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Renewable Energy Networks —a playground for Applied Theoretical Physics

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In view of critical CO2 emissions and depleting conventional resources, a transformation towards a sustainable energy system is needed. Applied Theoretical Physics and the Physics of Complex Networks are able to contribute to the solution of this grand challenge. We discuss a simple network model, which describes a future European electricity system with a high share of wind and solar power generation. The weather acts as the fluctuating driving force. Weather data covering multiple years are converted into prospective wind and solar power generation with good spatial and temporal resolution. The weather-driven network modelling represents a direct approach to obtain fundamental estimates on the required backup infrastructure of highly renewable large-scale energy systems. Estimates on the required amount of conventional backup power plants, transmission lines and storage will be given. The optimization of energy system costs is addressed, leading to new design concepts like the optimal heterogeneity and the benefit of cooperation. Related to diffusion processes on networks, flow tracing algorithms are described, which help to clarify how the resulting costs are shared in a fair manner. An extended outlook about current research on the coupling of the different energy sectors, the techno-economical design and socio-political implementation of decarbonization roadmaps into the future as well as the impact of climate change will be given at the end.

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