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Optimizing World-wide Utilization of Renewable Energy Sources in the Power Sector

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Abstract: **-** The increasing demand for fossil fuels in the power sector, security of supply and global environmental issues necessitate the transition of the current energy system towards a renewable-based supply. However, integration of renewable energy sources to the power system will result in challenging issues mainly due to the natural intermittent patterns. Therefore, it is necessary to investigate this issue in a systematic simulation-based analysis. The interesting questions within this framework are how such a renewable-based energy system should be structured, and how costly it might be.

The modeling approach, presented here, is the combination of an adequately precise geographical coverage with high temporal resolution. This methodology provides the requirements to properly mimic the geographical dependencies of energy supply and demand as well as short term intermittent patterns of renewable sources. The prescribed simulation technique is applied here to investigate the long term evolution of the global electricity sector. The model is applied to study how, in a prospective energy supply infrastructure, the transport of electricity between continents, timezones and hemispheres allows gaining profit from inter-seasonal and inter-diurnal variations of renewable energies.

Long-term power generation and transmission investment planning tool, URBS, has been applied here as a framework for developing the model of electricity supply system on the world-wide scale. Simulation has been performed with an hourly temporal resolution. The optimization algorithm is based on the concepts of linear programming with an economic objective function, representing the overall system cost. Minimization of the overall system cost is subject to restrictions, describing the energy system structure at each simulation step. These restrictive equations comprise the supply-demand balance as well as energy conversion, transport and storage losses, and technical limits of power plants. Model formulation and optimization process is realized with the application of General Algebraic Modeling System (GAMS) software package. Optimal power generation capacities, promising sites for installation of renewable technologies as well as inter-regional transport capacities result from the optimization process.

The current model comprises of 51 aggregated regions based on the spatial distribution of technical potential of renewable electricity and the demand. Hourly time series of GIS-based meteorological data and electrical load profiles, rescaled to a consistent spatial resolution, are aggregated to provide data for model regions. On the other side, techno-economic parameters of power plants and power transmission lines are feed to the model. Conventional existing as well as newly emerging technologies with associated cost reduction and efficiency improvement trends due to learning effects are considered. Hourly values of the capacity factor for wind energy converters and solar radiation are considered as constraints on the operation level of renewable technologies. Further restrictions on the permissible level of newly installed capacities are approximated based on the GIS (Geographic Information System) datasets of suitable areas for installation of wind parks and solar thermal power generation systems.

Key-Words: **-** Renewable Energy, Simulation, Linear Optimization, Power Supply, Geographic Information System (GIS)