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The role of storage technologies for the transition to a 100% renewable energy system in Ukraine

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Abstract

A transition towards a 100% renewable energy (RE) power sector by 2050 is investigated for Ukraine. Simulations using an hourly resolved model define the roles of storage technologies in a least cost system configuration. Results indicate that the levelised cost of electricity will fall from a current level of 82 €/MWh$_e$ to 60 €/MWh$_e$ in 2050 through the adoption of low cost RE power generation and improvements in efficiency. If the capacity in 2050 would have been invested for the cost assumptions of 2050, the cost would be 54 €/MWh$_e$, which can be expected for the time beyond 2050. In addition, flexibility of and stability in the power system are provided by increasing shares of energy storage solutions over time, in parallel with expected price decreases in these technologies. Total storage requirements include 0-139 GWh$_e$ of batteries, 9 GWh$_e$ of pumped hydro storage, and 0-18,840 GWh$_{gas}$ of gas storage for the time period. Outputs of power-to-gas begin in 2035 when renewable energy production reaches a share of 86% in the power system, increasing to a total of 13 TWh$_{gas}$ in 2050. A 100% RE system can be a more economical and efficient solution for Ukraine, one that is also compatible with climate change mitigation targets set out at COP21. Achieving a sustainable energy system can aid in achieving other political, economic and social goals for Ukraine, but this will require overcoming several barriers through proper planning and supportive policies.

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Keywords: energy transition; storage technologies; Ukraine, 100% Renewable Energy; energy system optimization

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1. Introduction

The landmark Paris Agreement of the 21st Conference of Parties to the United Nations Framework Convention on Climate Change recognized the need for global response to the impending threat of climate change [1]. As part of the agreement, such response involves limiting "global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C" through low greenhouse gas (GHG) emissions [1]. Among the countries ratifying the agreement was Ukraine, which targets that GHG emissions will not exceed 60% of the 1990 level in 2030 [2]. Importantly, Ukraine aims to achieve this target in a context of multiple, large-scale problems in the fore: armed conflict, net emigration, economic and industrial degradation [3], and over-dependence on imported fossil and nuclear fuel [4]. On one hand, it may seem ambitious to achieve such a GHG reduction target and fix the "many problems on the table" [2]. However, integrated and dynamic actions can attempt to tackle the multitude of problems through "efficient and effective policies and imposing of limitations of GHG emissions which are beyond current international obligations of Ukraine" [3]. On the other hand, Ukraine emission targets have been described as "unacceptable in terms of ambition" as they promote higher GHG emissions than are seen currently, and inadequate if Ukraine is to realize its "huge potential for climate action"[5].

Nomenclature

A-CAES	Adiabatic compressed air energy storage
CCGT	Combined cycle gas turbine
CCS	Carbon capture and storage
CHP	Combined heat and power
CSP	Concentrating solar thermal power
GDP	Gross domestic product
GHG	Greenhouse gas
GT/ST	Gas turbine/Steam turbine
GW/GWh	Gigawatt/Gigawatt hour
HHB	Hot heat burner
HVDC	High voltage direct current
ICE	Internal combustion engine
INDC	Intended nationally determined contribution
kW/kWh	Kilowatt/Kilowatt hour
LCOC/E/S/T	Levelised cost of curtailment/electricity/storage/transmission
LUT	Lappeenranta University of Technology
Mt	Megaton
MW/MWh	Megawatt/Megawatt hour
OCGT	Open cycle gas turbine
PHS	Pumped hydro storage
PP	Power plant
PtG, PtH	Power to gas, Power to heat
PV	Photovoltaics
RE	Renewable energy
SME	Small to medium enterprises
TES	Thermal energy storage
TW/TWh	Terawatt/Terawatt hour
WACC	Weighted average cost of capital
$_e$	electric units
$_{eq}$	equivalent units
$_{gas}$	gas units
$_{th}$	thermal units