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February 14, 2019

Power Demand Growth: What Does International Power Demand Growth Tells Us About the Outlook for the U.S. Power Sector?

Electricity generation in the contiguous 48 states totaled 4,014 million MWh in 2016, exceeding its pre-recession peak of 4,013 million MWh in 2007 after nearly a decade of stagnation. Flat U.S. power demand cannot be explained by the absence of population or economic growth; over the same period, the U.S. population grew by ~8% and U.S. GDP increased by ~12.5% in real terms. In this note, we examine the U.S. experience in an international context, and find that over the same period power demand has stagnated in every developed region of the world.

*Across the globe, the historical link between growth in generation and GDP has weakened markedly. In regions accounting for over 90% of global power output, generation has materially lagged GDP growth over the last five years. In the OECD countries of Europe, generation has lagged GDP growth by 1.1% p.a., in North America by 1.9% p.a., in Japan by 2.4% p.a. and in Australia and New Zealand by 2.9% p.a. (see **Exhibit 4**). Generation now lags GDP growth in the largest developing economies as well, including China and India. Globally, power demand growth over the last five years has lagged GDP growth by an average of 0.8% p.a.*

*While the International Energy Agency and others expect that the relationship between generation growth and GDP growth will soon revert to its historical mean, we are skeptical that U.S. power generation will accelerate in the years ahead. Consistent with our expectation, U.S. utilities' announced capex plans suggests that the industry is entering a period when capital expenditures will shift significantly, with stagnant electricity demand reducing the need for investment in generation and transmission while customer growth, grid hardening, the rollout of smart grid technologies and the advent of electric vehicles drive increased capex on the distribution grid (see **Exhibit 17**).*

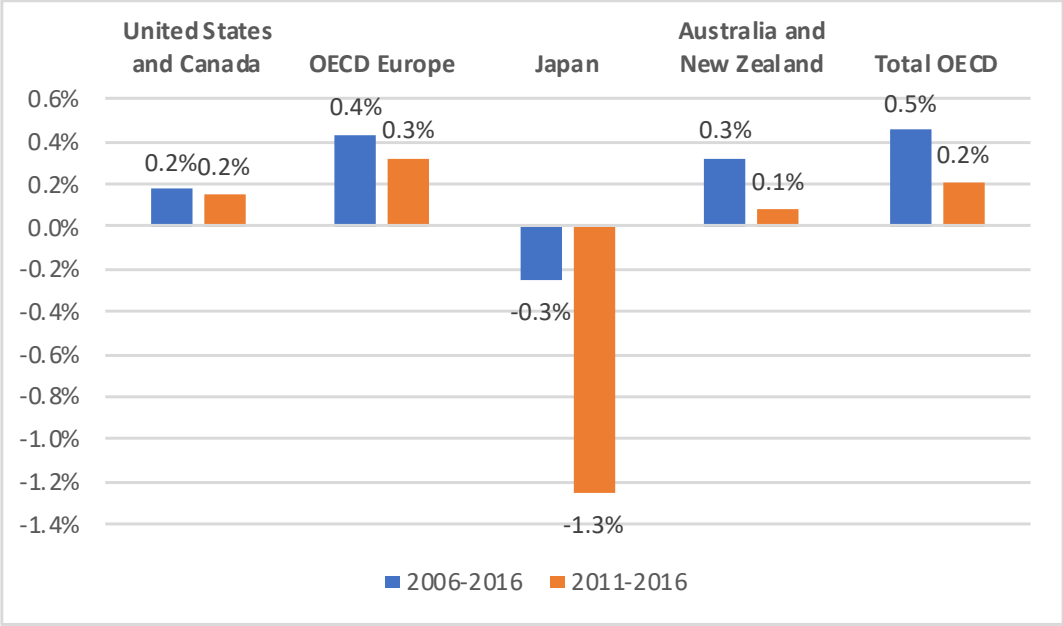
Two frequently mentioned drivers of a potential recovery in power demand are electric vehicles and cryptocurrencies (e.g. Bitcoin). Yet the 200,000 plug-in electric vehicles sold in the U.S. in last year added only two basis points to power demand. If EV sales continue to accelerate, however, this could change in the long term; by 2025-2030, EV sales could reach 2 million per year. If these sales include heavy duty as well light duty vehicles, every 1 million new vehicles could add 0.13% to U.S. power demand. By contrast, given that power consumption for cryptocurrencies is only ~0.10%-0.15% of total U.S. demand, our analysis suggests that, at current Bitcoin prices, mining demand is unlikely to grow rapidly enough to have a meaningful impact on aggregate U.S. electricity consumption.

*The limited potential for meaningful demand growth over the next decade supports our view that, within the electric utility industry, the most favorable long-term growth prospects may exist among transmission and distribution rather than vertically integrated utilities, and particularly those positioned to maximize capital expenditures and rate base growth in the distribution segment (see **Exhibit 20**). Of the publicly traded utilities whose regulated subsidiaries have the highest percentage of rate base growth in the transmission and distribution segments, we rank five among our most preferred utility stocks: Edison International (EIX), Exelon (EXC), PG&E (PCG), FirstEnergy (FE) and American Electric Power (AEP). (See **Exhibit 21**).*

Portfolio Manager's Summary

- As illustrated in **Exhibit 1** below, over the last decade, ***demand for electricity has stagnated in each of the high-income regions of the globe.***
  - Generation on the interconnected North American power grid, comprising the United States and Canada, has expanded at 0.2% p.a. over the 10 years from 2006 through 2016.
  - In the OECD countries of Europe, generation has expanded 0.4% p.a. over this period.
  - In Japan, generation has *contracted* at an 0.3% annual rate over 2006-2016.

Exhibit 1: CAGR in Electricity Generation in High Income Regions, 2006-2016



Source: OECD and U.S. Information Administration

- ***Only in the developing economies of the world is generation growing at significant rate*** (see **Exhibit 2**).
  - In the non-OECD countries of Asia (dominated by China and India), generation expanded 7.3% annually over 2006-2016.
  - Lower but still rapid rates of growth were realized in the Middle East (4.4% p.a.), Africa (3.1% p.a.) and the non-OECD countries of the Americas (2.6% p.a.).

- ***Importantly, growth in generation is decelerating across the globe.*** In both developed and developing regions, the growth in generation over the last five years (2011-2016) was slower than that over the preceding five years (2006-2011) (see **Exhibit 2**), despite the fact that the prior five were those that spanned the global financial crisis.

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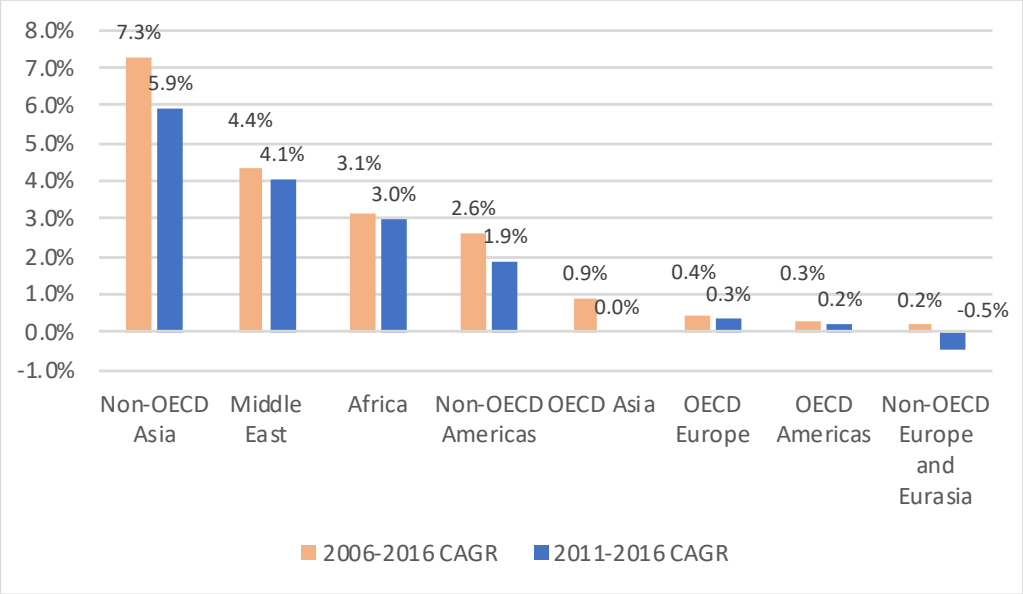
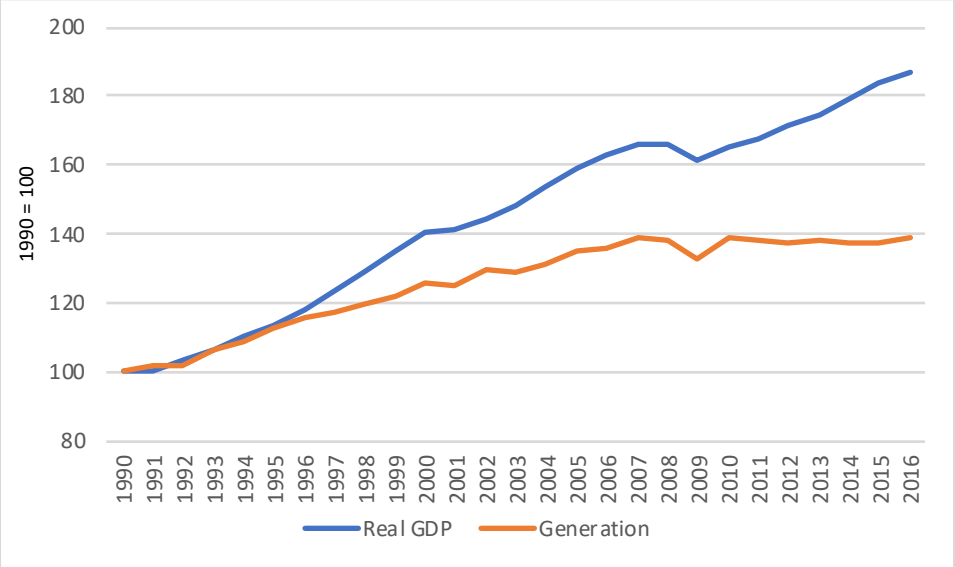
Exhibit 2: Growth in Generation by Region, 2006-2016 and 2011-2016 CAGRs



Source: OECD and U.S. Information Administration

- ***Generation growth is increasingly lagging the growth of population and GDP.*** The contrast is particularly stark in the United States, where power generation remained unchanged over the ten years from 2006 through 2016, while the U.S. population grew by ~8% and U.S. GDP increased by ~12.5% in real terms (see **Exhibit 3**).

Exhibit 3: US GDP (Constant 2009 Dollars) vs. US Power Generation (Millions of MWh) (Indexed so that 1990 = 100)



Source: Bureau of Economic Analysis, U.S. Energy Information Administration

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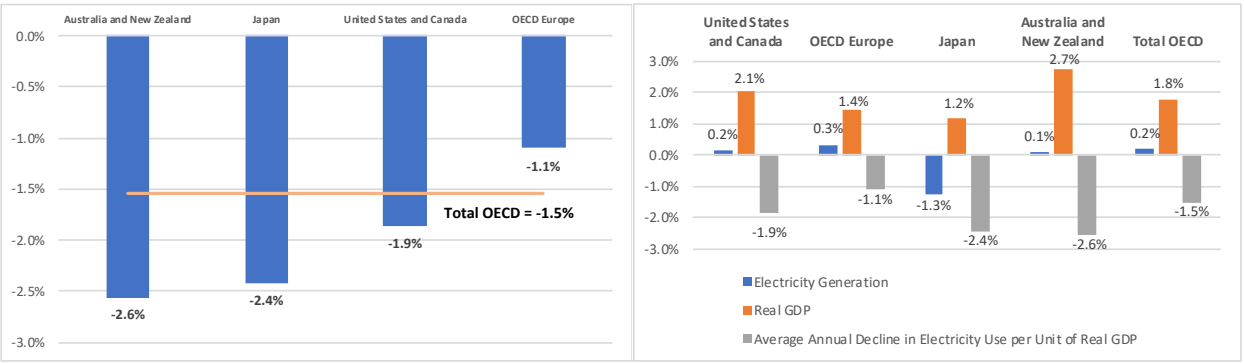
- ***The phenomenon of generation lagging economic output is found across all the high income regions of the world*** (see **Exhibit 4**).
  - Across the OECD member countries as a group, the growth in electricity generation has lagged the growth of real GDP by 1.5% p.a. over the last five years (2011-2016).
  - The disparity between growth in generation and growth in GDP was lowest in OECD countries of Europe (1.1 pa.) and highest in Australia and New Zealand (2.6% p.a.) and Japan (2.4% p.a.).
  - Generation on the North American power grid linking Canada and the United States lagged GDP growth in these countries by 1.9% over the last five years.

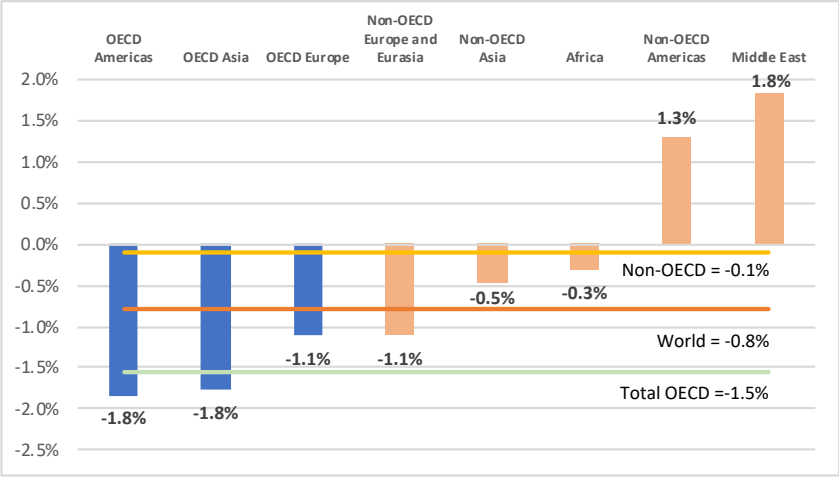
Exhibit 4: Average Annual Decline in Electricity Use per Unit of GDP (1), 2011-2016, High Income Regions



Source: OECD, U.S. Energy Information Administration

- ***Electricity generation is also lagging economic output in many developing economies.*** In Africa, electricity generation lagged GDP growth by 0.3% p.a. over 2011-2016; in the non-OECD countries of Asia, dominated by China and India, generation lagged GDP by 0.5% p.a. over the last five years; and in the non-OECD countries of Europe and Eurasia, including Russia, the gap was 1.1% p.a. (see **Exhibit 5**).

Exhibit 5: Average Annual Decline in Electricity Use per Dollar of GDP (1) 2011-2016, All Regions



1. Constant 2010 US$; GDP calculated at purchasing power parity
Source: OECD, U.S. Energy Information Administration

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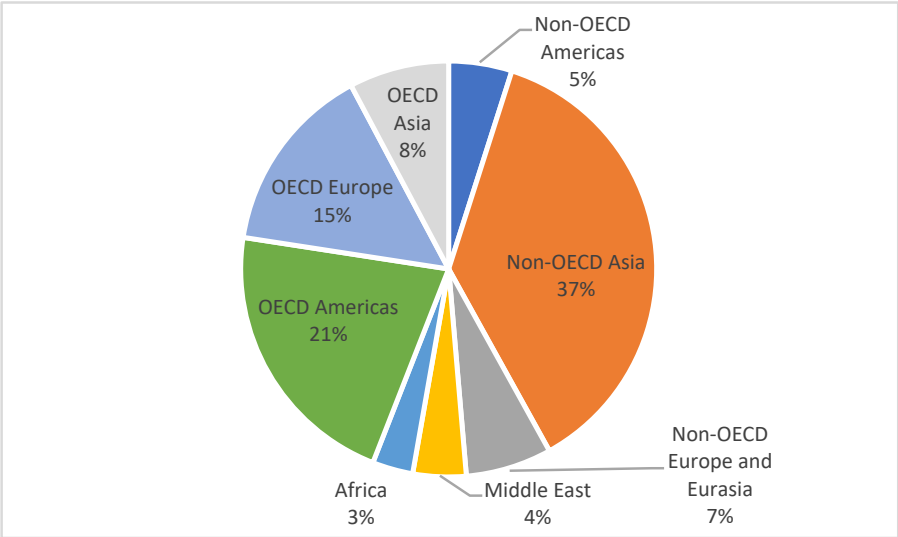
- To summarize these facts in a global context, over 2011-2016:
  - The OECD member countries of the world, which account for 44% of global power output, saw generation grow by 0.2% p.a., sustaining aggregate GDP growth of 1.8% p.a.;
  - The non-OECD countries of Europe and Eurasia, which account for 7% of global power output, saw generation *fall* by 0.5% p.a. while GDP grew by 0.4% p.a.;
  - In the non-OECD countries of Asia, which include China and India and account for 37% of global power output, generation rose by 5.9% p.a., lagging aggregate GDP growth of 6.4% p.a.;
  - Only in the Middle East and the non-OECD countries of the Americas, which together account for 9% of total power output, did generation growth exceed growth in GDP.

Exhibit 6: Breakdown of Global Generation by Region, 2016



Source: OECD, U.S. Energy Information Administration

- ***In regions accounting for over 90% of global power demand, in other words, growth in generation has materially lagged growth in GDP over the last five years.***

- ***Interestingly, however, various governmental and inter-governmental agencies expect this trend to reverse, with generation growth forecast to revert, in the high income regions of the world, to a ratio of GDP similar to that seen in prior decades.***
  - In its base case forecast, for example, the International Energy Agency assumes that the ratio of growth in generation to growth in GDP reverts to a range of 0.2x to 0.4x in the high income regions of the world, resulting in long term rates of growth (2016-2025) in generation of 0.7% p.a. in the U.S. and Canada, up sharply from 0.2% p.a. over the last five years; 0.5% p.a. in the OECD countries of Europe, up from 0.3% p.a. over the last five years; and approximately 0% in Japan, up from a negative 1.3% p.a. over the last five years (see **Exhibit 7**).

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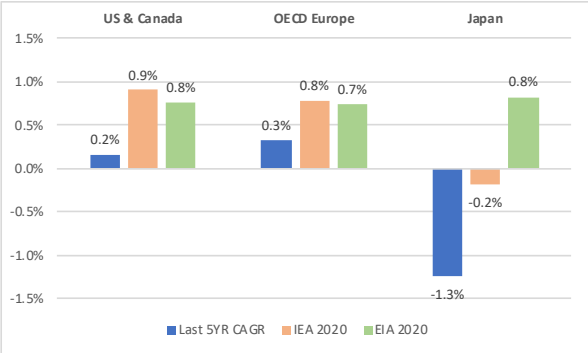
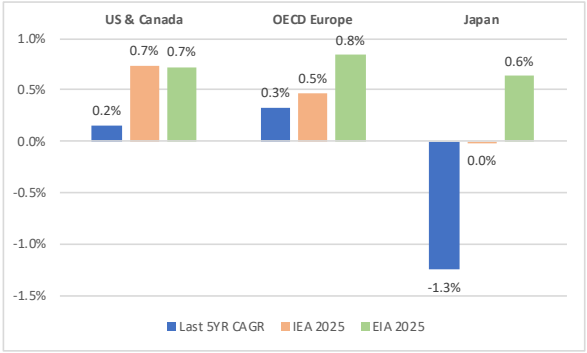
- Similarly, the U.S. Energy Information Administration foresees generation growth in the long term (2016-2025) recovering to 0.7% p.a. in North America, 0.8% p.a. in the OECD countries of Europe and 0.6% p.a. in Japan.

Exhibit 7: Generation in the High-Income Countries: 2011-2016 CAGR vs. IEA & EIA Forecasts

2016-2020



2016-2025

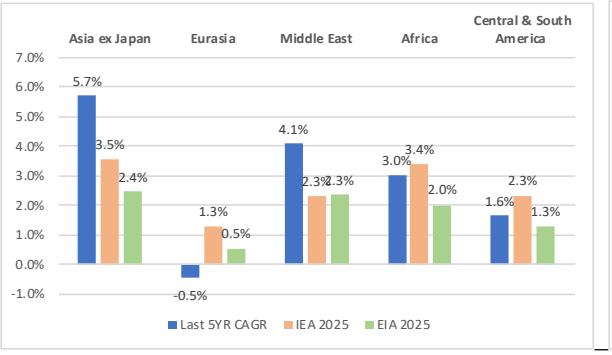


Source: U.S. Energy Information Administration, International Energy Agency

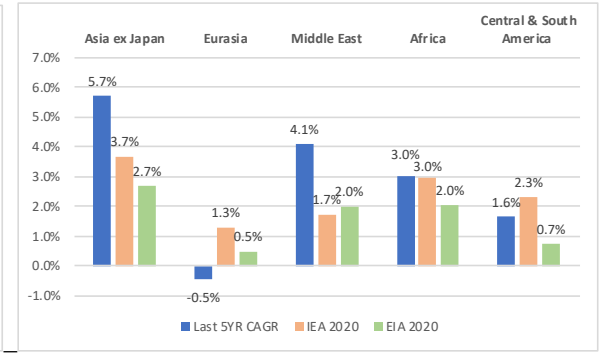
- ***By contrast, both agencies foresee the rate of growth in generation decelerating in the developing countries of the world (see Exhibit 8).*** This reflects (i) the historical pattern of power demand growth diminishing as economies transition from more energy-intensive primary industry and manufacturing to less energy intensive service industries, and (ii) the widespread adoption of electrical appliances and air conditioning as rising proportion of households enters the middle class – a transition which occurs only once.

Exhibit 8: Generation in Developing Countries: 2011-2016 CAGR vs. IEA & EIA Forecasts

2016-2020



2016-2025

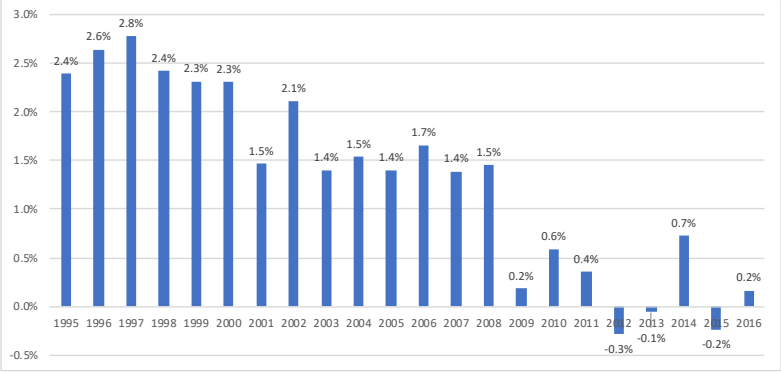


Source: U.S. Energy Information Administration, International Energy Agency

- ***Despite these forecasts, we remain skeptical of a recovery in power demand growth in the United States. Our view reflects (i) the stagnation of U.S. electricity generation since 2009, despite slow but steady economic recovery, (ii) the apparent decoupling of generation growth from GDP growth in the U.S., which, if persistent, will curtail the potential for any future acceleration in economic growth to drive an increase in power output, and (iii) the scope for further reductions in electricity use per unit of GDP.***

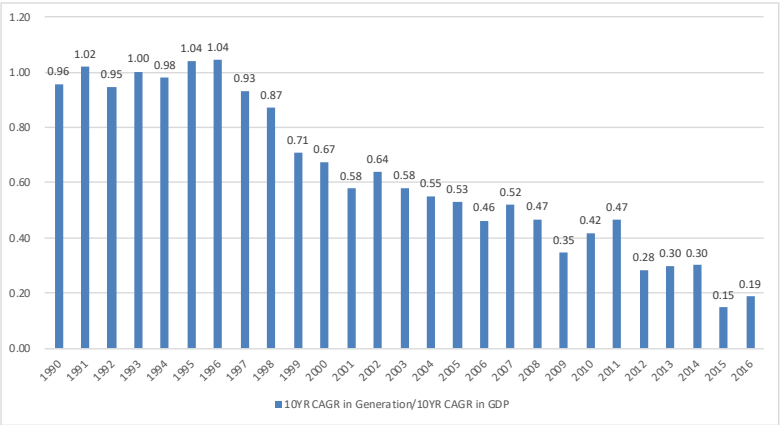
- **Exhibit 9** presents the growth in U.S. generation on a rolling five-year basis to smooth the impact of weather. As can be seen there, the five-year rate of growth in U.S. power output has hovered near zero since 2009.
- **Exhibit 10** compares the ratio of generation growth to GDP growth in the United States. Calculated on a rolling ten-year basis, this ratio has been in decline for 20 years. The ten-year growth rates realized through 2015 and 2016 suggest that for every 1.0% increase in GDP, generation has grown by only 0.15% to 0.20% -- significantly limiting the potential for future economic growth to drive higher power output.
- **Exhibit 11** compares the ratio of electricity generation per unit of GDP across the high-income regions. As can be seen there, the ratio of generation to GDP is 20% higher in North America than the OECD average. While this may reflect the extremes in temperature typical of many areas in North America, the region's relatively high use of electricity makes it difficult to argue that the potential for further efficiency gains has been exhausted. Moreover, as illustrated in **Exhibit 4** above, the decreases in the ratio of electricity generation to GDP realized in North America have lagged those realized in other high-income regions. On the North American power grid, generation has lagged growth in the combined GDP of the U.S. and Canada by 1.9% p.a. over 2011-2016; over the same period, materially higher efficiency gains were realized in Japan (2.4% p.a.) and Australia (2.6% p.a.).

Exhibit 9: Five-Year CAGR in US Power Generation (Lower 48 States), 1995-2016



Source: U.S. Energy Information Administration

Exhibit 10: Ratio of 10 Year CAGR in Generation to 10 Year CAGR in GDP



Source: OECD, U.S. Energy Information Administration

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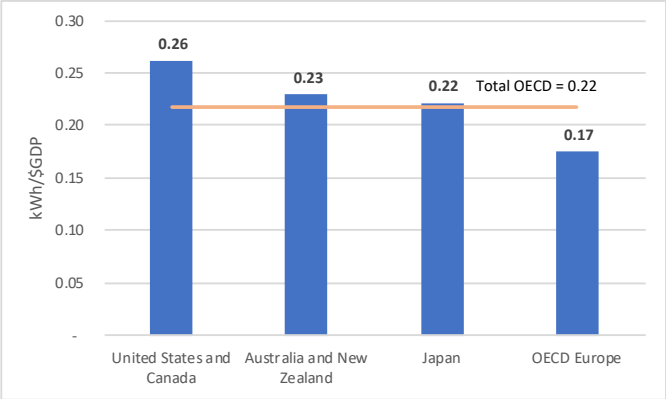
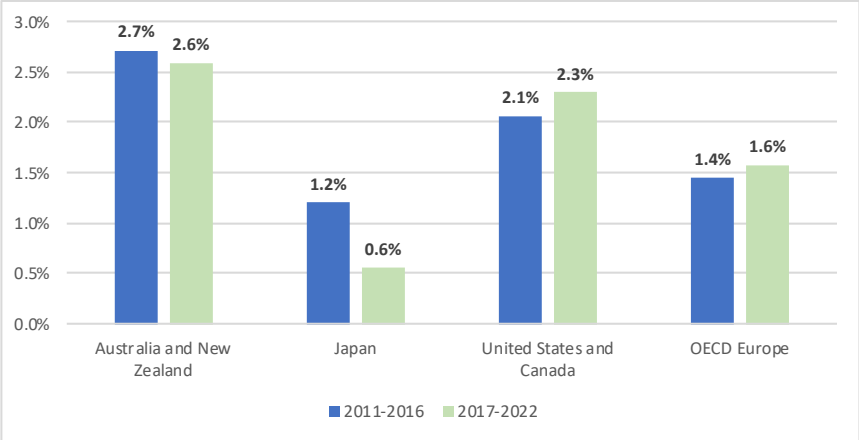
Exhibit 11: Electricity Generation per Dollar of Real GDP (1), 2016



1. Constant 2010 US$; GDP calculated at purchasing power parity
Source: OECD, U.S. Energy Information Administration

- The de-linking of GDP growth from generation growth since 2009, if persistent, has important implications for the future trajectory of U.S. power output. **Exhibit 12** presents historical and forecast rates of growth for GDP in the high-income regions of the world. As can be seen there, the OECD forecasts a material quickening of U.S. GDP growth, from 2.1% p.a. over 2011-2016 to 2.3% p.a. over the next five years (2017-2022). The impact on generation, however, could be minimal.
  - Over the last ten years, every 1% increase in U.S. GDP has been reflected in ~0.2% growth in generation (see **Exhibit 10**). If this ratio persists, a 20 basis point pick-up in GDP growth would imply only a 4 basis point increase in annual generation growth.

Exhibit 12: Historical and Forecast Growth in GDP Growth, 2011-2016 vs. 2017-2022



Source: OECD, U.S. Energy Information Administration

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- ***While we expect slow growth in U.S. power output to continue, the rate of growth in generation varies widely across the different regions of the United States.***
  - **Exhibit 13** presents the historical growth rates in GDP across the major geographic regions of the United States. As can be seen there, GDP growth has been materially more rapid in the states of the West, Southwest and Southeast than in the rest of the country.
  - As can be seen in **Exhibit 14**, this disparity in regional GDP growth is reflected in a broadly similar disparity in the rate of growth in generation across the various the NERC regions. Power demand growth is materially higher in the southwestern power markets of ERCOT and SPP, and in the southeastern power markets of SERC and FRCC, than in the rest of the country.
  - The exception to the rule is the WECC, which has experienced no growth in generation over the last three years despite its rapid growth in regional GDP. This may reflect variations in weather associated with the end of the region's severe drought.

Exhibit 13: GDP CAGRs by Geographical Region, over the Last 3, 5 and 10 Years

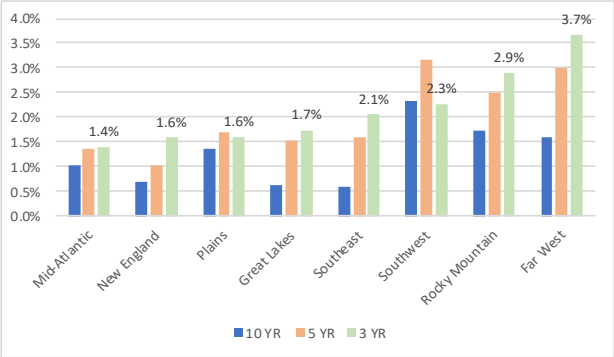
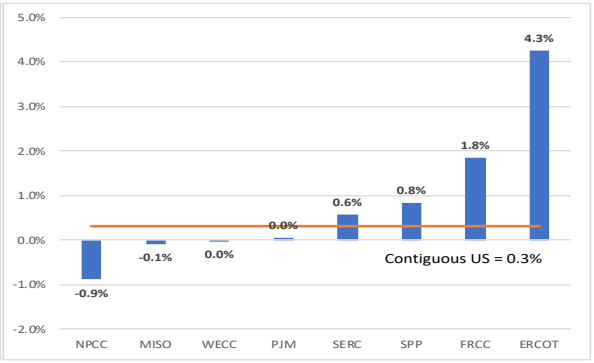


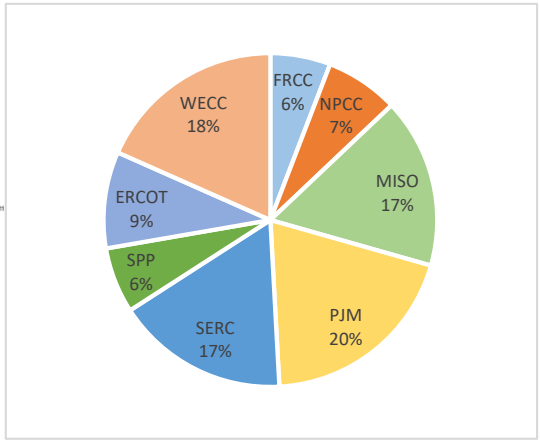
Exhibit 14: Growth in Generation by NERC Regions, 2013-2016 CAGR



Source: Bureau of Economic Analysis and U.S. Energy Information Administration

Exhibit 15: NERC Regions

Exhibit 16: Breakdown of U.S. Generation by NERC Region



Source: North American Electric Reliability Corporation

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Potential Drivers of Accelerated Demand Growth: EVs and Bitcoin

- While it is hard to identify any single historical use of power that could accelerate meaningfully in the near term, two new uses are frequently identified as potential sources of significant power demand growth: electric vehicles and cryptocurrencies.
- ***Electric vehicles (EVs) have been surging in popularity as range and performance increase and costs decline, but we do not see a significant impact electricity demand growth until the middle of the next decade.***
  - We have estimated in previous research[1] that if all vehicles in the U.S. were to be converted to EVs it would increase total U.S. power consumption by ~34%. With ~260 million vehicles, this implies a 0.13% increase in power demand for every 1 million increase in EVs on the road.
  - At the current pace of sales, we calculate that new EVs are adding ~0.2% p.a. to U.S. electricity demand.
  - If EV sales continue to accelerate, however, and if these sales come to include heavy duty as well light duty vehicles, the contribution of EVs to demand growth could increase materially. By 2025-2030, EV sales could reach 2 million per year. If these sales include heavy duty as well light duty vehicles, every 1 million new vehicles could add 0.13% to U.S. power demand.
  - Looking beyond 2030, EVs could add ~1% p.a. to power demand once EVs achieve 50% of new car sales, and as much as 2% when all new cars are EVs. (We note, however, that as EV sales increase, their impact on power demand may diminish as by that time many of the EVs sold would be replacing existing EVs.)
  - We have also analyzed EVs in Europe, and estimate the impact on power demand per 1 million electric vehicles to be broadly similar, although the growth of EVs may have a slightly faster timeline than the U.S.
- Cryptocurrencies are a much more recent phenomenon that have been capturing headlines for the energy intensity of currency "mining," which is really a form of transaction processing. ***Based on an analysis of energy consumption for Bitcoin mining, we believe that the potential impact is limited and, without another surge in the value of Bitcoin, the growth rate of energy consumption should begin to level off.***
  - Bitcoin currently represents a large majority of cryptocurrency energy consumption, as its mining process is the most energy intensive and it is the most popular cryptocurrency.
  - We estimate that global power demand for Bitcoin mining is currently 3-6 GW, or 25-50 TWh on an annual run rate and that this is >70% of cryptocurrency mining power consumption.
    - This is up ~30% from mid-December, but that is a much slower growth rate than the previous three months and the growth has slowed even more since late-January.
    - We believe this is the result of a decline in mining profitability to historic averages due to the drop in the price of Bitcoin by over 50% from its peak and the drop in transaction fees by almost 90% from their peak in December.

[1] See our note from April 18, 2017, *How Big is the Market for Batteries on the Grid?*

- Using the annualized consumption based on current Bitcoin mining power demand and increasing it by 40% to account for all other cryptocurrencies, cryptocurrencies are currently consuming ~35-70 TWh of electricity, or ~0.15-0.3% of global power consumption.
    - A doubling of demand in 2018 would increase global consumption by 0.15-0.3%, meaningful, but probably not a sustainable rate of growth in future years without another surge in Bitcoin pricing and transaction fees.
- For the U.S., the impact is a bit smaller, as ~12% of Bitcoin mining is believed to take place in the U.S.[2] Based on this estimate, cryptocurrency mining in the U.S. is currently using ~350-700MW, or ~3-6 TWh annually, ~0.075-0.15% of U.S. power demand.
    - A doubling of demand would be meaningful in the context of 0.2% demand growth over the past 5 years, but, as noted above, this growth rate is unlikely sustainable.
- For Canada, cryptocurrency is potentially more meaningful, as it is estimated to account for ~8% of globally mining, resulting in ~0.4-0.8% of Canada's power demand at the current level of cryptocurrency mining power consumption.

Investment Conclusion

- In previous research,[3] we have aggregated the announced capital expenditure plans of the investor owned electric utilities in the United States to estimate the likely composition of U.S. utility capex going forward. ***Consistent with our expectation of continued stagnation in generation, this analysis suggests that the industry is entering a period when capital expenditures by segment will shift significantly, favoring distribution over generation and transmission.***
    - We estimate that distribution capex is poised to grow at a 3.3% average annual rate from 2016 through 2025, while transmission capex will expand at only 0.9% annually and generation capex will decline by 0.1% p.a. (see **Exhibit 17**).
    - As a share of total utility capex, therefore, we expect distribution capex to rise from 34% of the total over the last five years (2012-2016) to 46% of the total over the next five (2017-2021). While transmission's share of capex is expected to be relatively stable at 28%, investment in generation will decline markedly, from 38% to 26% of the total (see **Exhibit 18**).

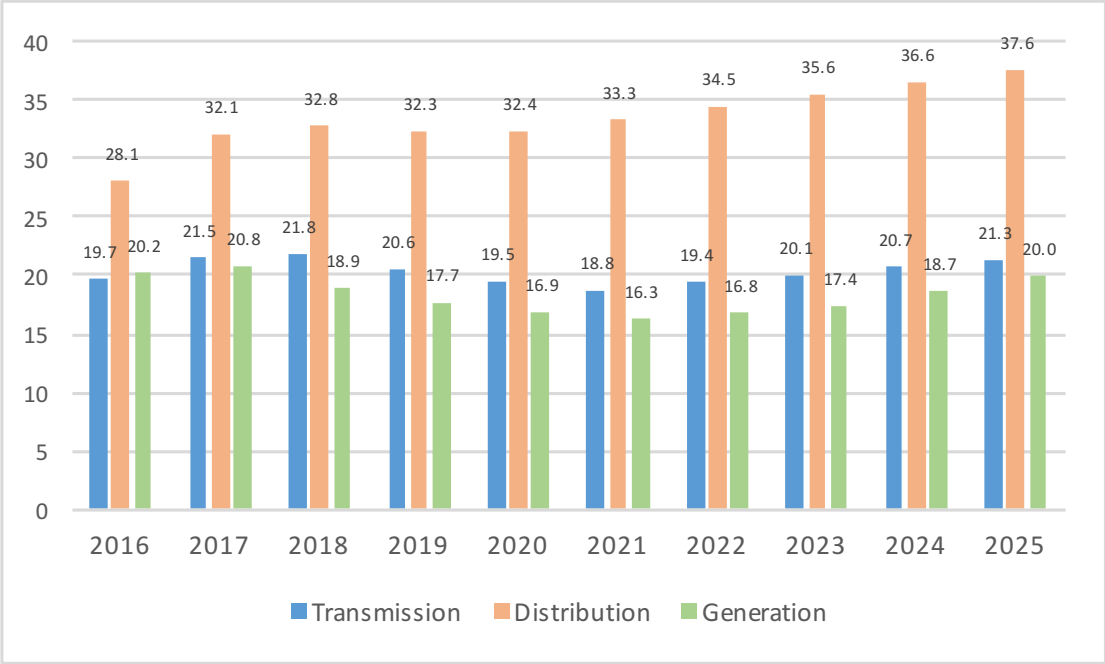
- ***The shift in industry capex from generation to distribution will be reflected in more rapid future growth in distribution rate base, while growth in generation and transmission plant in service should slow (see Exhibit 19).***
    - Growth in distribution rate base, which averaged 4.1% p.a. over the last five years (2011-2016), is expected to accelerate to 9.1% p.a. over 2016-2021. By contrast, we expect growth in generation rate base to fall from 5.7% p.a. to 4.5% p.a. Growth in transmission rate base is expected to decelerate from 12.0% p.a. over the last five years

[2] Global Cryptocurrency Benchmarking Study, Dr. Garrick Hileman and Michel Rauches, Cambridge Center for Alternative Finance, University of Cambridge, 2017

[3] See our note of October 2, 2017, *If This Is the Golden Age of Electric Utilities, What's Next? Or, How Fast Can Rate Base Grow in the Long Term and on What Will Utilities Spend?*

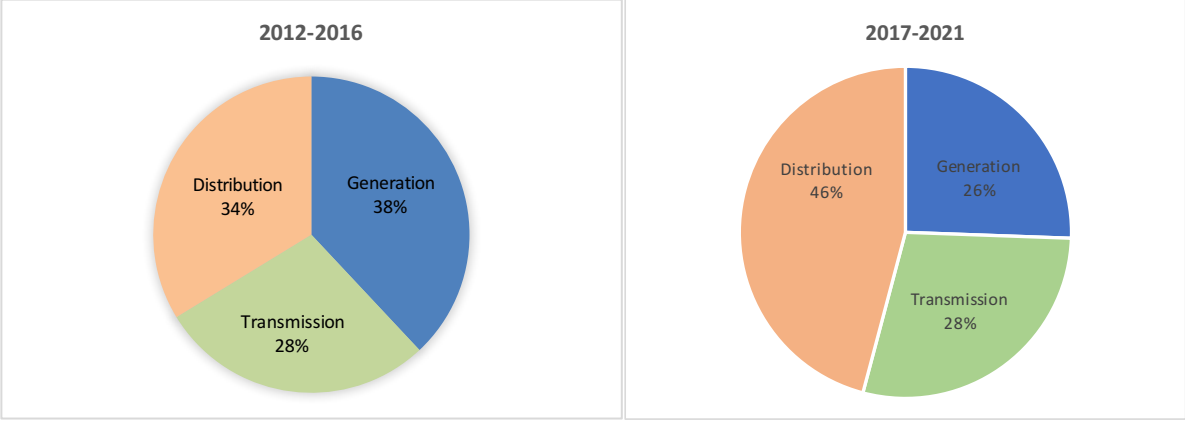
to 10.0% p.a. over 2016-2021. The estimated trajectories of net utility plant in service by segment are illustrated in **Exhibit 17**.

Exhibit 17: Estimated Capital Expenditures by Segment of the Publicly Traded U.S. Regulated Utilities, 2016-2025 ($ Billions)



Source: SNL, FERC Form 1, SSR analysis and estimates

Exhibit 18: Estimated Composition of Aggregate Capital Expenditures on Electric Plant by Segment (1)



1. For 2012-2016, our estimates of capex by segment are based upon the annual additions of gross utility plant in the generation, transmission and distribution segments, aggregated across all U.S. investor owned, regulated utility operating companies. For 2017-2021, our capex estimates reflect the disclosed capital expenditure plans by segment of the publicly traded, U.S. investor-owned regulated utilities.
Source: SNL, FERC Form 1, SSR analysis and estimates

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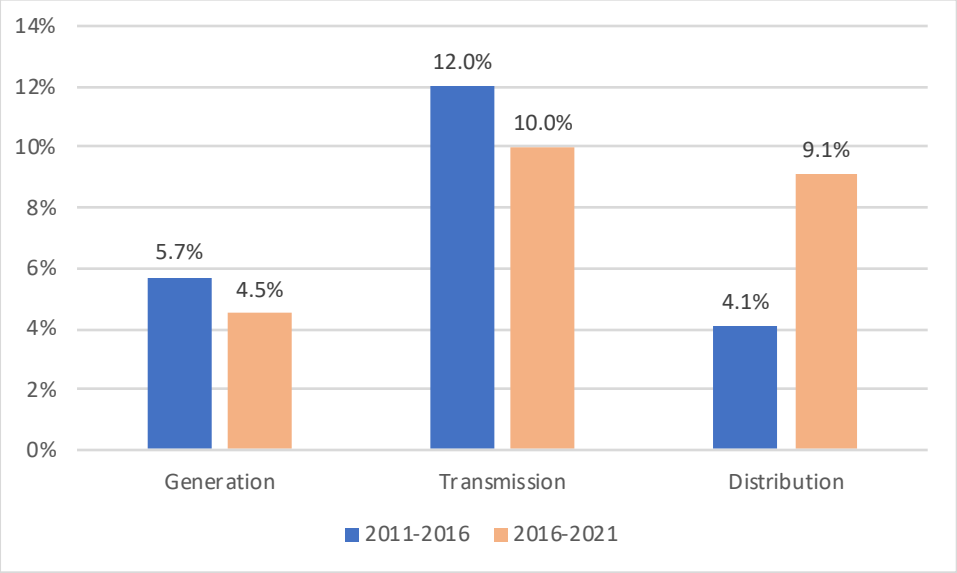
Exhibit 19: Growth in Aggregate Electric Rate Base of the U.S. Investor Owned Utilities, by Segment

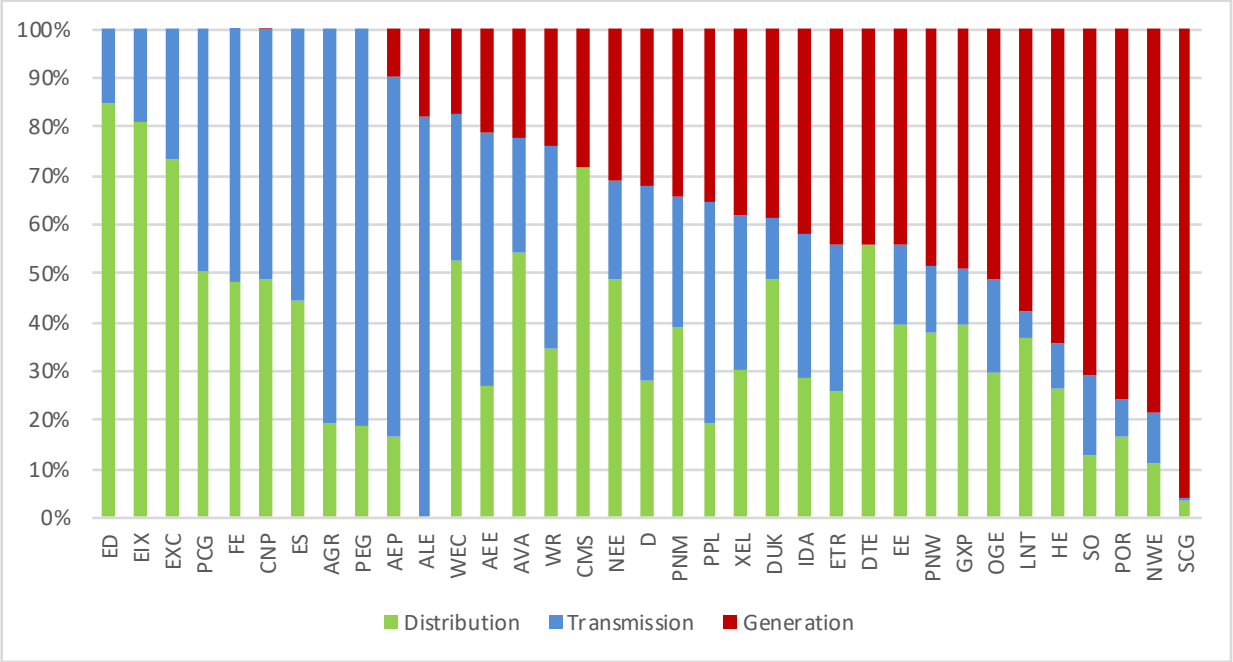


Source: SNL, FERC Form 1, SSR analysis and estimates

- While the utility industry is clearly transitioning to materially higher levels of distribution capex and rate base growth over the next five years, technological developments and changing regulatory priorities point to the potential for these trends to continue and possibly to gather strength over the long term.
  - Many utilities across the country are upgrading their distribution systems through the deployment of smart grid technologies, such as customer meters capable of measuring electricity consumption by the minute and wirelessly communicating this data to the utility; devices that allow major pieces of equipment, such as transformers and substations, to be continuously monitored for signs of impending failure, allowing maintenance to be conducted on an as-needed basis as opposed to on a calendar schedule; and sensors, relays and switches that allow distribution circuits to which the supply of power has been interrupted to be supplied from alternative sources.
  - The rising cost to customers of distribution system outages, as computers and portable electronic devices have become increasingly important, has caused regulators to impose higher reliability standards. Utilities have accelerated maintenance and replacement capex to reflect the mean-time-to-failure of critical components of the distribution grid. Utilities on the Atlantic and Gulf coasts are also spending significant amounts of capital on the storm hardening of their distribution grids, including the deployment of concrete power poles and the undergrounding of distribution lines.
  - Lastly, we expect distribution upgrades to continue in the years ahead as the grid integrates an increased amount of distributed generation, distributed storage and electric vehicles, whose charging will require increased transformer capacity, upgraded distribution circuits, and two-way communication capability to stagger charging loads.

- Within the industry, therefore, the most favorable long term growth prospects may exist among the transmission and distribution utilities, and particularly those positioned to maximize capital expenditures and rate base growth in the distribution segment. In **Exhibit 20**, we rank the publicly traded electric utilities in the U.S. by the composition of their planned capital expenditures over 2016-2021.
  - Of the publicly traded utilities whose regulated subsidiaries have the highest percentage of rate base growth in the transmission and distribution segments, we rank five among our most preferred utility stocks: Edison International (EIX), Exelon (EXC), PG&E (PCG), FirstEnergy (FE) and American Electric Power (AEP). (See **Exhibit 21**).
  - Conversely, among those utilities with the lowest contributions from transmission and distribution rate base are two that rank among our least preferred utility stocks: Portland General (POR) and Southern (SO).

Exhibit 20: Breakdown of 2016-2021 Growth in Electric Rate Base by Class of Asset



Source: SNL, FERC Form 1, SSR analysis and estimates

Exhibit 21: Heat Map: Preferences Among Utilities, IPP and Clean Technology

Preferences Among Utilities, IPPs and Clean Technology			
Sector	**Weighting**	**Favorites**	**Concerns**
Regulated Electric Utilities	Overweight	AEP, EIX, PCG	ALE, POR, SO
Hybrid Electric Utilities	Neutral	EXC, FE, NEE	D
IPPs	Underweight		
Renewables	Underweight		JKS
Yieldcos	Neutral	NEP	CAFD

Source: SSR analysis

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