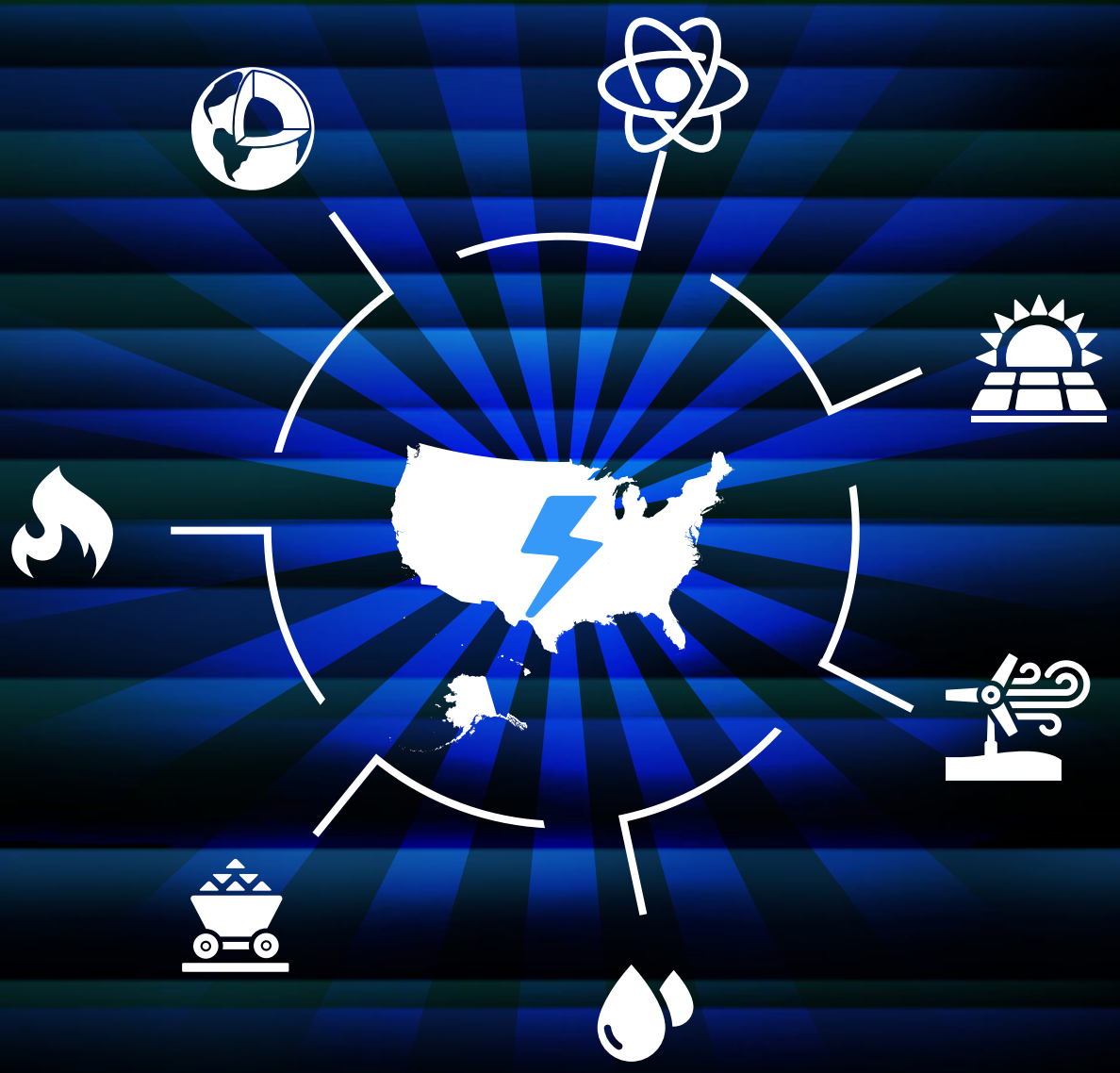
A FROST & SULLIVAN WHITE PAPER

# Energy in America: A New Era



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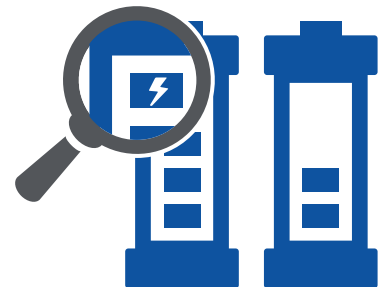
# Introduction

## Power and Energy are Necessities

Countries and economies need power and energy to thrive and prosper. Electricity has become a basic necessity for the health and welfare of humanity: an energy ecosystem that cannot feed demand will not only stifle economic prosperity, but can be a threat to a country's overall strength and wellbeing.

**Energy will be a focal point of rapid expansion and change in the next five to 10 years, and beyond**



The US is no exception to this. Our complex, and aging, power and energy landscape will need increasing investment to keep our country prosperous and economy flourishing. The next few years in the US are expected to see increasing investments in key sectors such as oil and gas, manufacturing, and infrastructure. Roads and bridges, communications networks, and water and power systems are all areas that are being seen as ways to expand the economy, strengthen our future, and in some cases repair years of neglect. All these markets and opportunities will need energy to build and energy to operate. This investment along with continued low gas and electricity prices and overall population growth—the US population is expected to increase by 16% by 2035—will make energy a focal point of rapid expansion and change in the next five to 10 years, and beyond.

## An Expanded Economy Equals a Growing Demand

This expansion of our economy means a need for more power and energy. Energy efficiency has improved markedly over the last decade, across generation, transmission and energy usage, and will offset some of the growing demand. But at the end of the day, in order to sustain our growing economy and population, more power capacity needs to be installed.

## The Market Demands Clean and Cheap Energy

This brings us to a crossroads as dichotomies persist in the industry: the market wants cleaner energy, at a reasonable price. Renewable power is now at a point where it is a significant part of our energy mix, with prices that are increasingly

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competitive with conventional power. Yet wind and solar still need some regulatory incentives and mandates to help make their business case, and mitigating the intermittent nature of the power generated by wind and solar adds cost and complexity.

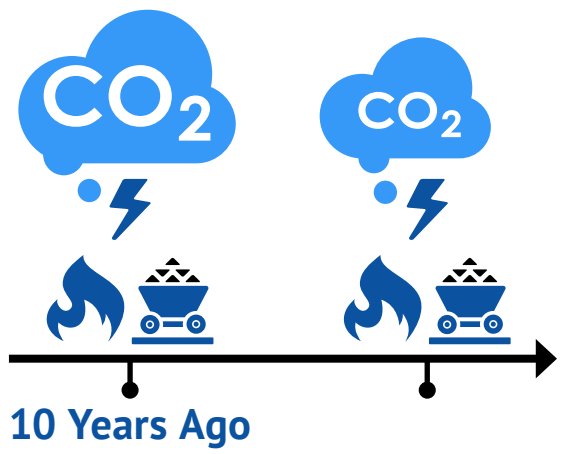
On the other hand, large scale power plants that produce a steadier, more reliable stream of energy are often fueled by fossil fuels or nuclear power carry concerns about environmental responsibility. Increasing efficiency across the energy ecosystem—from getting more power at the generation source, to decreasing losses across the grid, to needing less power to fulfill the same outputs at the end user—have helped considerably in mitigating at least some of the growing power demand.

However, as the US economy grows and energy-intensive sectors such as industry and construction in particular expand, we will need every Watt, BTU, and Joule that can be generated in the coming decades. It will be the responsibility of the power industry, legislators, and businesses to ensure this power, regardless of how is generated, is done so in a way that is efficient, low in cost, mindful of the environment and integral to our nation's security.

## Diverse Sources of Power Generation are Needed

The US will need energy from a diverse range of power generation technologies that are clean and efficient. To that end, the US has seen significant improvements across the power sector. According to the EIA, $CO_2$ emissions from electricity generation, which is still one of the largest polluters in the country, have been falling. In 2015, emission from electricity generation in the US were the lowest they had been since 1993, and 21% lower than what they were just 10 years earlier. In 2015 itself some of the drop was attributed to lower power usage. However in 2013 and 2014, power usage actually increased and carbon emissions still went down over preceding years.

**Gas and even coal can now generate electricity with far fewer emissions than the plants of even just 10 years ago**




Natural gas and renewable energy substituting aging coal plants have been driving this decrease in emissions. The challenge will be to continue expanding across all facets: expanding our economy, expanding our power generation, and expanding

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our share of lower-carbon power generation. For the first time, this is now possible thanks to startling new technological advances across the energy spectrum new gas and coal plants can now generate electricity with far fewer emissions than plants built 10 years ago.

And nuclear power remains our single largest source of carbon emission-free power. Rapidly growing renewable energy is also at the forefront of reaching our environmental goals, and can be further leveraged with smart energy storage solutions to help mitigate the technical challenges of variable power supply. Now is the time to evaluate, and in some cases reevaluate, power generation technologies to help grow the economy while protecting our environment.




# Our Current and Future Energy Mix

- **Natural Gas:** Natural gas will continue to rise as a proportion of the overall fuel mix, which will provide the US with a steady and efficient source of domestic power.
- **Coal:** Aging coal plants are being retired, however new technologies and a renewed interest in all domestic power sources of energy may also mean new plants will be considered.
- **Nuclear:** Nuclear will likely remain stable as a proportion of the nation's energy mix, with some aging reactors being decommissioned while new units will be coming online.
- **Renewable Energy:** Renewable energy will continue to have the highest growth rates of any power generation technology, wind and solar in particular, though hydro power can play a major role as well thanks to its advantages of renewable energy (no carbon footprint or fuel expenses) coupled with

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the advantages of more conventional power plant technologies (steadier, non-intermittent source of power).

A smart approach that recognizes the benefits of a clean and diverse power portfolio can be achieved, and can result in a stronger and more prosperous US economy.

## Thermal Power and the Low Carbon Future

he US has enjoyed sustained low natural gas prices and growing gas availability for many years. Demand from the power and industrial sectors is expected to continue to grow through at least 2040 for electricity, heat, and for use in industrial purposes, such as for feedstock to chemicals and pharmaceuticals. Low gas prices hence help drive economic growth in the industrial sector, which thereby further increases gas demand.

### Natural Gas—Efficient and Cleaner

For several decades, natural gas-fueled power has been an area of remarkable technical advances, both in terms of efficiency and emissions. Emission reduction systems worked across a gas power plant to help filter out effluence from the natural gas at the inlet, remove debris and pollutants that can cause emissions and also harm the efficiency and life span of the system. In the energy generating process itself, better combustion technologies meant that more energy could be generated with the same amount of fuel, while improving the rates at which CO2 could be captured. Newer power plants also have advanced capture and filtration at the exhaust to further improve the environmental footprint of the gas plant.

**Many of the country's future power plant capacity installations will be focused on gas**



However, this already advanced system is about to get a considerable upgrade thanks to the development of direct-fired supercritical oxy-combustion CO2 power cycle system. Until now, the most efficient natural gas power plant system was a combined-cycle plant, where excess heat from the gas turbine's generating function was captured, converted to steam and used to run a steam turbine for additional power generation. This helped greatly increase efficiency and trap more emissions from the earlier simple-cycle (i.e. gas turbine only) type of plant.

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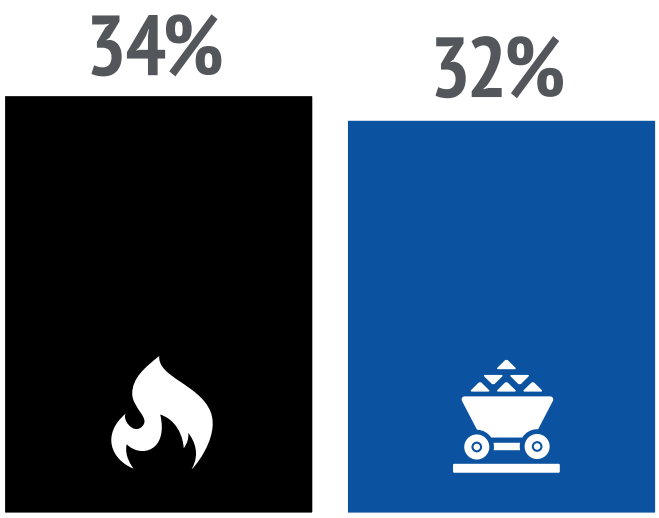
The new supercritical CO2 system is as efficient, and much cleaner, than the combined-cycle plant. The system collects all the CO2, along with nitrogen oxides and other pollutants, and without the need of separate carbon capture equipment, at high pressure resulting in a supercritical CO2 “fuel” which is a mix of CO2 and water. This fuel is used to directly drive a turbine generator to produce low-cost electricity.

The world’s first demonstration plant employing Toshiba’s supercritical CO2 system is, at the time of this white paper’s creation, under construction in Texas and expected to start operation in 2017. The demonstration plant, jointly developed by Toshiba, NET Power, LLC., CB&I, and Exelon Corporation, will validate the Allam Cycle, a new natural gas power system that operates at high efficiency and collects high-pressure CO2. Thanks to gas’ advantages—cheap, abundant, relatively clean—a significant amount of the country’s future power plant capacity installations will be focused on gas.

The EIA has estimated that by the end of 2016, natural gas will have ousted coal as the leading source of power in the US, about 34% vs. 32%, respectively. The US is expected to add nearly 19 GW of natural gas fueled power between 2016 and 2018, and considering power, industry, and the growing liquefied natural gas (LNG) export market, by 2035 the US may become the world leader in natural gas with roughly a quarter of the world’s supply.




At the end of 2016, natural gas had ousted coal as the **leading source of power** in the US

US supply for gas is quite rich and, thanks to expanding shale processing and improved drilling technologies, it should keep up with domestic demand in the coming years However, over time, the cycle of low gas prices driving industry, which in turn increases gas demand, will likely begin to inch up the price of gas, along with additional upward pressure from increasing exports of LNG. Hence it will be critical to augment this growth in gas power plants with other clean, efficient, and readily available domestic sources of energy.

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# Pros and Cons of Coal

Coal power may not be what comes to mind when discussing clean energy. Despite it's clear economic benefits—the US has a large domestic supply, the industry employed thousands of people, and also coal has a considerably higher reserve production ratio, i.e. it is more energy-dense than gas—it has also been a point of contention due to its high environmental impact. The improvements the US has seen in reduced carbon footprint have largely been from replacing aging plants with natural gas and renewables while keeping our nuclear footprint steady.

## Coal Plant Carbon Emissions Must be Reduced

But of course a better power to emission ratio is not enough. The absolute amount of emissions for a plant needs to decrease as well, and that is where carbon mitigation technologies come in. The industry had already advanced its carbon capture and storage (CCS) technology, which separates and sequesters carbon from the flue gas of a thermal power plant, whether coal, natural gas, biofuel or other fuel-and-combustion based system.

Now the market is evolving the CCS process further to one that only captures and stores the carbon, to carbon capture and utilization (CCU), which then uses the captured carbon for other processes such as crop cultivation or algae culture. This has the potential to turn carbon from waste to industrial input, and from a cost to a potential revenue stream. Toshiba, for example, has been a critical player in this market, and already has a proven carbon capture technology in play at the Saga waste incineration plant in Japan, which became operational in August, 2016.

Another example of advanced coal fired technology is integrated gasification combined cycle (IGCC) coal plan. In an IGCC plant, the carbon is first gasified into a synthesized gas, or "syngas." This extra step at the start pays off because the syngas can then be run first through a pair highly efficient gas turbines, the excess heat of which is then used to run a steam turbine. This is a substantially superior solution in terms of efficiency and power output over the conventional coal plant, where the heat from combusting the fuel was only used to create steam for a steam turbine. Not only is an IGCC plant more efficient, but the gasification process makes capturing and storing or utilizing the carbon easier. Hence this technology improves both plant efficiency and carbon footprint using the same concept. Syngas is a much-lauded "clean coal" technology that has been in discussion for decades but only recently become a reality.

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## Clean and efficient upgrades help ensure environmentally responsible energy from coal



The dirty and antiquated coal plants of yesteryear are a threat to the environment and are being shuttered. But this shouldn't detract from exploring the fuel as a responsible way of diversifying our energy portfolio. Including clean and efficient IGCC and CCS/CCU upgrades and new plants would help ensure environmentally responsible energy for sustained economic growth that is potentially less fiscally volatile in the long run than natural gas.

## Nuclear Power and Safety

Another technology that can provide clean and efficient power is nuclear. The main concern around nuclear has revolved around its safety, both in terms of operation and for the storage of spent waste. In terms of safety, the industry has made significant strides in this area, and "advanced passive" nuclear plants are able to avoid the potential for incidents in a few key ways, such as depending on gravity rather than fallible motors for cooling, and reducing human involvement and, thereby, error.

Once the safety of a nuclear plant can be thoroughly established, then the benefits of this long-running and carbon-free technology are clearer. On a global basis, Frost & Sullivan's report on world nuclear power markets (Global Nuclear Power Outlook, Study# 9AAE) shows that the demand for low carbon generation is the main long-term driver for nuclear power.

The US has about 100 reactors in operation, the largest fleet in the world, which supplies roughly 20% of the nation's electricity. This also accounts for about 60% of all of our carbon-free power. In October of 2016, the US added its first reactor in nearly 30 years. Five more are in construction, totaling 6 GW of power. Another 30 GW are currently being proposed. It remains to be seen how much will be built but many in the industry expect about 10GW will be online by 2030. Despite nuclear power's low operating costs and clean emissions, plants are still expensive to site and build, and hence rapid growth in this market is unlikely for the US.

Certainly wind and solar are hugely attractive in many respects, by being easier to site and quicker to build in many cases than a large nuclear plant. Their consistent

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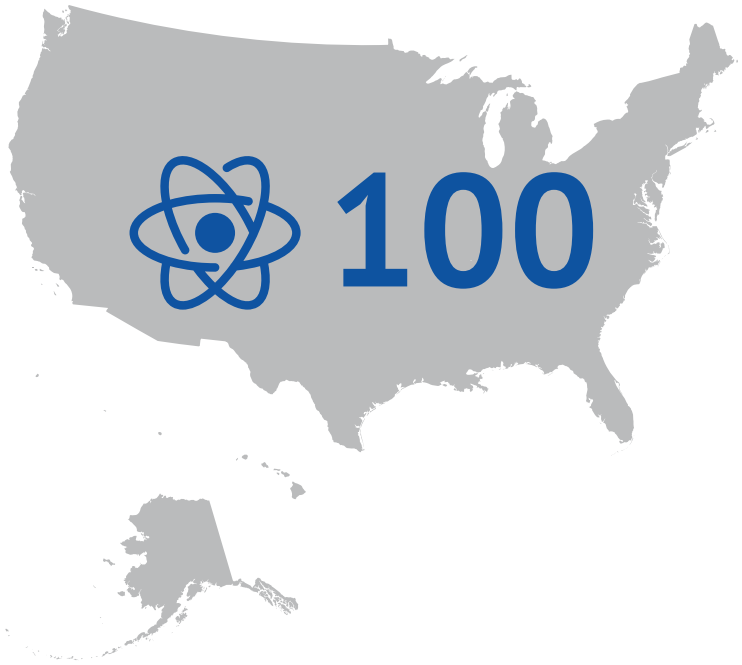


**The approximately 100 reactors in the US supply roughly 20% of the nation's electricity**

double-digit growth rates help illustrate this. But nuclear has a role to play if the country wants to expand its carbon-free power footprint.

## A Renewable Future

Renewable wind and solar power are the fastest growing energy source in the world today, increasing about 5% per year through at least 2035. This rapid growth rate has been helped by significant price declines, especially in solar, and costs are anticipated to continue to fall in the coming years. Thanks to economies of scale and increased efficiency in manufacturing and operations, Frost & Sullivan expects utility-scale solar photovoltaic (PV) power costs to decline 40% and on-shore wind costs to decrease by about 25% by about 2040. This is likely to result in an energy mix where by 2035 in the US, non-hydro renewable power generation may reach up to 20% of the nation's installed nameplate power, up from just 7% in 2016.

## High Growth Rates of Wind and Solar Power

Wind and solar have these high growth rates for clear reasons—they are carbon—and fuel-free in operation. They can be also be dispatched in a decentralized manner that is closer to or even at the end-user, versus a large conventional power plant that needs to be sited far from residentially-dense areas and may require expensive power grid expansion. And, aside from some concerns about damage to wildlife or reduced property values, solar and wind tend to be viewed as favorable and beneficial green energy in the mind of consumers.

## Challenges Have Been Largely Overcome

The main challenge for wind and solar for many years was the high cost versus other forms of power generation. However the industry has been able to largely overcome much of the challenge through a combination of lower technology prices

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and an increase in government green energy incentives and mandates, though these incentives can expire over time and result in some risk in estimating ROI. In the early 2000s, a rooftop solar system had a 20 year payback period. By 2016, that time frame had gone down to 5 years, or even 3 and in some cases less for homes with a combination of high power needs and in high-rate areas. This means that a large house with a high energy profile in Southern California can not only reduce its overall energy usage, but can actually go into a lower rate bucket meaning that the cost per kWh used goes down as well. Though as noted above, such favorable economics could reverse to some extent as they are dependent in part on government incentives.

**The payback time for rooftop solar has been reduced from 20 years to 3–5 years**



The rooftop solar industry has also developed intelligent new business plans where suppliers are essentially distributed, mini-utilities, such that the onerousness of PV ownership and maintenance is transferred to the supplier, not the homeowner, the latter of whom is essentially leasing the power by paying the "utility" solar power supplier a monthly amount that, even when combined with any remaining utility power, is still less than their previous utility-only bill. Despite each individual solar rooftop producing a relatively small amount of power, all the solar rooftops combined can have a significant effect on a state's power grid. By the end of 2016, California had over 5 GW of installed rooftop solar power, well exceeding the state's goal of 3 GW by 2017.

## The Storage Conundrum

All this power is a great boon to a carbon free energy system, but it also carries technical challenges, and hence costs, for utilities, grid operators, and the power generation asset owners. Wind and solar generate power on an intermittent basis, which means less power (and fewer revenues) generated from the same nameplate capacity than longer running "fueled" sources. This on-and-off generation, only producing power when there is adequate wind or sunlight, can be a strain on the power grid as well as a safety concern. It can also add costs by requiring energy storage to help mitigate the effect, or causing natural gas plants to run

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at lower capacity certain times of the day, which can create both financial and operation issues for the plants. However, these issues are being explored and the industry, needing all the power we can generate for coming decades, is looking to innovations and alternatives to help meet the power and environment goals.

## Unsung Heroes: Hydro Power and Geothermal

There are also the unsung heroes of renewable power that have many of the same benefits of wind and solar—i.e. carbon free operation—but without some of the drawbacks—intermittent power generation and low output per MW installed. Although less in the public eye, geothermal power and hydro power continue to advance clean energy goals with stable, market-tested solutions.

### HYDRO POWER

Pumped Storage Power Plant (PSPP) can be run on a complementary basis to wind and solar without the expense or environmental concerns associated with battery storage and under-operating aging gas plants. Hydropower plants have been in operation in the US for over a century, and new designs of PSPP greatly reduce the environmental impact to rivers and wildlife by using closed-loop systems, while providing fuel-free and carbon-free power.

PSPP is also more affordable in many cases than other forms of energy storage, and unlike chemical-based energy storage such as batteries, will not degrade their storage capacity over time. PSPP leverages gravity and low energy demands by pumping water to higher elevations when electricity demand is low, and releasing it to spin a turbine and generate power when usage is peaking.

The US currently has just over 20 GW of PSPP and, with nearly 50 projects under consideration at different levels, has the potential to more than double this capacity. The US could get more out of the growing installations of solar and wind—more safety, more up-time, more usage of power when the prices are at their peak—if it integrates clean PSPP as part of its renewable energy portfolio.

### GEOTHERMAL

Geothermal is also a key contributor to a carbon-free energy portfolio. The technology may seem staid compared to other alternatives. However, globally the industry is thriving, with over 20 new plants that came on line in 2014 and a steady 5% growth rate over the past few years. The global market may reach 15GW or more of installed capacity by 2020 and could see that doubled by 2030, according to the Geothermal Energy Association.

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# The geothermal market is witnessing technological advances to help **improve efficiency and further lower operating costs**



The market is also witnessing technological advances to help improve efficiency and further lower operating costs. Geothermal power already benefits from a steady source of "fuel" (the earth's heat) and lower operational expenses than other power plants, unlike the varying cost of fossil fuel plants or even the challenges for hydro plants during drought years.

However, a challenge to the long operational lives of the installations is the naturally occurring steam which often contains hydrogen sulfide, chloride, and other highly corrosive chemicals. Toshiba's super rotor improves both the lifespan and efficiency of the turbine with two key improvements: first, the system includes a moisture-removal process of the steam, and second, the rotor itself uses a material with greater anti-corrosion coatings that reduce the corrosion and erosion of the metal. One of the installations was in use at the Geysers geothermal plant in Northern California and the system was found in excellent condition during major inspection after being in use for more than ten years, a necessary amount of time to prove efficacy in the geothermal world where plants are expected to operate for decades upon decades. Toshiba's system has successfully kept the plant at high levels of efficiency with minimal evidence of corrosion.

## Powering the Future with Hydrogen

Long-term, the US can also embark on a carbon-free and sustainable energy future by harnessing the combined power of renewable energy and hydrogen. Hydrogen fuel cells produce only heat and water as emissions, both of which can be re-used in the electricity process or on-site for other needs, improving system efficiency.

Despite its immaculate emissions profile for energy generation, very little hydrogen is used this way in the US. Hydrogen is widely available and used extensively in various process industries, but the value chain is fossil-fuel intensive: 95% of US hydrogen produced from natural gas and a large portion of it is transported by trucks or ships.

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Hydrogen can be extracted from water using electricity in a process called electrolysis. In essence, electrolysis involves running a direct current through water to break the hydrogen atoms from the oxygen ones. The two elements are then captured and hydrogen is fed into a fuel cell, which, through a chemical reaction, combines the hydrogen back with oxygen and in the process generates electricity, heat, and water. The heat can also be leveraged for heating a building or industrial process at the site that the hydrogen is being produced.

Toshiba's H2One solution is an emission free, self-sustaining solution that uses renewable energy, battery energy storage systems, and all aspects of the on-site hydrogen system—extraction, storage, generation, and overall management of the system. Solar panels on a building provide the building with electricity. When solar power is at its peak, for example at mid-day during summer months, surplus electricity goes to the hydrogen generator to extract hydrogen from water through electrolysis. This hydrogen is stored on-site and used to generate electricity when the solar system is not making enough for the building at opposite times of the day and year—evenings in winter, for example. Intermittent solar power voltage is smoothed out with a BESS, and a highly sophisticated energy management system enables optimal real-time toggling between powering the building and generating hydrogen.

The systems can be scaled from small residential to large industrial applications. Wide-spread installations of self-sustaining, emission- and fuel-free hydrogen and renewable energy systems at commercial, industrial and residential sites could be a game changer in reducing carbon emission from the conventional power generation landscape.

# Growing our Economy with Clean, Safe, and Smart Power

## Our Power Portfolio is Ready

The US is at a pivotal point in its history. We can take advantage of renewed interest in expanding and improving our infrastructure to create a more stable and prosperous future. We can also learn from the industries of the past that cheap, but imprudent energy brings great economic growth in the short term, but costly environmental damage in the long term. However, with recent critical and far-reaching advances in power generation technologies across the spectrum—from distributed power to central plants, fossil to renewable to nuclear—for the first time

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we now have a confluence of technology, efficiency, environmental stewardship and financial incentive to build a power portfolio that will bring continued benefit well into future decades. We cannot grow our economy without generating more energy. And we cannot grow our future if that energy is not financially, technologically and environmentally responsible. We now have the broad options in front of us to be able to cleanly, and competitively, fuel our economic prosperity.

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WHAT NEXT?



## Learn more about Toshiba's innovative energy solutions:

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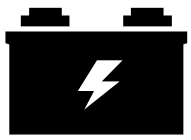
TOSHIBA

This is the first in a series of Frost & Sullivan white papers on the future of energy in the US, the series will dive deeper into the following subjects:



Energy Storage



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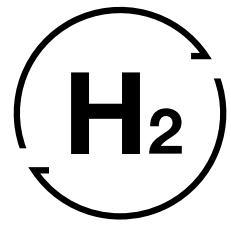


Hydrogen Energy

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