69th Annual AREGC Conference

scottmadden
MANAGEMENT CONSULTANTS

Smart. Focused. Done Right.®

California’s Combined-Cycle Costs in the Age of the Duck Curve

Regional Considerations of Renewable Penetration Impacts on Combined-Cycle, Non-Fuel O&M Costs

Quentin Watkins, Manager
ScottMadden, Inc.
June 26, 2018

How Are California's Combined Cycles Surviving?

To keep the lights on, California is increasingly reliant on renewables and gas-fired combined cycles (CCs). We thought it would be interesting to look more closely at the effects these new operational realities are having on costs, especially the effect of the "duck curve" on California's CCs. To do so, we decided to explore the following questions:

1. Are California's CCs running more and more often to support the duck curve year round?
2. Are California's CCs non-fuel operating and maintenance (NFOM) costs increasing due to more hours of generating, more starts, and more ramping?
3. How do NFOM cost trends for CCs in California compare to trends elsewhere in the United States, where renewable penetration levels are lower? (For this question, we used the Southeast as a basis of comparison)

Here's what we found:

1. **Output flat to declining:** Surprisingly, we also found there was no increase in capacity factors of California's CCs
   - In fact, capacity factors have been flat since 2012, declining year-over-year from 2015 to 2016
   - Plants are cycling more to support the duck curve year round
2. **California's CC costs have skyrocketed:** Our analysis confirmed that NFOM costs have increased markedly over the past 10 years
   - NFOM per megawatt hour (MWh) **more than doubled** from 2006 to 2016
   - A majority of the increase occurred from 2006 to 2013
   - NFOM per MWh has remained relatively steady since 2013
3. **Costs for comparable plants have decreased:** A peer plant's NFOM costs decreased between 2006 and 2016
   - The average capacity more than doubled in peer groups between 2006 and 2016

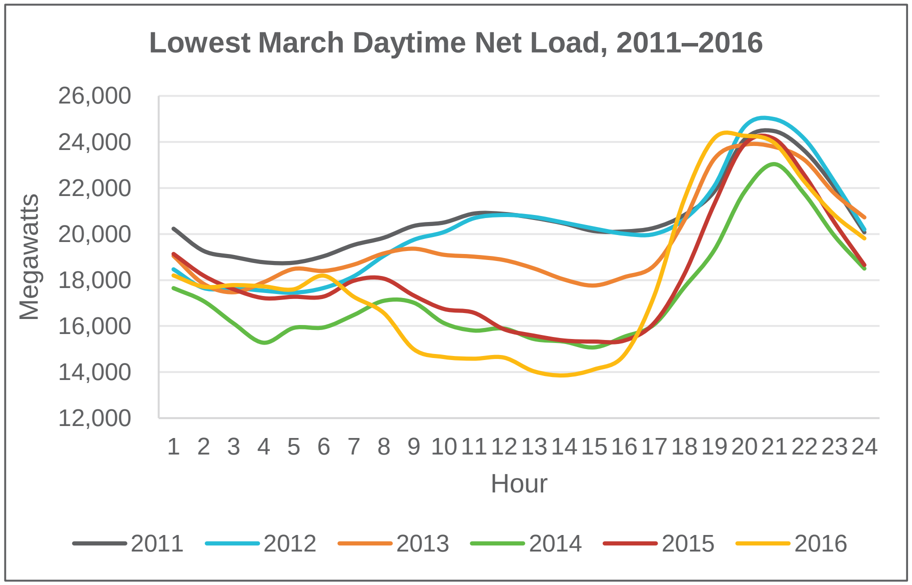
We found that the changing dynamics in California have led to higher costs and lower total net generation for California's CCs.

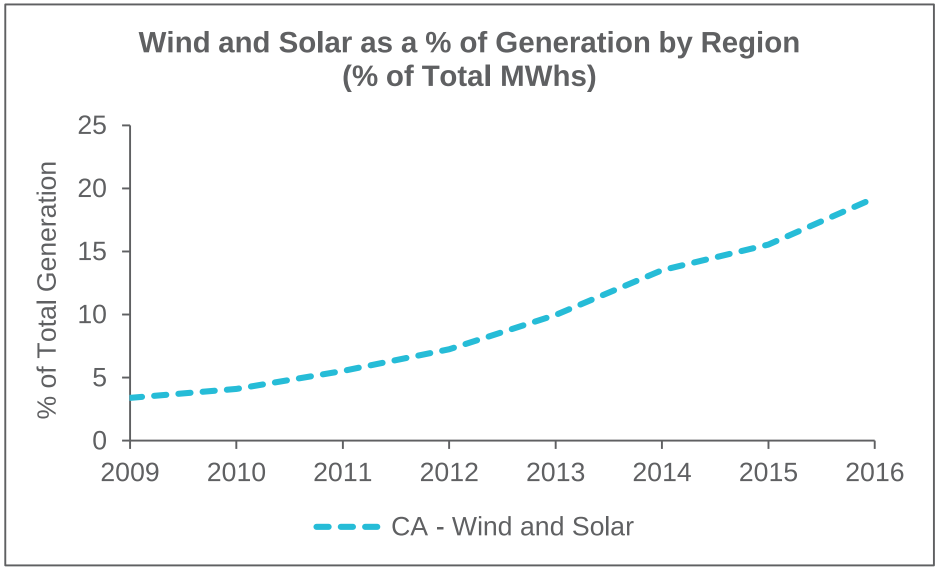
scottmadden MANAGEMENT CONSULTANTS

The California Duck Curve Is Real and Bigger than Expected

CAISO performed a detailed analysis to understand changing grid conditions. Its analysis showed that the net load, which is the load served by the electric system minus the load served by variable generation, will drop mid-day and quickly ramp to a late-day peak. This analysis resulted in the iconic "duck curve" chart

- Increasing penetration of renewable resources (primarily utility-scale solar) produces the iconic duck curve, indicating that as variable generation grows so too will the trough of load served by conventional supply in mid-day. The actual data confirms the prediction and shows it to have been conservative
- The CC plants examined in this analysis support the steep ramps, which occur when the system operator must rapidly bring on or shut down generation resources to meet increasing or decreasing electricity demand
- The difference between minimum and maximum net load has become more severe each year, and forecasts suggest this will continue





As the build-out of renewables is outpacing some of the most aggressive expectations in some power markets, particularly California, planners and grid operators are expressing more urgent concerns about resource availability to support ramping needs to maintain grid stability

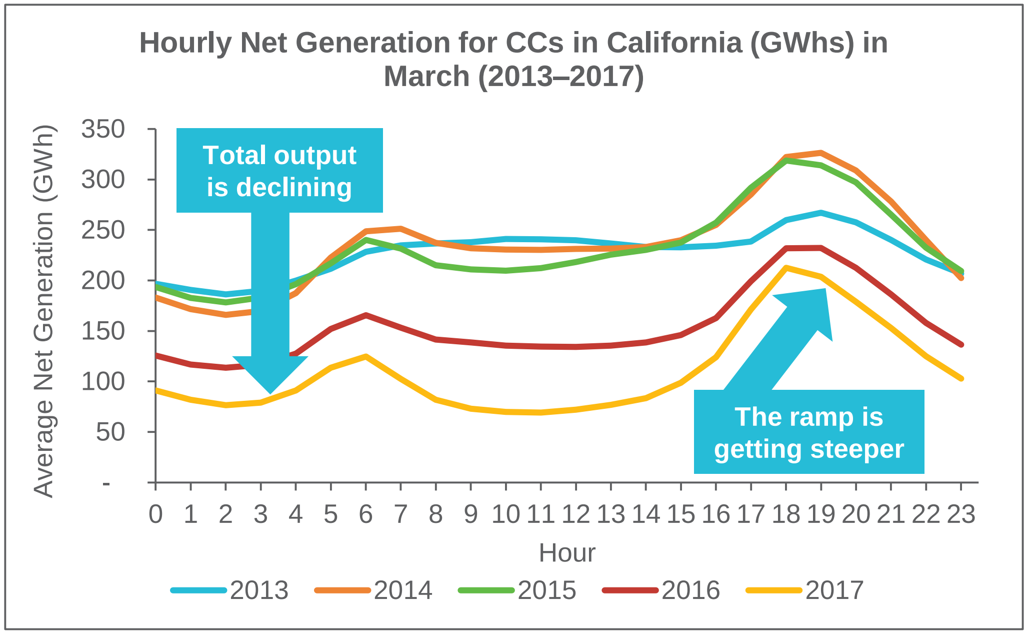
- A monotonic rise in renewables in California: Renewable growth in California is not rising and falling in fits and starts, it is growing steadily
- The build-out of renewables is expected to continue as states continue to solicit renewables
- Grid reliability will become an issue when intermittent resources become a sufficiently large portion of the generation assets, according to NERC

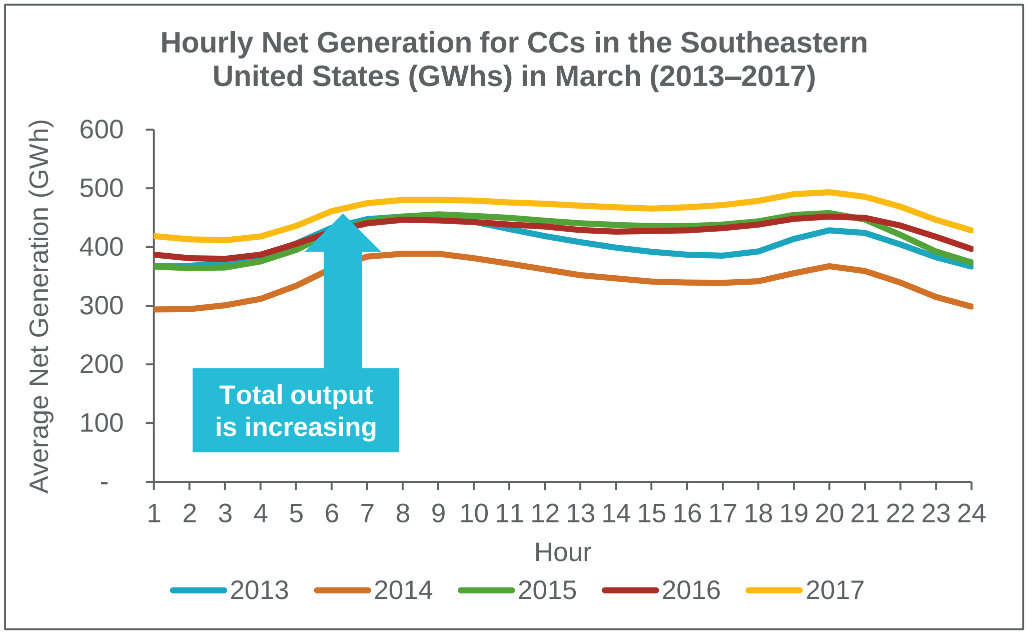
Introduction

Evidence of Cycling Becoming More Severe in California

The steady increase in renewable penetration in California may be driving the increase in NFOM costs for California's CCs

- The duck curve in California is supported by CC plants, which are flexible enough to ramp swiftly and provide enough capacity to fulfill the generation demand (i.e., combustion turbines are typically smaller and don't provide enough generation)
- The afternoon/evening ramp has become steeper, increasing the wear on plants
  - The graph on the bottom left shows that CC plants in California are generating less, but they are required to increase their generation more quickly than in years past
- The graph on the bottom right demonstrates a starkly different situation in the southeastern United States, where penetration of renewables is lower
  - CCs in the Southeast are running more in recent years, suggesting these units are being used more for baseload operations
  - Unlike California, in the Southeast, CCs are not needed to increase generation dramatically in the late afternoon hours





Note: Two NERC sub-regions (SOU and VACAR) were used as a proxy for the southeastern United States.
Sources: EPA CEMS data, ScottMadden analysis

scottmadden
MANAGEMENT CONSULTANTS

Initial Findings: Capacity Factor Is Flat to Declining

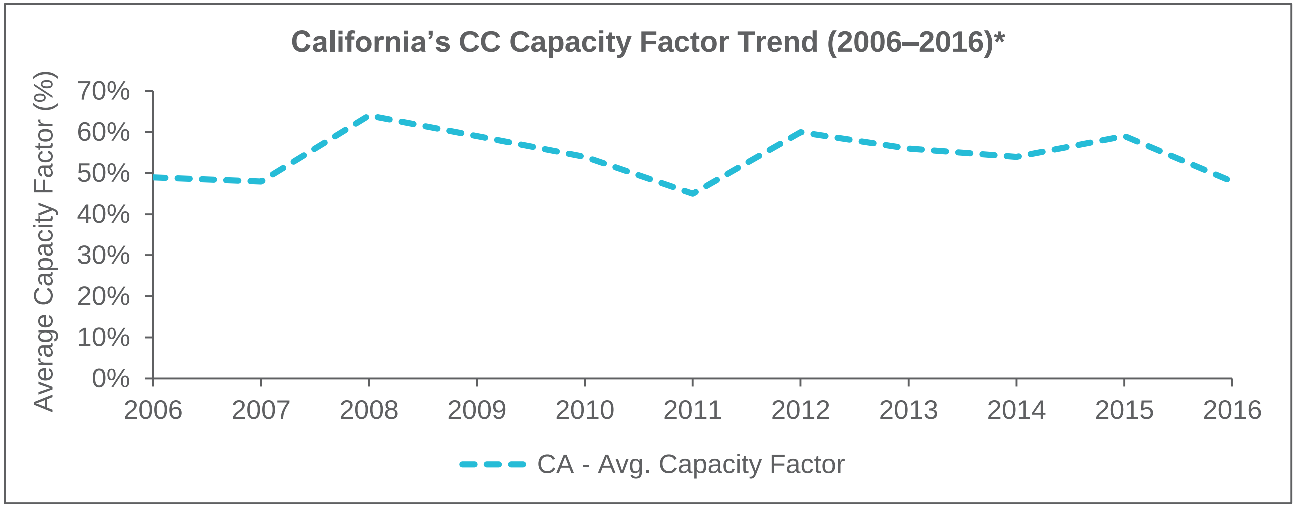
Question #1: Are California's CCs running more and more often to support the duck curve year round?

What we expected to find:

- An increase in California's plants capacity factors:
  - There was an increase in gas generation across the board as gas prices dropped
  - Severe drought prior to 2016–2017 could have reduced the generation from hydro plants (explored in depth later)

What we found:

- There was no increase in California's plants capacity factors (in fact, they have been flat since 2012, declining year-over-year from 2015 to 2016, perhaps due to an uptick in hydro)
- CC plants may be starting more, but they are running less overall
- California's CC plants are generating less, but ramping faster



**Outliers removed to ensure data integrity.*

Capacity factor for California's CCs has been flat since 2012, and it has declined year-over-year from 2015–2016.

Sources: FERC Form 1, SNL Financial, ScottMadden analysis

scottmadden MANAGEMENT CONSULTANTS

Initial Findings: California's CC Costs Have Increased

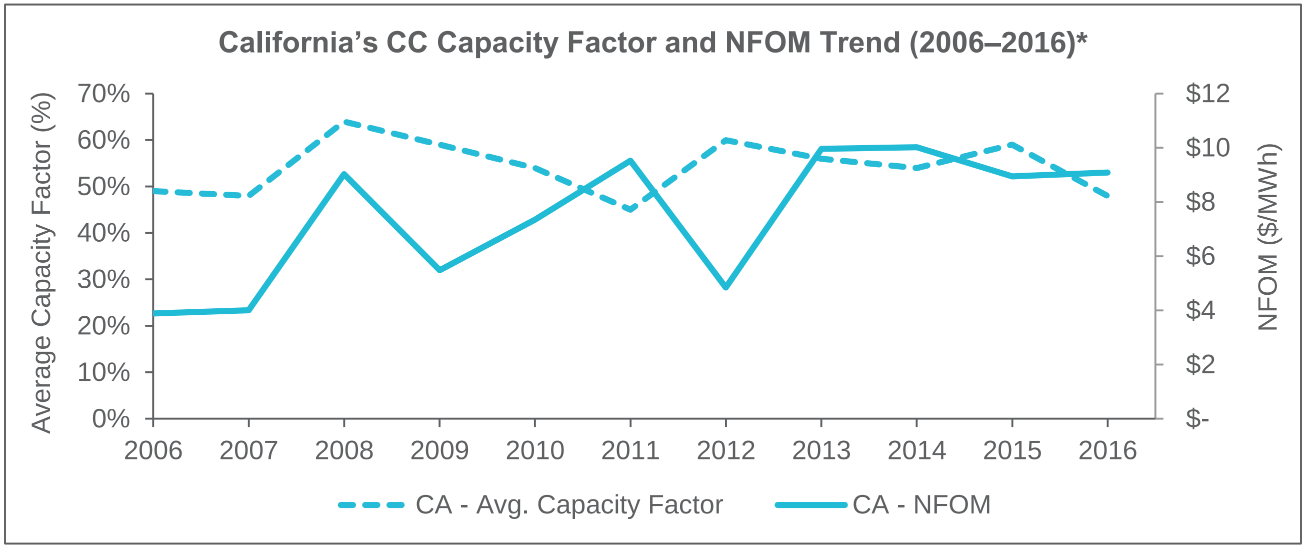
Question #2: Are California's CC NFOM costs increasing due to more hours of generating, more starts, and more ramping?

What we expected to find:

- An increase in California's CC NFOM costs:
  - An increase in the number of starts and stops could cause more wear and tear on the units
  - A less sustained generation may reduce the total generation

What we found:

- There was an increase in NFOM/MWh in California's plants despite the flat average capacity factor
- Since the typical pattern is for NFOM per MWh to remain constant with relatively flat average capacity factor, this would strongly suggest that cycling is increasing these costs



**Outliers removed to ensure data integrity.*

Costs are all real, depicted in 2016 dollars.

NFOM costs for California's CCs have increased in the past decade.

Sources: FERC Form 1, SNL Financial, ScottMadden analysis

scottmadden MANAGEMENT CONSULTANTS

Initial Findings: Comparable CC Costs Have Decreased

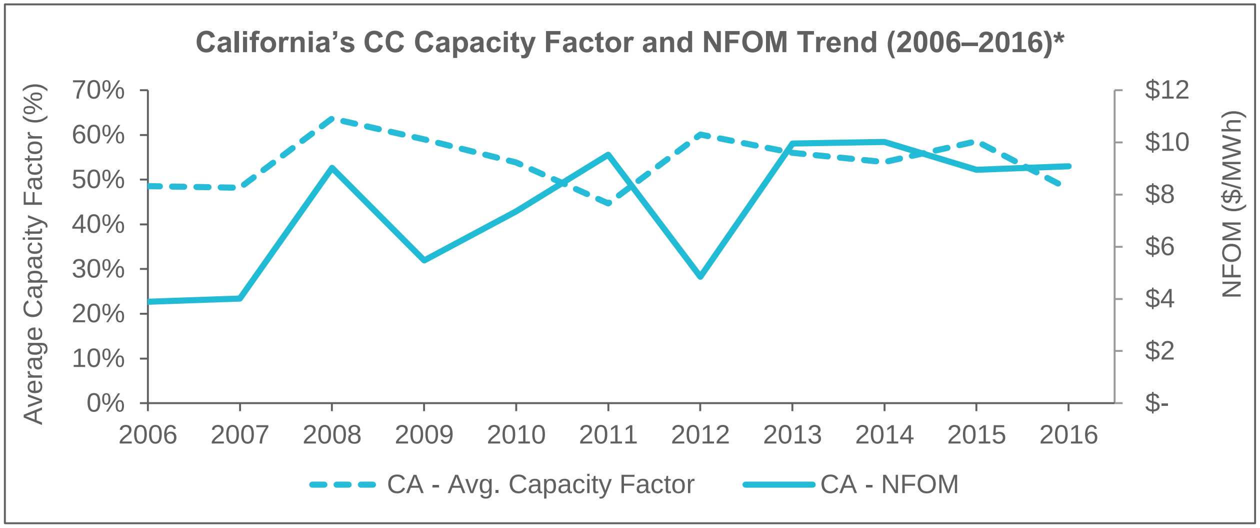
Question #3: How do NFOM cost trends for CCs in California compare to trends elsewhere in the United States, where renewable penetration levels are lower?

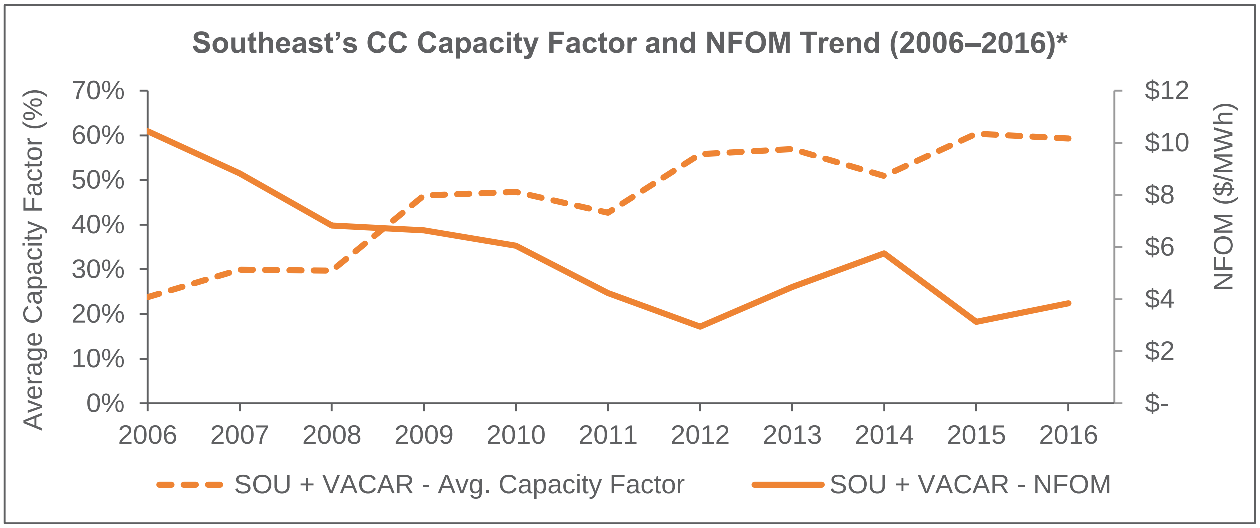
What we expected to find:

- In the Southeast, we expected to find an increase in CC plants capacity factors:
  - There is an increasing reliance on gas-fired generation capacity in the region due to decreasing gas prices and retirement of coal-fired capacity
- In the Southeast, we found a decrease in CC NFOM per MWh:
  - An increase in capacity factors means a larger denominator for per unit costs to be divided into (NFOM/MWh)
  - Plants may increasingly be running as baseload, which allows operators to plan maintenance and outages more effectively

What we found:

- We found exactly what we expected to find:
  - Comparable CCs in the southeastern United States experienced markedly higher output over the past 10 years.
  - Costs at comparable CC plants in a region with less renewable penetration have declined significantly over the past 10 years





**Outliers removed to ensure data integrity.*

Costs are all real, depicted in 2016 dollars.

Sources: FERC Form 1, SNL Financial, ScottMadden analysis

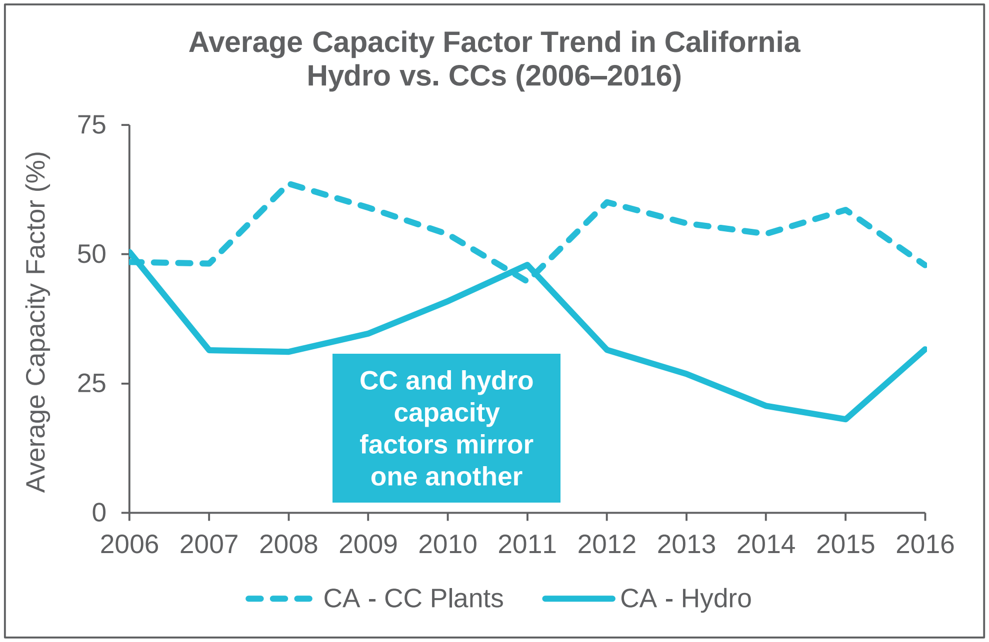
Costs for comparable plants in the southeastern United States have declined.

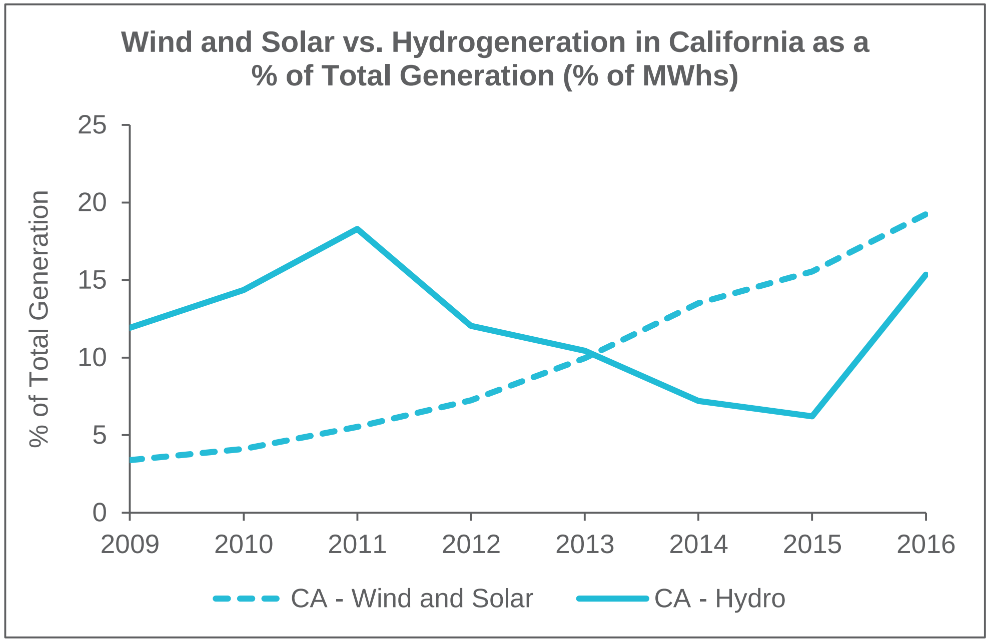
scottmadden
MANAGEMENT CONSULTANTS

What About the Impact of Hydropower in California?

Cheap hydropower from the northwestern United States may be displacing power from CCs in California—when it is available

- Hydro output could explain some capacity factor fluctuations, particularly as hydro generation in the northwestern United States has a tendency to displace other incumbent generation capacity, particularly in northern California
- California's CC plants and hydro capacity factors appear to be almost perfectly negatively correlated (see bottom left)
  - A drought in California from 2001–2015 led to a decline in hydro capacity factor and an increase in CC plants capacity factor
  - Those trends reversed in 2016, reflecting the wet winter and the corresponding availability of additional hydro power in 2016
- Hydro penetration as a percentage of total generation appears to be a function of availability compared to the consistent increase in other renewables, which have enjoyed generous policy support in California (see bottom right)





Sources: FERC Form 1, SNL Financial, ScottMadden analysis

Potential Takeaways and Considerations

These dynamics may be coming to a jurisdiction near you

- Renewable capacity has been steadily increasing in the United States, and regions which have seen, or are expected to see, a significant increase in solar and wind capacity may want to examine the potential cost and operational impacts on CCs
  - Future duck curve sightings may well occur sooner than expected in states with growing utility-scale solar and wind, such as Arizona, Georgia, Nevada, North Carolina, and Texas
  - Understanding the root cause and comprehensive impact of the duck curve is essential before developing strategies to address operational impacts on the rest of the generation fleet
- This could lead to significant changes in the cost profiles of CC fleets in other regions, and operators may need to fundamentally rethink how their fleets are operated
- CC operators everywhere need to be anticipating these dynamics and seeking opportunities to:
  - Implement strong asset **management** programs
  - Manage their generation fleets more efficiently

Other potential implications:

- **Grid modernization** initiatives and **demand side management** options may provide part of the solution in California and other regions with higher renewables if they enable or provide rapid capacity in response to the ramping needs in the late afternoon and evening
- Transmission and increasing regionalization (e.g., expansion of the **Energy Imbalance Market** in the West) could have huge implications for operating and balancing additional variable generation on the system while maintaining reliability
  - Additional regionalization efforts are being considered and evaluated throughout the United States
  - Importing and exporting power with neighboring systems may provide the ability to reduce curtailments when excess renewable generation is available and to reduce ramping when additional capacity is needed
  - System operators may need to rethink how inter-regional and intra-regional power flows and tie lines are managed

scottmadden
MANAGEMENT CONSULTANTS

Contact Us

Todd Williams

Partner

ScottMadden, Inc.
3495 Piedmont Road
Building 10, Suite 805
Atlanta, GA 30305
toddwilliams@scottmadden.com
O: 404-814-0020 M: 678-644-9665

scottmadden
MANAGEMENT CONSULTANTS

Smart. Focused. Done Right.

Quentin Watkins

Manager

ScottMadden, Inc.
2626 Glenwood Avenue
Suite 480
Raleigh, NC 27608
quentinwatkins@scottmadden.com
O: 919-781-4191 M: 404-863-8410

scottmadden
MANAGEMENT CONSULTANTS

Smart. Focused. Done Right.

scottmadden
MANAGEMENT CONSULTANTS

Appendix

Methodology

Peer Groups

- We developed a peer group of comparable CC plants in California and other regions for examination
  - California peer group:
    - We began with a list of all gas-fired CCs located in California, and we applied the following filters:
      - Regulated plants only (only rate-base, cost-of-service plants)
      - Capacity greater than 100 MWs
      - Removed co-generators
    - A peer group was identified using different NERC region/sub-region data
  - Comparable peer group from the southeastern United States:
    - We explored several potential options for peer groups, with the goal of identifying 15–20 comparable plants operating in markets which provided a contrast with California
    - Using the same filters used for the California plants, we identified a group of peer plants located in two contiguous NERC sub-regions in the southeastern United States—SOU and VACAR (Southeastern and Virginia and Carolinas)—to provide a basis of comparison

Data and Calculations

- Using data from publicly available filings (FERC and EIA), we assembled NFOM cost data, net generation, and capacity factor for each plant from 2006 to 2016
- NFOM cost was calculated on a per-MWh basis for each plant
- Finally, in order to provide a more precise understanding of renewable penetration trends, we collected data on renewable generation as a percentage of total regional generation for the two peer groups

*Outliers Removed

- Outlying NFOM values were removed from the sample
  - Values larger than the sample mean plus the standard deviation were removed

Regional Comparison

	California's CC Plants	SOU + VACAR CC Plants
# of Plants	11	18
Avg. MW	451	922
Avg. Year First Unit in Service	2003	2004
Avg. Year Latest Capacity Added	2007	2006

Note: After outliers removed

Additional Findings: Merchant CC Costs Follow Trend

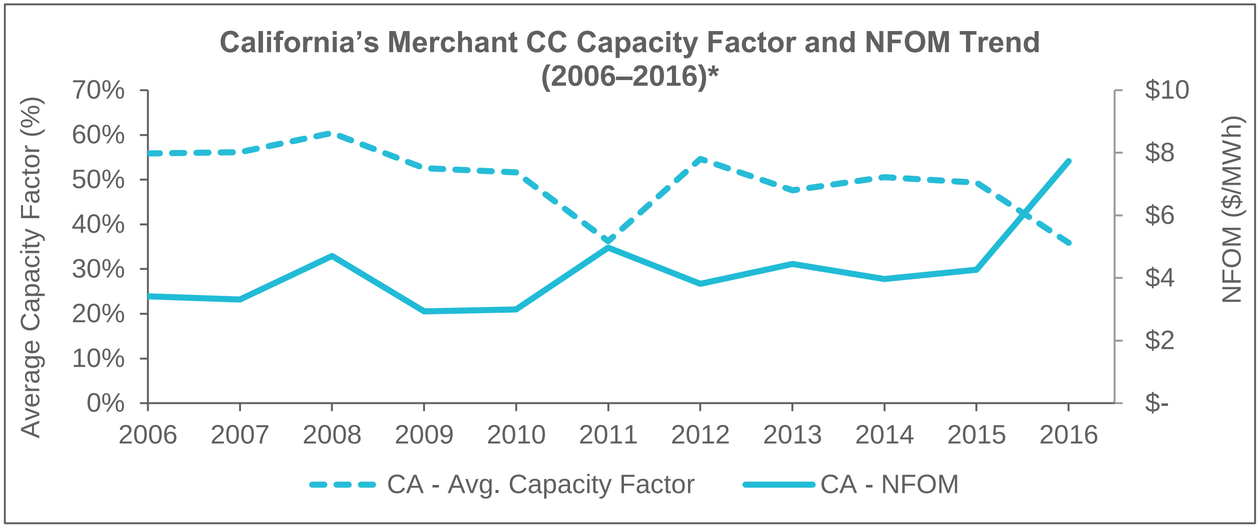
Question #3 (Cont'd): Do cost trends for CCs hold for merchant plants?

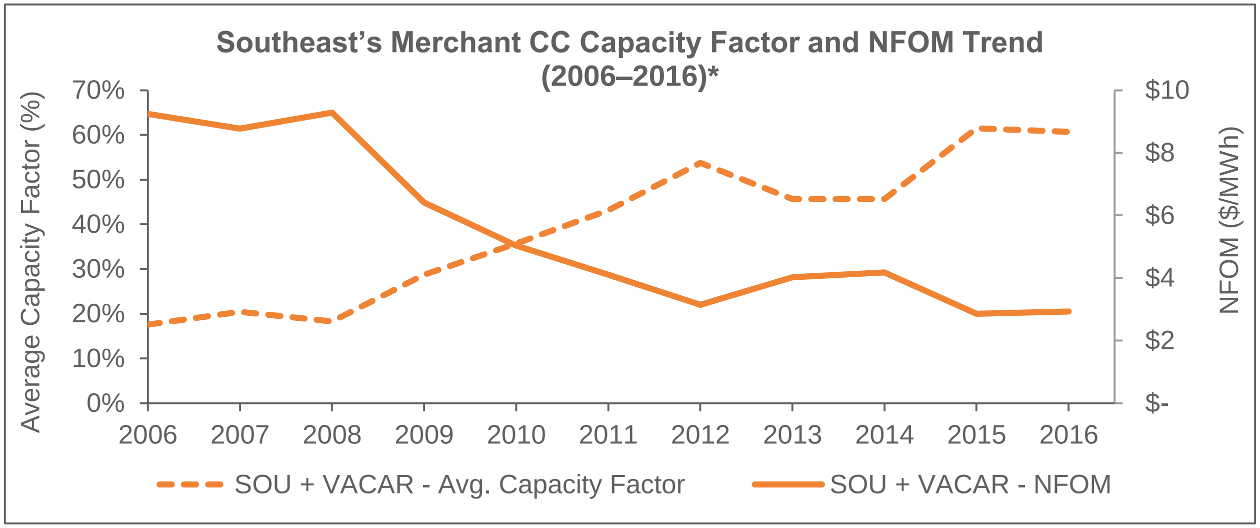
What we expected to find:

- In California, we expected to find an increase in merchant CC plants NFOM costs
  - An increase in the number of starts and stops could cause more wear and tear on the units
- In the Southeast, we expected to find a decrease in merchant CC NFOM costs
  - An increase in capacity factors means a larger denominator for per unit costs to be divided into (NFOM/MWh)
  - Plants may increasingly be running as baseload, which allows operators to plan maintenance and outages more effectively

What we found:

- We found exactly what we expected to find:
  - Merchant CCs in California experienced a rise in NFOM costs since 2006
  - Costs at merchant CC plants in the Southeast have declined significantly over the past 10 years





**Outliers removed to ensure data integrity.*

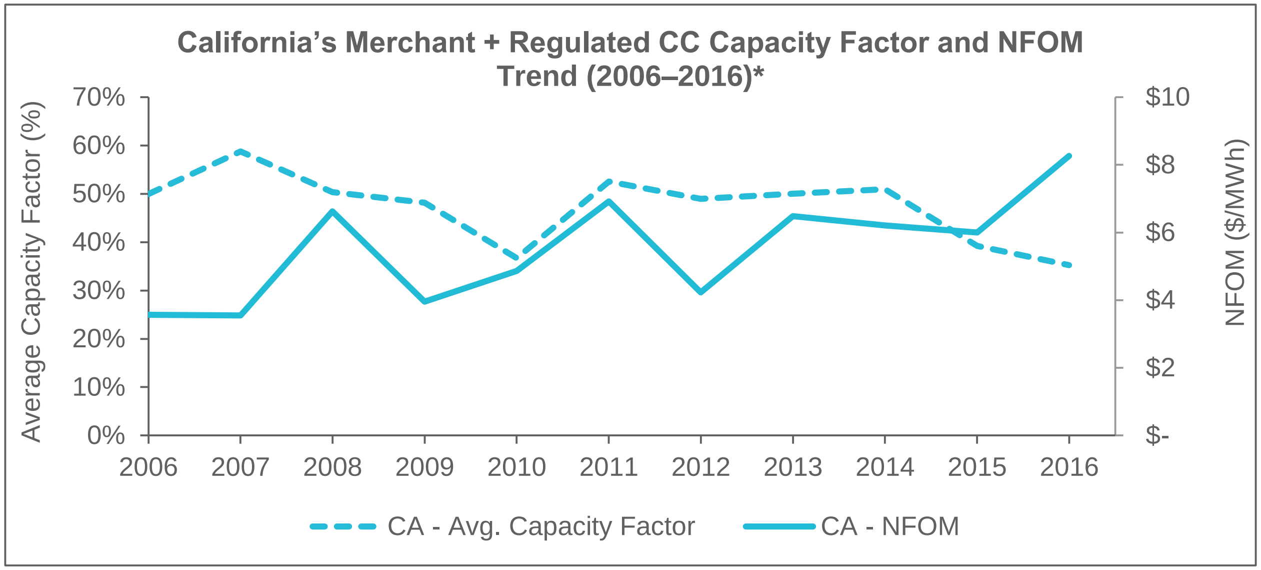
Costs are all real, depicted in 2016 dollars.

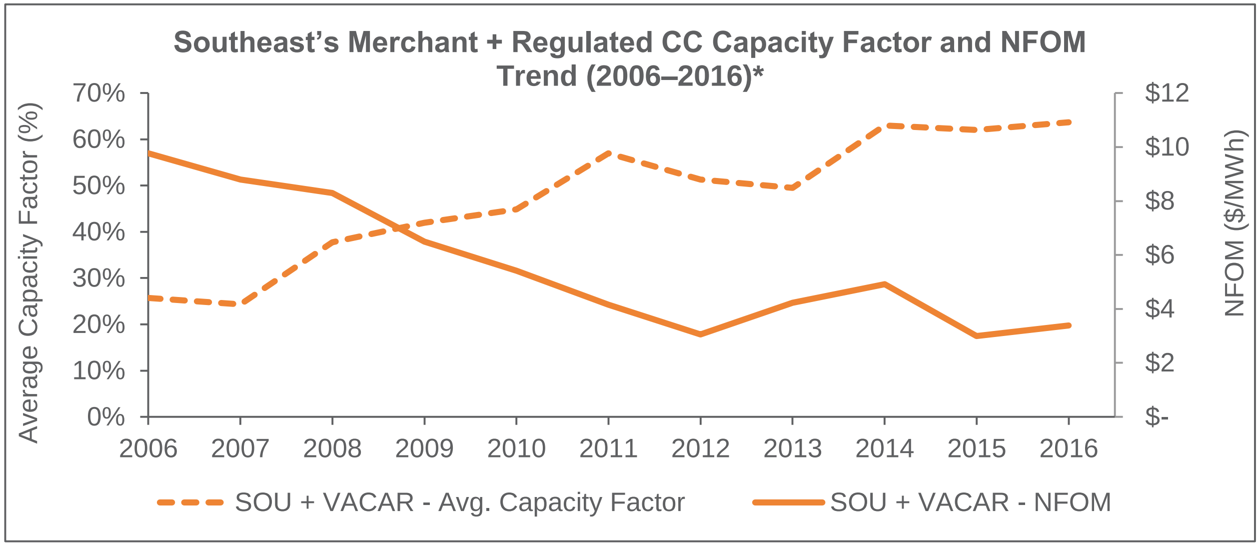
Costs for merchant plants follow the same trend as regulated plants.

Sources: FERC Form 1, SNL Financial, ScottMadden analysis

scottmadden MANAGEMENT CONSULTANTS

Additional Findings: Regulated + Merchant CC Costs





**Outliers removed to ensure data integrity.*

Costs are all real, depicted in 2016 dollars.

Sources: FERC Form 1, SNL Financial, ScottMadden analysis

scottmadden MANAGEMENT CONSULTANTS

Appendix

California Regulated CC Plant Details

Plant	Year in Service	Year Latest Capacity Added	Nameplate Capacity (MW)	NERC Sub-Region
Colusa CC (Maxwell)	2010	2010	668	CA
Cosumnes	2006	2006	535	CA
Desert Star Energy Center (El Dorado)	2000	2000	490	CA
Gateway Generating Station	2009	2009	586	CA
Magnolia Power Project	1984	2005	305	CA
Mountainview Power CC	2005	2006	1,066	CA
Palomar CC	2005	2006	570	CA
Redding CC	1989	2011	162	CA
Roseville Energy Park	2007	2007	162	CA
Scattergood Repowering CC	2015	2015	367	CA
Von Raefeld	2005	2005	154	CA

scottmadden
MANAGEMENT CONSULTANTS

Appendix

Peer CC Plant Details – SOU and VACAR NERC Sub-Regions

Plant	Year in Service	Year Latest Capacity Added	Nameplate Capacity (MW)	NERC Sub-Region
Barry CC	2000	2001	1,064	SOU
Jack McDonough CC	2011	2012	2,739	SOU
Lansing Smith CC	2002	2002	531	SOU
McIntosh Combined Cycle	2005	2005	1,302	SOU
Plant Ratcliffe (Kemper County CC)	2014	2014	824	SOU
Victor J. Daniel Jr. CC	2001	2001	1,085	SOU
Bear Garden	2011	2011	622	VACAR
Bellemeade Power Station	1997	1997	267	VACAR
Brunswick County Power Station	2016	2016	1,358	VACAR
Buck CC	2011	2011	697	VACAR
Chesterfield CC	1990	1992	495	VACAR
Dan River CC	2012	2012	706	VACAR
Jasper County	2004	2004	924	VACAR
L V Sutton CC	2013	2013	717	VACAR
Possum Point CC	2003	2003	615	VACAR
Sherwood H. Smith Jr. Energy Complex CC	2002	2001	1,227	VACAR
Urquhart CC	2002	2002	484	VACAR
Warren County Power Station	2014	2014	1,472	VACAR

scottmadden
MANAGEMENT CONSULTANTS