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# Smart Technologies for effective integration of VRE in Smart Grids

The transition towards high amounts of Variable Renewable Energy (VRE) requires a rethinking of the design, operation and planning of future power systems from a technical and economic point of view. This is because in a VRE system, supply and demand will need to be matched in a much more concerted and flexible way. This is required from two perspectives. From a technical perspective, VRE generation can be ideally combined with smart grid technologies, energy storage and more flexible generation technologies. From an economic perspective, the regulatory framework will need to be adjustable to account for the cost structure of VRE integration; to allow for new services and revenue channels; and to support new business models.

There are several technological options that can help to integrate VRE into the power system grid: system-friendly VREs, flexible generation, grid extension, smart grid technologies, and storage technologies. New advances in wind and solar PV technologies allow them to be used over a wider range of conditions and provide ancillary services like frequency and voltage control. Flexible generation requires changes in the energy mix to optimise production from both dispatchable and non-dispatchable resources.

Smart grid technologies can act as an enabler for VRE integration, given their ability to reduce the variability in the system by allowing the integration of renewables into diverse electricity resources, including load control (e.g. Demand Side Management (DSM), Advanced Metering Infrastructure (AMI), and enhancing the grid operation and therefore helping to efficiently manage the system's variability by implementing advanced technologies (e.g. smart inverters, Phasor Measurement Unit (PMU) and Fault Ride Through (FRT) capabilities). Energy storage technologies can alleviate short-term variability (up to several hours), or longer-term variability through pumped-storage hydroelectricity, thermal energy storage or the conversion of electricity into hydrogen or gas.

Due to the rapid technological progress and multiple grid integration options available, policy makers should build a framework for RE grid integration based on the current characteristic of the system, developing technological opportunities and long-term impacts and targets. In particular, policy makers should adopt a long-term vision for their transition towards renewables and set regulatory frameworks and market designs to foster both RE development and management of greater system variability. Such regulatory frameworks could include new markets for ancillary services and price signals for RE power generators that incentivise the reduction of integration costs.