An analysis of the energy storage requirements of the Austrian federal state of Tyrol depending on transmission network capacities in 2050

Florian Hasengst, TU Vienna, florian.hasengst@tuwien.ac.at

Overview

As part of Austria, the federal state of Tyrol is committed to the policy goal to decarbonize all sectors of Austria's energy system until 2040. This analysis would like to venture a further look into the year 2050 and raises the question of the necessary storage capacities.
In Tyrol, renewable energy sources are mainly generated by hydroelectric power plants. Due to the alpine locations and the expected political framework, the potential for wind power and PV is limited.
The availability of generation by hydroelectric power plants varies greatly depending on the season due to the climatic conditions. Therefore, the seasonal balancing of the energy represents a significant challenge.
Political decision-makers repeatedly voice the desire for self-sufficiency in the federal state of Tyrol when it comes to energy.
Therefore, one of the scenarios considered will assume that there are no electrical transmission lines to neighbouring regions. The other two scenarios consider different amounts of expansion of the transmission capacities.

Methods

The modelling is done with the energy system model BALMOREL [1]. BALMOREL is an open-source partial equilibrium model focusing on the power and heat grid. Its modelling language is GAMS. To reflect the sector coupling to hydrogen and transport, the model is expanded to include so-called add-ons. Investments in new generation capacities are modelled endogenously. The region under consideration is connected to its neighbours by electrical transmission lines. The transmission line capacities correspond to the TYNDP 2020 Distributed Energy Scenario. There is no cross-border energy exchange for other energy carriers (e.g., for heat or hydrogen)

The assumptions on energy demand and installed capacities of France, Germany, Switzerland, Italy, and the rest of Austria are based on European projects with a long-term approach.
For the generation profiles for wind and photovoltaic generation, there a detailed data from a reanalysis of historical weather data. Due to the unique topology of Tyrol, these volatile generation profiles are different from highly aggregated profiles of some other countries. Also, the potential of wind and solar power is limited due to topology and political restrictions. In a previous study, the potential for wind, PV, and other energy sources was assessed and is used here as a further constraint of the model.

In a future energy system, there are some possible demand-side flexibilities. In this case, their flexibility in the form of charging electric vehicles, load shifting of heat pumps in households, and production, storage, and electricity generation from hydrogen.
To add these functionalities to the core model of balmorel, specialised add-ons are used.

To reflect the demand for charging electric vehicles, there are two approaches. For the demand for private used cars which have the possibility to charge at a designated charging point, there is an EV-addon [2] to BALMOREL. This addon is based on driving patterns and calculates the demand for single vehicles. The vehicle fleet is aggregated and scaled up to the number of vehicles in each modeled country. This addon can be used with three different charging schemes, passive charging, smart charging and V2G-charging. To provide additional storage capacities the addon is used with the V2G charging.
All other electric mobility mods are represented unflexible by a load profile.
To enable load shifting capabilities the demand response addon [3] is used. This addon allows the model to deviate from a given profile, thereby providing demand-side flexibility. In this specific case, heat pumps in households are made more flexible.

The hydrogen addon enables the generation, storage and reconversion of hydrogen into electricity. The possible technologies for the hydrogen infrastructure consist of various electrolysers, storage systems and fuel cells.

Tyrol's energy system is heavily influenced by electricity generation from water. There are several hydro-powered storages with and without pumps. These hydropower plants are owned by two companies TIWAG and VERBUND. Mapping the real availability of hydroelectric power plants is a challenge. Since the model has perfect foresight for the simulated year, this is not the case for the power plant operators in reality. Therefore, further restrictions that restrict the supply of water are introduced based on historical data. One of these restrictions is time dependent minimum and maximum levels of storage content.

Three scenarios illustrate different approaches to energy storage usage in the future. In the first scenario, Tyrol is isolated from its neighbours. This scenario is not a reality or desirable today or in the future. Nevertheless, political actors often call for self-sufficiency. In the other two scenarios, the transmission line capacity is increased. These scenarios are intended to reflect the likely evolution of the more interconnected European electricity market. The expansion of transmission lines between the countries is based on scenarios from ENTSO-E. The inner Austrian connections are based on the planned developments of the Austrian transmission grid operator APG.

Results and conclusions

The preliminary results show that the existing storage volumes are not sufficient in the self-sufficiency scenario. Therefore, investments must be made in additional storage options. This extra storage will be built in the form of hydrogen pressure tanks and underground storage. While the pressure tanks operate as daily storage, the underground storage is used as seasonal compensation. The additional storages cause additional losses. This extra energy demand must be covered by building new power plants in Tyrol. Currently and in the future, the generation of hydro storage power plants will not be available for Tyrol alone. The system is operated based on market prices in the European interconnected grid. Therefore, the other two scenarios are also interesting.

These scenarios show that transmitting electricity to neighbouring regions impacts the power plants to be newly installed. New wind and PV systems will preferably be set up in regions where the supply is better than in Tyrol if there is sufficient transmission capacity. This mainly affects the supply of electrical energy from wind power plants in Germany or the supply from PV in Italy.

In all scenarios, infrastructure for hydrogen production has to be newly built. The size of hydrogen storage depends on the scenario. Bigger hydrogen storages enable more load shifting potential. Investing in fuel cells also allows hydrogen to be converted into electricity, giving the system another way to store energy over longer periods.

The selected modelling approach must be viewed critically concerning some assumptions. The reduction in the representation of a few neighbouring countries reduces the system's flexibility, resulting in overestimating the importance of Tyrol's measures. On the other hand, this allows the effects of changes in Tyrol to be shown more clearly. The approach shows a high sensitivity to the assumptions regarding the transmission network. Therefore, how the further expansion of the transmission grid in Europe is presented must be closely monitored.

Outlook

The realistic mapping of storage operation management requires further research. The available storage contents are subject to various restrictions. These range from seasonal fluctuations in the water supply to ecological restrictions and considerations such as use for tourism.
An extension to include a possible hydrogen network is also being considered.

References

[1] H. Ravn, M. Hindsberger, M. Petersen, R. Schmidt, R. Bøg, P.E. Gronheit, H.V. Larsen, J. Munksgaard, J. Ramskov, M.-R. Esop, G. Klavs, A. Galinis, R. Paprocki, M. Wawrzyszczuk, A. Gloukhov; Balmorel: a Model for Analyses of the Electricity and CHP Markets in the Baltic Sea Region (2001)

[2] From passive to active: Flexibility from electric vehicles in the context of transmission system development; Philipp Andreas Gunkel, Claire Bergaentzlé, Ida Græsted Jensen, Fabian Scheller; Applied Energy, Volume: 277; (2020); DOI: https://doi.org/10.1016/j.apenergy.2020.115526

[3] The role of demand response in the future renewable northern European energy system; J.G. Kirkerud, N.O. Nagel, T.F. Bolkesjø; Energy, Volume 235, (2021); DOI: https://doi.org/10.1016/j.energy.2021.121336