Load Forecast: Education on Model Drivers

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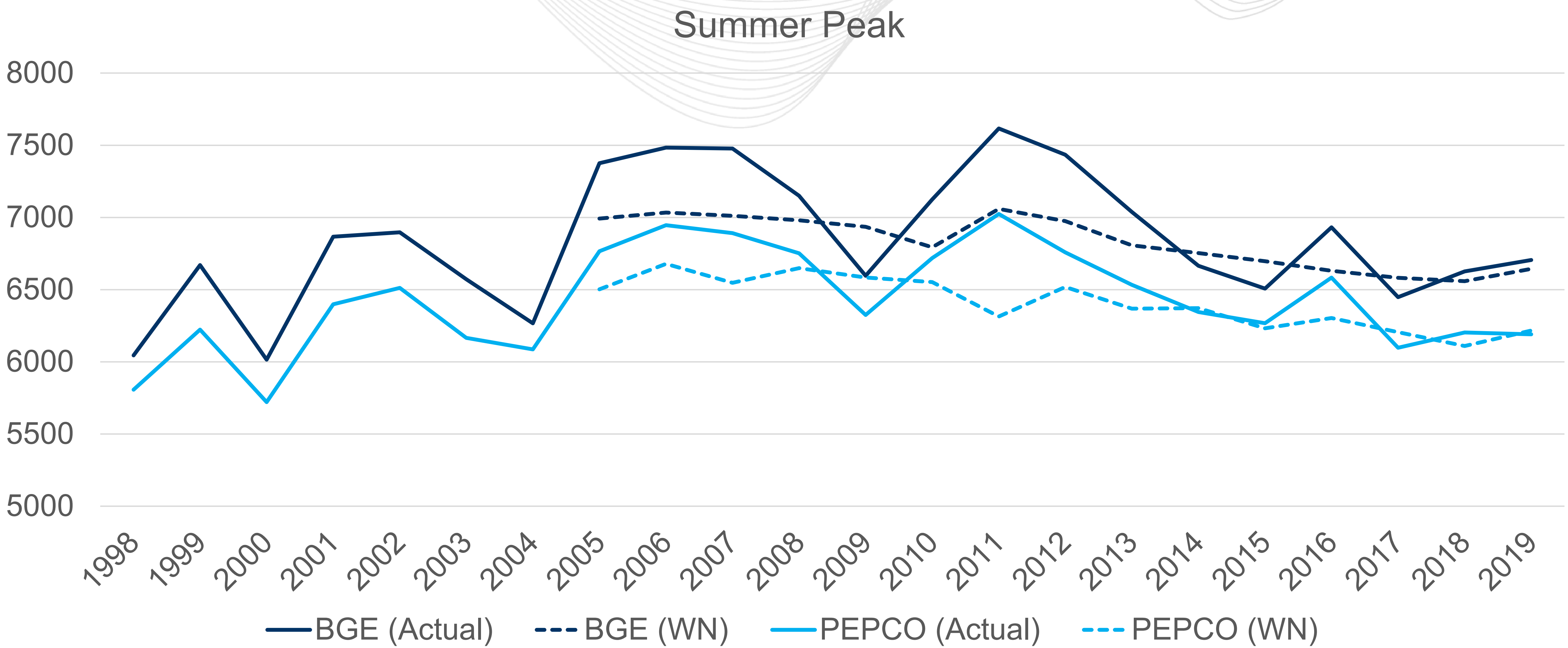
Resource Adequacy Planning

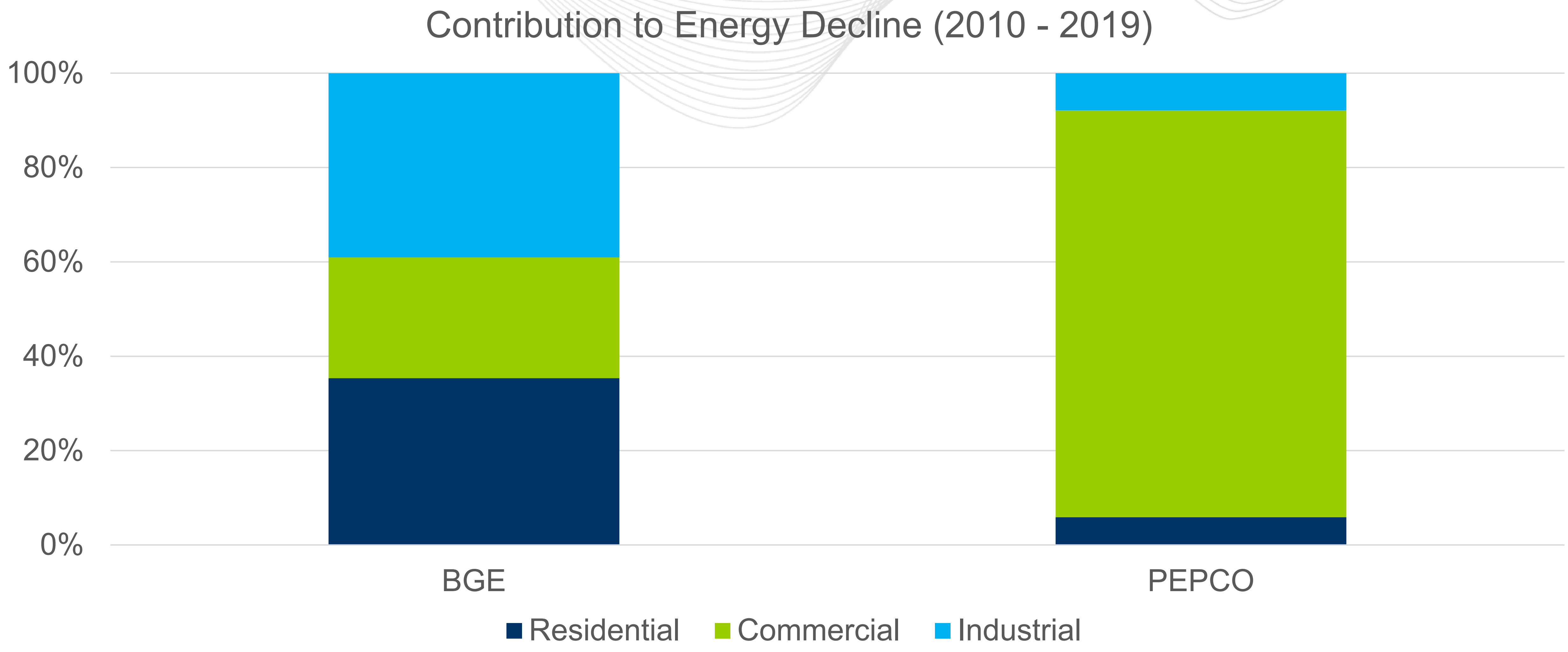
Load Analysis Subcommittee
October 22, 2020

- Why do we need sector models?
  - Looking at load trends can tell us what is happening. Sector models can give us greater insight into *why* things are happening.

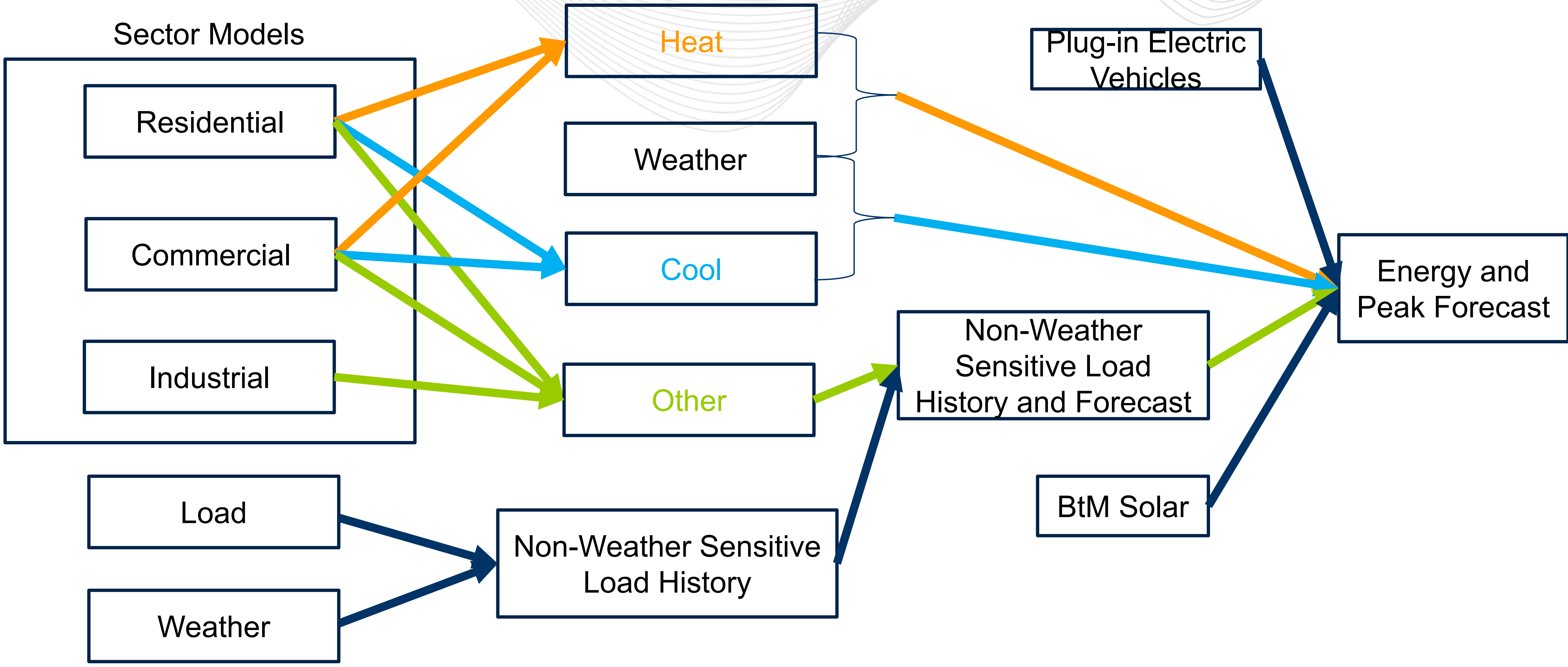
Example – BGE and PEPCO



Different Causes to Decline

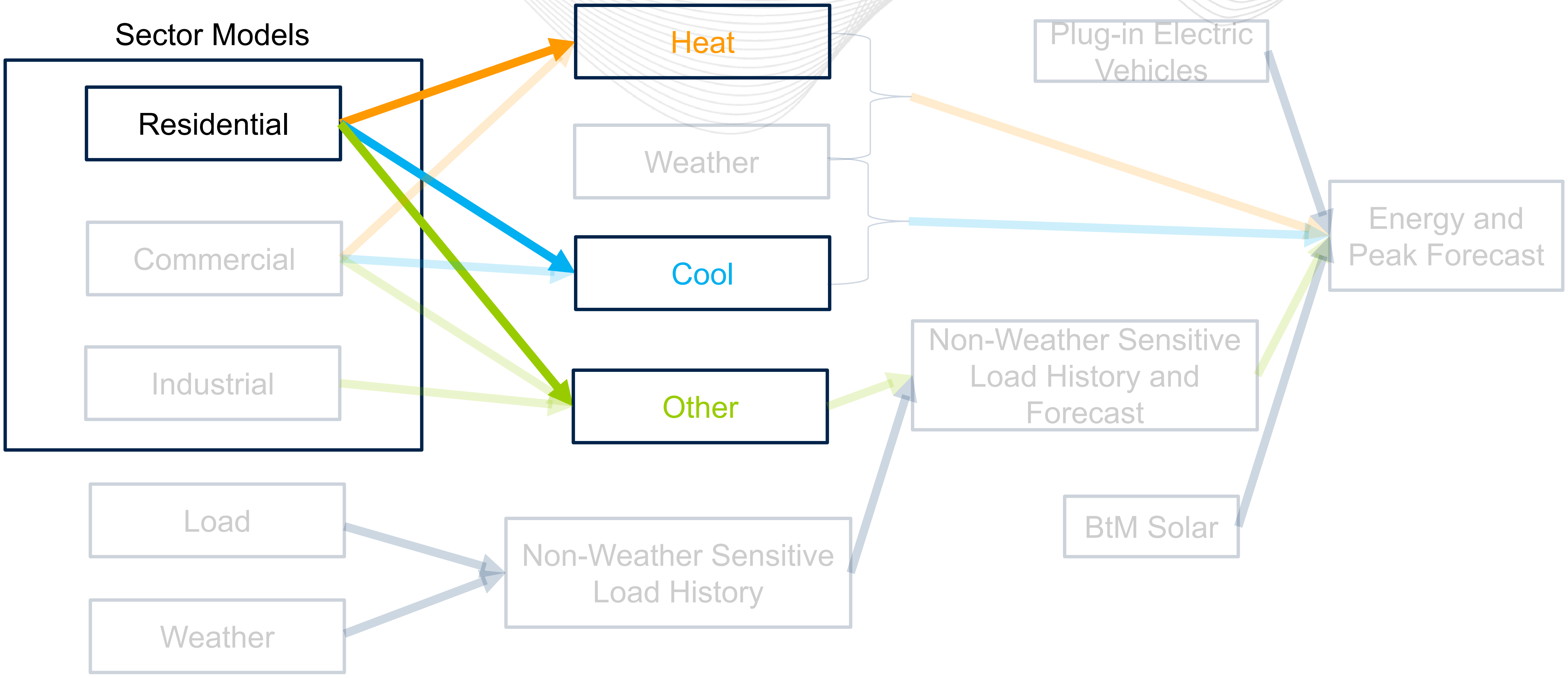


Load Forecast Model Flow

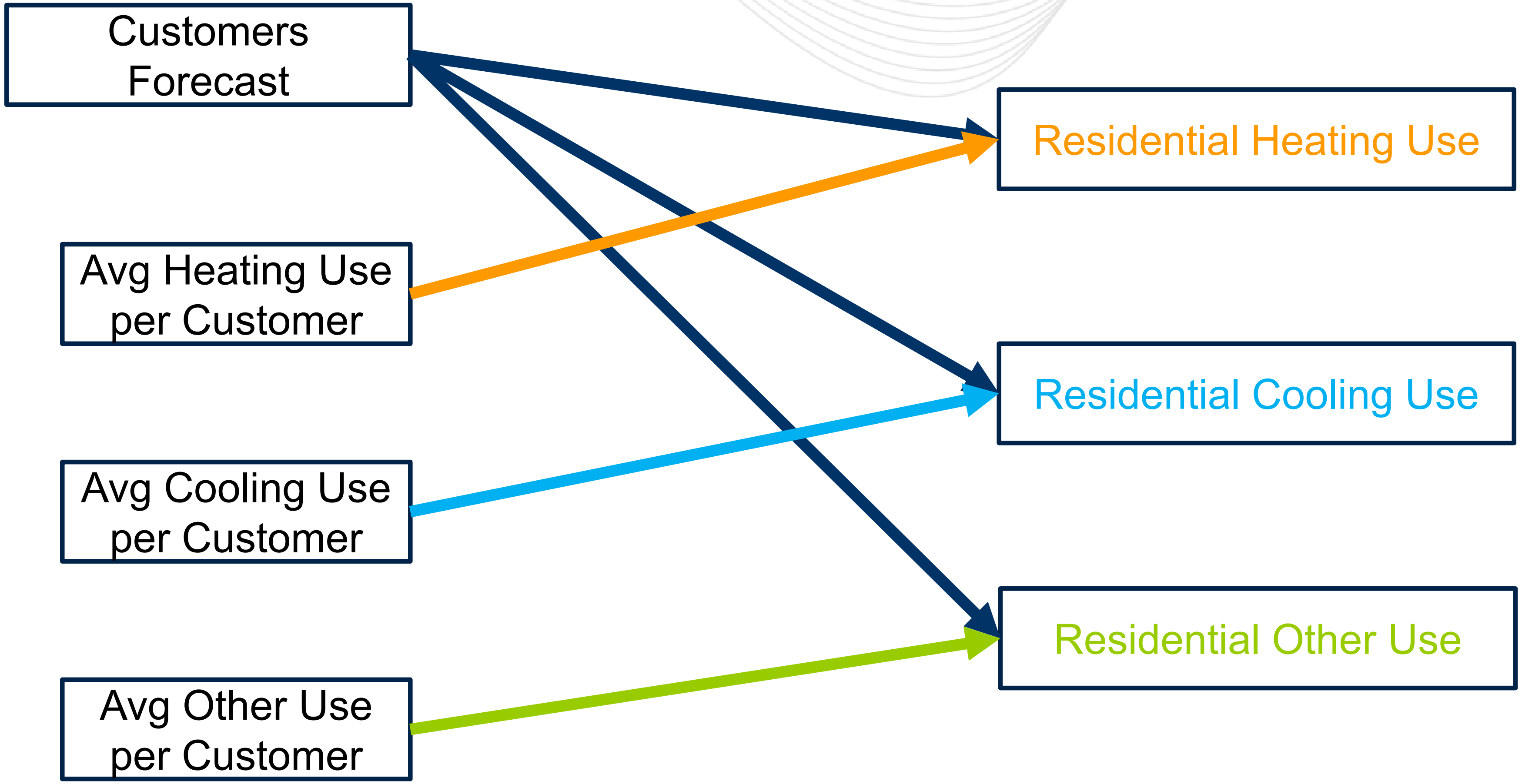


Residential Sector Focus

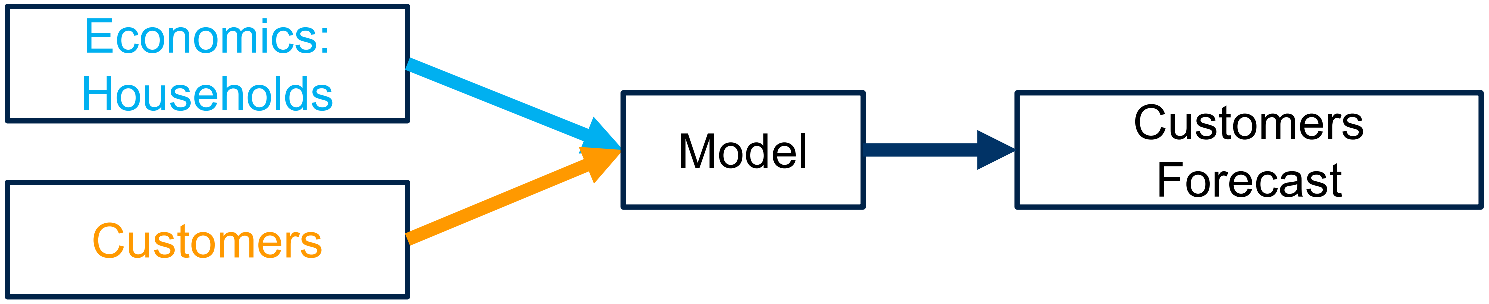
Residential Highlight



Residential Breakout – Category Use



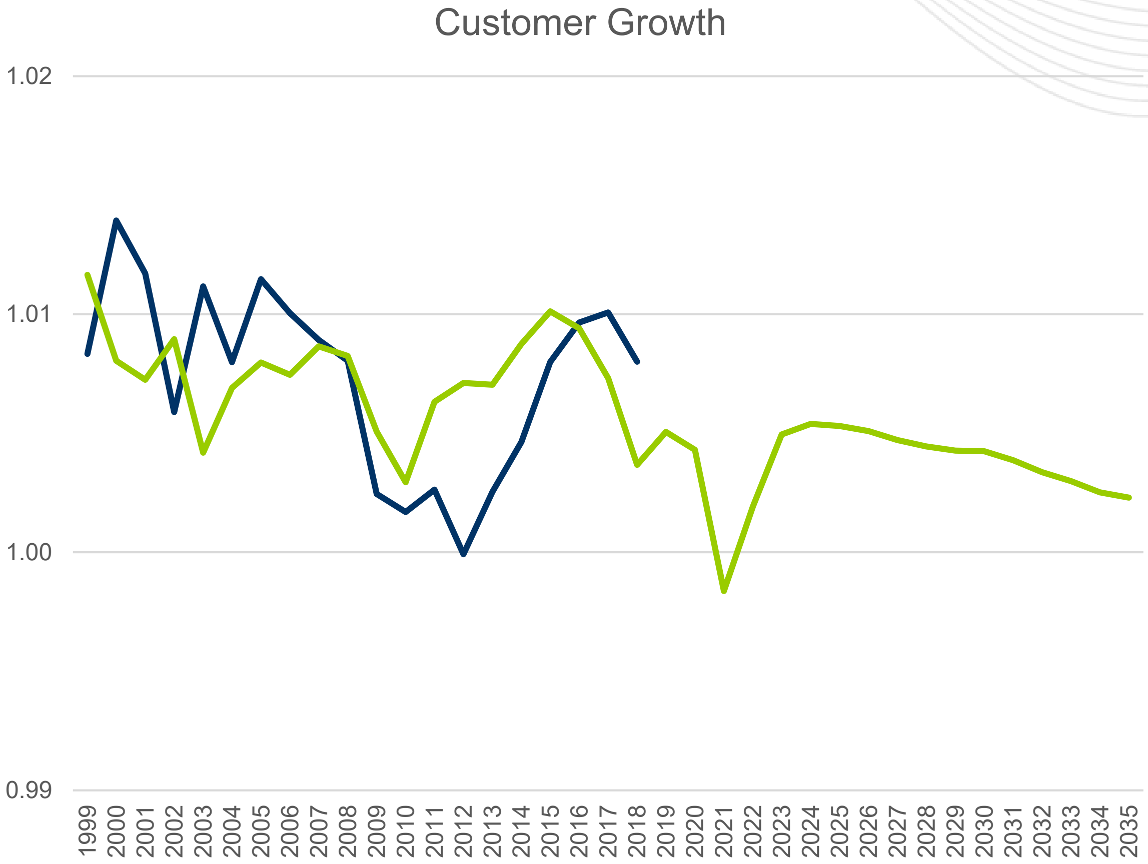
Residential Breakout - Customers

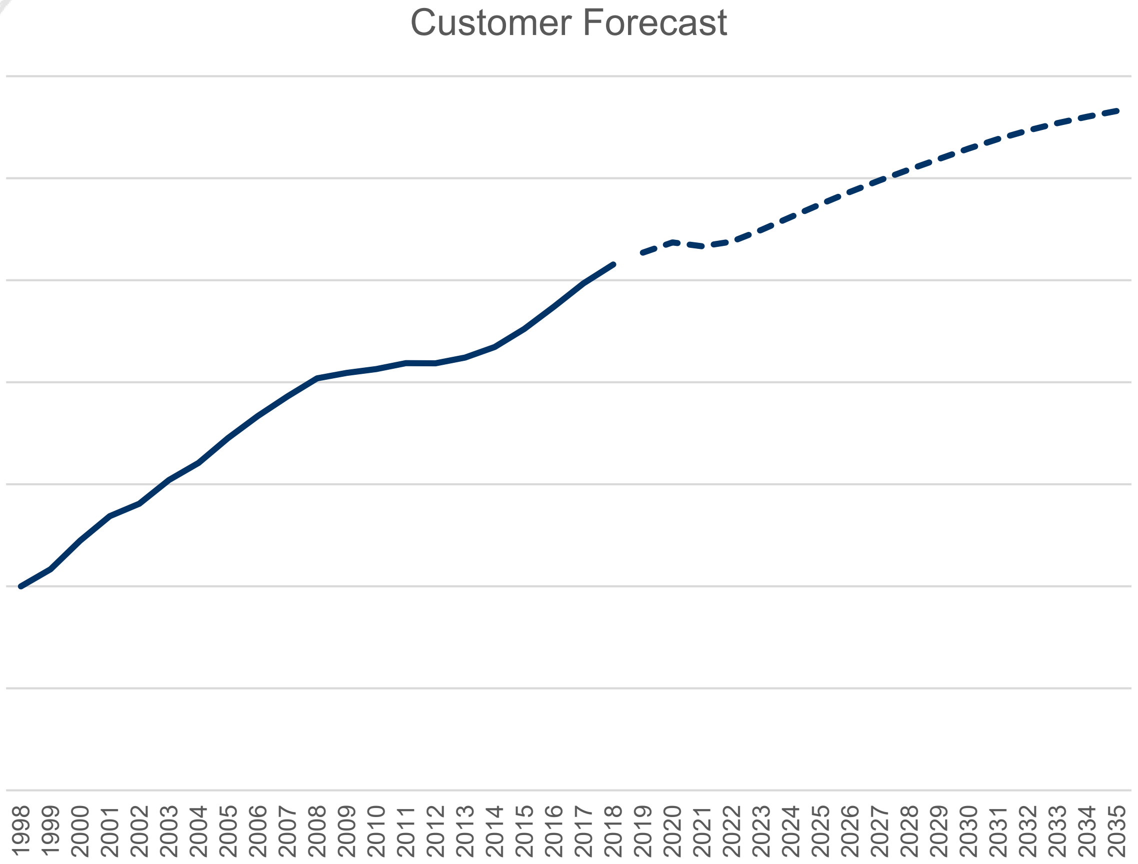


Residential Breakout - Customers

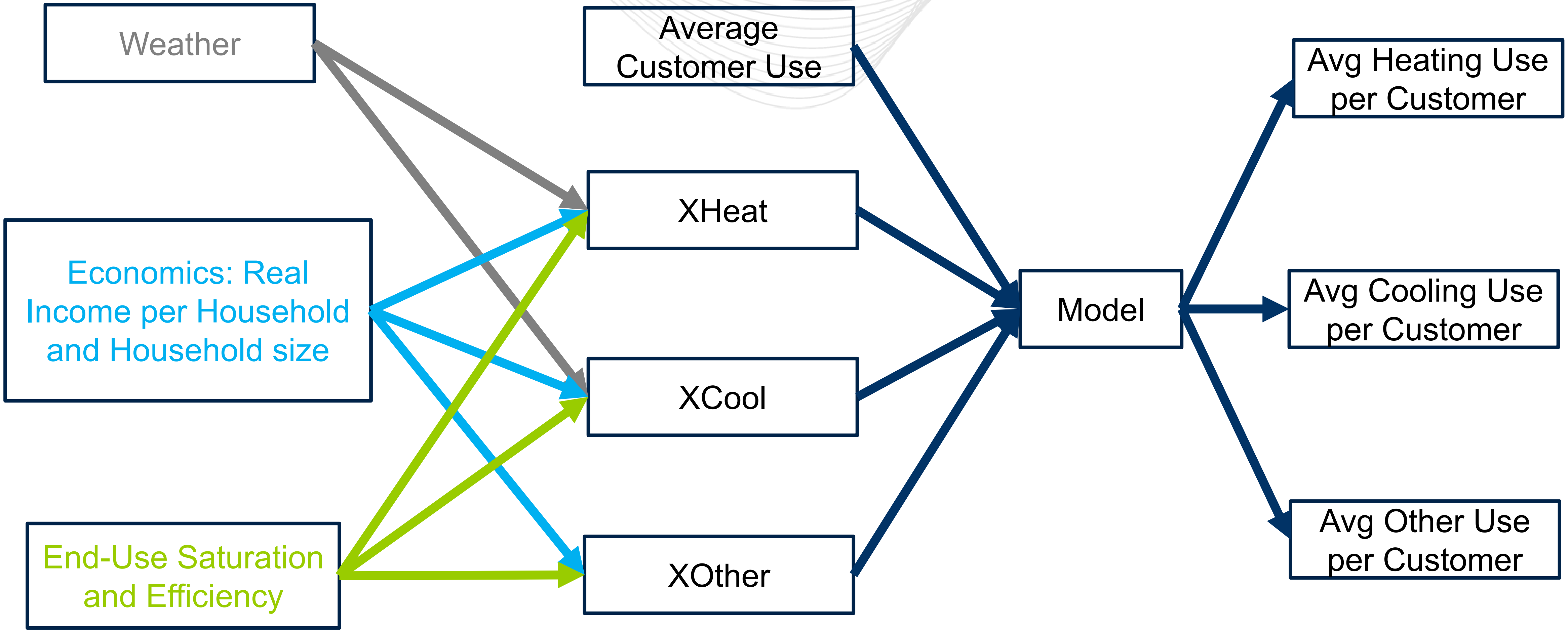
- diff_Cust = B1 * diff_HH + B2 * lag_diff_HH, where:
  - diff_cust is Customers[t]/Customers[t-1]
    - Source: EIA
  - diff_HH is Households[t]/Households[t-1]
    - Source: Moody's Analytics
  - lag_diff_HH is diff_HH[t-1]
    - Source: Moody's Analytics

Residential Breakout - Customers





Residential Breakout – Average Customer Use



Residential Breakout – Average Customer Use

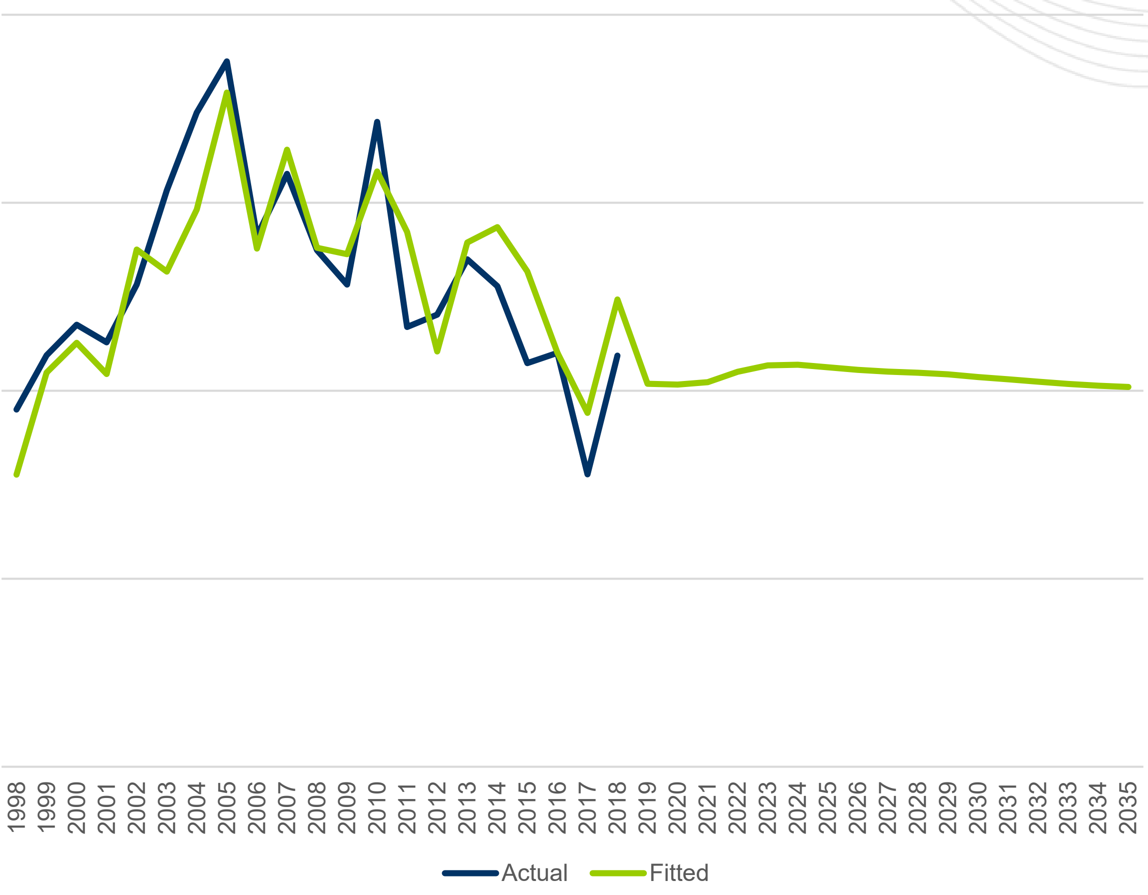
- r_use = B1 * xcool + B2 * xheat + B3 * xother, where:
  - r_use is average residential use per customer
    - Source: EIA
  - xcool is sae_cool * CDD_IN
    - sae_cool is the residential cooling equipment variable. Includes cooling equipment saturation/efficiency adjusted for economics.
    - CDD_IN is cooling degree days (1998=1.0)
    - Sources: EIA/Itron, Moody's Analytics

Residential Breakout – Average Customer Use

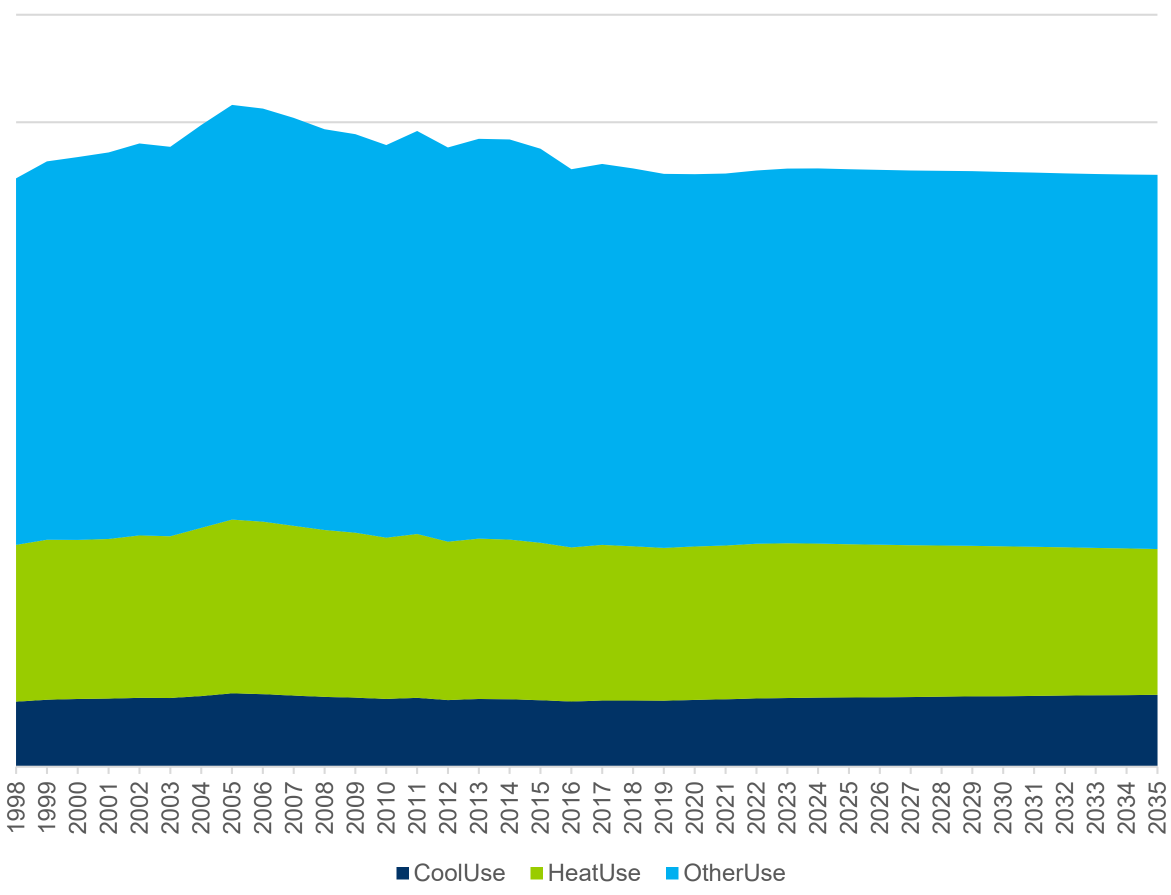
- r_use = B1 * xcool + B2 * xheat + B3 * xother, where:
    - xheat is sae_heat * HDD_IN
        - sae_heat is the residential heating equipment variable. Includes heating equipment saturation/efficiency adjusted for economics.
        - HDD_IN is heating degree days (1998=1.0)
        - Sources: EIA/Itron, Moody's Analytics
    - xother
        - Residential other equipment variable. Includes non-weather sensitive equipment saturation/efficiency adjusted for economics.
        - Sources: EIA/Itron, Moody's Analytics

Residential Breakout – Average Customer Use

Residential Avg Customer Use



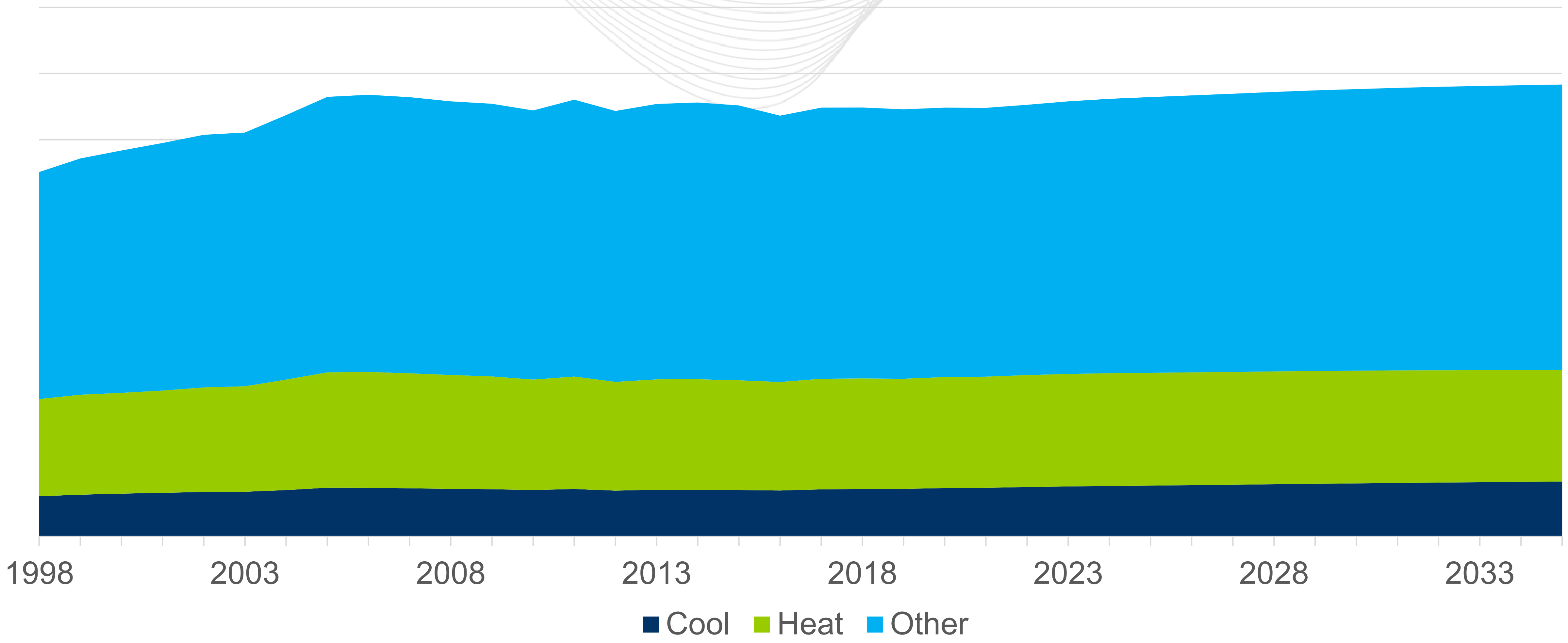
Residential Avg Cust Use by Type



Residential - Totals

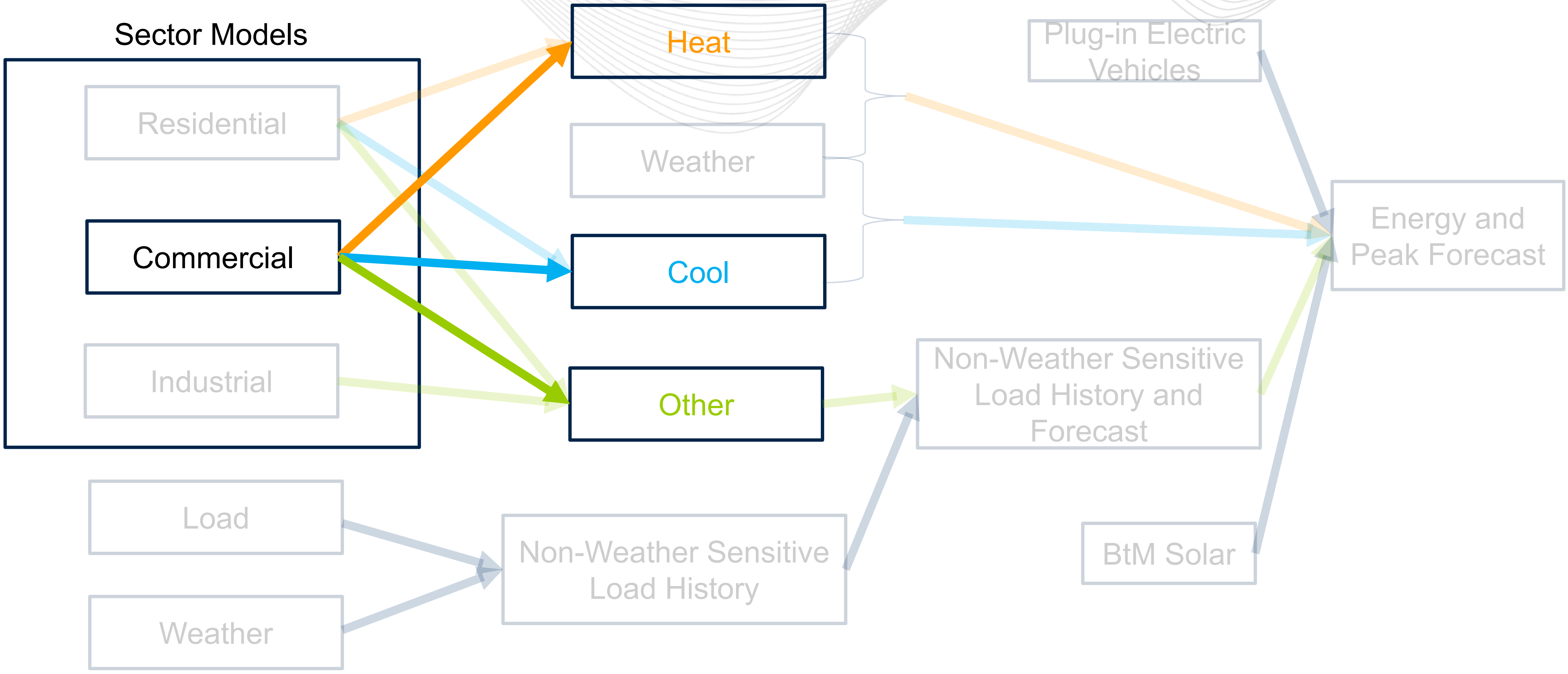
- Residential Cooling = Customers * CoolUse
- Residential Heating = Customers * HeatUse
- Residential Other = Customers * OtherUse

Residential Total Use



Commercial Sector Focus

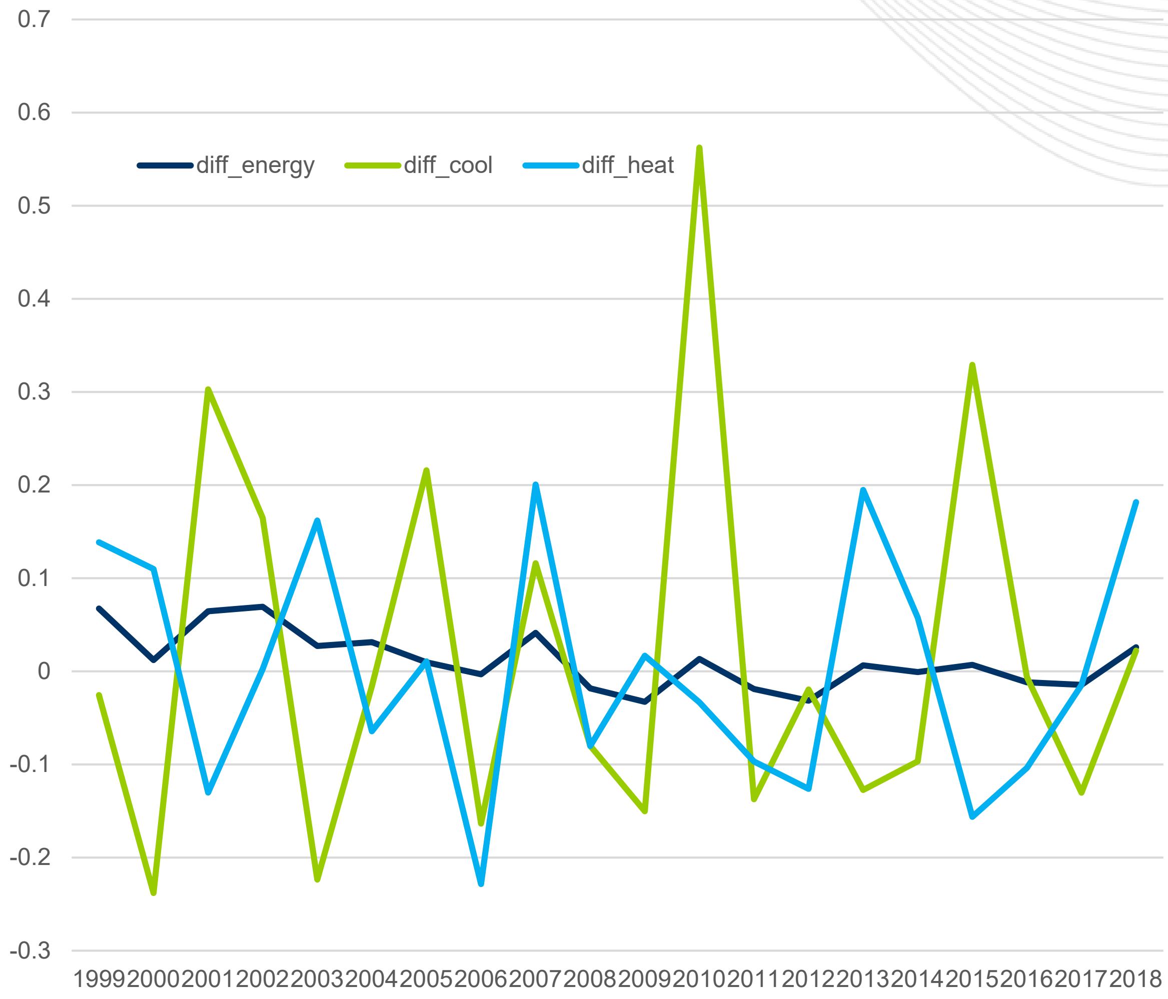
Commercial Highlight

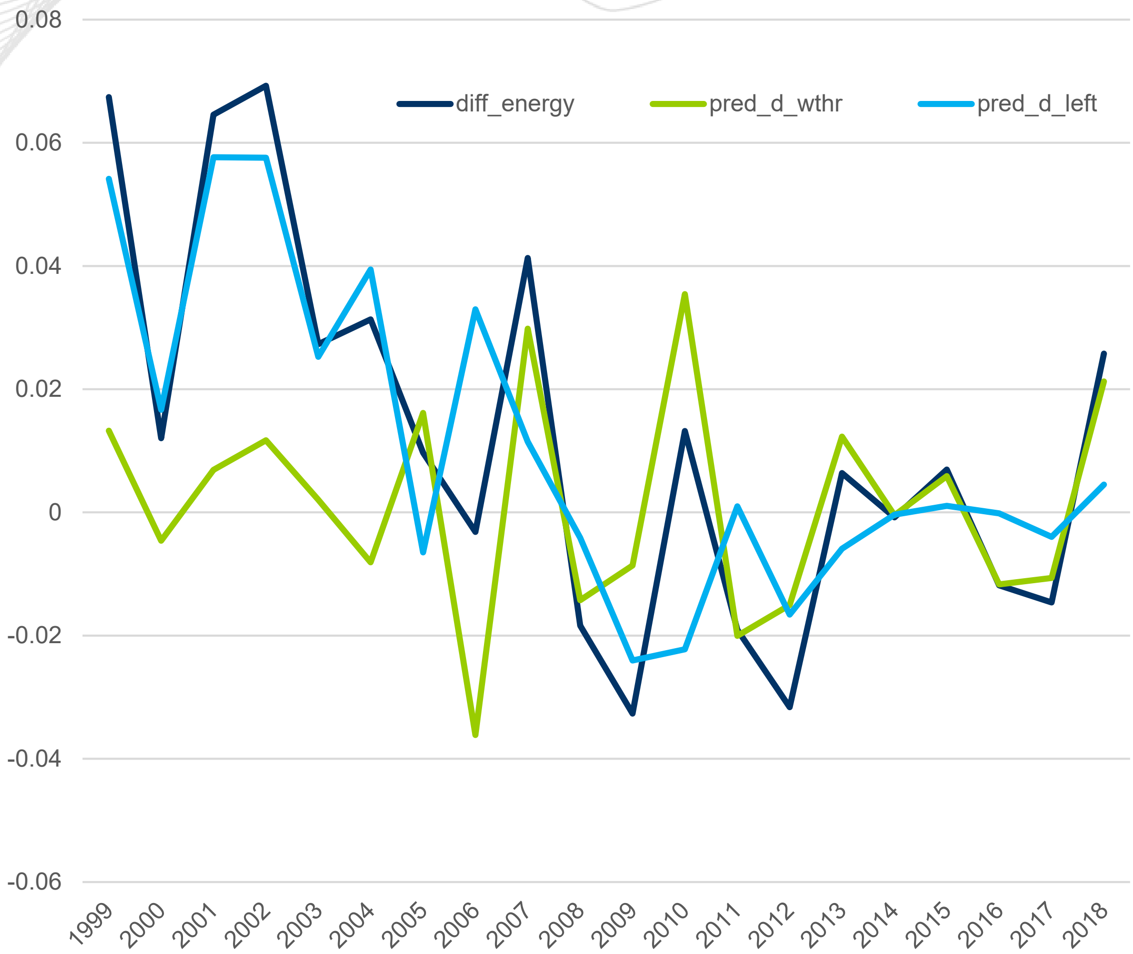


- First we seek to remove the year-to-year weather impacts to get at the underlying trend.

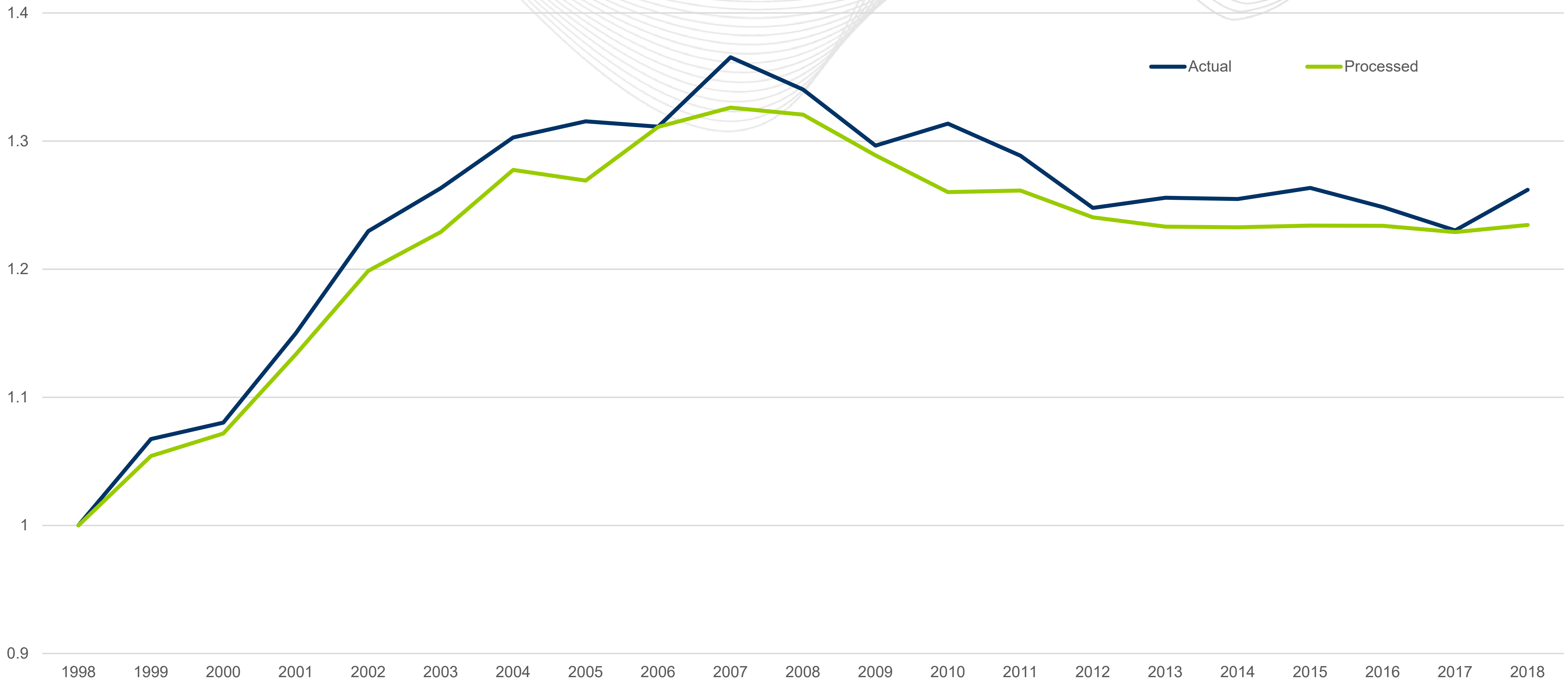
- Conceptually load growth can be decomposed into how much is due to weather and how much is due to underlying trends (economics and utilization).
  - diff_energy = B0 + B1 * diff_cool + B2 * diff_heat + rest
    - In this case rest is the error term
    - Seeking to isolate weather effect (pred_d_wthr = B1 * diff_cool + B2 * diff_heat)
    - pred_d_left = diff_energy – pred_d_wthr

Commercial Pre-Process

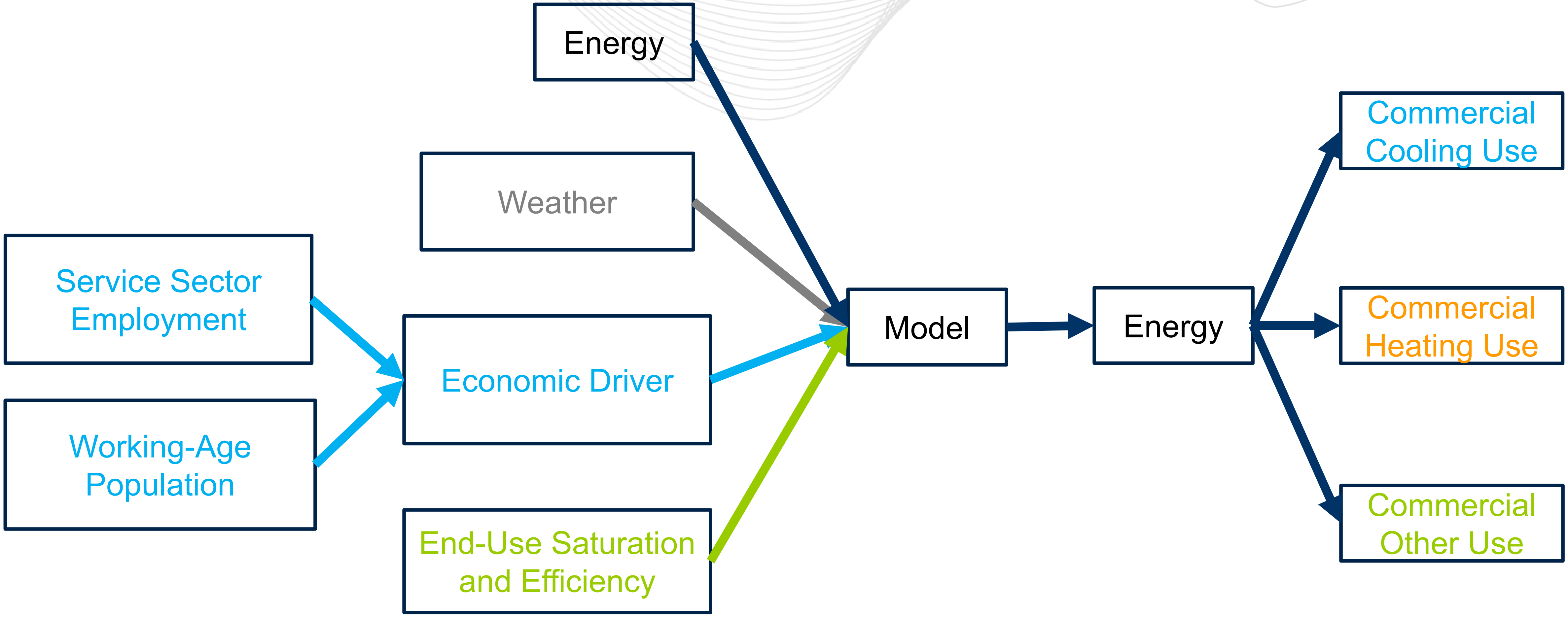




Commercial Pre-Process



Commercial Structure

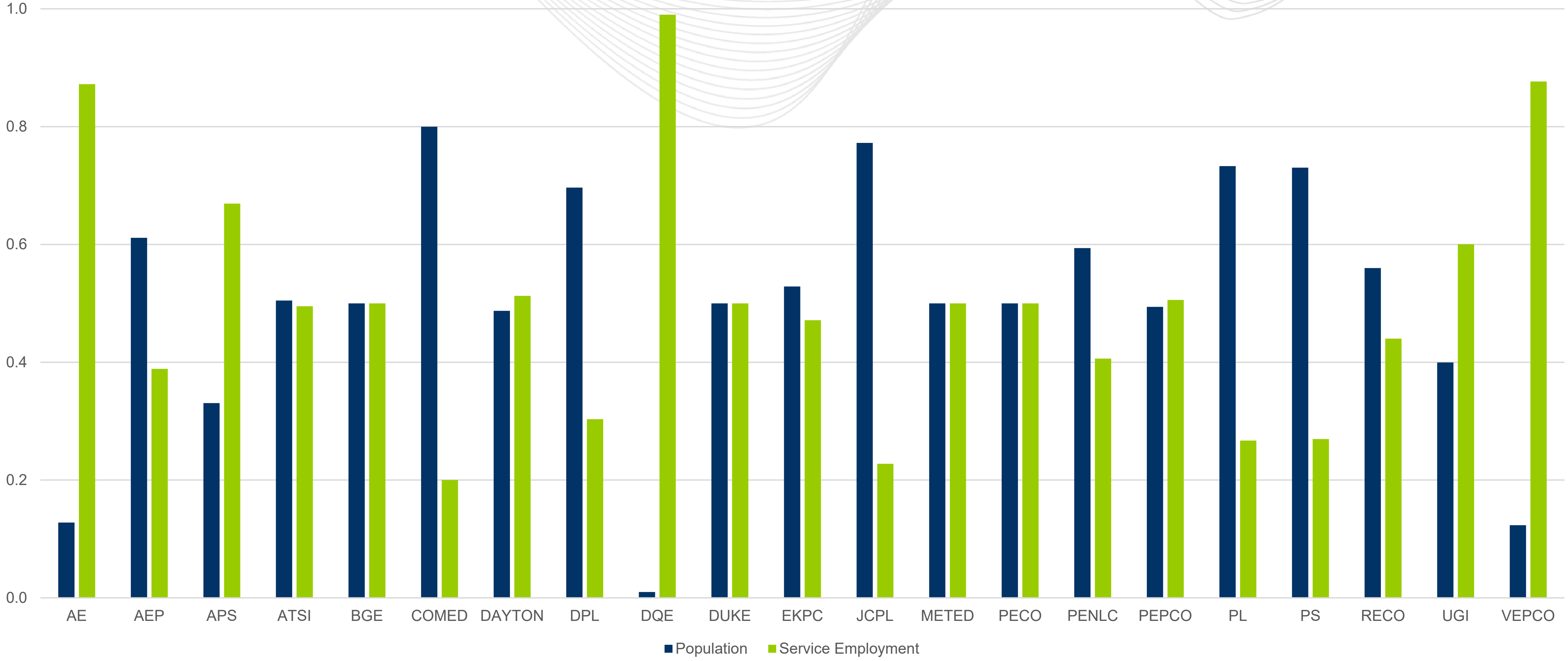


- Start with Service Employment and Working-Age Population, each computed as a product with end-use characteristics.

- Run a correlation analysis of commercial on each.

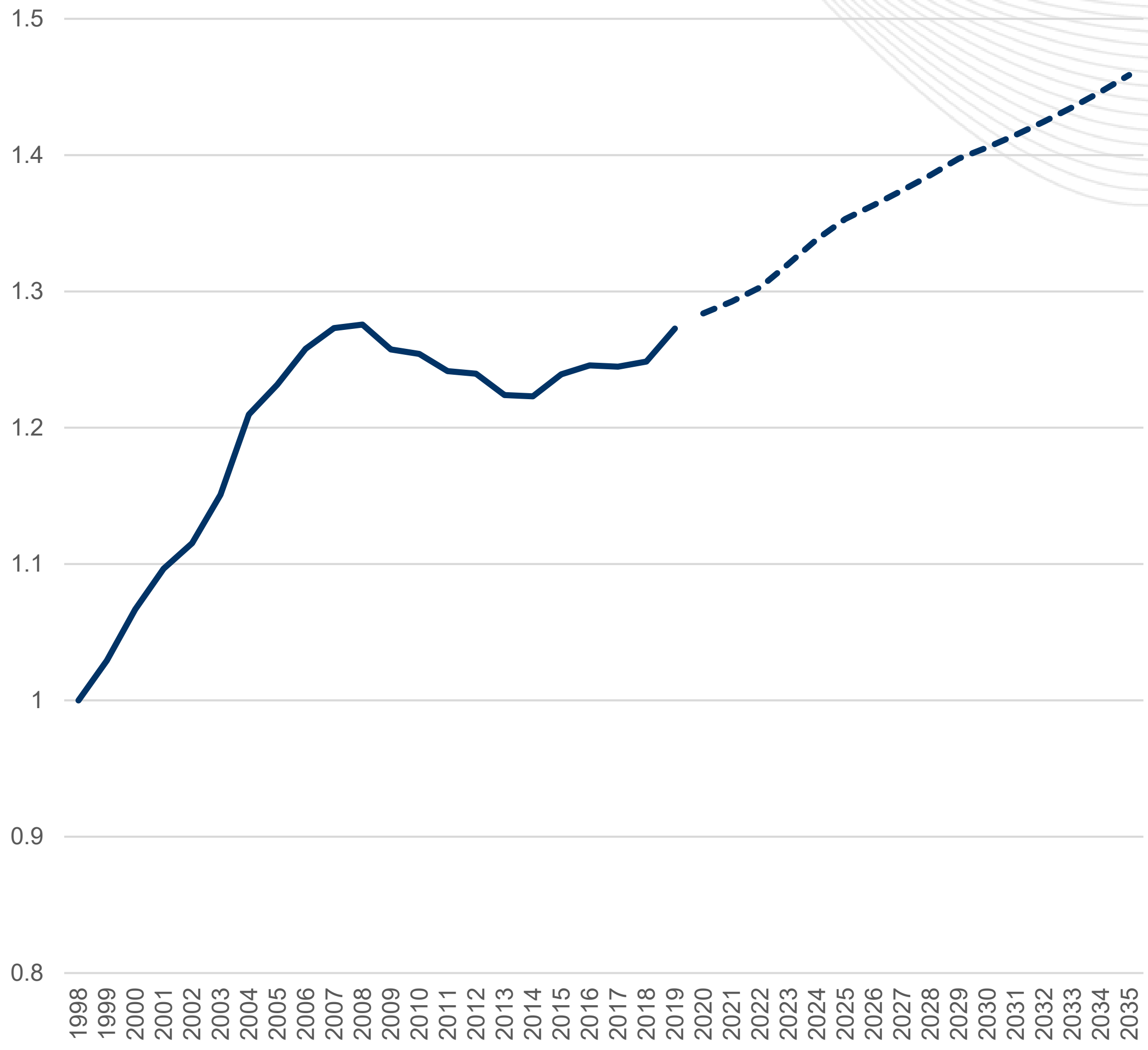
- Correlation results are then used to weight drivers.

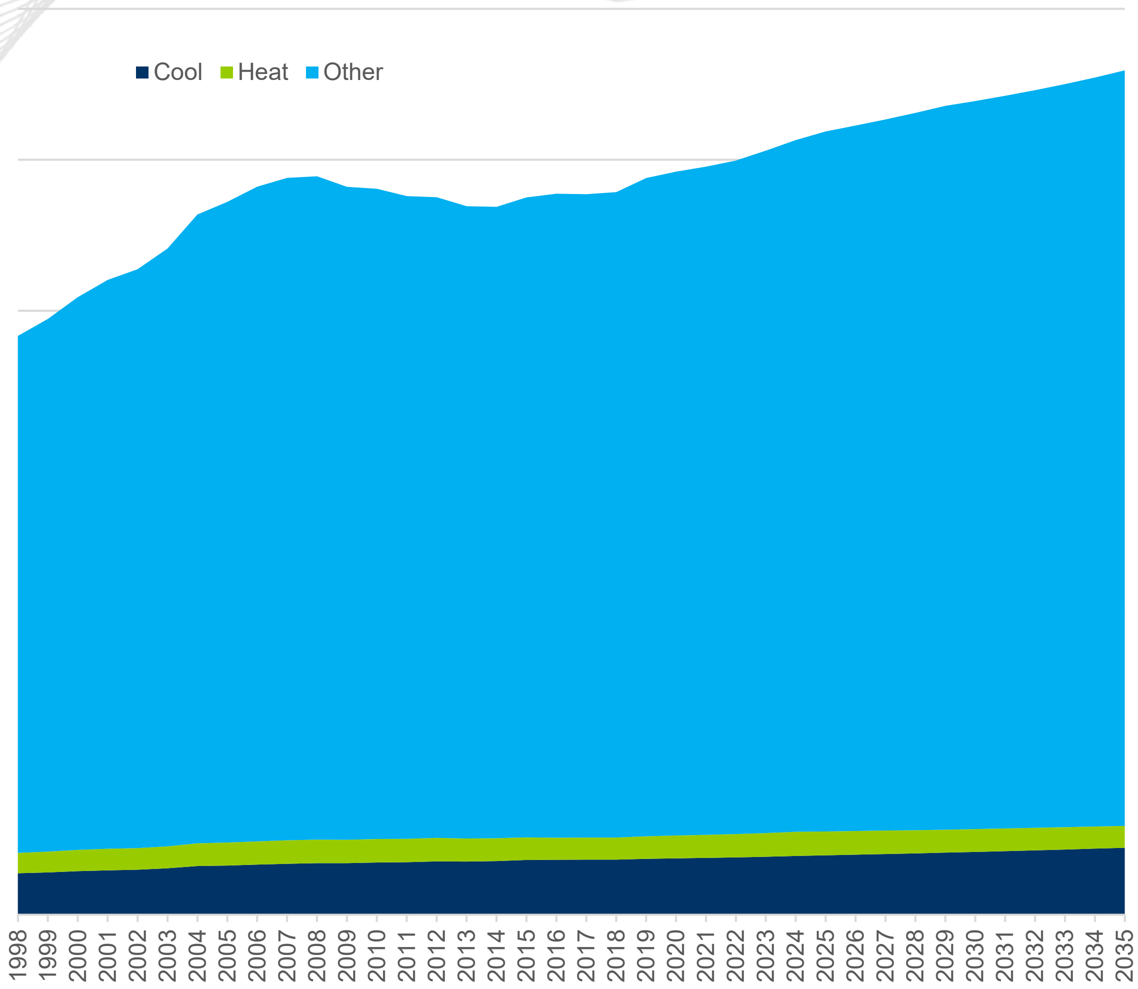
Commercial Driver Weighting



- comm_total = B0 + B1*driver + B2*trend + AR(1), where:
  - Driver is weighted combination of service employment and working-age population, each combined with end-use trends
    - Sources: Moody's Analytics, EIA/Itron
    - Trend is a linear time trend, used to help the model de-trend commercial sales (in other words, help the model account for how much of comm_total vs driver relationship is spurious)
    - AR(1) term included in response to residual pattern
- Results are then decomposed into Heat, Cool, and Other according to end-use data

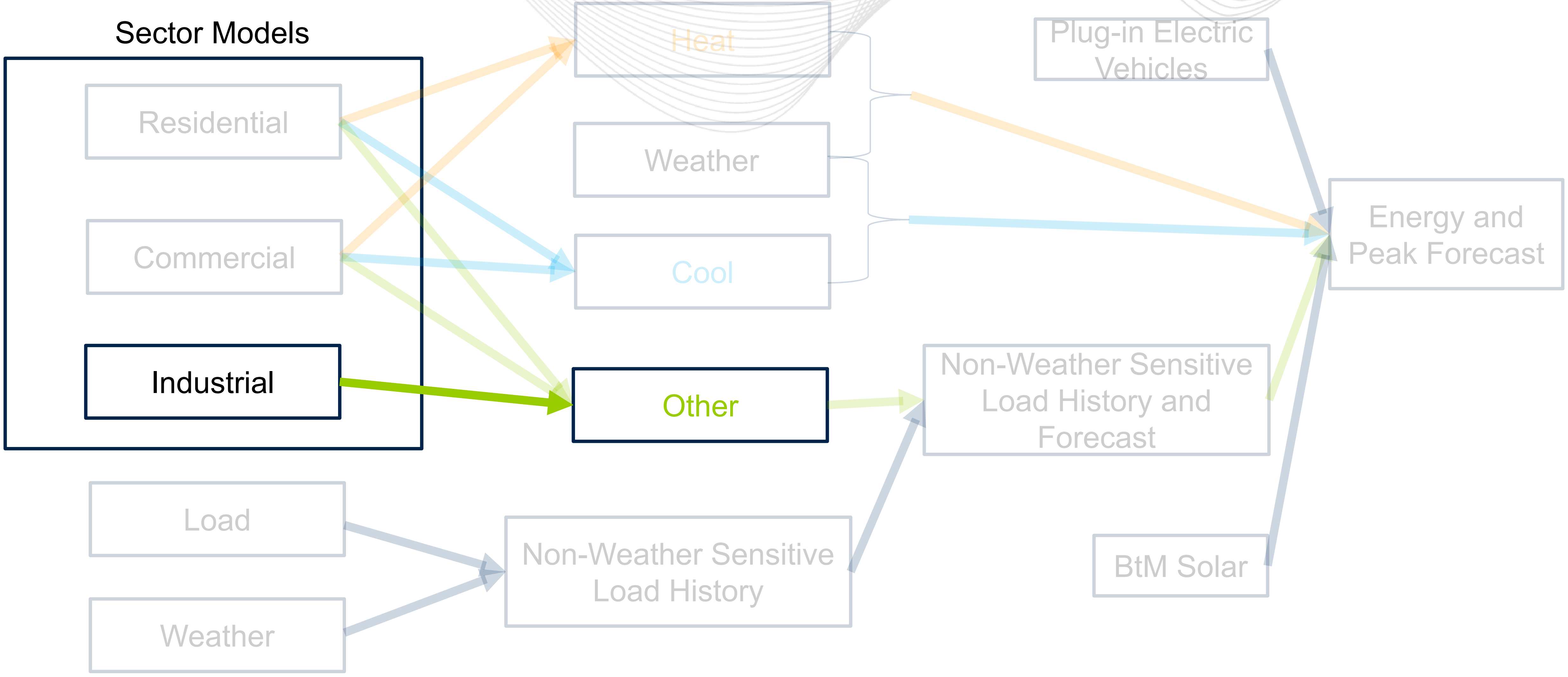
Commercial Forecast

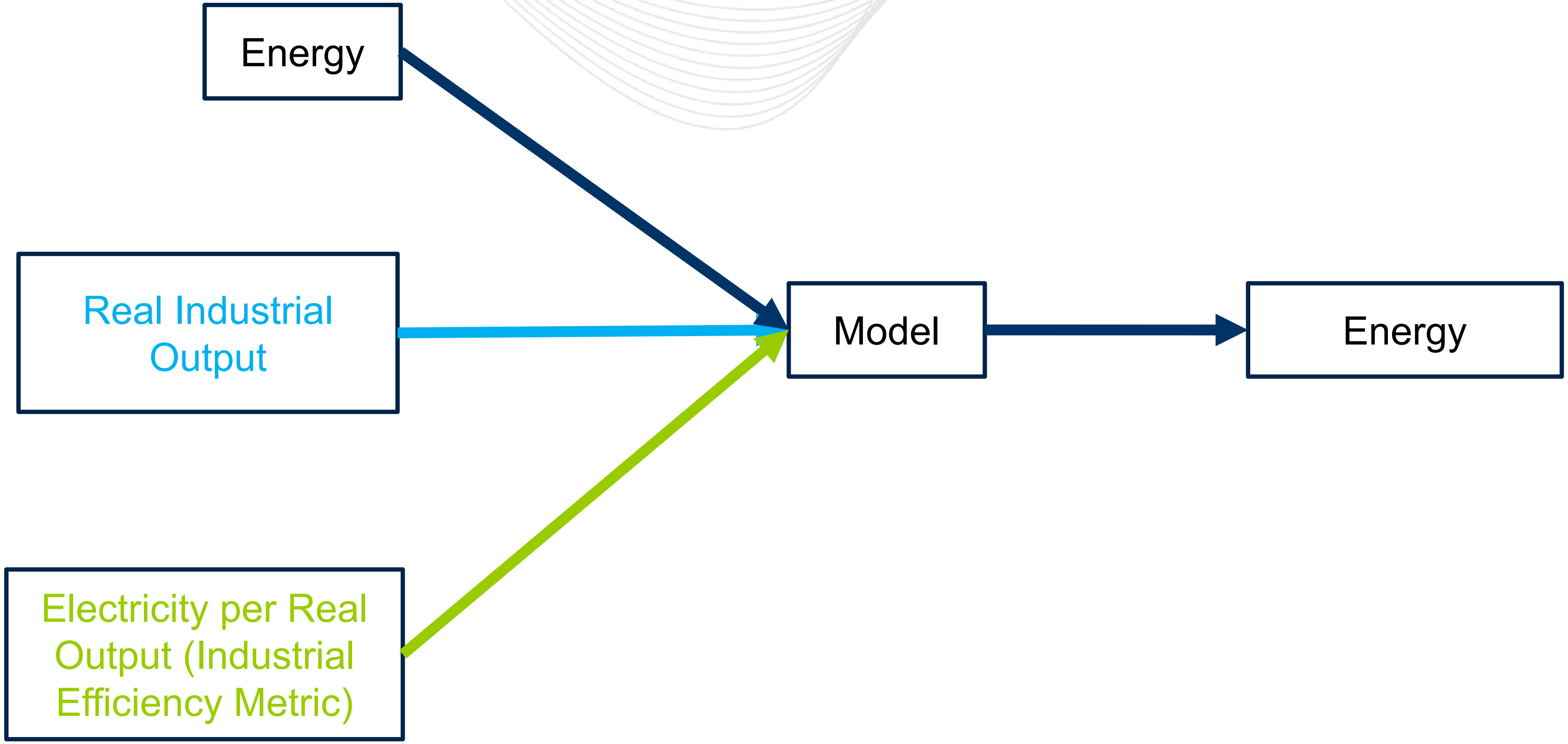




Industrial Sector Focus

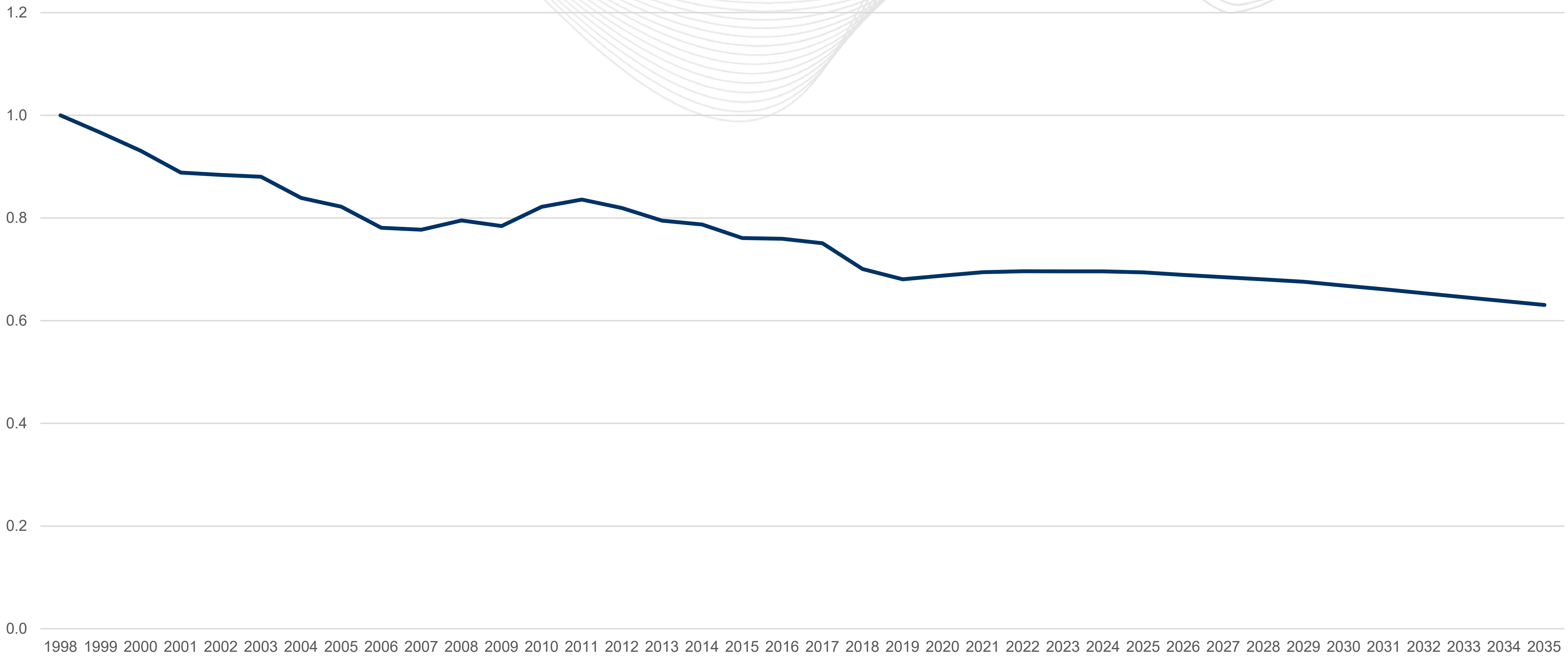
Industrial Highlight




Energy
Real Industrial Output
Electricity per Real Output (Industrial Efficiency Metric)
Model
Energy

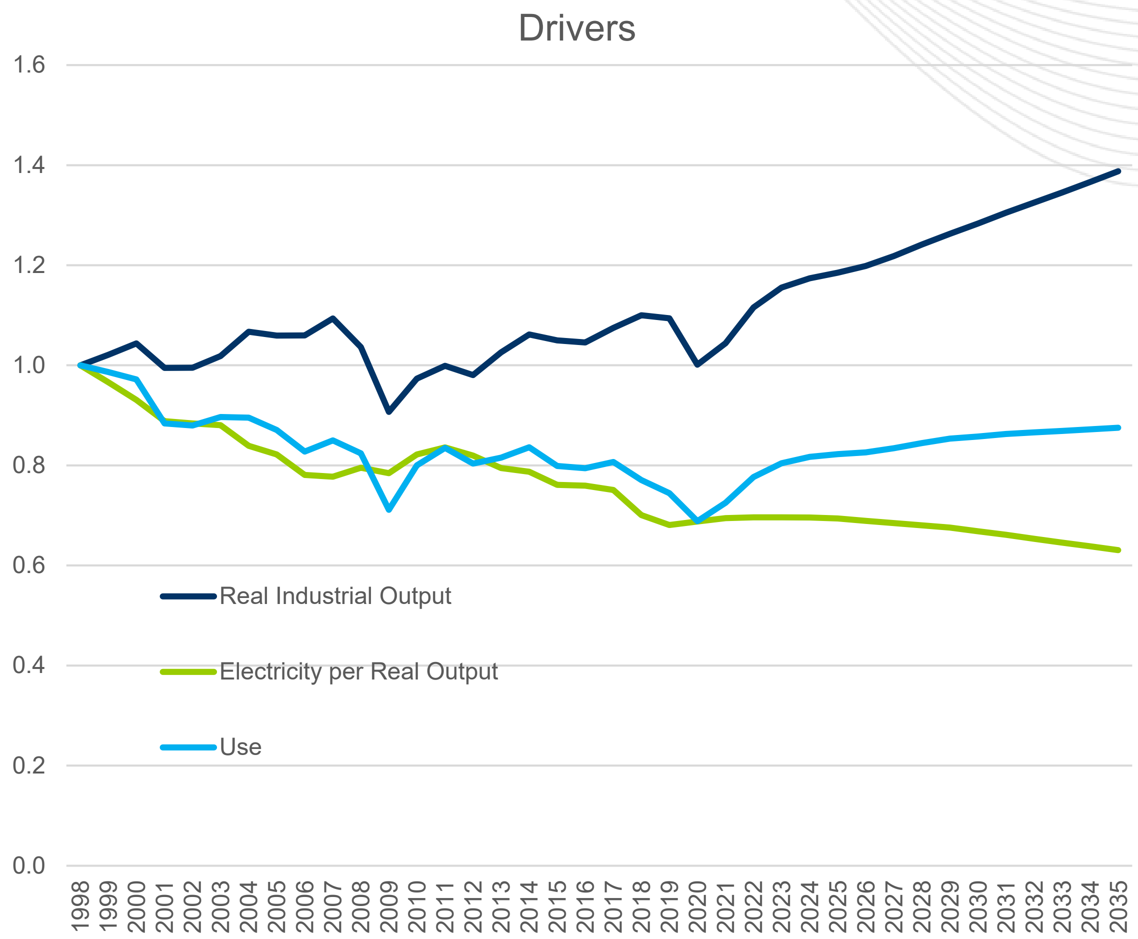
- Real Industrial Output (NAICS 21, 23, 31-33)
  - This concept is not forecast at metro area level by Moody's Analytics. Moody's Analytics does forecast states.
  - Take state productivity (output/employment) and apply to each metro area employment to get metro area output.
- Electricity per Real Output (Industrial Efficiency Metric)
  - National measure.
  - Captures how energy use has changed (sectoral changes as well as efficiency).
  - Source: EIA

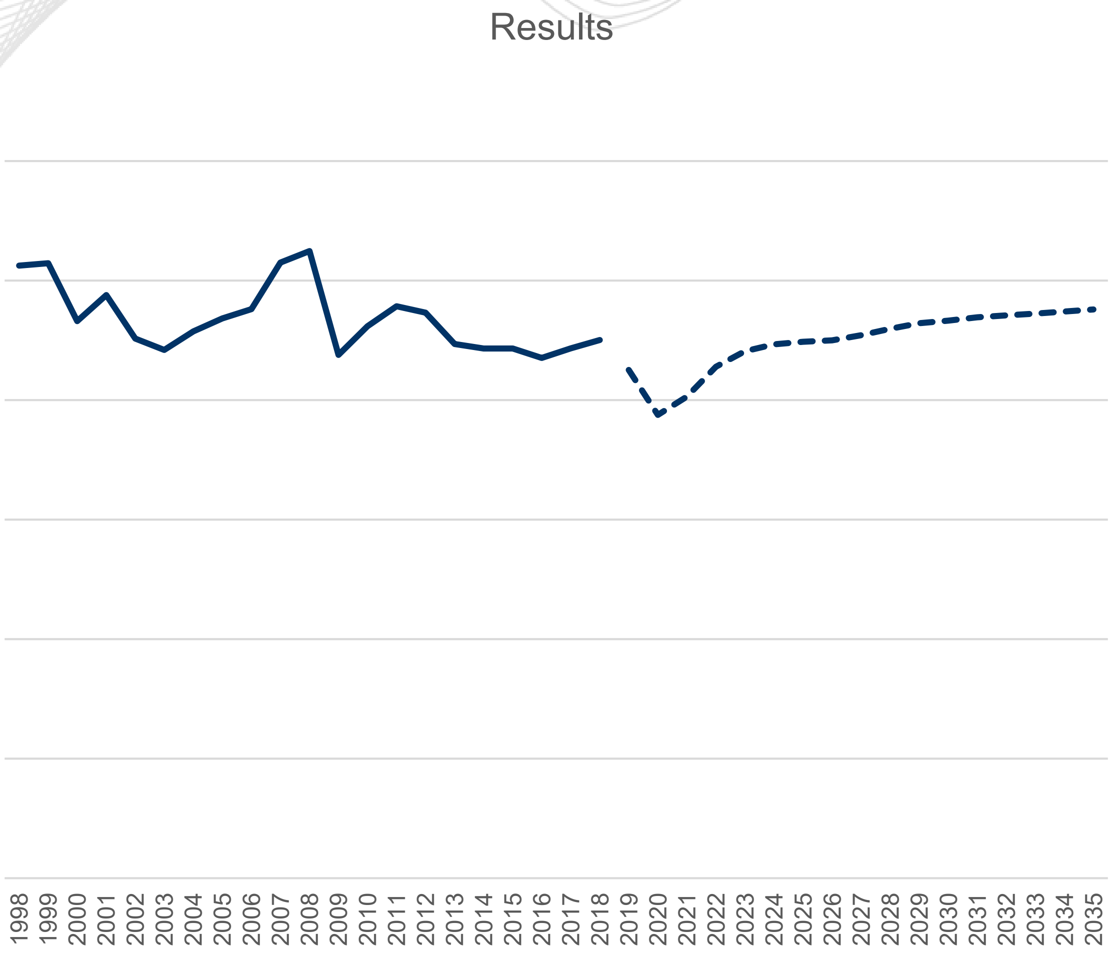
Electricity per Real Output (1998 = 1.0)



- industrial_energy = B1*use + AR(1), where:
  - Use is the product of real industrial output and electricity per real output
    - Sources: Moody's Analytics, EIA
  - AR(1) term included in response to residual pattern

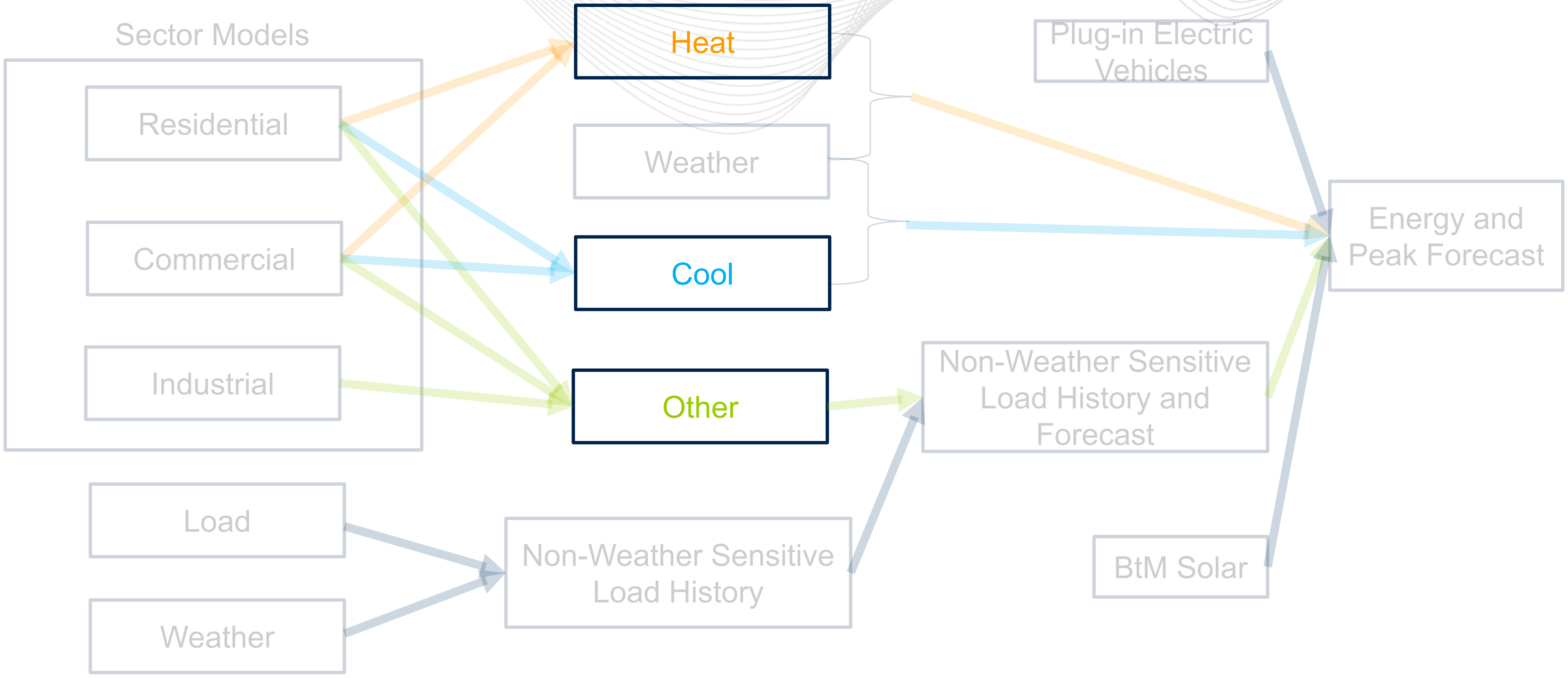
Industrial Model



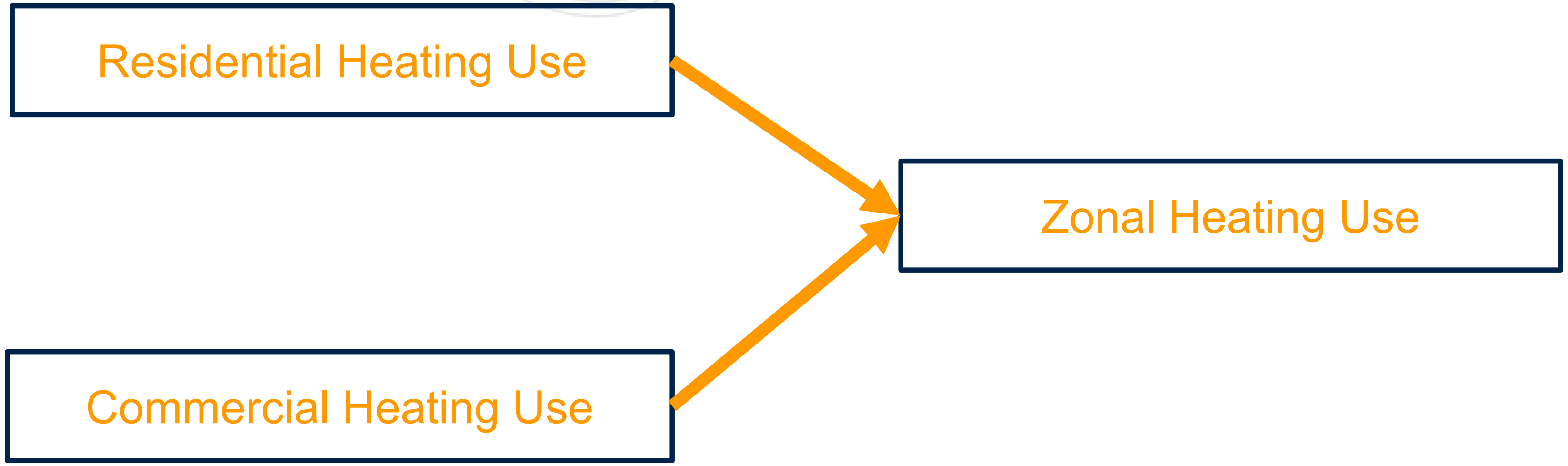


End-Use Index Focus

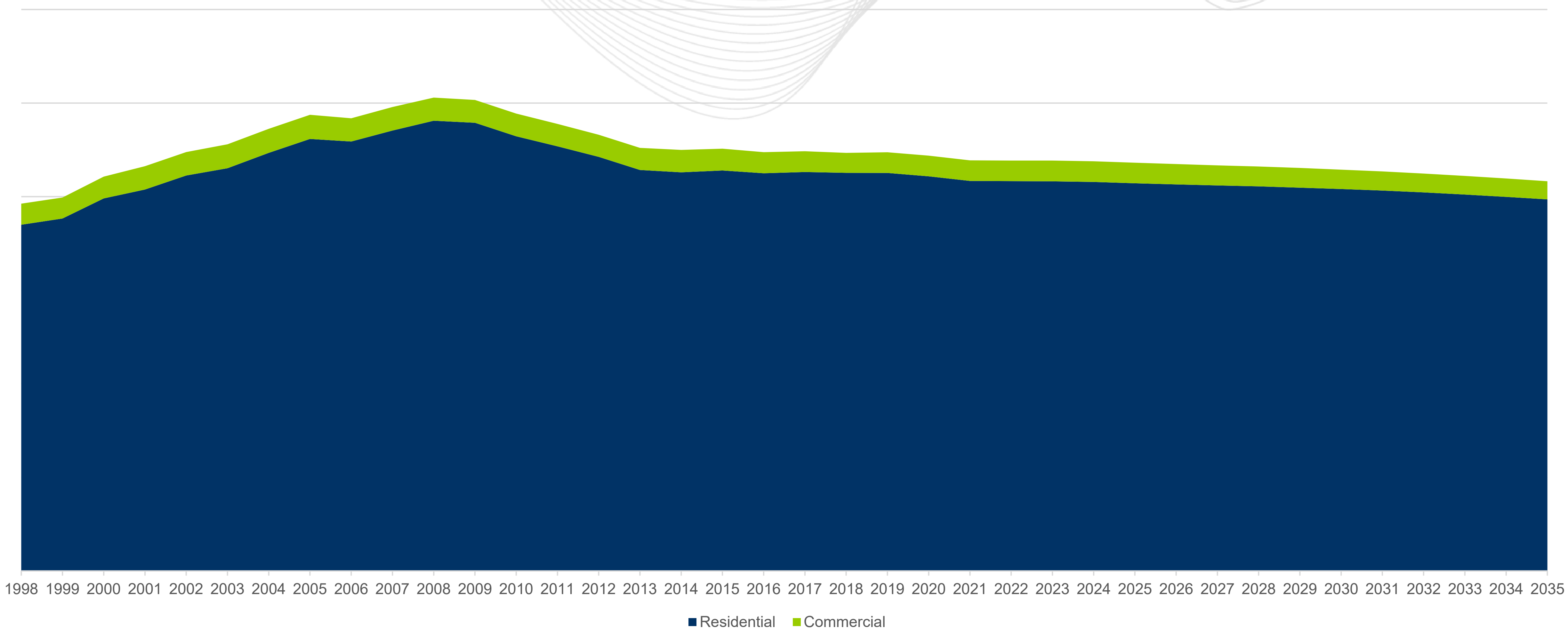
End-Use Indices Highlight



End-Use Breakout – Heating

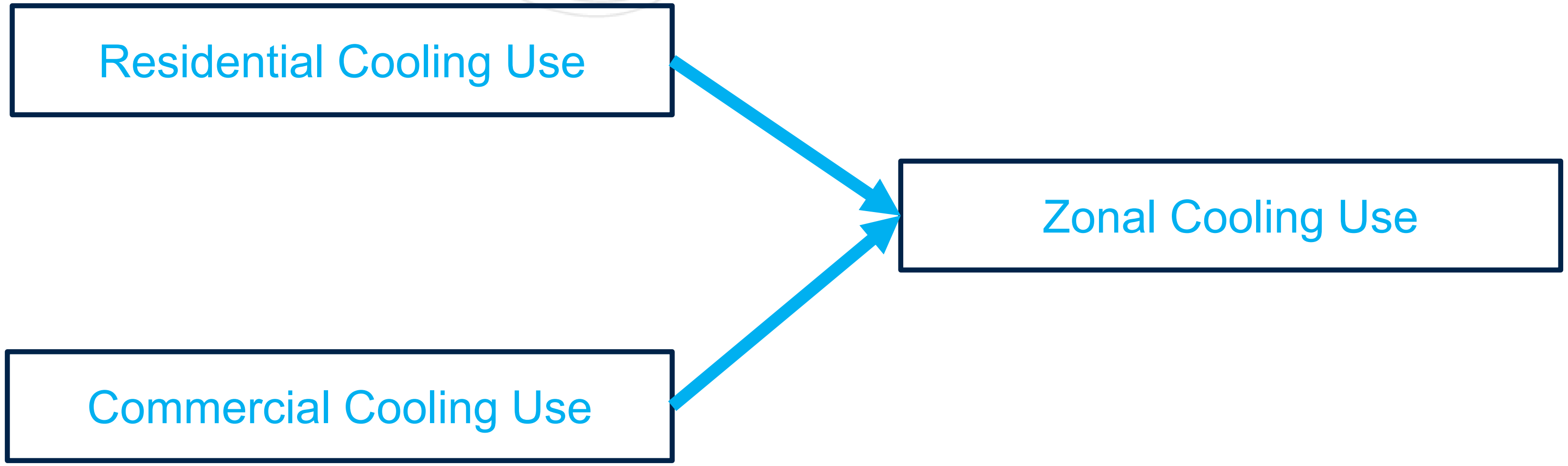


Heating

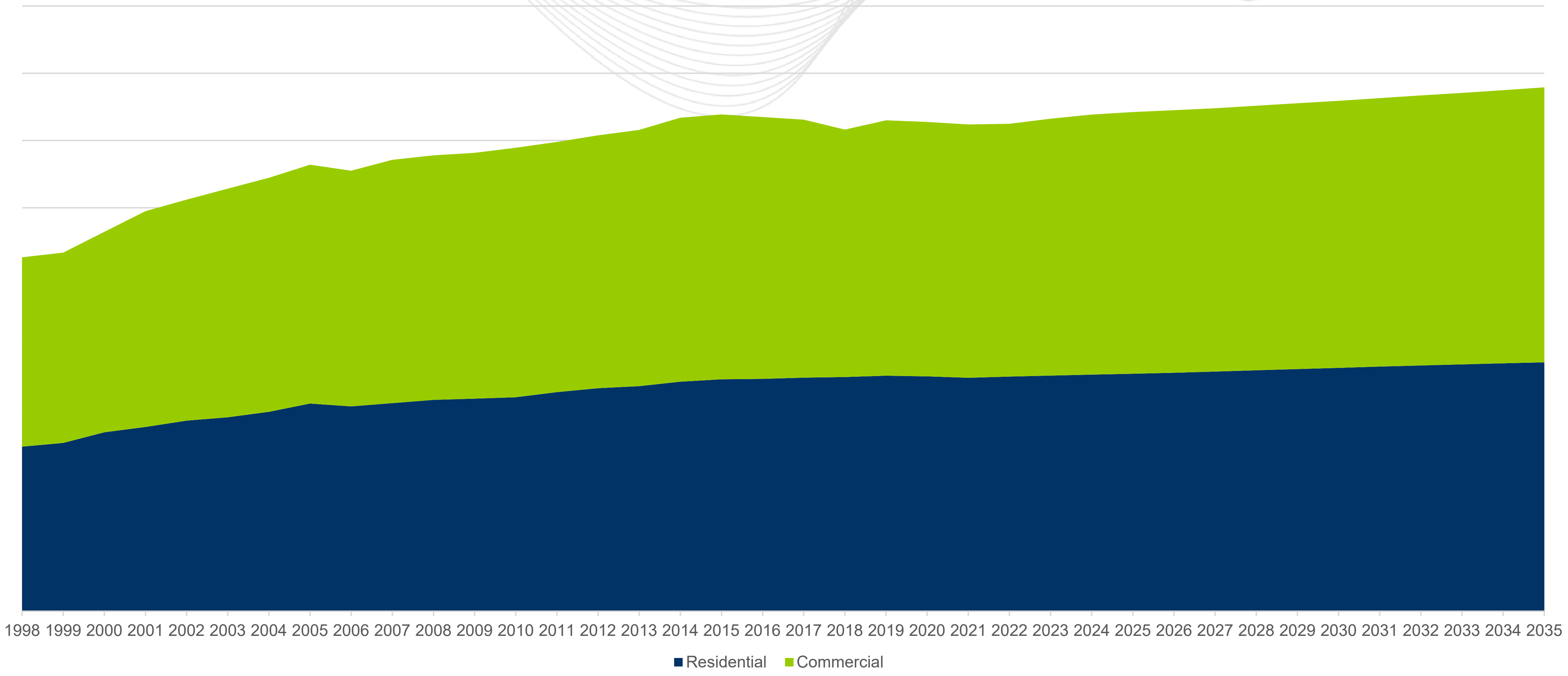


1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
Residential
Commercial

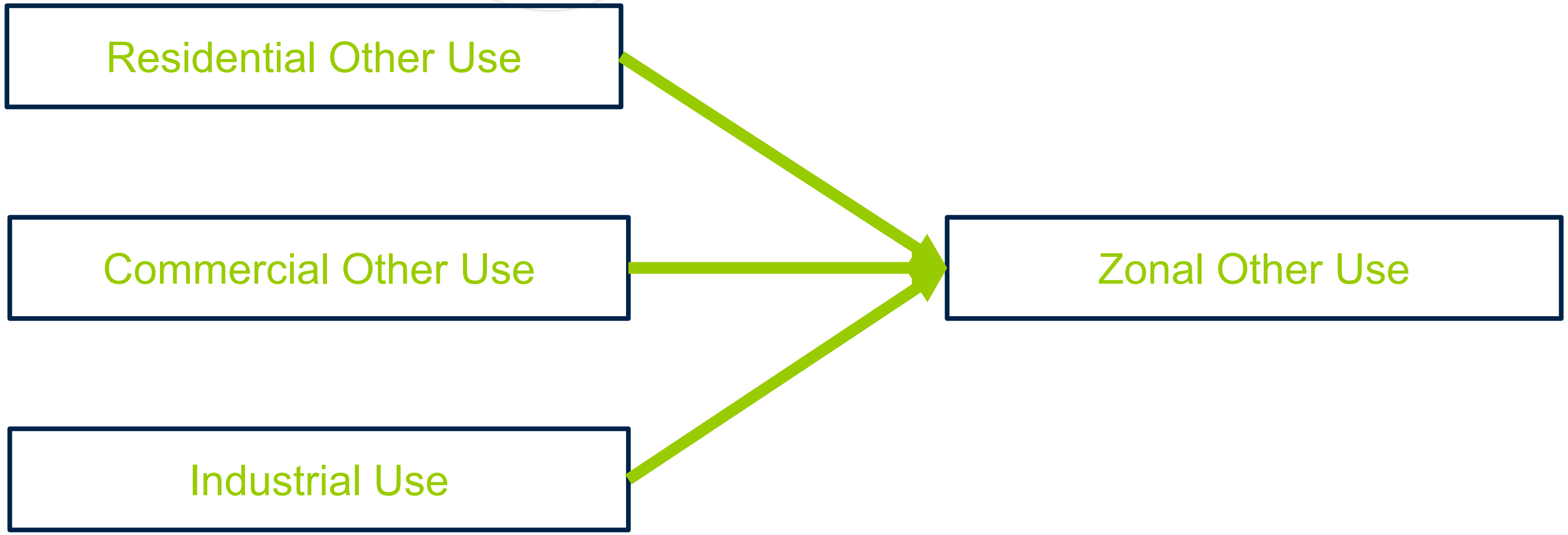
End-Use Breakout – Cooling



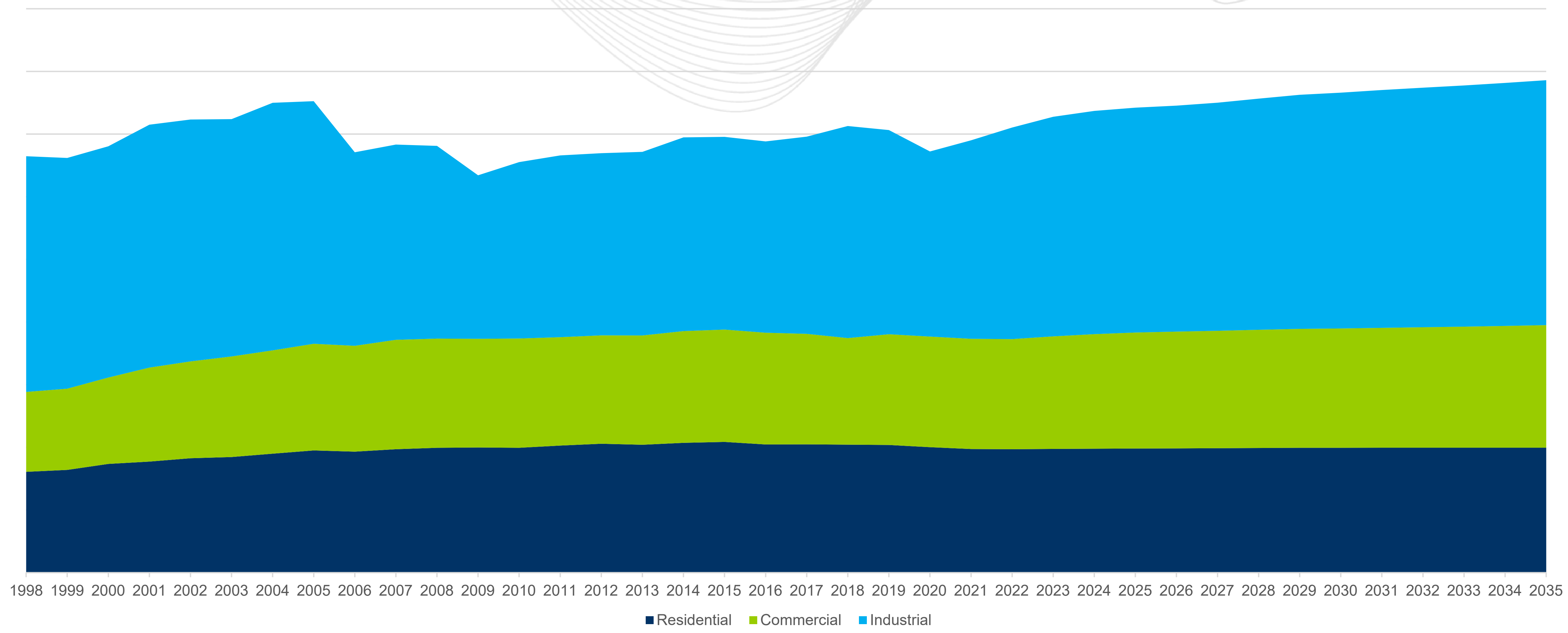
Cooling


1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
Residential
Commercial

End-Use Breakout – Other



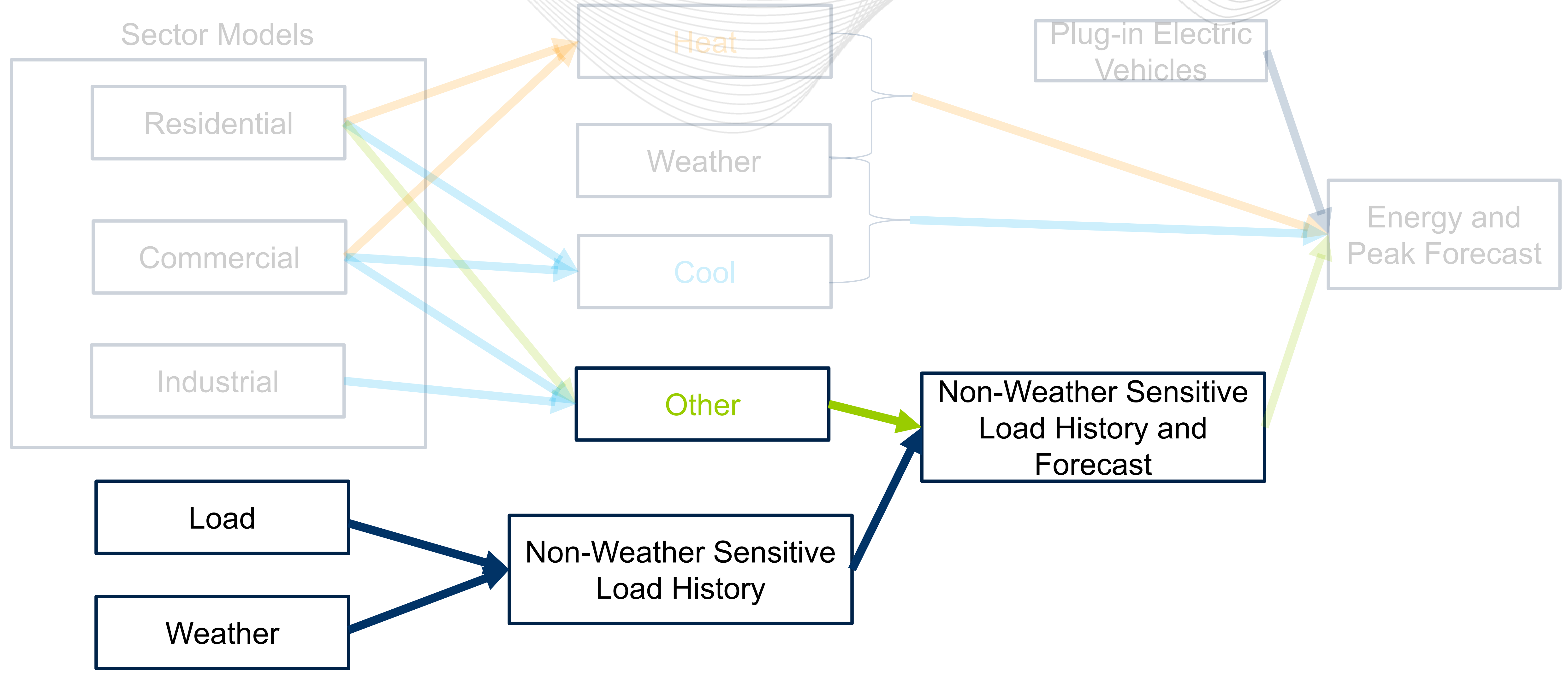
Other



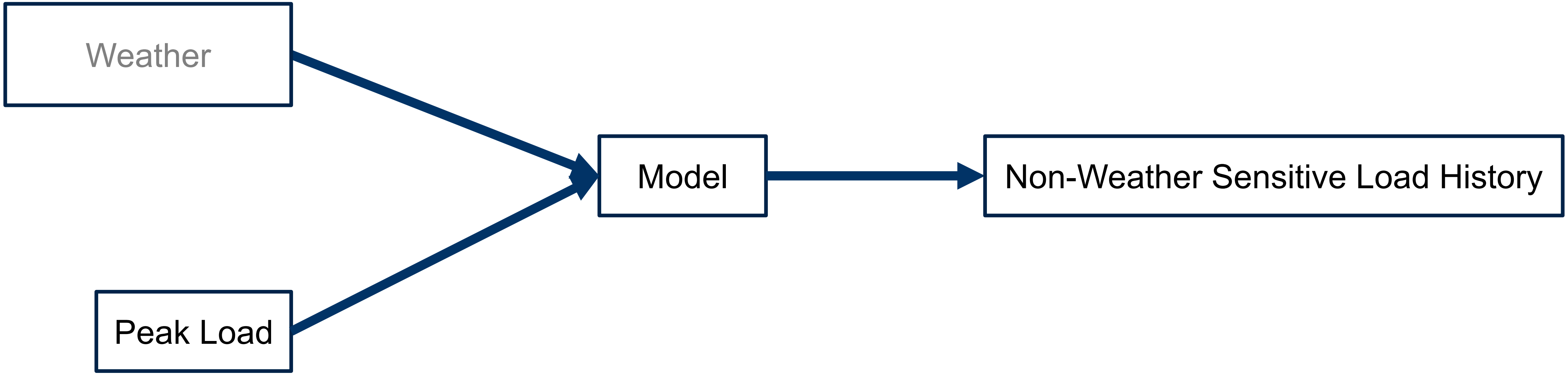
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
Residential
Commercial
Industrial

Non-Weather Sensitive Load Focus

Non-Weather Sensitive Highlight

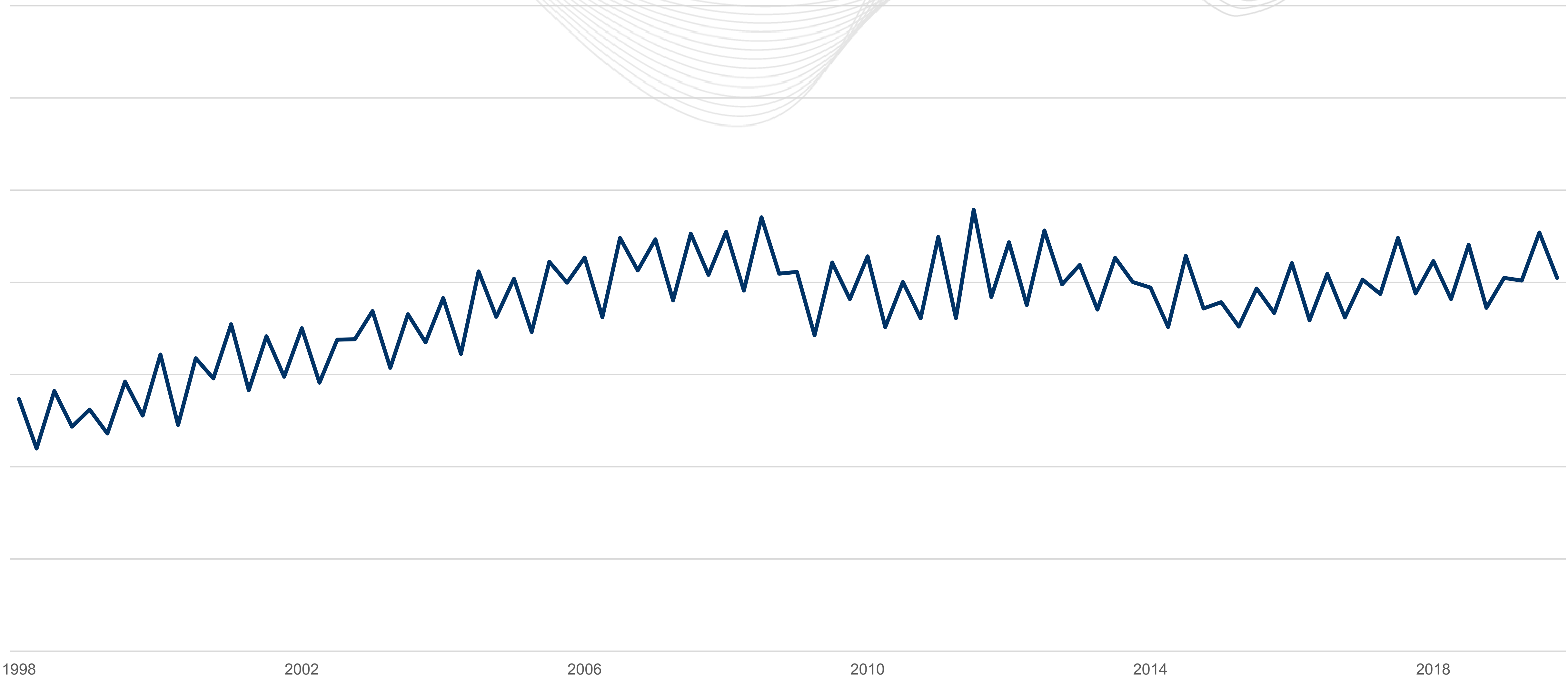


Non-Weather Sensitive History

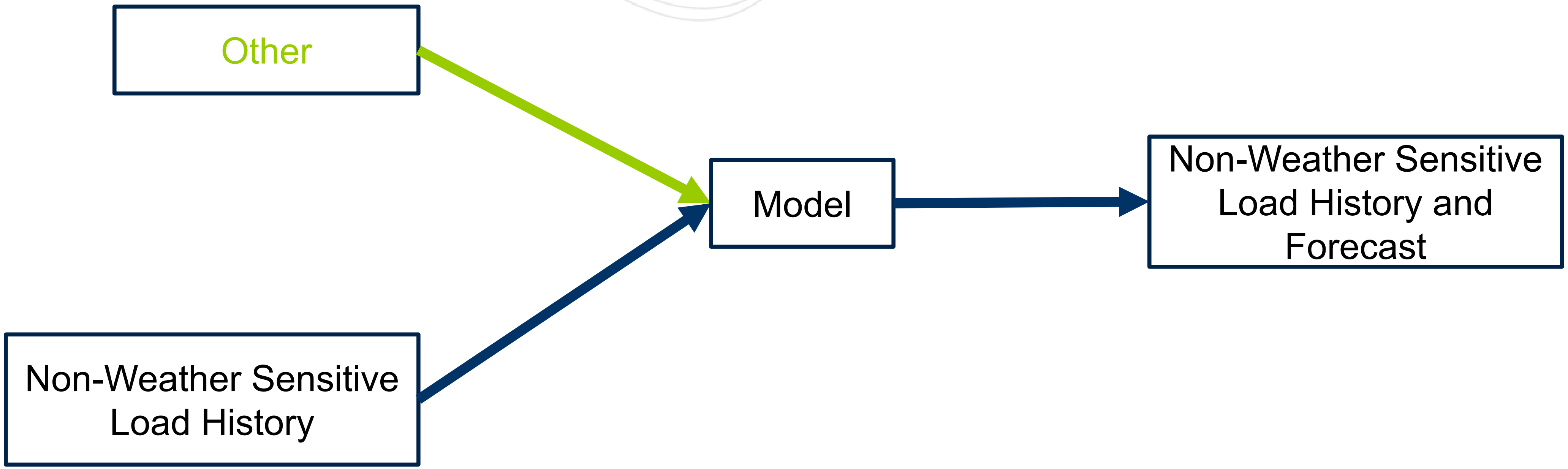


- Load = B1# * y# + B2# * spring_y# + B3# * summer_y# + B4# * fall_y# + B5# * sum# + B6# * win#, where:
    - Load is according to the model type under study (i.e. NCP, CP, ENERGY)
    - # equals a year 1998 through 2019
    - spring_y#, summer_y#, and fall_y# are binary variables equal to 1 when in that season of that year, and are 0 otherwise
    - sum# and win# are summer and winter weather variables respectively

Non-Weather Sensitive History

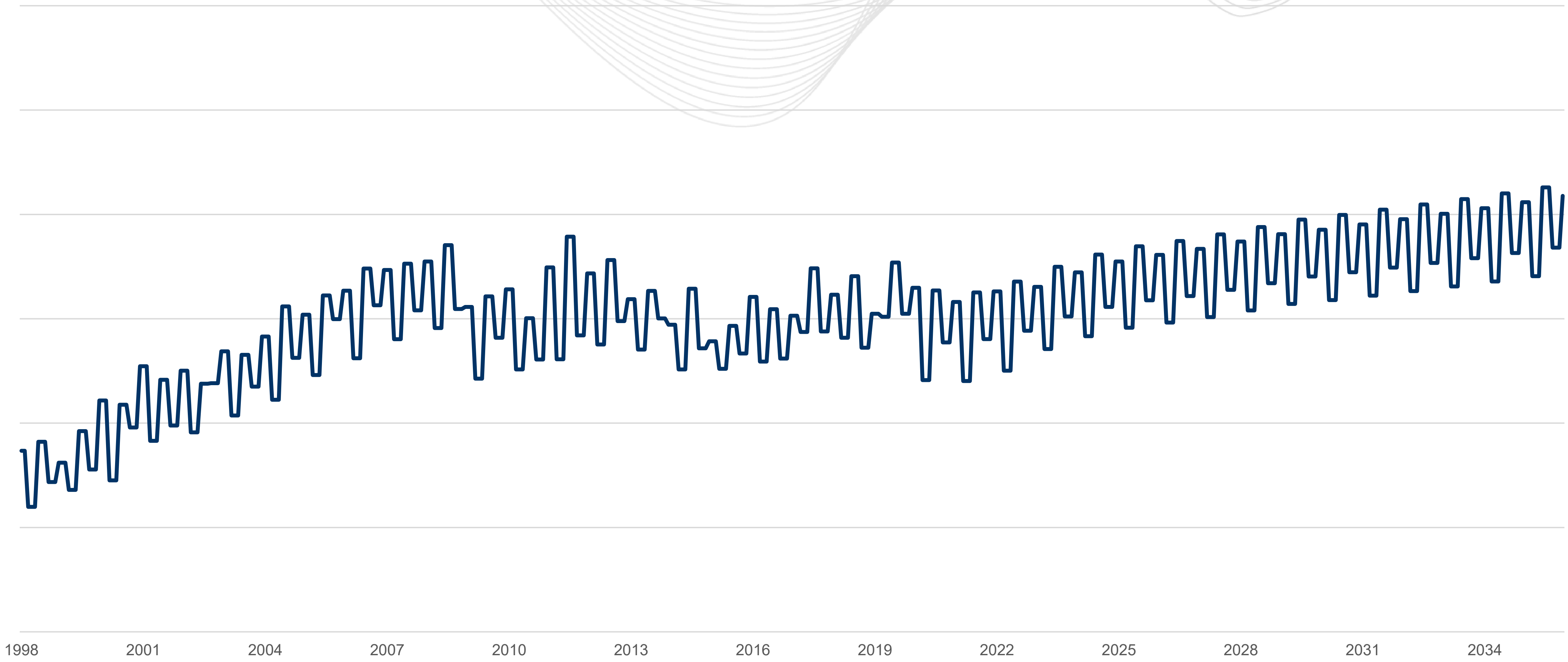


Non-Weather Sensitive Forecast



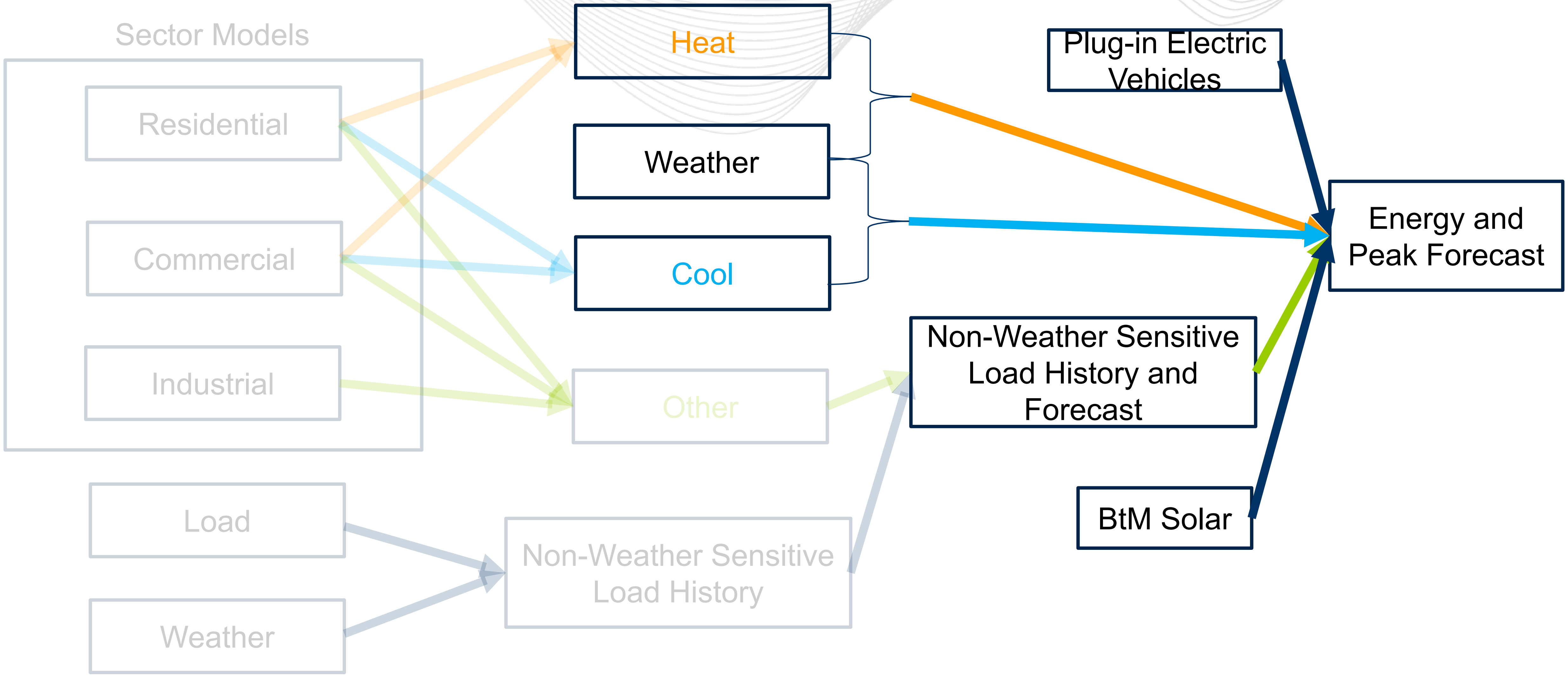
- NWS_load = B0 + B1 * trend + B2 * Other + B3 * summer_other + B4 * fall_other + B5 * spring_other + AR(1) + AR(4), where:
    - NWS_load is non-weather sensitive load according to the model type under study (i.e. NCP, CP, ENERGY)
    - Trend is a linear time trend, used to help the model de-trend non-weather sensitive load (in other words, help the model account for how much of nws_load vs other relationship is spurious)
    - Other is the other end-use index
    - summer_other, fall_other, and spring_other are the other index interacted with seasonal binaries
    - AR(1) and AR(4) term to capture residual pattern from prior period and prior season

Non-Weather Sensitive Forecast

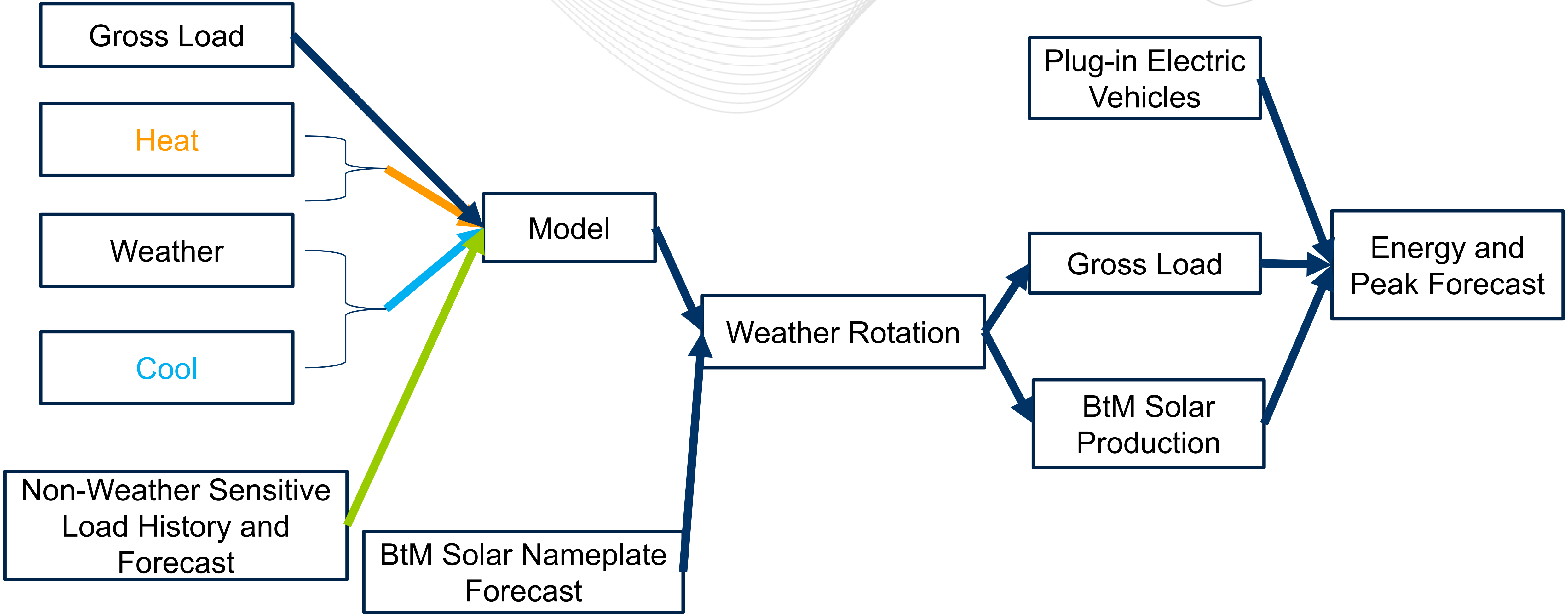


Final Forecast Focus

Final Forecast Highlight

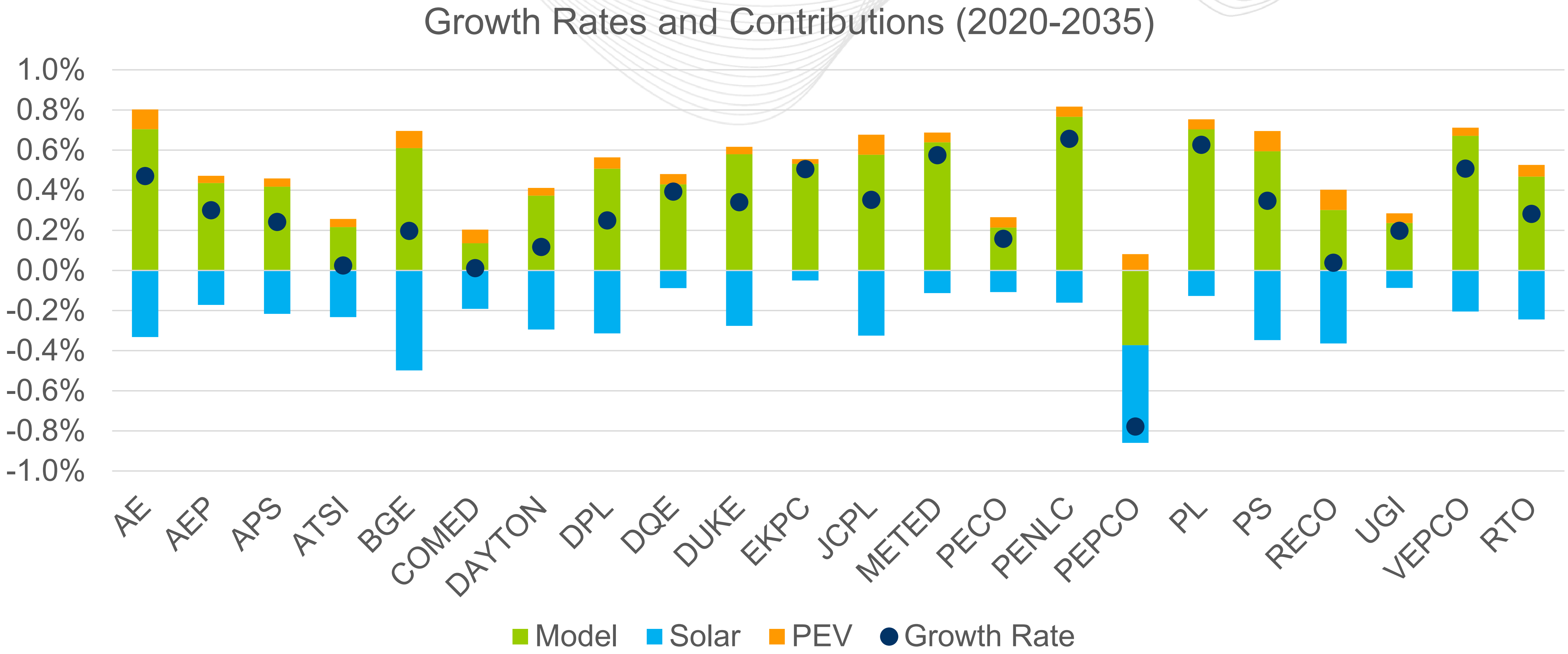


Final Forecast Highlight

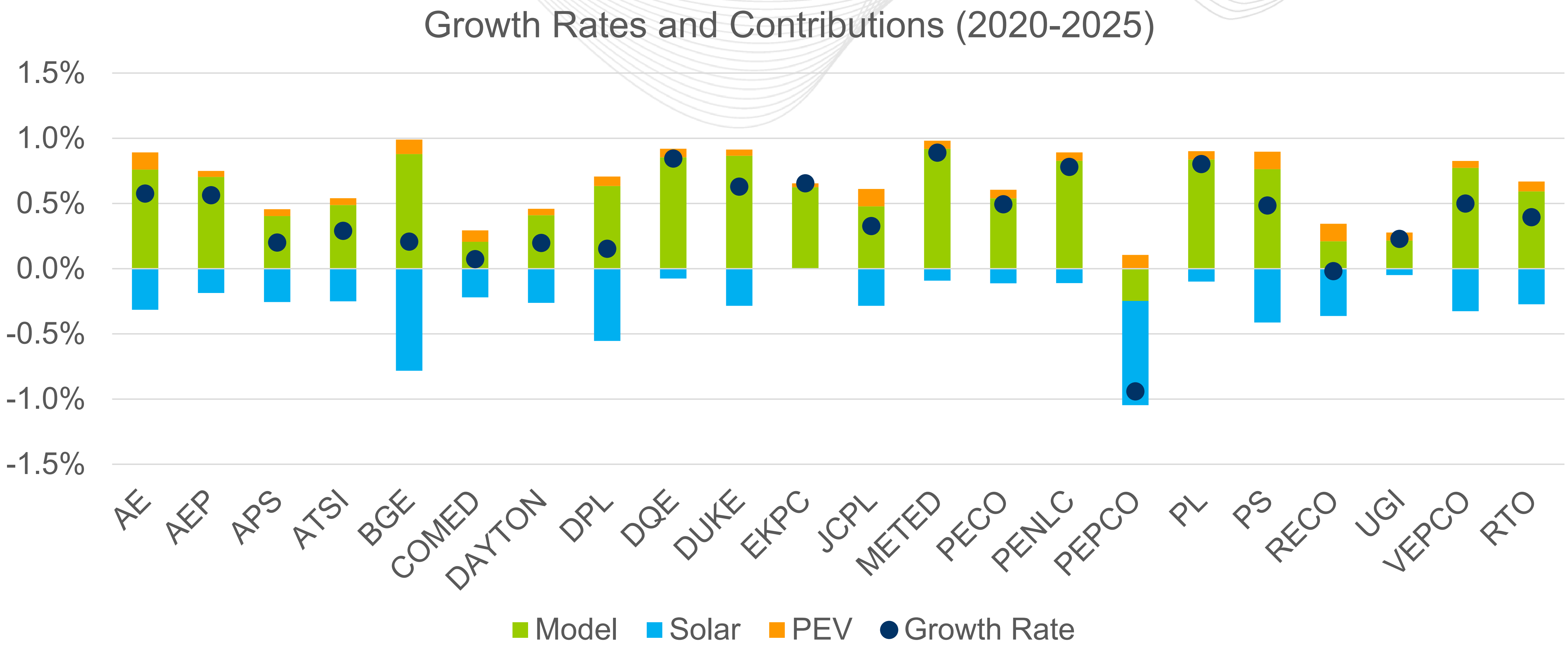


Explaining Trends

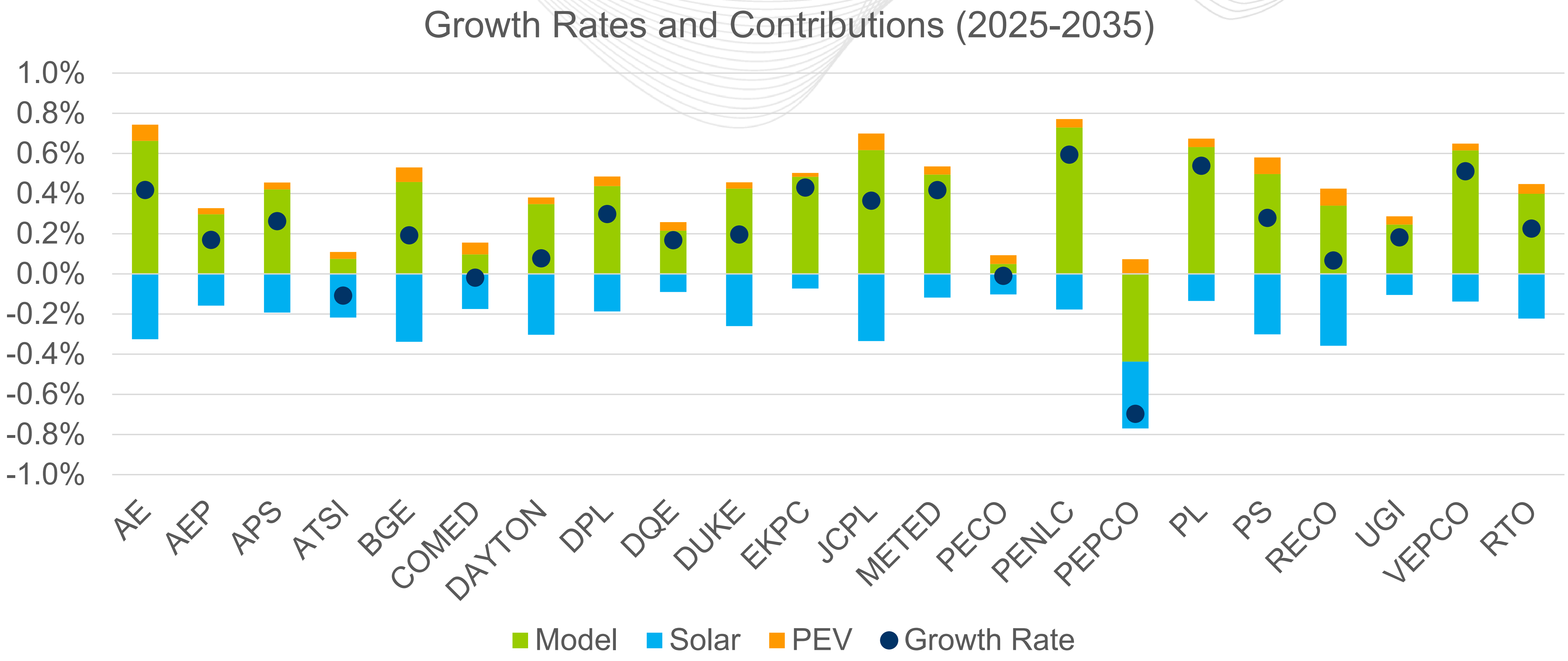
Contributions to Summer Growth



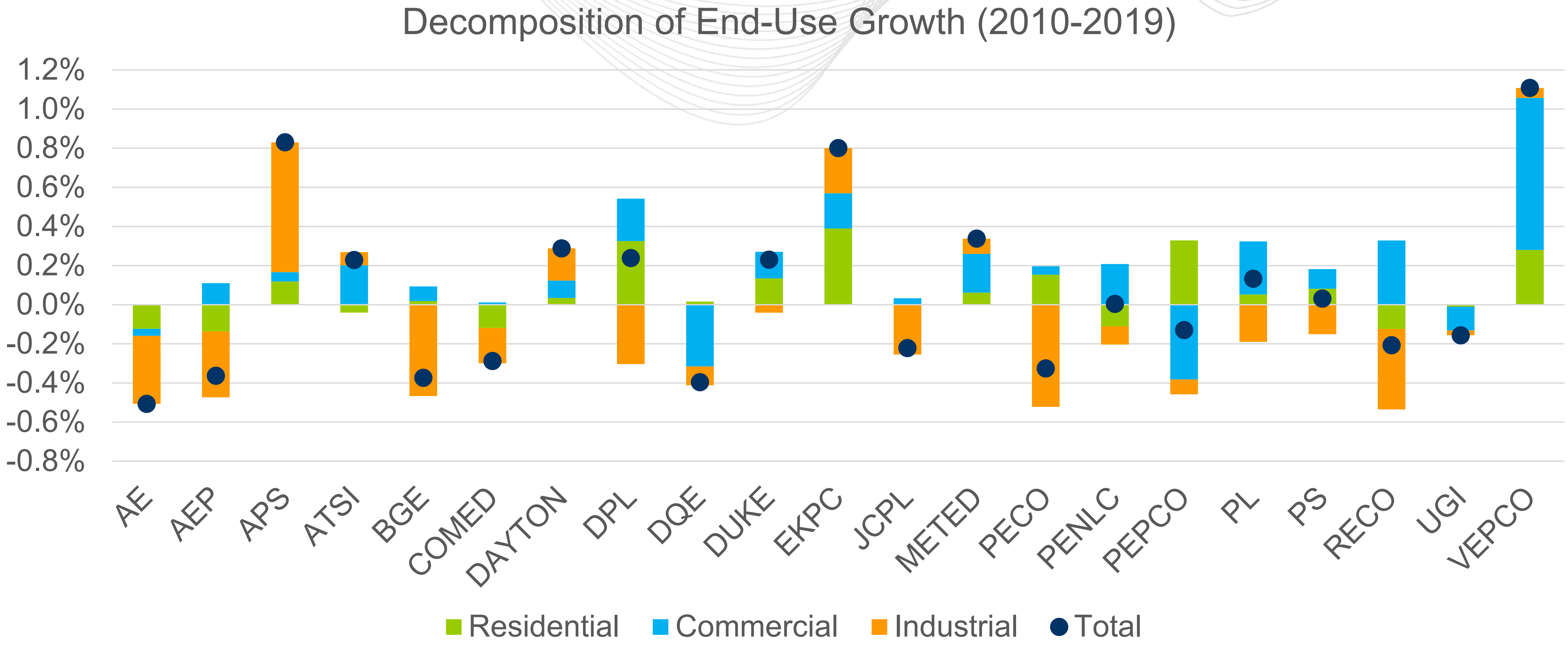
Contributions to Summer Growth



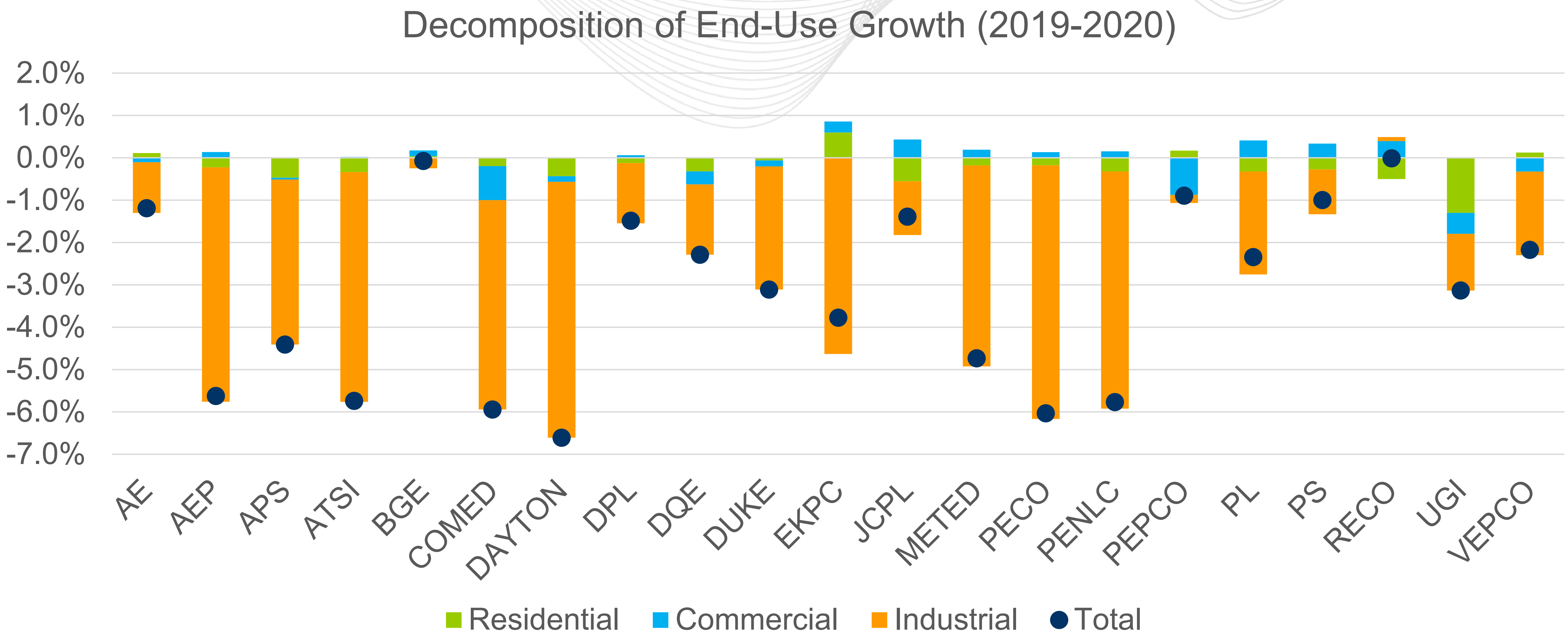
Contributions to Summer Growth



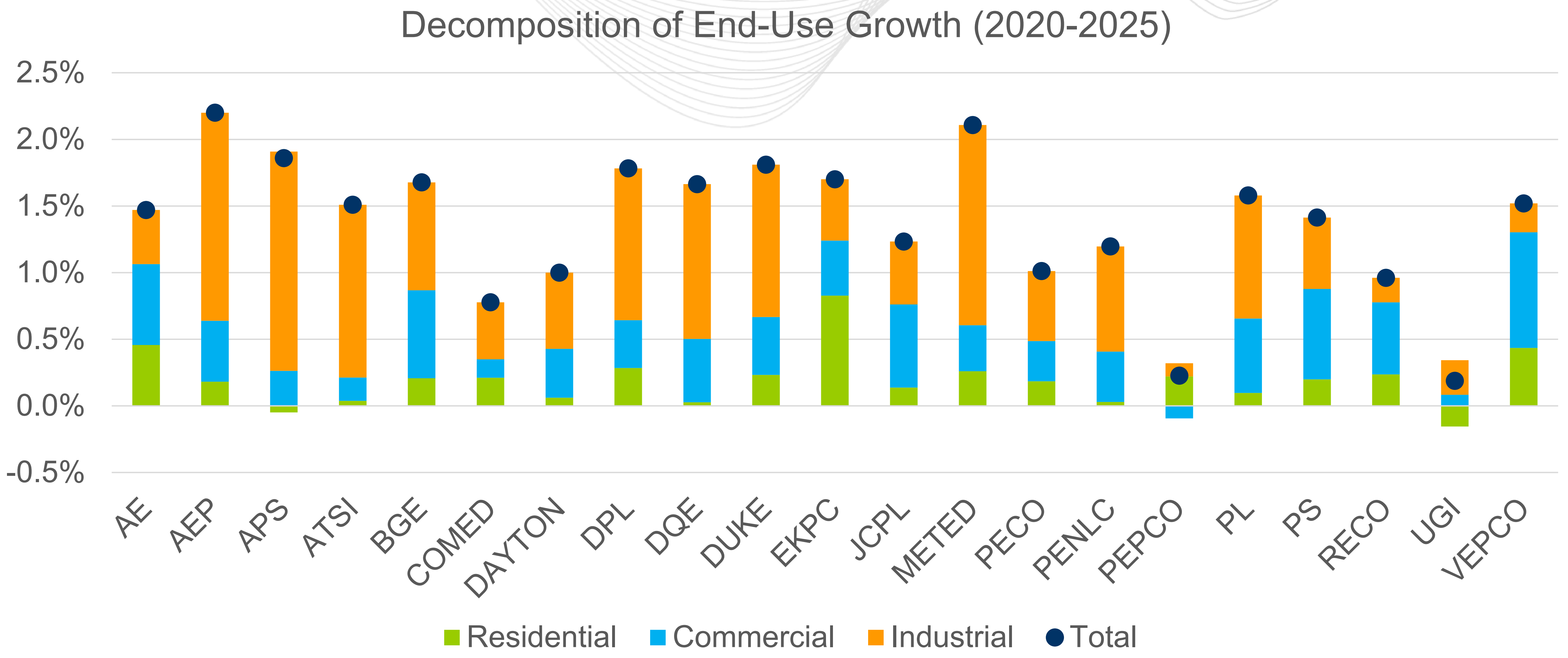
Summer End-Use Growth Decomposition



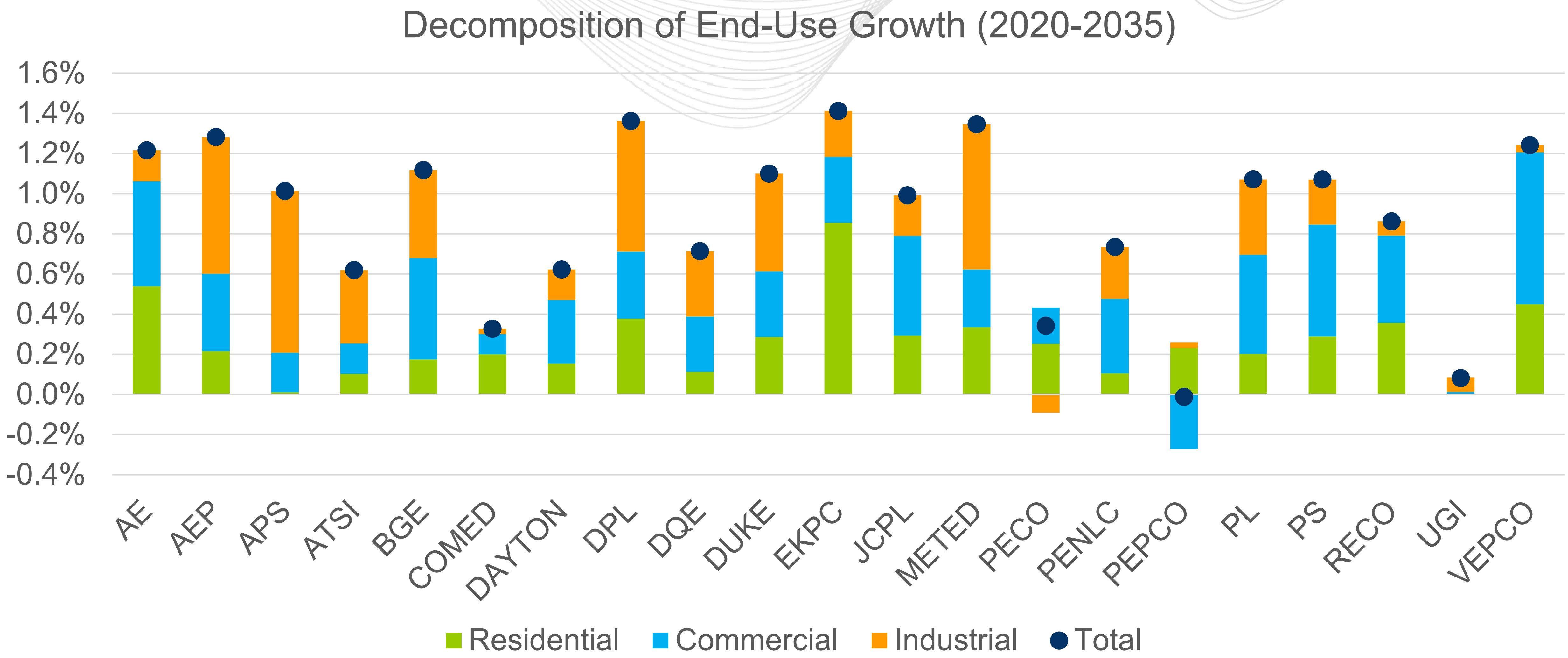
Summer End-Use Growth Decomposition



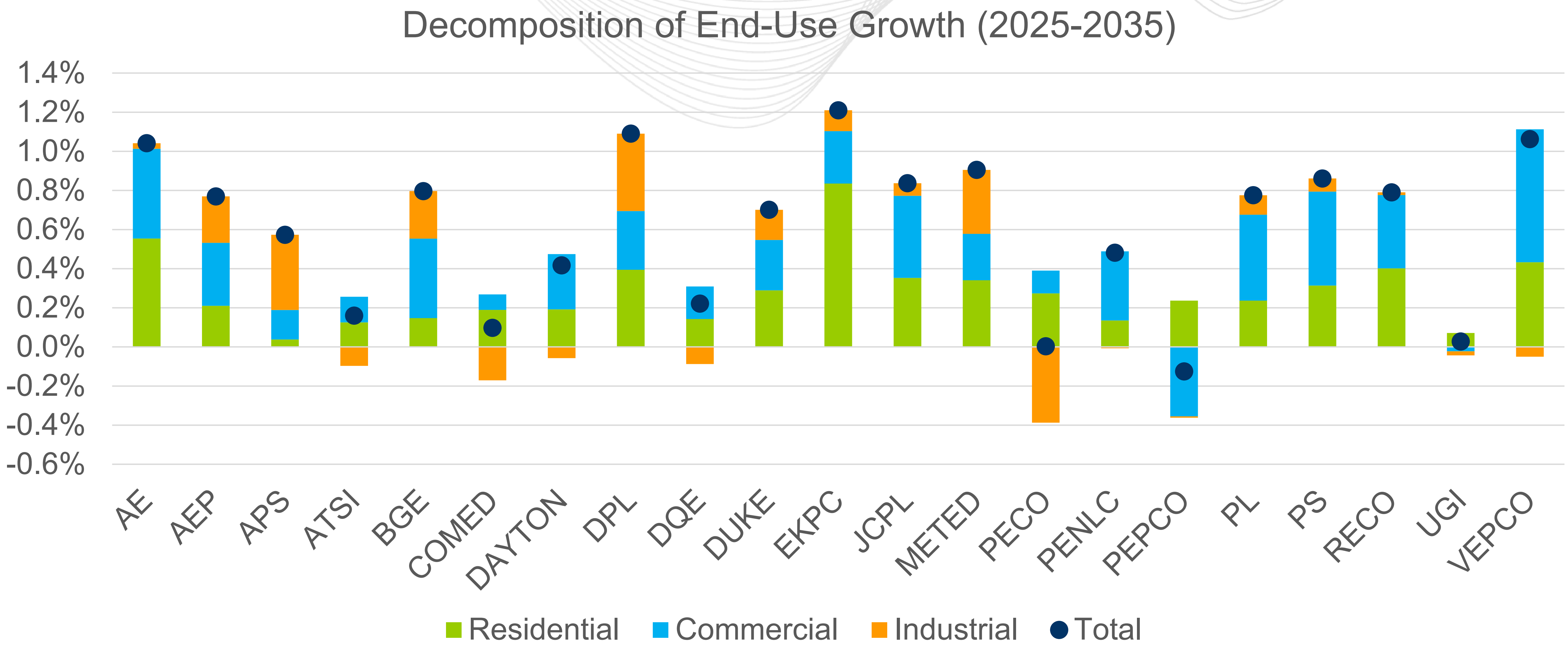
Summer End-Use Growth Decomposition – Recovery Period



Summer End-Use Growth Decomposition

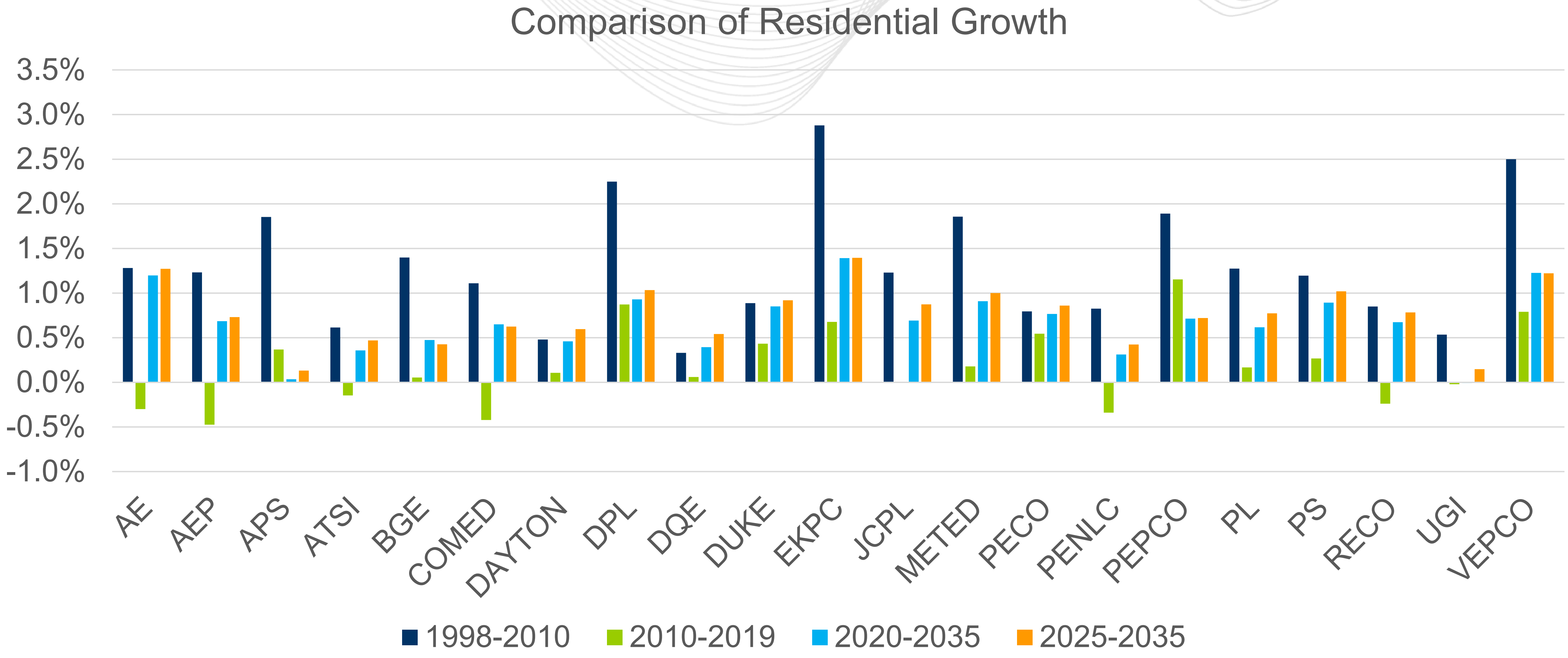


Summer End-Use Growth Decomposition – Long-Run Period

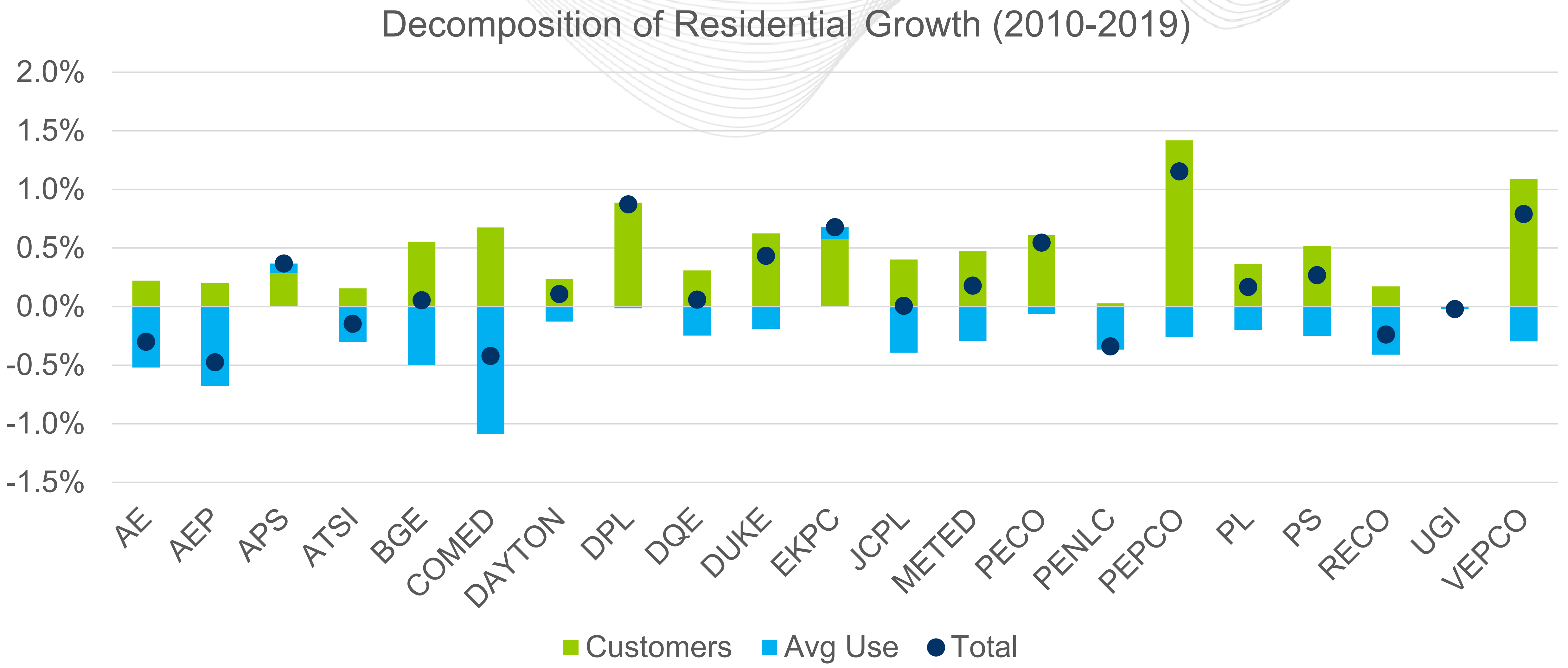


Residential

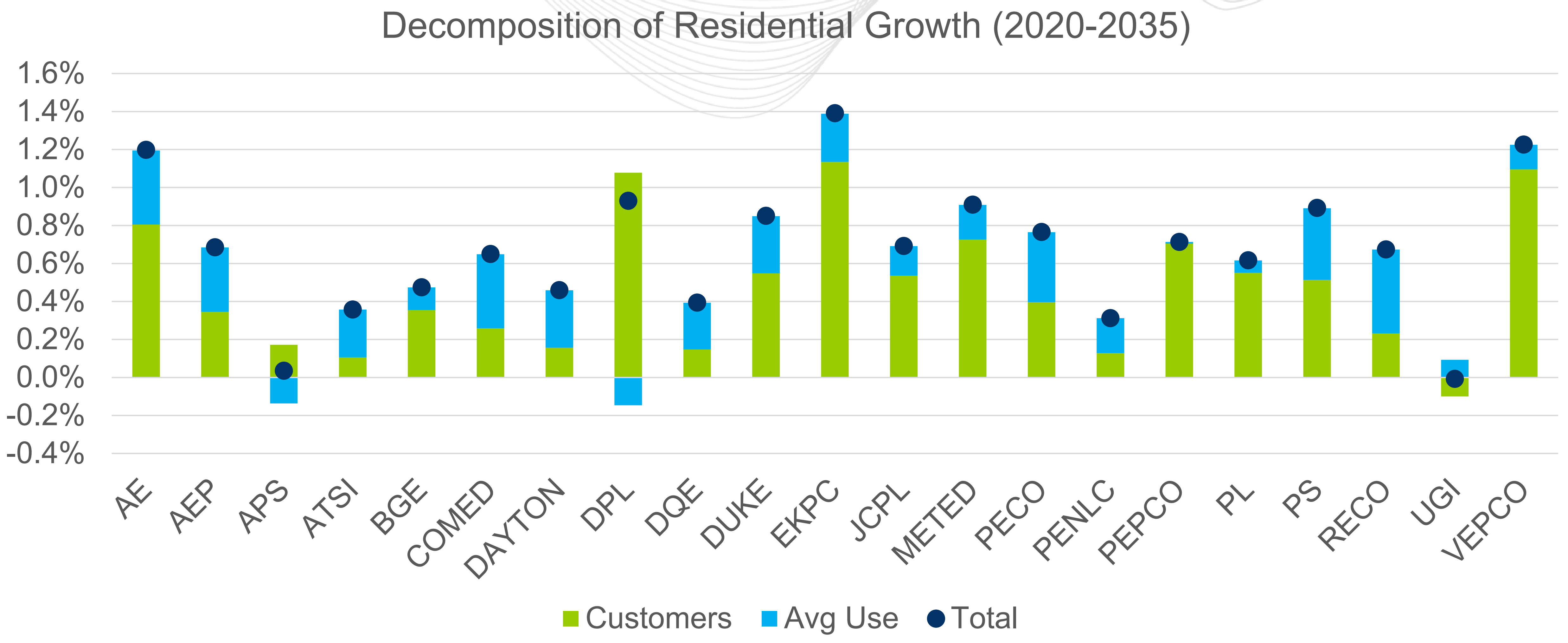
Residential Growth



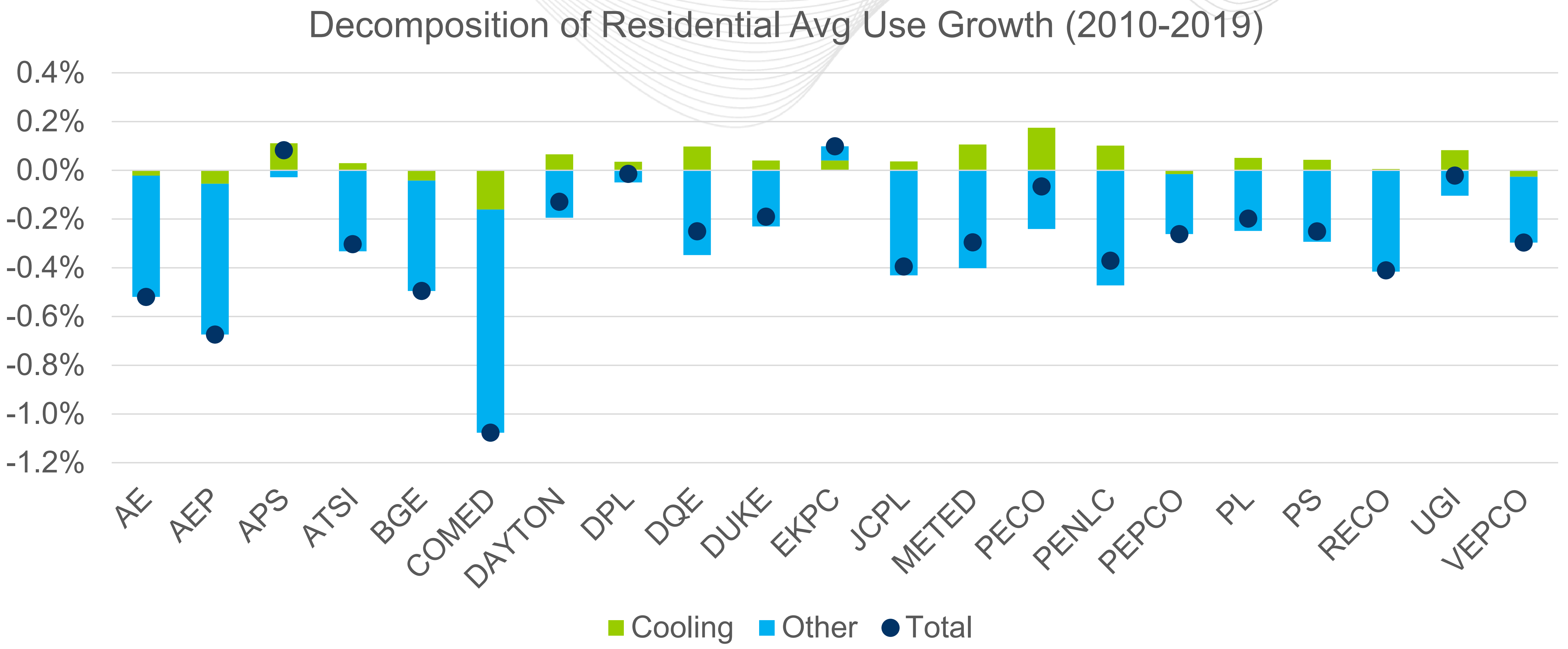
Residential Growth Decomposition



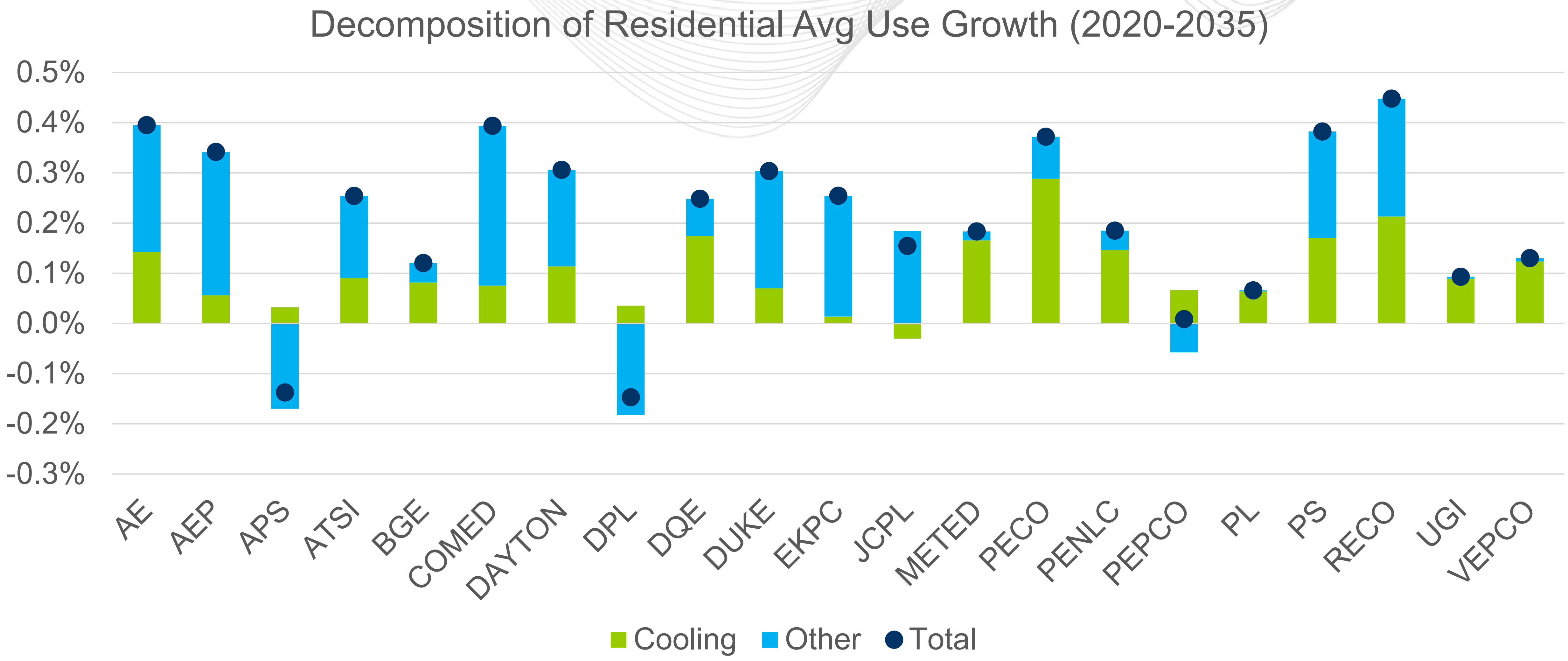
Residential Growth Decomposition



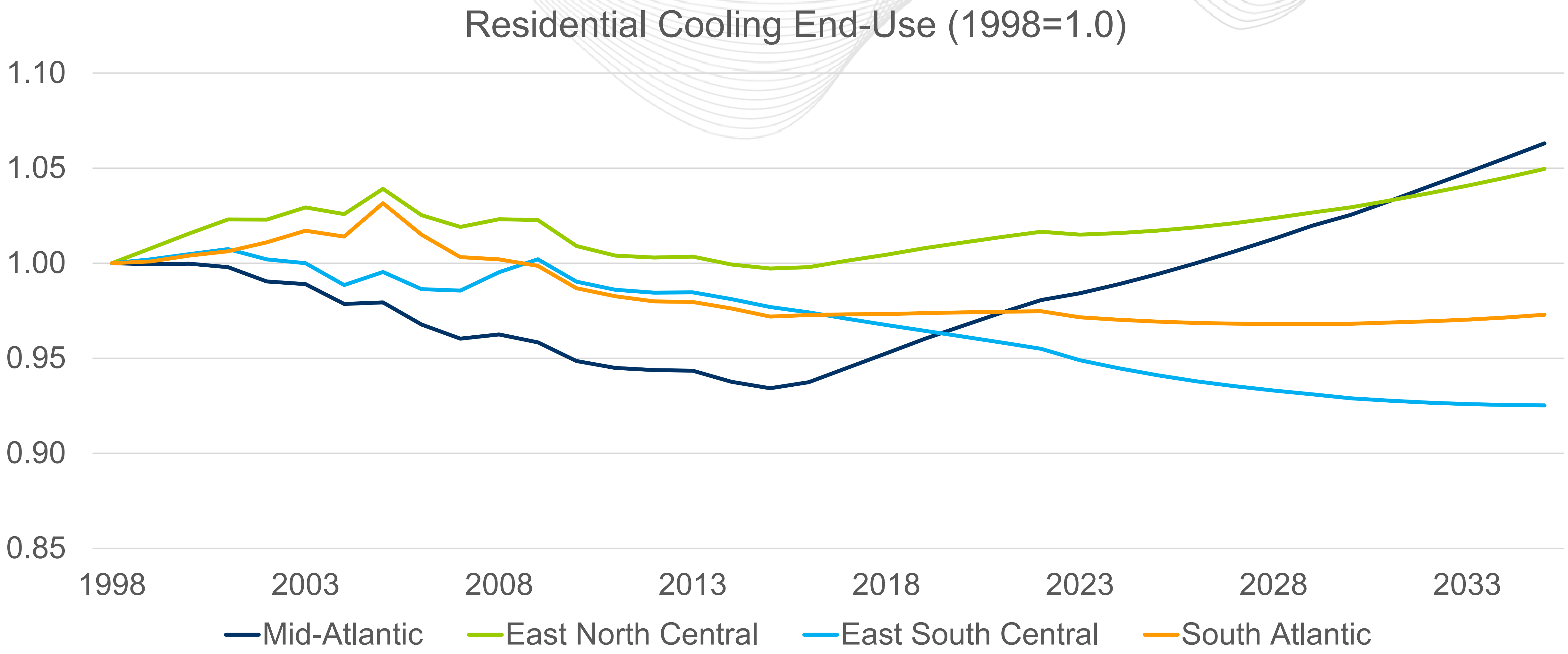
Residential Avg Use Decomposition



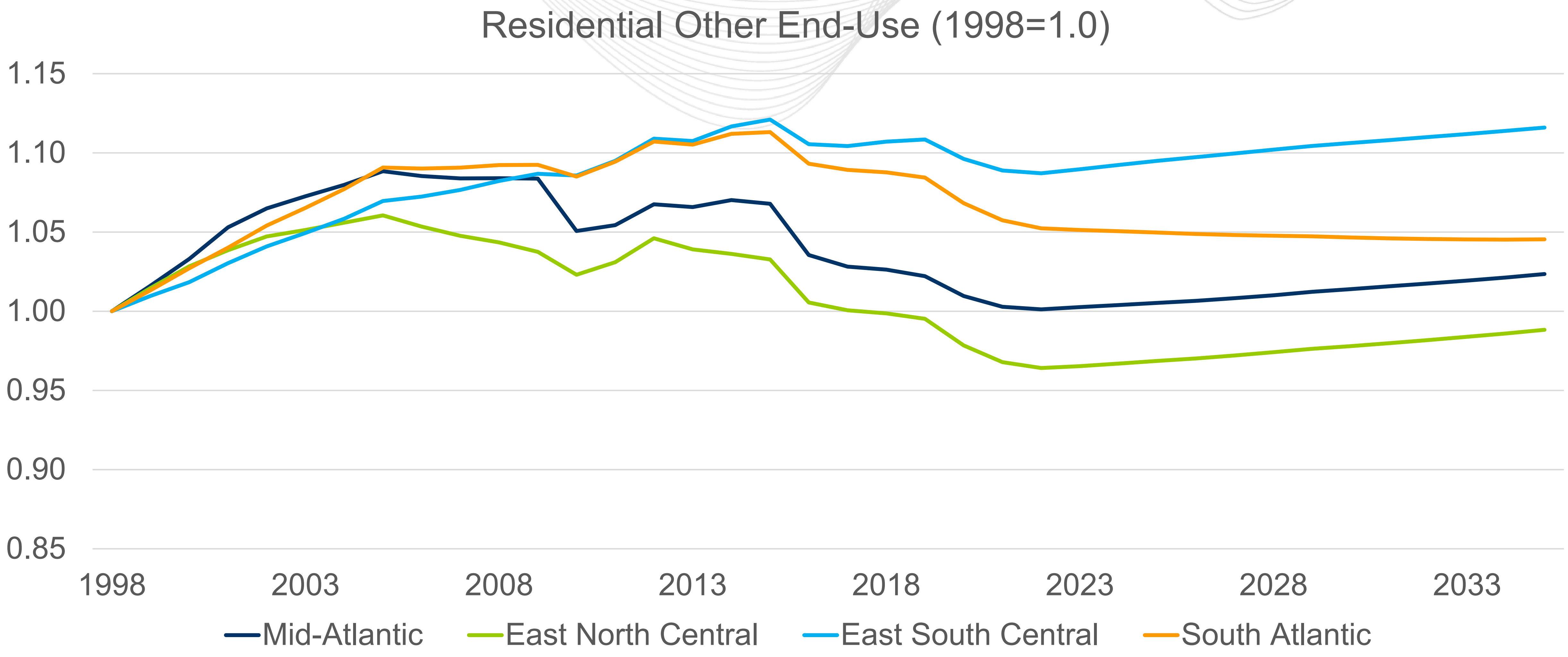
Residential Avg Use Decomposition



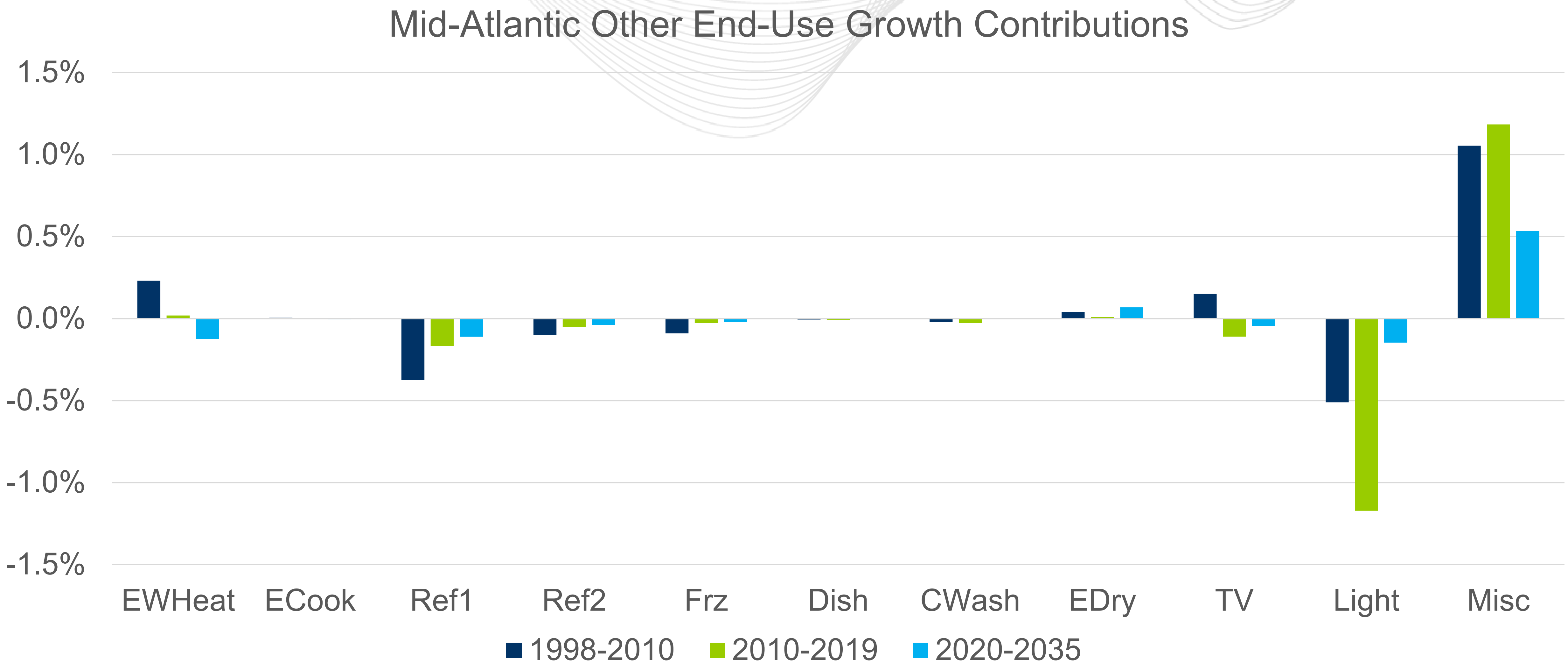
Residential Cooling End-Use Before Calibration Model



Residential Other End-Use Before Calibration Model

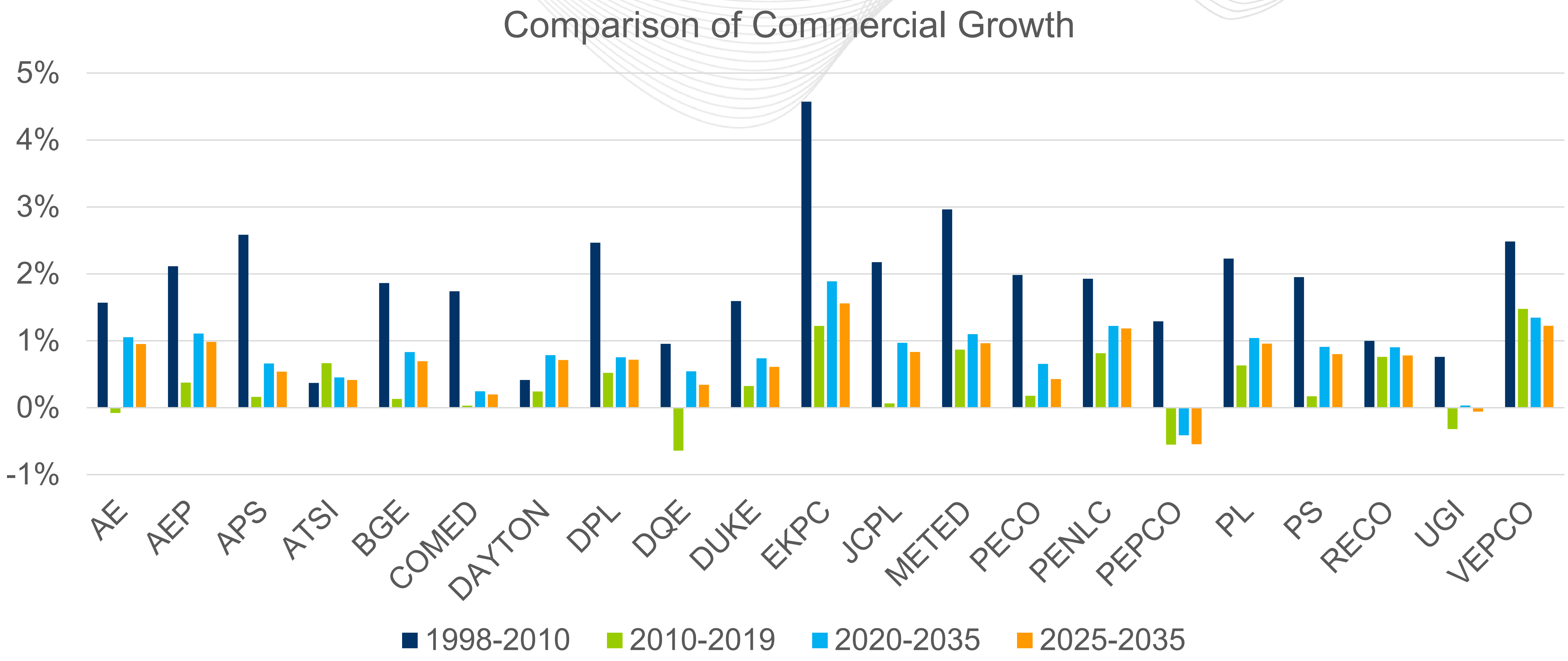


Residential Other End-Use Growth Decomposition

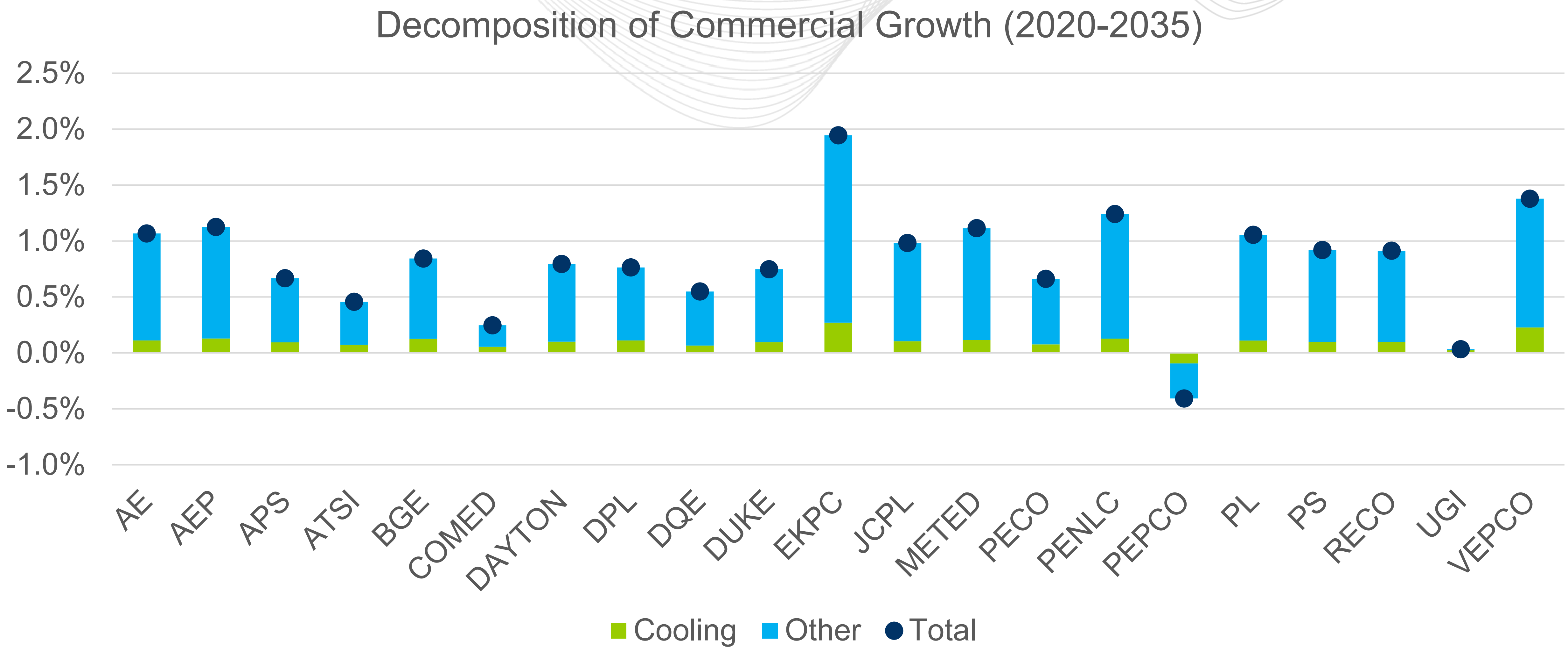


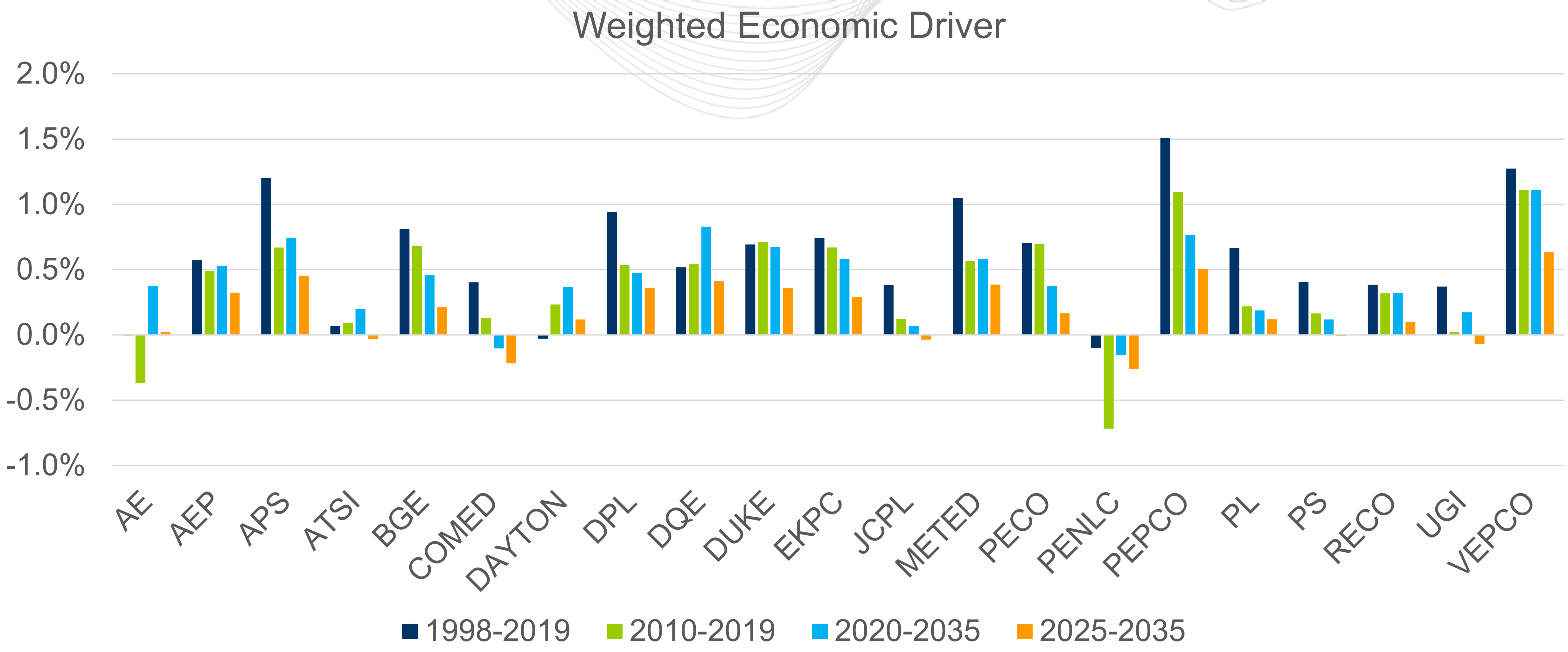
Commercial

Commercial Growth

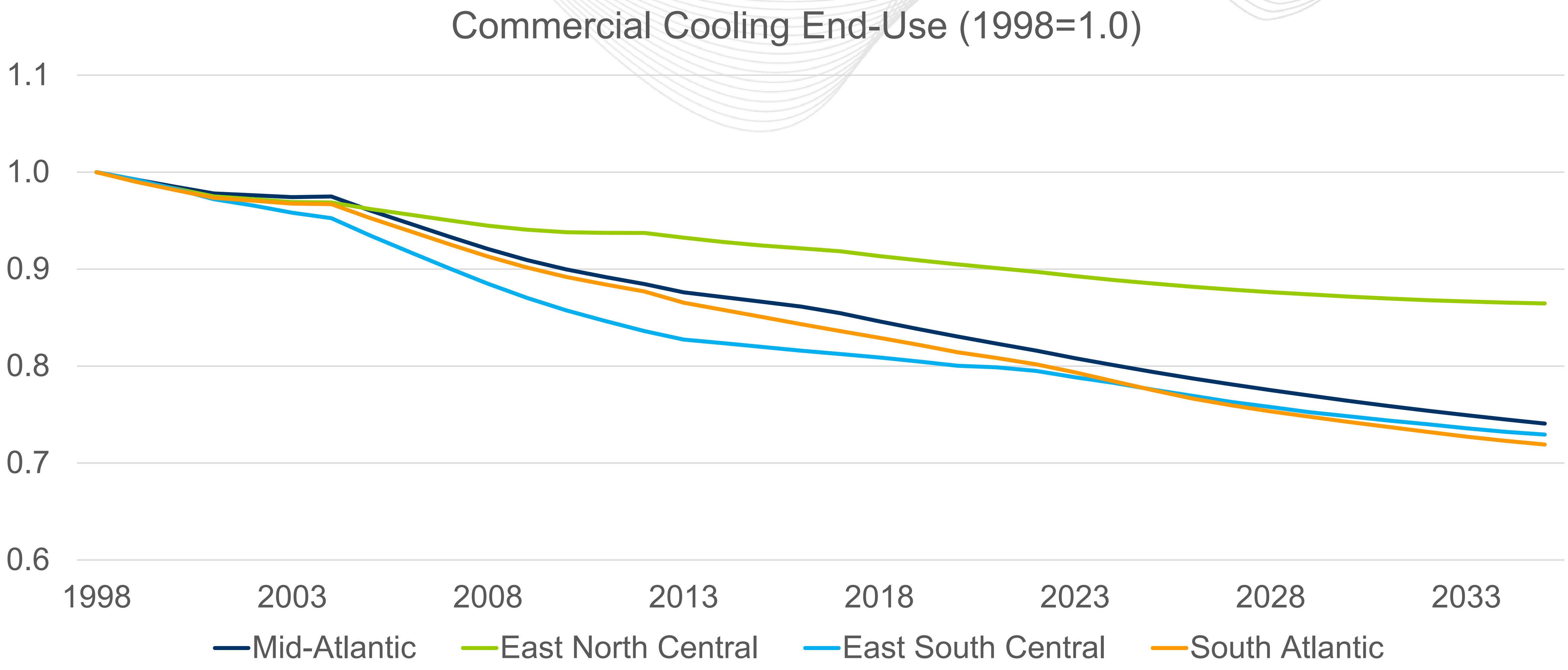


Commercial Growth Decomposition

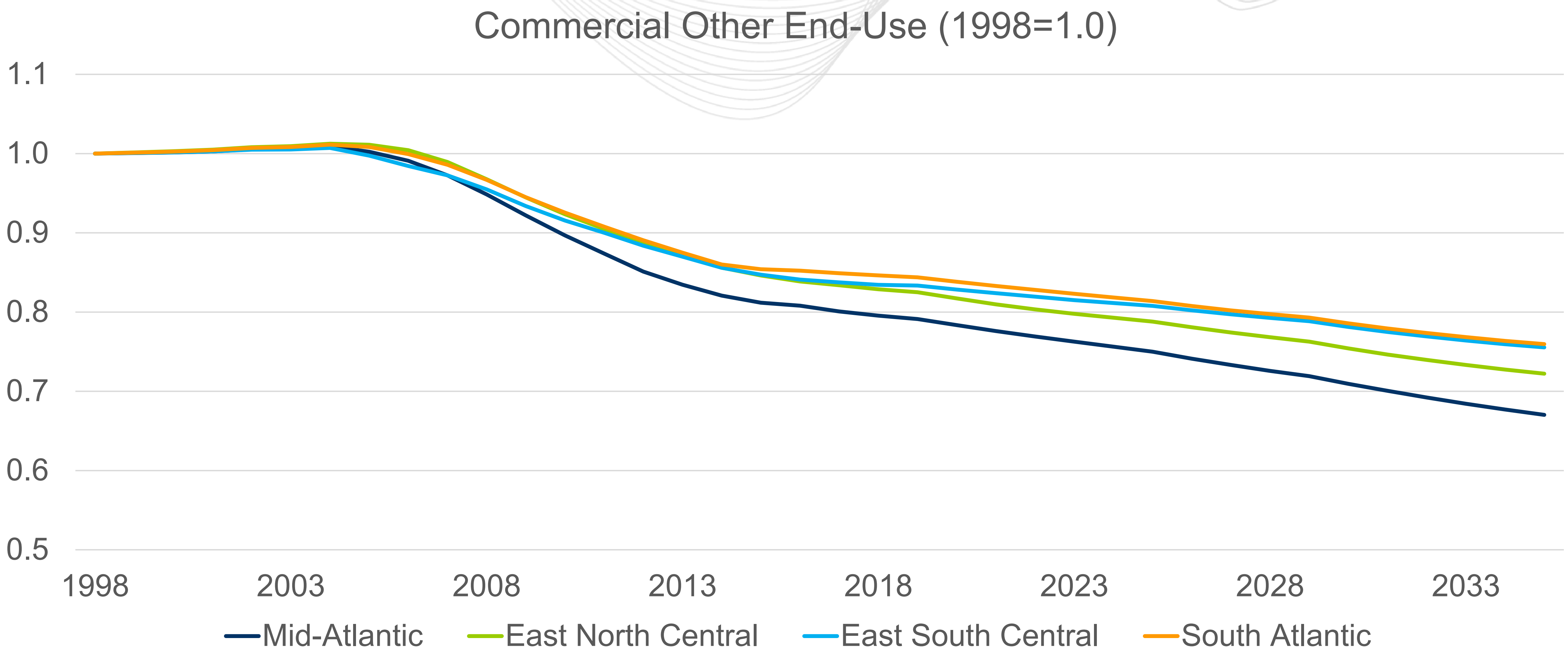



Weighted Economic Driver
2.0%
1.5%
1.0%
0.5%
0.0%
-0.5%
-1.0%
AE
AEP
APS
ATSI
BGE
COMED
DAYTON
DPL
DQE
DUKE
EKPC
JCPL
METED
PECO
PENLC
PEPCO
PL
PS
RECO
UGI
VEPCO
1998-2019
2010-2019
2020-2035
2025-2035

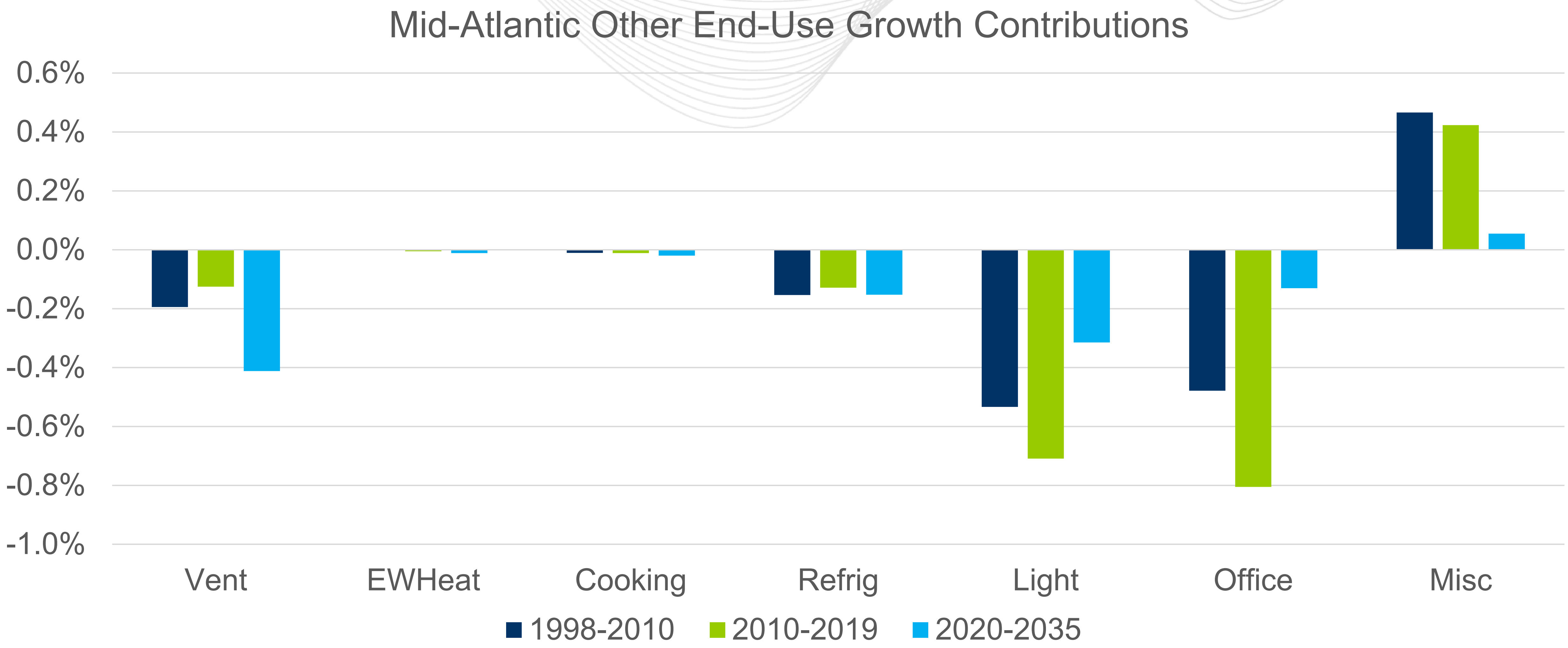
Commercial Cooling End-Use Before Calibration Model



Commercial Other End-Use Before Calibration Model

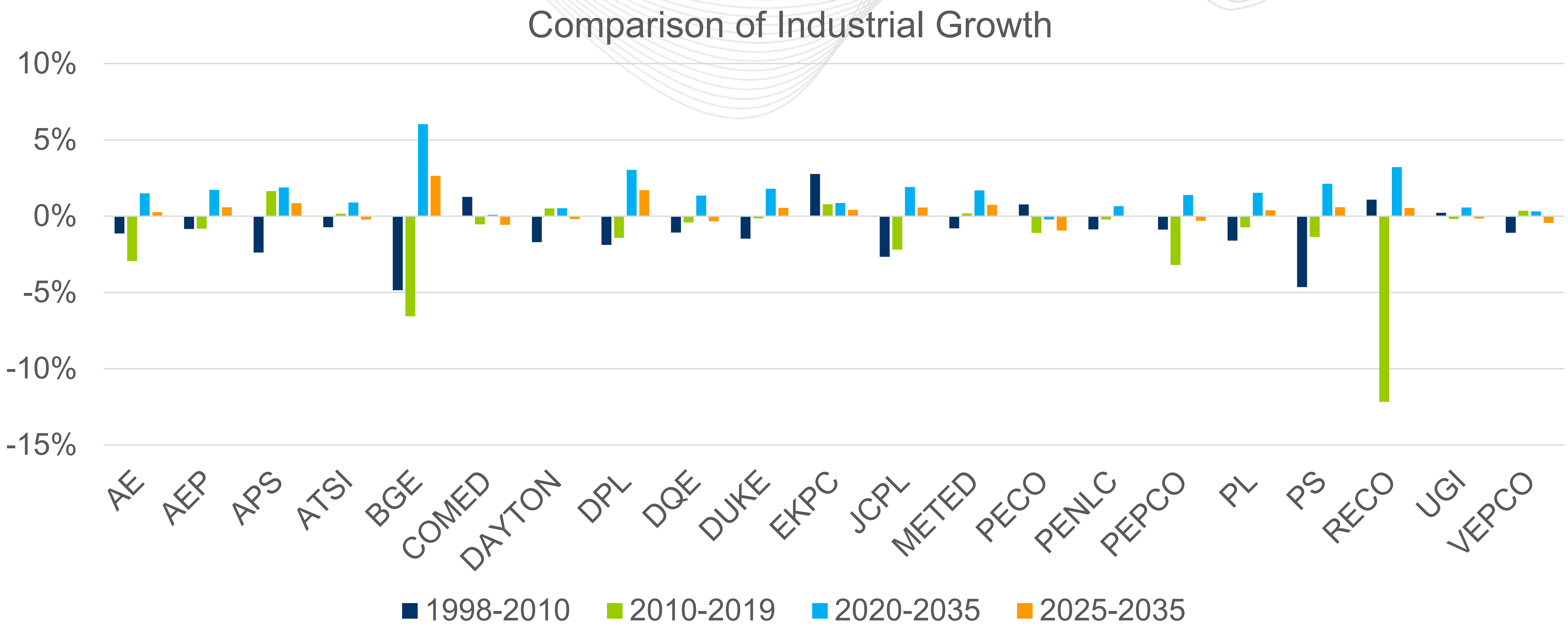


Commercial Other End-Use Growth Decomposition

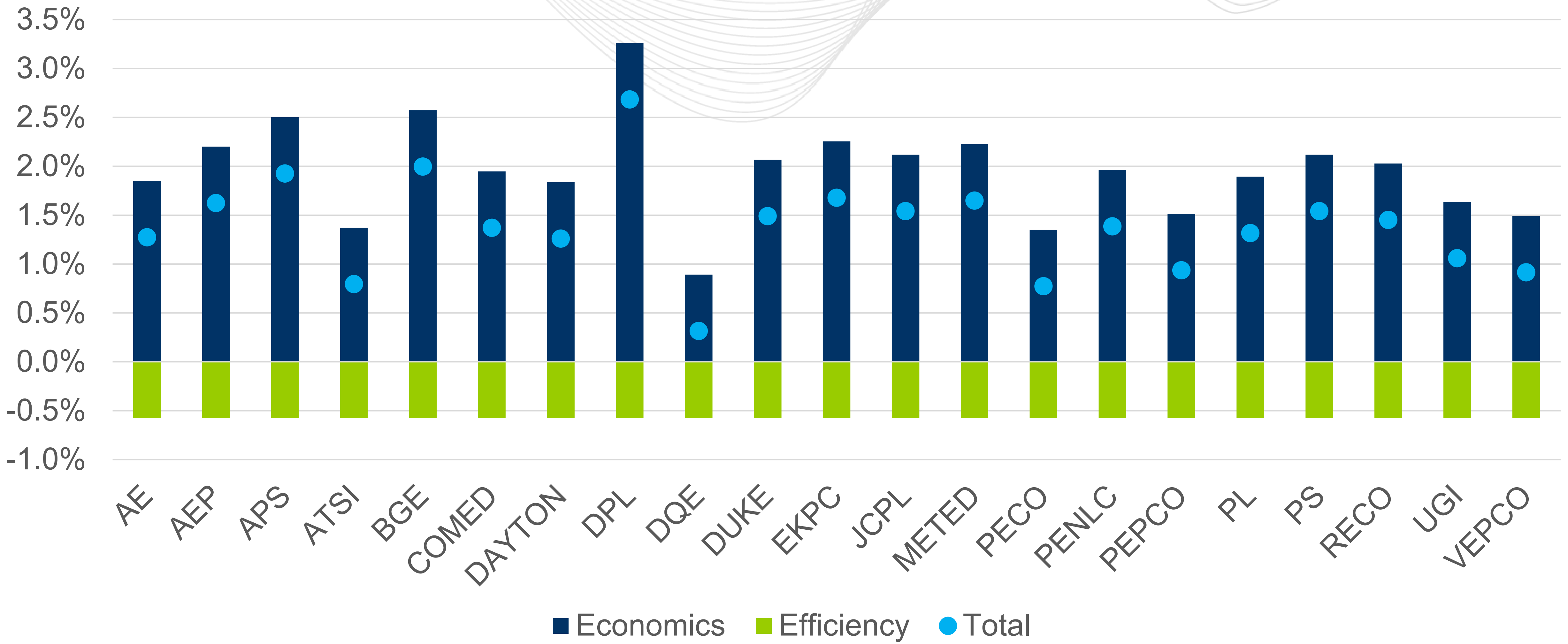


Industrial

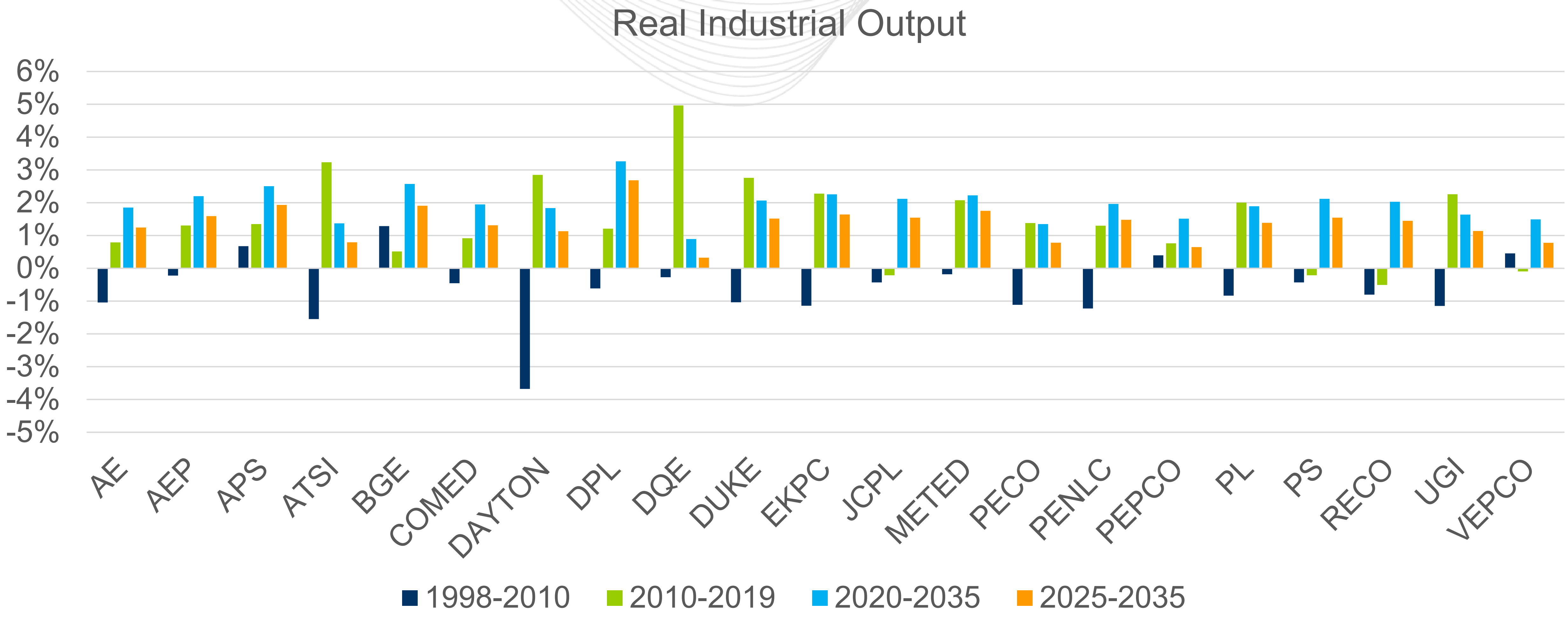
Industrial Growth



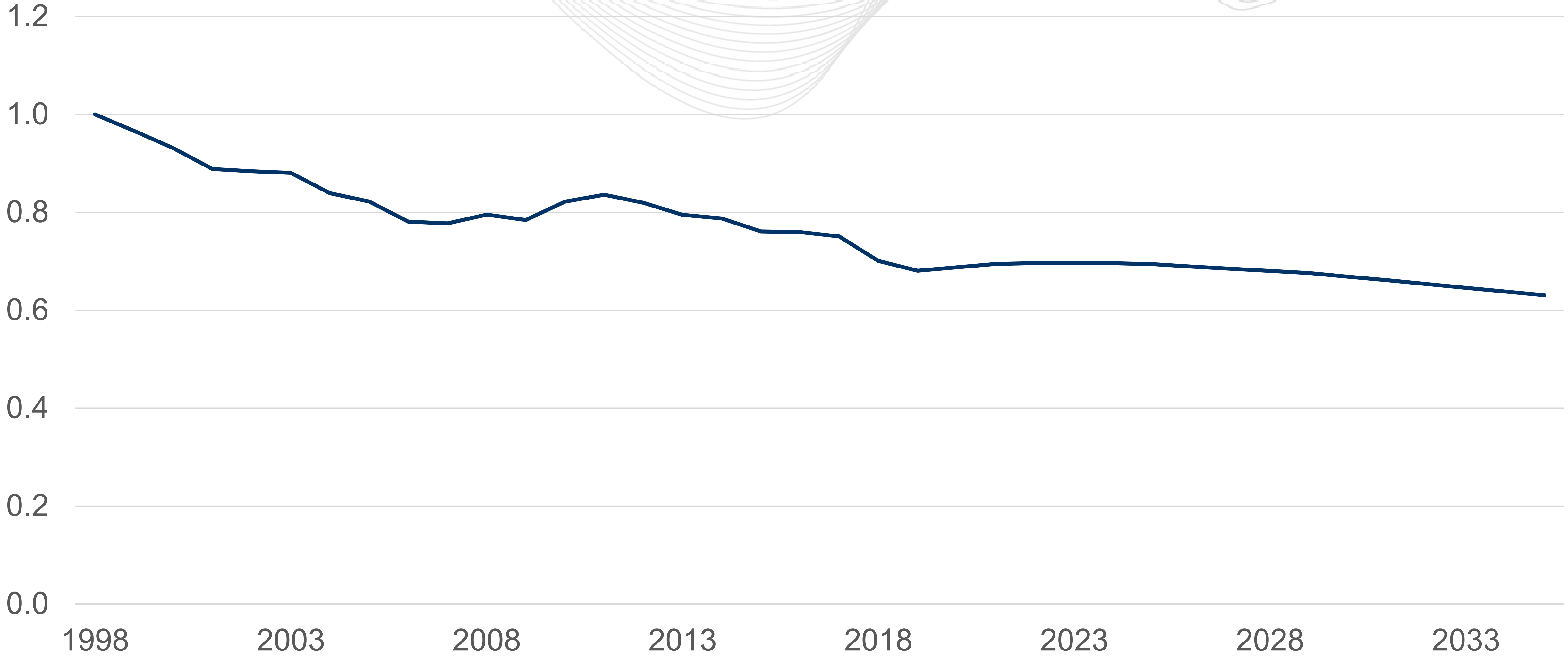
Industrial Driver Decomposition (2020-2035)



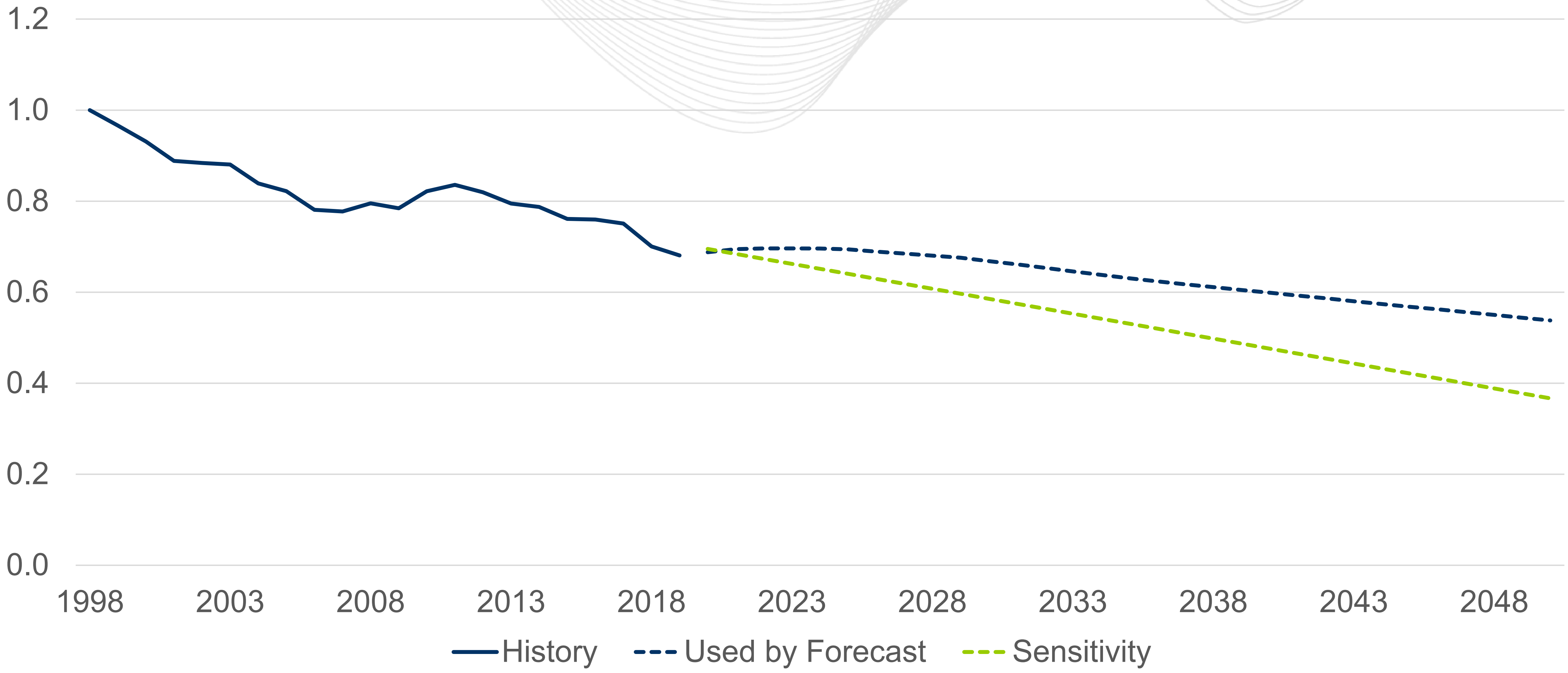
Industrial Economics Driver



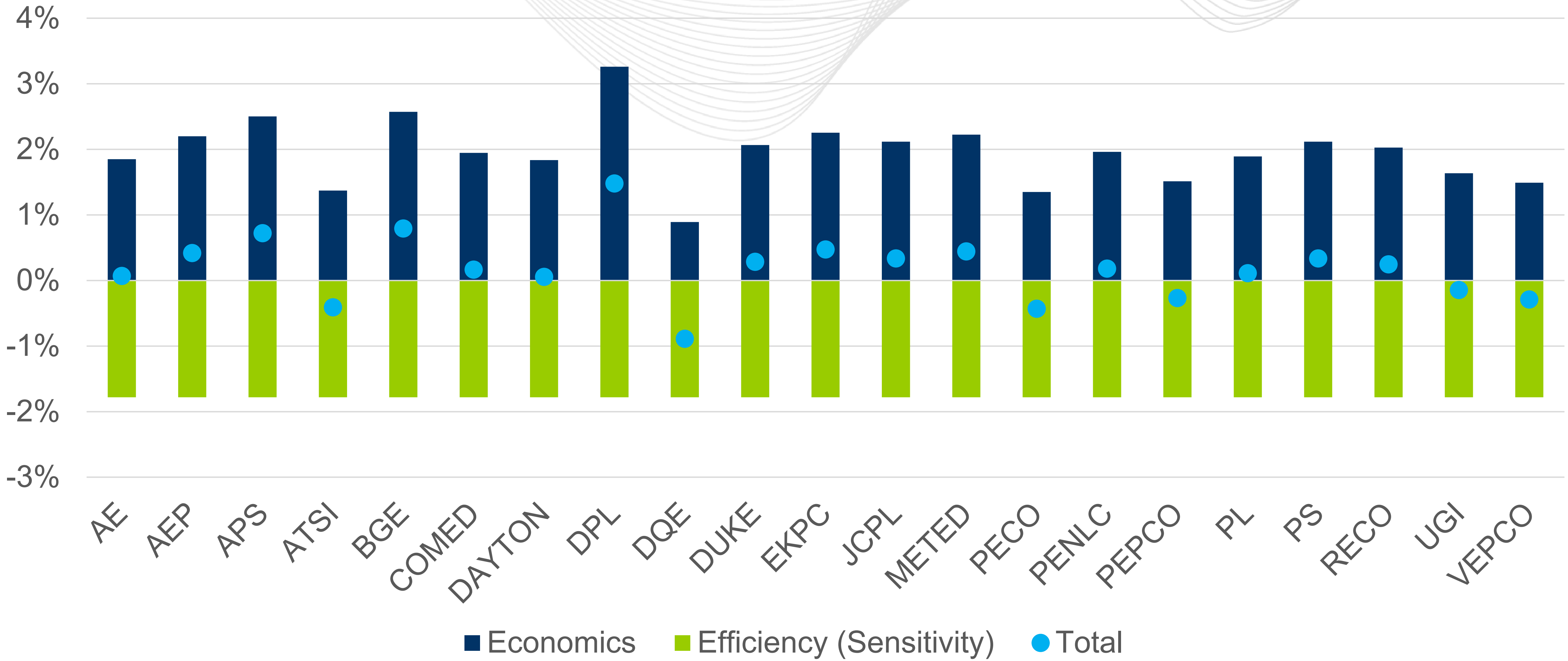
Electricity per Real Output (1998 = 1.0)



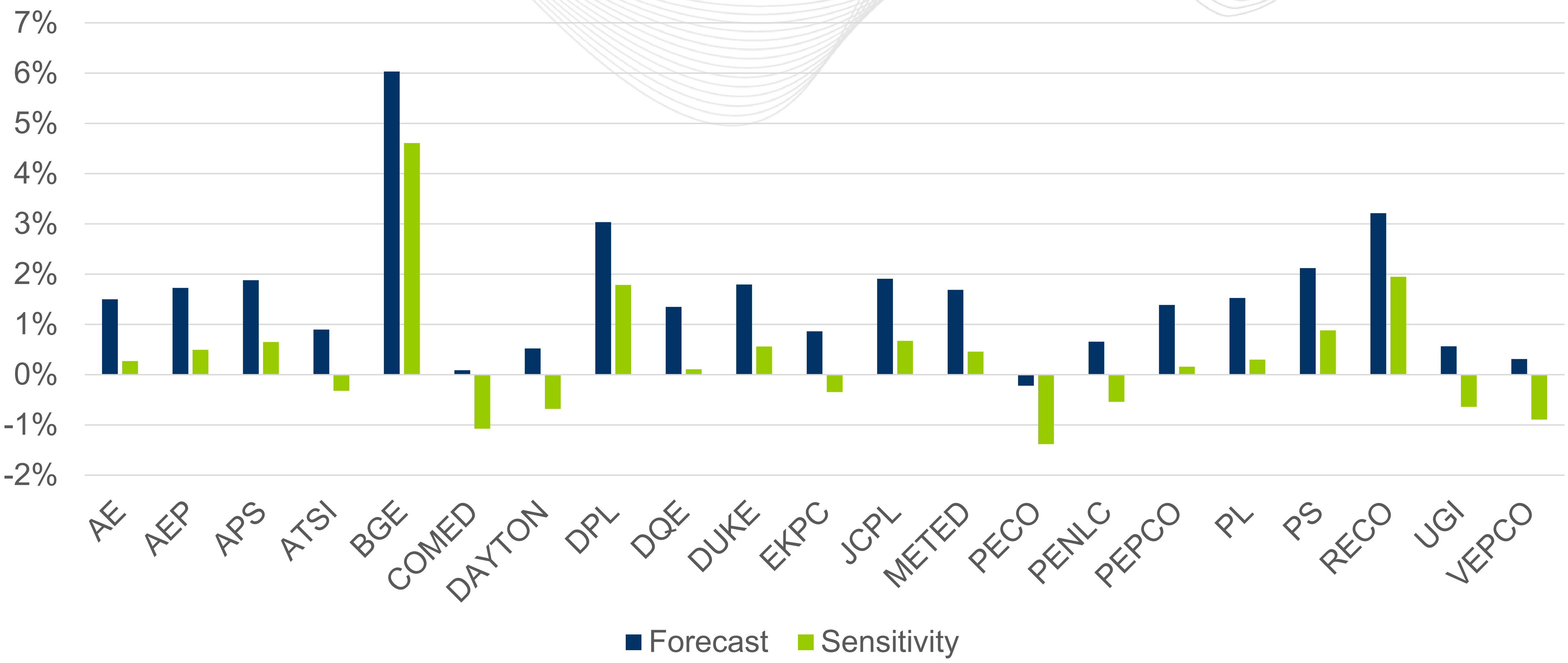
Electricity per Real Output (1998 = 1.0) - Sensitivity



Industrial Driver Decomposition (2020-2035) - Sensitivity

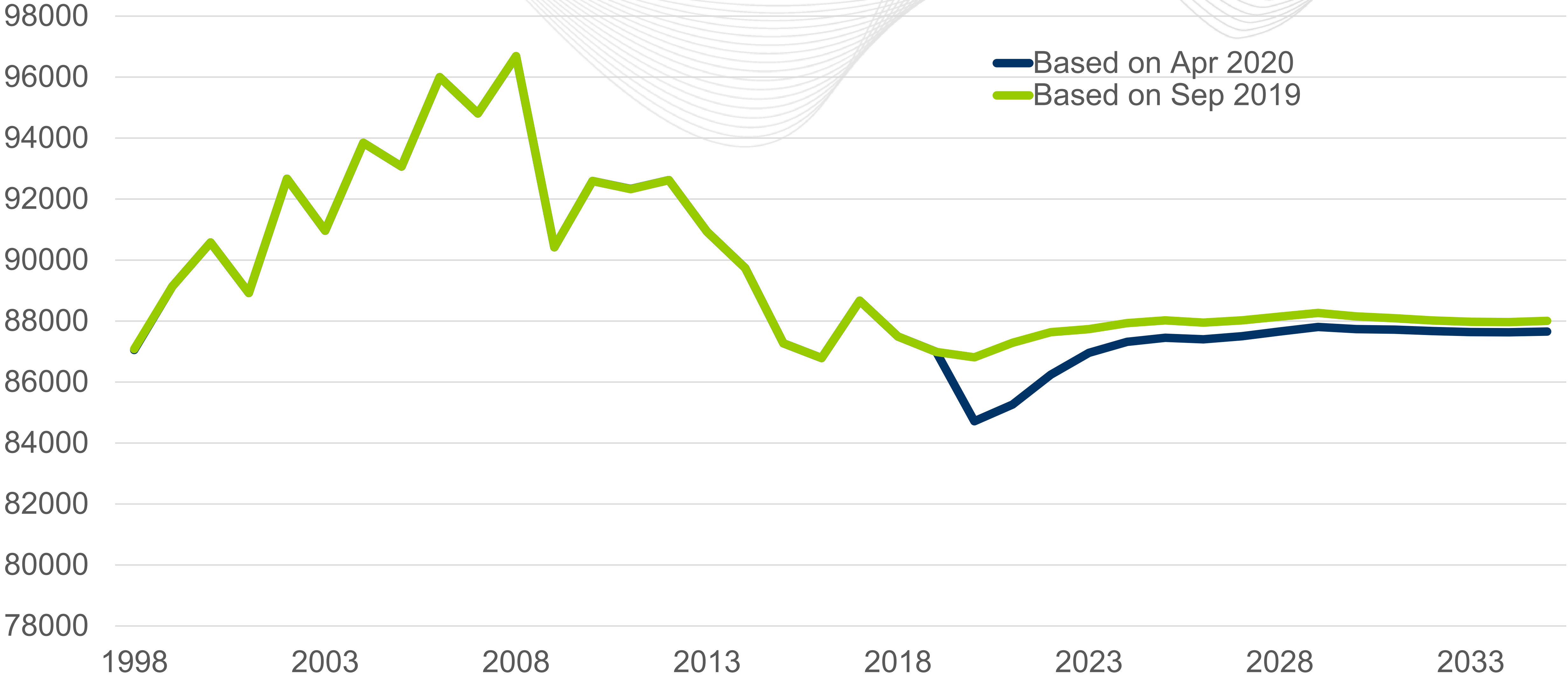


Industrial Growth (2020-2035) – Sensitivity Results



Non-Weather Sensitive

Non-Weather Sensitive – Effect of COVID-19



Sector Model Estimation Periods

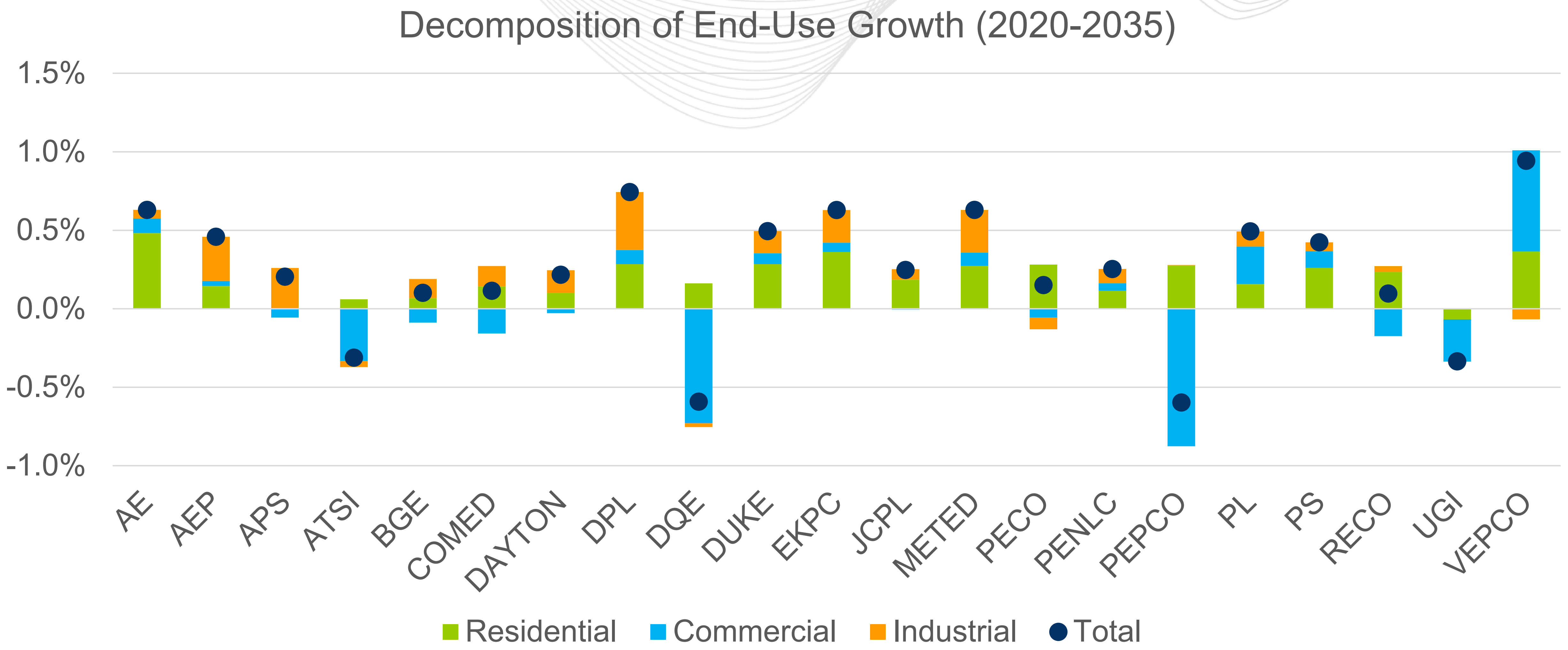
Estimation Period of Sector Models

- Residential, Commercial, and Industrial sector models are based on annual data. Because of data limitations, we use back to 1998. The 2021 Forecast will have data from 1998-2019 or 22 observations.
  - There is no rule on minimum observations.
  - Some say should target at least 10 observations per explanatory variable (sector models have 1-3 variables), thus ideally would have a minimum of 10-30 observations.
  - Stakeholder has expressed an interest in sector models only being run on most recent 10 years.
  - We have concerns that this would add instability in model fit.

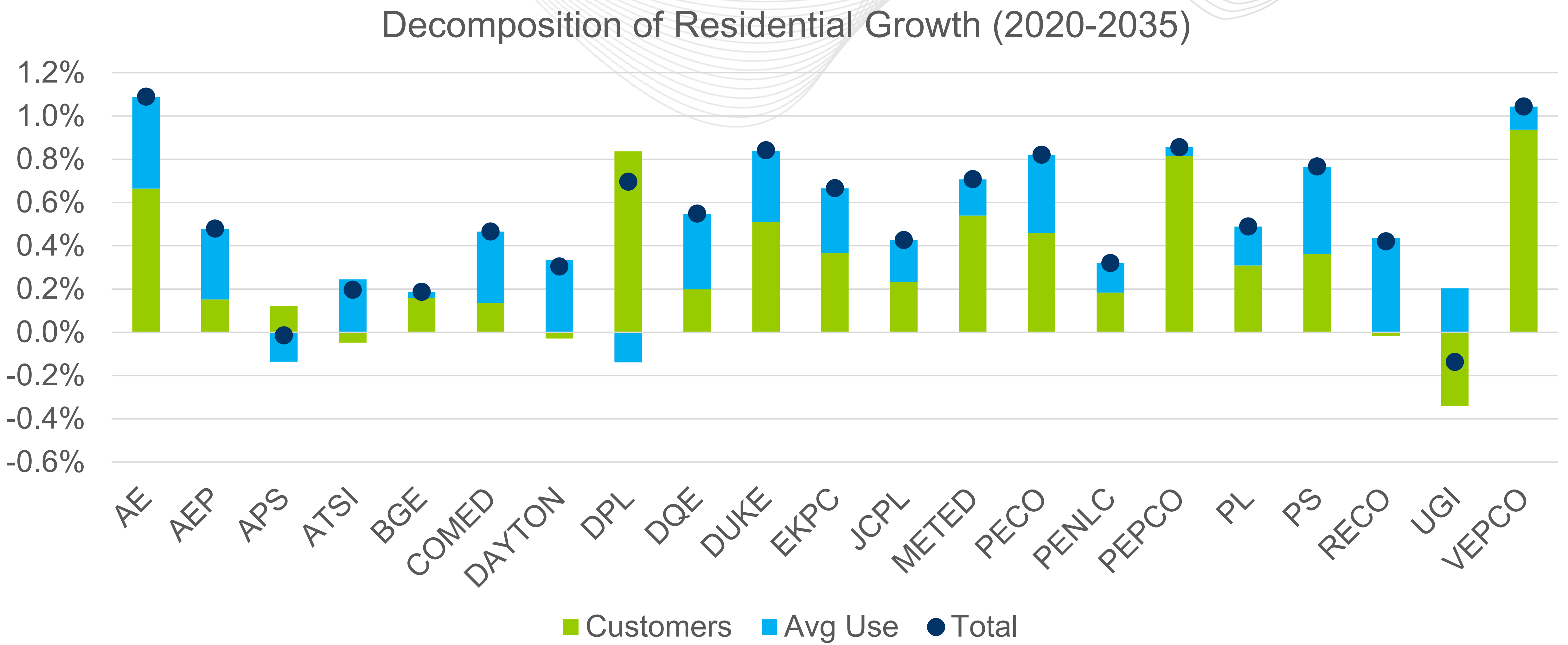
- Run Sector models used to calibrate end-use variables with data back to 2009. For a 2020 Load Forecast there would be sector data through 2018 (10 years).

- Run Non-Weather sensitive models with data back to 2009 to be consistent with Sector Model. Data for this model goes through 2019.

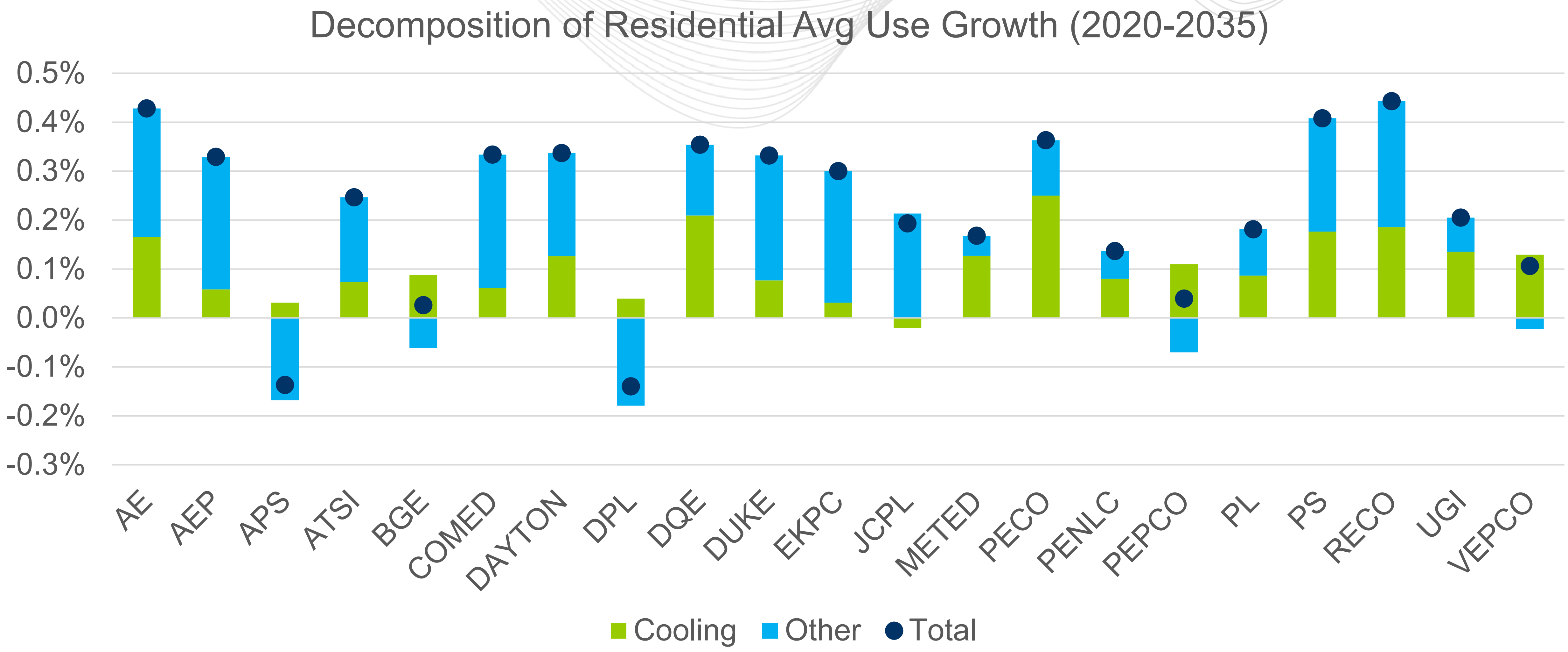
Overview of Sector Growth from Sensitivity



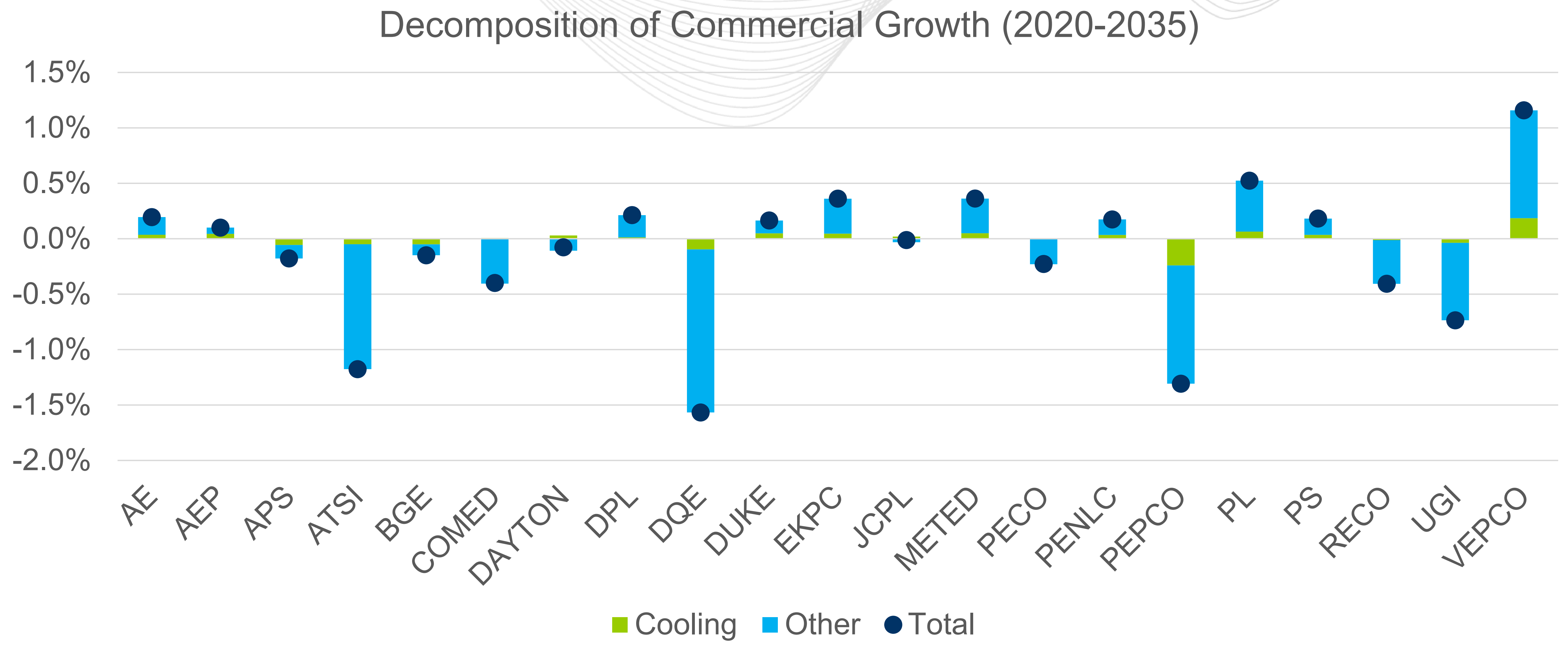
Residential Growth Decomposition - Sensitivity



Residential Avg Use Decomposition - Sensitivity

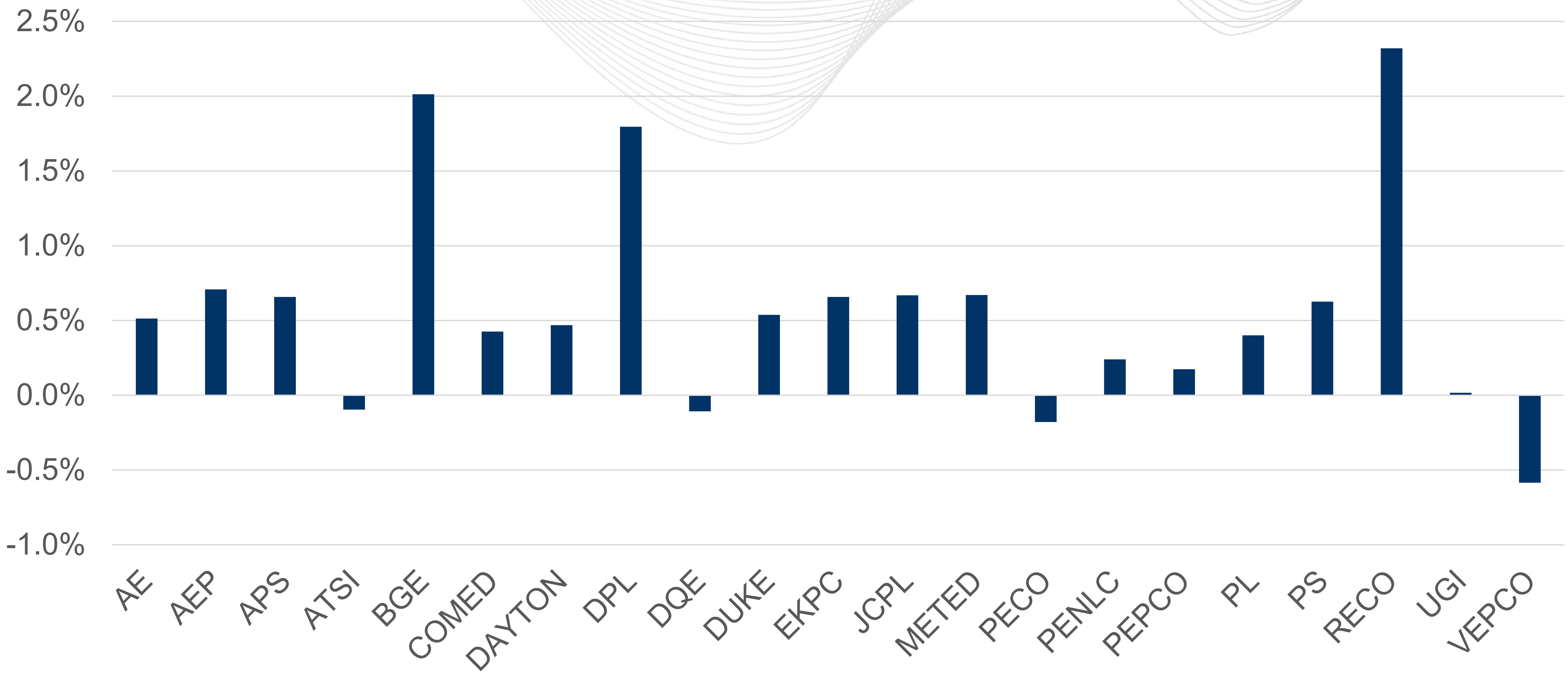


Commercial Growth Decomposition - Sensitivity

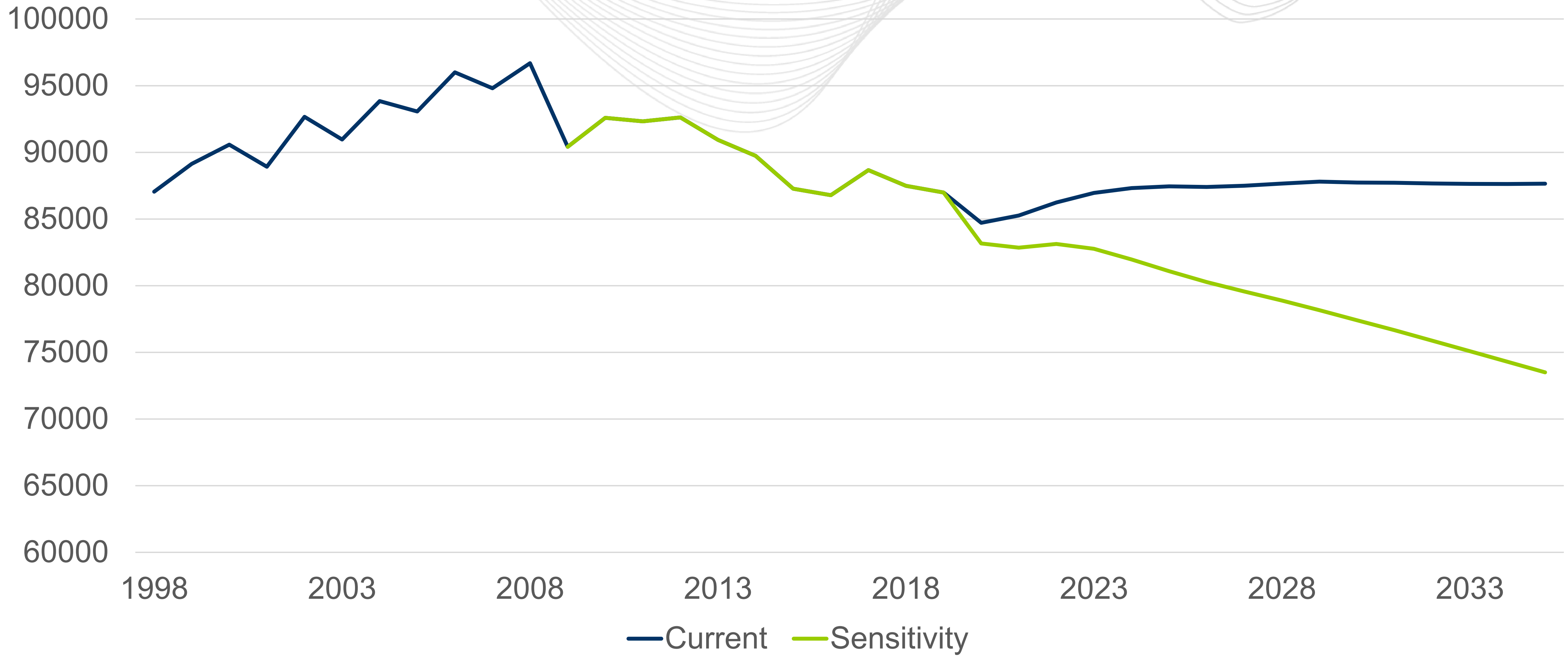


- In 8 of the zones modeled, coefficients on driver variable are not the correct sign (i.e. negative when should be positive). Cannot rely on a forecast where results are not consistent with theory.
  - Cause is likely tied to insufficient data for the model to produce stable/sound parameter estimates.

Industrial Growth - Sensitivity



Non-Weather Sensitive Load



Sensitivity Conclusion

- Commercial model results indicate that reducing the estimation period to 10 years is not stable.

- Non-weather sensitive results are not consistent with underlying drivers.
  - Negligible recovery from recession
  - Average annualized growth in the forecast period (-0.8%) exceeds that seen from 2010-2019 (-0.7%)
    - Realistic in the context of more modest efficiency gains?

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Load Forecast Model

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