Presentation

A North American Gas and Power Presentation for the UT Bureau of Economic Geology

IHSM N Am Gas and Power Scenarios: Boundaries of the Feasible

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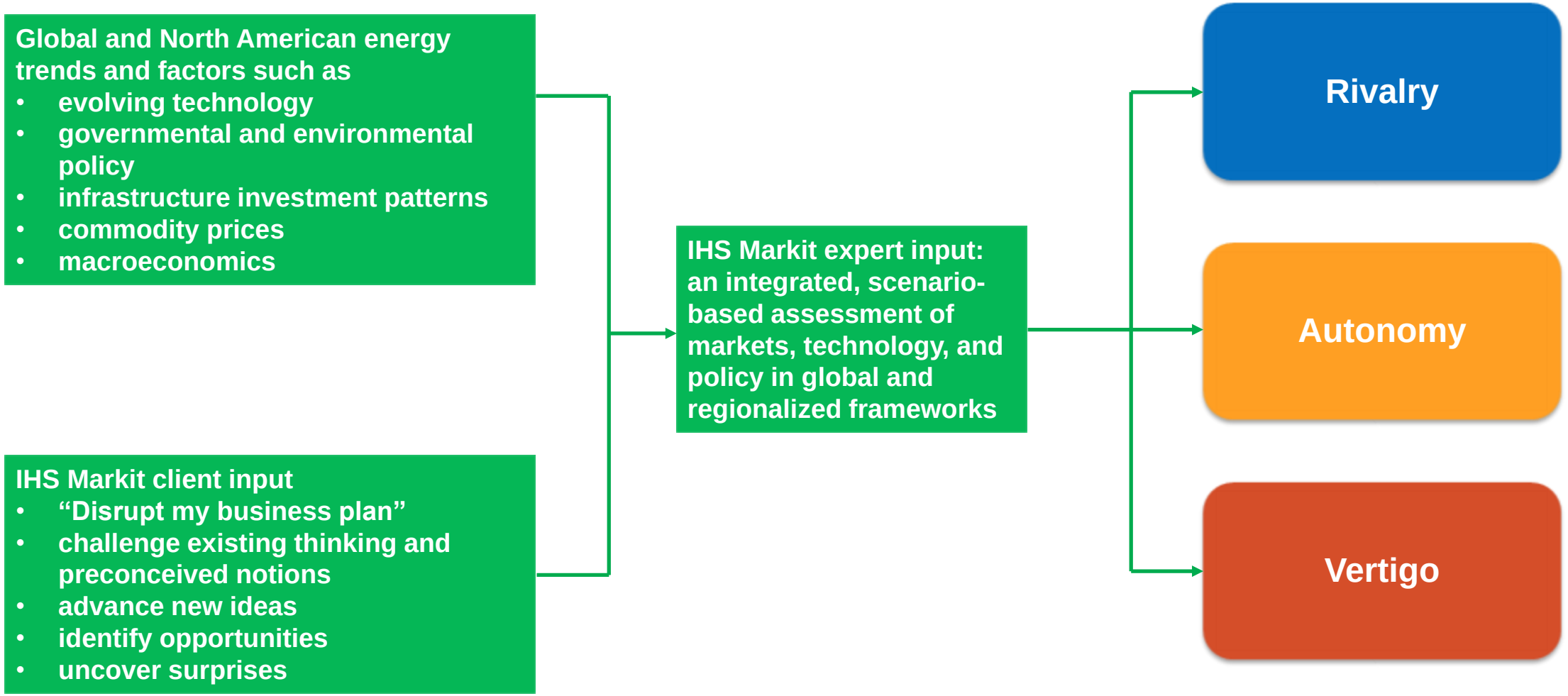
Old problems need new thinking

- “We cannot solve our problems with the same thinking we used when we created them.” – A. Einstein
- A scenario tells a “story”—a logical story—about the future.
  - There are three IHS Markit scenarios – **each scenario should be equally probable, and feasible**
- A scenario covers important trends and events, describes the key players and their actions, and explains the dynamics of the system or the set of questions under study.
- Scenarios combine expansive, qualitative thinking with the rigor of quantitative modeling.
- Scenarios provide a common language for discussing uncertainty and identify interdependencies.
- Scenarios make us explicitly identify and question our assumptions about the future.
- The aim is not to predict a precise order of events and outcomes, but rather to enable development of robust strategies that will stand up no matter what happens.

The IHS Markit scenario design is influenced by the energy landscape and is responsive to client input



The IHS Markit Scenarios as seen in a North American context

Rivalry

- Heightened competition
- A growing role for natural gas as a power fuel, rapid growth in renewable energy, the evolution of energy technology, and the decline of the US coal industry

Autonomy

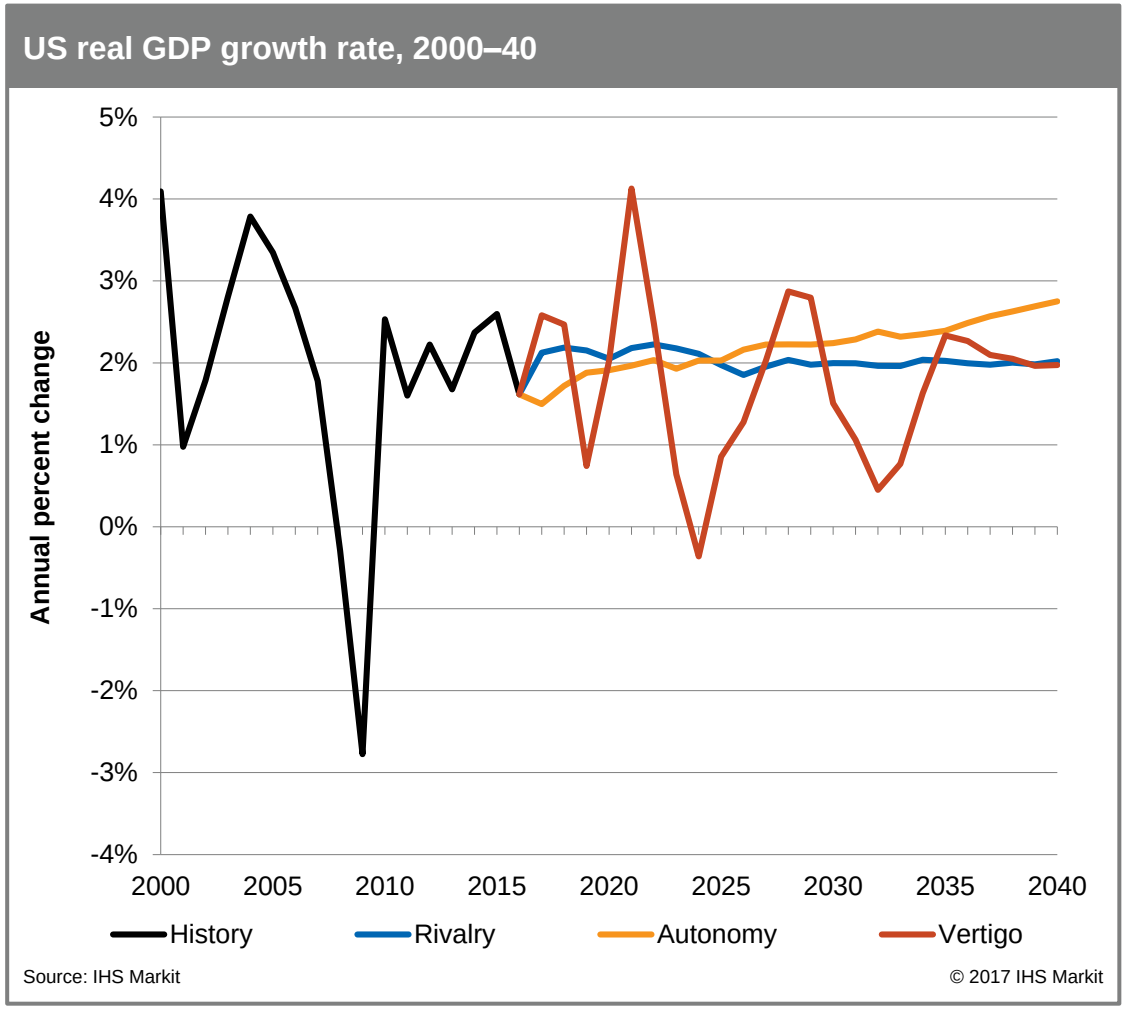
- Desire to reduce urban externalities and increase regional control of energy
- More rapid gains in technology
- Cairo Climate Concord of 2030

Vertigo

- Risk aversion
- Exacerbated fiscal cyclicality with asset and commodity price bubbles, slower technological progress, and lower growth

Macroeconomic assumptions underpin each scenario

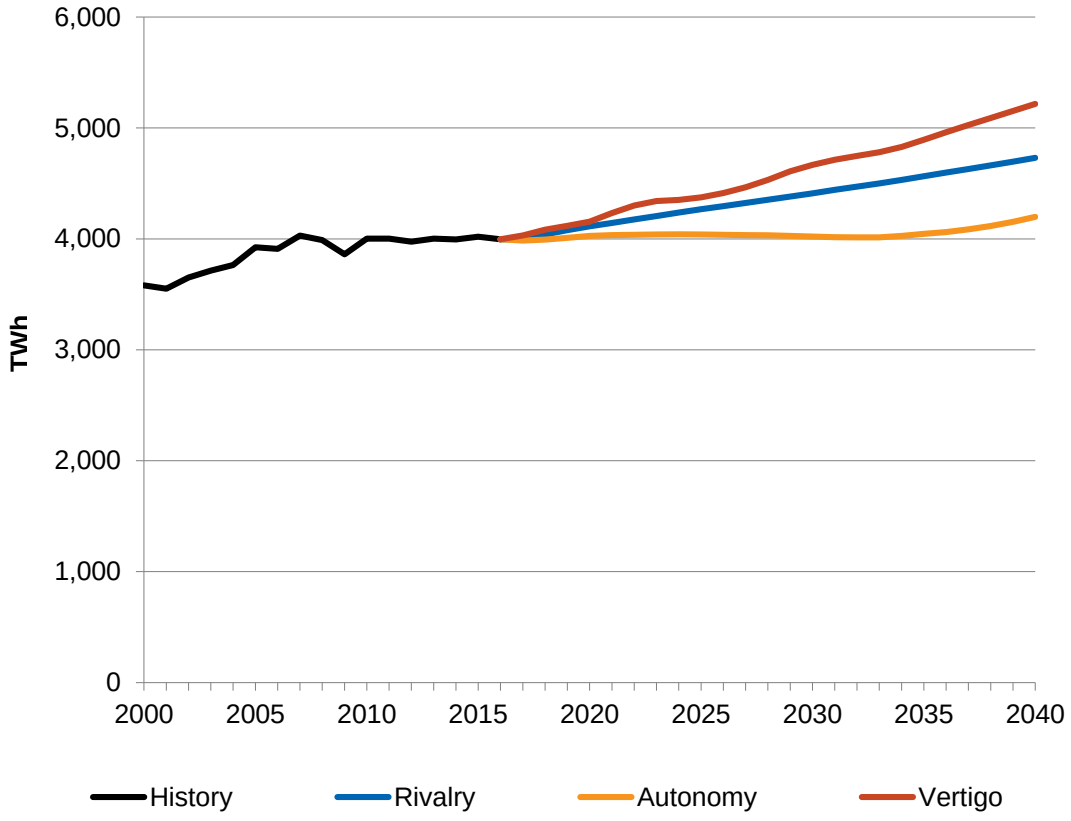
- **Rivalry.** A slow recovery peaks in the mid-2020s as post-crisis caution fades and investment recovers. This is followed by a period of fairly sustained growth of around 2% per year.
- **Autonomy.** Near- to medium-term economic growth is slightly weaker than in Rivalry as economic restructuring in major developing markets and gradual measures to address fiscal imbalances act as headwinds on the pace of economic growth. In the longer term, US entrepreneurs and their investors thrive, consumers benefit from lower energy costs, and higher productivity gains boost GDP growth. By 2040, US real GDP is 4% higher than in Rivalry.
- **Vertigo.** Shortages of skilled labor lead to an initial wage/price spiral. Stock prices, home prices go through boom/bust cycles, affecting household spending, commodity prices, and the overall economy. By 2040, US real GDP is 6% lower than in Rivalry.



US electricity demand – virtually no growth, to 1.1%; tells us something – *no contemplated return to historic growth rates*

- **Rivalry.** Despite a rebound in economic growth this decade, energy efficiency policy plays a prominent role in lowering the trajectory of net on-grid electricity demand growth, which rises 0.9% per year through the remainder of this decade and 0.7% per year in 2017–40.
- **Autonomy.** The impact of energy efficiency policies is even more pronounced than in Rivalry. Demand growth is curtailed to about 0.2% per year in 2017–40. Positive growth comes after 2030 when surging EV sales noticeably increase net on-grid electricity demand.
- **Vertigo.** Efficiency targets are rolled back, and as a result, the linkage between GDP and power demand growth remains quite strong throughout the scenario time frame. Net on-grid electricity demand grows at about 1.1% per year in 2017–40.

US net on-grid electricity demand, 2000–40 (TWh)

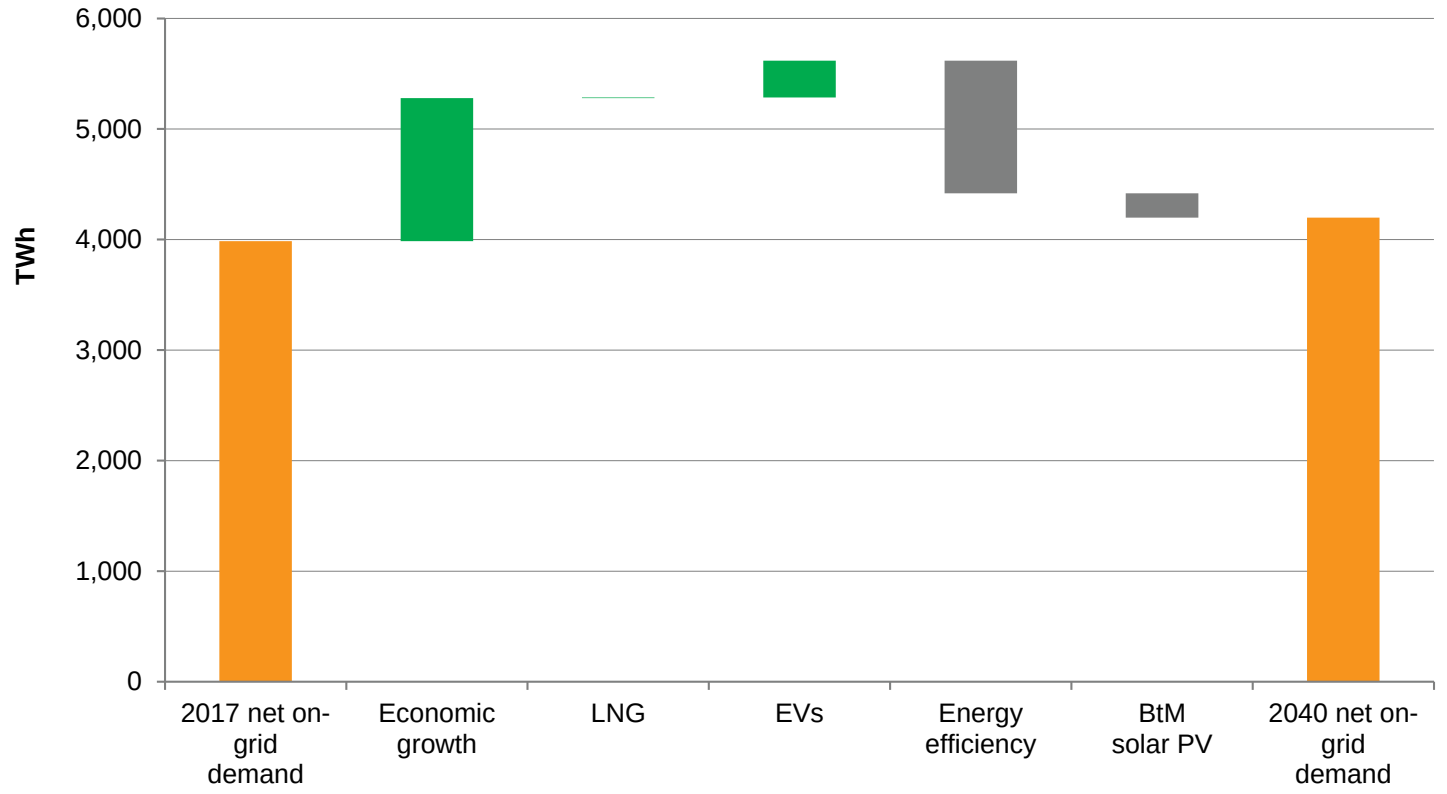


Source: IHS Markit

Example - drivers of electricity demand in the (almost) zero growth Autonomy scenario

- **Economic growth.** Absent other factors, economic growth would drive a roughly 33% increase in electricity demand by 2040 relative to 2017 levels.
- **LNG.** Grid-supplied electric-drive LNG projects in Texas and Georgia provide a small uplift to US electricity demand.
- **EVs.** Although accounting for 23% of US light-duty fleet and nearly 60% of sales by 2040, they are only 8% of net on-grid demand.
- **Energy efficiency.** Federal and state policies temper electricity demand growth, reducing demand by 23% from the level economic growth suggests.
- **BtM solar.** BtM generation from distributed solar PV systems grow to account for 6% of total electricity demand in 2040.

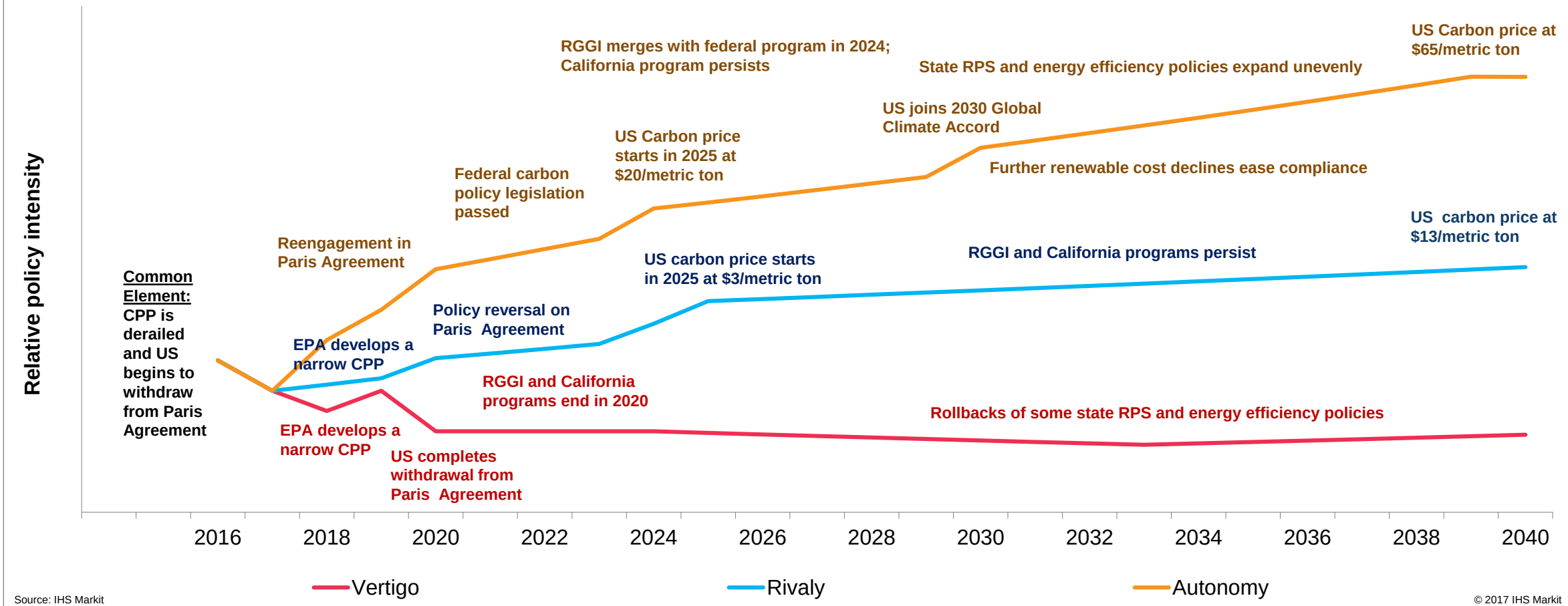
US components of Autonomy net on-grid electricity demand outlook, 2017–40 *



Notes: *US defined as the lower-48 continental states and the District of Columbia.
Source: IHS Markit

Future US clean energy policy: immense uncertainty in the possible power sector carbon and clean energy "trajectories"

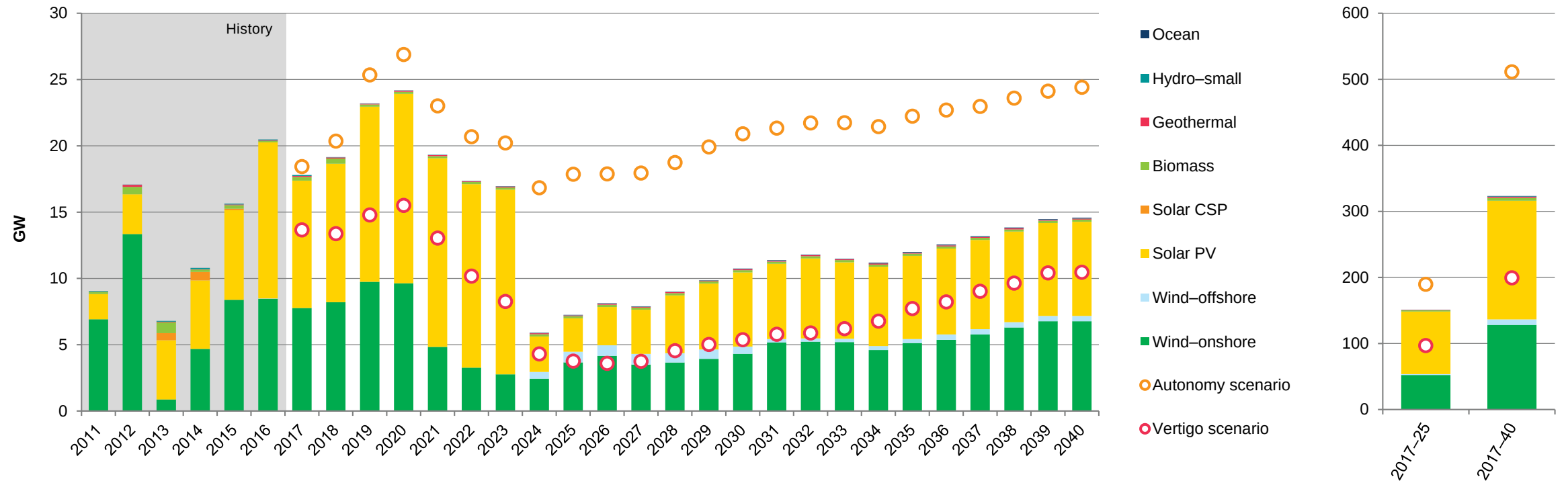
US Clean energy trajectories in IHS scenarios



Source: IHS Markit

Similarly for the resulting US renewable capacity additions by year and technology – more than 100% variance among the scenarios

US renewable capacity additions, 2011–40

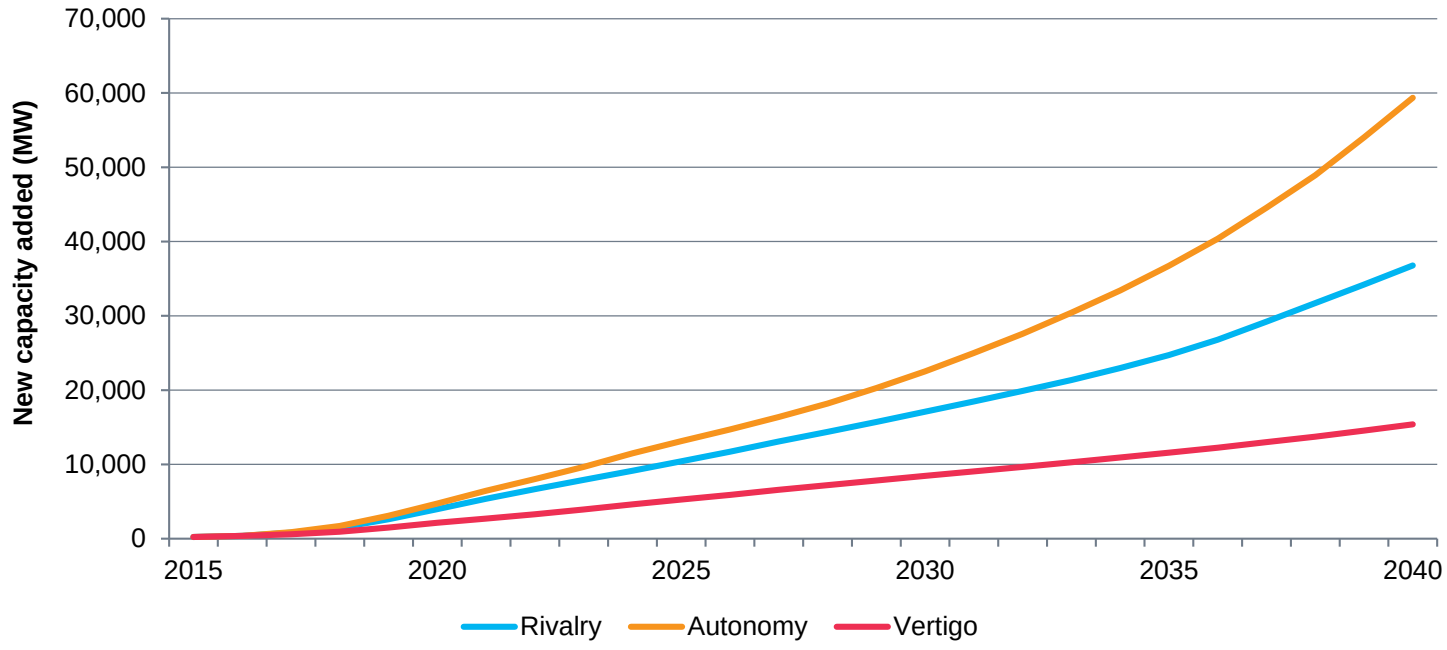


Source: IHS Markit

US cumulative renewable capacity additions to 2040 range from approximately 200–500 GW across the three scenarios. In all scenarios, the solar PV is the leading renewable technology.

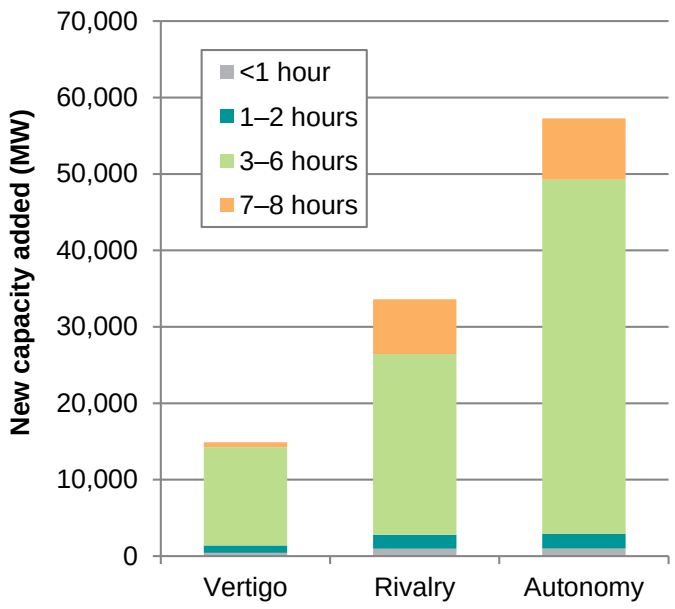
Grid storage installed capacity outlook in the US – a technology play

Cumulative grid storage installations, United States (2017–40)



Notes: Excludes batteries used solely for backup generation
Source: IHS Markit

Cumulative installations by duration (2040)



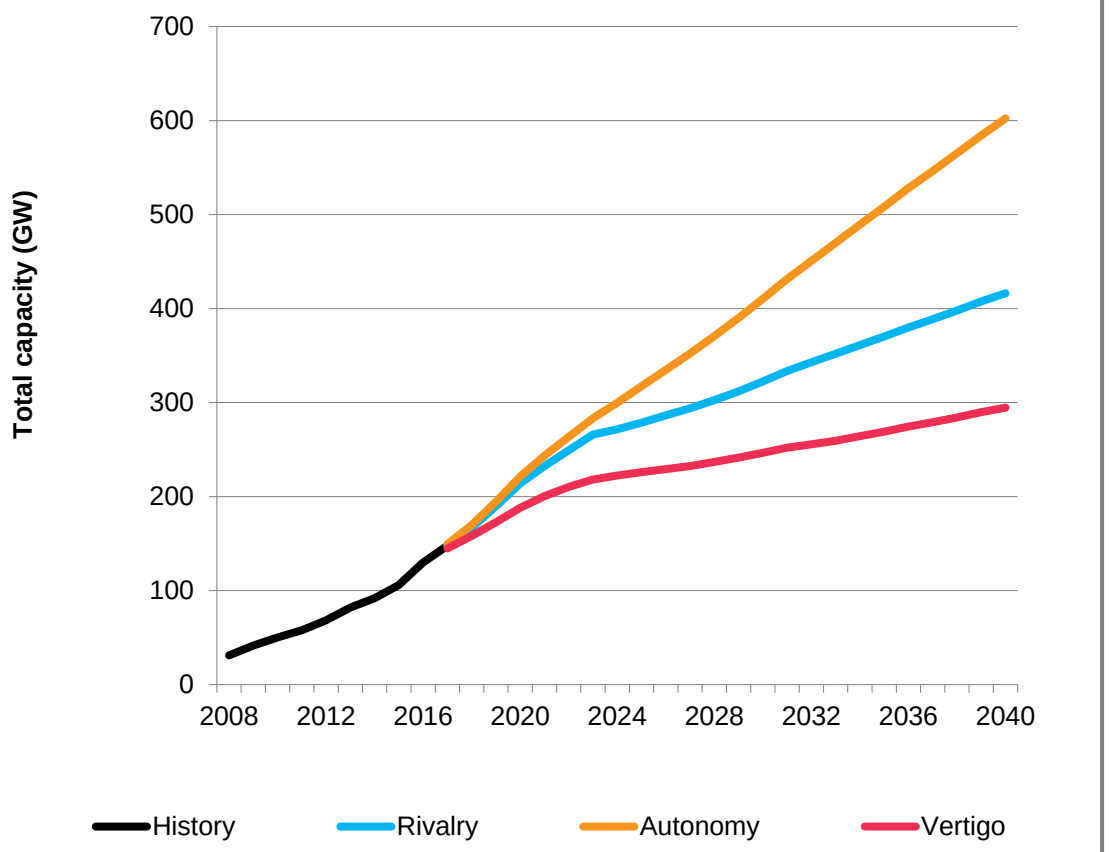
Notes: Excludes batteries used solely for backup generation.
Source: IHS Markit

While some growth is expected in all scenarios, aggressive cost declines in Autonomy make storage competitive as a peaking capacity resource in the mid-2020s which leads to exponential growth.

Note:
- Rivalry battery data is from the outlook scheduled to be released in September 2017, not April 2017.
- Capacity values shown are higher than those in related data tables as they include batteries with less than four hours of delivery capability.

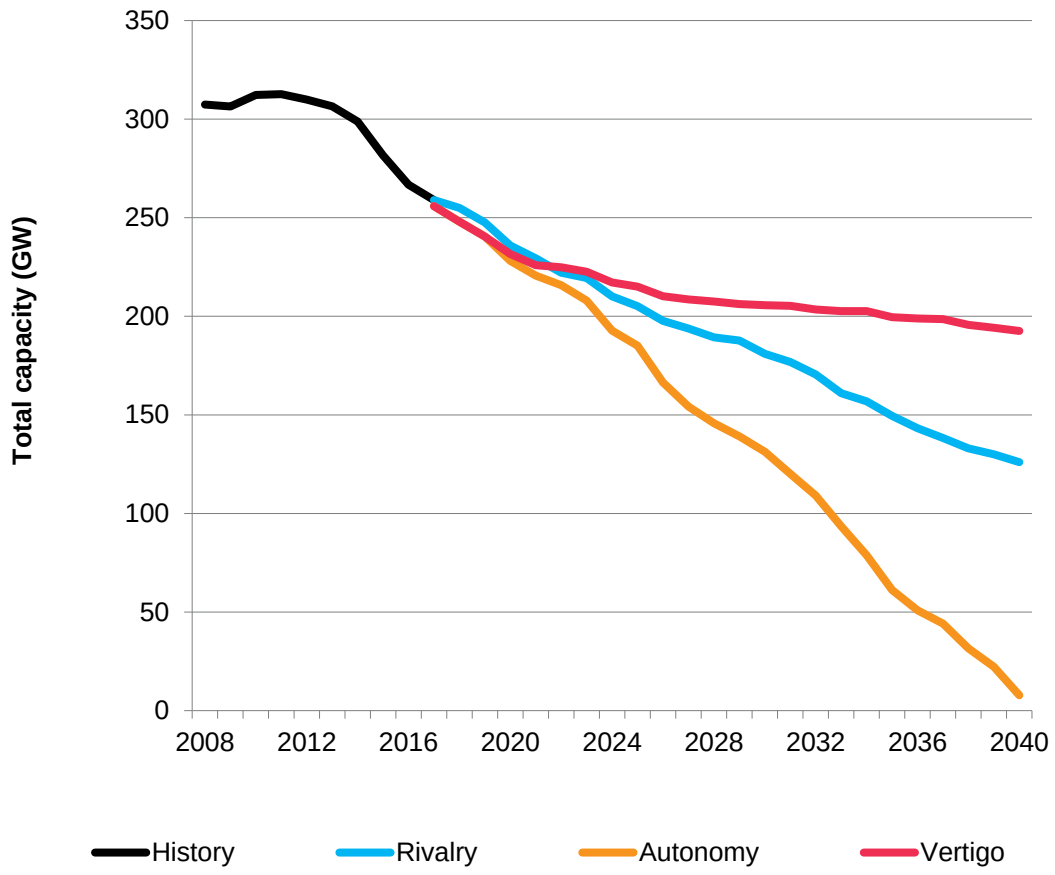
As renewables grow, US coal generation infrastructure declines as it ages and faces consistent pressure from other technologies

US renewable resources capacity summary (non-hydro)



Source: IHS Markit

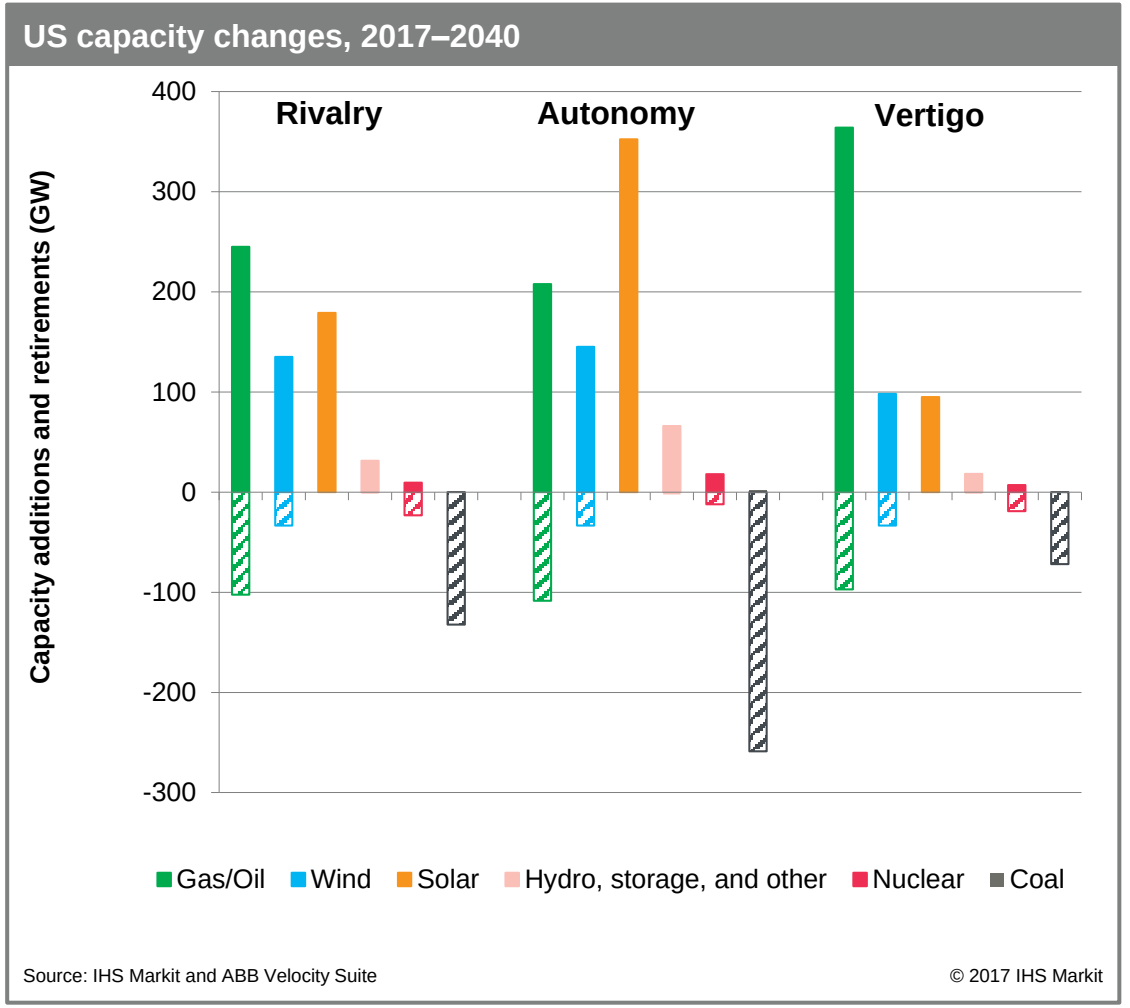
US coal capacity summary



Source: IHS Markit

US generation infrastructure: natgas is net positive in all; renewables growth shows greatest variance

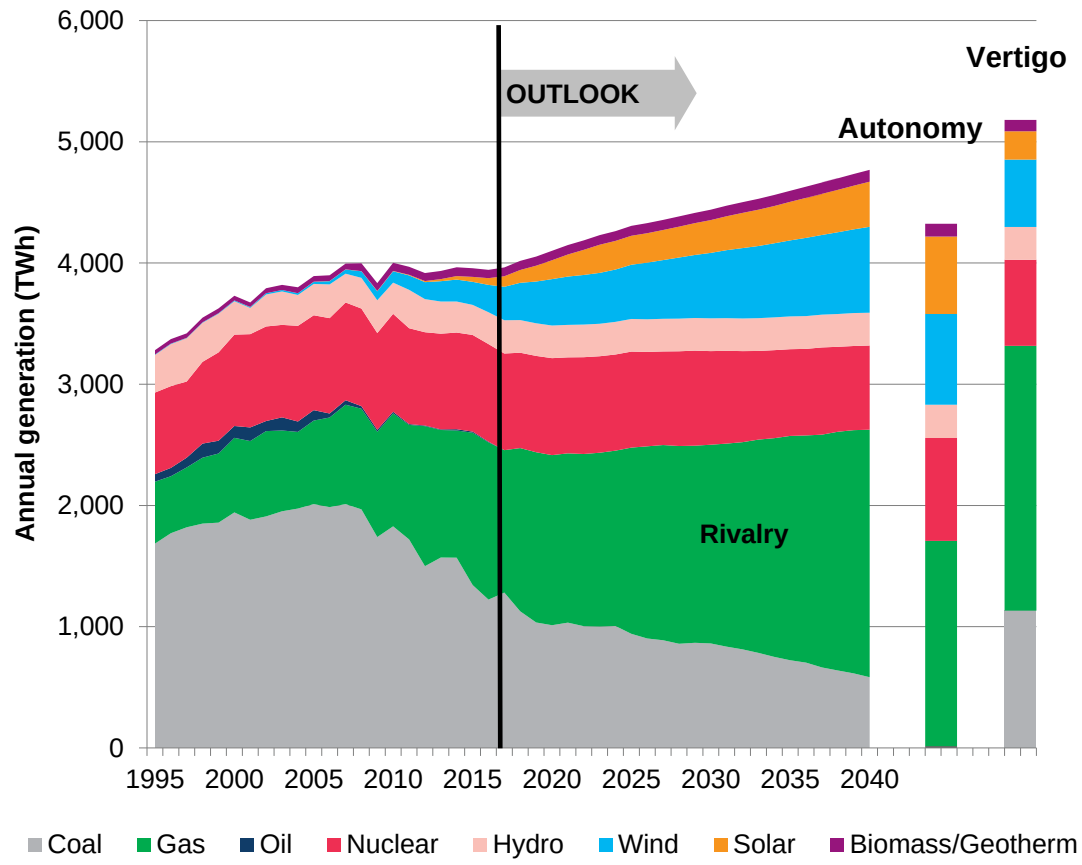
- Gas-fired units are the predominant source of new capacity additions in Rivalry and Vertigo.
- Despite the lower level of coal retirements, Vertigo has the largest amount of gas-fired capacity additions as higher levels of power demand growth and a lack of alternative energy sources drive the gas-fired capacity need.
- The increased levels of energy efficiency, renewables, and batteries along with a lower level of power demand growth tempers the need for gas-fired capacity in Autonomy, but there is still a need for considerable gas-fired capacity to replace coal generation retirements.
- In addition to the illustrated coal retirements, about 8-9 GW of coal-fired capacity is converted to gas-fired capacity in each scenario.



Momentum of existing capital stock yields gradual but substantial changes in US energy mix

- Coal-fired generation declines across the outlooks, driven by retirements and, particularly in Autonomy, dispatch competition due to low gas prices and high carbon prices.
- Gas-fired generation exceeds coal-fired generation in the United States in the entire outlook period in Rivalry, and is dominant in all three scenarios.
- Nonhydro renewables fuel generation share in 2040
  - Autonomy: 35%
  - Rivalry: 25% (more than double of today)
  - Vertigo: 17%
- Fossil fuel generation share in 2040
  - Autonomy: 40%
  - Rivalry: 55%
  - Vertigo: 65%

US power generation, 1995–2040

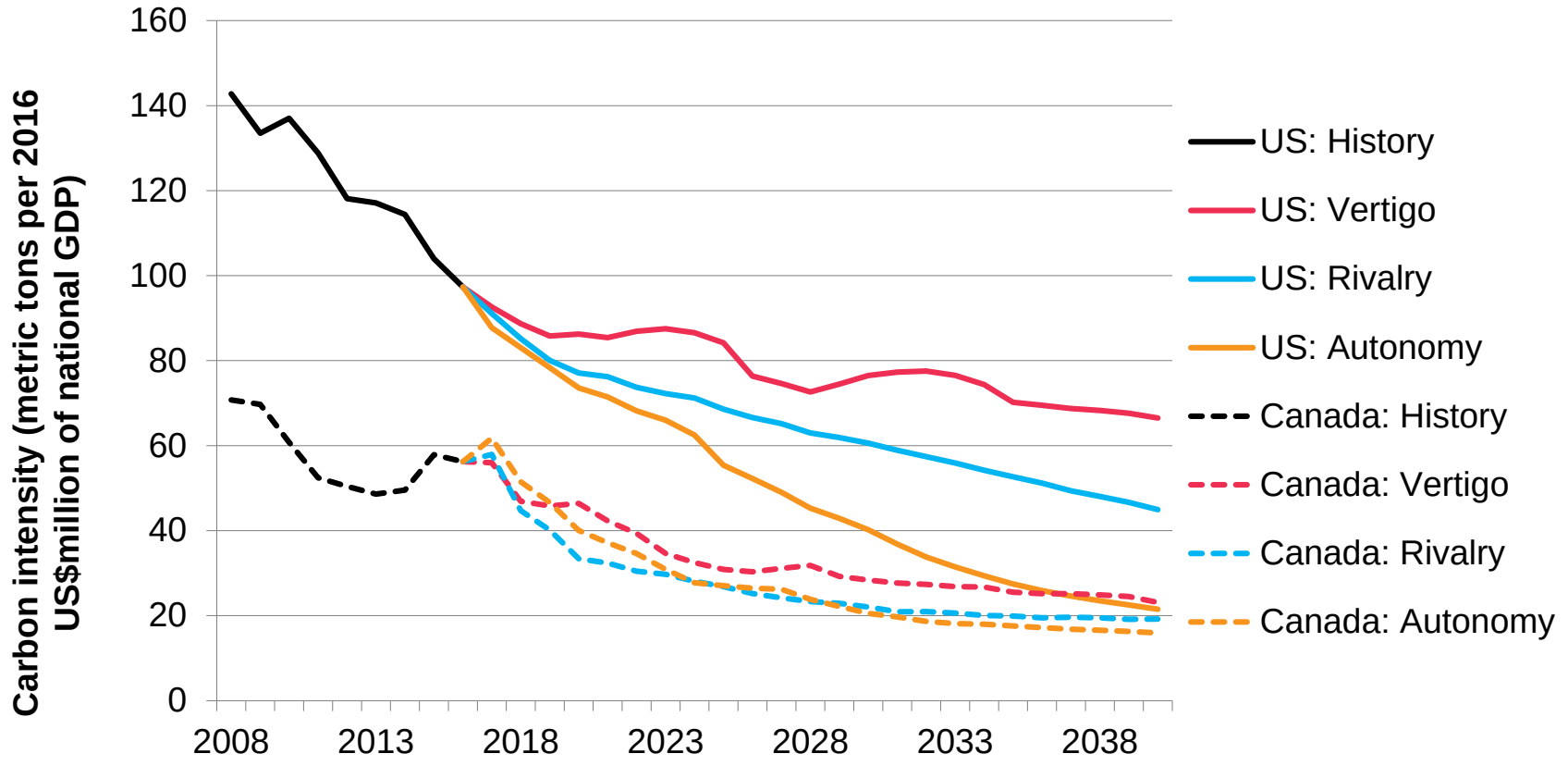


Source: IHS Markit and ABB Velocity Suite

US and Canadian power sector carbon intensity reflects resource mix differences

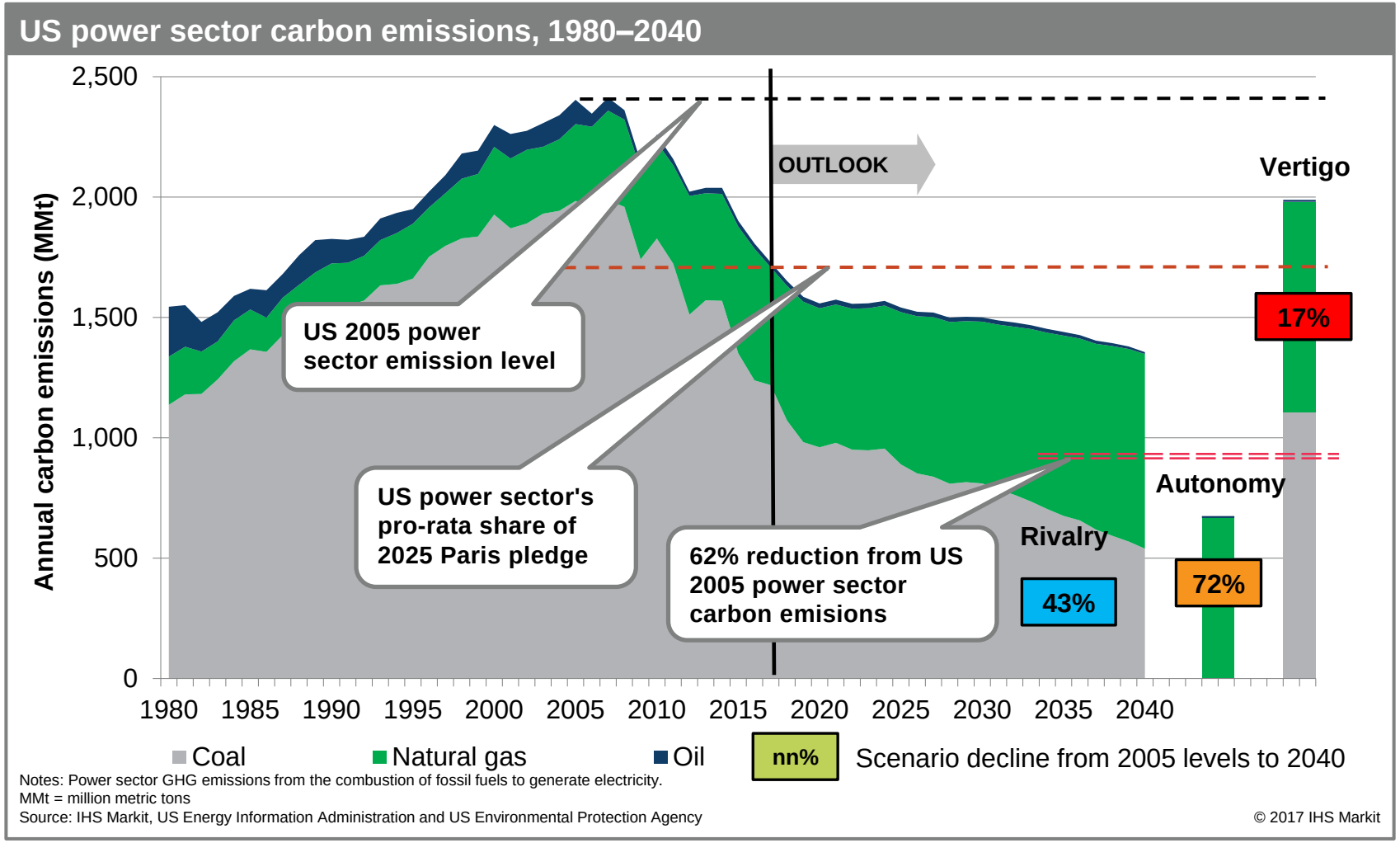
- The increase in renewable energy, decline in coal generation and coal-to-gas switching all contribute to lower power sector carbon intensities.
- Canada's abundance of hydroelectric power heavily influences the power sector carbon intensity.
- In the Autonomy scenario, US carbon intensity converges with Canada's by 2040, although total US power sector emissions are still 15 times higher than Canada's.

Power sector carbon emission intensity of the economy by scenario



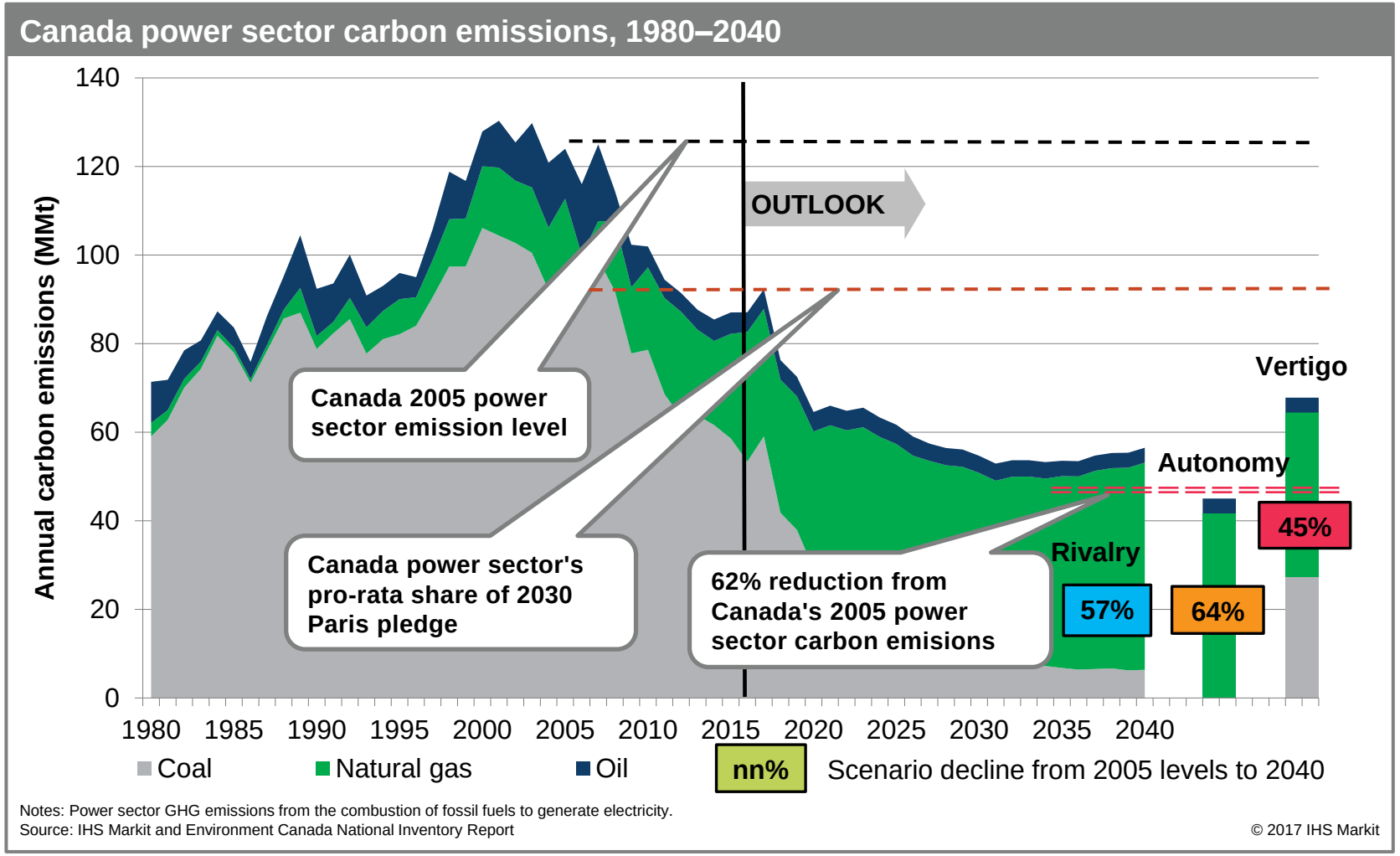
Notes: CO2 emission figures are from consumption of oil, natural gas and coal.
Source: History from US EIA, US EPA and Environment Canada; projections from IHS Markit.

US power sector CO_2 emissions reductions can meet a pro-rata share of the US Paris pledge in Rivalry and Autonomy



- US power sector carbon emissions have dropped substantially in the last decade owing to low natural gas prices, coal retirements, and renewable energy expansion driven by favorable policies and lowering costs.
- Future carbon emissions could vary over a wide range depending on policy, relative fuel prices, and power demand growth.
- Prior to its announcement to withdraw from the Paris Climate Agreement, the US pledge was a 26–28% economywide reduction from 2005 levels by 2025. While the pledge did not set sector targets, the power sector could more than meet a pro-rata share of that pledge in Rivalry and Autonomy.
- The US climate strategy submitted in 2016 to the United Nations Framework Convention on Climate called for an 80% reduction in 2005 economywide CO_2 emissions by 2050, which is consistent with a 62% reduction by 2040. In Autonomy, the power sector could comply with a pro-rata share of such a 2040 target, but it if such a strategy were implemented the power sector's target could be much lower and more difficult to meet.
- Vertigo's higher carbon emissions are driven by higher power demand growth, higher gas prices, and a slow down in the pace of coal asset retirements.

Canada's power sector CO_2 emission reductions more than meet a pro-rata share of its 2030 Paris pledge

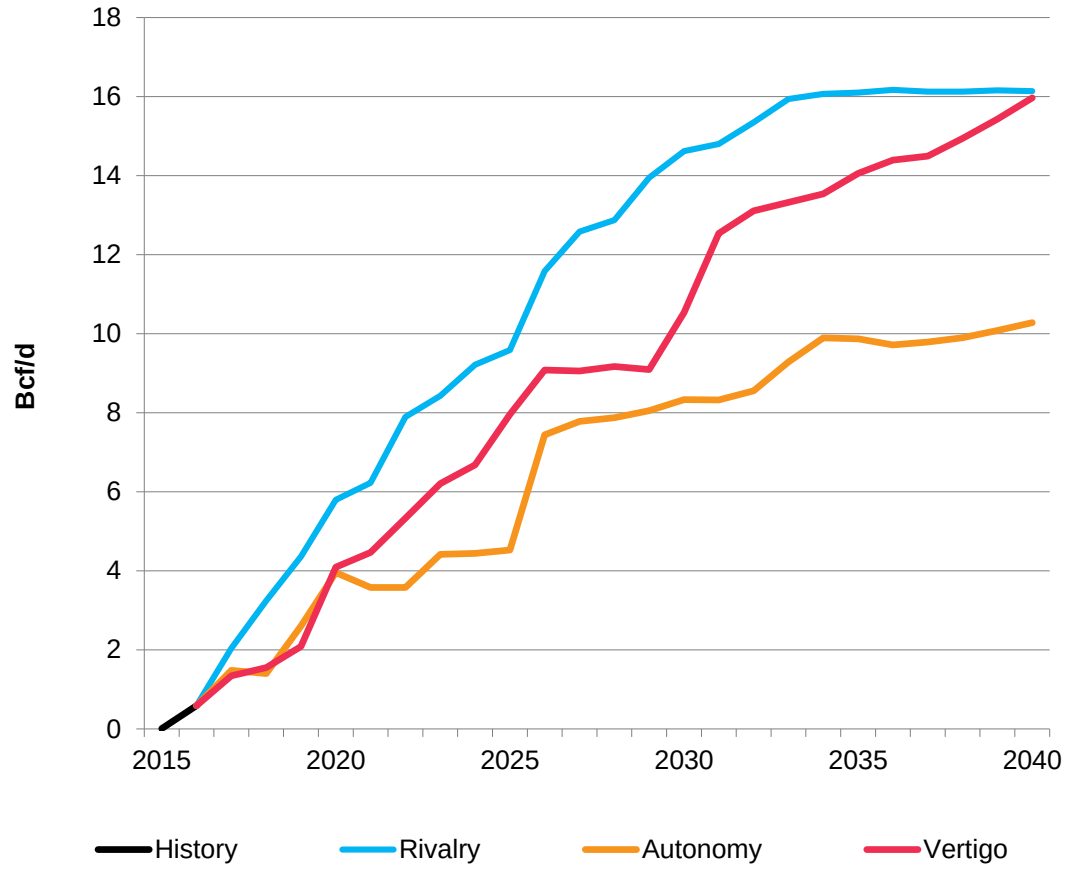


- Canadian power sector carbon emissions have dropped substantially in the last decade owing to low natural gas prices, coal retirements, and renewable energy expansion driven mostly by favorable policies.
- Future carbon emissions are expected to continue to decline, with the rate of coal asset retirement being the single biggest source of uncertainty.
- Canada's Paris Climate Agreement pledge is a 30% economywide reduction from 2005 levels by 2030. The power sector could more than meet a pro-rata share of that pledge.
- The climate strategy Canada submitted in 2016 to the United Nations Framework Convention on Climate called for an 80% reduction in 2005 economywide CO_2 emissions by 2050, which is consistent with a 62% reduction by 2040. In Autonomy, the power sector could comply with a pro-rata share of such a 2040 target, but it if such a strategy were implemented the power sector's target could be much lower and more difficult to meet.
- Vertigo's higher carbon emissions are driven by higher rates of power demand growth and a slow down in the pace of coal asset retirement relative to current federal and provincial requirements.

North American LNG exports—growth in any case

- North America becomes a significant net LNG exporter in all three scenarios.
- A narrowing oil/gas price ratio in Vertigo dampens LNG export volumes.
- Higher levels of global development of indigenous unconventional gas resources in Autonomy limit North American gas export opportunities but only after several export facilities are completed, leading to significant underutilization.

North American net LNG exports in scenarios

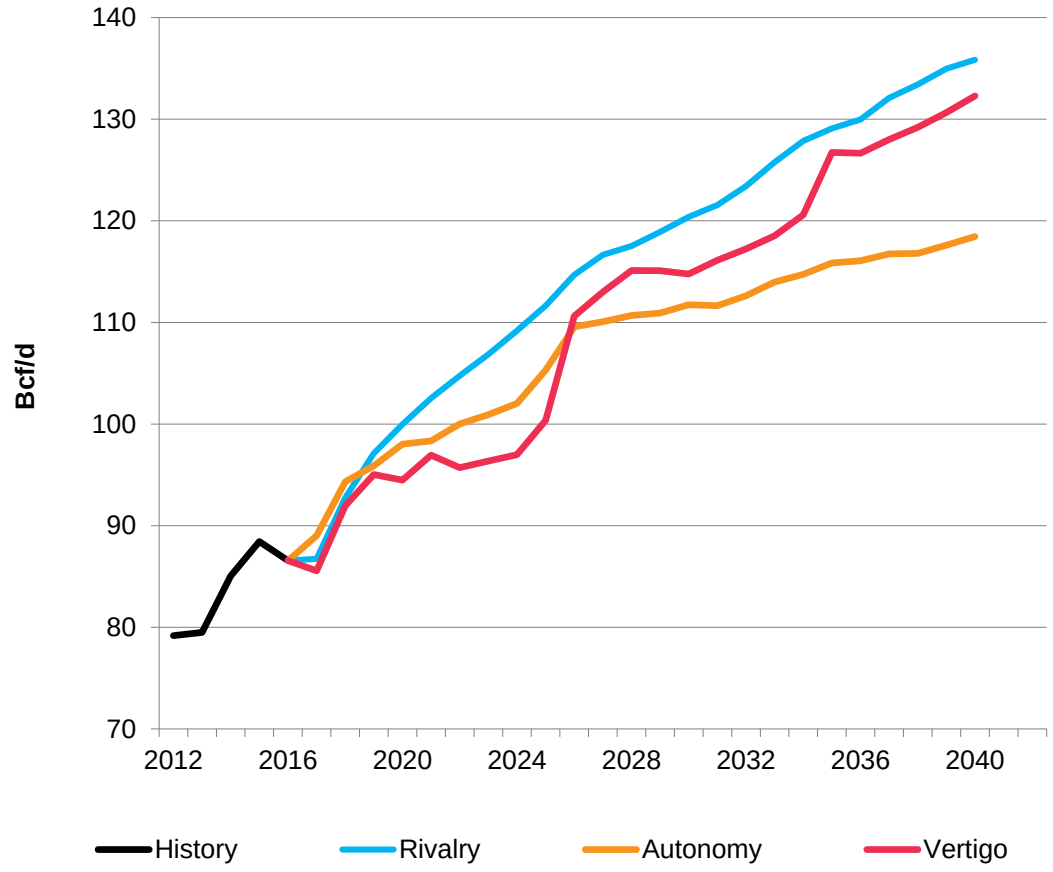


Source: IHS Markit

Total North American gas production—up or up

- **The recoverable natural gas resource base in North America is now sufficient to supply current demand for more than a century and to supply growing demand for several decades—but the cost dynamic is variable.** No classic exploration yet-to-finds are required, and an adequate resource base is a predetermined variable, applying to all scenarios.
- In Rivalry and Vertigo, North American production increases to meet demand, about 130–135 Bcf/d by 2040.
- In Vertigo, above-ground constraints on drilling and reluctance to sanction large capital-intensive acreage developments contribute to higher and more volatile price cycles.
- Less production is required to meet the lower demand that characterizes the Autonomy scenario. In this case total production grows to about 120 Bcf/d by 2040. In addition, the technology driver applies to gas production, with keen competition among producers on the supply margins.

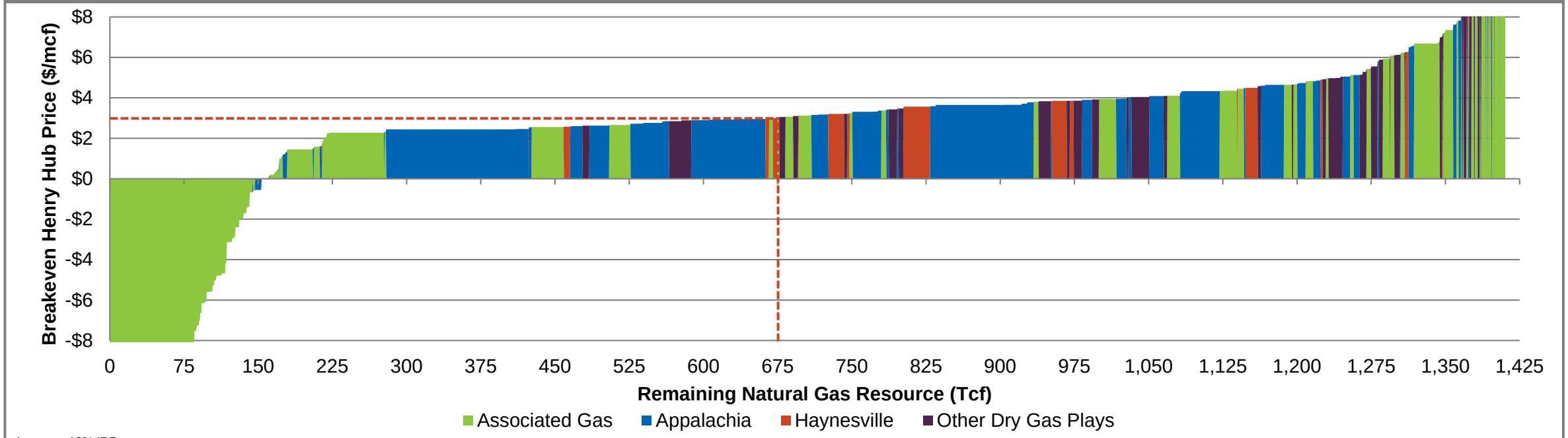
North American dry gas production across scenarios



Source: IHS Markit

Associated gas and Appalachia are the twin pillars of supply growth, accounting for about 60% of total US natural gas output, and even more of the lower cost resource base

US onshore gas cost curve

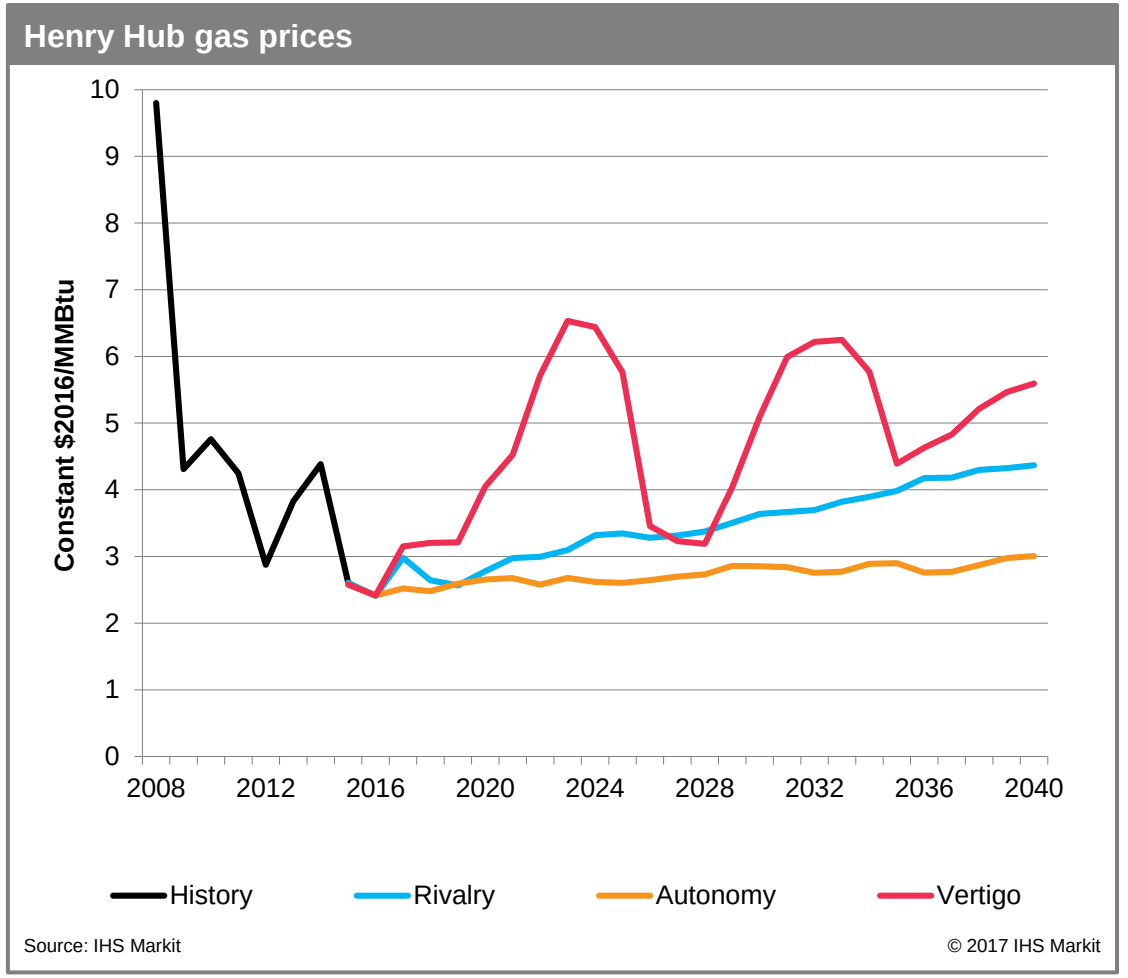


Assumes 10% IRR
Source: IHS Markit

- Appalachia and associated gas continue to drive US supply growth due to their prolific resource base, much of which is commercial at or below current Henry Hub pricing.
- Associated gas production is responsive to changes in oil prices rather than natural gas pricing. Highly productive liquids plays are distinct in that they are frequently among the lowest-cost sources of gas supply. This is due to cash flows from oil and other liquids offsetting the costs for natural gas gathering, transportation, and processing – in short, operators are often able to sell associated gas at a loss while still generating a satisfactory IRR on their wells.

Natural gas price outlook—the reality of the resource base means costs drive the price

- **In Rivalry,** the plentiful shale resource base and continuing improvements in extraction technology result in a slow increase in natural gas prices through 2040.
- **In Autonomy,** lower domestic and export demand serve to hold prices below those of Rivalry, and intense competition among marginal supply sources ensues. An ongoing productivity increase of 1–1.5% annually is sufficient to support long-term prices in this range given current knowledge of the resource base.
- **In Vertigo,** higher Henry Hub gas prices arise from a combination of above-ground constraints and producer caution and reluctance to invest in new areas. Instead, they exploit known plays more intensively and wait for significant price signals before increasing capital outlays. This strategy results in generally higher costs and a chronic mismatch between production and prices.



Q & A

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