Determination of long-term storage capacities for an energy system completely based on renewable Energies in Germany

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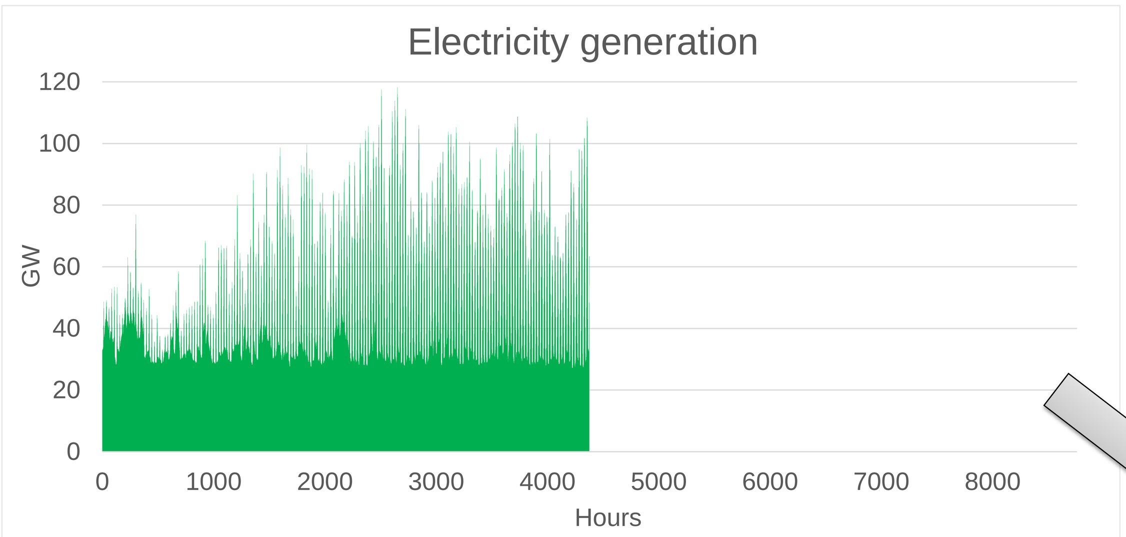
Basics

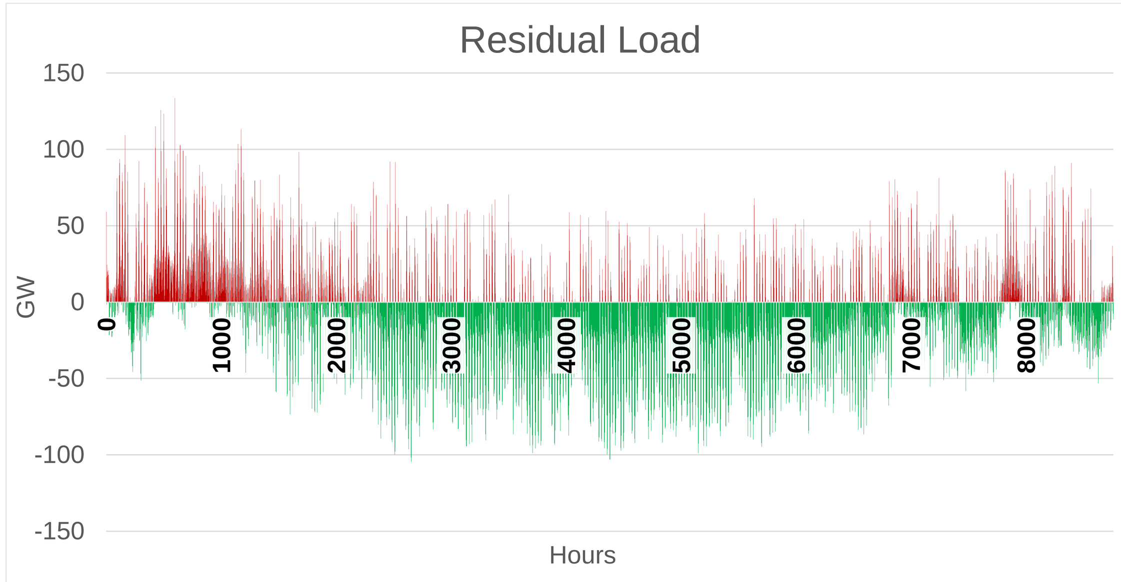
The volatility of renewable energies makes energy storage capacities necessary. Especially in times of dark doldrums. Energy that cannot be generated by PV modules or wind turbines must be provided by energy storage. Within the framework of this project, the required storage capacities of different technologies in times of dark doldrums in Germany were determined. The focus is on the energy demand for private heating purposes, private electric vehicles and the remaining electricity demand of private households.
The description used for the phenomenon or term "Dunkelflaute" (dark doldrum) is:

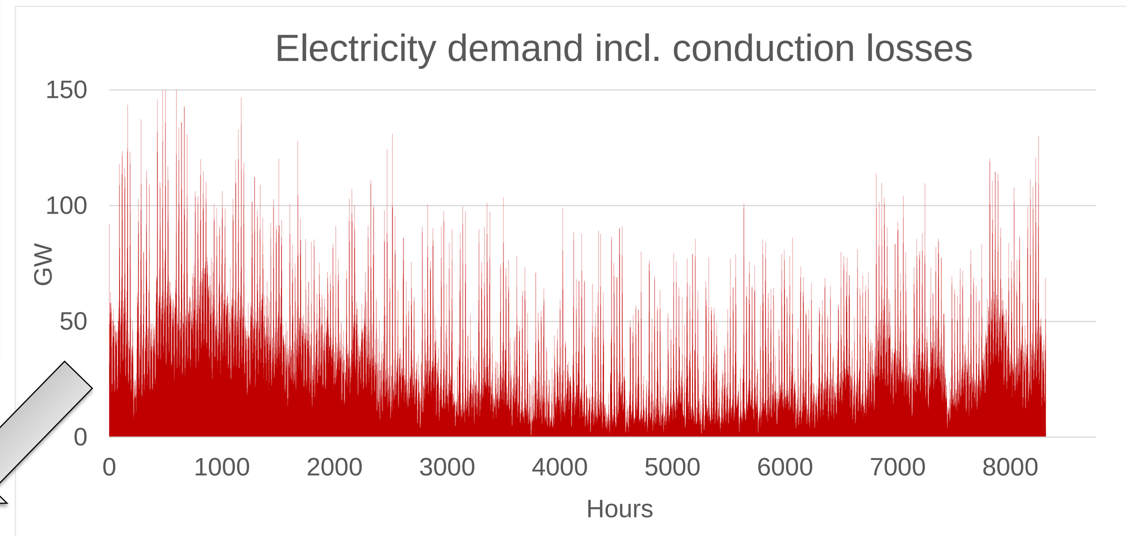
A dark doldrum occurs when, due to a lack of primary energy generation from the sun and/or wind, the energy consumption of an energy system exceeds the energy generation for a certain period of time. The period of the dark dark doldrum is the time between the start of a continuous discharge and the point in time when the state of charge of the long-term storage increases again.

Methodology

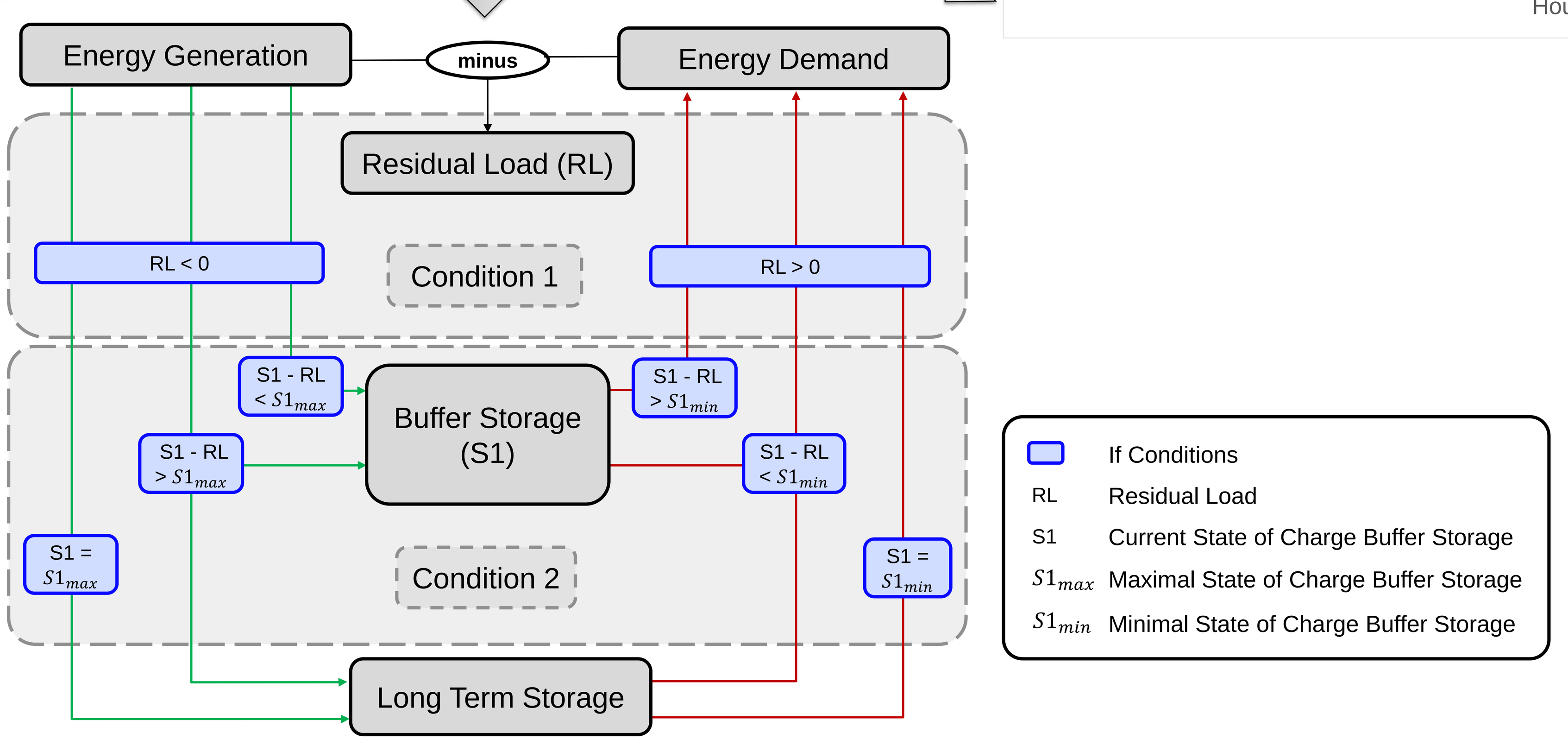
The creation of profiles for the energy generation as well as the consumption of private households, enables a simulation of the residual load and thus necessary storage capacities. The energy generation profiles are based on capacity factors of the installed capacities of renewable energies. Therefore, a scaling of the generation values to any nominal capacity scenario is possible. Since the consumption of private households does not correspond to the total consumption in Germany, the installed nominal capacity is adjusted on a percentage basis. For the consumption data of private households, profiles of e-mobility, electricity demand for heat provision, and other electrical demand were taken into account.

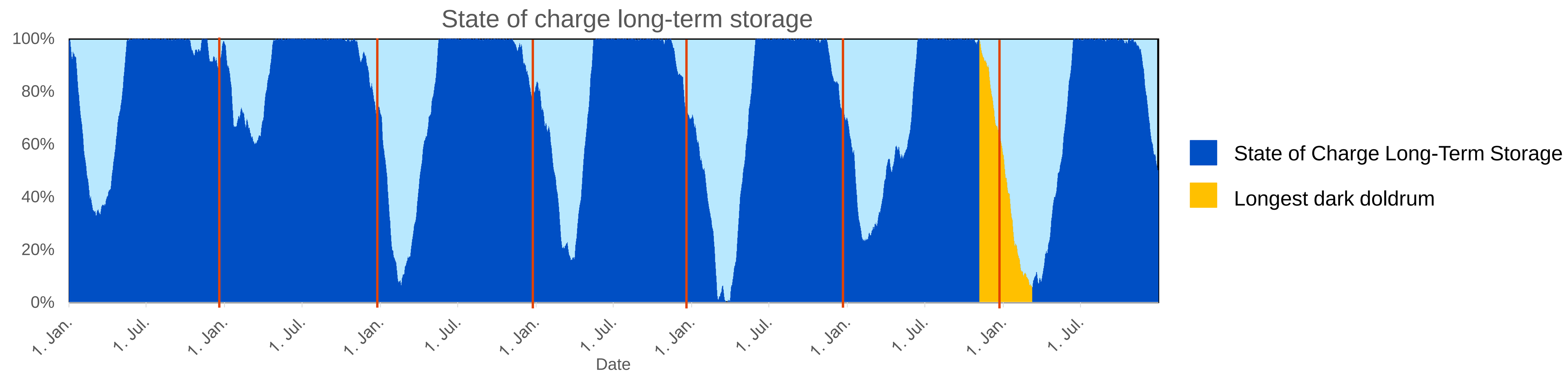






	2045		
	Total Installed nominal power	Scenario 2-1 Installed nominal power (consumption-adjusted)	Scenario 2-2 Installed nominal power +30% (consumption-adjusted)
Wind Onshore [GW]	150	36,48	47,43
Wind offshore [GW]	70,8	17,22	22,39
Photovoltaics [GW]	395	96,07	124,89
Biomass [GW]	2	0.49	0,63
Hydropower [GW]	5,3	1,29	1,68





Results

All results illustrated in this poster refer to scenario 2-2, which assumes the installed electricity generation of the year 2045, and Redox-Flow batteries as a Long-Term storage technology.
With the created Excel-Tool the minimum required long-term storage capacity can be calculated for different arbitrary scenarios and storage technologies. The integrated technologies are Redox-Flow batteries, Lithium-Ionen accumulators and Power-to-Gas (hydrogen). Based on the minimum required storage capacity, the state of charge of the long-term storage is calculated automatically, as shown in the figure „State of charge long-term storage“.
The simulated charging/ discharging behaviour also indicates, if the installed nominal energy generation is sufficient for covering the eletricity demand and charging the long-term storage for dark doldrums.
Also the length of the longest dark doldrum based on the given input parameters is calculated and shown in the figure „State of charge long-term storage“.

Conclusion and Outlook

The Excel-Tool enables the user to see how different input parameters have different effects on the required long-term storage capacities, the charging and discharging behavior of long-term storages and the event of dark doldrums. The calculated values are only indicators of how the long-term capacity behaves in different supply-demand relations. To improve the reliability of the simulated results for Germany the demand profiles should be expanded. Also, factors that also have an impact on the required long-term storage capacity, like e.g. electricity and hydrogen imports, heat storage and changes in infrastructure have not yet been considered.
To further exploit and revise the results, the next step is to analyse the considered energy system under financial and economic aspects.

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