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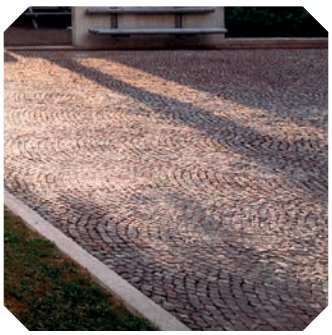

School of Economics and Business, University of Ljubljana (SEB LU)

Energy Challenges for the Next Decade

IS SECTOR COUPLING A WELL-DEFINED STRATEGY?

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Overview

The increasing amount of electricity generation from the variable renewable energy (VRE) sources sun and wind throughout the course of the energy transition to reach EU climate goals, is expected to result in frequent times of excess electricity production. According to Schaber et al. (2013), apart from commonly discussed measures, such as a European super grid or new electric storage options, the power surplus may be transformed to e.g. gas or heat and used in other end-sectors through Power-to-X (P2X) technologies, leading to an interconnection of sectors called Sector Coupling (SC) or Sector Integration (SI). The basic idea of SC is, to use electricity produced from VRE sources in other end-sectors, such as transport, industry and residential, whereas prices in times of excess electricity are economically favourable. The definition of this strategy, however, still lacks precision and the term is often used misleadingly. The core objective of this paper, thus, is to identify the current state of SC or SI, as well as to derive a clear definition of the strategy.

Method

Our method of approach includes a thorough analysis of existing literature on SC for a solid basis for future research on SC. A strict focus has been put on the specific term "sector coupling" for a better understanding of its overall purpose, benefits and system boarders. It shall be distinguishable from other similar approaches or methods on a different level.
In parallel, example data for Austria has been set up for a scenario with power generation from VRE, to show the variability and the basic potential and limits of storage and SC.

Results

Our thorough literature review shows, that definitions of SC are scarce and vary in the scope that is associated to the strategy. Authors seem to agree that SC is about linking the power sector to the transport, industry and residential (heating/cooling) sector and generally to fulfil this demand with renewable energy. Usually this is seen as a one way path from power to X. Whereas some papers put a strong focus on the use of free surplus energy from VRE to reduce e.g. VRE curtailment needs, other definitions emphasize the decarbonisation potential through renewable power for industry, heat and transport. According to Robinius et al. (2017), the concept and term of SC has become popular in the course of the German energy transition. It can be seen, however, that the approaches towards a SC strategy may differ in various parts of the world depending on a country's goals, VRE potential and perspectives on the topic. Authors from Denmark, such as Mathiesen et al. (2015), e.g. frequently mention the approach of merging the electricity, heating and transport sector in the context of Smart Energy Systems for the specific purpose of using surplus generation from wind power and integrating larger shares of VRE into the power market. Denmark is a pioneer in investigations of coupling the power to the heat sector to increase the integration of high wind power potentials. In 2004, a change in regulations for small CHP plants paved the way to use excess wind power in times of low demand for the economic production of heat. If Denmark supplements some of its CHP units with heat pumps and additional heat storage capacity, the integration of wind power can be raised from the present 20% to around 40%. When it comes to electric district heating (DH) from wind power via electric boilers and heat pumps, however, the country is still limited by a ban on installing electric heating in new buildings, which arose from the desire for more efficient energy utilisation. Figure 1 describes the economic use of power in the heat sector in times of low electricity prices that could be realised once the regulations are adapted further to allow electric boilers (El-boiler) in the country.

Figure 2 describes the pathways and examples of SC defined from our literature review. A sound and clear definition of SC and its scope is the final objective of our analyses and represents a main result of this paper. Re-electrification (e.g. Gas2P), is exempt from the SC strategy on purpose in our work, since it uses P2G as a storage option by integrating the power and gas vector (cross-vector integration or energetic SC), but not specifically to supply other end-sectors. Figure 3 shows the variability of power generation in Austria in an example of hydro, wind and solar power only. Due to the limited amount of wind potential in the country, generation surplus mainly occurs in summer times, whereas power scarcity is an issue in winter. Consequently, long-term electrical storage (pumped hydro and compressed air) is required, but capacities are spatially limited and alternative flexibility methods, via e.g. P2G, will be inevitable. Figure 4 describes the limits of storing surplus power on

a summer day. The short-term pumped hydro storage capacity is limited to 4.5 GW filled up in green, still leaving the orange area as excess power and SC potential.

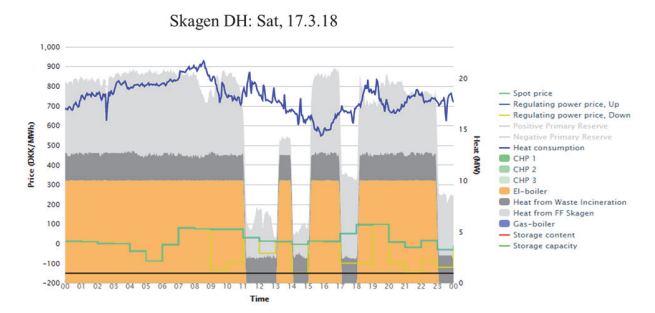

Fig. 1. Flexibility through P2Heat via el-boiler. (Source: http://www.energyweb.dk/skagen/?english&history)

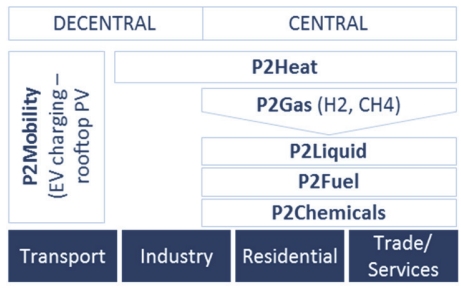

Fig. 2. Central vs. decentral approaches of SC from a spatial perspective (proximity of plant to use-location)

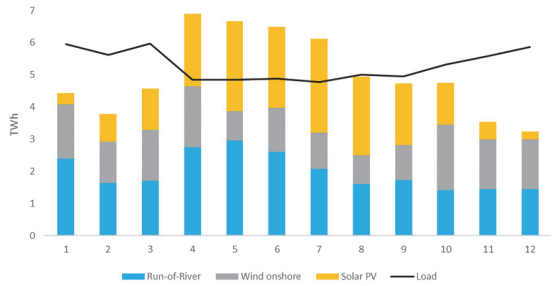

Fig. 3. Monthly generation in a 100% VRE scenario for Austria (Source: EEG TU Wien)

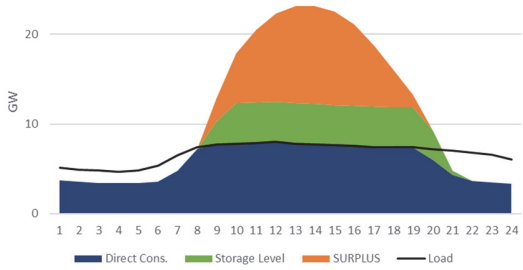

Fig. 4. Exemplary summer day: surplus generation and storage, AT 100% VRE. Short-term storage 4.5 GW (Source: EEG TU Wien)

Conclusions

- Up to now, no precise definition of SC and its scope is available in literature, concepts defined are not consistent.
- Many papers focus on specific P2X technologies and their technical potential for a future renewable energy system.
- Light needs to be shed on the myths, goals and scope of SC. The authors made a first attempt in this paper.
- SC is a promising option to shift pressure from the power sector to other end sectors and its enabling technologies (e.g. P2G) represent important flexibility options for long-term storage. As a result, a larger share of VRE sources can be integrated into the power market.

Finally, we suggest the following definition of SC: In a scenario with frequent excess power generation, due to the increasing share of VRE sources, SC represents a promising tool in an energy system by aiming at using this renewable power surplus in other end-sectors. The amount of excess electricity that cannot be stored in short-term storage within the power sector may be used directly or transformed to couple the power- to other sectors (transport, industry and heating) via P2X technologies. The SC strategy, thus, stands on three pillars: Firstly, SC aims at using excess renewable power in other sectors, which secondly enables a larger integration of VRE sources by offering relief to the power sector and avoiding curtailment needs and thirdly, promotes decarbonisation of the coupled sectors.

References

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