Energy Strategy

Fuel For Thought: What a Joe Biden Presidency Would Mean for the Energy Market

A watershed moment for the energy sector will occur in less than three months if Joe Biden wins the U.S. presidential election. The ex-Vice President under Barack Obama and 2020 presidential candidate has wide-sweeping policies regarding the power sector and economy-wide carbon emissions. In effect, Biden has taken the *Green New Deal* a step forward by assigning key deliverables, a timeline, and a price tag to complete this vision. Investment and mobilization of labour into non-emitting energy supply will completely eclipse that of the 1960s Moon Shot program and transform the economy in ways that are difficult to imagine. In the following pages, we explore the implications of Biden's climate agenda and clean energy plan for the utility-scale power sector.

The two key deliverables of Joe Biden's Sustainable Infrastructure and Clean Energy Future pillar of his Build Back Better platform are:

1. A carbon pollution-free U.S. power sector by 2035, and

2. U.S. economy-wide net-zero emissions by no later than 2050.

Both of these goals have dramatic implications for traditional carbon commodities like coal, crude oil, and natural gas. From a renewables perspective, aggregate end-user demand is not likely to decline substantially in the future, in fact it's likely to grow; thus, a supply gap will develop that must be filled by non-emitting sources.

Regarding the power sector: Roughly 63% of U.S. utility-scale electricity is generated through carbon-emitting fuel types, according to EIA data. The remaining 37% is from non-emitting sources including nuclear and hydroelectric, which account for 19.7% and 6.5% of aggregate capacity, respectively. If the United States were to phase out all carbon-sourced, utility-scale generation by 2035, the power sector would require 2.6 million GWh p.a. of sustainable, renewable capacity, assuming current demand levels for electricity. This supply gap amounts to ~81 Palo Verde nuclear plants or 1,226 Gemini Solar parks to be built, equating to ~$1.2-$1.3 trillion of EPC investment.

Regarding a net-zero economy: Carbon is deeply integrated in many forms of energy and product use. For example, removing carbon entirely from the economy would require energy to transition from being generated locally in internal combustion engines to utility-scale power generators or distributed via private civilian infrastructure that has yet to be built. The U.S. economy (i.e., not just the utility-scale power sector) consumes 94.6 exajoules p.a. of energy, of which 78.8 exajoules (83%) comes from coal, crude oil, and natural gas. Understandably, converting this much carbon-based energy into sustainable, renewable sources would require 8.5x the investment of just the power sector initiative. If Biden's plans are brought to fruition, November 3, 2020, might become the most important turning point for the energy sector for the next three decades.

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MARKET DATA

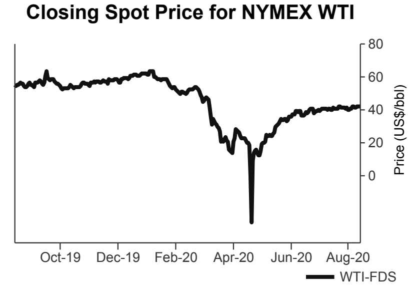
Spot NYMEX WTI (US$/bbl)	$41.66

FORECAST DATA

	2019A	2020E	2021E	2022E
NYMEX WTI (US$/bbl)				
Current	57.04	36.70	43.50	52.00
ICE Brent (US$/bbl)				
Current	64.18	40.55	46.00	55.00
WCC Heavy Oil (C$/bbl)				
Current	57.37	31.66	37.90	49.50

Energy Strategy

Closing Spot Price for NYMEX WTI



Source: FactSet.

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Wrap Your Head Around Biden's Energy & Infrastructure Plan

Democratic presidential candidate Joe Biden has outlined a Build Back Better agenda designed to rebuild the U.S. economy amid record-high unemployment following the COVID-19 pandemic. Three of the four main pillars of this agenda concern (1) an American-centric manufacturing and innovation program, (2) improving affordability for the caregiver and education workforce, and (3) advancing racial equity. The fourth pillar concerns building **new infrastructure and a clean energy plan**, the focus of this piece.

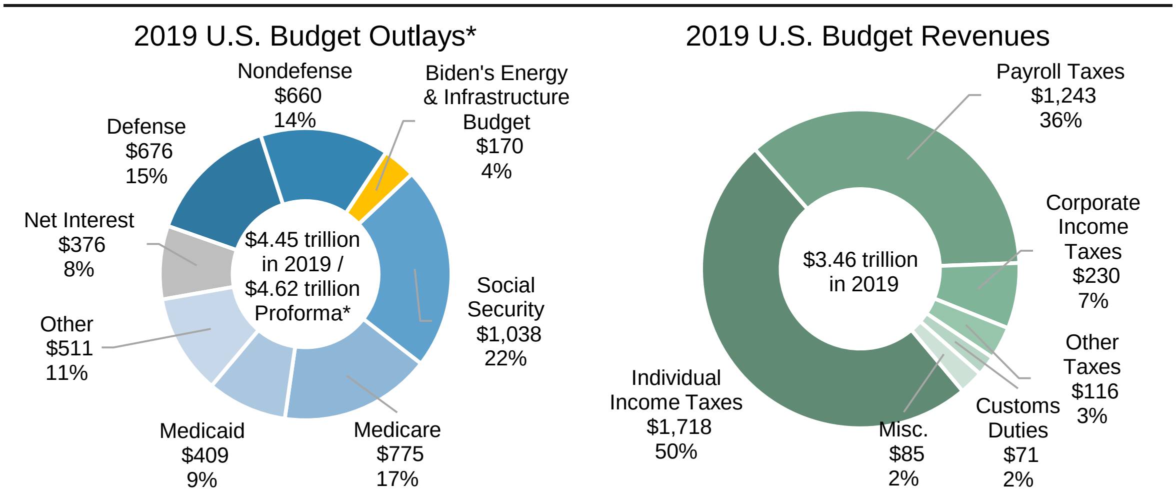
A green America founded upon a Green New Deal. Biden believes the **Green New Deal** is a *crucial framework* for meeting climate challenges (see **Biden on Climate**), which has become the foundation of all pillars in his platform, particularly the fourth. The *Green New Deal* is a broader resolution, which aims to (1) counteract systemic injustices and inequalities, (2) increase the amount and quality of employment, and (3) invest heavily in green/sustainable infrastructure and technology. The overarching goals of the framework are to achieve net-zero greenhouse gas emissions in order keep global temperatures within 1.5 degrees Celsius of pre-industrialized levels while *ensuring the prosperity and economic security of Americans*.

100% clean energy economy and net-zero emissions no later than 2050. Biden takes this framework a couple of steps forward by defining a handful of key deliverables, providing a budget, and timelines that will be of utmost importance to the energy sector:

- A carbon *pollution*-free U.S. power sector by 2035.
- Reduce the carbon footprint of U.S. buildings by 50% by 2035.
- U.S. economy-wide *net*-zero emissions by no later than 2050.

If we can land on the Moon, then we can clean up the Earth. The ambitious climate and environmental justice plan is advertised to cost U.S. taxpayers *just* **$1.7 trillion** through federal investment over the next 10 years. Additional private sector and state and local investments would bring the total to more than $5 trillion. More specifically, $400 billion over 10 years is earmarked for clean energy research and innovation. This amount is *twice the investment of the Apollo program, which put a man on the Moon, in today's dollars*. We have provided a pro forma version of the 2019 federal budget in Exhibit 1 to highlight that this would require a 4% increase in annual expenditure, representing 0.8% of annual GDP (i.e., of $21.4 trillion in 2019). Of course, government budgets in 2020 have recently ballooned with monetary and fiscal stimulus packages

Exhibit 1: Biden's Energy & Infrastructure Plan Sets Out $1.7 Trillion over 10 Years



Note: Figures in USD billions.
* 2019 pro forma budget with Biden's proposed Energy & Infrastructure plan.

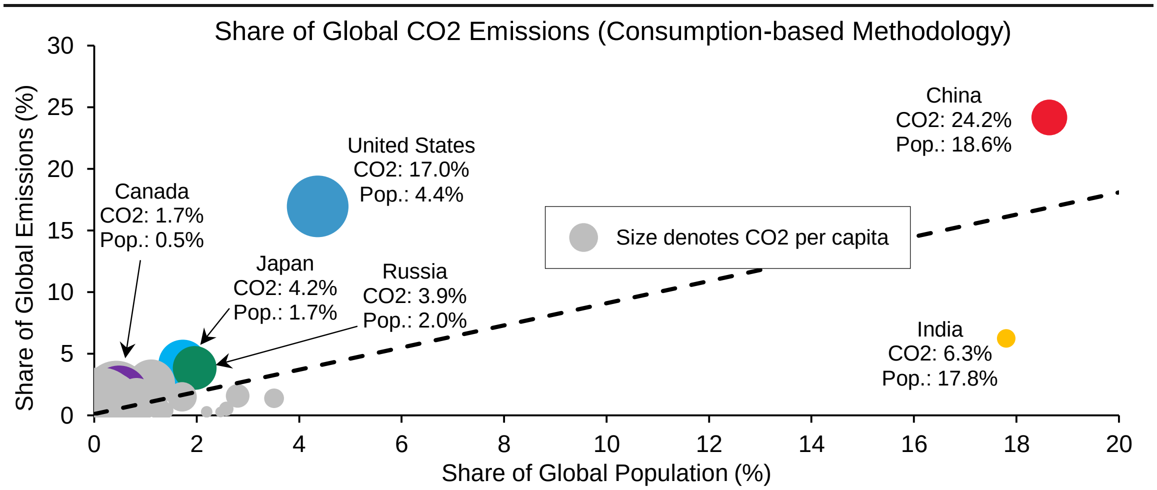
Source: U.S. Congressional Budget Office; Scotiabank GBM.

aimed at combating the economic fallout of COVID-19 that has slashed productivity/GDP. That said, the cost of the proposal does seem feasible, especially given that Biden has promised to **reverse the corporate income tax breaks** established by Trump via the **Tax Cut and Jobs Act of 2017**. Government revenues from corporate taxes plummeted $92.3 billion, from $297.0 billion in 2017 to only $204.7 billion in 2018, a reversal of which would pay for at least half of this increased expense. Presumably, economic growth and higher personal incomes spurred from this plan would then lead toward higher individual and corporate tax revenue in subsequent years to make up the remainder, while also potentially slashing some non-essential (i.e., Defense/Non-defense) discretionary spending.

Congressional approval might be required. While the Executive Office of the President provides the annual federal budget, and all bills for raising revenue (generally tax bills) must originate in the Democrat-majority House of Representatives, the **Antideficiency Act** voids any attempt to spend money for which there is no current appropriation. Congress can deliberate and pass appropriations bills based on the president's recommendations and congressional priorities, though there are a handful of work-arounds/remedies. This is where the Senate, in which Republicans currently hold a three- to five-seat majority, may have some negotiating power to seek concessions or attempt to filibuster. Alternatively, the next federal election could potentially see a flip in majority, with 33 senate seats up for re-election and two additional seats for special elections in November (i.e., 23 Republican and 12 Democrat seats). Given two incumbent independent seats that generally caucus with Democrats, four seats would need to flip to create a Democratic majority in the Senate, which would likely make passing Joe Biden's new infrastructure and clean energy budget manageable without significant alterations/concessions.

Global adoption is also needed to achieve the ultimate goal. Biden claims that he will *rally the rest of the world* to join this aggressive fight against climate change; however, we would note that achieving the overall target of a global CO_2 reduction would require adoption from nations that are less likely to heed the call or be able to financially afford it. That said, the United States is one of the most polluting countries in the world, both in absolute terms and on a per capita basis. Approximately 330 million Americans contribute ~17.0% of global emissions on a consumption basis, but represent only 4.4% of the global population. The top three emitters, being China, the United States, and India, respectively, contribute a combined 47.4% of global emissions, or roughly the mid-point of the New Green Deal emissions reduction targeted range. Consequently, these goals are technically achievable, but contingent on whether the United States can persuade those above the line (i.e., China, Japan, and Russia) to join; *most* European nations are already leading this effort.

Exhibit 2: Can the United States Pull Its Own Weight and Get Below the Line?



Note: China and the United States are the two largest polluters, but are #53 and #8, respectively, on a per capita basis. Canada is #13.

Source: ourworldindata.org; Global Carbon Project (GCP) data as of 2015; UN Population; Scotiabank GBM.

Given the importance of the United States in addressing global climate change, we will focus on the two overarching deliverables of the new infrastructure and clean energy platform and attempt to answer these questions: What could the energy sector look like under Biden's proposals? What could the major impacts be?

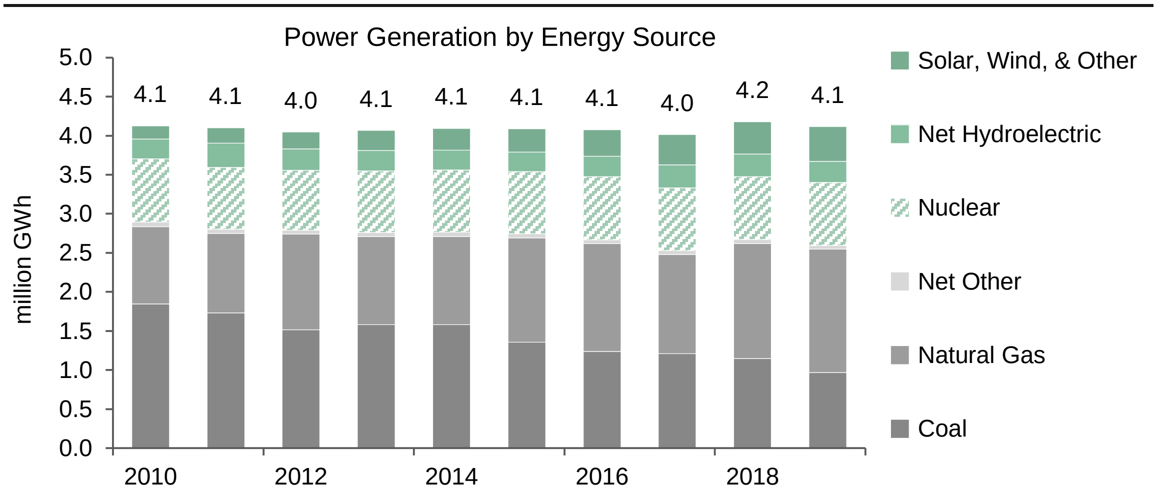
A Carbon Pollution-Free U.S. Power Sector by 2035

The demise of coal-fired generation entirely. Total electricity generation in the United States has been relatively constant over the last 15 years at ~4.1 billion megawatt hours; however, the fuel source mix that generates this power has changed dramatically in the last 10 years. The largest systematic change started a decade ago, at the beginning of Barack Obama's presidential terms; since then, there have been consistent declines in the coal-fired power generation sector (coal-fired generation has decreased 48%, or 881 million MWh p.a., over 10 years). While federal policy, such as the Obama administration's **Clean Power Plan**, likely kick-started the demise of coal-fired generation, the availability and plummeting cost of natural gas would have aided in the switch over time.

Natural gas *was* the bridge fuel. Given the relatively low reliability and capacity factors (i.e., utilization rates) of solar and wind, the power stack required another form of baseload supply, which leaves hydroelectricity, nuclear, and natural gas. Hydroelectricity is bounded by geographical constraints, and nuclear power had fallen out of social favour due to recent events such as the **Fukushima Daiichi nuclear disaster** in 2011. Consequently, the baseload capacity *shortfall* of declining coal-fired generation was made up for primarily by natural gas-fired generation (+60% or +594 million MWh p.a.) with intermittent generation provided by wind (+209 million MWh p.a.) and solar (+71 million MWh p.a.).

Will Biden nix natural gas and go straight to next generation nuclear? Natural gas is an emitting power source without an integrated **carbon capture, use, and storage** (CCUS) process. This means that ~63% of the U.S. power stack continues to produce CO_2, albeit at significantly lower levels than prior to the Obama administration. In order for Biden to fulfill his promise by 2035, the **United States would need to make up an additional 2.6 million GWh p.a. of non-emitting, sustainable net generation**. Very few natural gas power plants have CCUS integration for the same reason that coal plants don't – it is not cost-effective. Consequently, due to the variability of standalone solar and wind generation, nuclear power, particularly small modular reactors (SMR), are likely to retain a dominant position in the power sector, despite social and political sensitivities surrounding this fuel source. Notably, Biden has voiced support for **SMRs and funding research through ARPA-C**.

Exhibit 3: 63% of U.S. Power is CO_2-Emitting, with Another 20% from Nuclear and 7% from Hydro

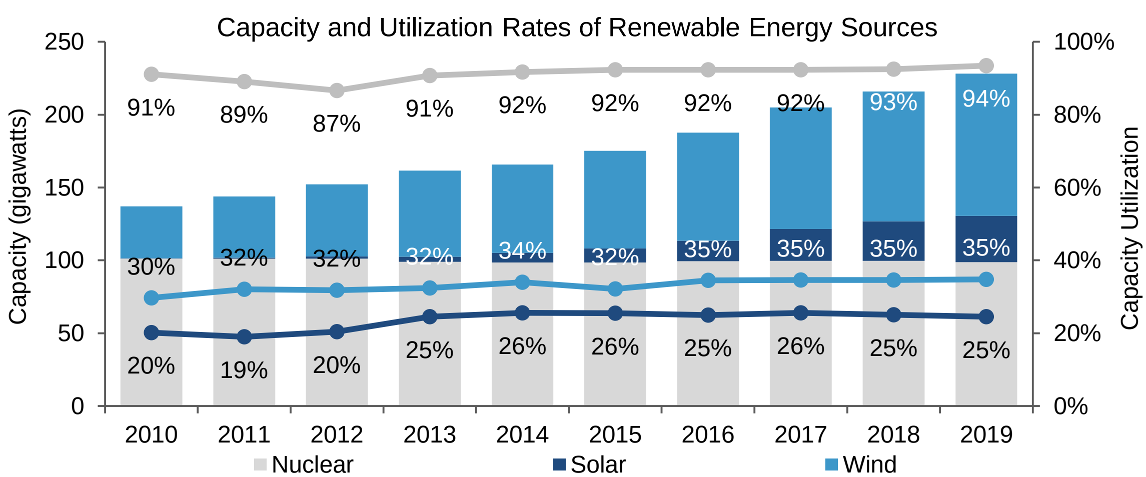


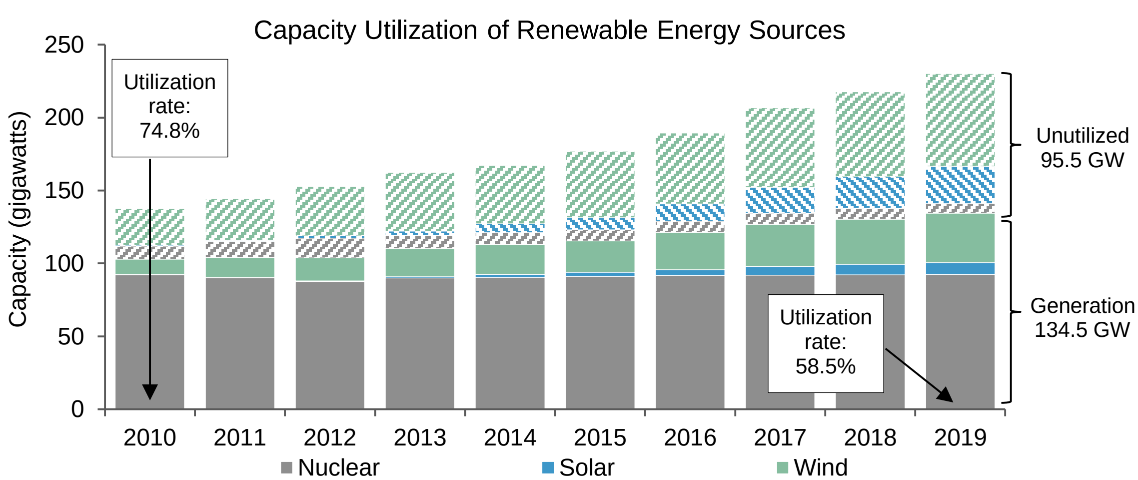
Source: DOE EIA; Scotiabank GBM.

Less bang for your buck. There are a few key facts to keep in mind regarding Biden's path forward with solar, wind, and nuclear power:

- **Solar utilization rates, on average, are ~25%.** We believe that solar panel efficiency will continue to improve over time, but there are limitations to reliability. Panels can be obscured by weather, such as clouds on rainy/snowy days or snow/sand/dust sediment. Additionally, sun procession across the sky can play a major role in northern latitudes (e.g., Anchorage, AL receives 19.5 hours of sun in June, but only 4.5 hours in December). As panels continue to become less expensive, we could see significantly more deployed to make up for sub-optimal placement.
- **Wind utilization rates, on average, are ~35%.** Chasing the wind can be less forgiving going forward. Certain locations are less ideal for wind turbine placement because of lack of consistent wind, location of population, wildlife endangerment, seaborne shipping safety, etc. Turbines cannot be installed just anywhere, and some of the best spots have been picked over by this point.
- **Nuclear utilization rates are ~94%.** Utilization rates have been climbing over the past decade, likely as a result of declining coal-fired generation, requiring a substitution for baseload demand. Notwithstanding turnarounds/maintenance, individual nuclear plants can maintain near-100% utilization rates over long periods of time.

Exhibit 4: Utilities Must "Over-Build" Solar and Wind Capacity and Use Batteries to Fill the Gap





Source: DOE EIA; Scotiabank GBM.

***Can* it be done? Theoretically, yes**. However, to put this level of investment into perspective, we have provided some calculations to compare the scale of change with the largest energy projects in the world and currently in the United States.

In Comparison with the Largest Facilities Ever Built

To achieve Biden's goal of 100% non-carbon emitting power by 2035, the United States would need to make up 2.6 million GWh of sustainable generation. This is a truly momumental task, perhaps beyond the scope of landing a man on the Moon within eight years of Kennedy's **Moon Shot** program in 1961. The Bhadla Solar Park in India is the largest photovoltaic (PV) facility in the world, with a nameplate capacity of 2,245 MW, producing ~4,944 GWh p.a. The United States would need to build 525 facilities like Bhadla to fully fill this gap on an absolute basis, and this could not be achieved without adequate battery storage for when the sun is not available. Likewise, wind power is typically little less reliable than solar and suffers from much of the prime locations in the United States being already picked over, thus producing less effective power per marginal project. The United States could build 30 copies of the largest existing power plant in the world (i.e., the Three Gorges Dam in China); however, it would require specific geographic features and would come with a host of **other environmental and social issues**. Alternatively, the United States could build one Palo Verde-type nuclear plant in each of the 50 states and then add another plant for the top 30 cities in the country to get to ~81 nuclear plants. In reality, the solution would be a combination of all these generation types, depending upon location dynamics and social licence. Notably, the Gemini Solar Project in Nevada will surpass Solar Star I & II to become the largest solar facility in the United States, which became possible only after **Trump's deregulatory** efforts.

Exhibit 5: The United States Would Need to Build a *90-Gorges Dam* (i.e., 30x the Three Gorges Dam)

Flat-panel photovoltaic		
5-yr average U.S. utilization	25.1%	
Estimated total capacity required	1,177,636	MW
Largest Solar Plant: Bhadla Solar Park, IND		
EPC project cost (ca. year build)	$1.4	billion
Nameplate capacity	2,245	MW
Capacity factor[1]	25.1%	
Annual output[1]	4,944	GWh p.a.
Required # of plants[1]	525x	Plants
Under Construction: Gemini Solar, Nevada		
EPC project cost (ca. year build)	$1.0	billion
Nameplate capacity	690	MW
Capacity factor[2]	35.0%	
Annual output[2]	2,116	GWh p.a.
Required # of plants[2]	1,226x	Plants

Onshore Wind		
5-yr average U.S. utilization	34.1%	
Estimated total capacity required	867,187	MW
Largest Wind Farm: Jiuquan Wind Power Base, Gansu CHN		
EPC project cost (ca. year build)	$17.5	billion
Nameplate capacity	7,965	MW
Capacity factor[1]	34.1%	
Annual output[1]	23,821	GWh p.a.
Required # of plants[1]	109x	Plants
Largest in the U.S.: Alta Wind, California		
EPC project cost (ca. year build)	$2.9	billion
Nameplate capacity	1,550	MW
Capacity factor	23.7%	
Annual output	3,216	GWh p.a.
Required # of plants	806x	Plants

Nuclear		
5-yr average U.S. utilization	92.6%	
Estimated total capacity required	319,786	MW
Largest Nuclear Facility: Kashiwazaki-Kariwa, JPN		
EPC project cost (ca. year build)	$22.1	billion
Nameplate capacity	7,965	MW
Capacity factor[1]	92.6%	
Annual output[1]	64,596	GWh p.a.
Required # of plants[1]	40x	Plants
Largest in the U.S.: Palo Verde, Arizona		
EPC project cost (ca. year build)	$5.9	billion
Nameplate capacity	3,937	MW
Capacity factor	92.6%	
Annual output	31,920	GWh p.a.
Required # of plants	81x	Plants

Hydroelectric		
5-yr average U.S. utilization	39.6%	
Estimated total capacity required	6,549,157	MW
Largest Hydro Dam: Three Gorges Dam, CHN		
EPC project cost (ca. year build)	$31.8	billion
Nameplate capacity	22,500	MW
Capacity factor	44.1%	
Annual output	87,000	GWh p.a.
Required # of plants	29.8x	Plants
Largest in the U.S.: Grand Coulee Dam, Washington		
EPC project cost (ca. year build)	$163.0	million
Nameplate capacity	6,809	MW
Capacity factor	33.9%	
Annual output	20,240	GWh p.a.
Required # of plants	128.1x	Plants

(1) Assumes average capacity factor in United States; (2) approximate capacity factor of neighbouring solar projects.

Source: Company reports; DOE EIA; Scotiabank GBM.

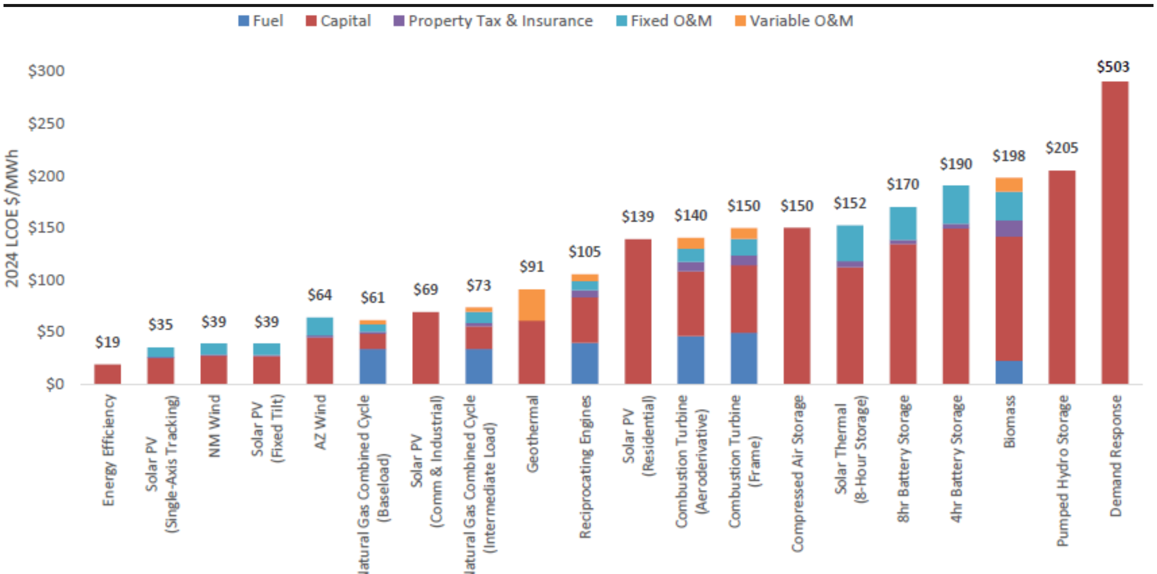
What About Cost?

Solar is the least expensive form of marginal power generation. Besides energy efficiency (i.e., customer efficiency programs), building single-axis tracking solar parks is the least expensive utility-scale power generation available, at $35 per MWh on a levelized-cost of energy basis (LCOE), according to **TEP data**. This compares with $39 per MWh for wind in New Mexico and $61 per MWh for baseload natural gas-fired combined cycle generation and $73 per MWh for intermediate load. However, we note that TEP uses a historical average delivered natural gas price of $4.68 per million Btu, which, in our view, is perhaps 40%-50% too high, but represents only 40%-50% of the overall cost of generation. In fact, the cost of new solar and wind projects today are close to competing with *existing* nuclear and coal generation that typically costs in the high-$20s to low-$30s per MWh range.

A major caveat: storage is very expensive. While it might appear that all new power generation should be either solar or wind, there are obvious drawbacks to this cost figure. Solar PV and wind lack dispatch characteristics available through natural gas generation and suffer from lower reliability in comparison with conventional technologies in coal, nuclear, and natural gas. Consequently, for solar to be truly effective, storage is required to adequately match supply with demand, which makes new projects considerably more expensive in comparison. Adding 4-hour battery storage typically costs $190 per MWh, whereas a larger 8-hour battery is moderately less expensive, around $170 per MWh, due to economies of scale – lower engineering, procurement, and construction (EPC) and fixed operation and maintenance (O&M) costs per MWh. Contrast this with new natural gas turbines, which cost between $125 and $140 per MWh (Reciprocating engines to Aeroderivative), and it becomes clear that intermittent demand is more cost-effectively served with natural gas (at present).

The solution is bundling solar with storage. Solar's generating capacity typically peaks in the early afternoon each day, depending on latitude and time of year. However, power-generation demand spikes in the evenings as families return home from work to turn on air-conditioning units, lights, various electrical applicances, and to charge more electric vehicles (in the near future). To solve the peak supply versus demand mismatch, solar can use storage to effectively *shift* said supply to the evenings or early mornings when the sun is not out; however, doing so can add 50%-100% to the total cost and dramatically changes project economics. The current convention is for solar plus co-located storage facilities to be sized to provide

Exhibit 6: Solar Beats Them All – Levelized Cost of Energy by Generation Type



Note: Assumed average long-term delivered natural gas price of $4.68 million Btu.

Source: TEP.

rated output (capacity of the plant) for ~4 hours. Under this configuration, these facilities are able to direct excess generation to storage during the day when utilization is highest and demand is low. Then, in the evening when demand peaks and solar irradiation is waning, the facility is in a postion to meet the heightened demand, when grid prices are often at thier highest, at full capacity for the duration of peak demand.

Case Study: Gemini Solar in Clark County, Nevada

Soon to be the largest solar power plant in the Unted States (eighth in the world). Solar Partners XI and Nevada Power Company have agreed to a power purchase agreement (PPA), which is estimated to provide 2,227 GWh p.a. from a solar PV array and battery facility. The solar panels will have the ability to deliver 690 MW at peak capacity and, we estimate, have a very high expected capacity factor of ~34.1%. Gemini will also feature a 3.7-hour, 380 MW battery storage facility capable of delivering 517 GWh p.a.

The quoted dispatch rate of $24.79 per MWh *appears* to be an incredibly good deal, but that is not the full price. In comparison with other generating types and solar projects, this price would provide a very low cost source of capacity. However, there is also a *full requirements period* when Gemini provides its capacity to the grid at 6.5x the dispatch rate, but for only five hours a day and for only three months (June though August). This full requirements period affords the project an additional 40% in revenue and presumably pays for storage. The effective average PPA price over an entire year would be 50% higher, close to $37-$38 per MWh. That said, this still appears to be a competitive price for power, especially when considering it includes the dispatchable, load-balancing storage facility.

Current-day supply gap for 100% non-carbon emitting power generation would require the United States to build 1,226 Gemini Solar projects. The EPC cost is estimated to be ~$1.0 billion for this project. This would suggest a $1.2-$1.3 trillion price tag for this specific portion of Joe Biden's vision; however, there are a few things to keep in mind:

Exhibit 7: Economics of the United States' Largest Solar Plant

Solar Panel Array		
Gross nameplate	746	MW
Deliverable	690	MWac
Hours	8,760	hours p.a.
Capacity factor	34.1%	
Produced	2,227	GWh p.a.
Battery Pack		
Change cap.	400	MW
Discharge cap.	380	MW
Duration	3.7	hours
Produced	517	GWh p.a.
Round-trip	95%	Efficiency
Net Generation		
Gross Solar	2,227	GWh p.a.
Battery charging	544	GWh p.a.
Net solar	1,683	GWh p.a.
Battery output	517	GWh p.a.
Net generation	2,199	GWh p.a.
Full requirements	206,310	MWh p.a.
Effective Average PPA		
Dispatch rate	$24.79	MWh
Full requirements	6.5	x dispatch rate
Full req. rate	$161.14	MWh
Dispatchable rev.	$49.4	millions p.a.
Full req. rev.	$33.2	millions p.a.
Gross revenue	$82.7	millions p.a.
Average PPA	**$37.58**	**MWh p.a.**

Source: PUC Nevada; Scotiabank GBM estimates.

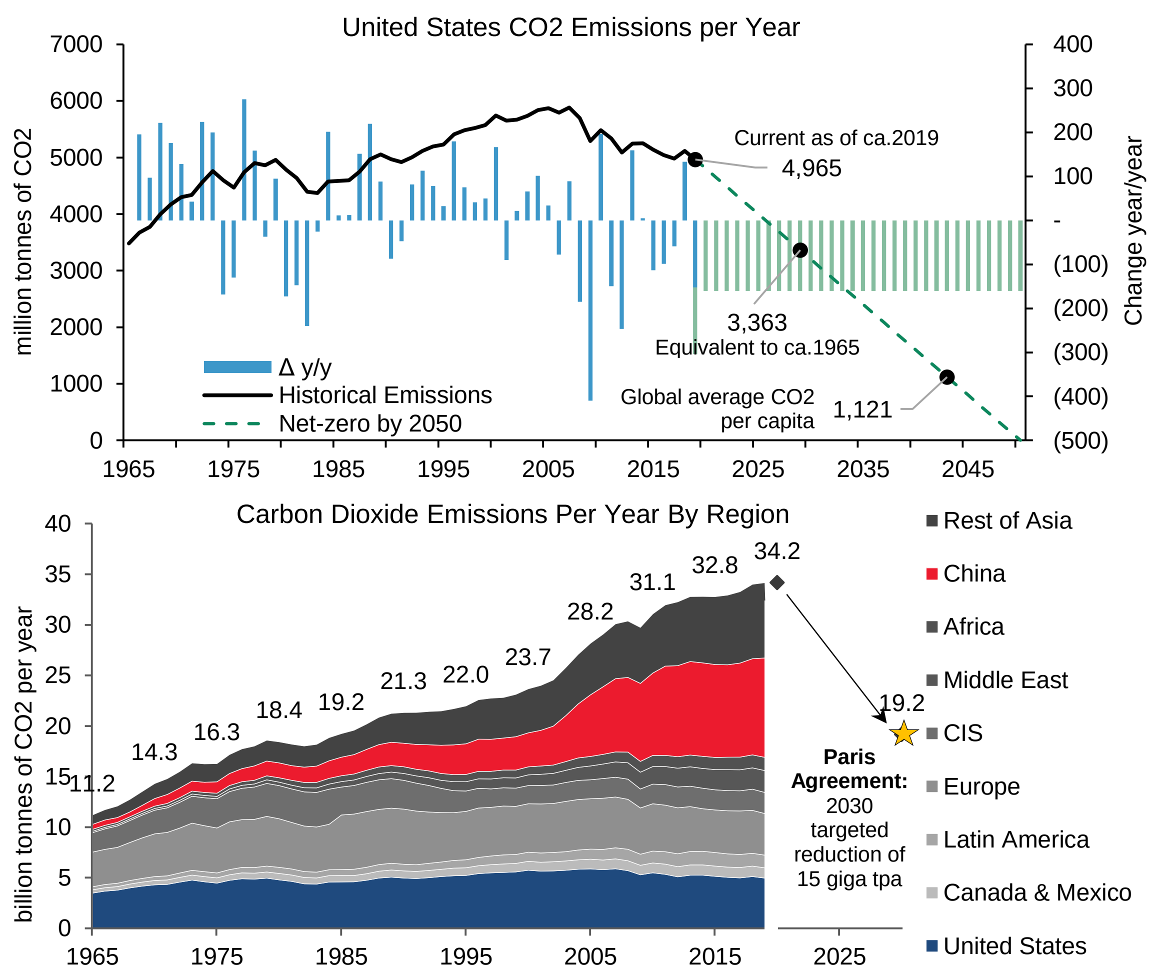
- First, there are a handful of other key deliverables in Biden's plan, such as achieving economy-wide net-zero emissions by no later than 2050, which goes well beyond just the power sector. This means that it is likely that the $1.7 trillion price tag is not entirely, or even mostly, earmarked for green energy. This policy will heavily rely upon private investment.
- Second, this price tag addresses only *today's* implied power supply gap if all carbon emitting sources were eliminated. Though power demand has been relatively flat over the past couple of decades, it is not likely to remain this way into the future, given changing consumer behaviour and the advent of electric vehicles.
- Third, the Gemini Solar project is ideally located in the desert of Clark County, on the southern tip of Nevada. Theoretically, the United States could completely fill the entire (current) supply gap with solar panels, using 28% of the Mojave desert using this solar project's dimensions (requiring ~35,000 square km). This project is already controversial, given its potential impact on wildlife, specifically the Mojave Desert tortoise, and its location on public lands adjacent to the Valley of Fire state park preserve.
- Finally, transmission loss and weather-dependent reliability would still become major issues when shipping power long distances to more highly populated regions in the Midwest and east side of the

continent. A local solution is required in those regions, which are less suited to solar parks simply due to solar availability (latitude, cloud cover, etc.).

Economy-Wide *Net*-Zero Emissions by No Later than 2050

Achieving economy-wide net-zero emissions is a truly Herculean task. As shown in Exhibit 2 on page 3, the United States is one of the most polluting countries in the world, both in absolute terms (second only to China) and on a per capita basis. Approximately 330 million Americans contribute ~17.0% of global emissions (on a consumption basis), but represent only 4.4% of the global population. Removing nearly a third (32%) of current emissions would bring the United States back to levels not seen since 1965, the earliest data that we have. A 77% reduction in emissions would finally align the United States with the rest of the world on an emissions per capita basis. The Paris Agreement now suggests that **CO_2 emissions need to be reduced by 7.6% every year for the next decade** to meet the lower, 1.5°C Paris target. While CO_2 emissions are a global problem, the United States will need to work significantly harder to achieve these goals even if **Biden rejoins the Paris Agreement on day one** of his presidential term.

Exhibit 8: Getting to Global CO_2 Emissions Per Capita Would Require a 77% Reduction



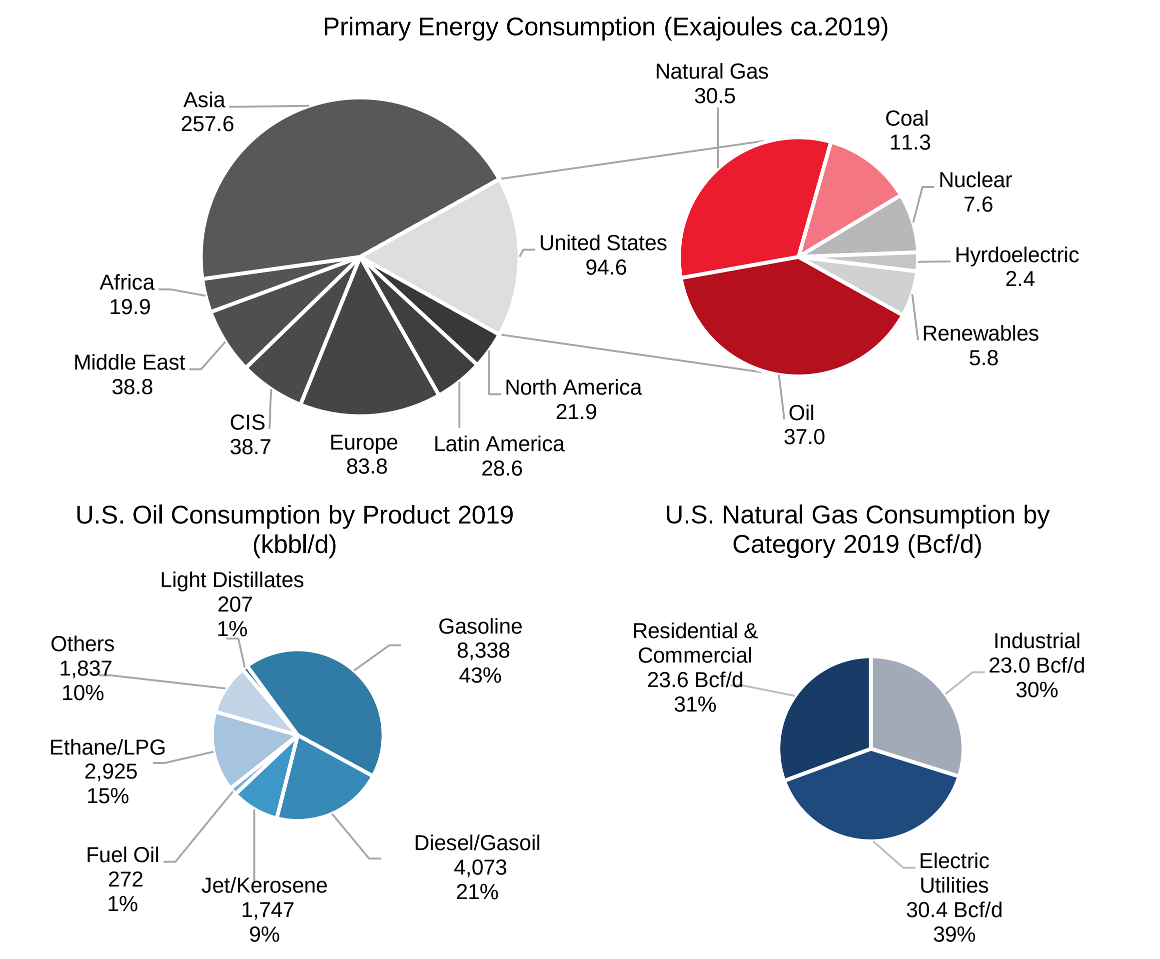
Source: BP; United Nations; Scotiabank GBM.

Getting to a Net-Zero Economy

The United States would need to grow non-emitting power generation (including nuclear) by 6.0x to get to net zero by 2050. In a rather simplified way of thinking about *all sources* of CO_2 emissions produced through primary energy consumption in the United States, we have done some calculations to figure out exactly how much would need to be converted to clean, non-emitting energy as of today's consumer patterns. Utility-scale power generation only accounts for ~16% of energy consumption in the United States. The remaining portions are distributed in different forms of consumption (e.g., transportation, heating, direct building and infrastructure use, general industry, chemicals, small-scale private power generation). The vast majority of these forms produce CO_2. The only ways to remove CO_2 emissions from the *entire economy* is to:

1. Completely remove coal, crude oil, natural gas, etc. as consumable commodities and replace them with a form of renewable, non-emitting energy (e.g., electric vehicles running on renewable power gen),
2. Provide a form of CO_2 capture, utilization, and storage (CCUS) to actively remove emissions from the atmosphere, and/or
3. Change behavioural patterns of society to drastically cut energy consumption.

Exhibit 9: The United States Consumes 94.6 exajoules p.a.; 83% of This Amount Is Carbon-Emitting



Source: BP Annual Statistical Review; DOE EIA; Scotiabank GBM

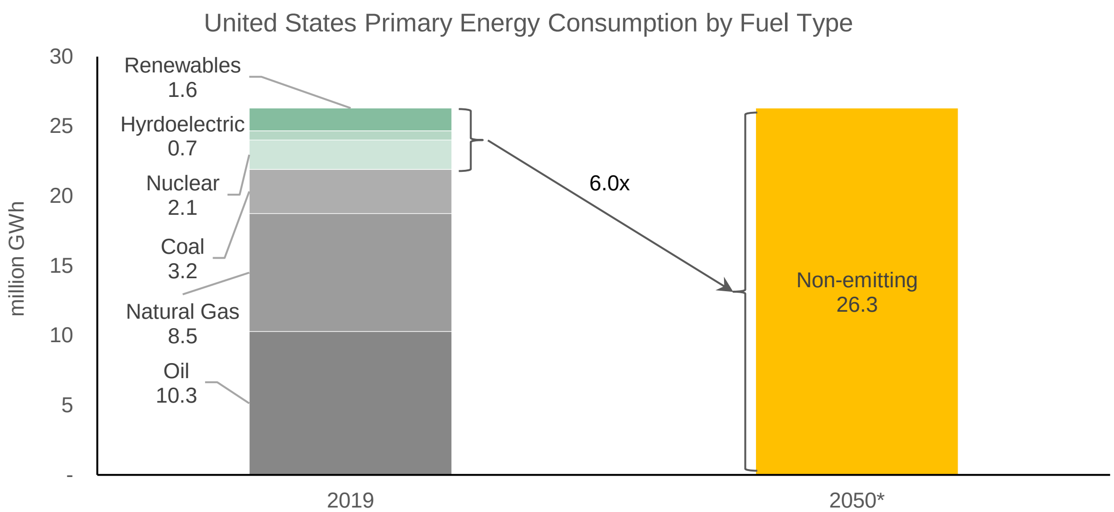
21.9 million GWh p.a. of non-emitting power generation is required by 2050 to get to net zero economy-wide. Of the 94.6 exajoules consumed by the United States each year, 78.8 exajoules (83%) come from coal, crude oil, and natural gas forms. According to BP, **one exajoule equals 278 terawatt-hours**; consequently, converting 78.8 exajoules to equivalent power generation would require 21.9 million GWh p.a.

Energy is consumed in many forms; for example, vehicles are simply miniature power plants that run on gasoline/diesel, etc. The internal combustion engine (ICE) converts potential chemical energy of gasoline/diesel into kinetic electrical energy for the vehicle to use. By swapping out the engine for a battery pack, the vehicle is simply swapping out the location of where this energy is/was converted from its original form. Consequently, to remove carbon energy entirely from the economy, each joule of energy created from a direct-use carbon emitting commodity must be, in a net-zero economy, generated at an non-emitting, renewable power plant. Therefore, assuming aggregate energy demand in the United States remains relatively stable, this means that:

- Natural gas demand will *decrease* by ~30 bcf/d by 2035 due to a non-carbon power stack and another 45-50 bcf/d by 2050 given the removal of carbon from the entire economy.
- Thermal coal demand will be completely *phased out* by 2035.
- Crude oil demand will *decrease* by ~17.3 million bbl/d (2.35 million tpa) by 2050.
- Nuclear, hydroelectric, solar, wind, and other renewable forms of power generation would need to *increase* by approximately 6.0x over the next three decades to make up this difference.

The 755 Gorges Dam. The scale of non-emitting power generation growth required, assuming no CCUS and constant power-generation demand, would mean that the United States will build either 10,356 Gemini Solar projects, 6,812 Alta Wind projects, 686 Palo Verde nuclear plants, or 1,082 Grand Coulee hydroelectric dams. This is the equivalent of 252 Three Gorge Dams being built over the next three decades. Truly a watershed moment for the energy sector.

Exhibit 10: Non-emitting Power Generation to Grow by 6x by 2050



* Assumes 100% non-carbon emitting **economy** in the United States by 2050 and using 2019 primary energy consumption (i.e. not just the current power-stack)

Source: BP Annual Statistical Review; Scotiabank GBM.

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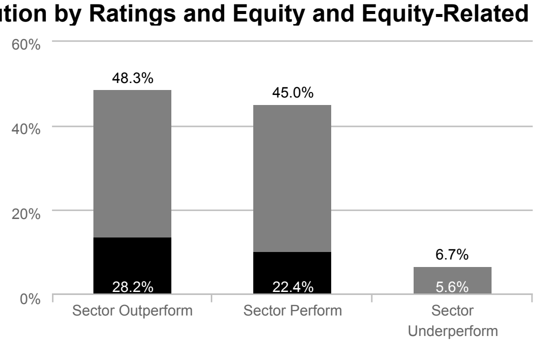

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