5.3 Energy Storage at utility scale as an enabler for CO_2 Mitigation

Appendix B

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MEDIO AMBIENTE
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This report is part of the study:
Technology Roadmap and Mitigation Potential of Utility-scale Electricity Storage in Mexico

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Appendix B.1: The role of Li-Ion batteries compared to Pumped Hydro Storage (PHS)

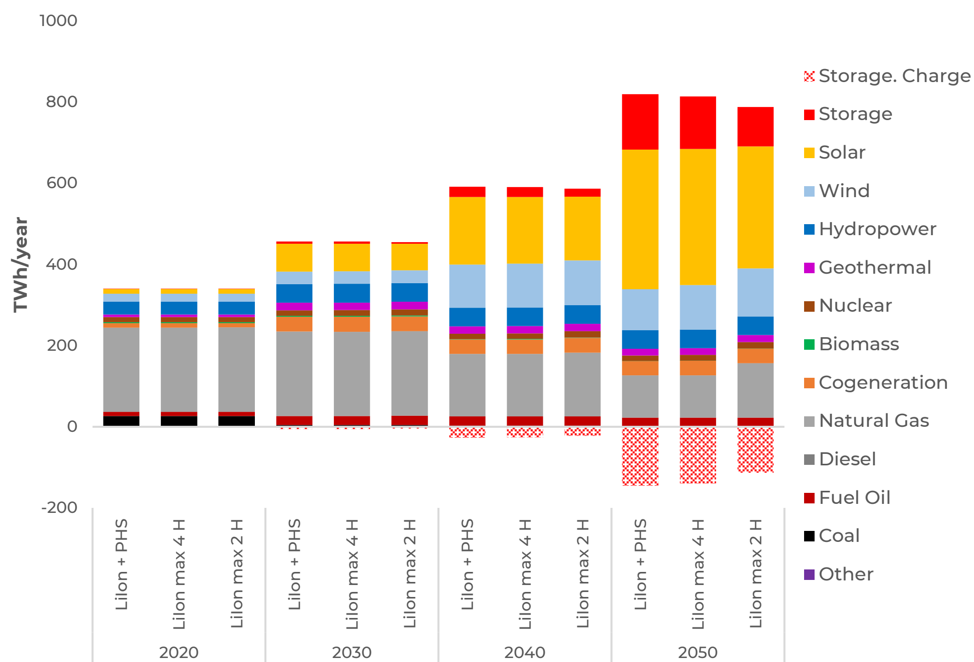

Figure B.1. Annual electricity generation by source in scenarios with Li-Ion + PHS without restrictions (Li-Ion+PHS) and scenarios with Li-Ion + PHS (Li-Ion max 4 H and Li-Ion max 2 hours) where Li-Ion is constrained to maximum hold 4 hours and 2 hours of maximum output, respectively.

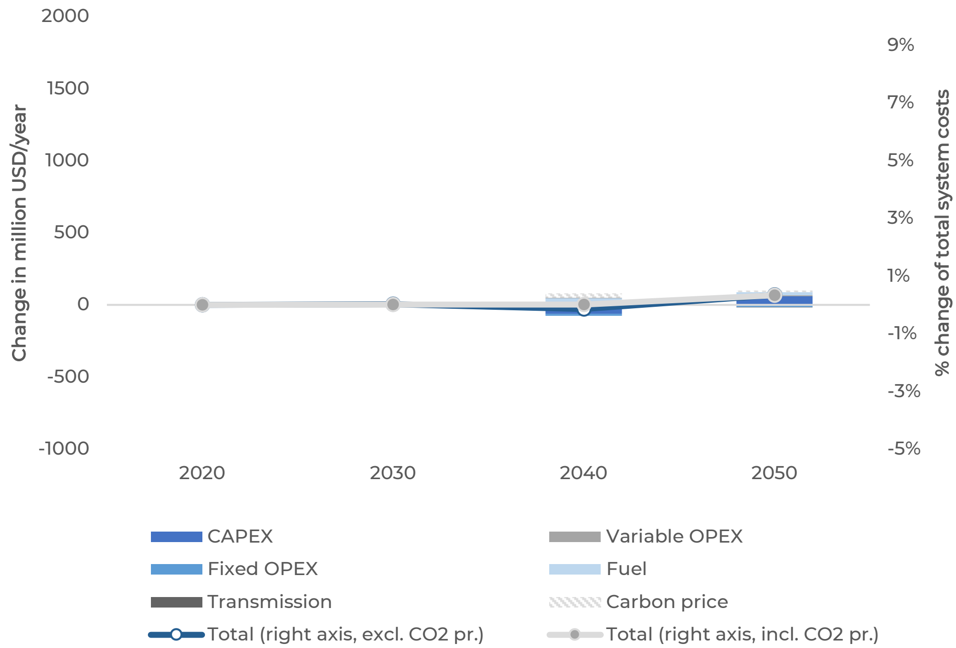

Figure B.2. Change in system costs in a scenario with Li-Ion + PHS (no restrictions) instead of Li-Ion only.

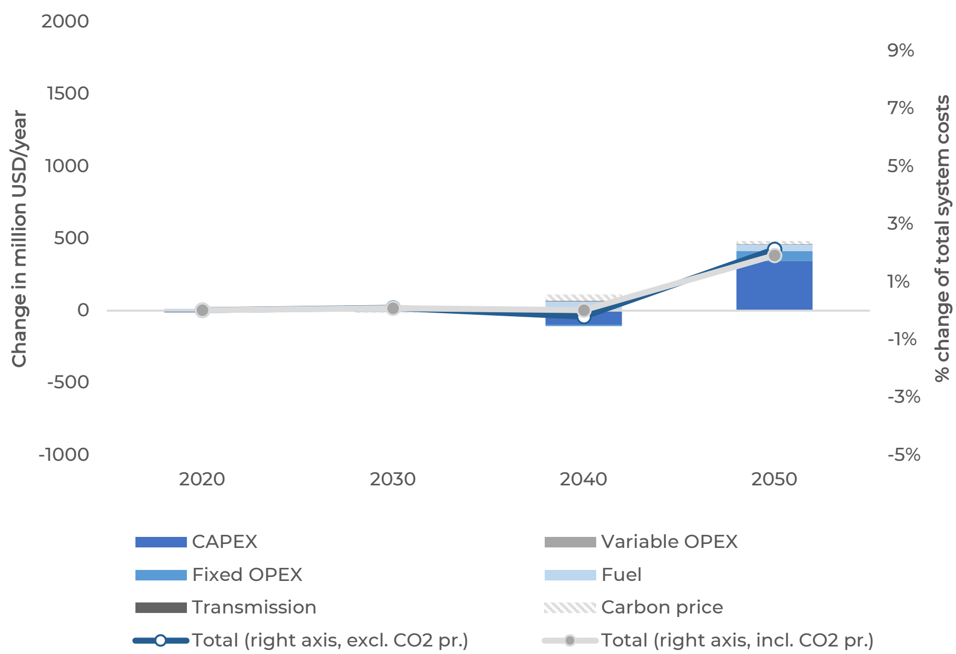

Figure B.3. Change in system costs in a scenario with Li-Ion (Max 4 hours) + PHS instead of Li-Ion only.

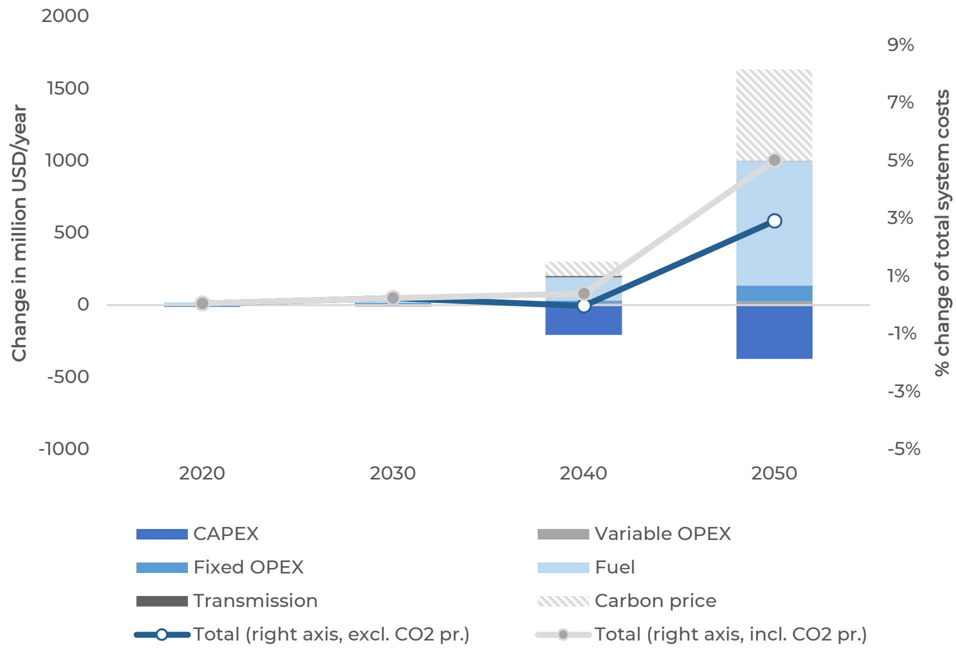

Figure B.4. Change in system costs in a scenario with Li-Ion (Max 2 hours) + PHS instead of Li-Ion only.

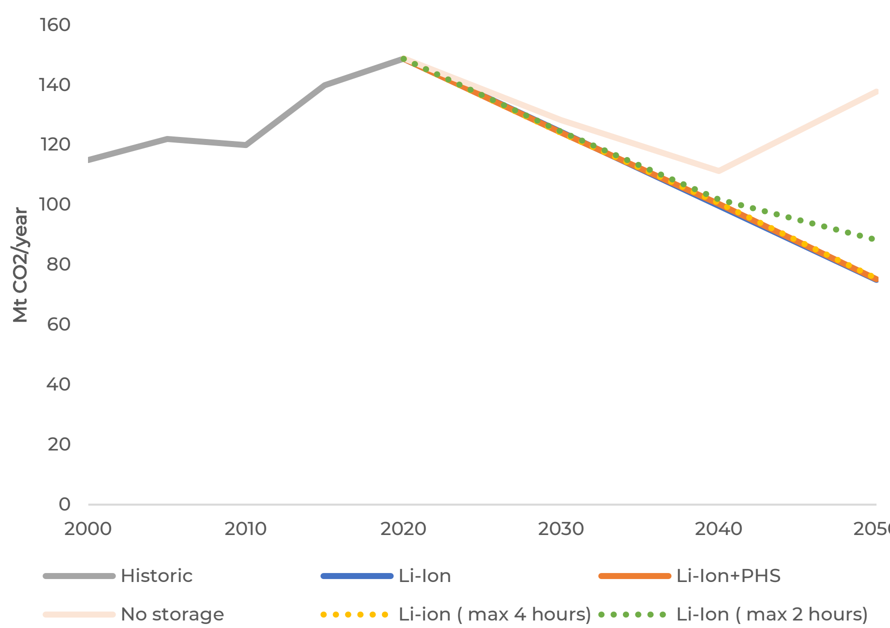

Figure B.5. Annual CO_2 emissions in the Climate scenario with Li-Ion (Max 2 hours) + PHS, Li-Ion (Max 4 hours) + PHS, Li-Ion (Unrestricted) + PHS and Li-Ion only.

Appendix B.2 – Sensitivity analysis results

Natural gas price

In the last 20 years, natural gas consumption has increased, and future upward trends are spurring discussions about energy sovereignty and potential technological lock-ins. As natural gas is a largely imported commodity, Mexico could be on a path towards larger import dependence and raised vulnerability to external price shocks, as consumption keeps raising: according to the National Hydrocarbons Commission, more than 70% of natural gas requirements are met by imports (CNH, 2019). At the same time, increased consumption could lead to technological lock-ins due to path-dependence in the energy system (Fouquet, 2016); (Brown, Chandler, Lapsa, & Sovacool, 2008): low-price gas availability in the short term could encourage investments in gas infrastructure, assuming a policy without elements of efficient use of fossil fuels giving rise to a risk of narrowing the operational pathway of decarbonization development in the long term.

Investing in natural gas infrastructure could be a quick fix to lower emissions in the short term, but such decisions could limit Mexico from alternative and cleaner mitigating technologies in the future. Additionally, even if those investments make financial sense, there is a considerable risk associated to price volatility. In this context, two alternative scenarios, a high (+ 2 USD/GJ) and a low (-1 USD/GJ) profile of gas prices, have been developed (Figure B.6).

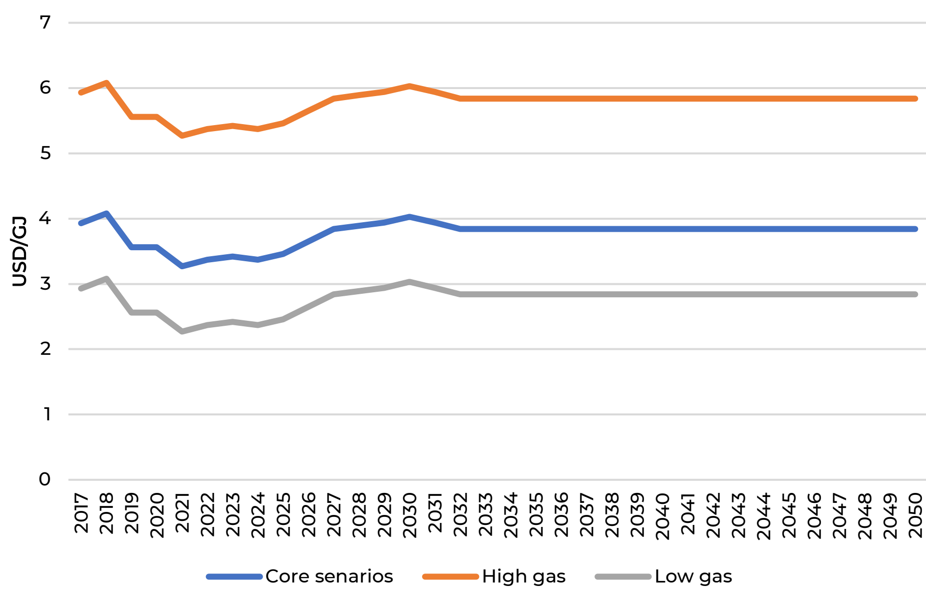

Figure B.1. Natural gas prices in three scenarios. In the high scenario, prices are increased by 2 USD/GJ. In the low scenario, prices are lowered by 1 USD/GJ.

The low price scenario (Figure B.7 and Figure B.8) shows that batteries in conjunction with solar are displaced already in 2030, while large wind displacement takes place in 2040 and 2050. Natural gas generation is generally boosted in all years. The high price scenario shows almost exactly the contrary: natural gas displacement by renewable technologies. Although the effect kicks in already as early as 2020, the largest impact is observed in 2030, where the costs of renewables are lower. Wind generation is generally more affected than solar PV.

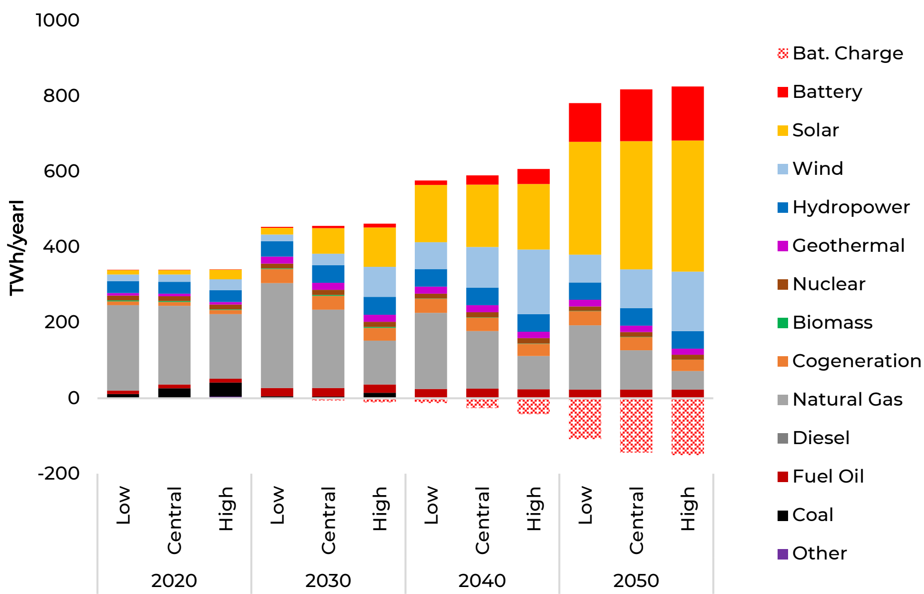

Figure B.7. Yearly electricity generation by source under different gas prices.

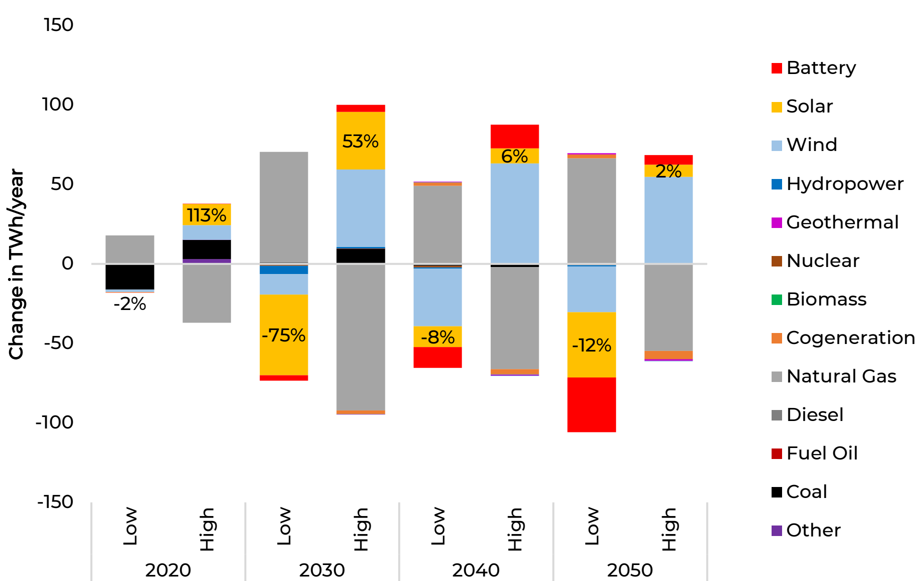

Figure B.8. Change in yearly electricity generation compared to a central gas price.

A low gas price entails some important savings in system costs, especially in the short term, where first fuel costs and then capital expenditures drive a 20% reduction in costs (Figure B.9). The system is less sensitive to gas prices in the long run; a result of a system being less dependent on gas and because RE-technologies are more competitive.

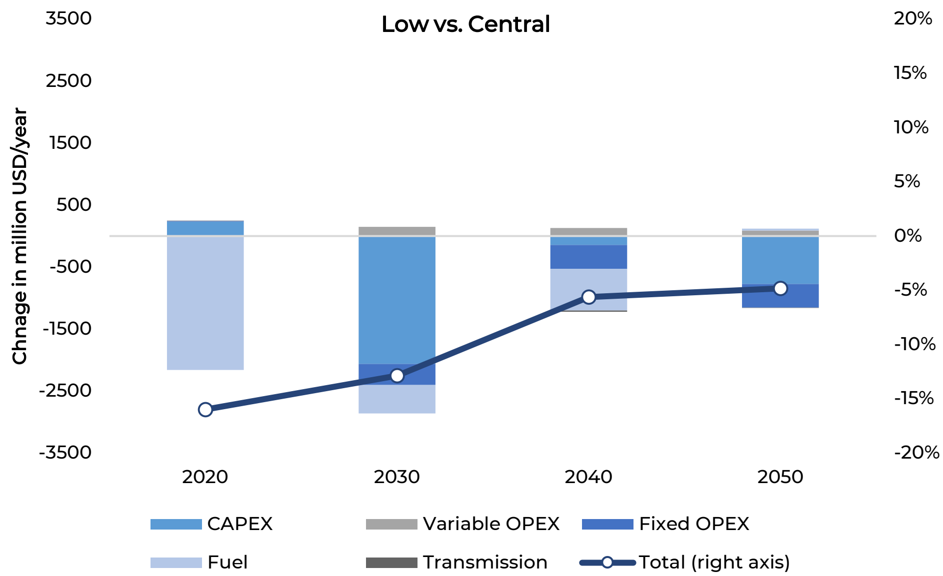

Figure B.9. Change in system costs under a low gas price compared to a central gas price.

Since the high price scenario has a larger absolute change of gas price (+2 USD/GJ), the increased costs are bigger in magnitude, compared to the low-price scenario (Figure B.10). However, a similar pattern is observed: in the short run, increased fuel costs and expenditure to (relatively) expensive technologies are driving the total system costs up. In 2050, the difference in cost lowers significantly because of technology catch-up and because the system is less dependent on natural gas.

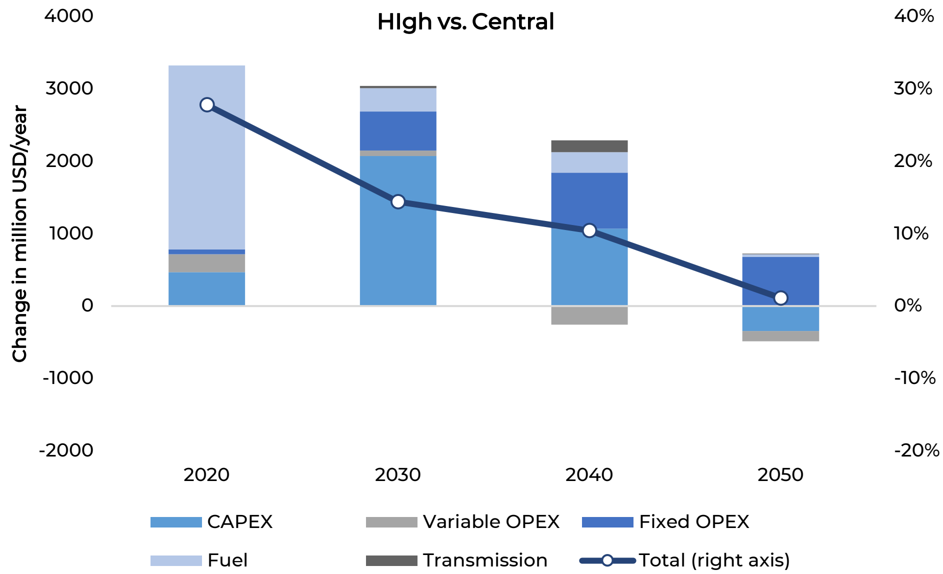

Figure B.10. Change in system costs under a high gas price compared to a central gas price.

Emissions are also greatly impacted by the gas price scenarios (Figure B.11). A high gas price can increase the decarbonization of the sector already in 2030, while a lower gas price raises emissions considerably.

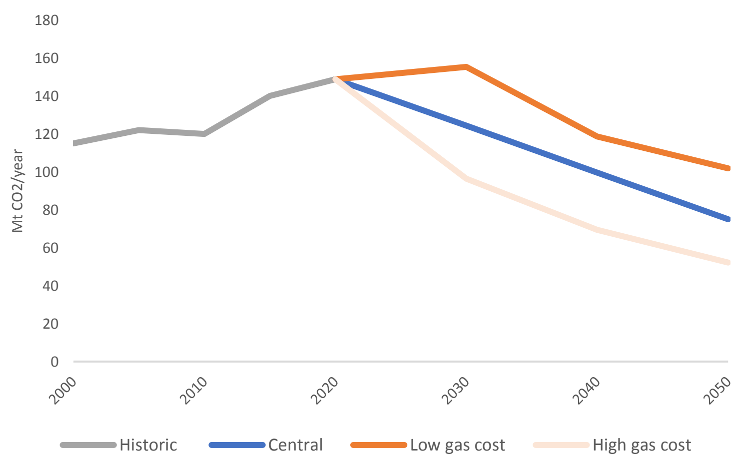

Figure B.11. Yearly CO_2 emissions in the Climate scenarios with a different gas prices.

The results show that increased natural gas prices, either in form sudden external shocks or as planned and steadily increasing tax, is a very effective way of reducing CO_2 emission from power generation. The special tax on fossil fuels currently excludes natural gas but an inclusion would lead a development that could avoid expensive lock-ins, improve energy independence and lower CO_2 emissions.

PV costs

Another important assumption involves the future development of the costs of renewable technology. In the main scenarios, solar PV investment costs are assumed to fall by 50% and 65% by 2030 and 2050, respectively, compared to 2016 values. According to IRENA (2019)[1] globally, the total cost of installing solar PV projects would continue to decline dramatically over the next three decades, averaging in the range of USD 340 to 834 kW by 2030 (reduction approx. 30% to 70%) and USD 165 to 481 / kW by 2050 (reduction approx. 60% to 86%), compared to the average of 1,210 USD / kW in 2018. According to IDB (2019)[2] the reduction to 2030 could be around 34%. For the sensitivity analysis, a rapid learning scenario and a slow learning scenario are developed, where investment costs are ± 10% of the estimate of main scenarios in 2030 and ± 20% of the estimate of main scenarios in 2050 (Figure B.12).

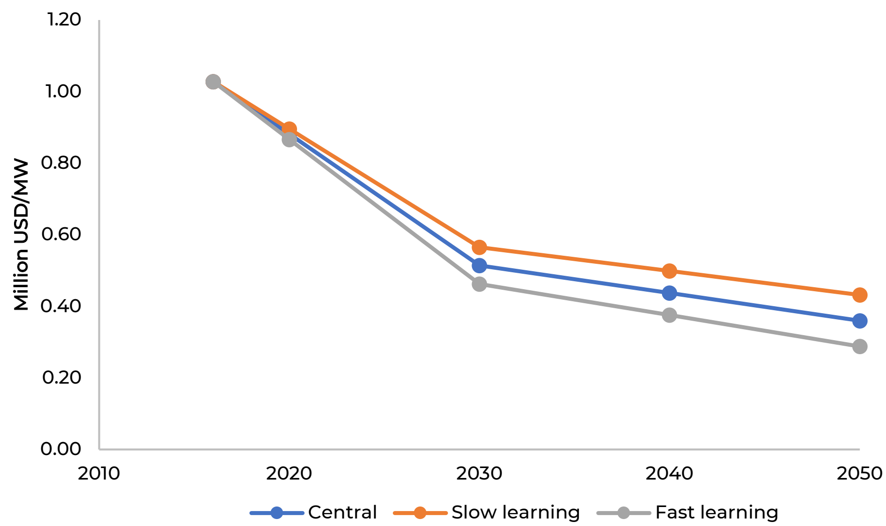

Figure B.12. Investment costs of solar PV in three scenarios. The costs are adjusted ±10% in 2030 and ±20% in 2050, with linear interpolation in the intermediate years.

The results are largely as expected (Figure B.13 and Figure B.14): under a fast learning scenario, more solar PV is deployed. An interesting phenomenon is that this effect is largest in the short-term (2030), where solar grows by 35%, displacing natural gas and a small amount of wind. Faster learning leads to more competitiveness and natural gas will be displaced earlier. Under the slow learning the opposite effect is observed, slowing solar growth greatly at first (-54% in 2030), while the relative effect is smaller in 2040 and 2050 (-15% and -9% respectively). Renewable generation is not hindered under slow learning, since generation keeps growing and solar energy is displaced equally by wind and natural gas.

[1] IRENA (2019), Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation: paper), International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/publications/2019/Nov/Future-of-Solar-Photovoltaic

[2] BID (2019) Evolución futura de costos de las energías renovables y almacenamiento en América Latina. García de Fonseca, L., Parikh, M., Manghani R. Nota Técnica No IDB-TN-01831. Diciembre 2019, Banco Interamericano de Desarrollo. https://publications.iadb.org/es/evolucion-futura-de-costos-de-las-energias-renovables-y-almacenamiento-en-america-latina

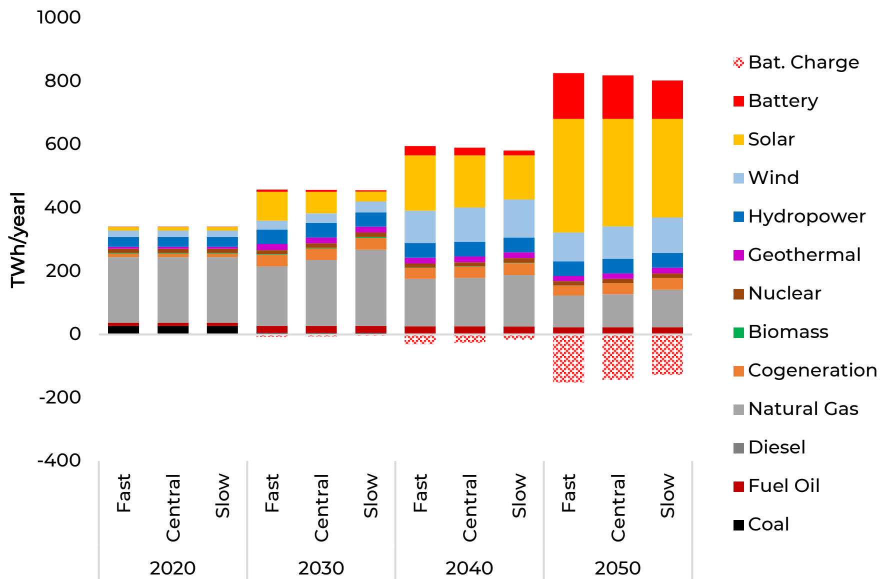

Figure B.13. Yearly electricity generation by source under different solar PV investment costs.

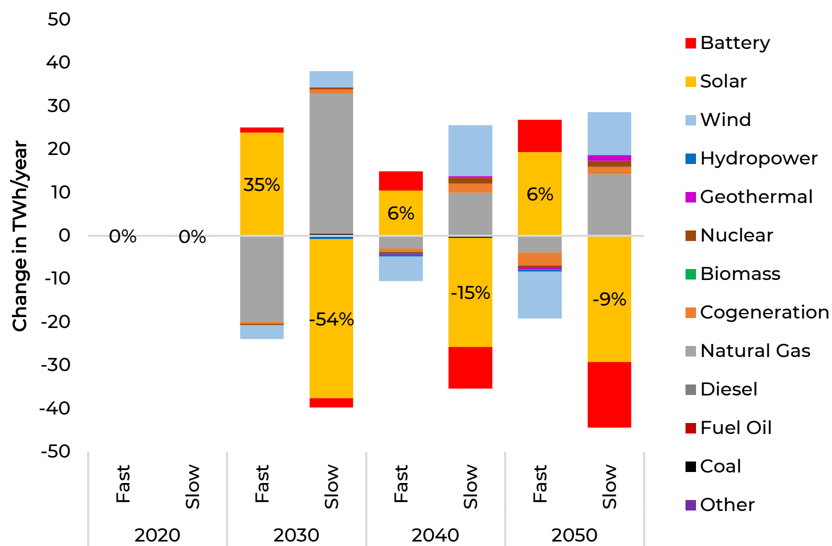

Figure B.14. Change in yearly electricity generation compared to central PV investment costs.

System costs behave similarly; at first, under fast learning, capital solar investments are quickly made being offset by fuel savings. Later, we observe large savings in capex and modest fuel savings (Figure B.15). The opposite happens in a slow learning scenario: initial fuel costs increases offset by decreased capital cost. Furthermore, both fuel costs and capital costs are increased, leading to a 4%-6% total system cost increase (Figure B.16).

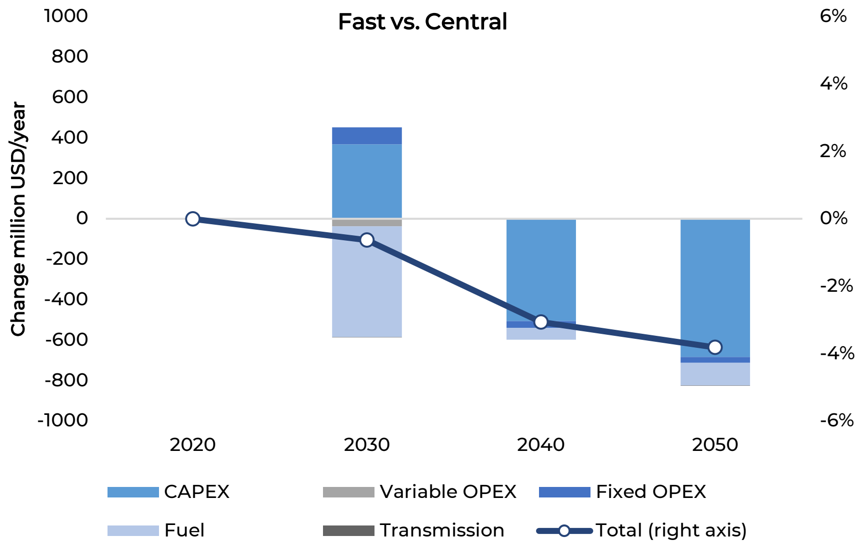

Figure B.15. Change in system costs with fast learning of PV compared to a central estimate.

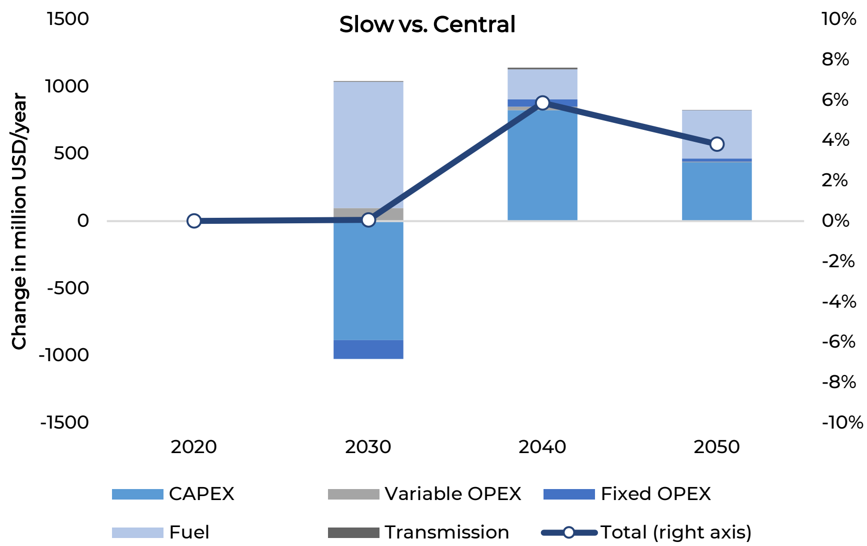

Figure B.16. Change in system costs with slow learning of PV compared to a central estimate.

The effect on emissions is not significant (Figure B.17): Under fast learning, some early mitigation is observed in 2030, but the effect is stabilized into the future. For slow learning, emissions grow in 2030, but stabilize in 2040 and 2050. It is important to note that the model does not capture lock-in effects of investing early and heavily in one technology: it ignores the sunk-cost fallacy that would make decision makers use obsolete technologies for as long as they can just because they have already invested in them.

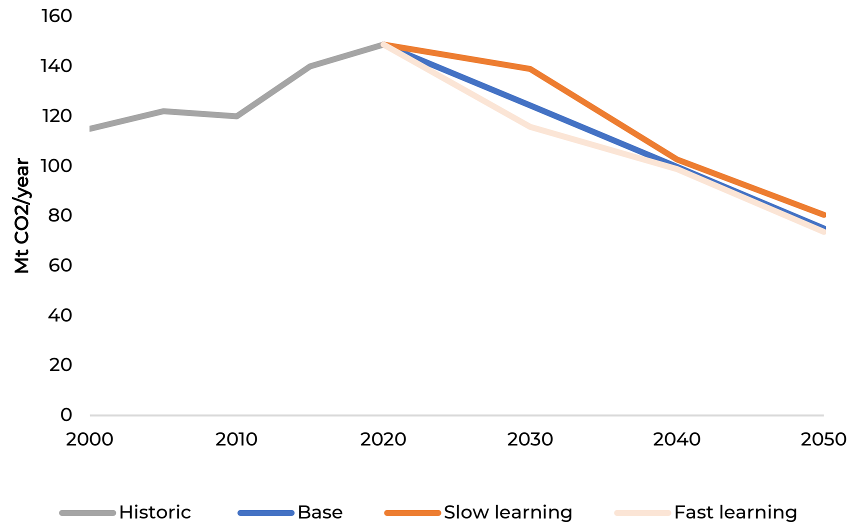

Figure B.17. Yearly CO_2 emissions in the Climate scenarios under different solar PV investment costs.

Battery cost

The same exercise as above is done for the cost of Li-ion batteries, by using the technology catalogue investment information for 2020 and 2030 and extrapolating those trends to obtain information from 2030 on. Both investment cost in million dollars per MWh for energy –volume– and capacity –load– are used, as well as the uncertainty scenarios for each cost information are shown in Figure B.18.

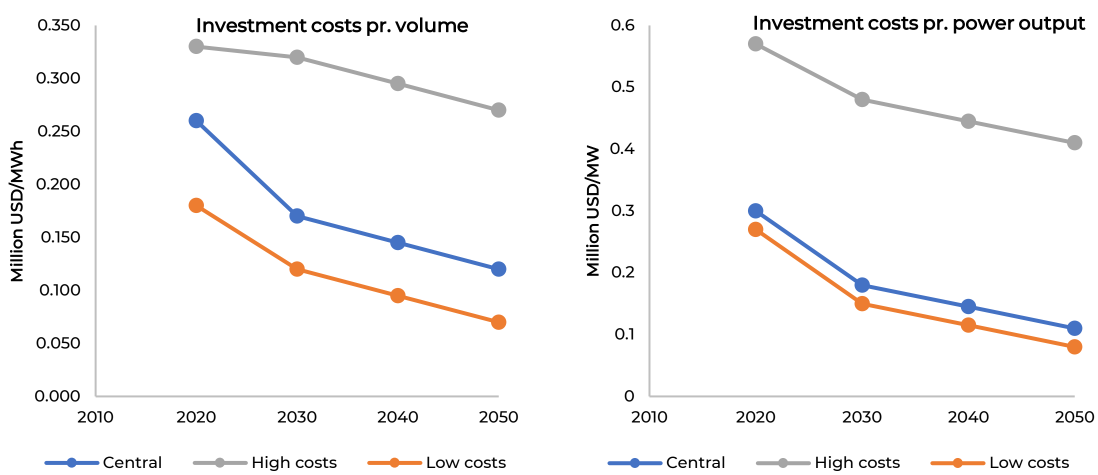

Figure B.18. Storage costs under high, central, and low investment costs.

Fast learning in storage technologies is associated with a larger deployment of Solar PV + Storage, especially in the middle and long term (23% in 2040 and 14% in 2050), while natural gas and wind technologies are displaced (Figure B.19). Actually, during the whole period in the central and fast learning scenarios natural gas generation decreases. On the other hand, the slow learning battery case illustrated the impact that having much less cost reductions in storage technologies can have in the development of the energy system. Less battery and solar PV is deployed and more natural gas is being used instead. This is heavily accentuated in 2050 where generation by solar PV is halved with respect to the central case (Figure B.20). That is a very considerable change in generation with approximately 16% of total generation in 2050 being replaced by natural gas.

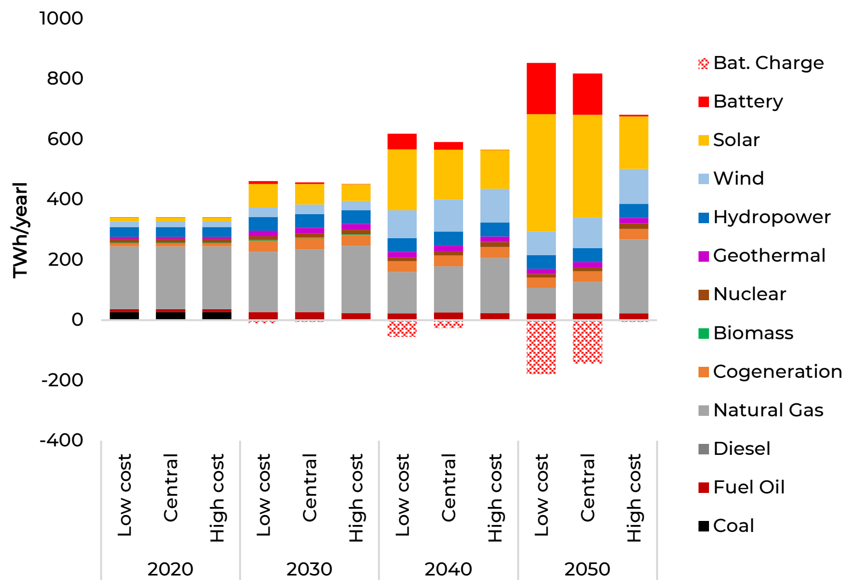

Figure B.19. Yearly electricity generation by source under different storage investment costs.

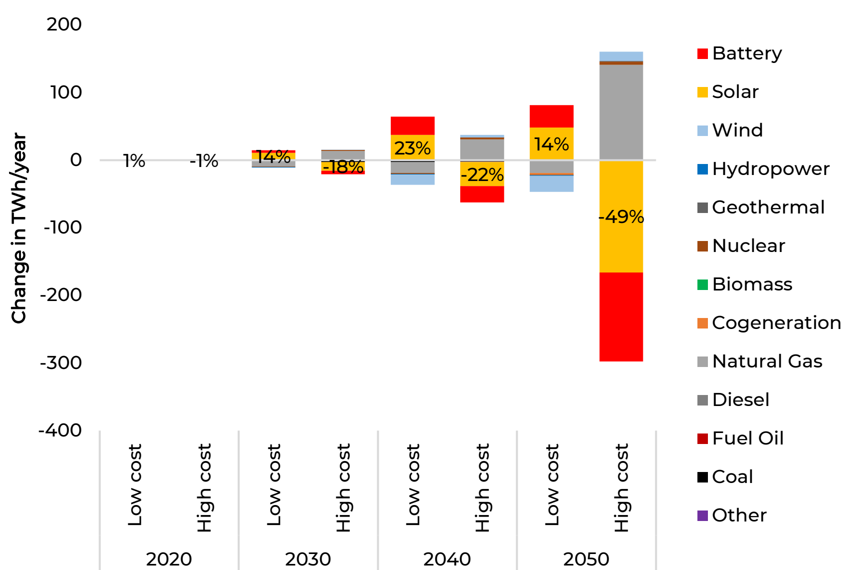

Figure B.20. Change in yearly electricity generation compared to central storage investment costs.

Fast learning of storage technologies leads to savings in fuel costs thanks to the displacement of natural gas, in addition to the capital expenditures' savings induced by the investment cost reductions, this yields system costs reductions of around 13% by 2050 (Figure B.21). In the slow learning scenario (Figure B.22), costs stay practically at the same level throughout time, but its composition changes notably. Fuel costs increase greatly –especially in 2050— thanks to a vast expansion of natural gas generation coupled with a reduction in storage and solar PV capital investments.

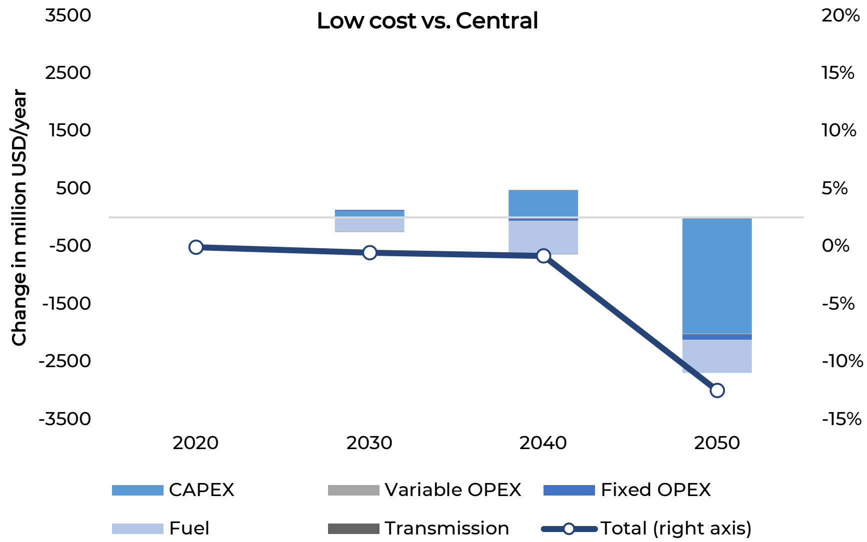

Figure B.21. Change in system costs with fast learning of storage compared to a central estimate.

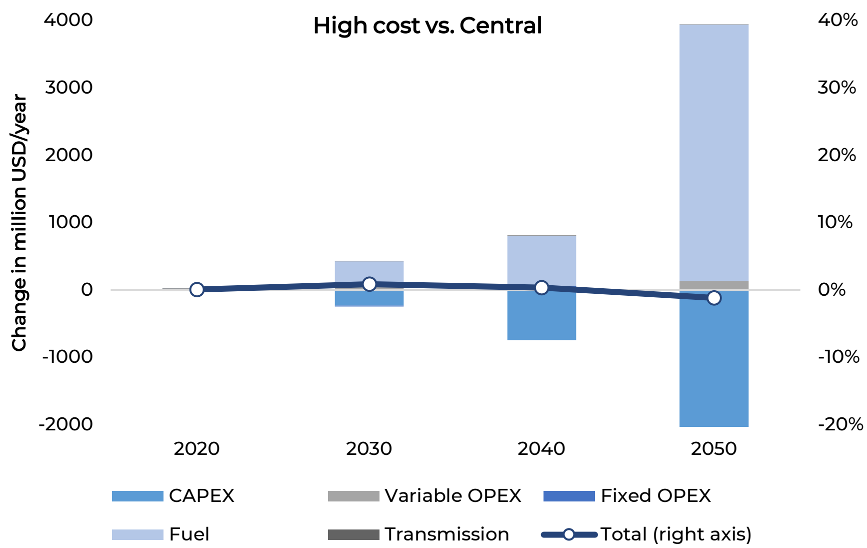

Figure B.22. Change in system costs with slow learning of storage compared to a central estimate.

The consequences of different learning scenarios in storage technologies in terms of emissions are illustrated in Figure B.23. Because of the magnitude of cost increments in storage technologies, a slow learning scenario will yield 60 $MtCO_2$ more emissions than in the central case, effectively losing all mitigation potential storage technologies can have. On the other hand, under a faster learning, emissions are reduced with respect to the central case, in around 10 $MtCO_2$.

From this analysis we can conclude that further cost reductions in the storage technology enhance its mitigation potential, and a slower reduction can result in that potential to be reduced.

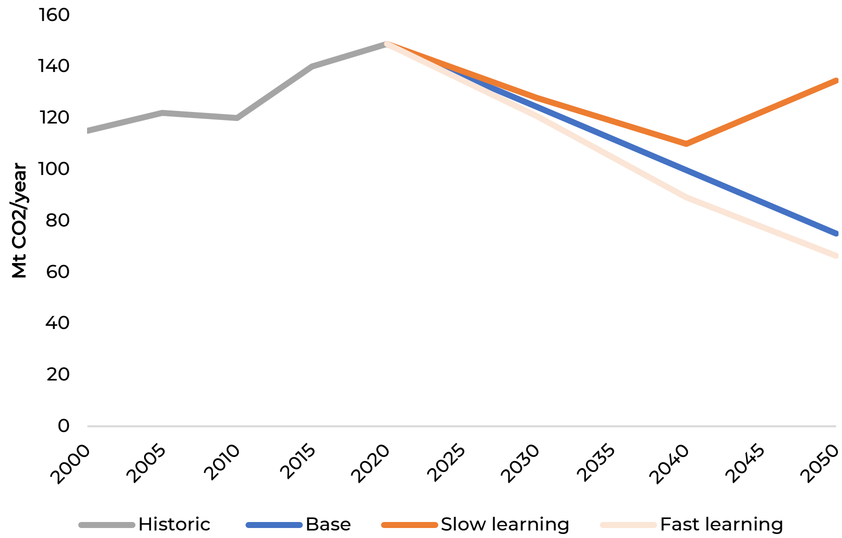

Figure B.23. Yearly CO_2 emissions in the Climate scenarios under different storage investment costs.