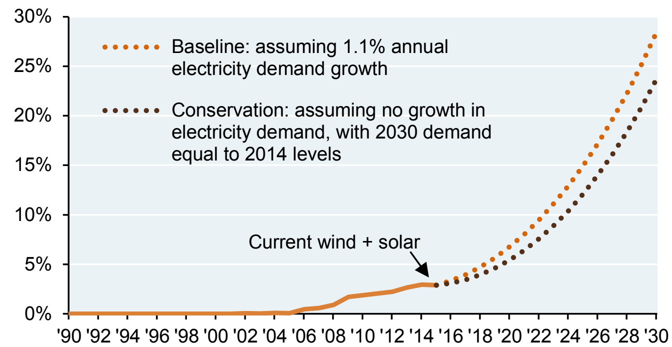
[III] A New York State of Mind: Thoughts on an ambitious new energy plan

In December 2015, New York State announced an ambitious energy plan designed to reduce GHG emissions by 32% by 2030[10]. The plan has several components, but there are two primary ones:

- *Cut energy use*. By 2030, reduce energy consumption in commercial, residential and industrial buildings by 23%.
- *Decarbonize the grid*. By 2030, generate 50% of electricity from renewable sources.

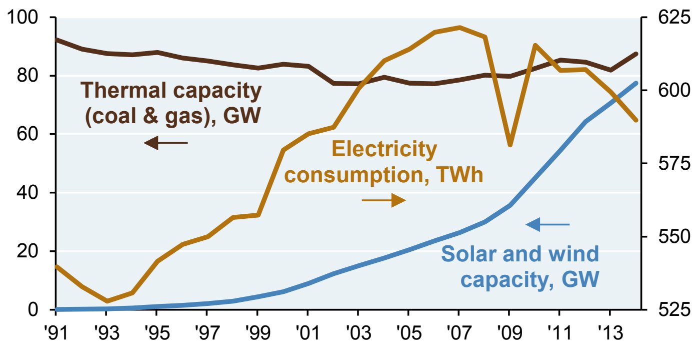
While the first objective is ambitious over a 15-year timetable, it relies on established methods of energy conservation. But will the second objective be a sentimental journey, or a real one? New York assumes that an eight- to ten-fold increase in wind and solar will propel it to 50% generation from renewables. However, New York is not a particularly windy or sunny place, which explains its low wind and solar penetration to-date. Furthermore, its projections may not adequately reflect wind and solar intermittency, which may result in substantial back-up thermal capacity needs. This phenomenon is observed in Germany after its 15-year renewable energy journey. Grid de-carbonization is critical[11] given adverse human health externalities associated with fossil fuels, but the economic and political levers required to make this vision a reality, and its associated costs, are still unclear.

New York State goals for wind and solar power by 2030
Wind plus solar energy as % of total electricity generation



Source: EIA, NYSERDA, JPMAM. December 2015.

Despite a large renewable energy build-out in Germany, almost no reduction in natural gas and coal capacity



Source: German Federal Ministry for Economic Affairs and Energy. 2014.

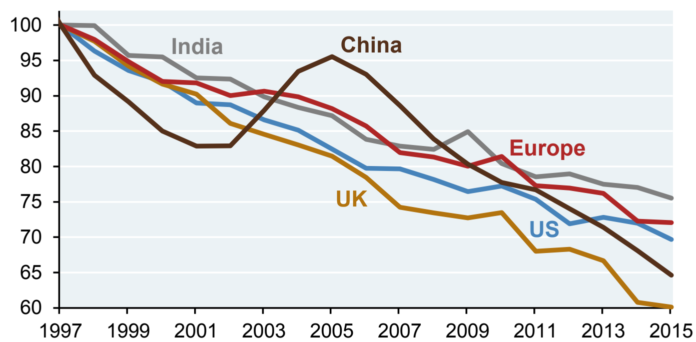
[10] **New York cites a 40% GHG reduction target, but this is vs. a higher 1990 baseline; the 2030 target is a 32% reduction when compared to 2014 emissions**. In addition to renewable sources of electricity energy and reduced energy consumption in buildings, New York also assumes GHG reductions from changes in **transportation**: increased use of plug-in electric vehicles (see pages 7-9); upgrade of less energy-efficient mass transit infrastructure, such as the NYC subway system; and reduced idling and enhanced traffic flow from sensors, improved traffic avoidance guidance and synchronized traffic signals.

[11] **Vaclav, on electricity grid de-carbonization:** "Underlying all of the recent moves toward renewable energy is the conviction that such a transition should be accelerated in order to avoid some of the worst consequences of rapid anthropogenic global warming. Combustion of fossil fuels is the single largest contributor to man-made emissions of CO_2 which, in turn, is the most important greenhouse gas released by human activities. While our computer models are not good enough to offer reliable predictions of many possible environmental, health, economic and political effects of global warming by 2050 (and even less so by 2100), we know that energy transitions are inherently protracted affairs and hence, acting as risk minimizers, we should proceed with the de-carbonization of our overwhelmingly carbon-based electricity supply – but we must also appraise the real costs of this shift."

Objective #1: New York's plan to reduce energy consumption in buildings by 23% by 2030

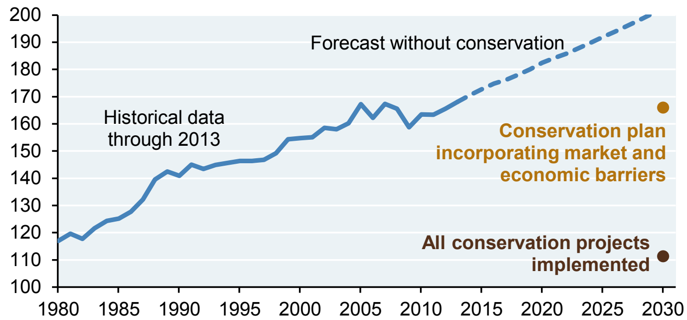
Conservation is a critical component of a more efficient energy future, and is a primary building block in most CO_2 emission plans. New York's conservation objectives rely upon established methods (solid-state/LED lightning, light fixture efficiency, heat pumps, adaptive and optimized thermostats, more efficient HVAC and insulation systems, reduced stand-by loads and smart plugs, remote appliance control, etc). Conservation has a good track record: since 1980, US energy use per sq ft has fallen by 21% and 11% in commercial and residential buildings. In Denmark, a conservation leader, energy consumption in buildings has fallen by 45% per sq meter since 1975. As shown in the first chart, energy intensity has declined in many regions, with conservation gains in buildings and machinery playing a large role.

Examples of declining primary energy intensity
Index, 1997=100, BTUs of energy per unit of real GDP



Source: National statistics offices, BP Stat. Review of World Energy. 2015.

NYSERDA electricity use scenarios
New York electricity sales, TWh, historical and projections to 2030



Source: NYSERDA, JPMAM. April 2014. Pre-1990 electricity sales extrapolated from published load data.

While New York's energy conservation methods are well-established, the magnitude of achievable savings is not easy to quantify. The New York State Energy Research and Development Authority (NYSERDA) is tasked with coming up with plans to reach the state's goals. NYSERDA reports released in 2014 contain two scenarios for energy conservation in buildings. In the first, all projects with positive economics are implemented, while in the second, market barriers to implementation and extra costs are incorporated. NYSERDA estimates that energy consumption could decline by 29% in the first case, and by 11% in the second.

The first case is ambitious; let's look at electricity, which accounts for 40% of total projected energy savings in buildings[12]. As shown above (right), in the first case, New York's electricity usage would fall by 35% and decline below 1980 levels, while in the second, 2030 usage would be roughly the same as in 2013. Double-digit electricity usage declines have occurred in some European countries (see table), so while New York's plans are very ambitious, they're not totally unprecedented.

All things considered, reducing energy consumption in buildings by 10%-15% seems quite achievable, while a 23% reduction would take a more aggressive action plan with explicit incentives for businesses and households to make the necessary investments in energy-saving technology.

Declines in TWh of electricity consumption, 2015 vs. prior peak	
Denmark	-34%
Belgium	-21%
Finland	-19%
UK	-16%
Italy	-12%
Netherlands	-11%
Sweden	-5%
Germany	-4%
Australia	-4%
France	-3%
Norway	-2%
Canada	-2%
US	-1%

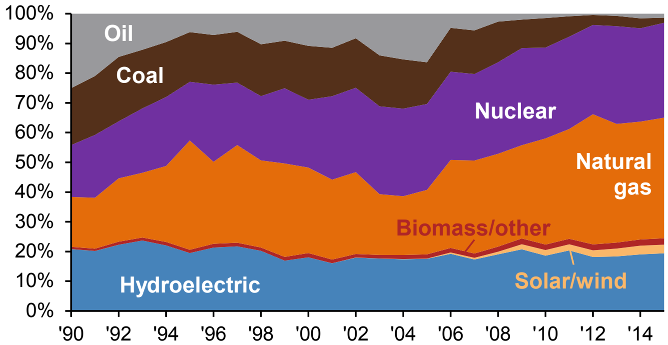
Source: BP Statistical Review of World Energy. 2015.

[12] Reduced natural gas use accounts for another 40% of building energy savings in NYSERDA's plan. The remainder is from reduced petroleum use.

Objective #2: a large expansion in New York's wind and solar power

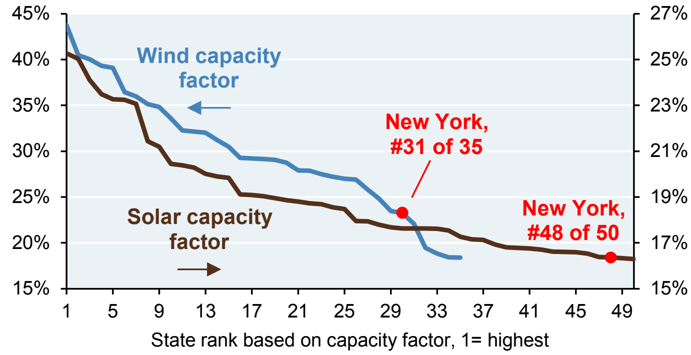
New York is not a particularly windy or sunny place. New York ranks 31st out of 35 states based on its wind capacity factors (a measure of electricity generation efficiency described below[13]), and with respect to solar, New York ranks 48th out of 50 states based on capacity factors from the National Renewable Energy Laboratory. Wind and solar only play a small role in New York electricity generation (around 3%), so a plan relying heavily on their expansion is worth examining. New York is also an interesting bellwether: its solar irradiance is similar to China, Japan, Russia, the UK, Germany and the Philippines, and its wind speeds are similar to India, Brazil and large parts of Central Europe.

Wind and solar: just 3% of NY electricity generation
NY state electricity mix, 1990 - 2015, % of total generation



Source: Energy Information Administration. December 2015.

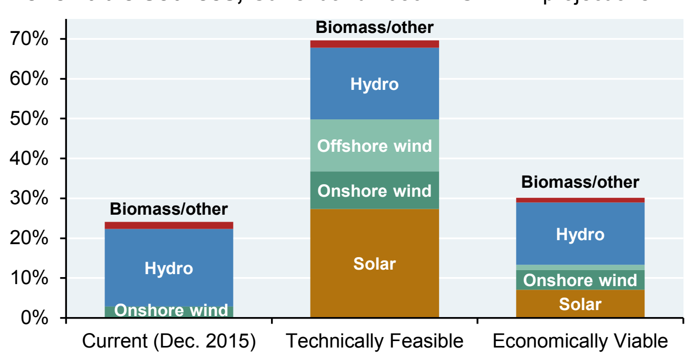
New York ranks near the bottom in terms of electricity generation efficiency from wind & solar, capacity factor %



Source: Wind Action Group, NYSERDA, NREL. April 2014.

The next chart shows NYSERDA's renewable energy projections for 2030 alongside New York's current renewable electricity mix. NYSERDA examines two different cases: a "**Technically Feasible**" case which assumes all projects are built irrespective of their cost, and an "**Economically Viable**" case which assumes projects are only built if they make economic sense. The latter benchmarks wind and solar against the most expensive form of generation (typically natural gas peaker plants), and results in 8x-10x growth in wind and solar power by 2030. If these generation goals were achieved, New York would make good progress, particularly if energy conservation reduces demand[14].

Share of New York State electricity generation from renewable sources, Current and 2030 NYSERDA projections



Source: NYSERDA, EIA, JPMAM. April 2014.

NYSERDA renewable energy scenarios for 2030:

- **Technically Feasible** case relies heavily on offshore as well as onshore wind, and a combination of utility-scale, residential and commercial solar power
- **Economically Viable** case mostly relies on onshore wind, and utility-scale and large commercial solar power
- In both cases, share of generation from biomass, hydroelectric, etc remain at current levels

[13] **Capacity factors** measure actual production relative to theoretical production (generation at full-power over the entire period). For example, assume a 1 MW wind turbine with potential output of 24 MWh in one day; if the turbine generated 8 MWh of electricity, its capacity factor would be 33%.

[14] In its 2014 renewable energy projections, NYSERDA assumed annual electricity demand growth of 1.1% to 2030, rather than incorporating the impact of conservation goals stated elsewhere in the plan. If electricity loads in 2030 were flat vs. today, the Economically Viable case would imply 37% renewable generation rather than 30%.

Our take on NYSERDA's assumptions. While there are over 500 pages of NYSERDA documents, wind and solar assumptions matter most since NYSERDA's 2014 analysis did not assume higher shares from biomass, biogas, hydropower, solar thermal, wave energy, etc. For the most part, the Economically Viable case assumptions regarding wind and solar seem reasonable to us:

- *Onshore wind capacity factors*. New York has 1.8 GW of onshore wind whose 2013 capacity factors were 23%-25%. Most plants were built from 2006 to 2009, and are located in New York's windiest counties (map). NYSERDA assumes capacity factors of 33% to 40% on future installations, levels typically observed in much windier states (see US map). However, two recent installations in New York show capacity factors in the mid 30s. As new GW of wind are added, the state average should rise, although 40% by 2030 seems like a stretch to us. Challenges include community receptivity[15] and degradation in capacity factors over time[16], a trend which has adversely affected wind investor returns.
- *Upfront capital costs for onshore wind and solar*. NYSERDA estimates of upfront capital costs for onshore wind ($2,380 per kW) and utility-scale solar ($1,720 per kW) look reasonable and are maybe too high, particularly for onshore wind where we have seen lower estimates of $1,600 to $2,000 per kW. As we discussed last year, learning curves show continued unit cost declines for wind, solar and battery storage as production volumes increase.
- *Capacity factors for utility-scale, commercial and residential solar PV*. NYSERDA assumptions of 14%-15% for all 3 types are reasonable, although commercial/residential capacity factors are often 2%-3% lower. NYSERDA estimates are consistent with NREL regarding areas with NY's solar irradiance.
- *Offshore wind*. Unsurprisingly, offshore wind's projected share falls by 90% in the Economically Viable case. While offshore wind speeds are generally higher than onshore, many estimates of their costs (including grid interconnection) more than offset this benefit. A 2014 paper from the University of Sussex determined that offshore wind is the most expensive commercially available renewable energy source in the UK, and that **rather than compelling economics**, its development reflects the alignment of political and financial interests of its advocates[17]. Papers like these are useful since they reflect the experience of countries with actual offshore wind installations; the US currently has none.
- *Distributed solar PV*. In the Economically Viable case, residential and small commercial solar PV disappears due to higher costs. What remains is a projected 10 GW build-out of large commercial and utility-scale solar PV. To-date, most utility-scale solar PV has been built in states that are much sunnier than New York. However, we believe that NYSERDA solar capital cost, capacity factor and levelized cost assumptions of 11 to 12 cents per kWh are reasonable (the latter 1-2 cents too low at most).

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[15] **There's local opposition in the air, but it may not have an impact given passage of anti-NIMBY legislation.** Three New York counties (Erie, Orleans and Niagara) passed resolutions opposing a proposed 200 MW project that entails 500-600 foot wind turbines across 20,000 acres. However, in 2011 Governor Cuomo signed Article 10 into law which allows the State to provide necessary approvals in a unified proceeding for clean energy projects, and which does not appear to require approvals from local communities.

[16] **Examples of wind capacity factor shortfalls and degradation.** A study by the Renewable Energy Foundation on UK and Danish wind farms found that capacity factors fell as wind farms aged, from 24% to 15% in year 10 in the UK, and from 22% to 18% at age 15 in Denmark. A similar study from the Imperial College of London found that wind farm output declines by 1.6% per year as turbines age. In 2012, when S&P downgraded several single-asset wind projects below investment-grade, S&P cited capacity factors that were below what industry experts had cited as lower-bound estimates, as well as operating costs that were 30% to 40% higher than original forecasts.

[17] **What explains the development of offshore wind?** "Our analysis demonstrates how the close alignment of economic and political interests of key actors within the specific context of the UK has led to the rapid deployment of offshore wind – by circumventing anti-onshore wind protest in the short term and meeting 2020 renewables targets in the medium term but at potentially high economic and political costs when the further deployment of offshore wind adds up to a significant impact on electricity bills". Source: *From laggard to leader: Explaining offshore wind developments in the UK,* Kern et al, University of Sussex, February 2014.

While NYSERDA's individual assumptions seem reasonable, there's another important question to answer: **what happens when there's not enough wind or solar irradiance to meet electricity demand?**

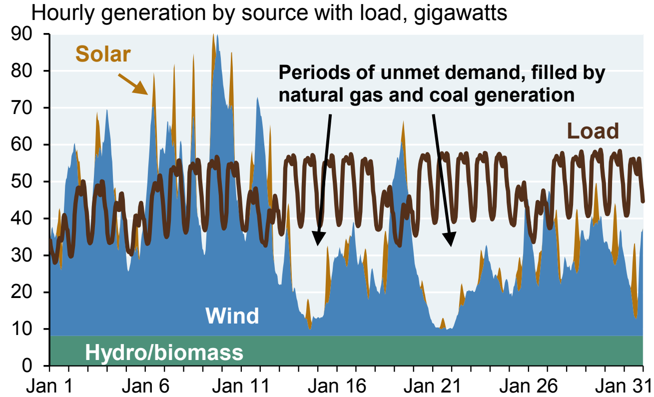
The issue of wind and solar intermittency: the need for back-up thermal generation capacity

Costs for wind and solar power cannot simply be compared to thermal sources without accounting for wind and solar intermittency, since back-up thermal capacity is typically needed for periods when there's not enough wind or solar power to meet demand. NYSERDA is aware of this issue and is not assuming that renewable capacity immediately displaces thermal capacity on a 1:1 basis. Based on our reading of the documents, NYSERDA assumes that thermal capacity is replaced at a constant rate that is less than 1:1. Even so, this may be optimistic, since existing research shows a *diminishing* (non-constant) ability to shutter thermal capacity as more wind and solar power are added to the grid[18].

However, our even bigger concern is that *everyone's* estimates of how much thermal capacity can be shuttered may be too high. Consider the next 2 charts from our 2015 energy paper[19]. Working with the Clean Air Task Force, we examined hourly generation and load patterns in both Germany and California. Even though Germany's planned build-out of wind and solar (*Energiewende*) would result in 80% of electricity coming from renewable sources over the course of the *year*, we estimated that its back-up thermal capacity needs would be practically unchanged vs. current levels, given periods of low wind and solar power during winter months. The same outcome occurred in our analysis of California. Results were not very different when assuming energy storage (via batteries, pumped storage or hydrogen fuel cells), "demand management" or geographical grid expansion. Unfortunately for New York, its winter solar irradiance is similar to Germany, and its winter wind is like California's (i.e., the worst of both).

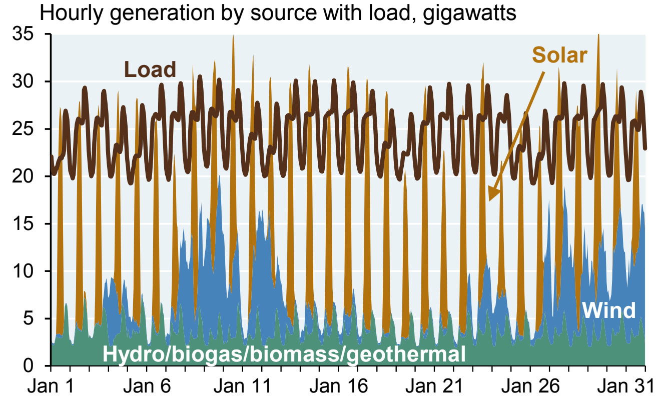
Even if wind and solar capacity were expanded to generate 80% of electricity from renewable energy over the course of the year, in winter months, there would be extended periods when extensive back-up thermal capacity is needed

Germany: January load vs. renewable generation
Hourly generation by source with load, gigawatts



Source: Germany grid operators, JPMAM. 2015.

California: January load vs. renewable generation
Hourly generation by source with load, gigawatts



Source: CAISO, JPMAM. 2015.

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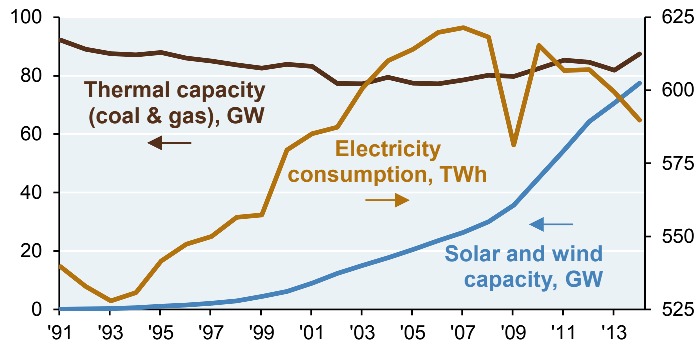
[18] Electricity grid analysts refer to **"capacity credits":** the amount of thermal capacity (natural gas and coal) no longer needed once wind and solar are added to the grid. The Lawrence Berkeley National Laboratory compiled various studies that all projected sharply falling capacity credits as wind and solar penetration increases. They are not alone; a 2015 paper from the Potsdam Institute for Climate Impact Research notes that integration costs in systems with high levels of renewable energy can be up to 50% of generation costs, and that the largest factor is the cost of back-up thermal power. **Hence the problem with analyzing renewable energy simply based on stand-alone levelized costs per kWh**. Lazard and Bloomberg New Energy Finance are well-known sources for levelized costs per kWh by generation source; they are usually cited in media reports on renewable energy without caveats on back-up power.

[19] See Brave New World, Annual Energy Eye on the Market, October 19, 2015.

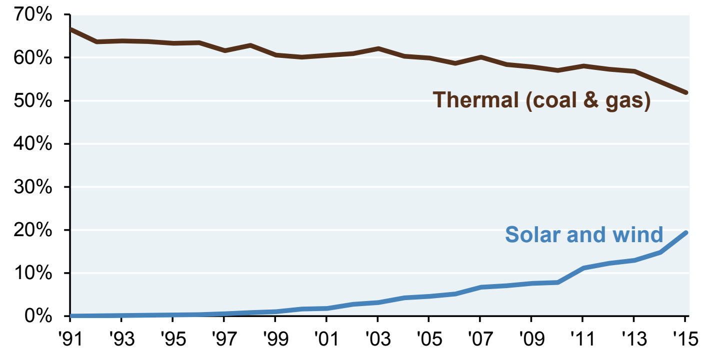
Here's some real-world evidence: **despite a large buildup of solar and wind capacity at a time of stable electricity consumption, Germany's thermal capacity is almost unchanged and is still very actively used**[20]. Thermal *generation* and CO_2 emissions have declined, but not thermal *capacity*. This may partly explain why Germany and Denmark, countries with the highest renewable capacity per capita in Europe, also have the highest residential electricity prices at around 0.30 Euro cents per kWh.

Despite a large renewable energy build-out in Germany, almost no reduction in natural gas and coal capacity



Source: German Federal Ministry for Economic Affairs and Energy. 2014.

The benefits: a 15% reduction in German thermal generation, Share of total electricity generation

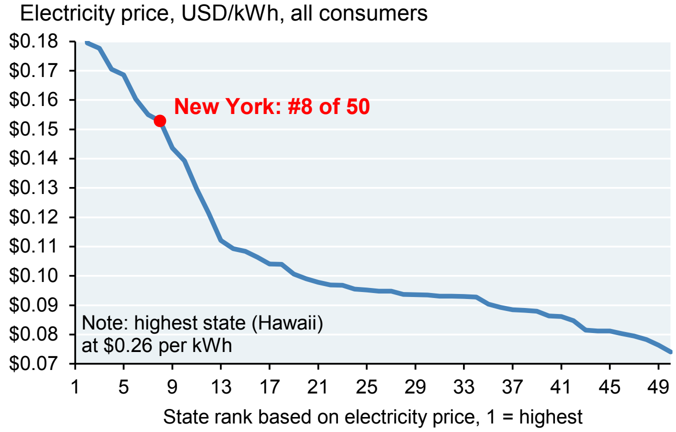


Source: German Federal Ministry for Economic Affairs and Energy. 2015.

All things considered:

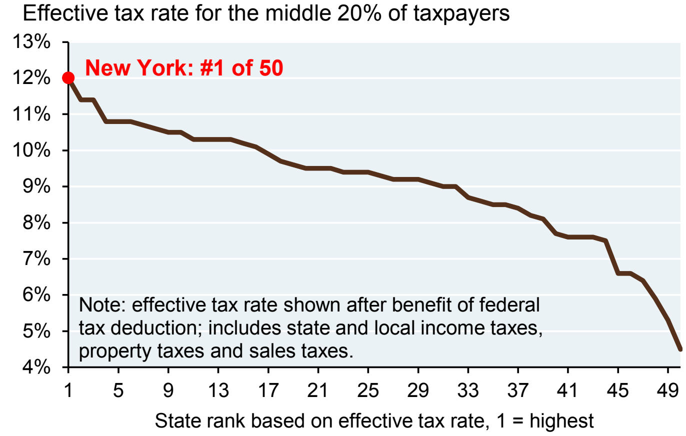
- New York's 50% renewable generation target is ambitious, particularly in just 15 years
- If Germany is any guide, New York's back-up thermal capacity needs may be higher than those assumed by NYSERDA
- Even though New York is relying on market forces to bring this transition about, taxes/subsidies and electricity prices will almost surely end up playing a role. Even before New York's energy transition begins, its electricity prices are the 8th highest in the US, and its state taxes are the highest in the US
- While renewable energy growth can drive electricity grid de-carbonization, its power density and intermittency dynamics suggest that some hard choices involving taxes, spending and electricity prices may eventually have to be made.

New York: 8th highest electricity price in the US
Electricity price, USD/kWh, all consumers



Source: Energy Information Administration. 2015.

New York: highest individual tax rates in the US
Effective tax rate for the middle 20% of taxpayers



Source: Institute on Tax and Economic Policy. 2015.

[20] Coal still accounts for 44% of electricity generation in Germany, and as shown in the linked chart, coal plants are still very actively used. In 2014, brown coal plant capacity factors were over 75%, close to their highest level in 25 years. Black coal plant capacity factors have fallen from their historical average of 50% to around 40% in 2014.