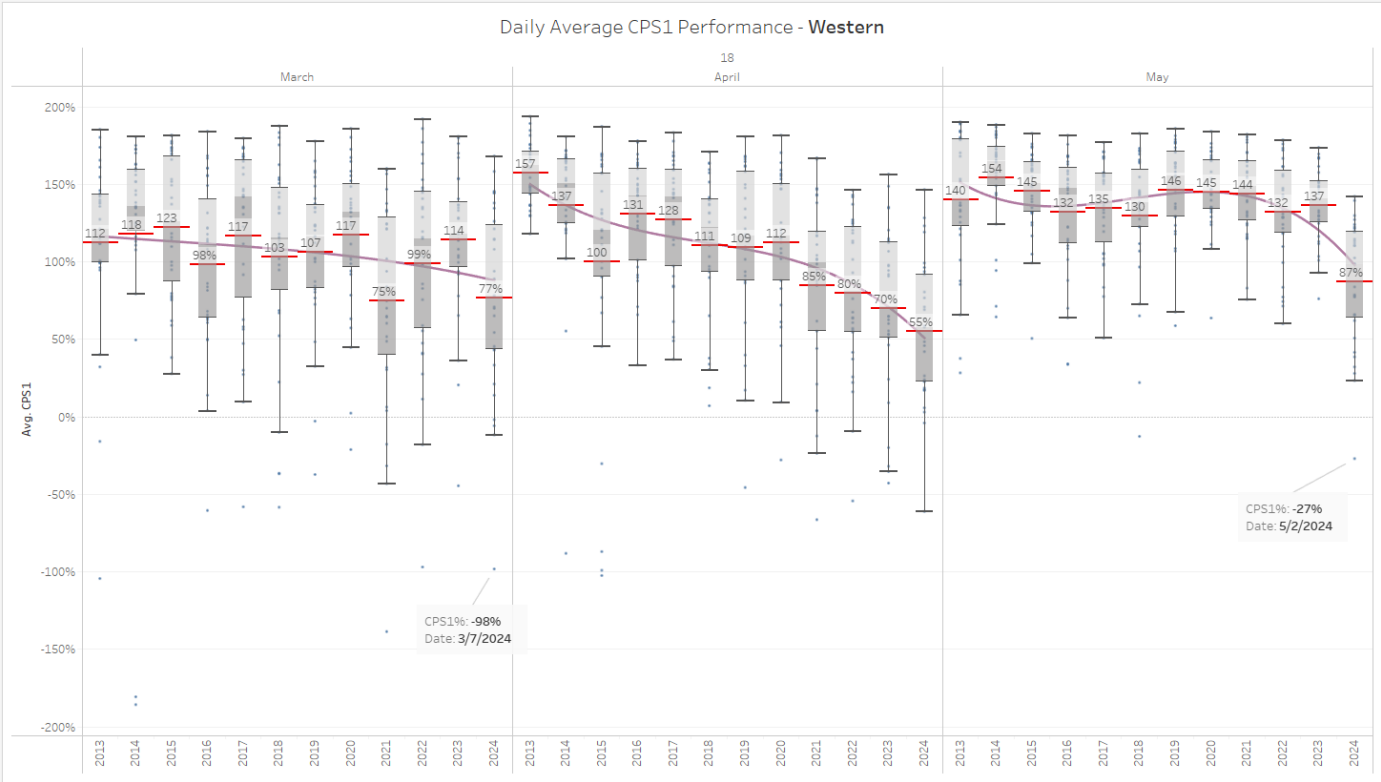
1. **March** continues to experience high variability year-over-year with significant outliers in 2024.
2. Is ~90% the new normal for **March**?
3. Average performance changes from 2023-2024:
    a. March decreased **15%**
    b. April decreased **13%**
    c. May decreased **16%**



HE 18

Takeaways:

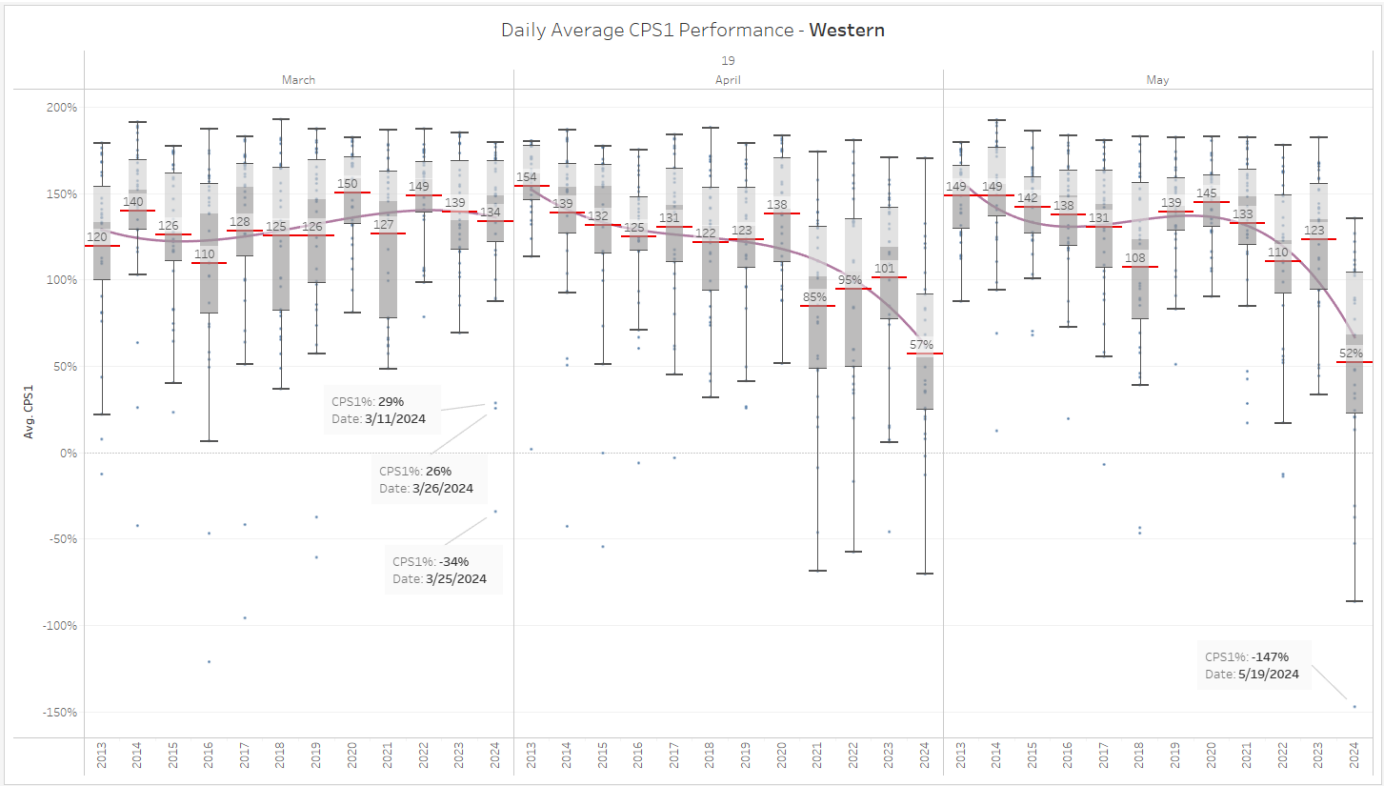
1. May took a huge hit in 2024 in average performance.
2. April has experienced a significant decline in average performance in recent years.
3. Average performance changes from 2023-2024:
    a. March decreased **37%**
    b. April decreased **15%**
    c. May decreased **50%**



HE 19

Takeaways:

1. **April** has experienced a significant decline in average performance and an increase in variability in recent years.
2. **May** took a huge hit in 2024 in average performance.
3. Average performance changes from 2023-2024:
    a. March decreased **5%**
    b. April decreased **44%**
    c. May decreased **71%**



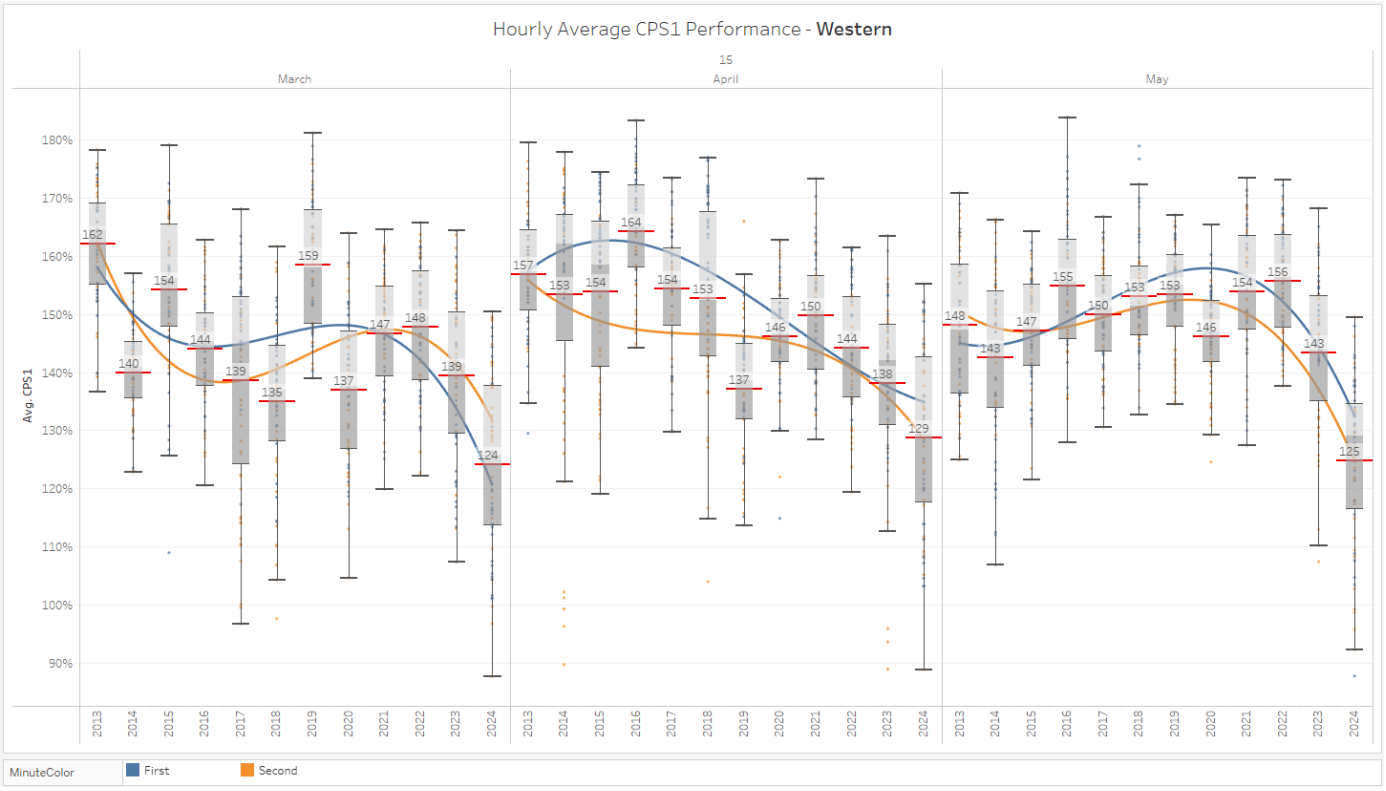
Hourly Performance

Based on the previous analysis, all months look to be contributing to the downward trend in Spring performance during **HE 15-17**. What is the data telling me at the hourly and minute level? These charts provide a look at solar PM hours during each of these months (year-over-year), for all days in the month, with HE across the top. This time, the dots represent minutes.

There are two separate polynomial trends comparing the **first half** of the hour to the **last half** of the hour. I color-coded the dots (minutes) to differentiate the minutes in the first half of the hour (blue) from the minutes in the last half of the hour (orange).

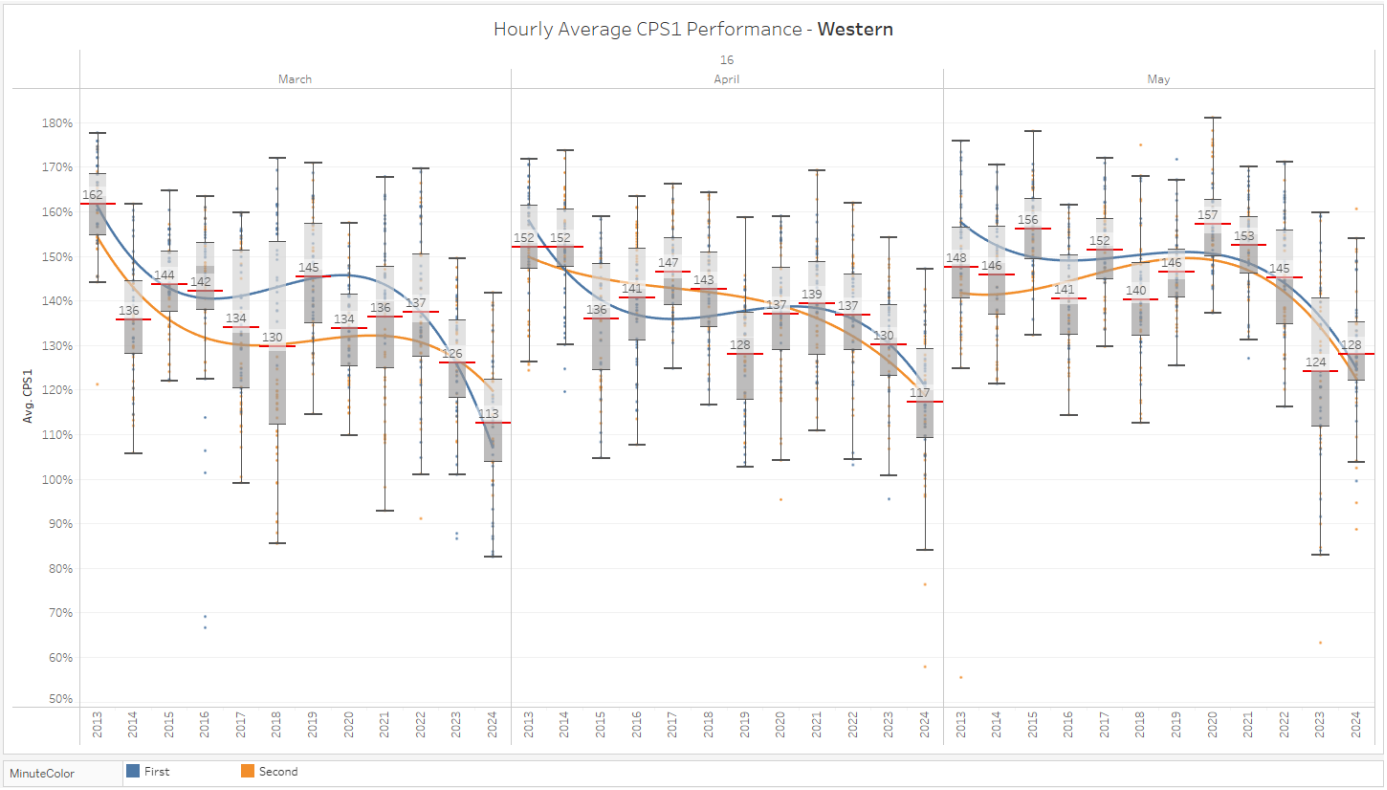
Takeaways (**HE 15**):

1. All months show downward trends in recent years **throughout** the hour.



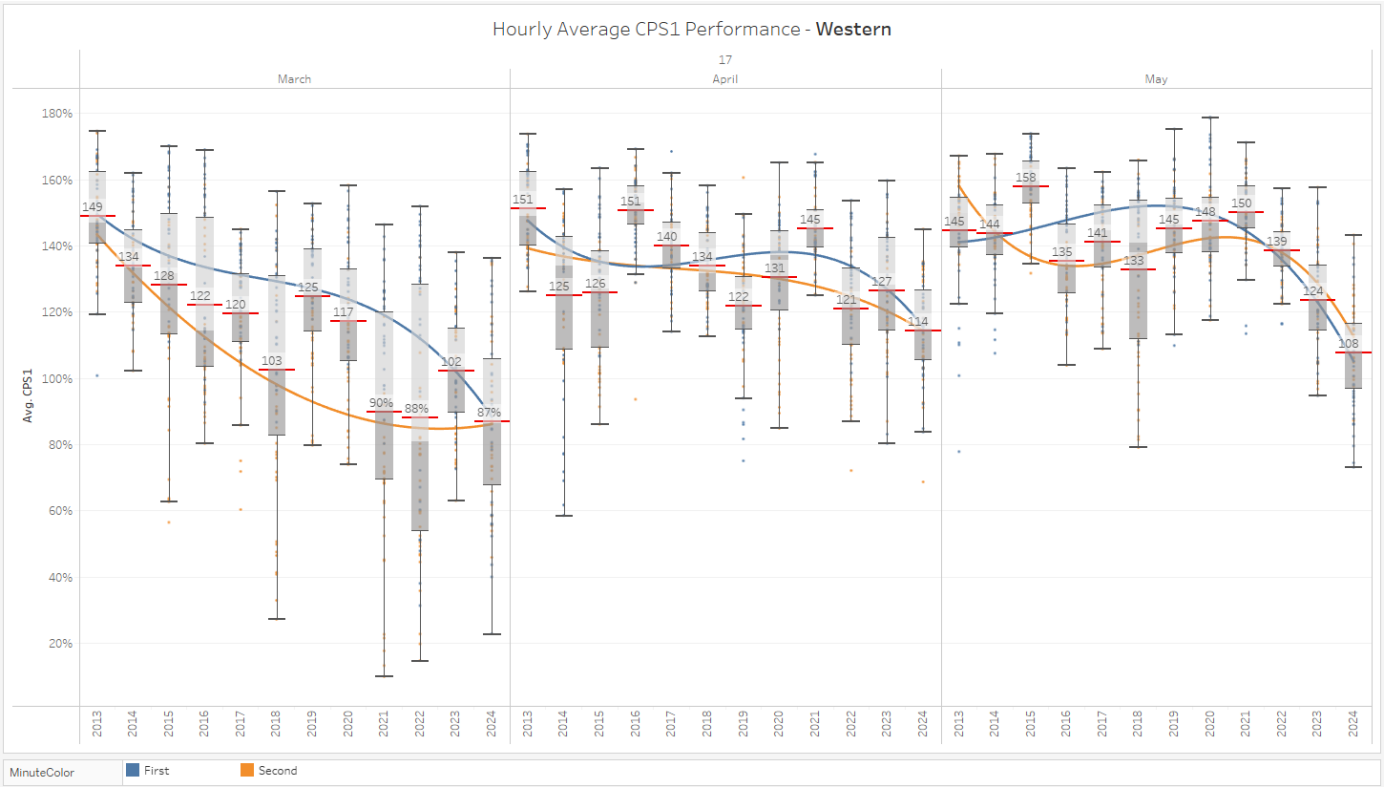
Takeaways (**HE 16**):

1. All months show downward trends in recent years **throughout** the hour.
2. **March** shows a greater struggle during the **first half** of the hour in recent years.
3. **April** shows a greater struggle during the **second half** of the hour in recent years.



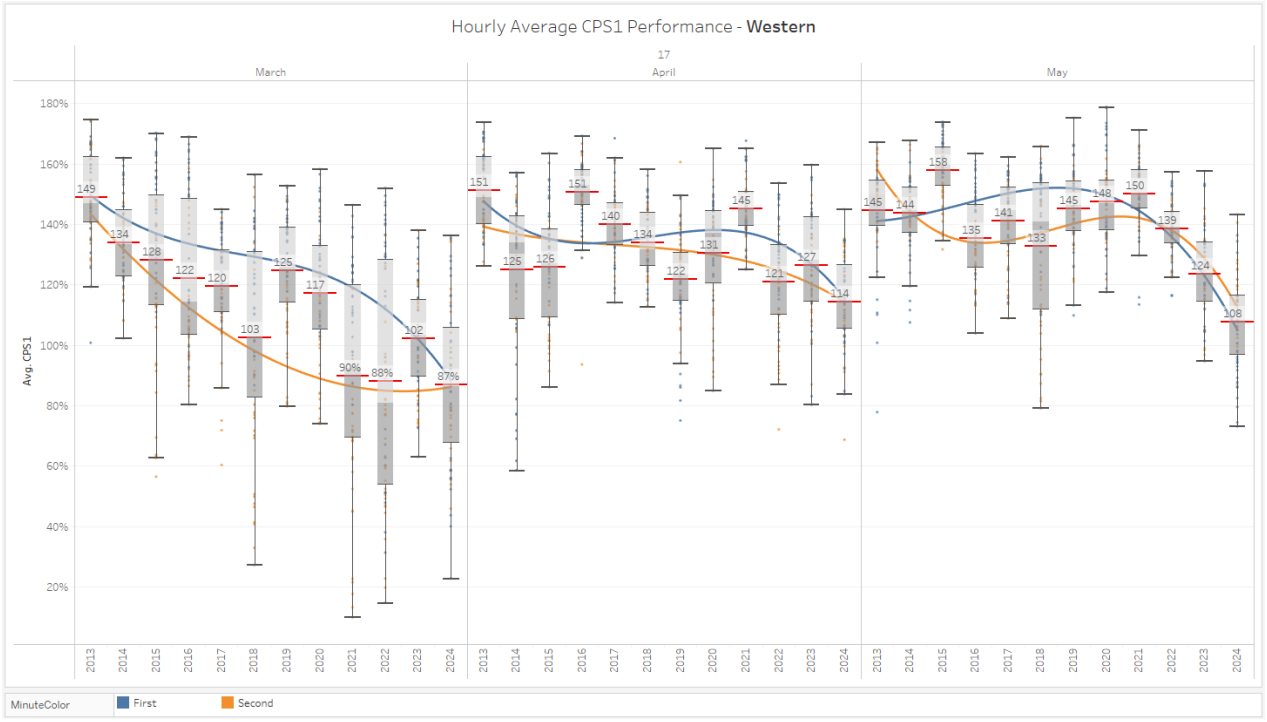
Takeaways (**HE 17**):

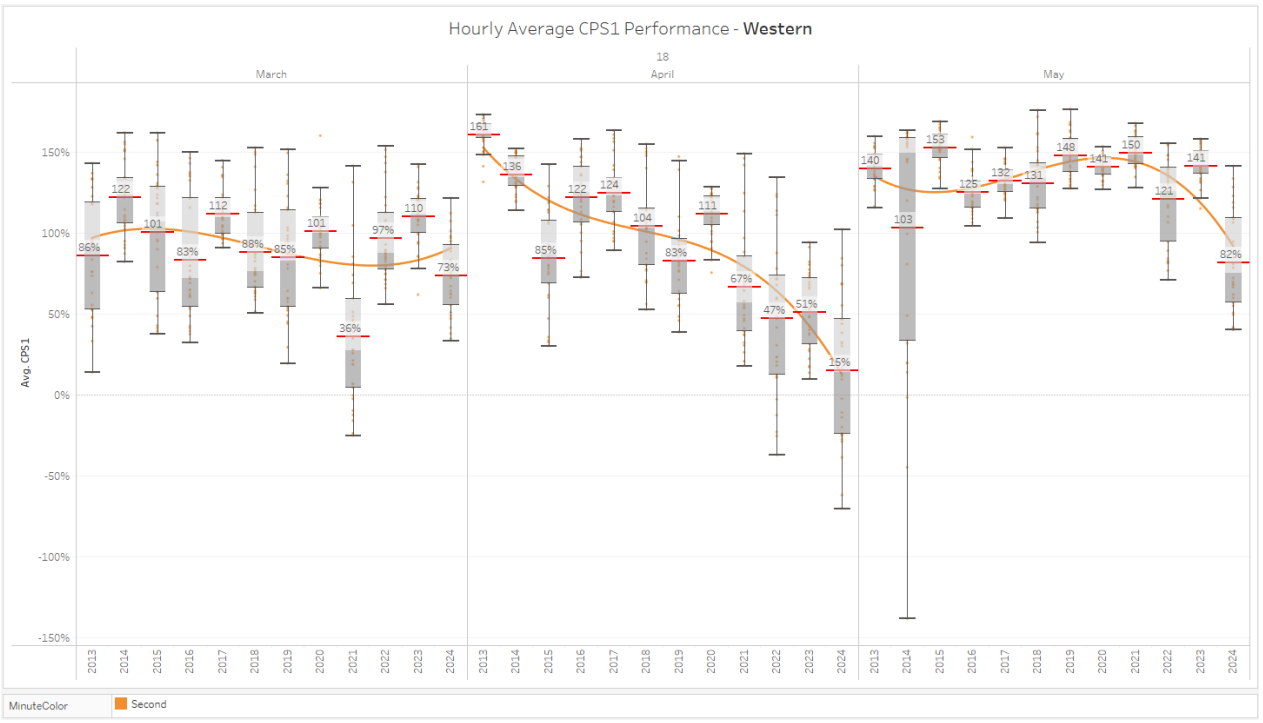
1. All months show downward trends in recent years **throughout** the hour.
2. **March** and **May** show a greater struggle during the **first half** of the hour in recent years.
3. **March** looks to have improved average performance during the **second half** of the hour in recent years.



Takeaways (**HE 18**):

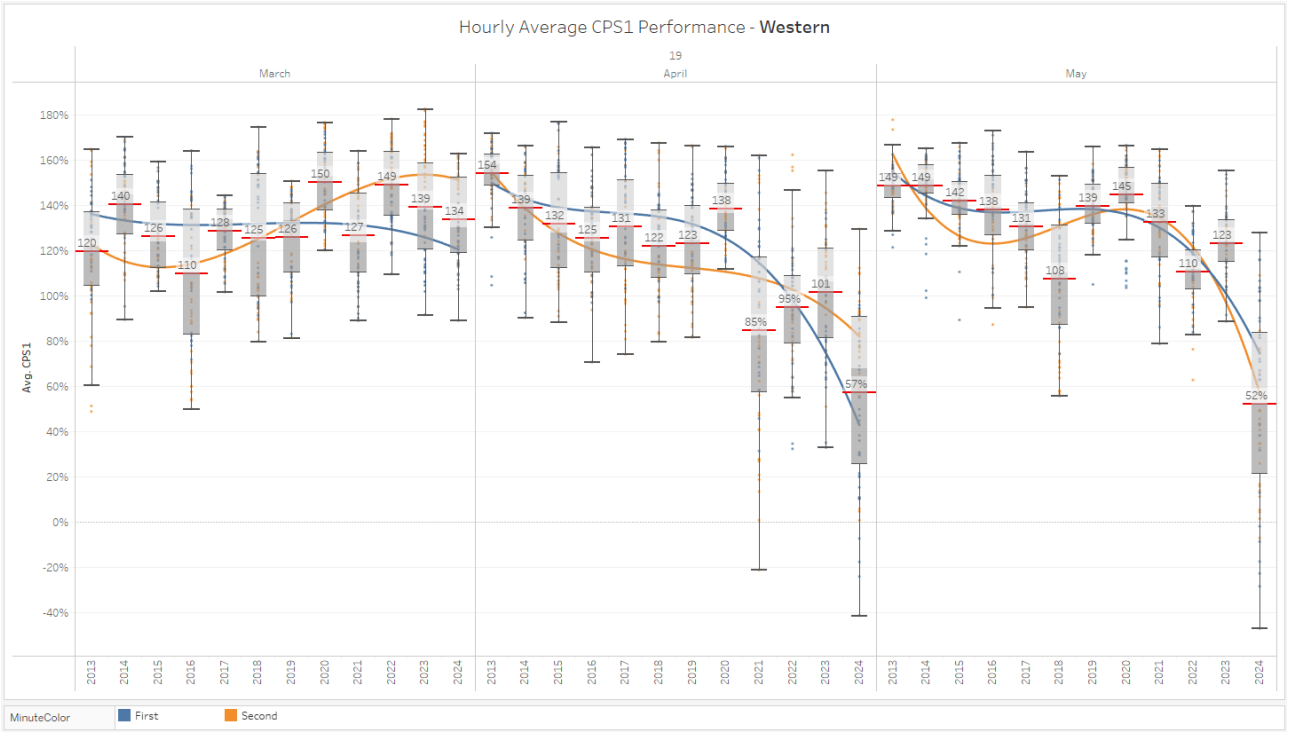
1. April shows a downward trend during the **second half** of the hour in recent years.
2. **March** and **May** show a greater struggle during the **first half** of the hour in recent years.
3. **March** and **April** have experienced increased variability **throughout** the hour in recent years.

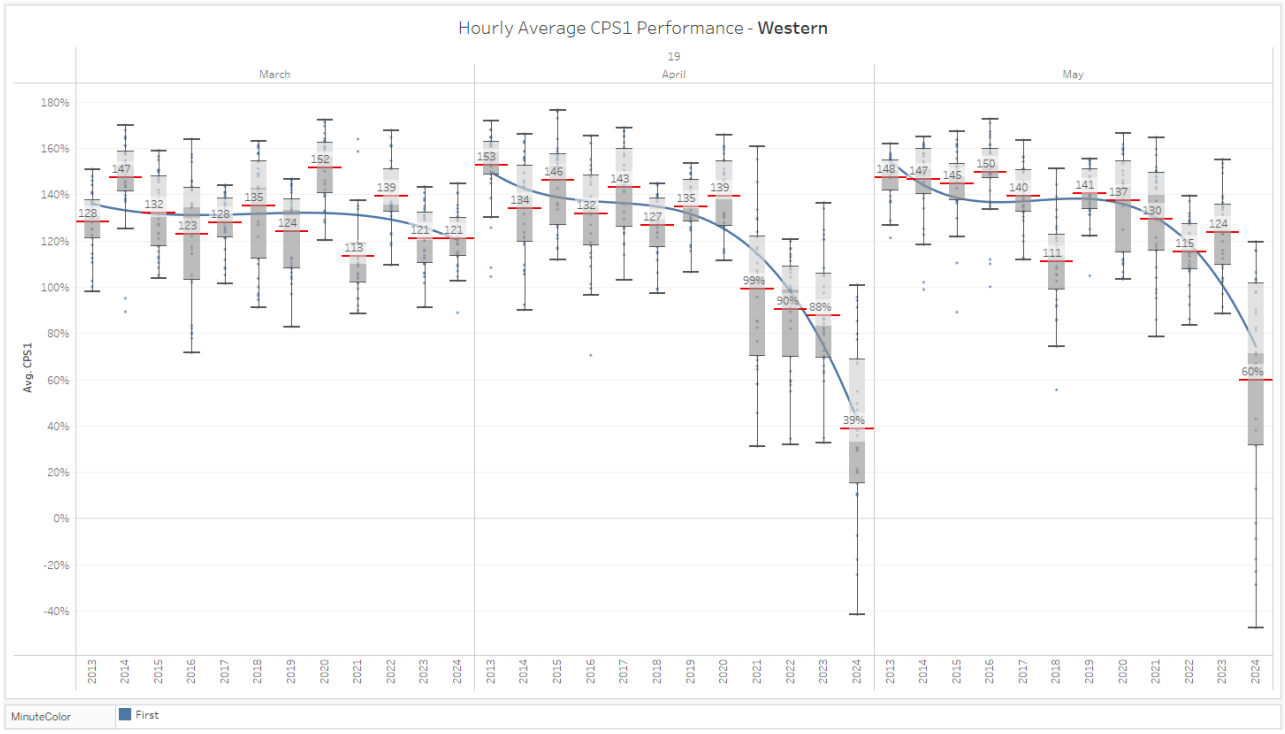




Takeaways (**HE 19**):

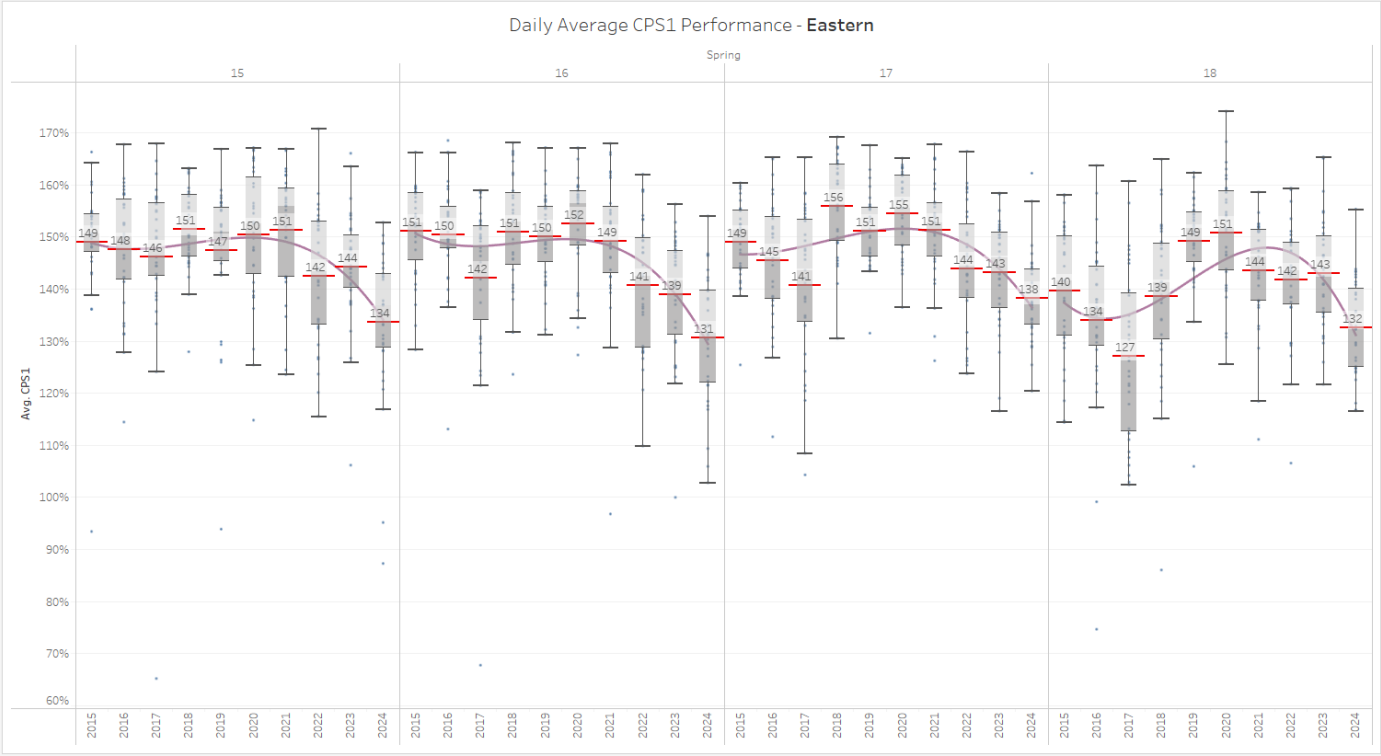
1. **April** and **May** show downward trends **throughout** the hour in recent years.
2. **March** shows increased average performance during the **second half** of the hour in recent years.
3. **April** has experienced increased variability **throughout** the hour in recent years.





Eastern Interconnect

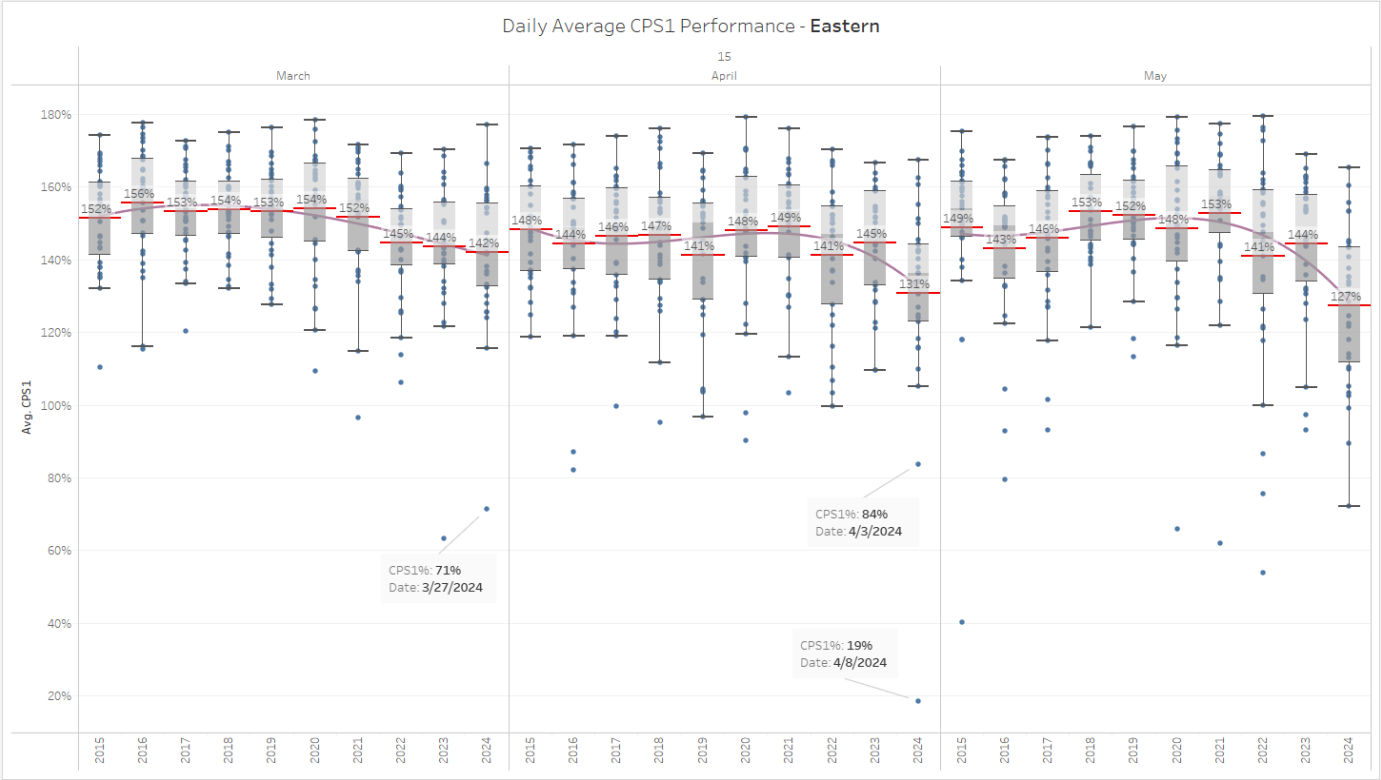
These charts represent **Spring** data from 2015-2024. If we focus on the purple polynomial trendline, the average CPS1 performance shows a downward trend in all HE hours year-over-year.



HE 15

Takeaways:

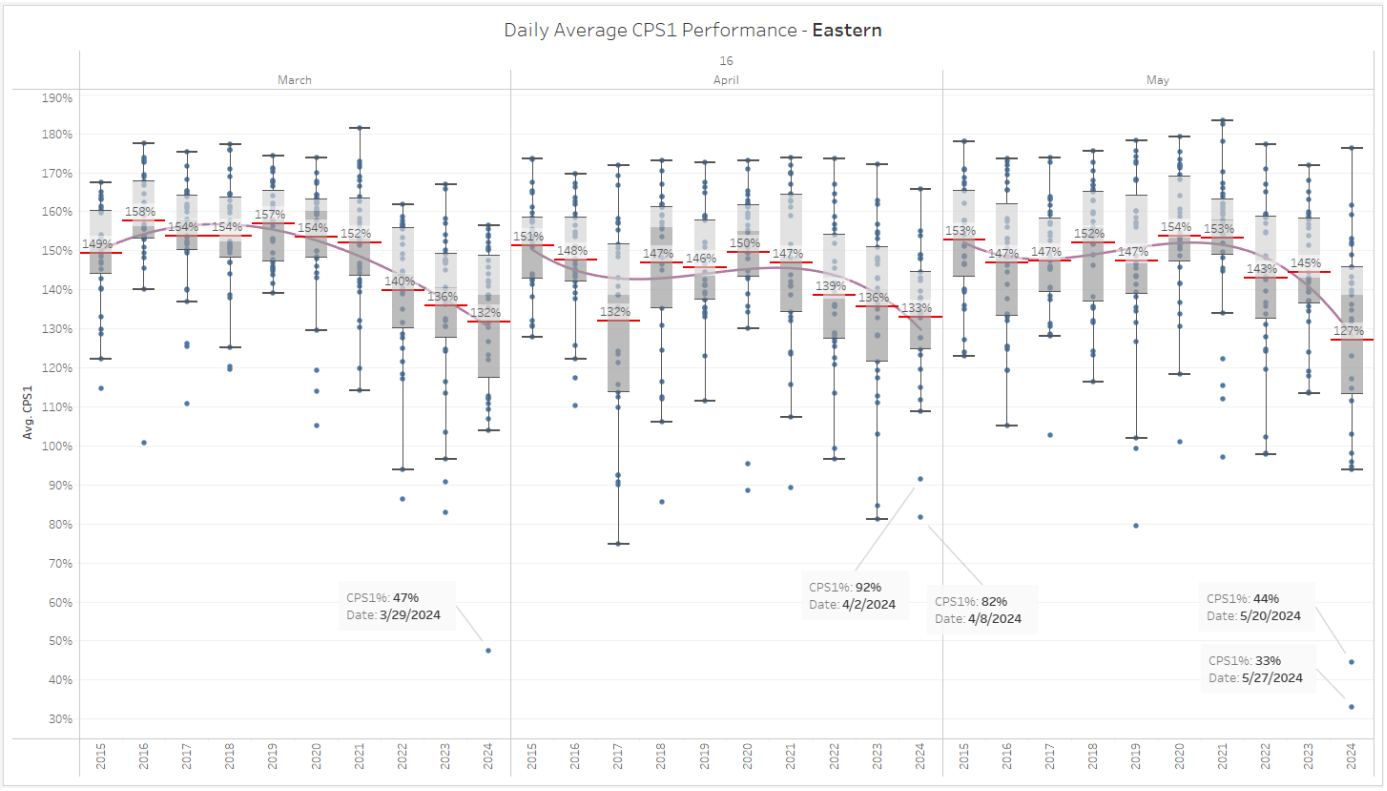
1. **April** and **May** have experienced a decline in average performance in recent years.
2. May has experienced increased variability in recent years.
3. Average performance changes from 2023-2024:
    a. March decreased **2%**
    b. April decreased **14%**
    c. May decreased **17%**



HE 16

Takeaways:

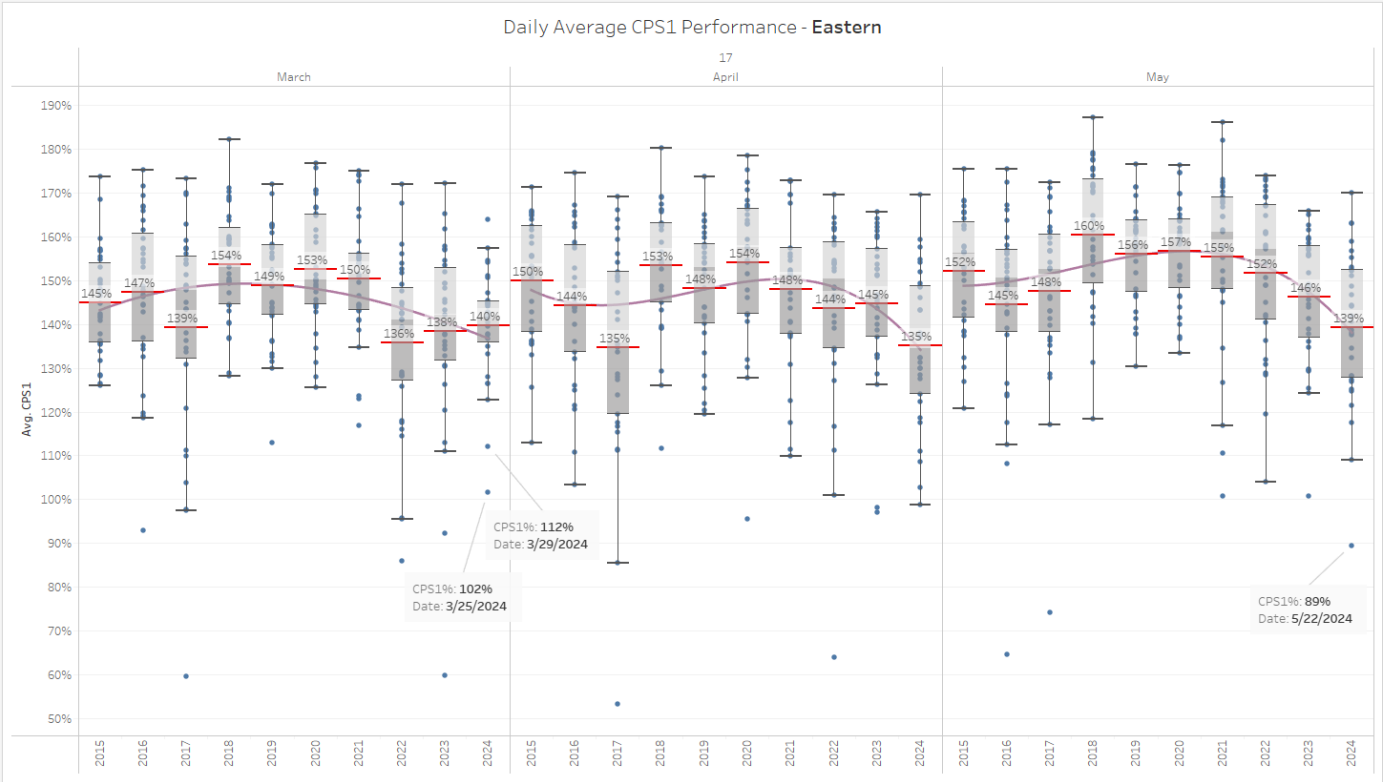
1. **March** and **May** have experienced a decline in average performance in recent years.
2. Average performance changes from 2023-2024:
    a. March decreased **4%**
    b. April decreased **3%**
    c. May decreased **18%**



HE 17

Takeaways:

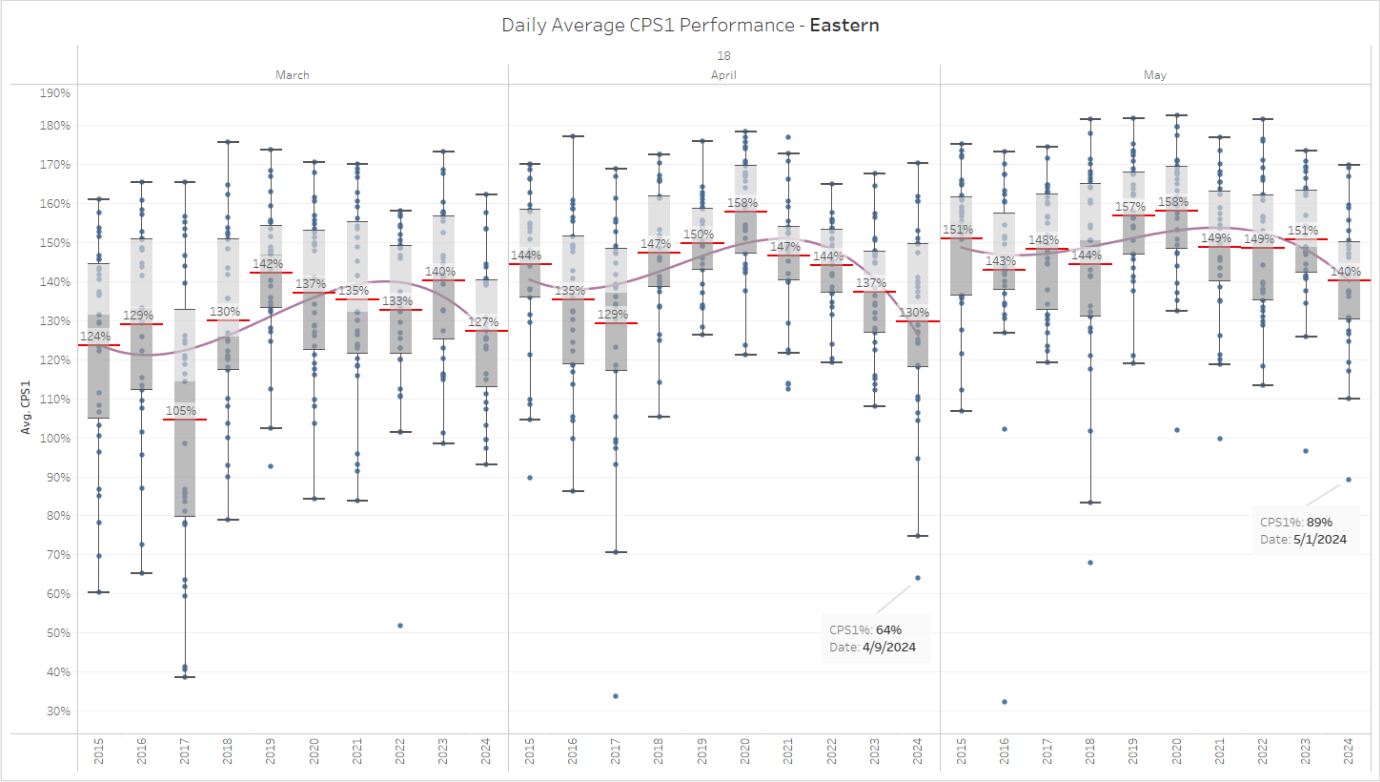
1. **April** and **May** have experienced a decline in average performance in recent years.
2. March has seen an improvement in variability in recent years.
3. Average performance changes from 2023-2024:
    a. March increased **2%**
    b. April decreased **10%**
    c. May decreased **7%**



HE 18

Takeaways:

1. **April** has experienced a decline in average performance in recent years.
2. Average performance changes from 2023-2024:
    a. March decreased **13%**
    b. April decreased **7%**
    c. May decreased **9%**



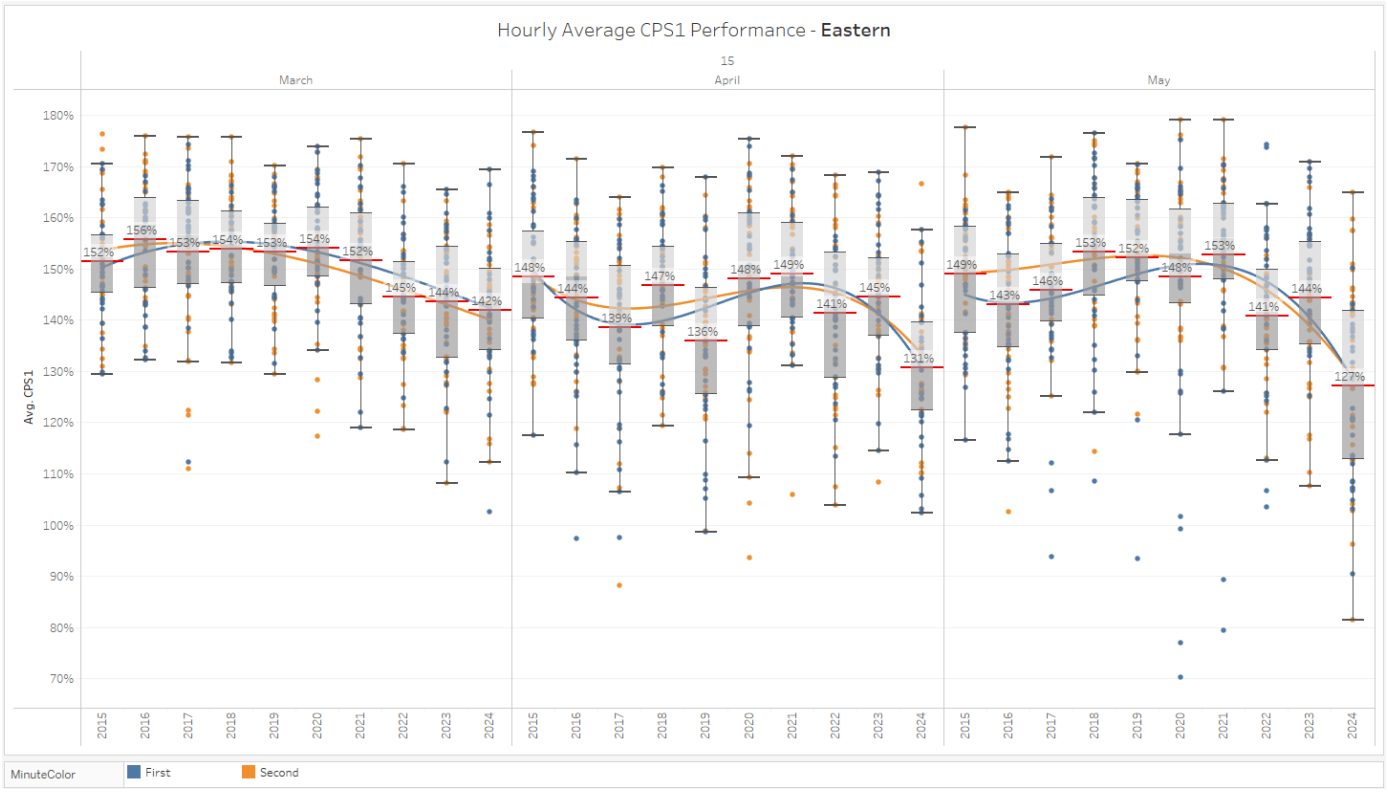
Hourly Performance

Based on the previous analysis, all months look to be contributing to the downward trend in Spring performance during **HE 15-18**. What is the data telling me at the hourly and minute level? These charts provide a look at solar PM hours during each of these months (year-over-year), for all days in the month, with HE across the top. This time, the dots represent minutes.

There are two separate polynomial trends comparing the **first half** of the hour to the **last half** of the hour. I color-coded the dots (minutes) to differentiate the minutes in the first half of the hour (blue) from the minutes in the last half of the hour (orange).

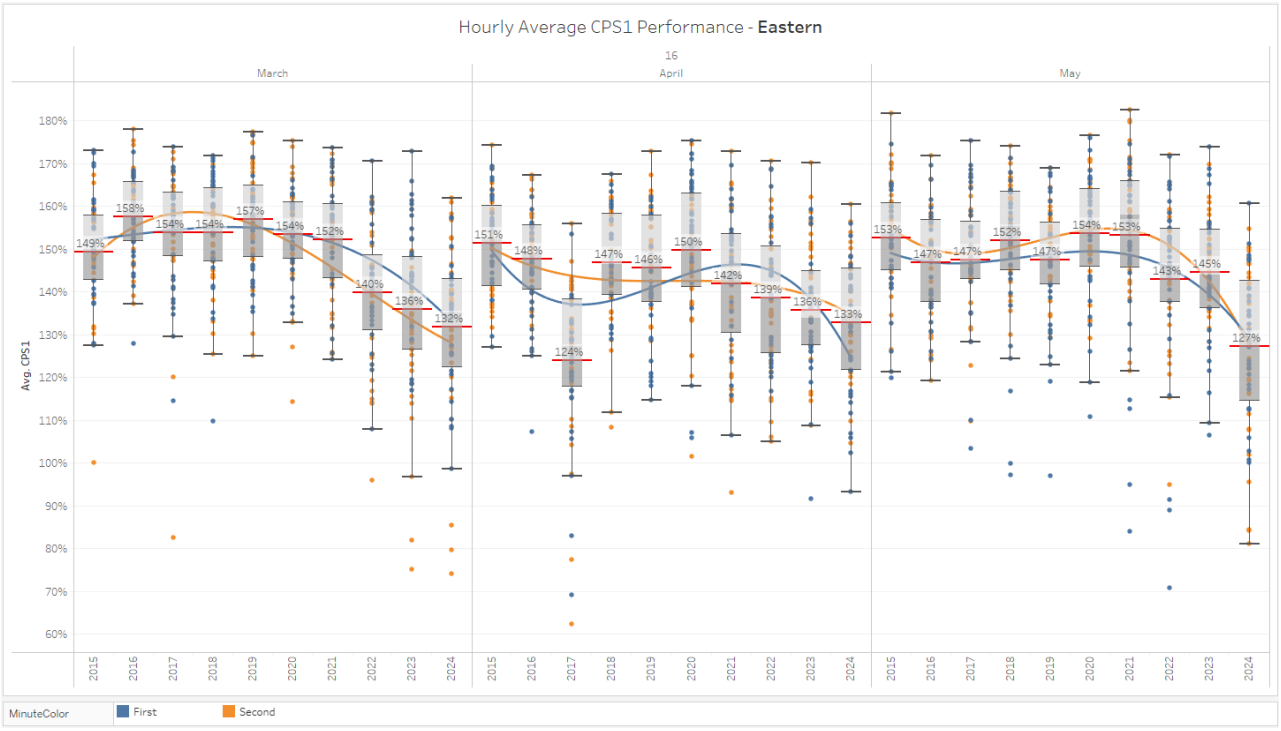
Takeaways (**HE 15**):

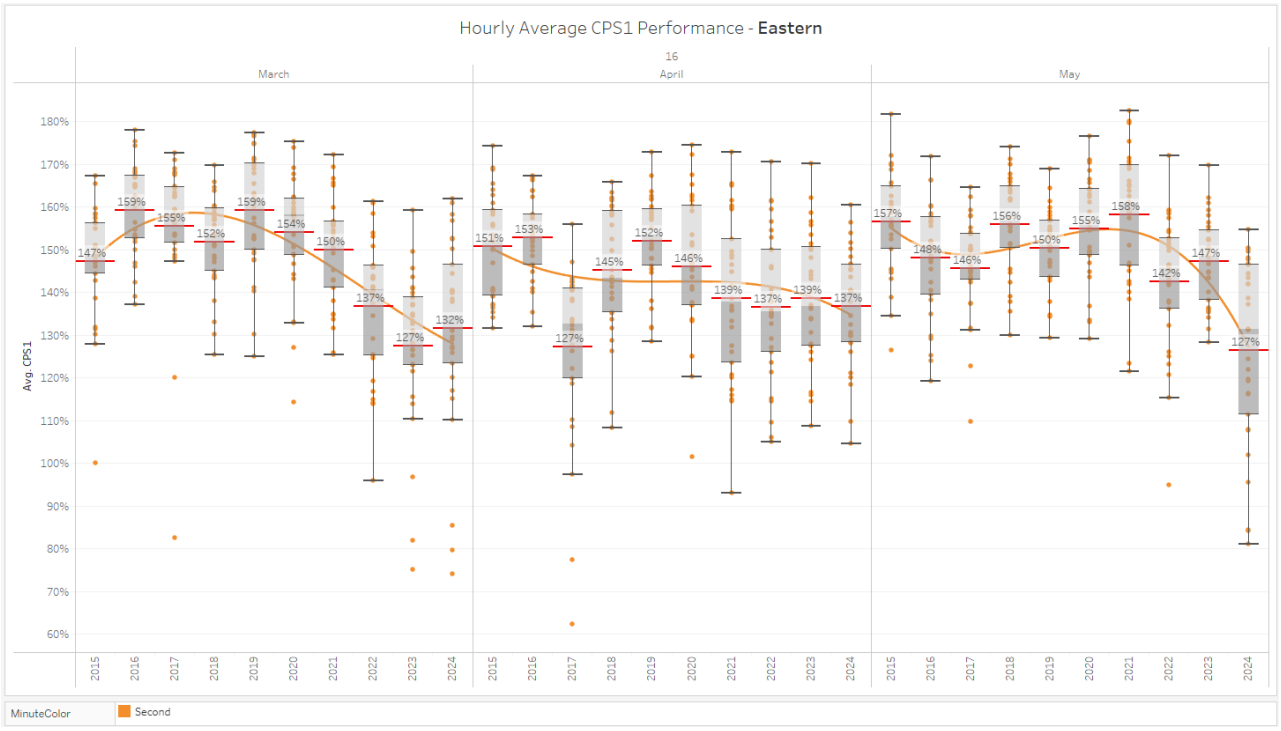
1. All months show downward trends **throughout** the hour in recent years.
2. **May** has experienced increased variability during the **second half** of the hour in recent years.



Takeaways (**HE 16**):

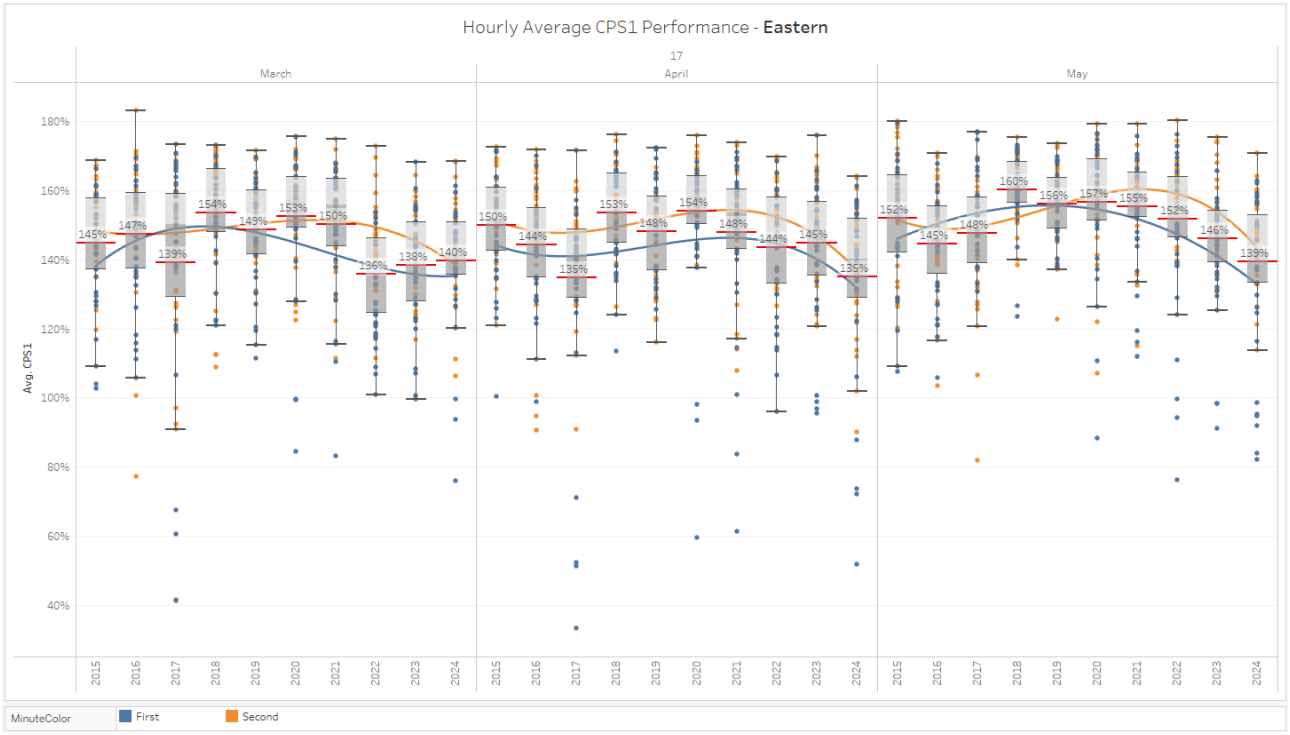
1. All months have experienced downward trends during the **first half** of the hour in recent years.
2. **March** and **May** have experienced inconsistent average performance during the **second half** of the hour in recent years.

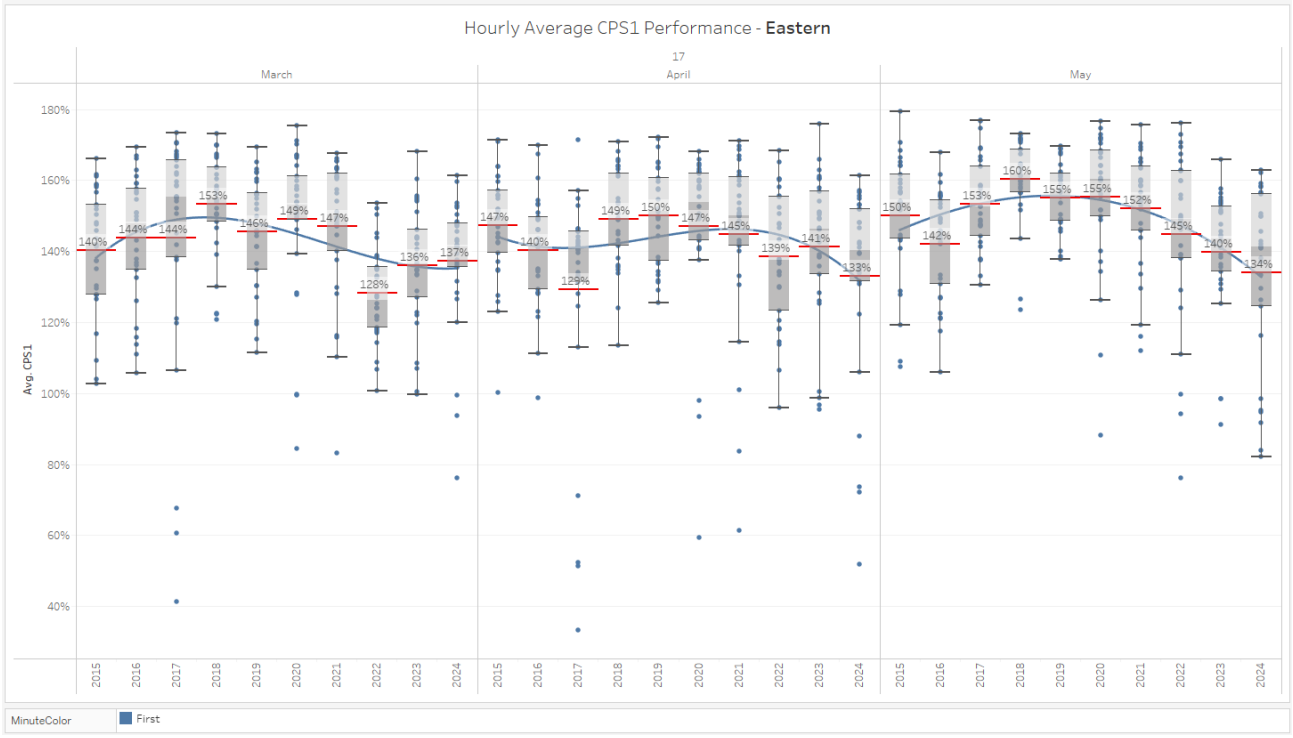




Takeaways (**HE 17**):

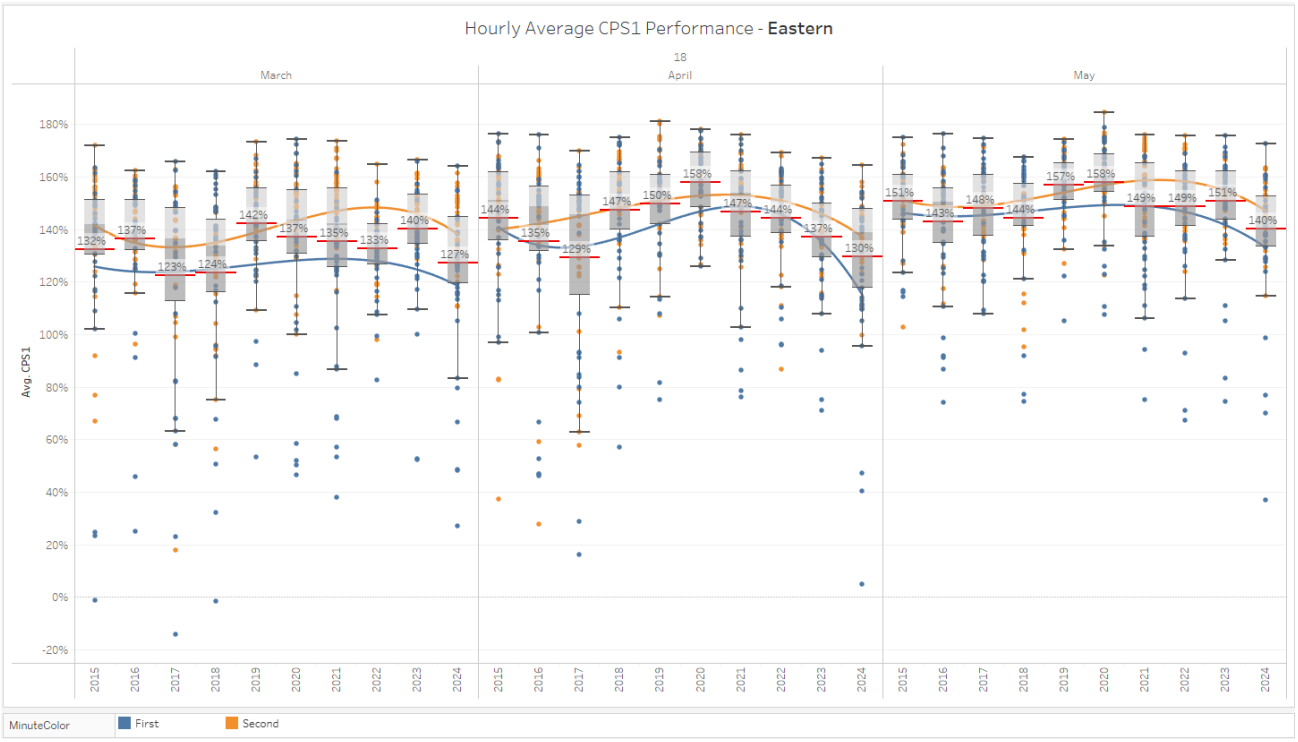
1. **May** shows downward trends **throughout** the hour in recent years.
2. **May** has experienced increased variability during the **first half** of the hour in recent years.

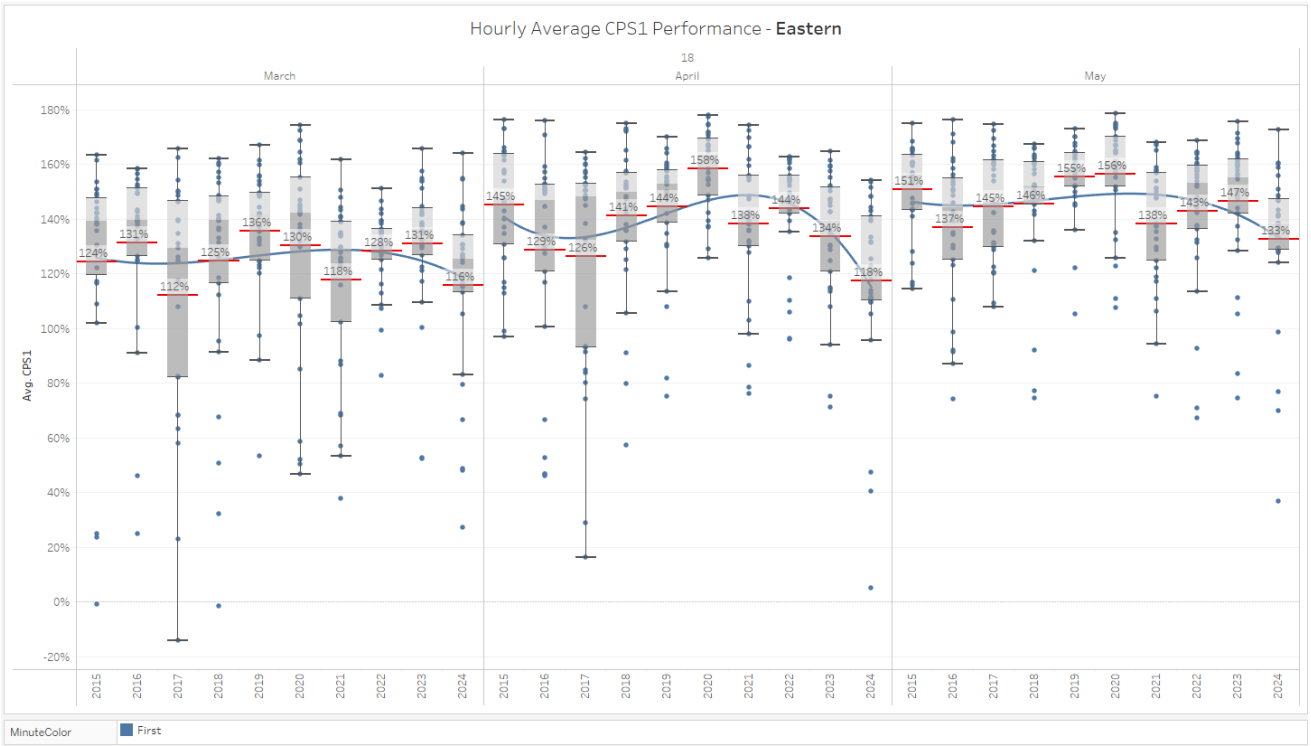




Takeaways (**HE 18**):

1. **March** took a hit in average performance during the first half of the hour in 2024.
2. April shows a downward trend during the **first half** of the hour in recent years.





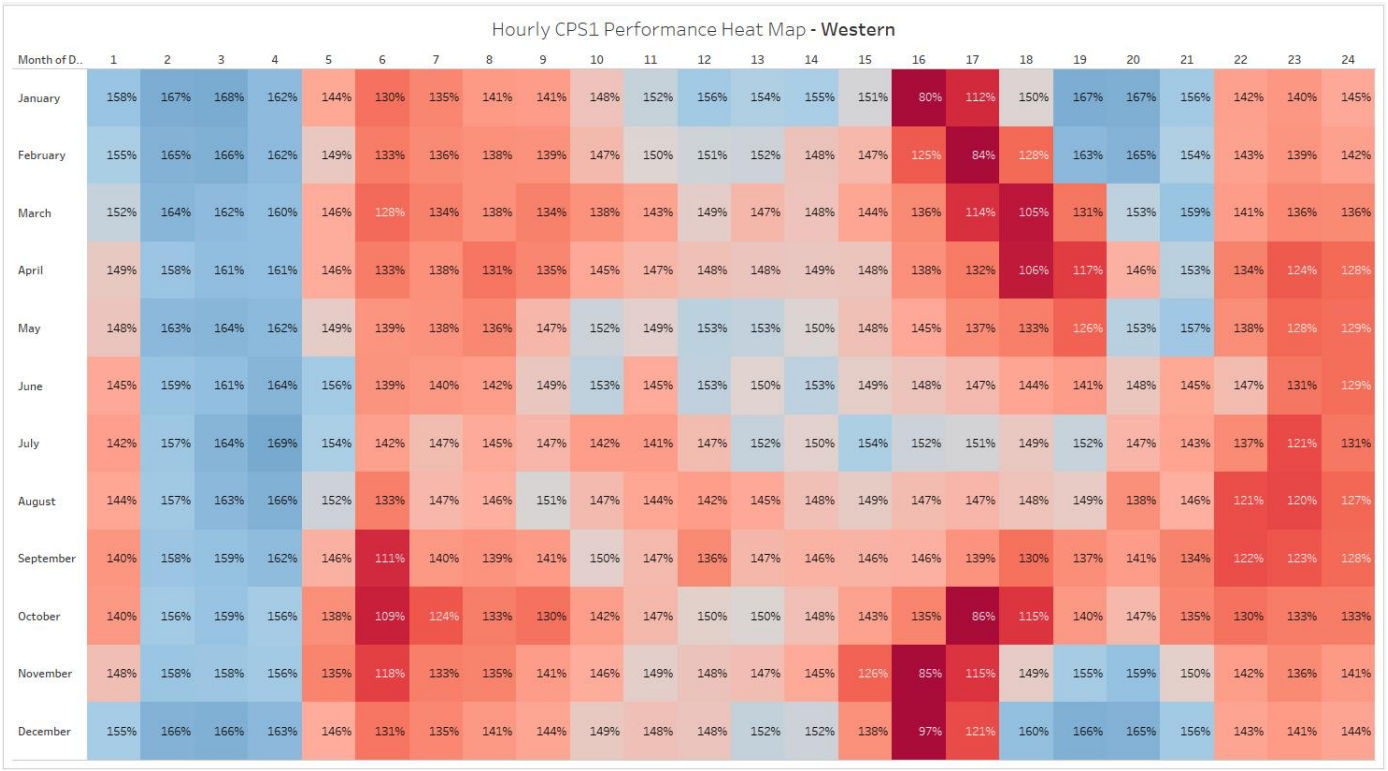
Heat Map Charts

These charts show hourly patterns throughout the year and help us identify the hours we should be focused on. If we don't show data at the hourly level, it averages out and we can't see these indicators.

Western Interconnect

Takeaways:

1. This chart represents data from 2013–2024.
2. The Winter and shoulder months have more of an impact to average performance during solar PM hours than the Summer months.
3. There seems to be a predictable pattern of off nominal frequency twice per day.
4. The succeeding page will show YTD performance for comparison.

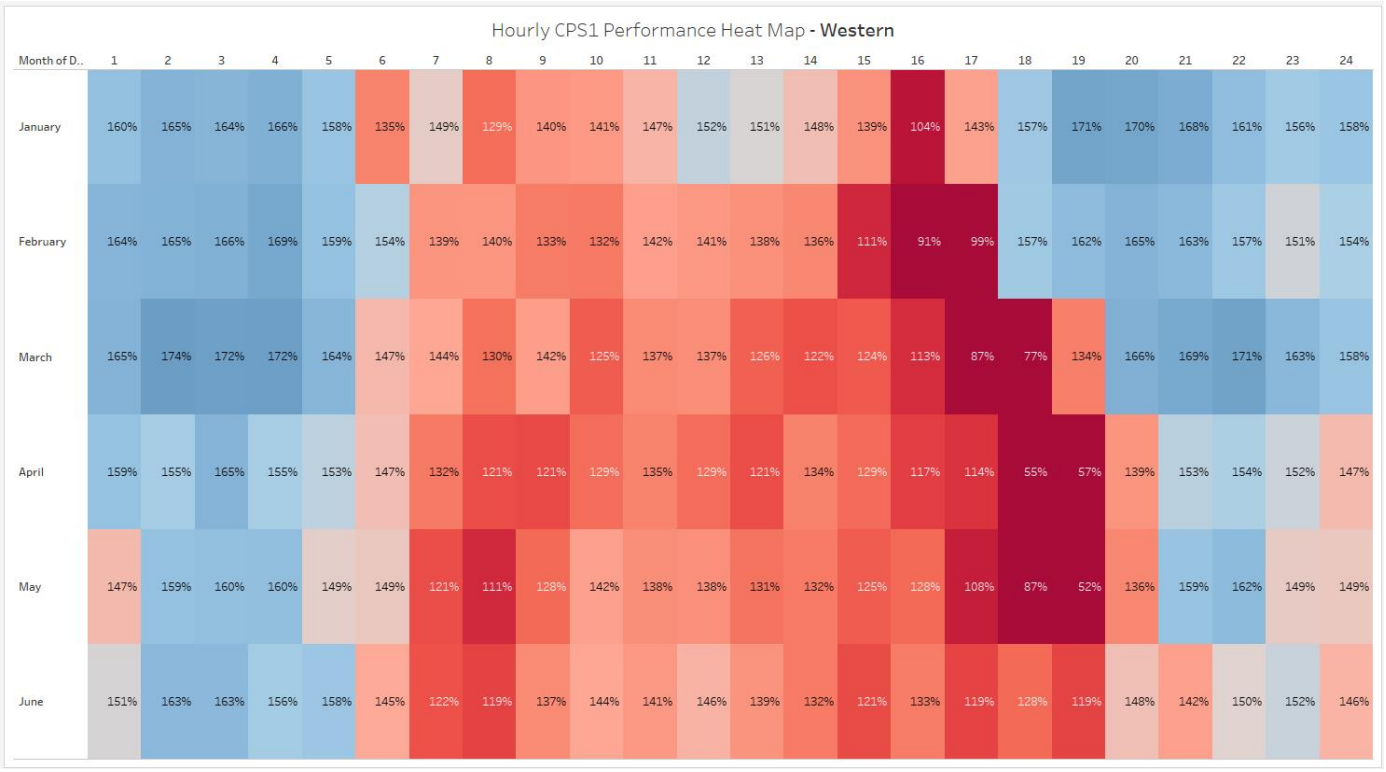


Month of D..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	158%	167%	168%	162%	144%	130%	135%	141%	141%	148%	152%	156%	154%	155%	151%	80%	112%	150%	167%	167%	156%	142%	140%	145%
February	155%	165%	166%	162%	149%	133%	136%	138%	139%	147%	150%	151%	152%	148%	147%	125%	84%	128%	163%	165%	154%	143%	139%	142%
March	152%	164%	162%	160%	146%	128%	134%	138%	134%	138%	143%	149%	147%	148%	144%	136%	114%	105%	131%	153%	159%	141%	136%	136%
April	149%	158%	161%	161%	146%	133%	138%	131%	135%	145%	147%	148%	148%	149%	148%	138%	132%	106%	117%	146%	153%	134%	124%	128%
May	148%	163%	164%	162%	149%	139%	138%	136%	147%	152%	149%	153%	153%	150%	148%	145%	137%	133%	126%	153%	157%	138%	128%	129%
June	145%	159%	161%	164%	156%	139%	140%	142%	149%	153%	145%	153%	150%	153%	149%	148%	147%	144%	141%	148%	145%	147%	131%	129%
July	142%	157%	164%	169%	154%	142%	147%	145%	147%	142%	141%	147%	152%	150%	154%	152%	151%	149%	152%	147%	143%	137%	121%	131%
August	144%	157%	163%	166%	152%	133%	147%	146%	151%	147%	144%	142%	145%	148%	149%	147%	147%	148%	149%	138%	146%	121%	120%	127%
September	140%	158%	159%	162%	146%	111%	140%	139%	141%	150%	147%	136%	147%	146%	146%	146%	139%	130%	137%	141%	134%	122%	123%	128%
October	140%	156%	159%	156%	138%	109%	124%	133%	130%	142%	147%	150%	150%	148%	143%	135%	86%	115%	140%	147%	135%	130%	133%	133%
November	148%	158%	158%	156%	135%	118%	133%	135%	141%	146%	149%	148%	147%	145%	126%	85%	115%	149%	155%	159%	150%	142%	136%	141%
December	155%	166%	166%	163%	146%	131%	135%	141%	144%	149%	148%	148%	152%	152%	138%	97%	121%	160%	166%	165%	156%	143%	141%	144%

Takeaways (**2024**):

1. Average performance is lower across the board in all hours than in the overall plot.
2. Lower average performance is beginning to bleed over into **HE 19**.

2024



Eastern Interconnect

Takeaways:

1. This chart represents data from 2015-2024.
2. HE 21-HE 24 have historically shown lower CPS1 performance in the Eastern Interconnect.
3. The succeeding page will show YTD performance for comparison.

Hourly CPS1 Performance Heat Map - **Eastern**

Month of D..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
January	156%	160%	162%	160%	157%	144%	147%	157%	157%	155%	158%	157%	162%	162%	161%	154%	139%	154%	163%	160%	157%	154%	155%	147%
February	157%	162%	162%	161%	158%	142%	151%	157%	156%	153%	156%	155%	157%	160%	159%	155%	145%	144%	161%	159%	156%	150%	153%	149%
March	157%	162%	162%	159%	156%	140%	149%	156%	155%	155%	157%	155%	157%	157%	159%	157%	155%	148%	146%	156%	154%	149%	152%	150%
April	150%	159%	161%	159%	154%	142%	154%	157%	156%	158%	157%	153%	154%	155%	152%	150%	155%	157%	154%	151%	152%	145%	146%	148%
May	150%	159%	162%	161%	155%	145%	154%	151%	154%	155%	155%	151%	153%	154%	155%	155%	159%	161%	161%	155%	150%	142%	141%	147%
June	148%	157%	160%	163%	160%	156%	156%	153%	153%	151%	150%	150%	154%	157%	156%	159%	161%	164%	157%	155%	143%	141%	140%	144%
July	148%	159%	164%	164%	164%	155%	161%	152%	145%	147%	147%	146%	154%	157%	160%	160%	165%	164%	158%	155%	147%	146%	141%	142%
August	148%	159%	163%	164%	161%	149%	161%	156%	150%	150%	148%	147%	154%	157%	160%	160%	163%	165%	159%	151%	148%	145%	139%	143%
September	151%	160%	163%	163%	156%	140%	157%	159%	150%	151%	151%	147%	156%	159%	161%	161%	165%	163%	160%	145%	148%	148%	143%	146%
October	151%	160%	163%	161%	154%	138%	148%	158%	158%	156%	159%	156%	157%	158%	159%	158%	158%	155%	158%	156%	148%	146%	145%	148%
November	155%	160%	162%	158%	155%	142%	153%	157%	155%	154%	157%	155%	156%	160%	157%	147%	143%	157%	162%	158%	152%	150%	151%	149%
December	155%	159%	162%	159%	158%	146%	151%	154%	154%	151%	156%	156%	159%	161%	160%	151%	142%	161%	163%	161%	157%	153%	151%	146%

Takeaways (2023):

1. **HE 6-7** continue to be an issue in 2024.
2. The Spring months are redder than in the overall plot. *This could be weather-related.*

2024