Modeling the energy system of California Decarbonization through coupling of power and transport sectors

Author: Evelina Mileva[1], M.Sc.
Advisor: Kais Siala[2], M.Sc., Dr. Ing. Matthias Huber[3], Martin Küppers[3], M.Sc.
Examiner: Prof. Dr. Thomas Hamacher[2]

[1]Munich, Germany, Technical University of Munich, ev.mileva@gmail.com
[2]Munich, Germany, Technical University of Munich, kais.siala@tum.de
[3]Munich, Germany, Siemens AG, matthias.huber@siemens.com

Keywords: carbon neutrality, power sector, battery electric vehicles, charging infrastructure

1 Motivation and Background

In the last years California has experienced extreme global warming impacts, scorched by one of its worst drought in over a millennium, followed by the state's historically largest and most destructive wildfires in 2017 and 2018 [1], [2]. In September 2018, the state of California issued ambitious targets toward 100% carbon neutrality by 2045, requiring multisectoral advanced decarbonization measures [3]. A model based optimization of the energy system of California is used to investigate the challenges related to the complete decarbonization of the power sector and the parallel electrification of the currently biggest greenhouse gas emitter in the state: the light duty vehicle fleet, assuming a 75% battery electric vehicle adoption rate by year 2050 (**Figure 6-1**) [4].

2 Methodological Procedure

Two main scenarios are developed to compare the optimal generation capacity expansion path of the state through year 2050: a Reference scenario reflecting a business-as-usual case and a SB100 scenario, based on the assumptions that the renewable energy targets established in law by the Senate Bill No.100 are reached [5] (Figure 6-2). Beside the modeling of the power sector, two different approaches for implementing battery electrical vehicles (BEV) in the used optimization model are developed: unflexible and flexible charging approach. This allows the detailed investigation on the effect of BEV on the energy system of the state, as well as the development of an optimal mix of required BEV charging stations through 2050. The general structure of this thesis is divided into six chapters, as shown in Figure 6-3 .

3 Results and Discussion

The results show that in order to reach 100% carbon neutrality in the power sector, when relying primary on in-state generation a massive solar and lithium ion battery expansion is required, considering that the potential of pumped-hydro storage systems is limited. The solar storage strategy relying on about 210 GW photovoltaic power combined with 53 GW/414 GWh lithium ion capacity in 2050 (Figure 6-4) leads to high amounts of curtailed energy due to solar generation overbuilding, which is necessary to meet the demand during wintertime periods. Taking into account an option for diversifying the renewable portfolio of the state 17% of the total demand in year 2050 is covered by wind import from Wyoming, reducing the total installed power capacity up to 100 GW (Figure 6-5). This underlines the critical importance of renewable integration strategies, including out of state resources diversity. The electrification of the light duty vehicle fleet requires additional capacity, depending on the used charging strategy (Figure 6-6). The modeling results show that a flexible charging pattern may reduce the necessary battery storage energy capacity by up to 39% compared to the unflexible option (Figure 6-7 and Figure 6-8). Although flexible charging requires expensive workplace and public charging infrastructure (Figure 6-9) it results in 45% lower electricity charging costs compared to the unflexible approach.

4 Conclusion

This work has shown that California has a lot of challenges to face to fully eliminate carbon emissions from the electricity and transport sector, but also that parallel efforts toward facing these challenges can provide a synergistic opportunity. The ambitious targets of the golden state are achievable and necessary, giving an encouraging example for the rest of the world, that it is time to join together and act against global warming.

5 Literature

[1] California Energy Commission, "Toward a clean energy future," 2018. [Online]. Available: https://www.energy.ca.gov/2018publications/CEC-100-2018-001/ CEC-100-2018-001-V2-CMF.pdf.

[2] N. Dana, "The Guardian," 3 Sept. 2018. [Online]. Available: https://www.theguardian.com/environment/climate-consensus-97-per-cent/2018/sep/03/californias-response-to-record-wildfires-shift-to-100-clean-energy. [Accessed 8 Nov. 2018].

[3] J. Edmund G. Brown, "Executive Order B-55-18 To Achieve Carbon Neutrality," 10 Sept. 2018. [Online]. Available: https://www.gov.ca.gov/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf

[4] California Air Resources Board, "California Greenhouse Gas Emissions from 2000 to 2016 - Trends of Emissions and Other Indicators," 2018. [Online]. Available: https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2016/ghg_inventory_trends_00-16.pdf.

[5] J. Edmund G. Brown, "Senate Bill No. 100, California Renewables Portfolio Standard Program," 10 Sept. 2018.[Online].Available: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100.

6 Appendix

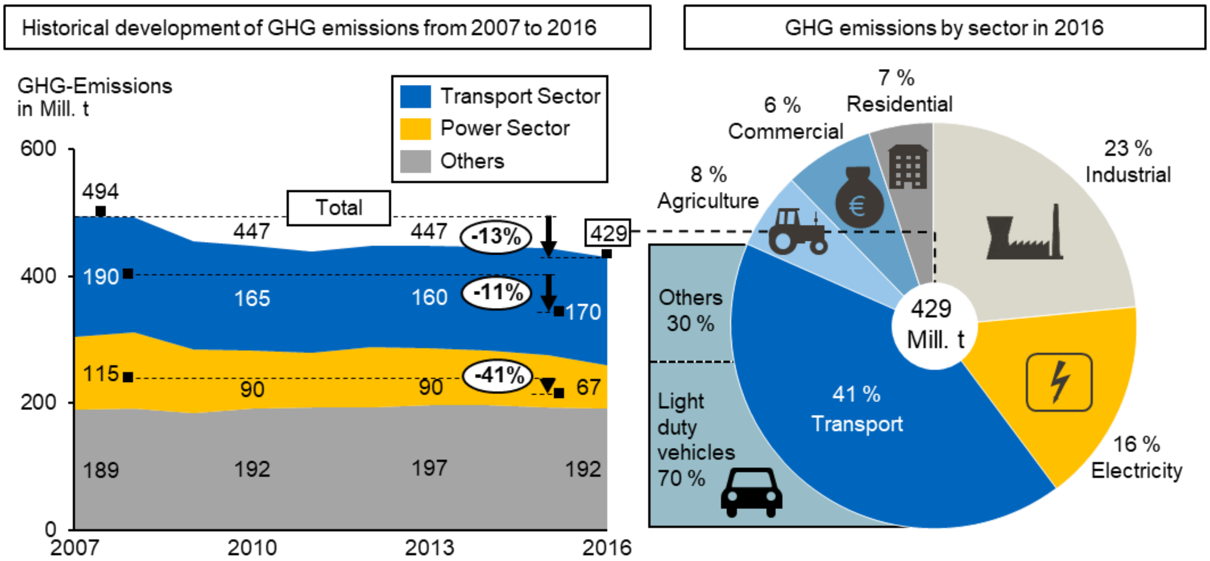

Figure 6-1 Emissions breakdown by sector

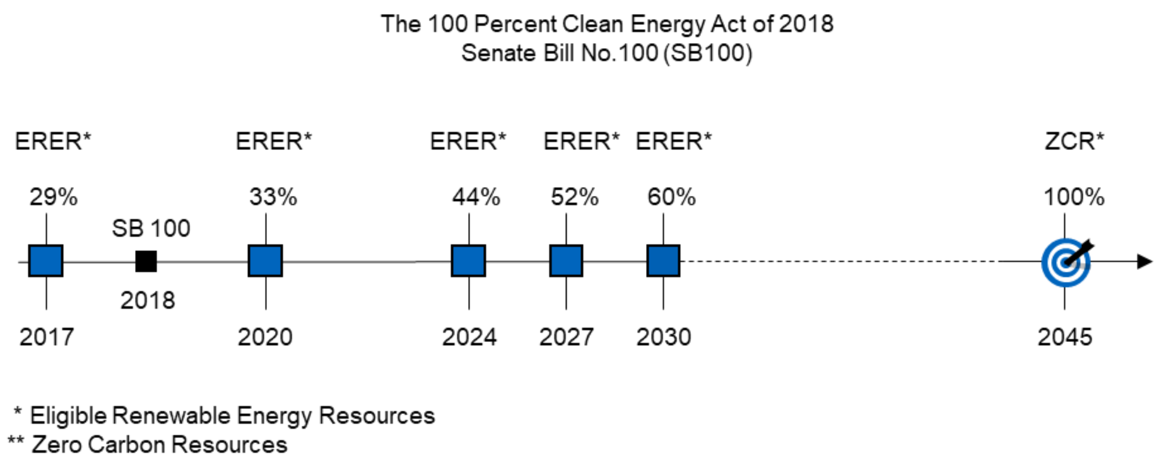

Figure 6-2 Renewable Portfolio Standards and Senate Bill No.100
*/** Zero-carbon sources include all ERES and non-carbon sources (e.g. large hydro, nuclear).

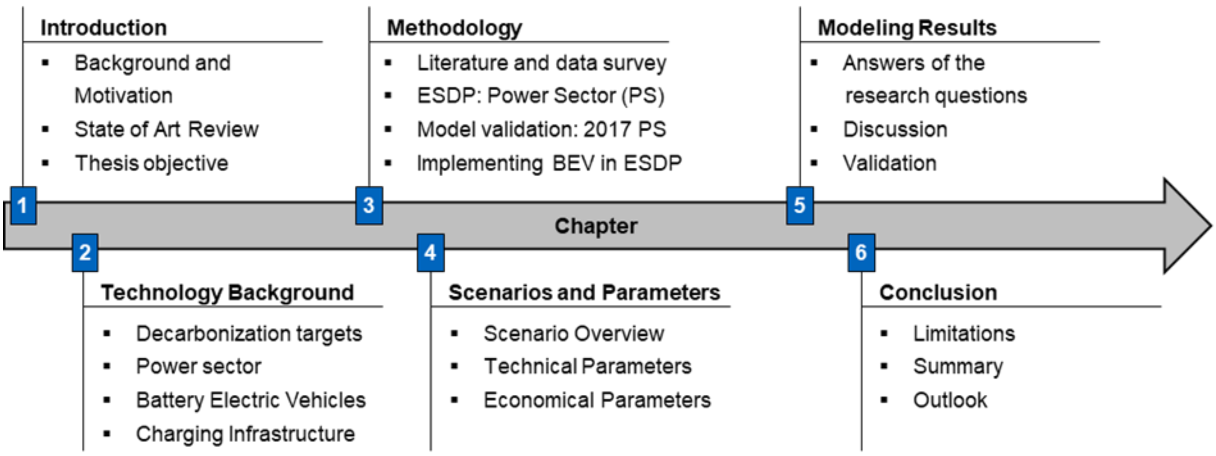

Figure 6-3 Structure of the work

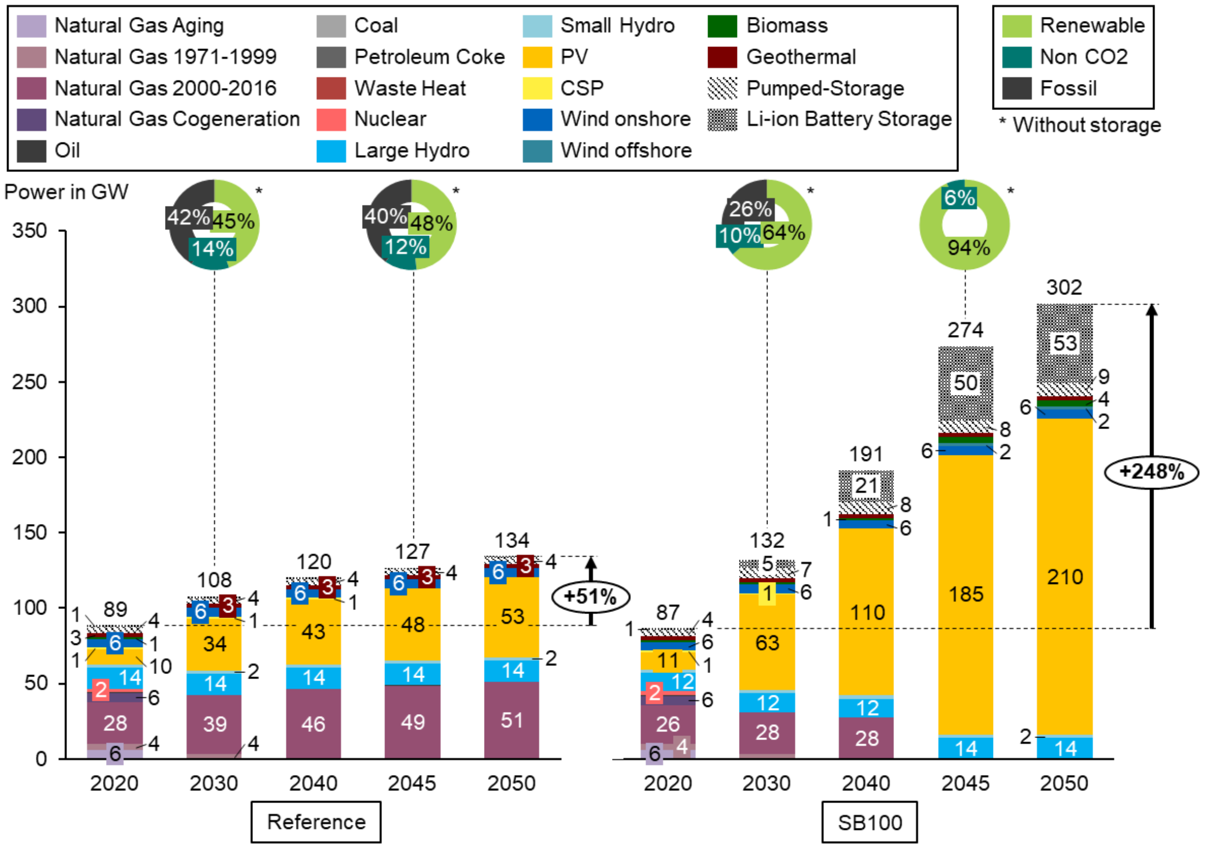

Figure 6-4 Cost-optimal in-state power mix through 2050: Reference- and SB100 scenario

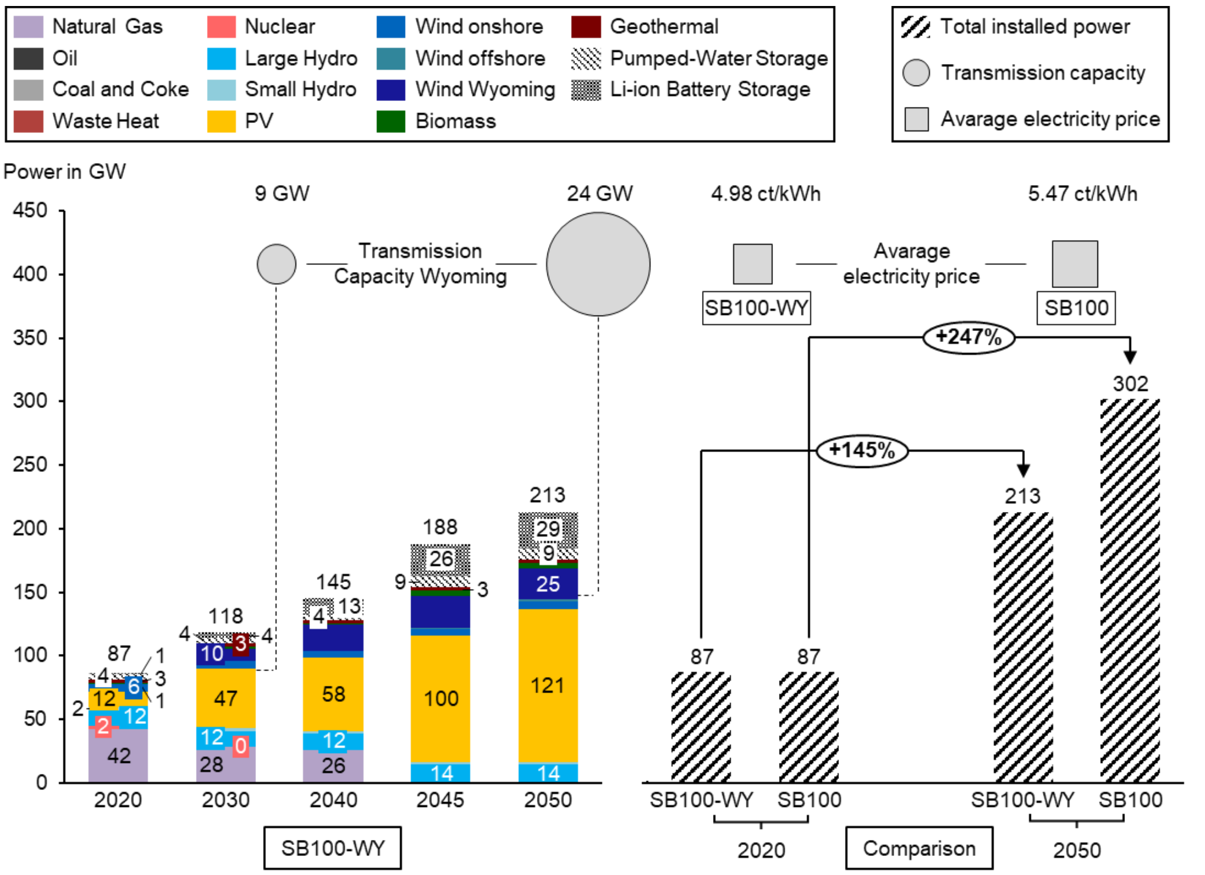

Figure 6-5 Power mix diversity: SB100 Wyoming Wind (left) compared to SB100 (right)

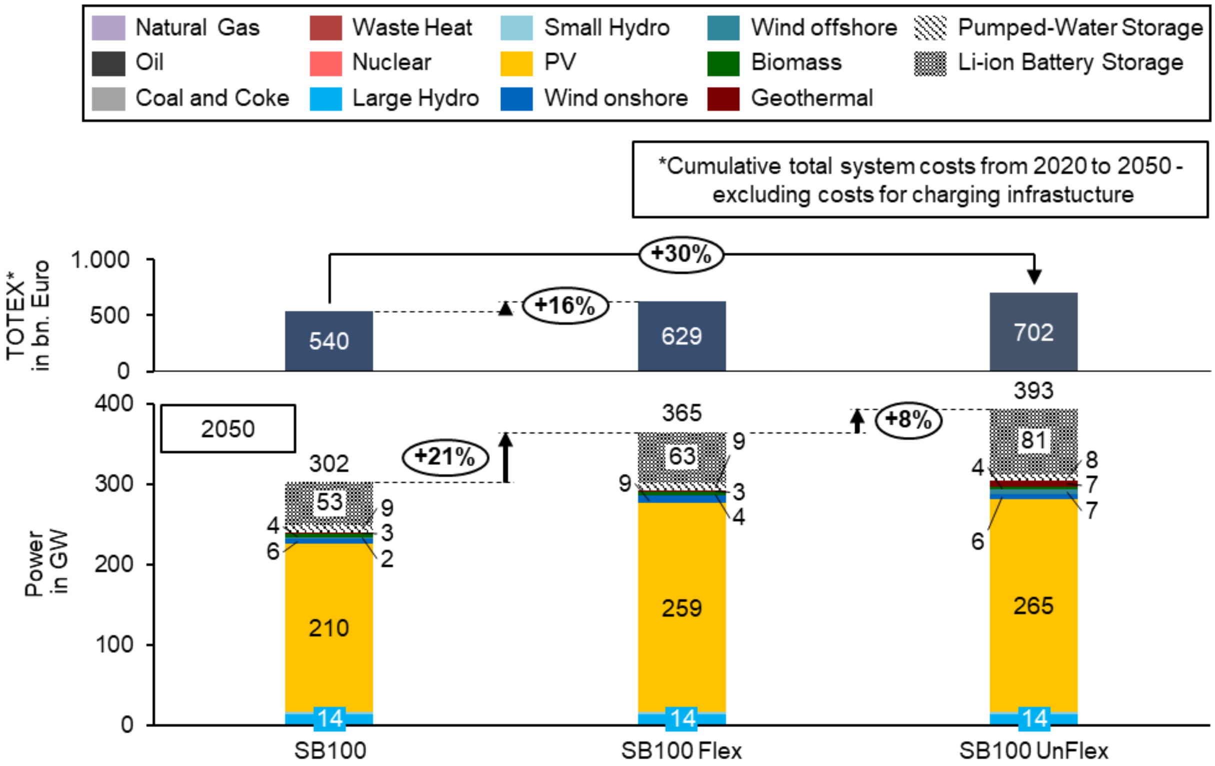

Figure 6-6 Impacts of Battery electric vehicles on the power sector. Cost optimal power mix through 2050: SB100 Flex and SB100 UnFlex scenarios

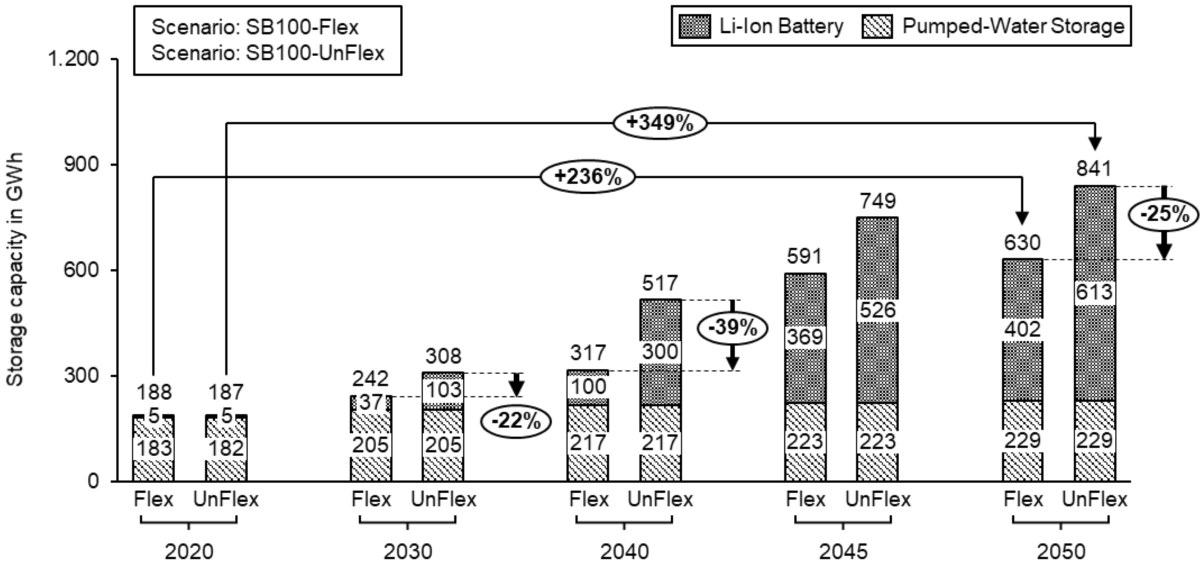

Figure 6-7 Required storage capacity: SB100-Flex and -UnFlex scenarios

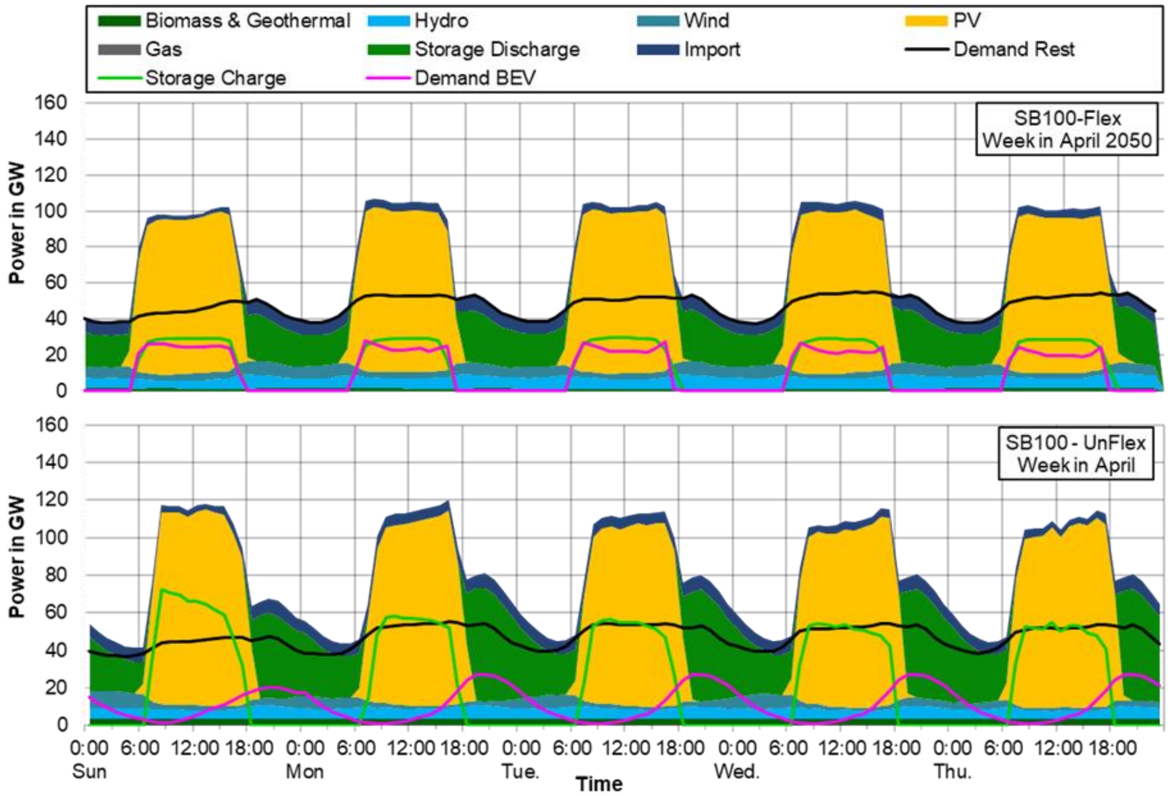

Figure 6-8 Typical week in 2050: SB100-Flex and SB100-UnFlex scenario

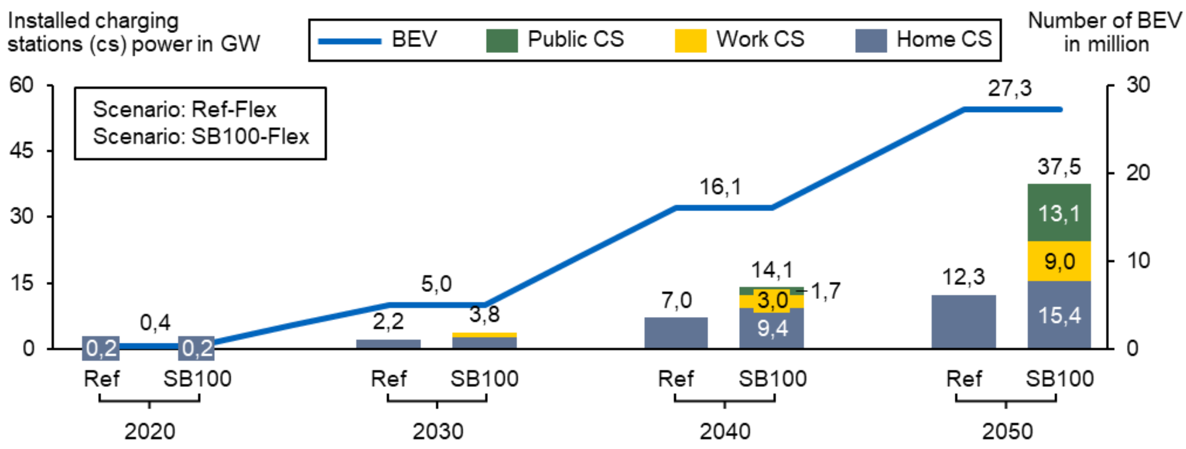

Figure 6-9 Charging station mix: Reference-Flex and SB100-Flex scenario