Saudi Arabia: World leader in solar power?

Can KSA meet >50% of its electricity demand through solar?

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Arthur D Little

Content

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Executive summary

The Kingdom of Saudi Arabia (KSA) has laid out an ambitious plan to modernize the country and move its economy away from its dependence on oil. A key part of this plan is to begin meaningfully tapping one of the country's most abundant natural resources: solar power. Already, the Kingdom has pledged to have 9.5 GW of installed capacity by 2023. The shift is described by officials at King Abdullah University of Science and Technology (KAUST) as not only a move toward sustainable energy, but also as a way for the Kingdom to become a world leader in solar technology, training a new generation of Saudi's in the technology and eventually become an exporter of both solar panels and solar electricity. Furthermore, the recent MoU with Softbank to deploy 200 GW of solar PV in the Kingdom reinforces the drive and ambition to fully exploit the natural resources the country has been blessed with.

The investment in solar energy will be a great opportunity for the Kingdom to become a leader in the adoption of renewables in the Middle East and attain its emissions goals for the Paris Climate Accord.

The target is ambitious, yet not impossible. At Arthur D. Little, we believe the Kingdom can generate 50% of its electricity from Solar by 2030 without a major paradigm shift, or technological barrier. A strong government vision/ leadership combined with relevant policies to support schemes that bring benefits to PV owners can take the Kingdom beyond the stated goals.

1. KSA's ambitious diversification target

At the heart of KSA's Vision 2030 is the plan to move away from oil dependence. This is dependence not just on oil exporting as the key component of GDP, but also as a major factor in its electricity production. KSA currently produces 40 percent of its electricity from oil, compared to a world average of just 4.3 percent. To change this, Vision 2030 already outlines various steps and goals relating to reducing the amount of oil used for domestic electricity generation, and to increasing the role renewable energy plays in the energy sector.

Some of the myriad goals set by the plan and related to this include, but are not limited to:

- Achieving significant growth of renewable energy generation capacity: 3.45 GW in 2020 and 9.5 GW in 2023, representing 4 and 10 percent of domestic generation capacity, respectively.
- Raising the share of non-oil exports in non-oil GDP from 16 to 50 percent.

However, more is possible…

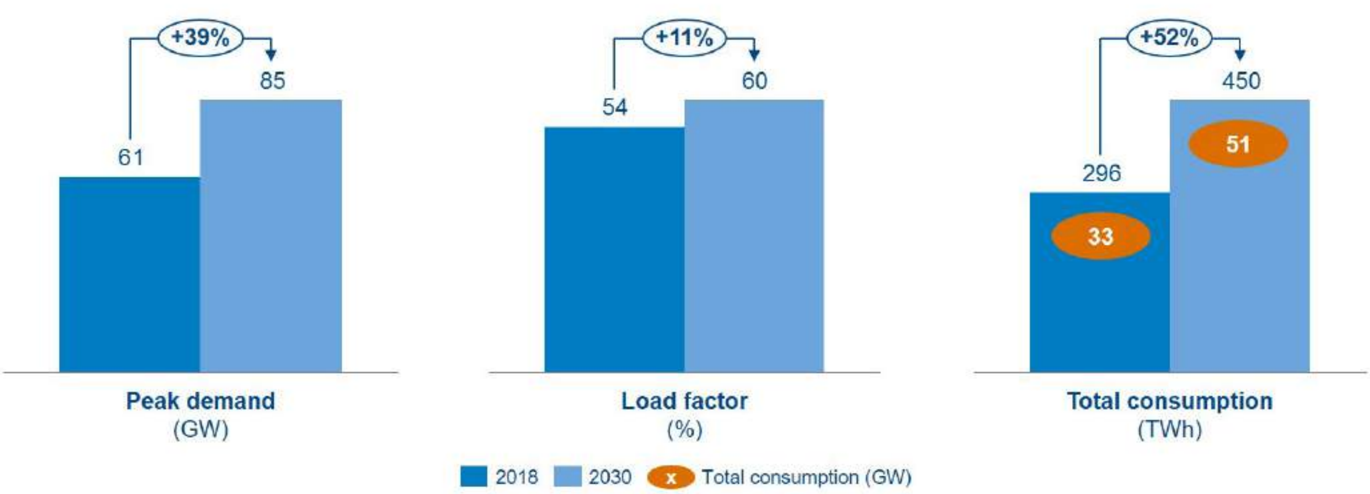
While this vision for KSA is uplifting, it is also achievable. Just a decade ago, experts would have laughed at the idea that any country could install and efficiently operate 9.5 GW of solar by 2023. Now, it is a foregone conclusion. The price of solar generation technologies has come down so dramatically that its levelized cost of energy (LCOE) is now competitive with natural gas and far cheaper than unsubsidized petroleum, which currently accounts for 40 percent of electricity production in the Kingdom. Similarly, the price of energy storage continues to fall and is already becoming commercial in select island nations at utility scale. In fact, without any major technological paradigm shift, KSA could produce well over half of its electricity from renewable sources, with the majority coming from solar power. All that is needed is a clear map, strategic investment, and the political will to get it done.

Setting a target of 50 percent of electricity demand met with renewable power will give birth to several new, high-skilled industries, while also positioning KSA as a technological and environmental leader.

Several factors may act as enablers to achieve the 50 percent renewable objective:

- KSA's location and climate make the country perfect for solar energy, due to levels of solar irradiation higher than that of all of Europe, with far cheaper and less populated land.
- Costs of solar technology have been declining dramatically, allowing for both utility and residential photovoltaics (PV) to be competitive with traditional power generation.

Figure 1: Peak demand, load factor and total consumption
2018 – 2030 evolution



Source: Arthur D. Little analysis

2. Talking numbers: KSA's current and expected electricity supply and demand

To understand what type of investment and policies will be necessary, one should understand the Kingdom's future power consumption and peak load demand. Two major changes are projected to take place in the Saudi economy that will affect these numbers: energy efficiency policies and convergence in electricity use to GDP to that of benchmark countries.

Electricity demand growth in KSA remained flat between 2015 and 2016 as a result of price reform and thus less wastage, as well as refocusing of GDP growth away from oil-based exports – a stated goal of Vision 2030. The demand was stable during use of this model; KSA could mitigate the need to maintain high fossil capacity with the deployment of enough energy storage or the use of CSP modules. The demand was stable between 2015 (294 TWh) and 2016 (296 TWh).

Despite the recent reform, the electricity prices in KSA do not incentivize adoption of energy efficiency measures. However, as the government embarks on a subsidy reduction program from 2018 to 2025, there may be adoption of such policies. Additionally, the government established the National ESCO, mandated with implementing energy efficiency transformations on all public buildings. Energy efficiency programs in buildings can provide up to a 27 percent decrease in consumption. These savings arise from various retrofit investments in KSA's buildings, which will be discussed at length in a later section. A 27 percent reduction is expected if all investments are made, but assuming a conservative approach in which investments are made in shorter-time-period projects – i.e., more basic retrofits – we still expect at least a 15 percent reduction to the power demand.

Assuming the electricity consumption growth rate converges to 1.5 times that of GDP by 2030, as per benchmarked countries such as Brazil, Egypt, and India, the IMF forecasts KSA's GDP growth to hit 2 percent in 2022. As a result, power consumption growth rates will decline to 3.0 percent in 2030, resulting in demand around 450 TWh by 2030.

KSA registered a peak load demand of 61 GW in June of 2017. The vision, as it stands, assumes peak load demand will hit just below 120 GW in 2030, as KSA plans to increase electricity generation capacity to 120 GW by 2032. Currently the system has a load factor (ratio of average demand to peak demand) of 54 percent. Assuming the continuity of this load factor to 2030, this would imply peak demand of 113 GW based on a pre-efficiency installed average power demand of 534 TWh. The same energy efficiency programs are predicted to allow for a 30 percent reduction in peak demand to 85 GW, leading to an increase in load factor to 60 percent.

3. Integration of Solar power in KSA's energy mix

Current installed capacity for power is 87.75 GW, whereas crude oil as a source accounts for 40 percent. Assuming a 50 percent solar energy target, this implies that a base supply still driven by fossil fuel sources has to account for 42.5 GW during peak demand (projected peak demand ~ 85 GW), with the remaining to come from solar. Due to the difference between the demand curve and the solar PV load curve, a significant amount of storage is needed to "shift" the energy generated by PV when demand is low.

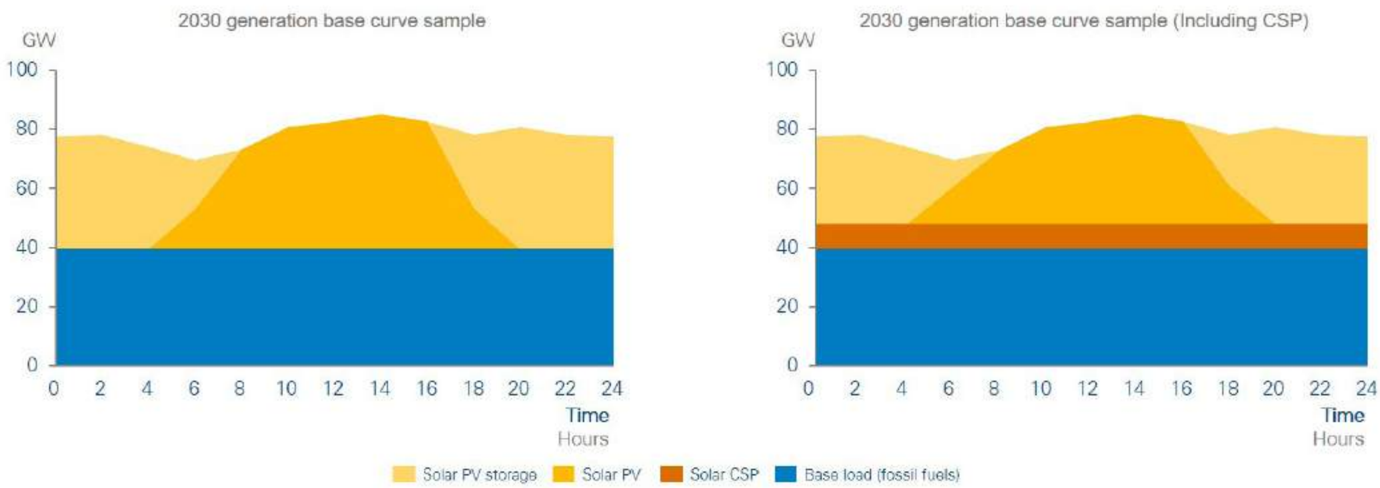
For this scenario a total of 170 GW of solar PV installed capacity will be needed, which is similar to the number proposed by Softbank in the memorandum of understanding (MoU) with KSA (assuming an average capacity factor of 25 percent for the new utility and distributed solar panels). Additionally, we calculate that 465 GWh of energy storage will be needed to match demand for electricity with supply. It's important to note that while 170 GW of installed capacity seems like a monumental task, China installed over 50 GW of PV in 2017 alone.

We predict most of the demand for solar PV will be done through utility-scale PV. That said, building integrated PV (BIPV) technology will be a major aspect of the shift to solar. According to an exhaustive study carried out by the University of Dammam related to the layout of Saudi buildings country wide, smart deployment of rooftop PV technology could potentially provide up to 30 percent of domestic electricity demand. The government has already opened an online application portal for locals to apply to have PV panels installed on their roofs. However, for such extensive deployment, government mandates will likely be necessary. According to these estimates, KSA would be able to capture 6 GW from BIPV by 2030.

CSP can help

Concentrated solar power (CSP) is a newer solar generation technology that captures and concentrates the sun energy to provide the heat needed to generate electricity. A key attribute of CSP is that it can be equipped with a heat storage system to generate electricity when the sky is cloudy or even at night, leading to much higher load factors than traditional PV. CSP installed global capacity reached 4.8 GW in 2016, increasing 5x in the last six years, with Spain and the US as the global leaders.

Figure 2 – 2030 generation base curve sample comparison (with and without CSP)



Source: Arthur D. Little analysis

Figure 3 – 2030 generation base curve sample comparison (with and without CSP)

		PV + storage	PV + storage plus 10% CSP	PV + storage plus 20% CSP
Solar PV	GW	170.0	136.0	102.0
CSP	GW	0	10.6	21.3
Total solar installed capacity	**GW**	**170.0**	**146.6**	**123.3**
Total storage required	GW	465.3	357.2	249.1

Source: Arthur D. Little analysis

Adding CSP to the base generation will diminish the necessity of storage and provide more flexibility to the system as a whole. We considered different levels of CSP + storage, which ultimately leads to lower overall installed capacity, but due to higher installation costs of CSP, also leads to higher total investment. With 21 GW of solar installed capacity coming from CSP, demand for energy storage would be reduced from 465 GWh to 249 GWh.

These estimates have been based on average operating conditions. In reality, extra capacity will be required to accommodate occasional inclement weather, such as sandstorms and cloudy days, which drastically limit the amount of power that that solar panels can generate.

Supply management

Reaching parity between solar and fossil energy by 2030 is a real option for KSA, and that comes with two options to manage supply. KSA can use fossil as a central capacity and solar as a supplementary supply, or vice versa.

Given the high responsiveness of fossil fuel plants and the increasingly central role that we predict solar to play, power from fossil fuels could be reserved for the night and unusual peaks, idling at other times. While such idling is an inefficient use of capital, it is a straight trade-off with the solar curtailment, resulting in models that have solar as supplementary rather than central capacity. This "solar-central" model would also allow for minimum energy storage investment, something that could be useful if storage prices fail to fall as quickly as generally predicted. In this scenario, even without the use of CSP, energy storage capacity could be reduced from 465 GWh to 70 GWh, keeping the same contribution from fossil fuel targets.

Using this model, KSA could mitigate the need to maintain high fossil capacity with deployment of enough energy storage or use of CSP modules.

Figure 4: Supply management option

Source: Arthur D. Little analysis

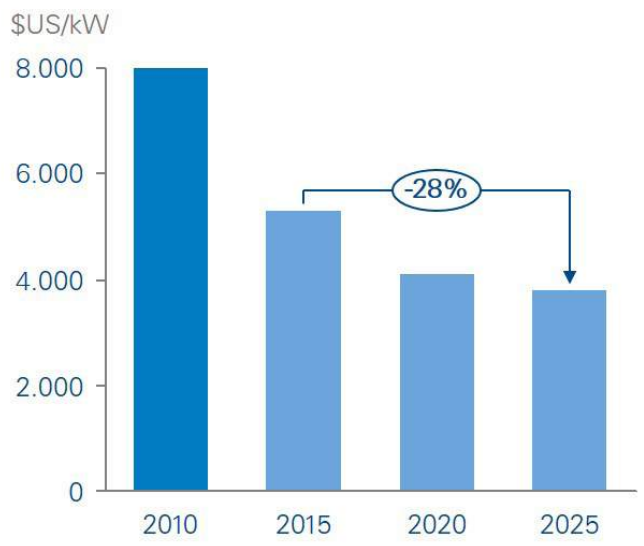
Technology will not be the constraining factor

Solar generation technology has been in the market for more than 50 years, and is no longer an experiment but a commercial reality. Both PV and CSP technologies have enjoyed significant cost reductions in the past decade.

Solar PV installation costs have decreased between 58 and 69 percent since 2010, driven by lower module and inverter costs and higher efficiency of modules. Solar deployment around the world has increased 3x in the last decade, and this level of investment has created an optimized supply value chain.

Further technological advances in solar PV modules, economies of scale and balance of solar PV system (BoS) costs could drive the global weighted installed cost down by 57 percent in the next decade. Solar modules' prices also will decrease, driven by lower polysilicon production costs. These possible reductions in solar PV installation costs will lead to LCOE of utility-scale projects falling by 59 percent in 2025, with project costs in the range of USD 0.03 to USD 0.12/kWh. Another important factor that could lead to a further decrease in cost is the assumption of the cost of capital. In our calculations, we assumed an average cost of capital of 7.5 percent, which, under current macroeconomic conditions, could be on the high end.

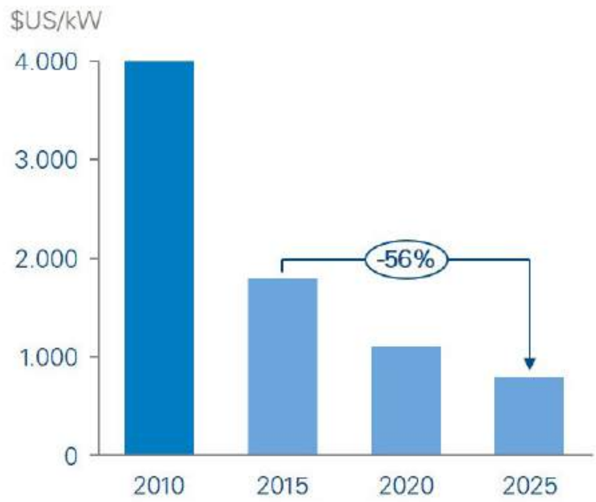
Figure 5: Solar CSP installed cost



Source: Arthur D. Little analysis

Current CSP investment costs are typically between USD 4.00 and USD 8.00/kW, as thermal energy storage increases the installation costs substantially. That said, energy storage also allows for higher load factors, and therefore lowers the LCOE. Global weighted installed costs are expected to decrease in the range of 33–37 percent, reaching USD 3.50/kW in 2025. Cost reduction drivers are mainly driven by efficiencies in solar-field costs and EPC savings as the CSP industry reaches a global and mainstream scale. This decline in installed costs will lead to LCOE reduction of 16–38 percent, reaching a range of USD 0.09 to USD 0.12/kWh in 2025.

Figure 6: Solar PV installed cost



Source: Arthur D. Little analysis

The biggest challenge of increasing the percentage of electricity derived from solar is the issue of curtailment, when the amount of solar produced at peak hours is greater than the ability of the grid to consume it. Several factors can contribute to a grid's ability to smooth out the demand curve and successfully use all solar power generated:

- Power exports: The first and most easily implementable method is to directly export excess electricity to other markets. Once national demand for peak solar reaches saturation, excess electricity can be exported to neighboring countries that are able to accommodate.
- Smart grid: Similarly, smart-grid technology is a way to smooth out demand, reducing curtailment and thus allowing for either less solar to be installed or less energy storage to be required. Smart grid technology would allow devices to draw power only when it is cheap (i.e., when the solar-generated electricity would otherwise be lost).

- Energy storage: Finally, the most obvious and substantial technology for reducing curtailment is battery technology, both distributed residential through home batteries such as Tesla's PowerWall, and through utility-scale batteries. Lithium battery cost has decreased 19 percent p.a. since 2010 and is expected to fall another 64 percent until 2030. Electric vehicle (EV) demand is also a key element for further battery cost reduction. Battery demand is expected to increase tenfold in the next 25 years, primarily led by EV demand. Further curtailment could be reduced by the adoption of vehicle-to-grid (V2G) technology, something that already exists but requires adaptation to the grid and the use of smart metering. This would smooth out demand further by treating EVs as batteries for storing power when it is cheap, and supplying it when it would otherwise be expensive.

Another sensible option is the use of pumped hydro energy storage (PHES) projects, a technology that consists of transporting water between two reservoirs at different elevations to store and deliver electricity. Saudi Electricity Company (SEC) has already started the feasibility study and tender design of a project at Wadi Baysh Dam in the mountain area near to the Gulf of Aqaba as part of its current renewable energy program.

When taken together, exports, demand response, batteries, electric vehicles, and V2G technologies will all be important enablers in making a shift to 50 percent solar viable and cost effective. California's National Renewable Energy Laboratory estimates that with even a baseline implementation of all of these enablers, the LCOE of PV will drop to USD 0.07/kWh. With full implementation of these enablers, LCOE of PV has potential to go all the way to USD 0.03/kWh, which would make the shift to solar with PV extremely competitive.

Policies to enable a "bright" future for KSA

KSA's internal investment policy is going in the right direction to address the challenges ahead, notably the fact that there are already some ongoing investments in this field. Examples include the creation of new "economic cities" and NEOM and the development of strategic plans to build solar plants with 80 percent of their components made domestically. The Saudi Arabian General Investment Authority (SAGIA) was created to govern and regulate investment by issuing licenses and promoting investment, as well as offering valuable opportunities to foreign investors. Examples include participating in the market and ultimately signing power-purchase agreements (PPAs), permission to transfer capital and profit abroad, investment protection and double taxation prevention (international mutual agreements). SAGIA represents a clear expression of the government's renewed interest in attracting foreign investment to develop its nascent renewable energy sector.

However, more is needed

In order to stimulate effective distributed PV solar generation, KSA has to support schemes that bring benefits to PV owners. Some valid options might pass to the creation of (i) tax credits that allow the owners of installations that generate energy from renewable sources to reduce the costs of these systems with tax benefits in the installation and in write-down; (ii) net metering, which KSA has already embarked upon, allowing prosumers to maximize their use of the power they generate by receiving credits for power consumption from the grid; (iii) feed-in tariffs that allow "prosumers" to sell the electricity they generate to their power retailer instead of using it; (iv) incentives and subsidies to defray the cost of distributed generation systems deployment; and (v) issuance of certificates that allow utilities to demonstrate their compliance with production quotas of green energy, in which a minimum percentage of the power sold by utilities and energy retailers has to come from renewable sources.

Conclusion

The prospects for solar power continue to get sunnier. Solar is already cheaper than traditional fossil fuels, and forecasts show prices continuing to drop. Supplementary technologies, such as energy storage, are getting cheaper and more efficient. It is not hard to envision power infrastructure designed around solar power.

Rather than continue to focus on curtailment management, which is a function of using fossil fuels for base-load energy production, a more aggressive strategy could be to consume all solar electricity produced, bringing required curtailment as close as possible to zero. In this scenario, fossil fuels would be used to fill in gaps, while reasonable solar energy storage would serve as the country's base load for electricity generation.

For the Kingdom of Saudi Arabia to realize this solar-centric economy, no paradigm shift in technology or prices would be necessary. KSA electricity tariffs for 2018 stated a base tariff of USD 0.05/kWh for residential consumption, a price largely subsidized by domestic fuel prices, which substantially differs from market prices. If market prices were used instead, the real electricity price faced by Saudis would be in the range of USD 0.08/kWh.

A solar-centric power base for KSA is not an unrealistic fantasy – it is an entirely plausible and strategic future that is very much in reach. In fact, given how easily KSA could meet this 50 percent solar target, the real question becomes this: why not aim for even more and solidify Saudi's standing as the world's leader, not just in oil, but also in renewable energy for generations to come? The numbers say "yes".

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