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Energy Storage in Global and Transcontinental Energy Scenarios: A Critical Review

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Abstract

There are a fast growing number of global energy scenarios based on high shares of renewable energy (RE). However, many of them lack comprehensive analyses of energy storage systems. A review of global scenarios reveals that energy storage systems are assessed mainly qualitatively; quantitative assessments of global energy storage demand are scarce. The possible future roles of energy storage systems are plentiful: they can be used in short-term control (e.g. in power grid frequency control), as a medium-term balance mechanism (to shift daily production to meet demand), as long-term storage (seasonal shift), or to substitute grid extensions. Typically, only power storage is considered, if energy storage is assessed at all. Scenario-makers do not always assess the dynamics and synergies of energy storage systems in the power, heat and mobility sectors.

To date, publications of the dynamics between continent-wide renewable energy production, transmission grids and energy storage capacities are not numerous. The existing body of research indicates that transmission lines connecting individual countries are regarded as a key component in enabling RE-based, low-cost energy systems. However, various issues could restrain the implementation of proposed grid connections. These barriers could be overcome by partially substituting energy grid reinforcements with energy storage solutions. Furthermore, less storage related curtailment of renewable energy could lead to improved energy system efficiency and cost. Therefore, energy scenarios that capture quantitatively different configurations of international energy exchange and its influence on regional storage systems are needed. High spatial and temporal resolution energy system models are needed to assess scenarios for high share of renewable energy supply and demand for energy storage.

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1. Introduction

Climate change, optimal resource use and desire to better understand aspects of large-scale renewable energy (RE) deployment have motivated scenario-makers to explore pathways to and aspects of high RE futures [1]. Substantial growth in RE deployment in recent years undoubtedly has spurred increased attention to high RE scenarios. Over the mid-term, Intended Nationally Determined Contributions (INDCs) can set light on the current ambition level of RE uptake. Cumulative RE supply levels in Brazil, China, the European Union and Indonesia are set to increase from 7980 TWh/year in 2012 to 14,830 TWh/year (86% increase) in 2030 according to a recent report [2] based upon INDCs. Renewable electricity generation in Brazil, India, Mexico and the United States is set to increase from 630 TWh/year in 2012 to 2250 TWh/year (257 % increase) in 2030. The substantial RE growth indicated in INDCs is in line with leading institutional projections of rapid RE deployment in the years to come [3]. Moreover, partly excluded and partly included in INDCs, growing number of subnational and corporate targets show even more stringent greenhouse gas (GHG) reduction and RE deployment goals [4,5,6]. Significant health benefits, job creation and reduced cost of imported fuels have been estimated to result from more ambitious renewable energy deployment [7].

Nomenclature

CAES	Compressed Air Energy Storage
CCGT	Combined Cycle Gas Turbine
DSM	Demand Side Management
EUMENA	Europe-Middle-East-North-Africa
H_2	Hydrogen
HVDC	High Voltage Direct Current
PHS	Pumped Hydro Storage
RE	Renewable Energy
RPM	Renewable Power Methane
V2G	Vehicle to Grid
VLS-PV	Very Large Scale-Photovoltaics

Several studies suggest that on the European level the further integration of electricity transfer capacities would deliver cost savings in the total system. Grid integration is argued to be an economically beneficial measure in achieving long-term energy and climate policy targets: integrating high shares of renewables, increasing competition in the market, thus leading to lower electricity prices, and increasing security of supply. A recent study found the cost savings ranging between 2 – 21% compared to a scenario without grid expansion [8]. In a concept study several opportunities enabled by a global grid were identified: smoothing out electricity supply and demand, minimizing power reserves, reducing storage demand and reducing volatility of electricity prices. Power system security could be on the one hand reduced (reliance on overseas source of energy) and on the other enhanced (relief of congestion) [9]. Thinking broader, current energy systems are already heavily dependent on fuels imported from thousands of kilometers away [10], and a global grid could actually reduce the dependence on overseas energy. Some of the targets above could be at least partly addressed by energy storage as well, thus the research questions of this study arise: Is the role of energy storage assessed in influential global energy scenarios? What is the quantified demand for energy storage in global scenarios? To some extent the issue of building supergrids has already departed the academic circles and been taken on by various initiatives in Europe and applications in Asia; ten years after the ground-breaking TRANS-CSP study by the DLR [11], industry rooted initiative Dii [12] and non-profit civil society initiative Desertec Foundation [13] are carrying on the concept of importing solar power from North Africa to Europe. The North Sea grid project co-funded by European Union (EU) is yet another example [14]. In Asia, the State Grid Corporation of China is poised to construct about 160 GW of high voltage connections by 2016 (116 GW had been constructed by the end of 2014) [15]. According to the Global Energy Storage Database [16], the grid connected energy storage capacity installed in China amounted to 33.3 GW in 2015, mainly based on pumped hydro storage.