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ScienceDirect

Energy Procedia 135 (2017) 126–142

Energy Procedia

www.elsevier.com/locate/procedia

11th International Renewable Energy Storage Conference, IRES 2017, 14-16 March 2017, Düsseldorf, Germany

Impact of Battery and Water Storage on the Transition to an Integrated 100% Renewable Energy Power System for Saudi Arabia

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Abstract

Saudi Arabia can transition to a 100% renewable energy system by 2040 including the integration of the power, desalination and non-energetic industrial gas sectors. Single-axis tracking PV and battery storage contribute the highest to the final LCOE of the system. By 2050, single-axis tracking PV accounts for 77% of the total electricity generation. Battery storage accounts for 44% of the total electricity demand. Desalination plants provide additional flexibility to the energy system. Through sensitivity analysis, it is found that decreasing the capex of desalination plants results in a decrease in battery storage output and ultimately the total system capex throughout the transition. However, the required SWRO capex decrease seems to be higher than possible, leading to a lower cost flexibility provided by solar PV and battery storage than possible by very low cost water storage. This is because the relatively more expensive SWRO desalination prefers baseload operation for total energy system cost reasons.

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Peer-review under the responsibility of EUROSOLAR - The European Association for Renewable Energy.

Keywords: 100% renewable energy; Saudi Arabia; energy transition; battery; water storage; flexibility

1. Main text

Energy storage is seen as a cornerstone of the green energy revolution [1,2]. The intermittent nature of solar and wind resources can be overcome with different types of flexibility (supply side management, demand side management, grids, sector coupling, storage), thereof energy storage is regarded as one of the most important, enabling a faster transition towards a 100% renewable energy system [3,4,5]. With the increase in global installed capacities of renewable energy power plants, there is a surge in demand for energy storage capacities. The Bloomberg New Energy Finances (BNEF) New Energy Outlook 2016 report forecasts global storage capacities to increase to 25 GW by 2028 from the 1 GW installed today [6].

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Peer-review under the responsibility of EUROSOLAR - The European Association for Renewable Energy.
10.1016/j.egypro.2017.09.496

Nomenclature

a	annum
b	billion
BNEF	bloomberg new energy finance
CSP	concentrated solar power
capex	capital expenditures
EV	electric vehicle
FLH	full load hours
GW	giga watts
KSA	kingdom of saudi arabia
LCOE	levelised cost of electricity
MED	multiple effect distillation
MSF	multi stage flash
opex	operational expenditures
PV	photovoltaics
PtG	power-to-gas
RE	renewable energy
SNG	synthetic natural gas
SWRO	seawater reverse osmosis
TWh	terra watt hour
UAE	united arab emirates

Luo et al. [2] explains that with improved power to energy ratios, lithium-ion batteries are currently experiencing by far the fastest growth of all storage options and being used in small and utility-scale applications. Consequently, there has been a sharp decline in the capex of batteries as presented by Liebreich from BNEF [7]. The price of the electric vehicle (EV) lithium ion battery price is estimated to have fallen from 770 €/kWh in 2010 to 243 €/kWh in 2015 [7]. The report forecasts the cost to plunge even more sharply to 162 €/kWh by 2018, a 77% fall in cost between 2010 and 2018.

In a recent study, we investigated the least cost pathway for the Kingdom of Saudi Arabia (KSA) to transition from the current fossil-based power sector to a 100% renewable energy based system by 2050, whilst integrating the increasing desalination sector with the power sector [8]. It was found that Saudi Arabia can achieve a 100% renewable energy power system by 2040 with a power sector dominated by PV single-axis tracking and battery storage. Single-axis tracking PV contributed 210 GW out of the total 403 GW by 2040. The contribution increased to 369 GW out of a total of 520 GW by 2050. Battery storage contributed up to 30% of the total electricity demand in 2040 and the contribution increases to 48% by 2050. The combination of PV and battery storage provided the least cost option to meet Saudi Arabia's power and desalination sector demands. This was mainly due to the sharp anticipated decrease in PV and battery storage.

In the study in [8], it was found that the integration of the power and water desalination sectors provided the least cost transition pathway as opposed to the independent transition of the two sectors. The desalination plants and water storage provide additional flexibility to the system, enabling better utilization of the renewable energy generated. This leads to a reduction in the demand for battery and power-to-gas (PtG) storage in the transition. The study [8] highlights the relationship between water and battery storage in the energy transition pathway for Saudi Arabia.

Located between the Persian Gulf and the Red Sea, Saudi Arabia is one of the largest arid countries without any permanent rivers or lakes. Whilst the global average renewable water resource per capita per year is 6000 m^3, Saudi Arabia has only 84.8 m^3/(capita·a) [9]. In spite of the water scarcity, Saudi Arabia has the third highest water consumption per capita at 250 liters/(capita·d). This is only behind the United States and Canada. The country's water

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