German Economic Team

UZBEKISTAN

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Assessing power plant park scenarios for 2030

by Dr. Georg Zachmann, Clemens Stiewe

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The German Economic Team (GET) advises the governments of Ukraine, Belarus, Moldova, Georgia and Uzbekistan regarding the design of economic policy reform processes and a sustainable development of the economic framework. As part of the project we also work in other countries on selected topics.

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In addition, GET supports German institutions in the political, administrative and business sectors with its know-how and detailed knowledge of the region's economies.

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Executive summary

Uzbekistan's electricity demand increased significantly in the past decade and is expected to grow further due to increasing population and GDP. At the same time, the existing power plant fleet is ageing and units will need to be replaced. Already today, electricity generation does not always meet demand and individual consumers need to be switched off. Consequently, significant investment in new generation capacities will be needed to meet the expected electricity demand in 2030.

We analyse three scenarios for the development of Uzbekistan's power plant fleet until 2030. We find that existing projects exceed the expected demand for 2030 significantly and hence the most expensive baseload technology (in our model nuclear) would not be needed. In addition, the decreasing cost of wind and solar technology imply, that replacing some baseload gas-fired power plants (CCGTs) by renewables and back-up gas turbines (OCGTs) can reduce cost further.

Our results strongly depend on assumptions on the cost and capabilities of technologies as well as demand patterns. We make those transparent in the paper to allow for an informed discussion.

	(1) Baseline	(2) No nuclear	(3) RES and peakers to replace some CCGT
Annual variable cost (USD m)	3,080	3,518	3,344
Annual capital cost (USD m), 10% interest rate	3,875	1,595	1,749
Total cost (USD m)	**6,955**	**5,113**	**5,092**

Content

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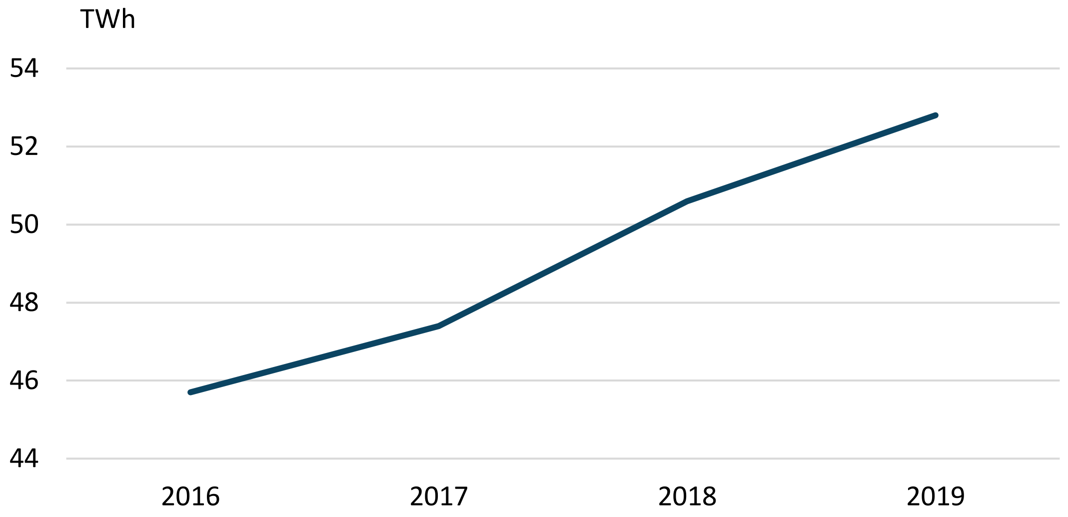
1 Why Uzbekistan's power plant park needs to be modernised

Uzbekistan's electricity demand increased significantly in the past years (see Figure 1). This was due to increasing population and economy (see Figure 2). As both are expected to continue their growth throughout the next decade electricity demand could reach up to 100 TWh by 2030. At the same time the existing power plant fleet is ageing and units will need to be replaced[1].

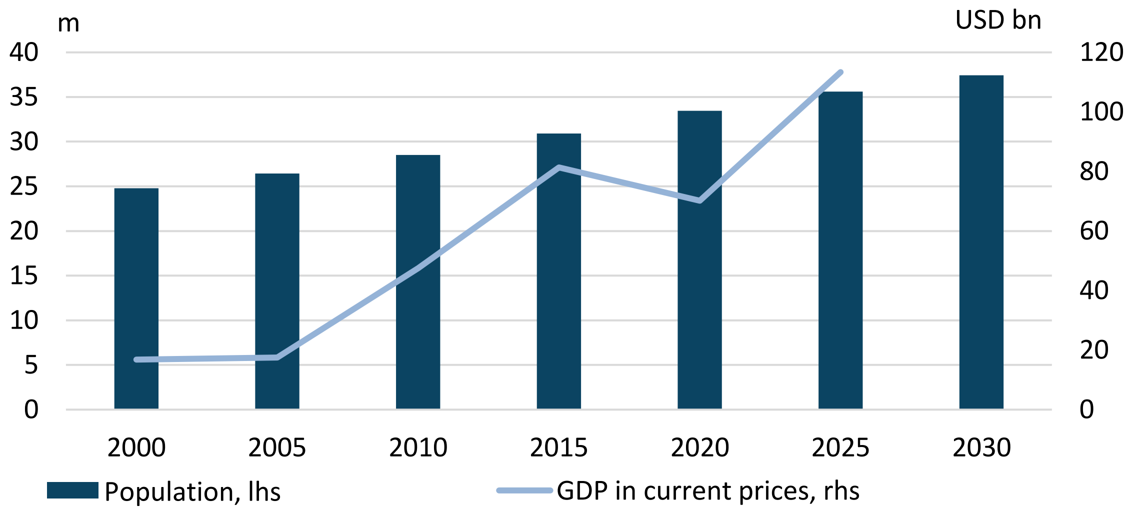
Already today, electricity generation does not always meet demand and individual consumers need to be switched off. Consequently, significant investment in new generation capacities will be needed to meet the expected electricity demand in 2030.

Figure 1: Net electricity consumption



Source: MinEnergo

Figure 2: GDP and population development (after 2015 forecast)



Source: UN, IMF

[1] In the past 27 years only 5 GW of a total plant fleet of about 13 GW were built.

2 Setting the right capacity targets ensures most economic modernisation pathway

The Uzbek government has ambitious plans for the development of the power plant fleet by 2030. Projects for significant investments in a first nuclear power plant, a large built-up of new combined cycle gas turbines (CCGTs) as well as wind and solar parks add up to 20 GW of new capacities within only 10 years. The significant investment cost of these projects will have to be refinanced through electricity prices in one way or another. Hence, it is important to have an open debate, whether all of these plants will be really needed and whether combinations of technologies exist that are able to meet demand at lower cost.

To inform this debate we analyse different scenarios for Uzbekistan's 2030 power plant fleet. For each scenario we model whether this fleet is able to meet demand in each hour of the year and what the capital and variable cost of operating this system are. To do this, we establish for each scenario the cost-optimal dispatch of the electricity system.

3 Scenarios for Uzbekistan's electricity system in 2030

The aim of this exercise is to compare the government strategy for modernising Uzbekistan's electricity system with two alternative setups of the country's electricity system. We evaluate the different power plant park scenarios by optimising the hourly dispatch of power plants for one exemplary day, using the open-source and Python-based electricity system model Calliope.

For each hour of the day, this electricity system model calculates the cost-optimal match of electricity supply and demand under certain technical constraints[2]. While supply side characteristics – i.e. power plant capacities – differ between the scenarios, demand is the same for all scenarios and defined by hourly national electricity demand (in MW)[3]. To account for a foreseeable surge in Uzbekistan's electricity demand in the next ten years, the hourly demand data was scaled up to match 100 TWh per year in 2030, which represents a 50% increase from 2017.

Wind speed and solar irradiation data for Navoi, Uzbekistan was taken from the open-source platform Renewables.ninja[4] to calculate hourly renewable capacity factors. For hydro electricity generation we assumed that the 2017 average capacity factor (49%) applies for 2030. Moreover, we assumed the flexibility of hydro power plants to be limited due to agricultural constraints. Hence, they generate baseload electricity with the given capacity factor, i.e. at around half of installed capacity. Imports and exports, network constraints as well as reserve margins are not modelled in this exercise.

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[2] These constraints include, among others, ramping capabilities of power plants. For example, we assumed that combined-cycle gas turbine (CCGT) plants can ramp up/down 1.2% of their installed capacity in one minute, i.e. 70% in one hour (MIT 2011).

[3] For the load profile we used hourly Uzbek data for one day in January 2017.

[4] https://www.renewables.ninja/

Scenario 1 – Baseline

In our baseline scenario, Uzbekistan's power plant park is built according to the 2030 government strategy. This implies the commissioning of the country's first nuclear plant, replacing soviet-era gas plants with modern CCGTs, adding flexible open-cycle gas turbines (OCGT) as peaking plants and expanding existing hydro power capacities.

Moreover, a significant amount of wind – 1.7 GW – and solar/photovoltaic (PV) – 5 GW – capacity is installed to take advantage of the country's abundant resources for renewable electricity generation. Renewables enjoy priority dispatch, i.e. they can always feed in as much electricity into the grid as they are able to produce given the respective wind speed and solar irradiation conditions. Table 1 displays the installed capacities for all three scenarios.

Scenario 2 – No nuclear

Our second scenario essentially mirrors the setup of the first scenario but does not install the planned nuclear plant. The aim of this scenario is to check whether abandoning the nuclear plans would be economically preferable, both in terms of saving capital cost as well as utilising the remaining capacities – which are built according to the 2030 plan – more efficiently.

Scenario 3 – RES and peakers to replace some CCGT

Scenario three builds on scenario two – i.e. the planned nuclear plant will not be commissioned. Apart from that, there are more changes to the electricity system setup: In order to model a system with less baseload and more flexible and renewable power, the installed capacity of CCGTs is reduced by 2 GW. Moreover, flexible OCGT capacity is doubled to 3 GW. We also allow for a higher share of renewable electricity generation by adding 1GW of wind and 1GW of solar compared to scenarios one and two.

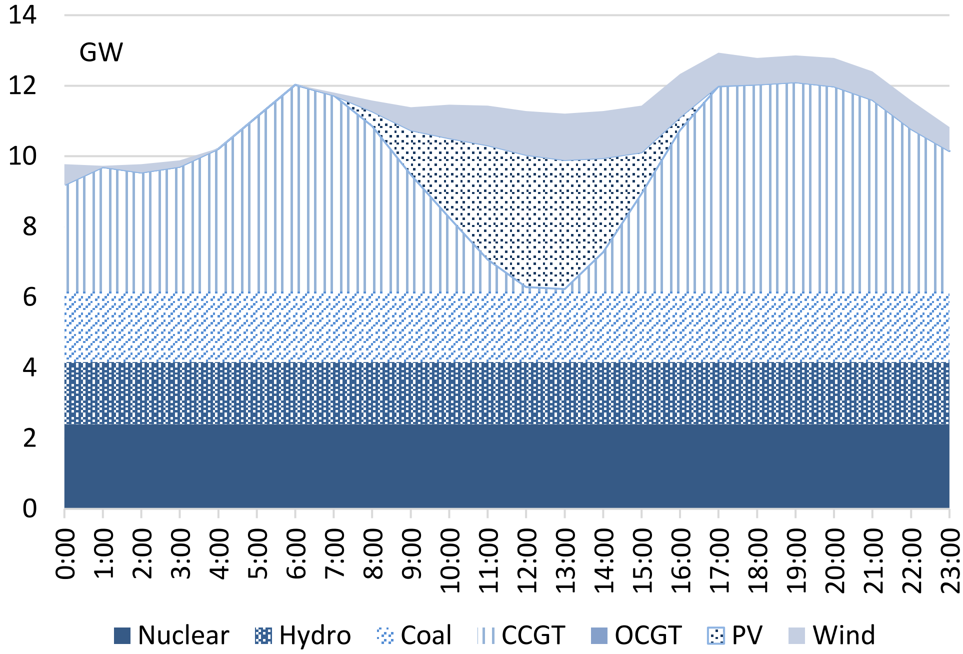
Table 1: Scenarios and parameters

			Scenarios and installed capacities (GW)		
Techs	*Capital cost (mln $/MW)*	*Variable cost ($/MWh)*	**(1) Baseline**	**(2) No nuclear**	**(3) RES and peakers to replace some CCGT**
Nuclear	9.5	30	2.4	0	0
Coal	-	45	2	2	2
CCGT	1	50	7.5	7.5	5.5
OCGT	0.83	60	1.5	1.5	3
Hydro	-	0	3.6	3.6	3.6
PV	1	0	5	5	6
Wind	1.3	0	1.7	1.7	2.7

Sources: Lazard 2019

4 Results: Comparing capacity utilisation between scenarios

Figure 3: Hourly generation and capacity factors for scenario 1 – Baseline



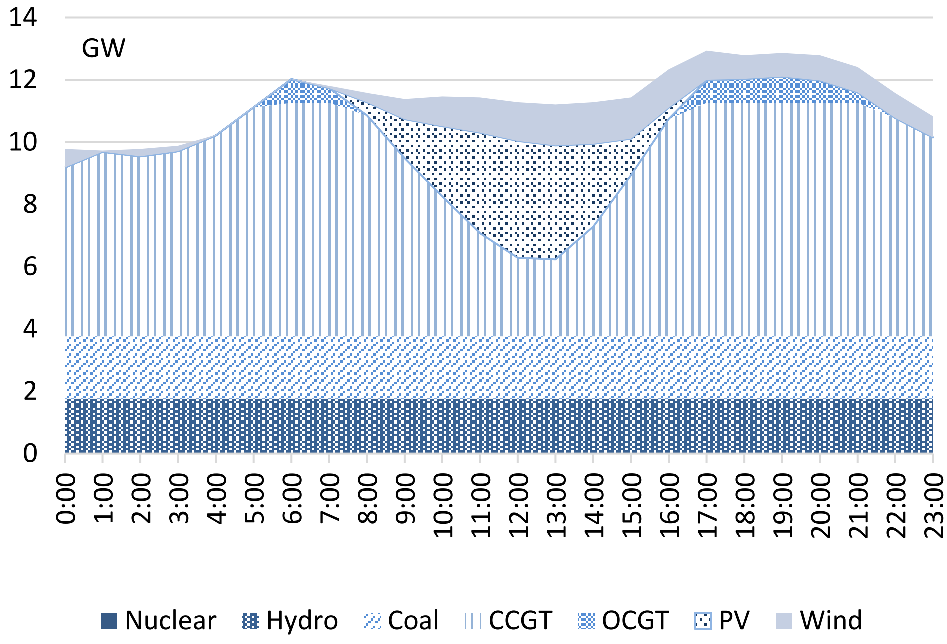
Capacity factors per technology	
Nuclear	100%
Coal	100%
CCGT	51%
OCGT	0%
Hydro	49%
PV	16%
Wind	40%

Source: own calculation

Figure 3 shows the optimisation results for the hourly dispatch of Uzbekistan's power plant park under scenario one. Three technologies – nuclear, hydro and coal – serve baseload generation. CCGTs, which have higher variable costs than coal plants, need to completely ramp down and up again during noon, when solar generation peaks and residual load (load minus renewable generation) is lowest. Due to the high share of baseload generation in the system, it hence shows that CCGTs completely lose their role as baseload technology and become load-following. This highly inefficient utilisation of CCGTs is also evidenced by a capacity factor of only 51%.

In this baseline scenario, OCGTs are not dispatched at all – peaks are served by CCGTs only. Still, they could provide fast-starting operating reserve to balance fluctuations of load and renewable generation. A capacity factor of 16% for solar represents below-average solar irradiation, which is due to using January data. In summer, average capacity factors in Navoi can reach 24%, which in this setup would imply that coal plants, and potentially hydro too, would have to ramp down during noon.

Figure 4: Hourly generation and capacity factors for scenario 2 – No nuclear



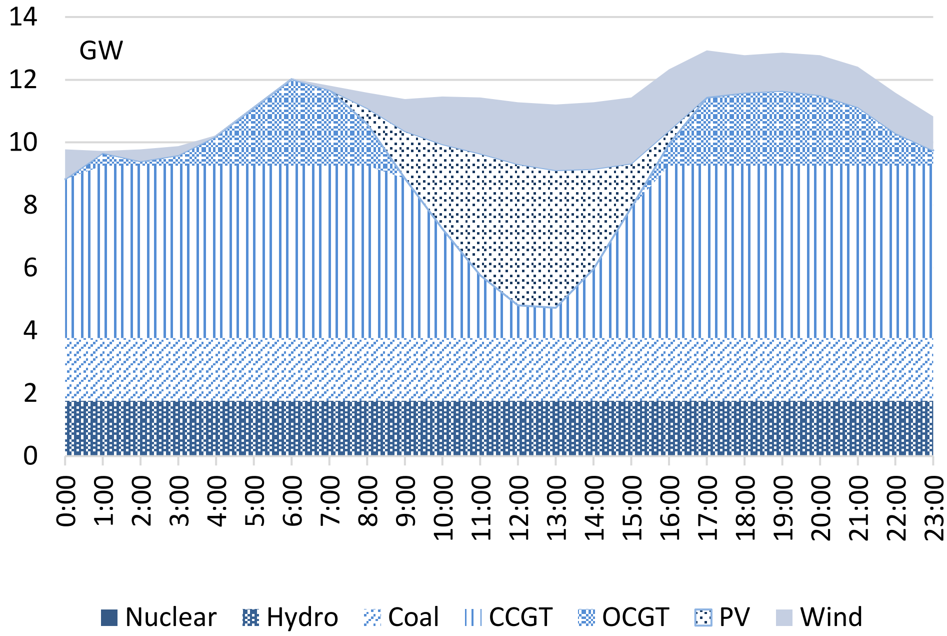
Capacity factors per technology	
Nuclear	0%
Coal	100%
CCGT	80%
OCGT	13%
Hydro	49%
PV	16%
Wind	40%

Source: own calculation

Scenario two shows that without the planned nuclear plant, CCGT utilisation would be much higher (80%) and thus more efficient. Figure 4 shows that during the entire day, 2 GW of CCGT plants could generate baseload. In the morning and evening, the entire capacity of 7.5 GW could operate at full capacity.

During these hours, OCGT plants would then kick in to serve peak demand. Still, their maximum capacity factor is only 56%, indicating that OCGT could serve even more peak demand. This in turn would allow to use less CCGT units as load-following generators.

Figure 5: Hourly generation and capacity factors for scenario 3 – RES and peakers to replace some CCGT



Capacity factors per technology	
Nuclear	0%
Coal	100%
CCGT	85%
OCGT	32%
Hydro	49%
PV	16%
Wind	40%

Source: own calculation

The results for scenario three show that a further flexibilisation of Uzbekistan's electricity system, together with a higher share of renewables, can be economically beneficial. At their reduced total capacity of 5.5 GW, CCGT utilisation is improved from 80% to 85% compared to scenario two. Still, Figure 5 shows that the drop in residual load around noon forces a high share of CCGT units to ramp down and up again.

The fast-starting OCGTs would operate quite frequently, which is evidenced by their high capacity factor of 32%. In the morning, they would even operate at 90% of their capacity.

The result that CCGT baseload generation is limited is found for all three scenario and represents a central message of our modelling exercise: In a world with renewable capacities at more than 50% of peak load, the share of stable baseload generation will need to decline significantly. Instead, these future systems need to exploit the benefits of flexible generation, import and export, storage and demand response etc. to be able to successfully balance renewable electricity generation.

Table 2: Variable, capital and total costs for three scenarios

	(1) Baseline	(2) No nuclear	(3) RES and peakers to replace some CCGT
Annual variable cost (USD m)	3,080	3,518	3,344
Annual capital cost (USD m), 10% interest rate	3,875	1,595	1,749
Total cost (USD m)	**6,955**	**5,113**	**5,092**

Source: own calculation

A comparison of variable[5] and fixed/capital cost for the three scenarios reveals that the baseline scenario has the lowest variable but excessively high capital cost due to nuclear capital cost, making it score worst in terms of total cost.

Scenario two, which builds no nuclear plants, can thus more than halve capital costs compared to scenario one. However, the higher utilisation of gas-fired CCGTs and OCGTs results in higher variable cost.

Since scenario three builds more renewables, which produce electricity with variable costs of zero, total variable costs can be reduced compared to scenario two. Even a higher utilisation of relatively inefficient gas peakers cannot reign in this positive effect of higher renewable generation. Although capital cost in scenario three are somewhat higher than in scenario two, scenario three has the lowest total cost of all scenarios. A further decline in renewable capital cost in the next ten years could make the winner even more clear.

5 Outlook: More detailed modelling needed to identify bottlenecks

Our results indicate that systematically planning the power plant fleet can significantly reduce the cost of the electricity system compared to a project-by-project assessment[6]. We, however, have to highlight significant limitations of our quick analysis. Our assumptions on cost and capabilities of technologies as well as expected demand patterns are strongly simplified. For example, including the seasonality of hydro-power, wind and solar or allowing some flexibility of hydropower plants can change the results. We also do not consider constraints in the electricity and natural gas network or cross-border electricity exchanges. And our dispatch model does not include a stochastic reserve planning. For a more complete assessment corresponding data needs to be made available. But we think that our initial assessment provides a good basis for discussion, which technical and economic details would be worthwhile considering.

Finally, we show that much higher shares of wind and solar generation would be sensible to keep generation cost in check. But going from virtually zero to more than 6 GW of varying renewables in just ten years implies important technical and administrative changes in Uzbekistan's electricity system, that would need to be more carefully studied.

[5] Variable cost for the modelled day have been scaled up to match annual costs.

[6] The alternative to systemic planning of the power plant fleet is to design a well-functioning electricity market.