Co-benefits analysis in the 1.5°C National Pathways Explorer

Technical Background document for Poland and Pakistan

Contributors:
Anne Zimmer, Jonas Hörsch

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1 Underlying scenario for the co-benefits analysis

1.1 Defining contributions of solar and wind technologies

The choice of which renewable energy technology should be installed is typically not dominated by cost factors only, but also influenced by national priorities. For our '*Accelerated coal phase-out'* scenario, we define the share that each renewable energy (RE) technology type contributes to filling the "coal generation gap," based on local information and input from local experts (see Table 1). Table 1 shows the assumed contributions of solar PV rooftop, PV utility scale, wind onshore and wind offshore to filling the coal generation gap for our *Accelerated coal phase-out scenario*.

Table 1: Assumptions on solar and wind shares for replacing coal

Assumed shares for by RE technology for covering the coal generation gap	**Poland**	**Pakistan**
Contribution of solar PV roof top	25%	11%
Contribution of solar PV utility scale	28%	45%
Contribution of wind onshore	22%	40%
Contribution of wind offshore	25%	4%
Sum of contributions	100%	100%
Source:	Forum Energii Scenario, own assumption for splitting PV rooftop and utility scale based on RE potentials.	IGCEP (2021) and World Bank (2022); own assumption for offshore wind based on RE potentials.

1.2 Resulting generation and capacity information for Poland and Pakistan

Below you find the underlying scenario data for the *BAU scenario* assuming that coal power generation capacities develop according to current (policy) plans for Poland and Pakistan.[a] Please note that - as the co-benefits analysis is focusing on replacing coal with wind and solar – the scenario data is not representing the full power system of the country.

Please also note the remarks on the interpretation of the scenarios in the 1.5°C national pathway explorer methodology section on "Assessing co-benefits of replacing coal with renewables in the power sector," sub-section "Note on the interpretation of the scenarios and caveats of the approach" (Section 8.2.3).

[a] Business-As-Usual with regards to coal power generation plans.

1.2.1 Poland - Electricity Generation

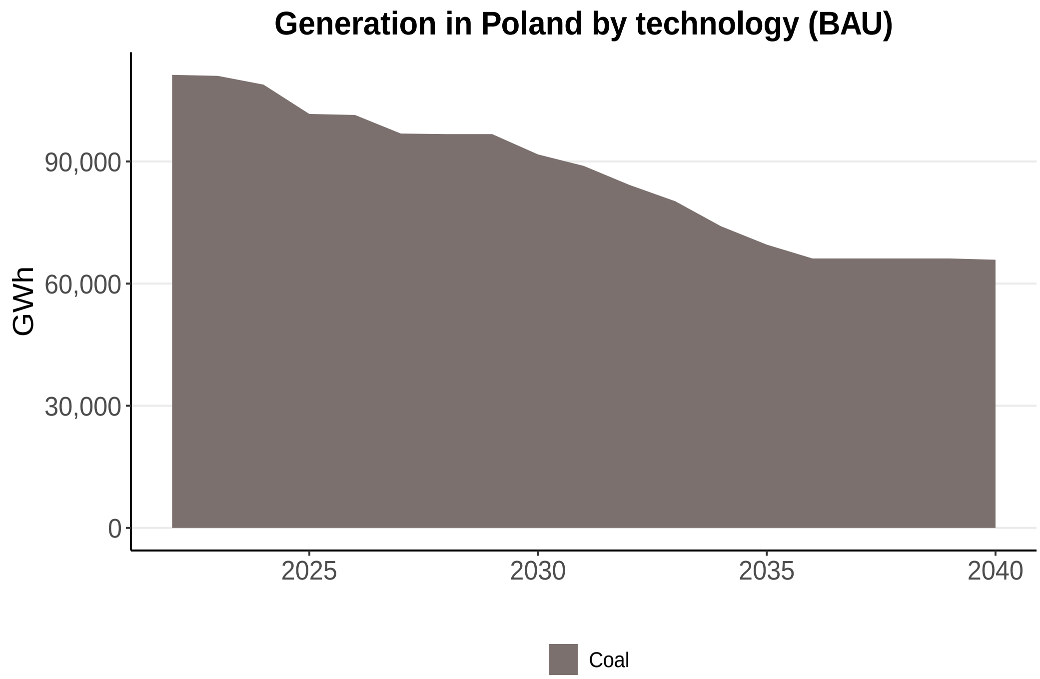

Figure 1: Poland - Planned coal development (BAU) Scenario - Electricity generation from coal

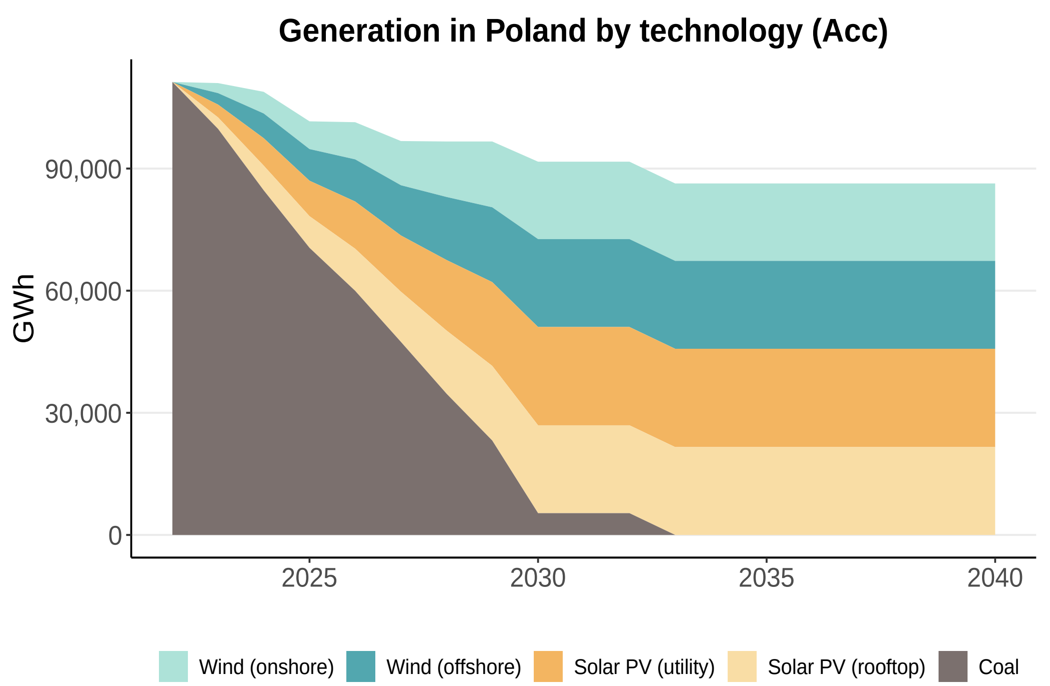

Figure 2: Poland- Accelerated coal phase-out Scenario - Generation from coal and REs replacing coal to cover the coal generation gap of an accelerated phase-out

1.2.2 Poland - Electricity generation capacities - Installed capacities

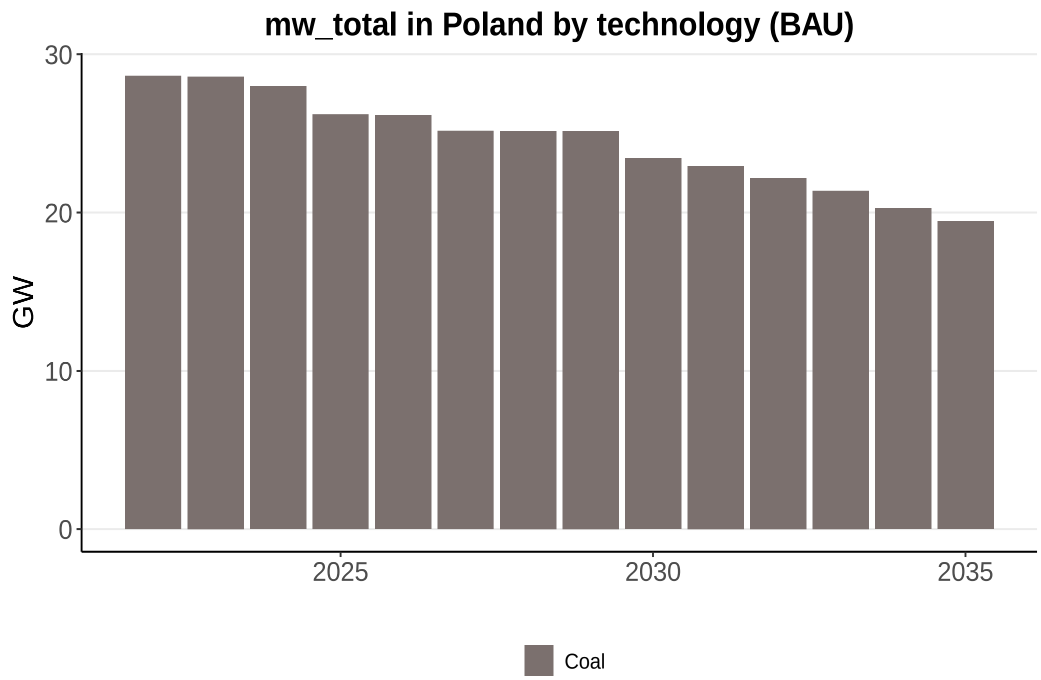

Figure 3: Poland - Planned coal development (BAU) Scenario - Installed capacities for coal

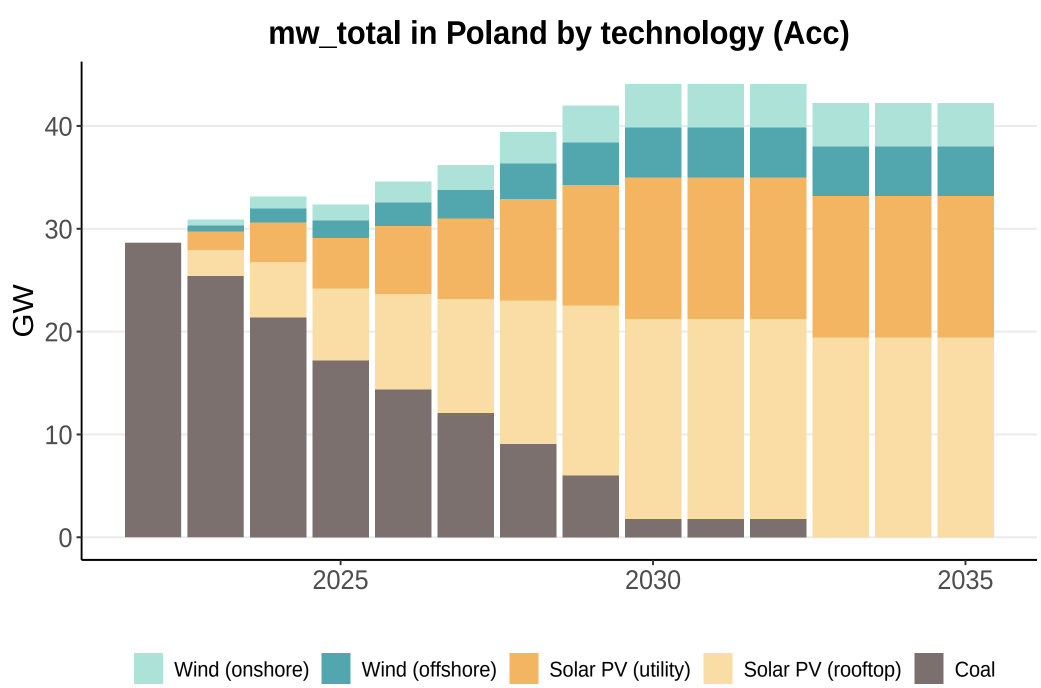

Figure 4: Poland Accelerated coal phase-out Scenario - Installed capacities (coal and REs replacing coal to cover the coal generation gap)

1.2.3 Pakistan - Electricity Generation

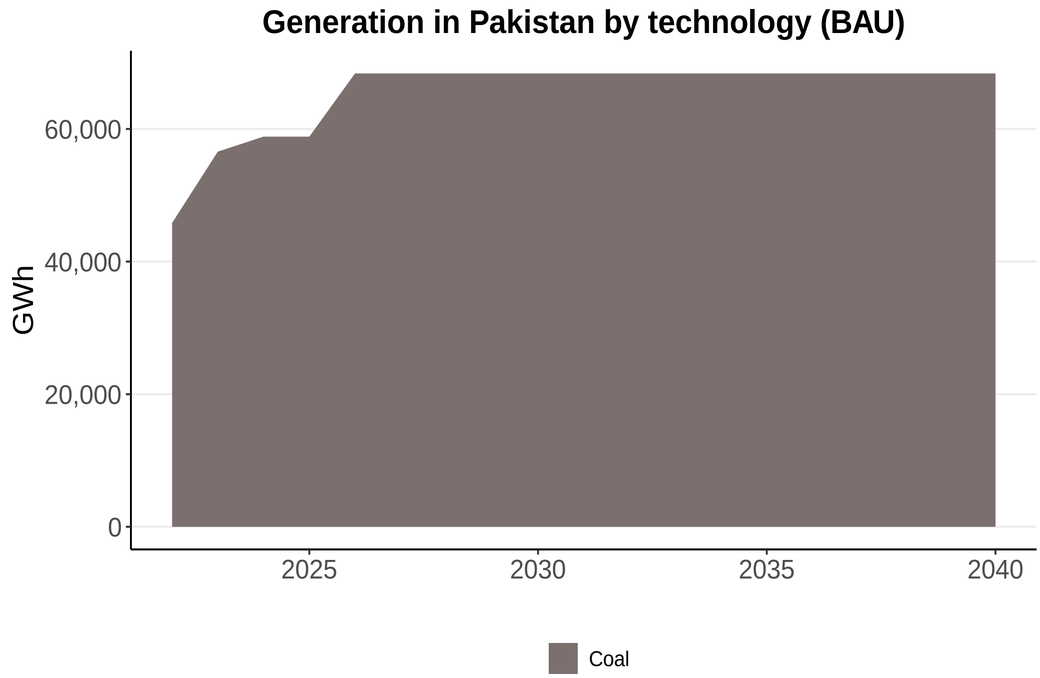

Figure 5: Pakistan - Planned coal development (BAU) Scenario - Electricity generation from coal

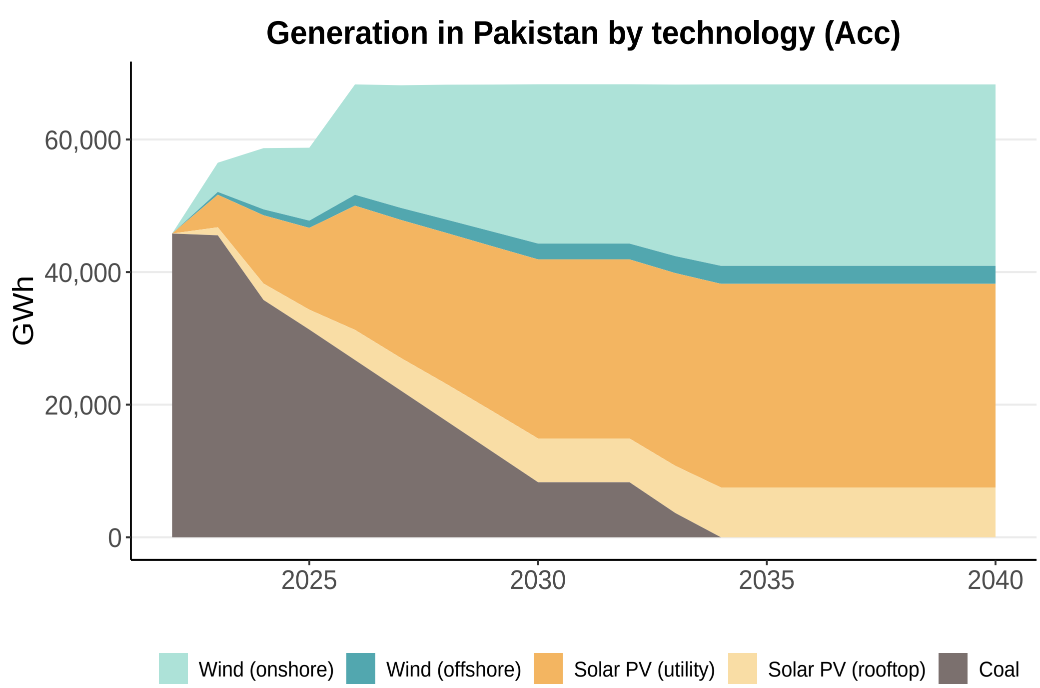

Figure 6: Pakistan - Accelerated coal phase-out Scenario - Generation from coal and REs replacing coal to cover the coal generation gap of an accelerated phase-out

1.2.4 Pakistan - Electricity generation capacities - Installed capacities

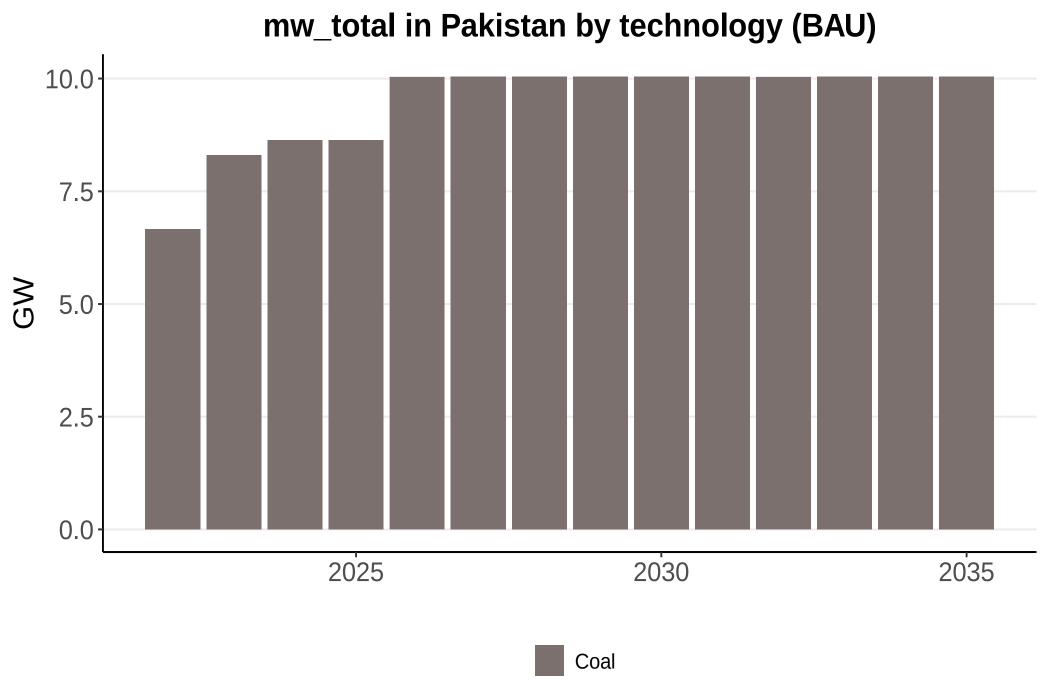

Figure 7: Pakistan - Planned coal development (BAU) Scenario - Installed capacities for coal

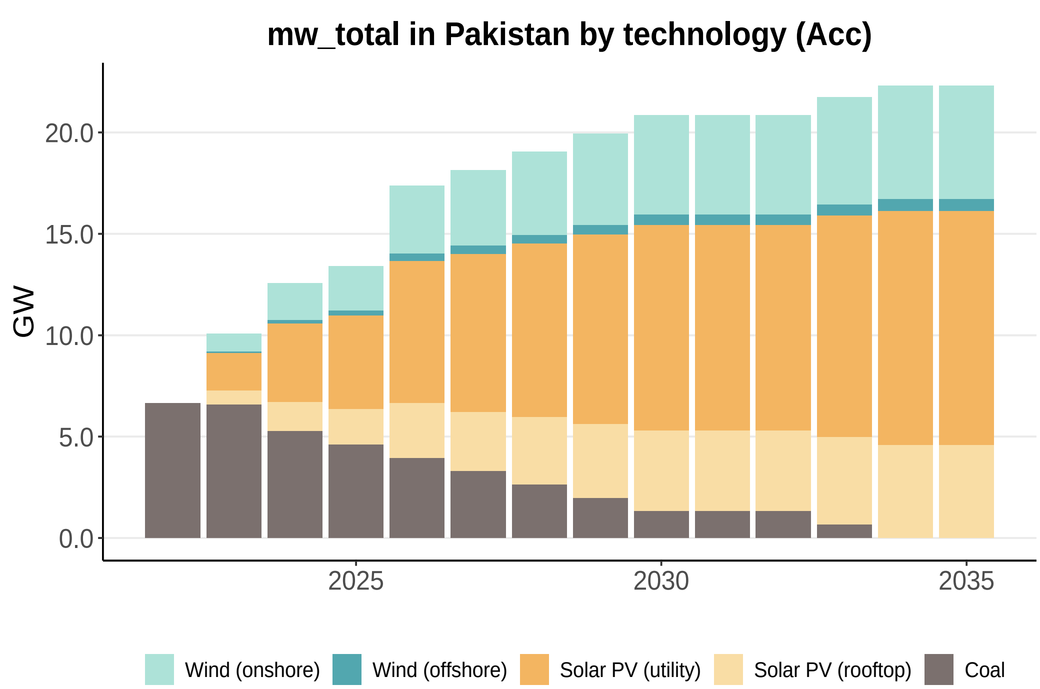

Figure 8: Pakistan - Accelerated coal phase-out Scenario - Installed capacities (coal and REs replacing coal to cover the coal generation gap)

2 Assessing employment impacts from replacing coal power generation with renewable energy

2.1 Methodological approach for estimating the employment impacts from replacing coal with RE

The underlying basic (simplified) rationale is illustrated in

Figure 9. Newly installed capacity for electricity generation in a given year creates jobs in local manufacturing of technology parts (to the degree these are produced within the country, as defined by the local share of manufacturing) and jobs in construction and installation of these added capacity over the construction period. The total capacity that is in place and running in a given year is contributing to jobs in operation and maintenance over the lifetime of the respective installation.

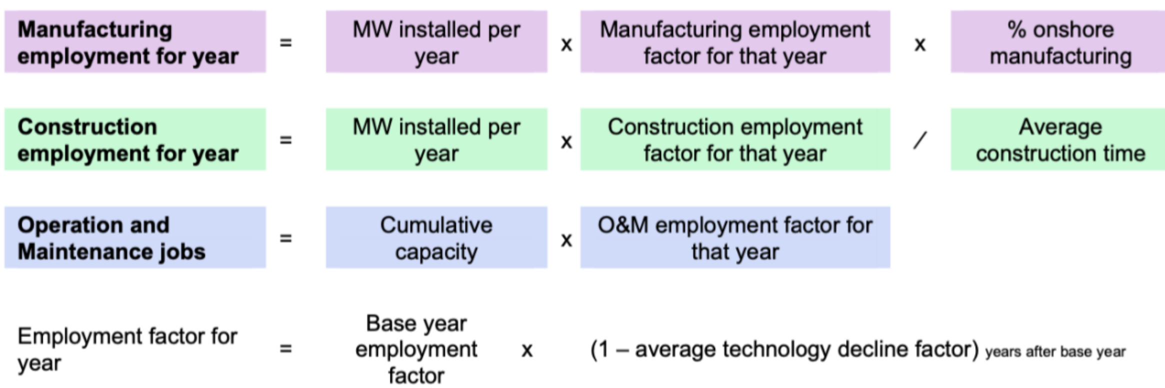

Figure 9: General overview on methodology. Source: (Rutovitz et al., 2020)

2.1.1 Poland – Applied employment factors and local share assumptions

Table 2 shows the respective employment factors that we have applied for Poland. We have derived country-specific employment factors for operation and maintenance (O&M) of coal power plants based on available data in the JRC study from Alves Dias et al., (2018). The resulting coal O&M employment factor can be considered conservative to the regard that it would rather overestimate coal jobs as it is considerably higher than the Ram et al., (2020) coal O&M job factor would have been. While there is data available on total (estimated) jobs in solar and wind for Poland from EurObserv'ER and IRENA statistics , the employment numbers do not allow for differentiation between jobs related to construction and installation, operation and maintenance and manufacturing, thus not allowing us to derive job type specific employment factors for Poland (EurObserv'ER, 2022). Moreover, the employment numbers from EurObserv'ER state to include direct as well as indirect employment which hinder direct comparability with our approach which focuses on direct employment only.

Consequently, we have applied the factors from Ram et al. (2020) regionally, adjusted for Europe applying Ram's regional adjustment factor for the other employment factors.

Table 2: Employment factors applied for Poland

Technology	Type	2022	2025	2030	2035	Source
Coal	Construction & Installation	12.16	12.34	12.71	13.09	Ram et al. (2020)
Coal	Local manufacturing	5.86	5.95	6.13	6.31	Ram et al. (2020)
Coal	Operation & Maintenance	0.51	0.51	0.51	0.51	Own calculation based on data Alves et al. (2018)
Solar PV rooftop	Construction & Installation	17.15	15.08	12.67	11.32	Ram et al. (2020)
Solar PV rooftop	Local manufacturing	4.42	3.89	3.26	2.92	Ram et al. (2020)
Solar PV rooftop	Operation & Maintenance	1.52	1.54	1.59	1.64	Ram et al. (2020)
Solar PV utility scale	Construction & Installation	7.18	6.39	5.50	4.90	Ram et al. (2020)
Solar PV utility scale	Local manufacturing	3.70	3.29	2.84	2.53	Ram et al. (2020)
Solar PV utility scale	Operation & Maintenance	0.76	0.77	0.79	0.82	Ram et al. (2020)
Wind offshore	Construction & Installation	7.48	7.16	6.70	6.27	Ram et al. (2020)
Wind offshore	Local manufacturing	14.58	13.97	13.07	12.23	Ram et al. (2020)
Wind offshore	Operation & Maintenance	0.17	0.16	0.16	0.15	Ram et al. (2020)
Wind onshore	Construction & Installation	3.00	2.77	2.44	2.42	Ram et al. (2020)
Wind onshore	Local manufacturing	4.41	4.07	3.58	3.56	Ram et al. (2020)
Wind onshore	Operation & Maintenance	0.29	0.28	0.27	0.27	Ram et al. (2020)

Note: Employment factors in construction and installation as well as local manufacturing are in 'job years per MW' while employment factors for operation & maintenance are in 'jobs per MW'. Decline factors and regional adjustment factor for Europe from Ram et al. (2020) applied.

For **local manufacturing jobs**, which are also temporary, we assume that the manufacturing jobs occur in the first year of the construction and installation period, applying the assumption on the 'local share' as shown below (see

Table 3). This 'local share' defines how much of the added capacities are manufactured within the country, thus contributing to local jobs, while the rest is imported from other countries. We approximate these technology-specific local shares based on data from the research article from Pietrzak et al., (2021), who conducted an assessment of the energy transition in Poland, among other things, listing the number of companies in Poland which produce equipment for RE.

Table 3: Poland - local share assumptions for local manufacturing (1=100%)

Technology	2022	2025	2030	2035
Coal	0.70	0.7	0.7	0.7

Technology	2022	2025	2030	2035
Solar PV rooftop	0.14	0.2	0.3	0.4
Solar PV utility scale	0.14	0.2	0.3	0.4
Wind offshore	0.34	0.4	0.5	0.5
Wind onshore	0.34	0.4	0.5	0.5

2.1.2 Pakistan - Applied employment factors and local share assumptions

Table 4 shows the respective employment factors that we have applied for Pakistan. We have derived country-specific employment factors for construction and installation of coal power plants based on available data from the CPEC Authority Website from the Ministry of Planning, Development and Special Initiatives listing information on completed energy projects including among other things data on created construction jobs for coal power plants in Pakistan (CPEC Authority, 2022). To account for regional differences in productivity levels, we apply a regional adjustment factor to the Ram et al. base employment factor for coal-related manufacturing jobs as suggested by Ram et al. (2020). However, instead of applying the suggested regional adjustment factor for SAARC, which we consider very high for the level of development of Pakistan, we decided to apply the regional adjustment factor for MENA countries for Pakistan instead, although Pakistan itself is not a MENA country.[b,c]

For renewable-related jobs in Pakistan, we have applied the country-specific employment factors for solar PV rooftop and utility scale as well as onshore wind from the recent World Bank report, applying an employment factor approach to for assessing renewable energy jobs for Pakistan (World Bank, 2022). For this study, the World Bank authors have conducted industry surveys and interviews and derived Pakistan-specific employment factors for solar and wind. The World Bank study does not include offshore wind. To account for the higher employment intensity of offshore wind, we assume that offshore wind employment factors are twice the employment factors for onshore wind from the World Bank study (2022). Comparing this with the offshore wind employment factors from Ram et al. (2022), we are again mostly conservative as Ram et al. assume C&I and O&M employment factors for offshore wind to be around three times higher compared to onshore wind.

Ram et al. suggest to also apply a so-called decline factor to account for 'learning' over time. For Pakistan, we decided to keep the self-derived employment factors constant over time.

Table 4: Employment factors applied for Pakistan

Technology	Type	2022	Source
Coal	Construction & Installation	4.55	Own calculation based on data from CPEC
Coal	Local manufacturing	9.86	Ram et al. (2020) adjusted with regional adjustment factor for MENA
Coal	Operation & Maintenance	0.96	Own calculation based on data from CPEC
Solar PV rooftop	Construction & Installation	16.00	World Bank (2022)
Solar PV rooftop	Local manufacturing	4.40	World Bank (2022)
Solar PV rooftop	Operation & Maintenance	2.10	World Bank (2022)
Solar PV utility scale	Construction & Installation	5.70	World Bank (2022)
Solar PV utility scale	Local manufacturing	4.40	World Bank (2022)
Solar PV utility scale	Operation & Maintenance	0.80	World Bank (2022)
Wind offshore	Construction & Installation	7.40	Assumption 2x EF for onshore wind from World Bank (2022)
Wind offshore	Local manufacturing	0.40	Assumption 2x EF for onshore wind from World Bank (2022)
Wind offshore	Operation & Maintenance	2.40	Assumption 2x EF for onshore wind from World Bank (2022)

[b] South Asian Association for Regional Cooperation (SAARC)
[c] Ram et al.'s regional adjustment factors for SAARC countries would require multiplying the base employment factor with the adjustment factor of 3.99 for 2020. The MENA regional adjustment factor instead is 1.94.

Technology	Type	2022	Source
Wind onshore	Construction & Installation	3.70	World Bank (2022)
Wind onshore	Local manufacturing	0.20	World Bank (2022)
Wind onshore	Operation & Maintenance	1.20	World Bank (2022)

Note: Employment factors in Construction and Installation as well as local manufacturing are in 'job years per MW' while employment factors for Operation & Maintenance are in 'jobs per MW'. No decline factors applied.

For local manufacturing jobs, which are also temporary, we assume that the manufacturing jobs occur in the first year of the construction and installation period, applying the assumption on the 'local share' as shown below (see Table 5). We derived these technology-specific local shares for Pakistan based on assumptions from the World Bank (2022). We interpolate to derive the local shares for each year to estimate the respective local jobs in manufacturing for each technology.

Table 5: Pakistan - local share assumptions for local manufacturing (1=100%)

Technology	2022	2025	2030	2035
Coal	0.140	0.2	0.2	0.2
Solar PV rooftop	0.052	0.1	0.3	0.5
Solar PV utility scale	0.052	0.1	0.3	0.5
Wind offshore	0.040	0.1	0.2	0.3
Wind onshore	0.040	0.1	0.2	0.3

2.2 Results of the employment analysis by scenario

Please also note the remarks on the interpretation of the scenarios in the 1.5°C national pathway explorer methodology section on "Assessing co-benefits of replacing coal with renewables in the power sector," subsection "Note on the interpretation of the employment estimates and caveats" (Section 8.3.2).

2.2.1 Poland - Estimates job gains and losses comparing the BAU and the Acc scenario

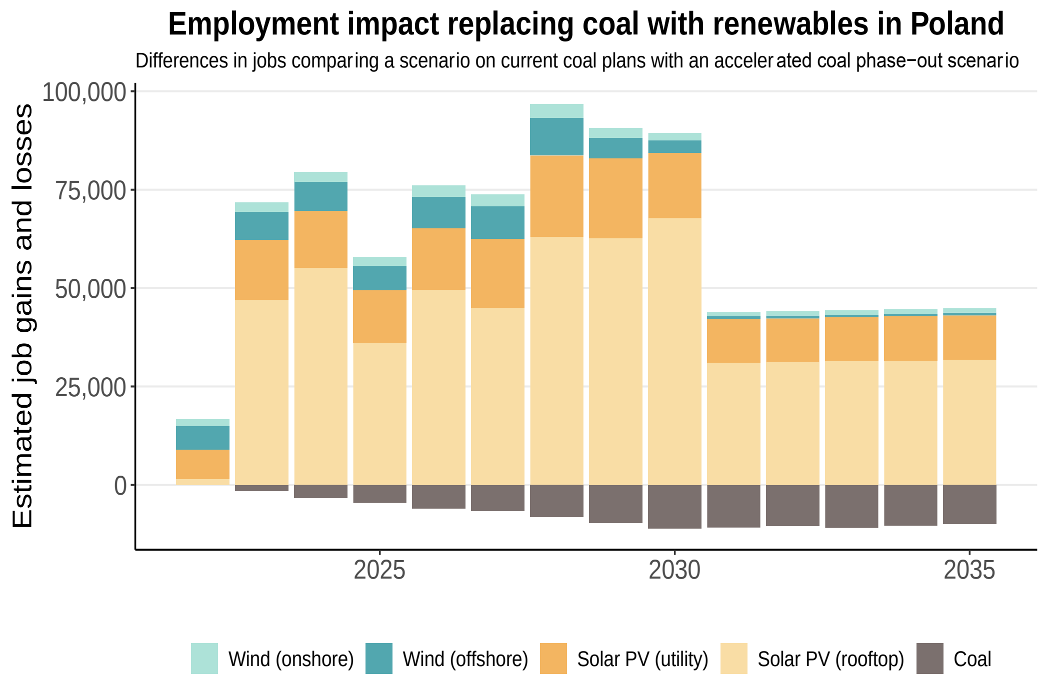

Figure 10: Comparison of job impacts from replacing coal power generation with solar and wind (Difference in jobs between the accelerated coal phase-out scenario and the BAU coal-phase out scenario)

2.2.2 Poland - Employment results by scenario

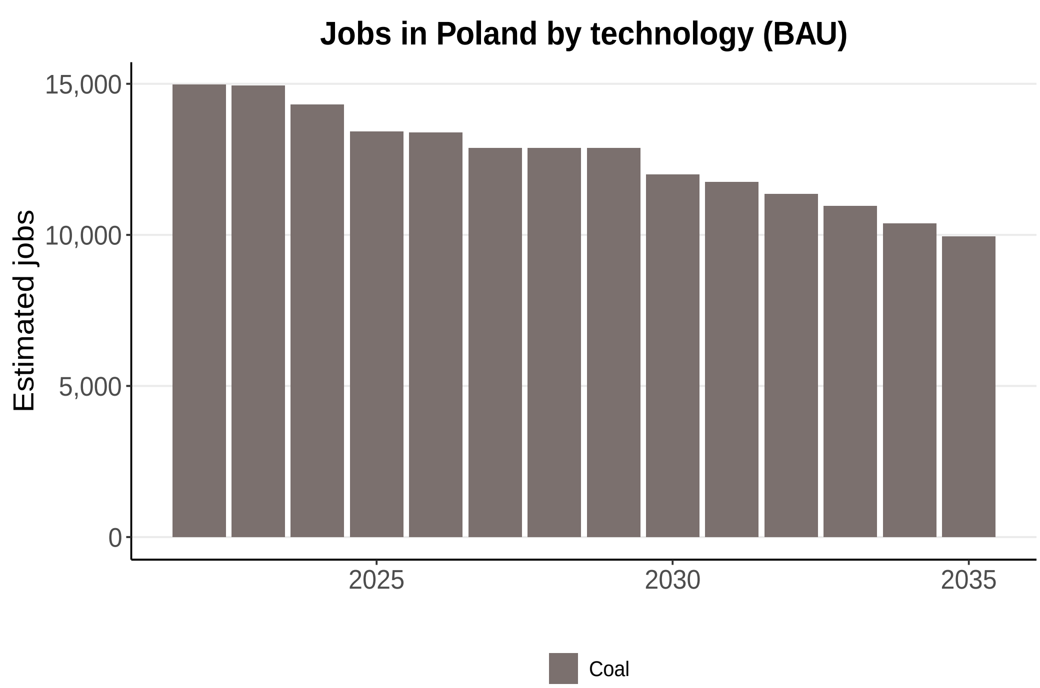

Figure 11: Planned coal development (BAU) - Job estimates related to power generation by technology

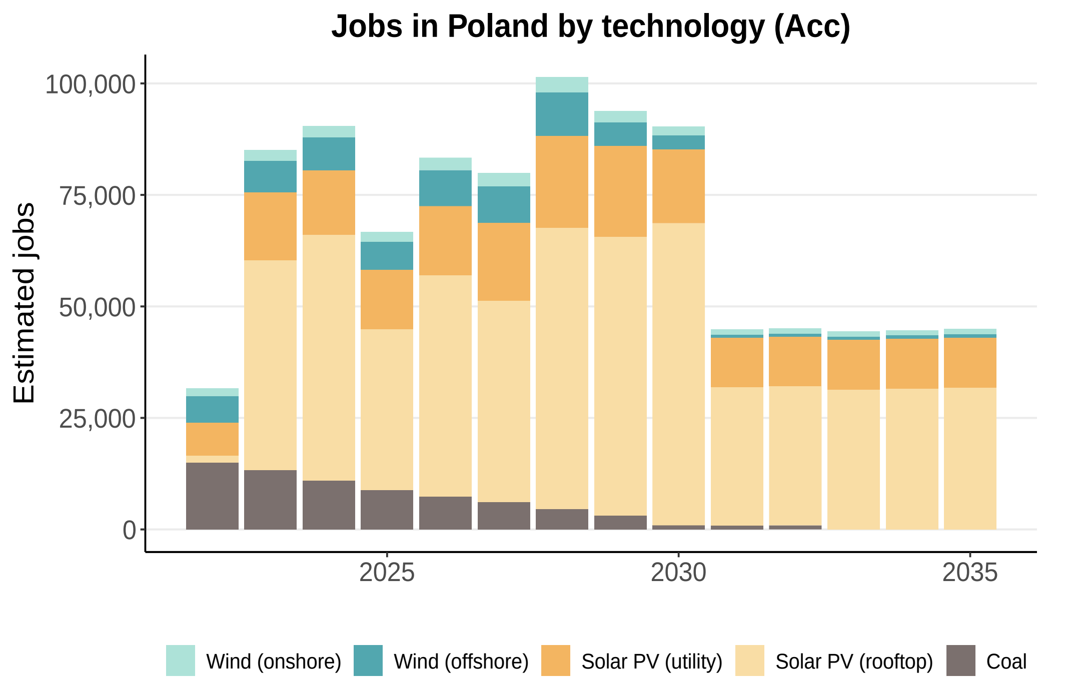

Figure 12: Accelerated coal phase out scenario (Acc) - Jobs by technology for coal and REs power generation replacing coal to cover the coal generation gap of an accelerated phase-out

2.2.3 Poland - Detailed employment results by job type

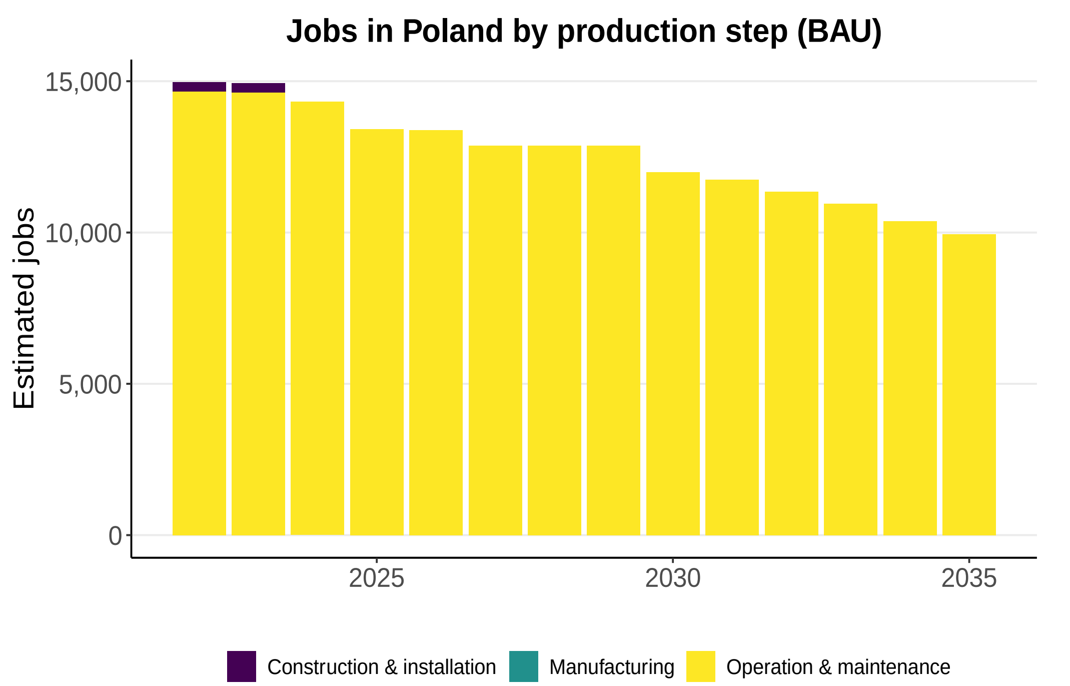

Figure 13: Planned coal development (BAU) - Job estimates by type of employment

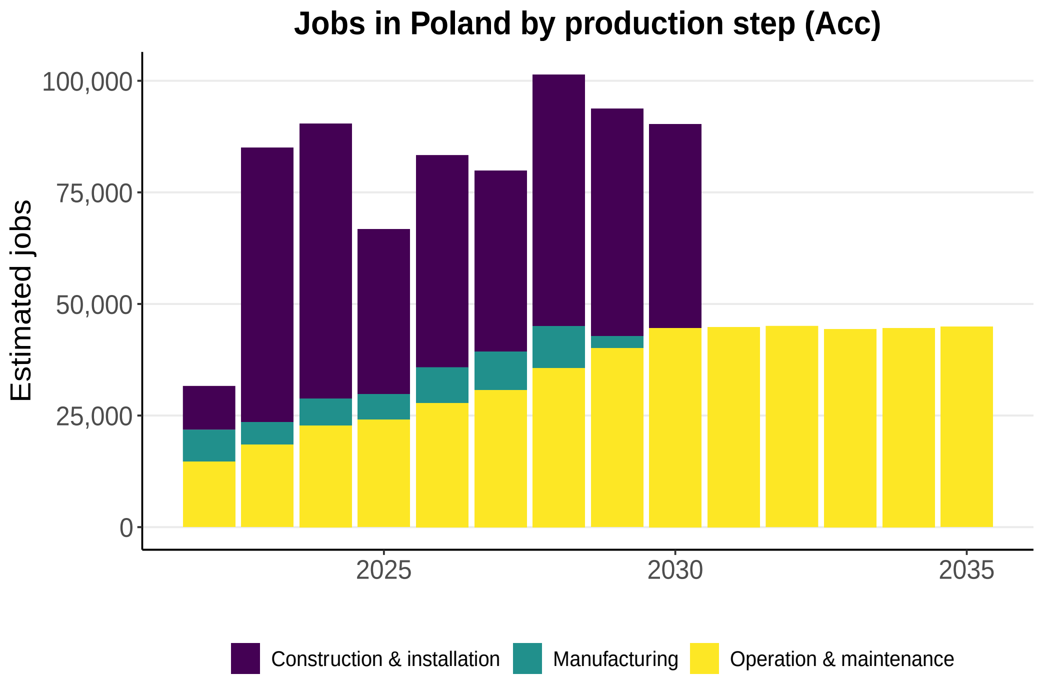

Figure 14: Accelerated coal phase-out scenario - Jobs by type of employment

2.2.4 Pakistan - Estimates job gains and losses comparing the BAU and the Acc scenario

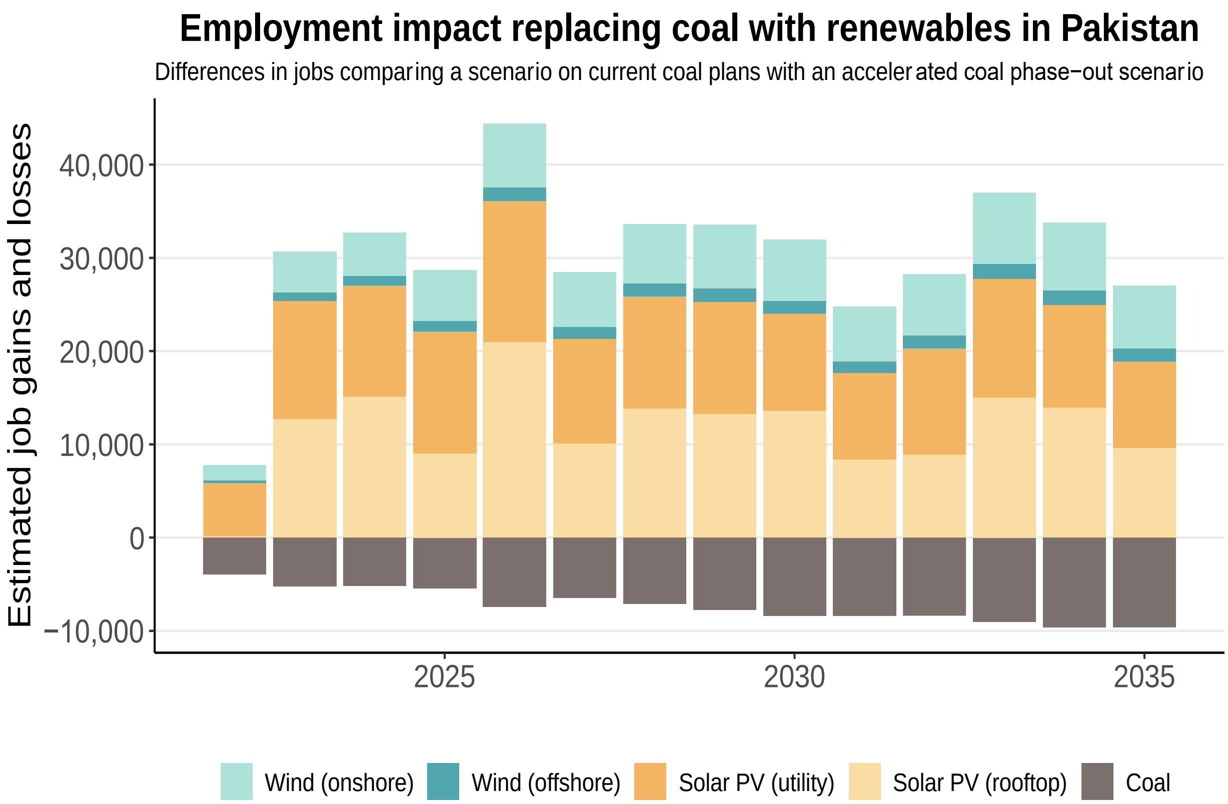

Figure 15: Comparison of job impacts from replacing coal power generation with solar and wind (Difference in jobs between the accelerated coal phase-out scenario and the BAU coal-phase out scenario)

2.2.5 Pakistan - Employment results by scenario

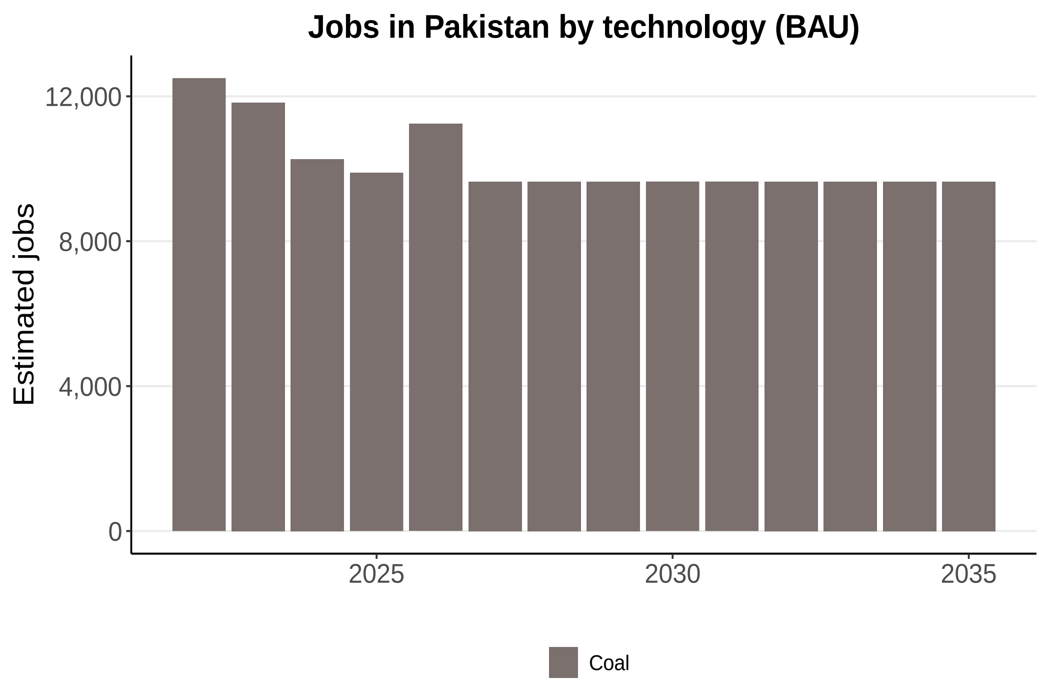

Figure 16: Planned coal development (BAU) - Job estimates related to power generation by technology

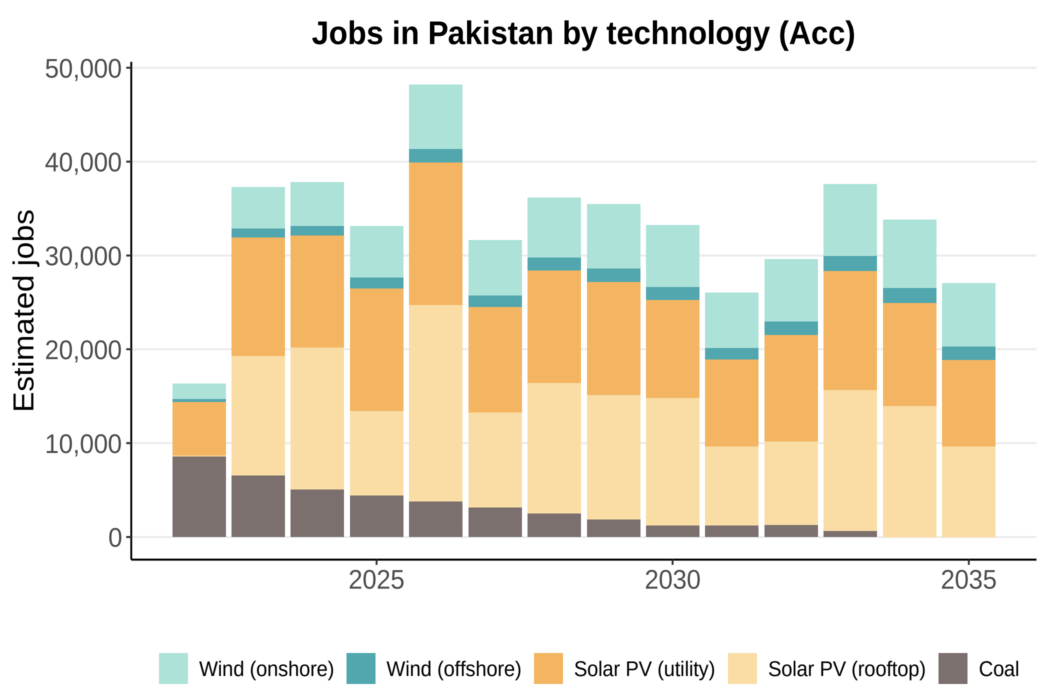

Figure 17: Accelerated coal phase out scenario - Jobs by technology for coal and REs power generation replacing coal to cover the coal generation gap of an accelerated phase-out

2.2.6 Pakistan - Detailed employment results by job type

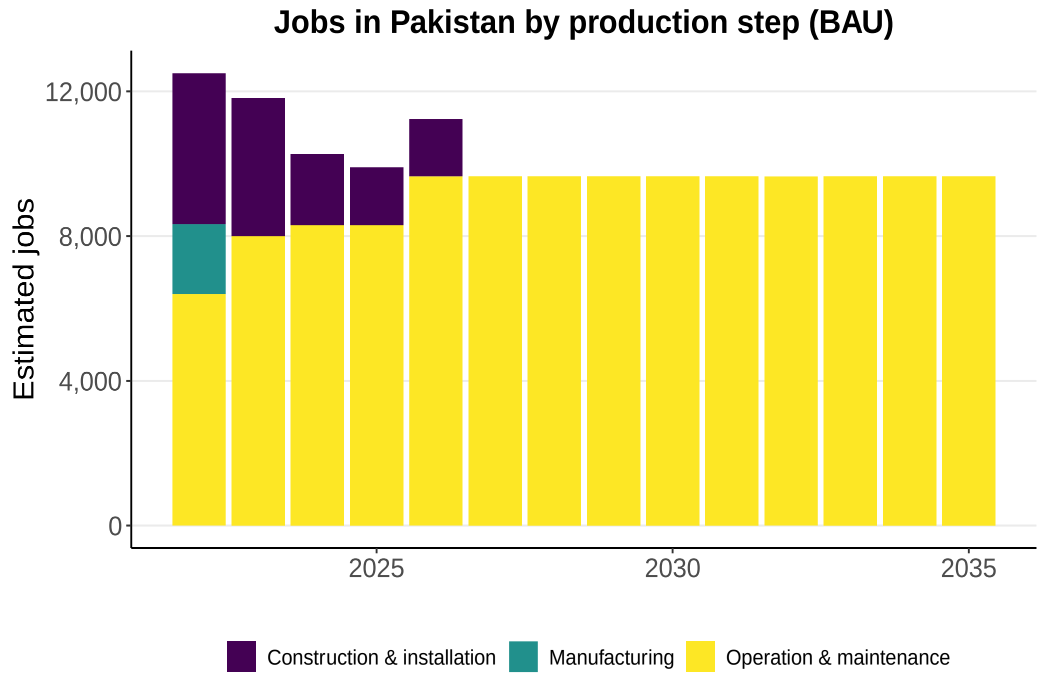

Figure 18: Planned coal development (BAU) - Job estimates by type of employment

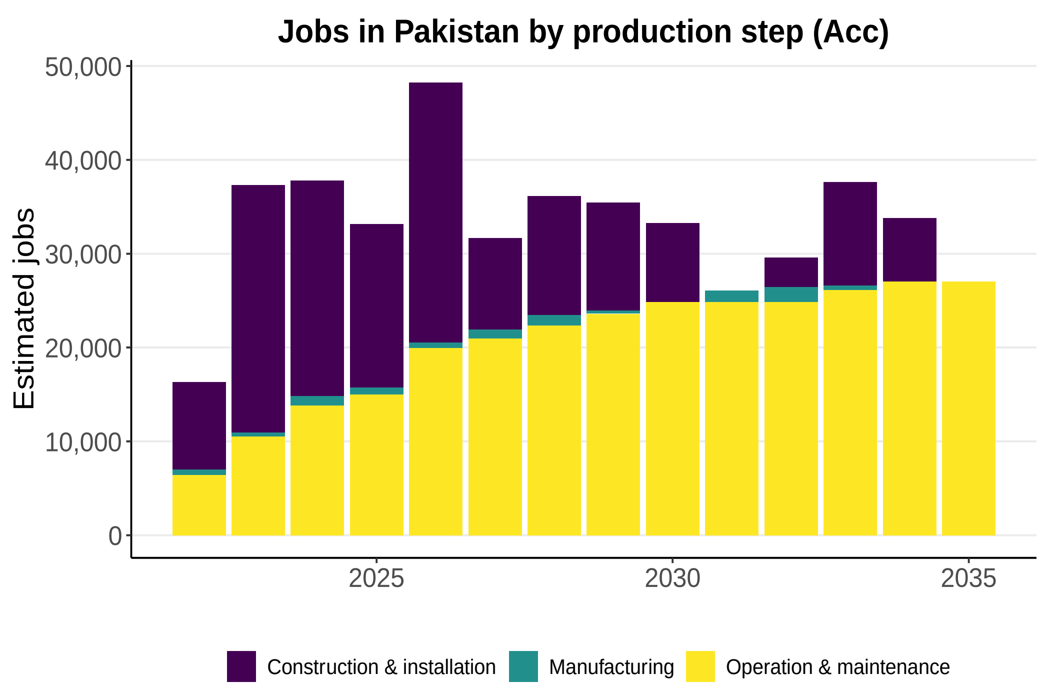

Figure 19: Accelerated coal phase-out scenario - Jobs by type of employment

2.3 Comparison of results with available data and literature

2.3.1 Poland - Comparison of employment estimates

To put our estimates into perspective, we compare them with employment estimates for current jobs in Poland. Our results show that the number of coal-fired power generation jobs in Poland that would be lost by an accelerated coal phase out would be strongly overcompensated by a factor of four or more by newly created employment opportunities in wind and solar replacing coal power generation. We estimate that while up to 11,000 jobs in coal plant operation and maintenance could be lost compared to the current coal plans, at least 44,000 and up to over 90,000 new jobs in renewable energy could be created from replacing the coal capacities that are phased out earlier than currently planned by solar and wind power generation. Other sources confirm that the employment potential for Poland in the RE sector could be high, stating that over 90,000 new jobs have been created in Poland in 2020 from the solar sector only, making Poland one of the largest providers of solar jobs in the EU (SolarPower Europe, 2021). The authors of the report (SolarPower Europe, 2021) argue that, while this may seem a surprisingly high number at first, this number can be explained by the majority of the polish RE installations currently being small scale PV rooftop residential installations, which have a higher job creation impact compared to larger scale PV utility or also wind installations.

In contrast, the EurObserv'ER renewables factsheet for Poland (2022) estimates about 10,900 jobs in full-time equivalents (FTE) for wind and 21,700 jobs for solar PV and CSP in 2020 and the IRENA statistics for Poland estimate around 9,700 jobs in wind and 29,400 jobs in solar PV in Poland for 2020. However, although these job estimates are considerably lower than the estimates of SolarPower Europe (2021), they need to put into context with the installed capacities for (grid-connected solar) and especially the newly *added* capacities for 2020; EurObserv'ER's "State of the Renewable Energies in Europe 2021" Report states a total installed capacity of solar PV of 3.9 GW in Poland for 2020, with capacity additions of 2.4 GW between 2020 and 2021. In our accelerated coal phase out scenario, the annual capacity additions for solar PV would be roughly double the 2021 capacity additions for many years, thus driving job creation in local manufacturing and construction and installation. Moreover, the total installed capacities for solar PV in our accelerated coal phase out scenario would be more than 32 GW in 2035, thus increasing current total installed PV capacities in Poland by a factor of about eight, creating operation and maintenance jobs related to PV.

Our analysis focuses on direct jobs in local manufacturing of technology parts, construction and installation as well as operation and maintenance of power coal, wind and solar capacities. Other existing electricity generation technologies have not been taken into account. Additional jobs related to storage can be expected when transitioning towards solar and wind, which are not taken into account here. Jobs in **coal mining** are also not included in this analysis. Estimates from the World Bank (2021) suggest that in 2019 there have been around 92,600 people working in the Polish coal mining industry (incl. lignite), but coal production trends in Poland have been declining since the 1990's and discussions on a Just Transition process are ongoing (Ruppert Bulmer et al., 2021). Statistics from the Polish Website "Polski Rynek Wegla" state that in June 2022, 74,848 people have been employed in Polish hard coal mining.

2.3.2 Pakistan - Comparison of employment estimates

This section aims to put our results into context and compare our estimates with results from other studies or available data.

The current share of RE power plants (counting wind, solar and bagasse but excluding hydro) are around 5.4% in Pakistan's energy mix according to the latest State of the Industry Report from 2021 of the National Electric Power Regulatory Authority NEPRA. The same report states the total installed capacity of RE power plants (wind, solar and bagasse) connected with the system of the National Transmission and Despatch Company to have been 2,047 MW (as of 30-06-2021), with 1,248 MW installed wind and 430 MW solar PV. NEPRA also confirms that there is considerable potential for building out solar and wind in Pakistan.

The World Bank study (2022) estimates that a 'High Wind Pathway' could create 117,832 solar and wind jobs between 2021 and 2030, with 48,204 jobs for 2021-2025 and 69,627 jobs for 2026-2030 when taking both temporary jobs (such as local manufacturing and construction and installation) as well as permanent jobs (like operation and maintenance) into account. For a 'High Solar Scenario', they estimate an even higher job creation potential of 140,295 solar and wind jobs between 2021 and 2030, with 54,177 jobs for 2021-2025 and 86,118 jobs for 2026-2030. The estimates for the job creation potential in wind and solar from the World Bank (2022) thus suggests our estimates are of a plausible order of magnitude. The study of the World Bank moreover also looks into requires skills and training needs.

Given that we do not cover the full energy system in our analysis and does not account for already existing RE capacities, our employment estimates cannot directly be compared to current job numbers for solar and wind. However, whenever possible, we have based our job estimates on available job data, e.g. by deriving the employment factors for coal based on reported job data. Based on existing installed wind projects, employment estimates are presented on the CPEC website indicating that, for example, the 100 MW UEP wind farm in Jhimpir, Thatta, has created 900 (temporary) jobs in construction and 39 (presumably permanent) local jobs.

However, it needs to be noted that an accelerate coal phase out may also affect jobs in **coal mining**, which have not been accounted for in our study. It is estimated that Pakistan's coal mining sector employs over 100,000 employees in around 400 coal mines (IndustriALL Global Union, 2022). While this is a considerable number of jobs, these jobs are also considered to be high risk jobs of getting injured or even killed as work conditions and safety standards are reportedly very low in Pakistan's' coal mines. Websites report hazardous work conditions with low pay, including child labour and chronic diseases. It is estimated that since 2010, at least 523 workers have been killed in Pakistan's coal mines with another source even claiming that each year, between 100 and 200 mine workers die, with 176 miners having died and 180 having been injured in mine accidents last year. While these sources are not official statistics and need to be considered with caution, they indicate that alternative job opportunities need to be created for Pakistan's people and a transition towards wind and solar could contribute to this.

3 Assessing air pollution reduction and health benefits of an accelerated coal phase-out

Please note the remarks on the interpretation of the results and the caveats of the approach in the 1.5°C national pathway explorer methodology section “Note on the interpretation of the air pollution and health estimates and caveats” (Section 8.4.2). We consider the following types of diseases contributing to overall premature deaths from coal-power generation: chronic obstructive pulmonary disease (COPD), lung cancer (LC), ischemic heart disease (IHD) and stroke (ST).

3.1 Poland – Results

3.1.1 Comparing premature deaths for the Acc and the BAU scenario

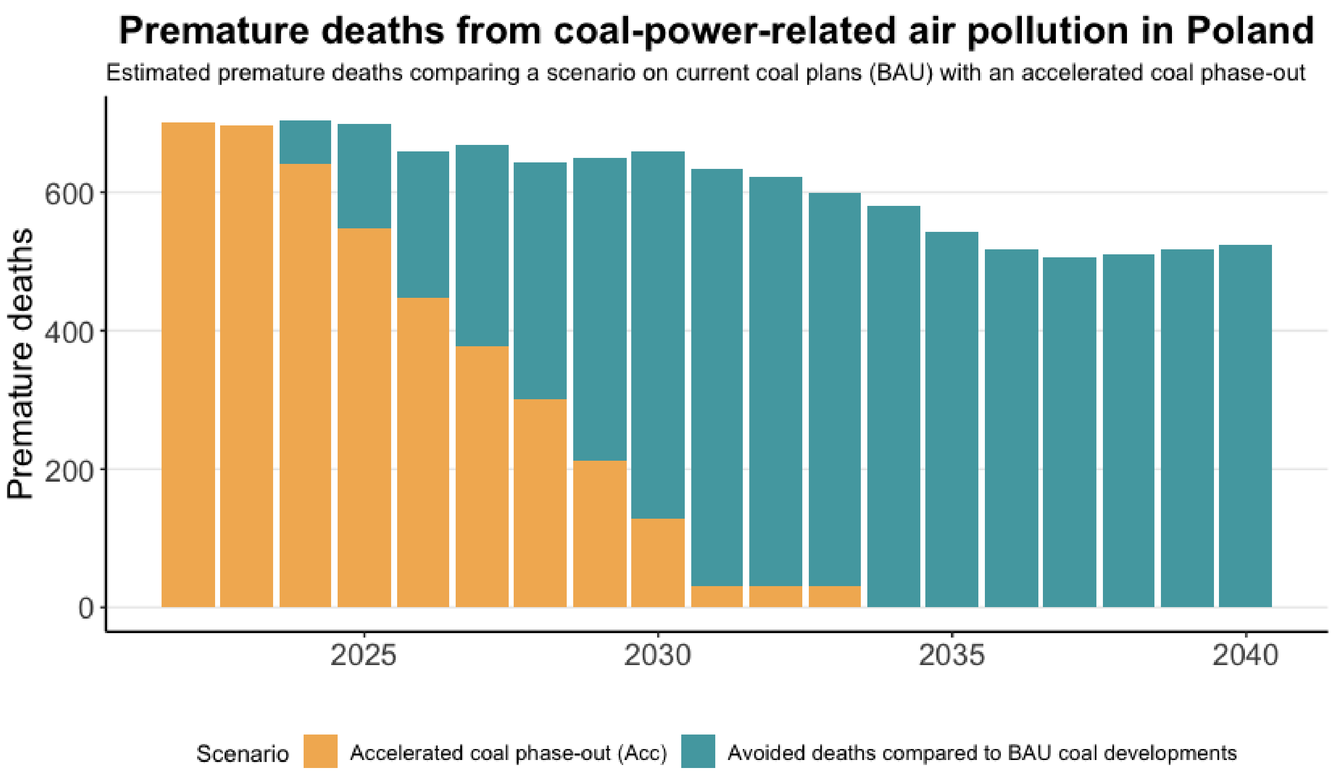

Figure 20: Comparing the estimates premature deaths related to coal-fired power generation for an accelerated coal phase out scenario with a scenario on current coal plans

3.1.2 Results by scenario and disease type

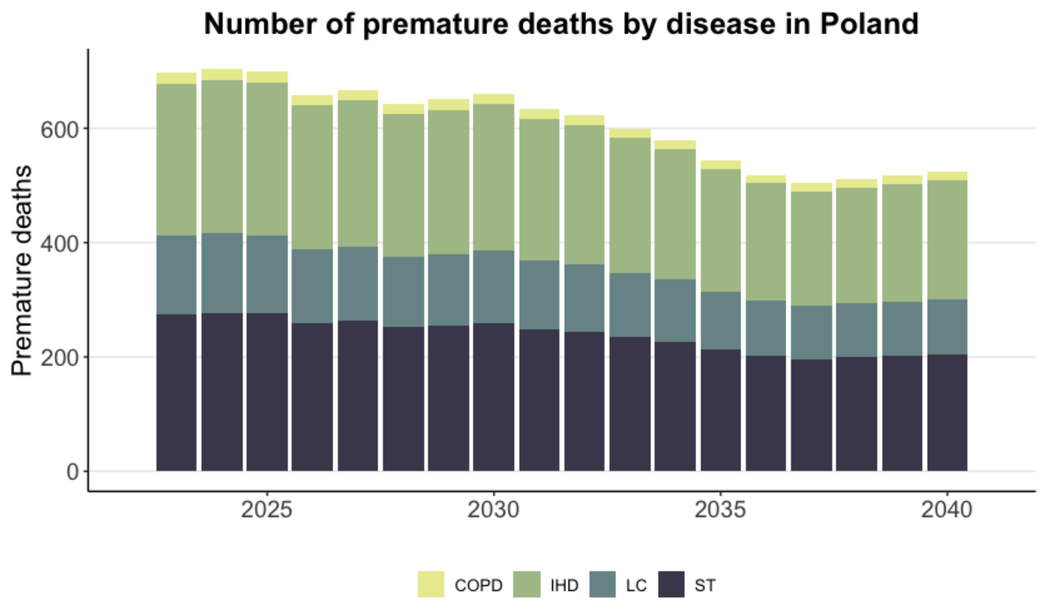

Figure 21: BAU Poland – Estimated premature deaths from coal-fired air pollution by type of disease

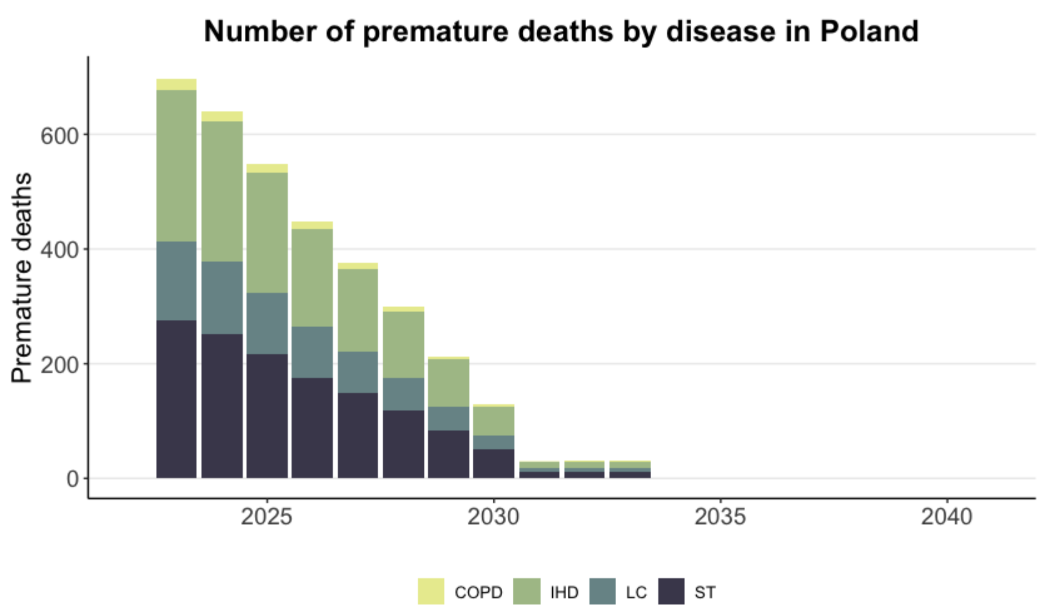

Figure 22: Accelerated coal phase out scenario Poland – Estimated premature deaths from coal-fired air pollution by type of disease

3.2 Pakistan – Results

3.2.1 Comparing premature deaths for the Acc and the BAU scenario

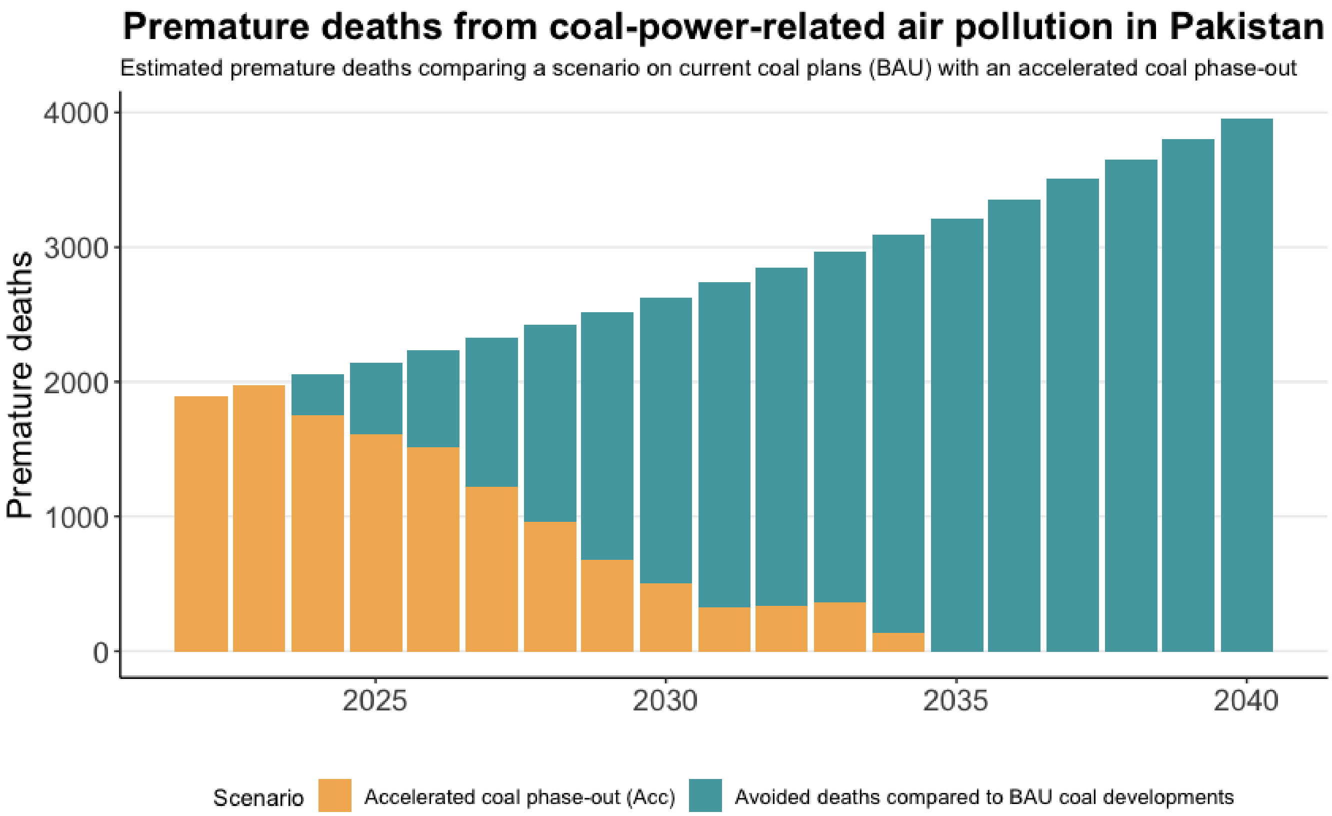

Figure 23: Comparing the estimates premature deaths related to coal-fired power generation for an accelerated coal phase out scenario with a scenario on current coal plans

3.2.2 Results by scenario and disease type

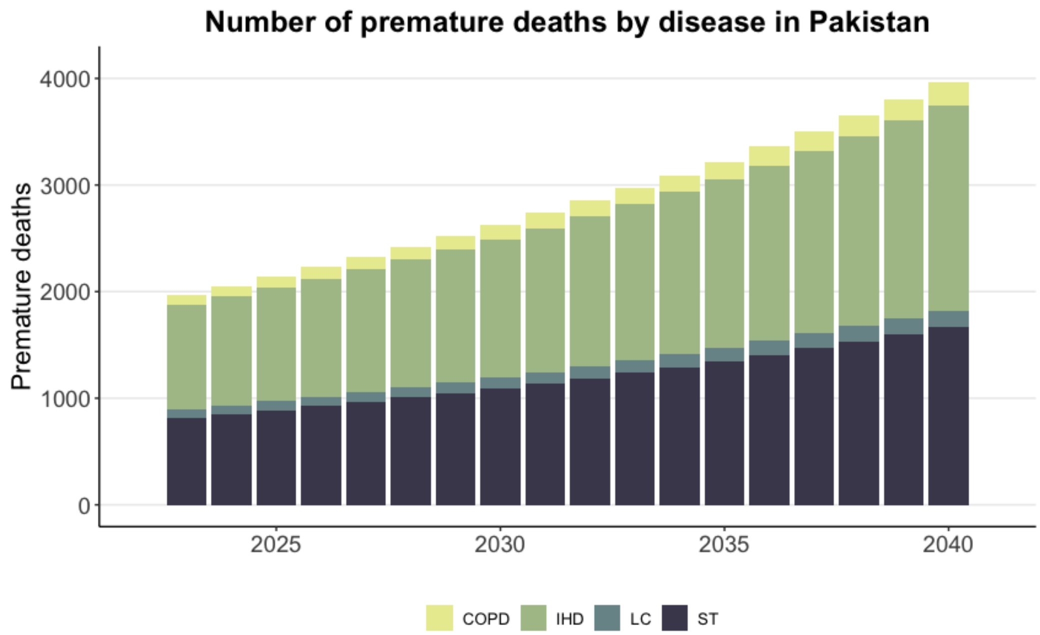

Figure 24: BAU Pakistan – Estimated premature deaths from coal-fired air pollution by type of disease

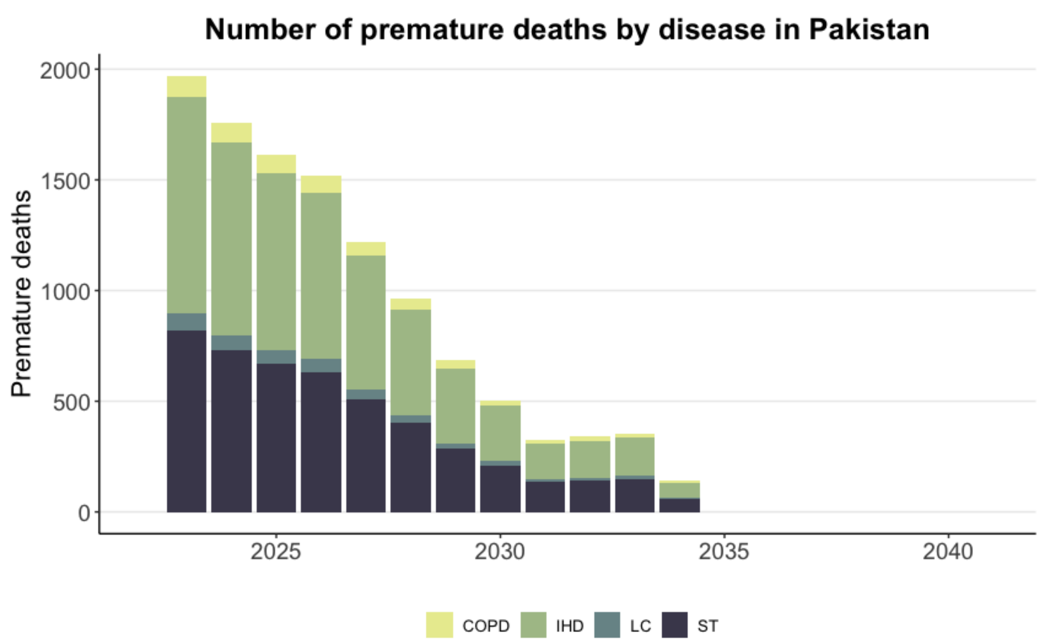

Figure 25: Accelerated coal phase out scenario Pakistan – Estimated premature deaths from coal-fired air pollution by type of disease

4 References

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