Minsk pumped hydro storage

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The use of moving water in rivers to provide useful energy has been practiced for millennia. Since the 1880s, hydroelectricity has been a major component of global electricity production. In 2019, global installed hydroelectric power capacity reached 1310 Gigawatts (GW) [1]. Energy production from hydro in 2018 was 4300 Terawatt-hours (TWh) which represents 17% of global electricity production [2].

Hydroelectricity is valuable in an electricity system because it is easily capable of following variable load by varying the flow of water through the turbine. This minimizes the need for slow-response coal-fired and nuclear power systems to follow electricity demand as it rises and falls.

When normalized for population, mountainous countries including Iceland, Norway, Bhutan, Canada and Switzerland head the list (figure 2). The rapid response capability of hydro can be used to help balance electrical supply and demand. A premium is normally paid for flexible, rapid response hydro energy, and some countries earn substantial income by exporting hydroelectricity.

Pumped hydro energy storage (PHES) has been in use for more than a century to assist with load balancing in the electricity industry. PHES entails pumping water from a lower reservoir to a nearby upper reservoir when there is spare power generation capacity (for example, on windy and sunny days) and allowing the water to return to the lower reservoir through a turbine to generate electricity when there is a supply shortfall (for example, during the evening).

PHES comprises about 96% of global storage power capacity and 99% of global storage energy volume [3]. Some countries have substantial PHES capacity to help balance supply and demand (figure 3). For example, Japan"s PHES capacity was constructed to help follow varying power demand, allowing its nuclear and fossil fuel fleet to operate at nearly constant power output.

Batteries occupy most of the balance of the electricity storage market. Battery storage includes utility, home and electric vehicle batteries. Batteries are rapidly falling in price and can compete with PHES for short-term

storage (minutes to hours). PHES is much cheaper for large-scale energy storage (overnight or several days) and has much longer technical lifetime (50-100 years). All prices in this article are in United States dollars.

The global electricity system is rapidly transitioning away from fossil fuel power systems and towards renewable energy (figure 4) [4]. About two thirds of net global annual generation power capacity additions are solar photovoltaics (PV) (figure 5) and wind (figure 6). This is because of rapid declines in the cost of PV and wind.

Construction of new hydroelectric systems is declining. Reasons for this include competition from solar and wind; opposition on environmental and social grounds; and many of the good sites have already been developed. Hydro generation is fundamentally limited by availability of suitable rivers, whereas wind and solar have effectively unlimited resources in most regions.

Solar and wind are variable electricity sources, with power output rising and falling according to the availability of sunshine and wind. Terawatts (TW) of solar and wind will be deployed as part of deep renewable electrification [4] of the global energy system.