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Employment opportunities from a coal-to-renewables transition in South Korea

National and provincial level employment impacts of replacing coal-fired power generation with solar, wind and storage

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Summary

In this work, we assess the direct employment effects at the national and provincial level for two scenarios focusing on coal in the power sector:

- a Current Policies scenario (*CPol* scenario) that follows South Korea's 9th Basic Plan for Electricity Demand and Supply, which lays out its planned capacity for its power sector, and
- a Coal-to-Renewables (and storage) transition scenario (*CtR* scenario), where coal is phased out from the electricity system by 2029 and replaced by renewables and storage.

The provincial level analysis in this work could inform discussions on alternative local employment options to facilitate a just transition in South Korea.

Key findings

- The estimated average job potential of the Coal-to-Renewables scenario exceeds that of the Current Policy scenario by almost 2.8 times from 2020 to 2030, summing up all job types and technologies that were assessed.
- Overall, in the Coal-to-Renewables scenario, we find South Korea could create more than 62,000 more jobs per year on average in the first half of this decade, and more than 92,000 jobs per year in the second half of the decade, when compared to current policy plans.
- We find job losses related to coal phase out would be outweighed by newly created jobs in renewable energy and related storage technologies for all provinces across South Korea.
- Importantly, even provinces reliant on coal could obtain a net benefit from newly created jobs in construction and installation, operation and maintenance of solar PV and wind as well as related storage, outweighing fossil fuel-related job losses.
- Provinces in which coal power plants are located could boost their employment potential by a factor of at least 1.3 (Incheon, Gangwon-do), 1.4 (Chungcheongnam-do, Gyeongsangnam-do) and 3.1 (Jeollanam-do) by taking advantage of their renewable energy potential, compared to current policy plans.
- Roughly 42,500 additional jobs per year on average could be created in local manufacturing of renewable energy technology parts and in relation to offshore wind and hydrogen, which are not assigned to provinces in our analysis, and not included in the provincial level job-gains.
- The overall job creation potential in the operation and maintenance of newly installed renewable and storage installations alone could outweigh the job losses from closing all coal power plants across South Korea by 2029.
- Policies to facilitate green job creation are essential to generate support for a coal phase out before 2030 in South Korea, in line with the Paris Agreement.

The need for a coal-to-renewables transition

South Korea ratified the Paris Agreement on 3 November 2016, committing to make a fair and ambitious contribution to limit global warming to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels. The Intergovernmental Panel on Climate Change's (IPCC) Special Report on 1.5°C highlights that global greenhouse gas emissions will need to decline about 45% below 2010 levels over the next decade to keep the 1.5°C warming limit in sight [1].

Phasing out fossil fuels from the energy system is key to achieving such rapid emission reductions.

In previous work, Climate Analytics has demonstrated that in order to meet the Paris Agreement 1.5° temperature limit, globally unabated coal-fired power generation will need to be phased out by 2040, and at least a decade earlier in OECD countries such as South Korea [2]; this has been confirmed in the recent "Net Zero by 2050" roadmap released by the International Energy Agency (IEA), which also highlighted that no new gas infrastructure should be built. [3] For South Korea, analyses by Climate Analytics[1] as well as by others[2] conclude that coal would need to be phased out before 2030 to be Paris compatible.

However, despite its stated commitment to the Paris Agreement, South Korea's targets and policies paint quite a different picture.

In 2019, South Korea was the ninth largest carbon emitter in the world, with 2017 per-capita CO_2 emissions of 12.15 tonnes CO_2/person [4]. South Korea aims to become carbon neutral by 2050; however its NDC-target, pledging 24.4% reduction in total greenhouse gas emissions by 2030 relative to 2017 levels, is rated as "highly insufficient" by the Climate Action Tracker[3][5], and its 9th Basic Plan[4] still sees a continued role for coal generation, with 29 GW of coal power projected to be online in 2034.

This is at odds with the need for South Korea to phase out coal from its electricity system before 2030 to be in line with what would be needed for achieving the Paris Agreement [6,7]. The planned expansion of gas power plants envisaged is also inconsistent with benchmarks demonstrating a progressively diminishing role for natural gas in South Korea's power system in a 1.5°C consistent future [6]. In this brief, we focus on the phase out of coal

[1] Climate Analytics in collaboration with Solutions for our Climate (SFOC) concluded that coal would need to be phased out in by 2029 in South Korea to be on track for the Paris Agreement [26]. Generally, South Korea would need to move away from fossil fuels within the next decade to be on an emission pathway which is in line with the Paris agreement as another recent analysis by Climate Analytics shows [27].

[2] Chungnam National University, the Carbon Tracker Initiative and SFOC indicate in a recent analysis that a coal phase out by 2028 is the most economical choice [28].

[3] NDCs (Nationally Determined Contributions) rated "highly insufficient" by the Climate Action Tracker are NDCs that are assessed to be falling outside the country's "fair share range" and are not in line with holding warming below 2°C – even less to the Paris Agreement's stronger 1.5°C limit. If NDCs from all governments were rated within this category, global mean temperature increase would reach between 3°C and 4°C.

[4] The 9th Basic Plan for Electricity Demand and Supply, released by the Ministry of Trade, Industry and Energy (MOTIE) in December 2020, outlines Korea's basic energy policy for the years 2020-2034, including projections for energy demand developments and envisaged capacity developments for different electricity generation technology groups until the end of the planning period in 2034.

power generation and replacing it with solar and wind power generation as well as storage for given policy plans related to capacity developments of other technologies. The analysis for a natural gas phase out is beyond the scope of this study.

A necessary, rapid phase out of coal has raised concerns about job losses and negative economic impacts in affected regions where power plants are located. These concerns can be a key barrier to increasing policy stringency in many regions where coal or other conventional energy sources historically have played a large role. The need for a Just Transition to respond to transformational changes societies are facing to deal with climate change has to be proactively addressed by governments.

A recent body of literature suggests that there would be substantial employment benefits from transitioning to renewable energy and phasing out conventional energy sources in Korea (e.g. Hong et al. (2019) [8], SNU (2019) [9], Korea Labour Institute (2017) [10]).

In this brief, we explore the direct employment impacts[5] of a coal-to-renewable (and storage) transition in South Korea in line with a Paris compatible coal phase out before 2030. We compare this with the projected outcomes under current policies (that are modelled in line with the 9th Basic Plan).

By identifying the opportunity presented by such a coal-to-renewable transition, this brief provides insights on employment impacts that are of relevance for policymaking by assessing the employment impacts from a coal phase out in line with the Paris Agreement, and going beyond the findings of existing studies to look at provincial level impacts.

[5] Direct employment refers to employment that is generated specifically by the activities of the electricity sector, without accounting for employment in other sectors created by production linkages (i.e. not accounting for indirect employment effects further down the supply chains or induced employment effects by additional income spend throughout the economy). Jobs are estimated in full-time equivalents and job years (for construction and installation and manufacturing) or jobs per year (operation and maintenance) meaning that part time or temporal work is also represented as long as the type of job falls into the definition of a direct job.

Scenarios for a coal phase out in South Korea

In this brief we present two scenarios that represent different trajectories with regard to the role and timing of phasing out coal-fired power generation in South Korea, and assess the resulting effect on employment.

The first scenario, the current policies (*CPol*) scenario, is largely based on the projections (both for electricity demand and technology-related capacity development) from the 9th Basic Plan for Electricity Demand and Supply (9th Basic Plan) [11]. This scenario provides the reference against which we compare a Coal-to-Renewable (*CtR*) scenario.

The *CtR* scenario sees coal phased out from the power system by 2029 (in line with benchmarks consistent with the Paris Agreement), and a direct replacement of phased out coal capacity with renewables coupled with storage. We outline the design of the scenarios briefly in.

Table 1 below and the methodology in Box 1, with a further, detailed description in the Technical Annex accompanying this brief.

Table 1 *Overview on assumptions and scenario design*

Scenario (label)	Assumptions and scenario design
Current Policies (*CPol*)	• **Coal power capacity:** The coal power trajectory follows policy plans defining envisioned shut down (or conversion) dates by unit. Total installed capacity peaks in 2024, declining thereafter. 24 units are converted from coal to gas power plants by 2034 as defined in the 9th Basic Plan. • **Renewables and storage capacity:** As defined in the 9th Basic Plan, total installed renewable energy capacities increase to 78 GW in 2034. To obtain projections on total and added capacities differentiating between different renewable energy technologies, we use the techno-economic electricity system model PyPSA (see box on methodology as well as Technical Annex for details).
Coal-to-Renewable (*CtR*)	• **Coal power capacity:** Coal-fired power capacity follows a Paris Agreement consistent unit-level decommissioning schedule presented in previous work (see also reference [12] as well as Technical Annex of this brief). Using a 'regulator' perspective, the unit-level

	phase out schedule prioritises the shut-down based on the unit-specific carbon intensity. • **Renewables and storage capacity:** Power generation capacities for renewable energy and related storage needs required to replace coal are derived using the techno-economic electricity system model PyPSA (see Box 1 on methodology as well as Technical Annex for details)
Shared assumptions	• **Electricity demand:** Follows the projections for demand from the 9th Basic Plan. It is assumed that electricity supply needs to cover demand plus a stability reserve, which increases over time from 17% to 22%.[6] • **Renewable costs:** For assumptions on renewable energy costs used as an input for the techno-economic optimisation of the electricity system, we assume medium renewable energy cost projections[7] provided by IRENA (see Technical Annex). • **Other technologies (i.e., apart from coal and renewables):** Power generation capacities for other technologies are also modelled as defined in the 9th Basic Plan. This includes the categories nuclear, natural gas, pumped hydro, as well as other less relevant technologies.

An important consequence of our modelling assumptions with respect to capacity developments of other technologies (i.e. not coal, renewables or storage) is that the related employment would not differ between the two scenarios as capacity developments follow the same trajectory and can be disregarded for this analysis as there are no differences in employment impacts when comparing the two scenarios resulting from these other technologies.

Further work that evaluates a gas phase out trajectory aligned with the Paris Agreement would be necessary to evaluate employment effects of a Paris aligned energy system transformation. We present a brief overview of the methodology applied in this brief in the box below, with further details in the Technical Annex.

[6] Transmission and distribution of electricity and related jobs are not explicitly modelled. Since transmission costs represent a small fraction (5-10%) compared to the rest of the electricity, their inclusion would not have significantly altered the results. The distribution system will need a significant expansion driven by the specific electrification of transport and heating implemented [29], which is outside of the scope of the model presented in this report.

[7] We assume medium costs instead of low renewable energy costs also provided by IRENA to provide more conservative estimates.

Box 1: Methodology

In this brief, we estimate the national and provincial employment impacts of an accelerated phase out of coal from South Korea's electricity system, building off previous work where we modelled a unit-level phase out schedules consistent with the Paris Agreement [12]. We aim to address the question, "what would be the employment effects of a coal-to-renewable transition in the South Korean electricity system?".

We first assessed the subnational techno-economic potential of solar PV rooftop, PV open field (utility-scale), offshore wind and onshore wind, based on modelling with high-resolution gridded data (see Technical Annex for more details).

The resulting spatially-explicit information on regional solar and wind potentials allows us to identify the cost and maximum potential of renewable capacity in each province. We use this data, in addition to the unit-level phase out schedule, as an input to a model based on the PyPSA (Python for Power System Analysis) framework to identify the optimal location and amount of these technologies (from a techno-economic perspective), as well as associated storage needs necessary to replace coal. We assume that the electricity demand trajectory is exogenously given by policy plans (in the 9th Basic Plan) and is identical in both scenarios to allow better comparison of employment impacts. This implies that electricity demand increases resulting from sector coupling and the electrification of other sectors such as transport are not taken into account in this study. Focusing on replacing coal power generation with solar and wind power generation and storage, we assume that the capacity trajectories of other technologies follow policy plans as outlined in the 9th Basic Plans to highlight the impacts of a coal phase out. Thus, while the PyPSA model takes the technology mix of the whole South Korean power system into account, this study does not aim to model a 100% renewable energy trajectory nor do we assess how the trajectories for natural gas[8] or other technologies would need to differ from current policy plans to be compatible with the Paris Agreement.

We assign the capacities to the province level exploiting information from the spatially explicit modelling of solar and wind potentials as well as the geolocation of coal power plants. The scenarios are constructed till 2034, but we present and assess results till 2030 (by when coal is completely replaced in the *CtR* scenario).

We calculate the employment effects (direct jobs[9] at the national, and subnational level) of both the *CPol* and *CtR* scenarios, building on an employment factor approach that has previously been applied in Rutovitz et al. (2015) and Ram et al. (2020) [13,14]. We tailor this approach to the South Korean context by deriving employment factors for South

[8] The 9th Basic Plan foresees natural gas capacities to increase in the nearer term before declining in the longer term. For our analysis, we follow the policy plans apart from the Coal-to-Renewables scenario not transforming any coal power plants into natural gas power plants as in the case in the Current Policy Scenario.

[9] See also footnote 5.

Korea where data availability permits (see section 3.3 of the Technical Annex for a detailed description).

We apply these factors to the capacity mix derived using PyPSA to derive estimates for jobs related to local manufacturing, construction and installation, operation and maintenance (and decommissioning – see Box 3) of power generation capacities.

Employment estimates are assigned to the province level in line with the capacity mix derived using PyPSA for location-dependent jobs, i.e., jobs in construction and installation as well as operation and maintenance of coal, natural gas, solar PV (small-scale and utility scale), battery storage (small-scale and utility-scale) and onshore wind. Jobs not directly attributable to specific provinces, i.e., jobs in South Korean manufacturing (all technologies) and jobs in offshore wind and hydrogen-related technologies (all job types), are considered at the national level only.

The resulting capacity mixes (only capacity deployment that has an effect on the employment results is represented) are presented in
Figure *1* for the two scenarios.[10] The Current Policies (*CPol*) scenario foresees a slight increase in coal capacities with units currently under construction coming online until 2024. In line with the 9th Basic Plan, selected coal units will be converted to run on natural gas reaching 8 GW *converted* natural gas capacity by 2030. In order to meet growing electricity demand, limited amounts of utility-scale solar PV, onshore wind and utility-scale battery storage are also added to the system.

The Coal-to-Renewable (*CtR*) scenario is characterised by a stringent reduction of coal capacity based on the unit-level decommissioning schedule and a complete phaseout of coal by 2029. In the near term, coal is replaced by onshore wind, utility-scale solar PV and utility-scale battery storage. In the second half of the decade, additional technologies including rooftop solar PV systems and associated prosumer-scale batteries, offshore wind as well as long-term storage options in the form of hydrogen (see also Box 2) are added to the system.

[10] See Technical Annex for a full display of capacities as modelled, including capacity described in .

Table 1 of this brief which are not considered in the employment analysis.

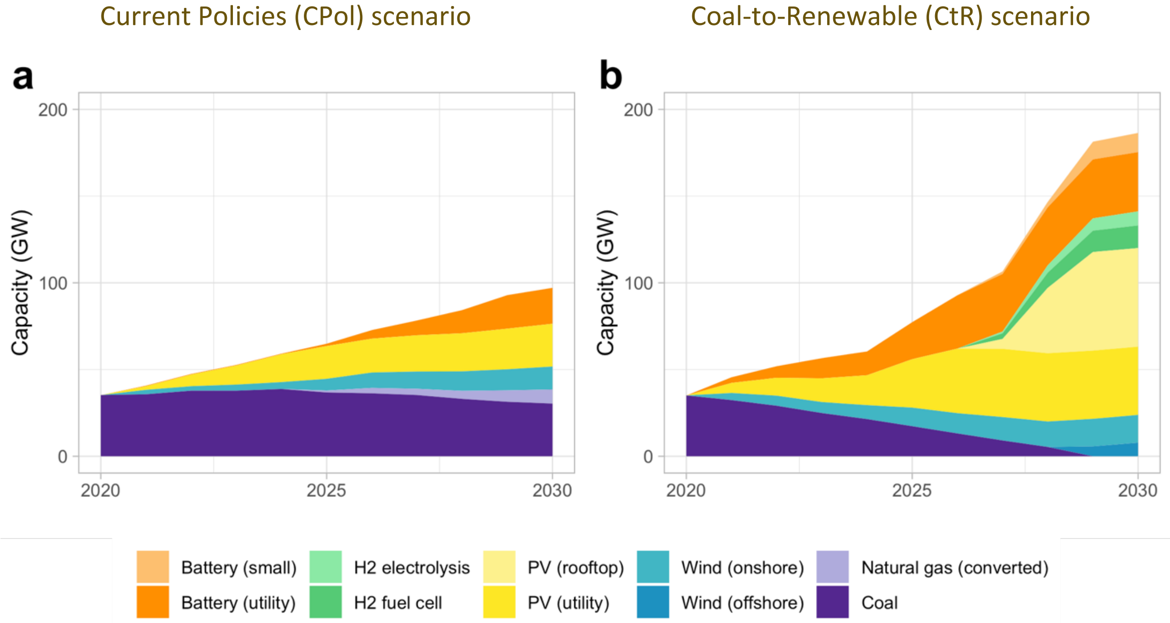

Figure 1 *Electricity generation capacity developments under the CPol (Panel a) and the CtR (Panel b) scenarios directly related to phasing out coal as considered in the employment analysis. Hydrogen storage capacity (in MWh) is not shown.*

Box 2: Hydrogen

Hydrogen has the potential to displace fossil fuels in many energy-dependent processes, like aviation and shipping, iron and steel processing or cement production. It is made either by splitting water with electricity (*electrolysis*) or from fossil fuels or biomass (with *reforming* or *pyrolysis*), which releases their carbon content. Hydrogen produced by electrolysis from renewable energy is called *green hydrogen* and is the only carbon-free option for hydrogen production, in contrast to *grey hydrogen* produced from fossil fuels and *blue hydrogen* which combines hydrogen production from fossil fuels with carbon capture and storage (CCS).

In the power system, hydrogen complements variable renewable energy generation as a storage option. Hydrogen produced with electrolysis during periods with higher renewable generation can be stored in underground caverns, tanks or pipes. In fuel cells, or retrofitted gas turbines, hydrogen can be transformed back to electricity when needed. Since the conversions lose up to two thirds of the energy (35-41% of round-trip efficiency), its efficient use is limited to long-term storage for weeks and seasons and no substitute for battery storage (which can store electricity for shorter periods).

The underlying analysis in this work is restricted to the production of *green hydrogen* from renewable sources in electrolysers and its reconversion to electricity in fuel cells. Power capacity developments (approximately 8 GW electrolyser and 13 GW fuel cells in 2030) are shown in

Figure 1. The energy capacity of the modelled pipe storage (ca. 60 kt H2 in 2030) is not represented.
A recent report by IRENA puts the global need for green hydrogen production capacity compatible with a Paris Agreement temperature limit at 270 GW by 2030 [15]. Globally, large-scale green hydrogen production plants under development, including private initiatives, already exceed 200 GW [16]. While an increasing number of countries have adopted hydrogen policies, the most ambitious government targets for green hydrogen production are currently set by the EU, which aims to build at least 40 GW of electrolysers by 2030 [17], and Chile, which aims to build 25 GW electrolysers by 2030 [18].

While South Korea's Hydrogen Economy Roadmap launched in 2019 aims to increase the use of hydrogen in transport and the development of hydrogen fuel cells, no explicit target for electrolyser capacity has yet been defined [19].

Significant uncertainty remains around the availability of production facilities and storage infrastructure, as well as the exact level of cost reductions achievable by scaling-up hydrogen production.

To ensure the robustness of our results with regard to alternative assumptions on hydrogen development, we present employment estimates for a sensitivity analysis with only 1.4 GW of electrolysers in 2030 and a related moderate increase of electricity prices in the Technical Annex. For this sensitivity analysis we assume that fuel cells are defined to follow a constant growth path in line with the target of fuel cell power plants in 2040, with electrolyser and storage capacity developed accordingly. Figure 6 in the Technical Annex shows that for this slower build-out of hydrogen, the estimated employment impacts are higher than in the main *CtR* scenarios shown in this brief. While hydrogen-related jobs are about two-thirds lower, over 20,000 additional jobs per year associated with batteries and offshore wind alone are created associated with additional capacities to compensate the slower growth in hydrogen storage.

Employment benefits of replacing coal power with wind and solar

Total employment impacts

Phasing out coal before 2030 and replacing it with renewables combined with storage results in a marked increase in job creation compared to the *CPol* scenario, particularly in the second half of the decade (2025-2030). Over the whole decade (2020 to 2030) and across technologies and job types, we estimate close to 42,500 jobs per year on average in the *CPol* scenario compared to almost 120,000 jobs per year on average in the CtR scenario. The estimated average job potential of the Coal-to-Renewables scenario is thus exceeding the job potential of the *CPol* scenario about 2.8 times.

While both scenarios (*CtR* and *CPol*) see near-term employment driven largely by scaling up of onshore wind, utility-scale solar PV and related utility-scale batteries, the *CtR* scenario shows more rapid growth. In the second half of the decade, jobs in the *CtR* scenario are also created by the development of rooftop solar PV and associated small-scale batteries, offshore wind and hydrogen-related storage.

In both scenarios, the expansion of renewable energy and storage installations leads to significant job creation in the local manufacturing as well construction and installation of renewable energy and storage installations. South Korea's strong market position in manufacturing batteries, as well as the existing local experience in manufacturing of solar panels, means that increasing renewable energy capacity to replace coal could lead to significant job creation in manufacturing, construction and installation, which we see in the *CtR* scenario.

In contrast, manufacturing and construction and installation employment generation is limited in the *CPol* scenario until 2025. It increases in the second half of the decade, with planned construction of renewable and storage capacity leading to considerable job creation in both manufacturing and construction and installation in both scenarios. However, job creation in the *CtR* scenario substantially exceeds that in the *CPol* scenario.

Towards the end of the decade, when the last coal unit is replaced by renewable energy and related storage in *CtR* scenario and employment creation in local manufacturing and construction and installation to replace coal slows down, employment in operation and maintenance plays an increasing role providing job opportunities over the lifetime of the installed renewables-based power generation infrastructure. This is substantially higher than the estimated jobs in operation and maintenance in the *CPol* scenario.

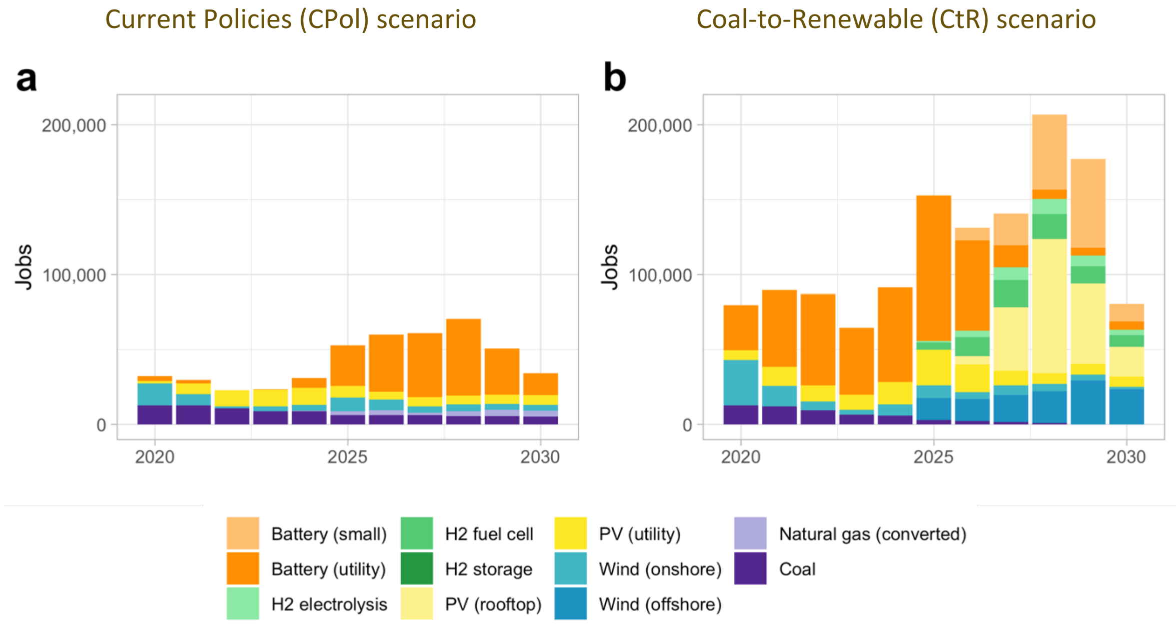

Figure 2 *Aggregated total employment impacts by power generation technology aggregated over job types, comparing job estimates for the CPol scenario and the CtR scenario. Note that employment shown here focuses on jobs impacts affected by the transition to replace coal power generation, while jobs related to capacity that is assumed to be the same across scenarios are not shown.*

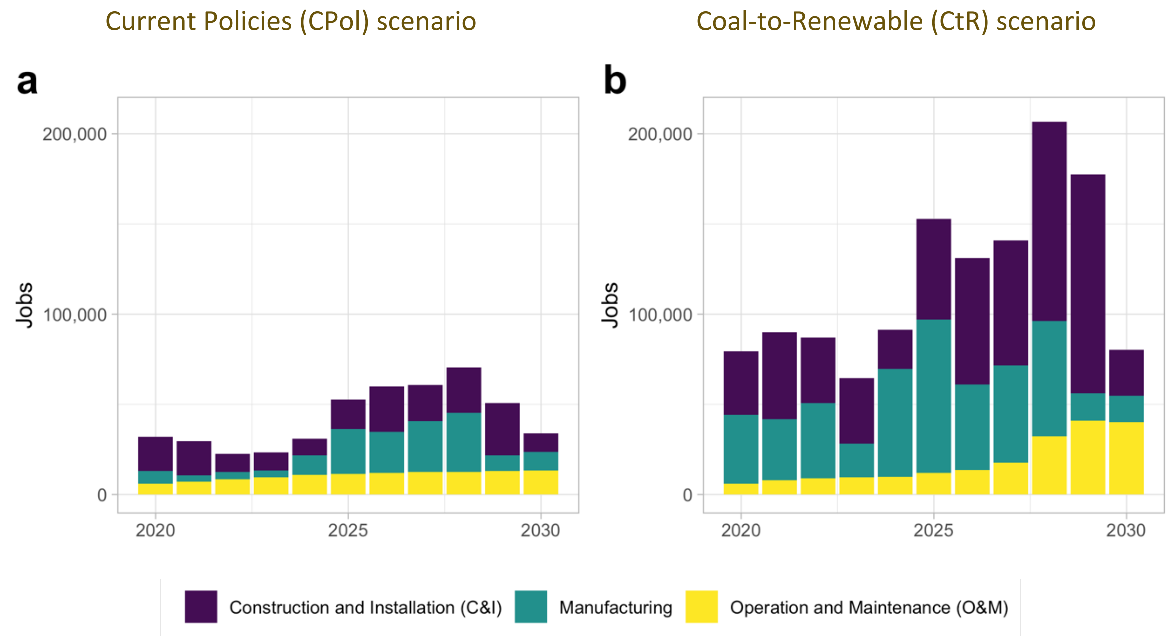

Figure 3 *Aggregated total employment impacts by job type aggregated across all considered technologies, comparing job estimates for the CPol scenario and the CtR scenario. Note that employment shown here focuses on job impacts affected by the transition to replace coal power generation, while jobs related to capacity that is assumed to be the same across scenarios are not shown.*

Employment impacts by job type and technology

The composition of jobs varies depending on the technology deployed. For instance, the majority of coal-related jobs are in operation and maintenance (O&M) of coal-fired power plants, with around 6000 people employed nationwide at the end of 2020.[11]

In the *CPol* scenario, O&M jobs are projected to develop in line with coal capacity developments with a slight increase until 2024, and steadily be replaced by jobs related to natural gas in the second half of the decade as selected coal-fired power plants are retrofitted to burn natural gas in line with the 9th Basic Plan (Figure 3). As a slowly increasing amount of solar PV, onshore wind capacity and related battery storage capacity are installed in the *CPol* scenario, employment in operation and maintenance related to renewable energy slowly increases, but remains at a comparatively low level until 2030.

In the *CtR* scenario, with coal-fired power generation being phased out by 2029 and no coal-to-gas plant conversions, coal O&M employment declines steadily and vanishes by 2030 - however, new O&M jobs related to renewable energy are created, outweighing the O&M job losses related to coal.

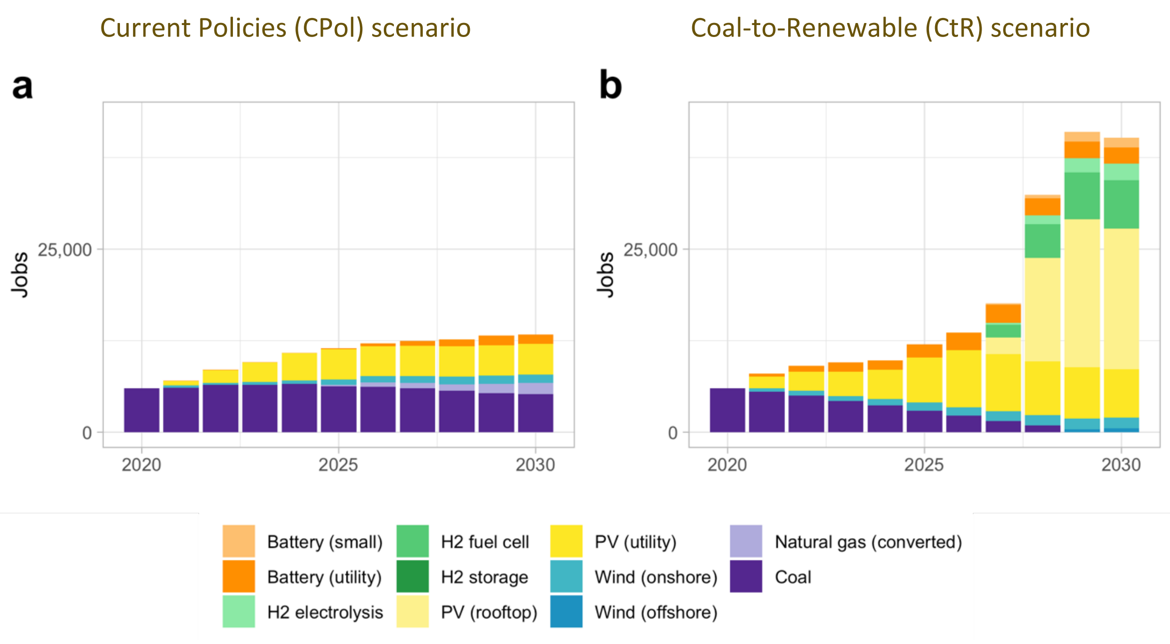

Figure 4 *Coal phase out related employment impacts in operation and maintenance comparing estimates for the CPol scenario and the CtR scenario. Note that employment shown here focuses on job impacts affected by the transition to replace coal power generation, while jobs related to capacity that is assumed to be the same across scenarios are not shown.*

While the total number of O&M jobs in the *CPol* scenario and in the *CtR* scenario are at a comparable level until the middle of the decade, employment potential in O&M is

[11] Current employment statistics in coal power plants have been reported by the power plant owners to the parliament member's office of the National Assembly. The data has been shared with the authors by a national assembly member who is part of the Trade, Industry, Energy, SMEs and Start-ups Committee.

considerably higher in the *CtR* scenario compared to the *CPol* scenario in the second half of the decade. This is largely driven by the greater amount of installed capacity of solar PV and related battery storage towards 2030.

At the same time, new O&M jobs in hydrogen-related technologies will be created towards the end of the decade. Employment estimates related to hydrogen-related technologies should be interpreted with caution due to uncertainties surrounding the future costs and technological development; as well as the scarcity of empirical evidence on associated employment impacts.

Shifting away from coal while satisfying projected electricity demand requires building new capacity of different power generation and storage technologies. While the O&M jobs described above accrue over the lifetime of the respective installations once the power generation infrastructure is installed, there is additional potential for job creation in construction and installation (C&I) and local manufacturing resulting from the expansion of renewable energy capacity.

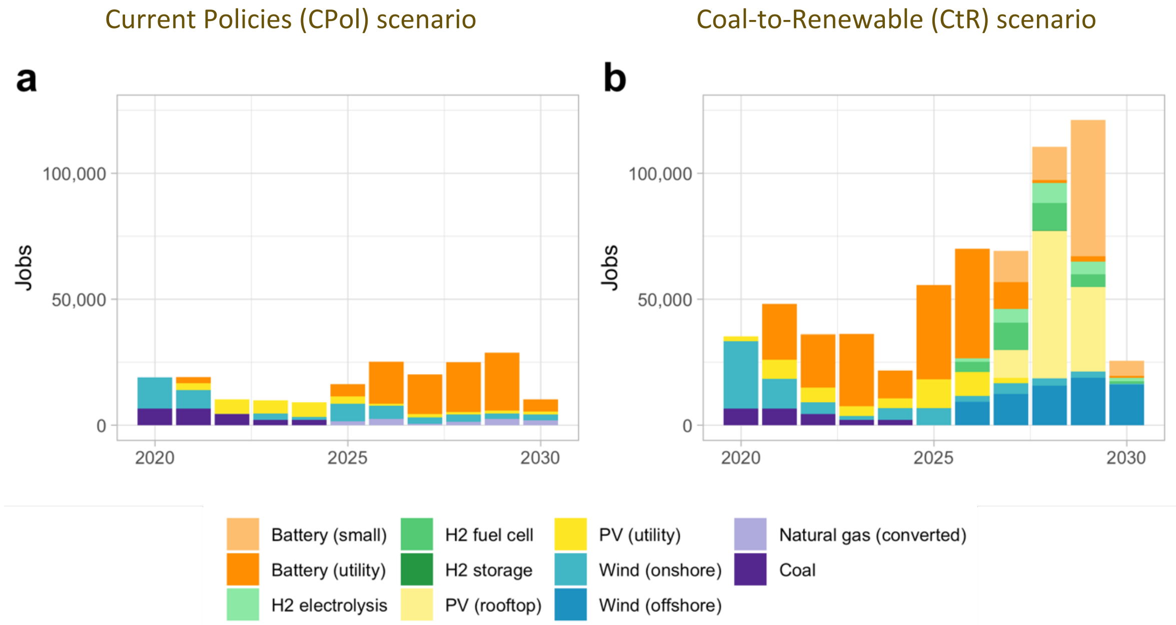

Figure 5 *Coal phase out related employment impacts in construction and installation comparing estimates for the CPol scenario and the CtR scenario. Note that employment shown here focus on jobs impacts affected by the transition to replace coal power generation, while jobs related to capacity that is assumed to be the same across scenarios is not shown.*[12]

[12] It should be noted that these C&I job estimates may not necessarily manifest exactly in the year indicated. Instead, our results aim to provide an estimate on the employment potential related to construction and installation of added capacity and differences between the *CPol* scenario and the *CtR* scenario. For example, our model estimates suggest substantial employment potential in C&I of onshore wind capacity and battery storage already in 2020 and 2021. This results from PyPSA optimising the build out trajectory for utility-scale solar and onshore wind as well as storage capacity from 2020 onwards, with the model results suggesting that a substantial ramping up of these capacities already in the very near-term would be optimal from a techno-economic perspective in both scenarios. As the construction and installation of new power generation infrastructure precedes the moment these new capacities go online in PyPSA, estimates on C&I-related jobs are also involving a certain lead time depending on the technology-specific construction duration. To model the job impacts per year related to C&I, we therefore assume that the related job years per MW of added capacity are distributed evenly across the assumed construction period including the year when the capacity goes online in the power system.

Our results show that the employment potential related to construction and installation of new power generation infrastructure to move away from coal is substantially higher in the *CtR* scenario compared to the *CPol* scenario, particularly in the second half of the decade (see
Figure 5).

In the *CtR* scenario, the estimated C&I employment potential in the first half of the decade is mainly driven by the expansion of onshore wind and utility-scale solar PV and related battery storage capacity, while in the second half, technologies such as offshore wind, rooftop solar PV and hydrogen technologies offer even greater C&I employment potential.

Jobs in construction and installation of coal are equivalent across scenarios and only play a minor role in the short term as no additional coal capacities apart from those under construction are planned in either scenario after 2024. Accounting for the envisaged conversion of coal power plants into natural gas power plants in the *CPol* scenario, a limited number of jobs in construction and installation of natural gas-fired power generation capacity can be expected.

However, given the significant stranded asset risks of natural gas power plants, this short-term gain in employment masks potential long-term detriments if those gas power plants built are no longer needed in the medium term.

Box 3: Decommissioning of coal-fired power generation infrastructure

Similar to the process of construction and installation creating jobs when new infrastructure is built, the process of phasing out coal can also generate jobs if phased out power generation infrastructure is actively decommissioned and dismantled as equipment needs to be removed and buildings need to be demolished or restructured. While we do not consider jobs related to decommissioning of coal power plants in the main analysis, the literature suggests that about 1.65 job years/MW of decommissioned coal power capacity could be created [14].[13]

Overall, nearly 41 GW of coal-fired generation capacity will need to retire within the next eight years in South Korea in order to be in line with a Paris agreement emission threshold. Applying the above-mentioned employment factor to approximate job creation potential related to the decommissioning of phased out coal infrastructure, we estimate that in the *CtR* scenario 68,000 job-years could be generated by

[13] For other power generation or storage technologies, one could also consider employment effects related to decommissioning or replacement at the end of the respective lifetime. As we focus on assessing the employment impacts of replacing existing coal power plants with newly added solar and wind installations (or in the case of the CPol Scenario partly transforming coal power plants into natural gas power plants), and the respective lifetimes of these technologies are above ten years, decommissioning or replacement of this newly built infrastructure falls outside of the time horizon considered for this analysis. In the longer term, there would also be employment potential related to replacing renewable energy infrastructure.

decommissioning of coal-fired generation capacities in the period 2020 to 2030, corresponding to more than 6000 jobs/year, on average.

In the *CPol* scenario, 8 GW of coal-fired power generation would be converted to natural gas-fired generation capacity and only 3 GW of coal would be phased out without conversion until 2030 following the policy plan of the 9th Basic Plan. While repowering a coal-fired power plant with natural gas-fired technology also requires coal-specific infrastructure to be decommissioned in order to be replaced by natural gas turbines, it may be expected that part of the critical infrastructure (such as transmission lines, cooling water systems and substations) may be kept for continued usage. While the conversion plan is yet to be fixed, in case part of the existing infrastructure is reused, it can be expected that less decommissioning jobs accrue in case of a conversion to natural gas compared to a full decommissioning of coal power plants.

Given limited empirical evidence for employment factors for such a conversion, we assume the same employment generation per MW decommissioned and therefore present an upper bound of decommissioning jobs in the case of conversion to gas. Summing up the resulting estimates for jobs years from 2020 to 2030 for the *CPol* scenario, about 18,000 job-years could be generated in the decommissioning of the coal infrastructure, which is to be converted to natural gas in the *CPol* scenario, corresponding to about 1600 jobs/year, on average.

For the technology parts which are manufactured within South Korea, the scaling up of new renewable energy capacity and storage involves jobs in local manufacturing of technology parts for added power generation capacities. Our results indicate that (see Figure 6).

To account for the fact that not all technology parts installed within South Korea are manufactured domestically, we build on available data to derive technology-specific assumptions on the share of local manufacturing and the development over time (see Technical Annex). Given the strong position of Korean battery manufacturers in the global market [20], the estimated job potential in local manufacturing is largely dominated by jobs in battery storage manufacturing assuming a local manufacturing share of 80%.

As the focus of this analysis is on the domestic coal phase out, we do not consider manufacturing jobs associated with exports of technology parts.

While there is uncertainty around the true local shares and their future development, especially for hydrogen-related storage (see Box 2), our results indicate the considerable job creation potential in manufacturing of renewable energy-related technology parts, which may still be shaped by policy making.

As the assumed technology-specific and time-specific local shares are the same across scenarios, differences between local manufacturing job estimates in the *CPol* scenario and the *CtR* scenario result from different priorities in which technologies to expand. Note that, similar to the results for C&I employment, these manufacturing jobs may not necessarily manifest exactly in the year indicated in Figure 6 as manufacturing is happening with a certain lead time, yet we aim to provide a picture of the order of magnitude of the job potential.[14]

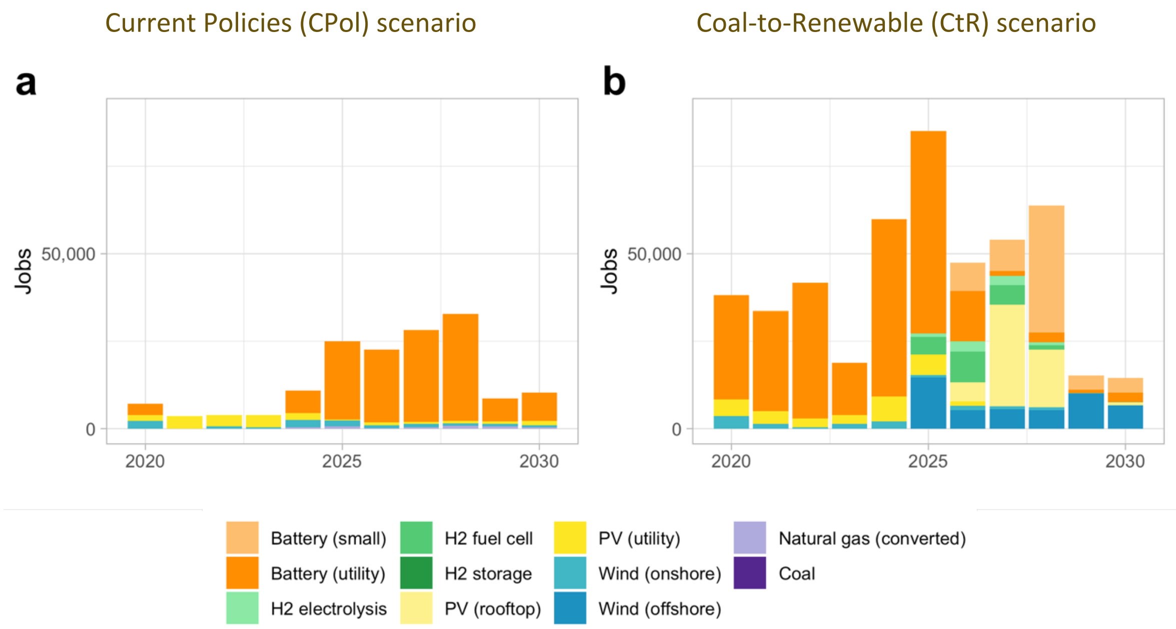

***Figure 6** Coal phase out related employment impacts in local manufacturing comparing estimates for the CPol scenario and the CtR scenario. Note that employment shown here focus on jobs impacts affected by the transition replacing coal power generation while jobs related to capacity that is assumed to be the same across scenarios is not shown.*

Local employment impacts

All Korean provinces experience a net increase in overall employment generation in the electricity sector in the *CtR* scenario compared with the *CPol* scenario (Figure 7). However, while the decline in coal-related jobs is outweighed by the large employment potential related to renewable energy technologies, it is important to consider the extent to which employees can take advantage of overall job creation potential and to shift from shrinking industries to new jobs in expanding and sustainable areas. In this context, it also matters in which regions coal jobs are lost while renewable energy-related jobs are created.

Provinces in Korea vary significantly in terms of their current electricity generation systems and their renewable resource potentials. Changes in employment will therefore also differ across provinces over the period from 2020 to 2030. While work in construction and installation as well as operation and maintenance need to happen on site and can thus be assigned to the province where the capacities are installed, employment in manufacturing is not necessarily created in the province where new installations are added. Also, the siting of

[14] We make the simplifying assumption that manufacturing jobs are created in the year before the respective technology-specific construction duration starts, partly leading to high estimates of job potential for the year 2020 already.

offshore wind generation and hydrogen storage may be chosen strategically[15] and therefore the related jobs are not directly attributed to specific provinces for our analysis. In this section, we therefore discuss primarily employment attributable to provinces, i.e. C&I and O&M in coal, natural gas (converted from coal), solar PV, onshore wind and battery storage.

Over the entire period from 2020 to 2030, with an accelerated phase out of coal and replacement by renewable energy entails the largest job gains for the province Gyeonggi-do (around +78,000 net additional job-years), followed by Gyeongsangbuk-do (about +57,000 net additional job-years) and Jeollanam-do (about +39,000 additional net job-years). Accounting for population size, this implies the largest local job gains for the province Jeollanam-do (around +2,300 net additional job-years per 100,000 inhabitants, i.e. about 210 jobs on average per year per 100,000 inhabitants), followed by Gyeongsangbuk-do (about +2,200 net additional job-years per 100,000 inhabitants, i.e. about 200 jobs on average per year per 100,000 inhabitants) and Chungcheongbuk-do (about +1,700 additional net job-years per 100,000 inhabitants, about 160 jobs on average per year per 100,000 inhabitants).

Renewable buildout varies over time, province and scenario. While a large part of renewable capacity is already built by 2025 in Gyeongsangbuk-do, the majority of employment generation in Gyeonggi-do and Jeollanam-do occurs in the second half of the decade, primarily from solar PV and battery-related jobs.

South Korea's coal-fired power plants are concentrated in five provinces, with more than half of current capacity located in Chungcheongnam-do. Other coal-fired power plants can be found in Gyeongsangnam-do, Incheon, Gangwon-do and Jeollanam-do. As to be expected, Chungcheongnam-do experiences the highest fossil-related coal and natural gas job losses in the *CtR* scenario compared to the *CPol* scenario, with more than 23,000 job-years less in fossil-fuel related employment[16] in the *CtR* scenario compared with the *CPol* scenario in the period 2020-2030.

However, these are outweighed by more than 48,000 additional job-years in the construction and installation and operation and maintenance of renewable and battery technologies between 2020-2030. While the *CtR* scenario also projects less coal and natural gas-related employment than in the *CPol* scenario for the provinces Gyeongsangnam-do, Incheon, Gangwon-do and Jeollanam-do, the number of job-years created in renewables and storage substantially exceeds fossil job losses (see Figure 7).

[15] Locations may be partly influenced by policy decisions.

[16] Jobs in local coal power plants as well as those jobs related to the envisaged conversion of coal to natural gas power plants following the 9th Basic Plan in the Current Policy scenario.

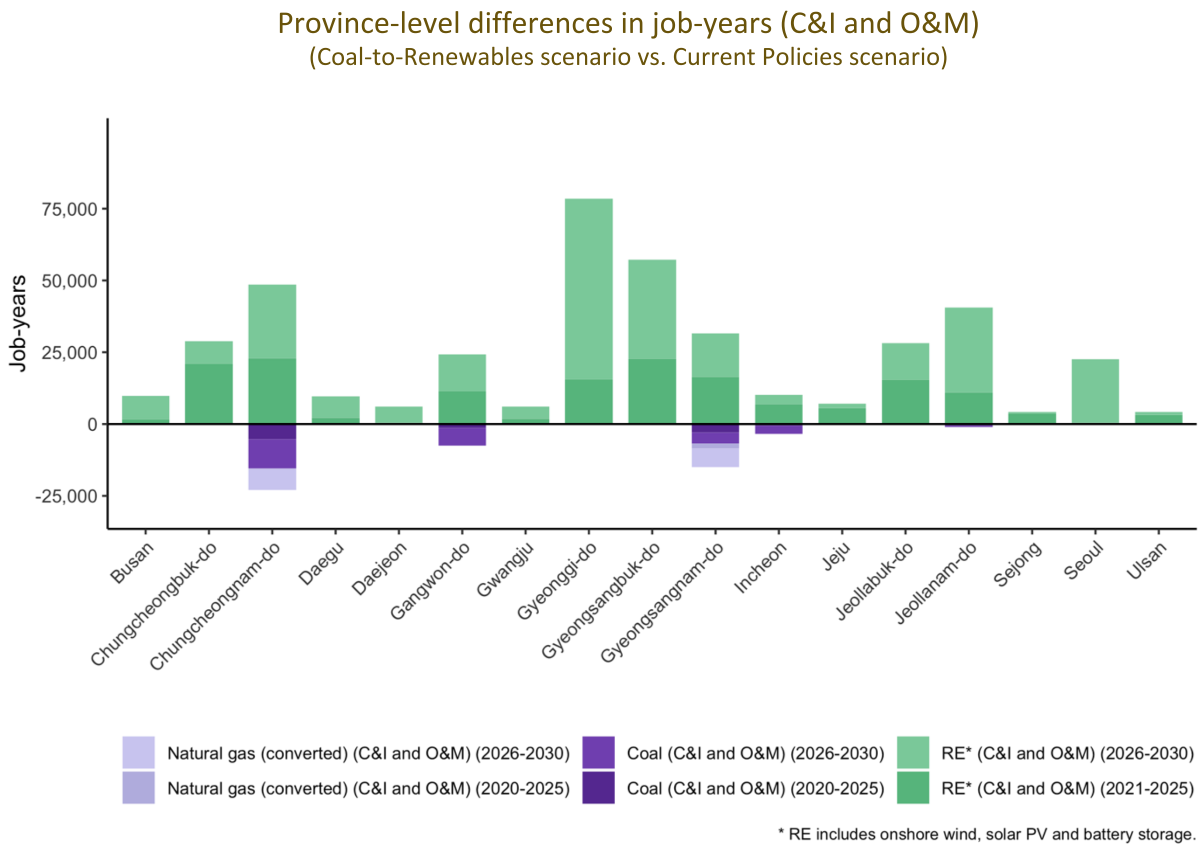

Figure 7 *Province-level employment differences comparing the job potential of the Coal-to-Renewable Scenario to the estimates jobs in the Current Policy Scenario. Numbers refer to job years for the periods indicated in the legend, comprising only job types attributable to provinces, i.e. C&I and O&M in coal, natural gas (converted from coal), solar PV, onshore wind and battery storage. Jobs that are not bound to the location of the installed power generation capacity are not included.*

On a per-capita basis, all provinces experience net job gains under the *CtR* scenario compared with a *CPol* scenario as employment generation in renewable technologies outweighs job losses in coal and gas-related employment (
Figure 8). Jeollanam-do will experience the largest benefits under the *CtR* scenario compared with the *CPol* scenario. In the period 2020-2030, more than 2300 *additional* job-years/100,000 inhabitants will be created in the province, while less than 100 job-years/100,000 inhabitants will be lost in coal-related jobs overall.

While, largest per-capita job losses in fossil-fuel related employment occur in Chungcheongnam-do, amounting to just over 1000 job-years/100,000 inhabitants, this province will also benefit from a net increase in overall C&I and O&M jobs corresponding to more than 2100 additional job-years/100,000 inhabitants in the *CtR* scenario compared to the current policy trajectory for the period 2020-2030.

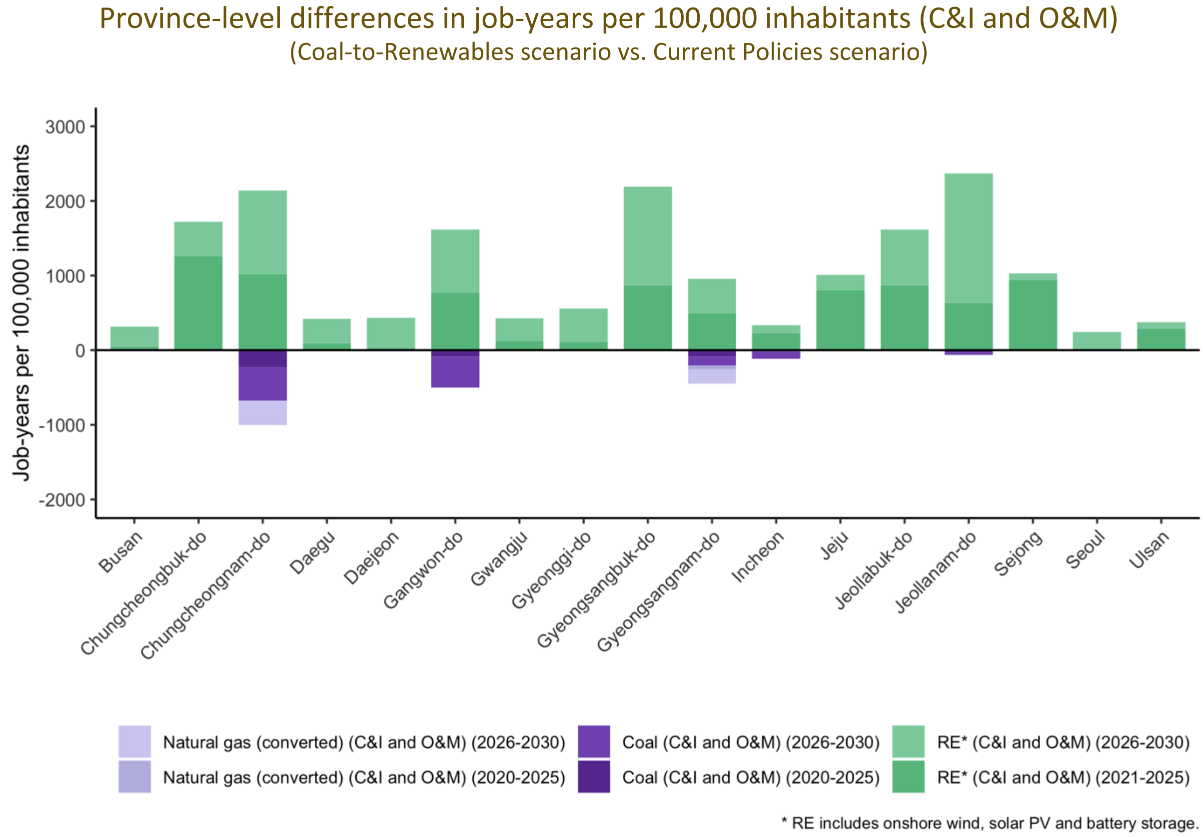

Figure 8 *Per capita (per 100,000 inhabitants) province-level employment differences comparing the job potential of the Coal-to-Renewable scenario to the estimates jobs in the Current Policy scenario (see also caption of Figure* ***7****).*

A map of the regional distribution of the job creation effects is shown in Figure 9 (2020 to 2030). Comparing the two scenarios separately in the short term (until 2025) and in the medium term (2026-2030) clearly shows the employment benefits of phasing out coal until 2029 and replacing it with renewable energy. All provinces, including those phasing out coal-fired power plants, see additional job creation both in the short term and in the medium term in the *CtR* scenario compared with the *CPol* scenario.

In the first half of the decade (not shown), the greatest relative employment benefits in the *CtR* scenario compared with the *CPol* scenario accrue in Jeollabuk-do, where employment potential in the *CtR* scenario exceeds that of the *CPol* scenario by a factor of six. The province showing the smallest job gain across the two scenarios in the first half of the decade is Gangwon-do, where still 1.3 times as many jobs are created in the *CtR* scenario compared with the *CPol* scenario.

In the second half of the decade, the relative difference in job-years created between the two scenarios is driven by the expansion of solar PV on rooftops accompanied with small batteries. Overall, all provinces show higher employment creation under the *CtR* scenario than under the current policy trajectory.[17] In the particular, densely populated provinces

[17] In the particular, densely populated provinces such as Seoul, Daejeon and Busan benefit from a substantially higher job creation potential under the *CtR* scenario than under the *CPol* scenario in the medium term. This is partly stemming

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2020-2030 job gains (C&I and O&M, in job-years) in CtR scenario compared to CPol scenario

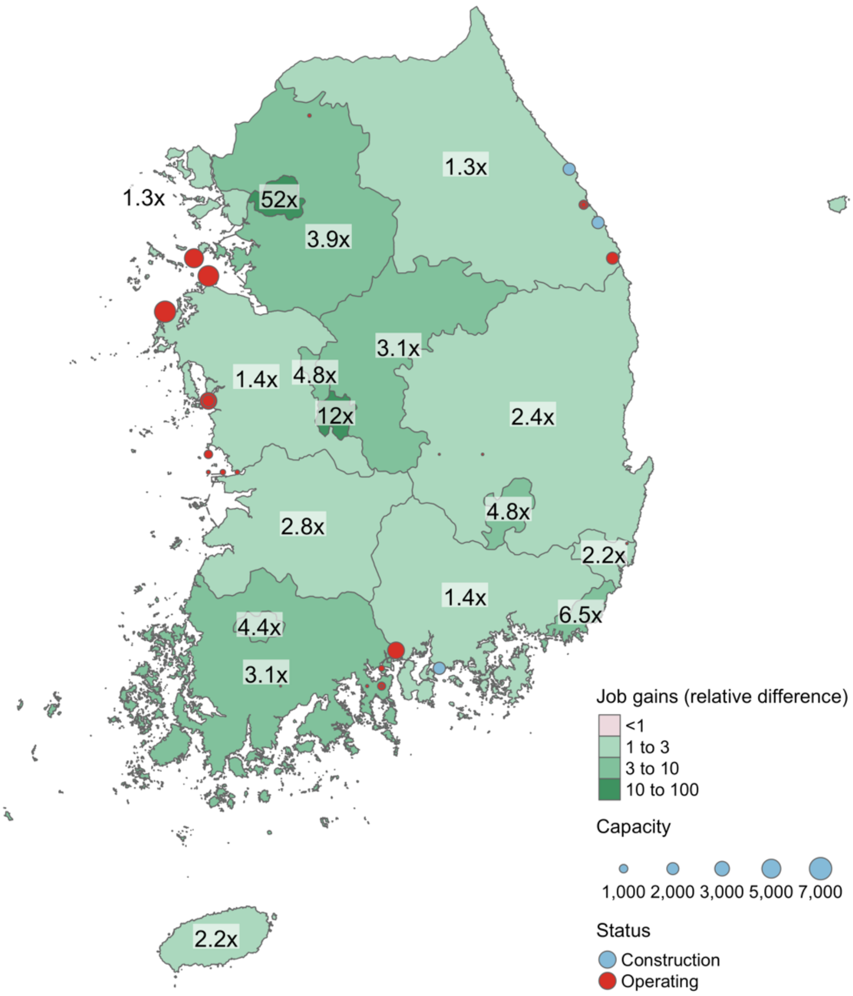

Figure 9: *Difference in overall job-years between the CtR scenario and CPol scenario (2020-2030), including jobs in the C&I and O&M of coal, natural gas (converted), solar PV, onshore wind and battery storage. Factors shown indicate how the province-level job potential compares between scenarios. For example, 2x means that the CtR scenario supports twice the number of job years than is estimated for the Current Policy scenario. Note that additional jobs that have not been assigned to provinces (local manufacturing, offshore wind and hydrogen) are not included in these numbers. Coal power plant capacity and location are shown by circles.*

In addition to jobs in C&I and O&M in coal, natural gas, onshore wind, solar PV and battery storage, a substantial number of jobs will be created that are not necessarily assigned to specific regions, but whose location may be chosen strategically.[18] This includes jobs in C&I and O&M of offshore wind turbines, hydrogen-related technologies and manufacturing of all technologies. These jobs are not shown in the province-level estimates, but amount to about

from the assumption for modelling the solar PV rooftop potential that areas with more people have more rooftops. For megacities with very high population density, the interpretation of the results may require some caution.

[18] Policy makers may for example support building up manufacturing industries in certain parts of the country that are more heavily affected by job losses.

42,500 additional jobs per year on average in the *CtR* scenario compared with the *CPol* scenario over the period 2020-2030.

Reaping the employment opportunities while facilitating a Just Transition from coal to renewable energy

This analysis illustrates that the employment impacts related to an accelerated replacement of coal power with renewable energy can be substantial for South Korea. We show that there is the potential for employment creation not only on the national level, but also at the subnational level for all provinces, including those which would need to close down coal power plants.

Overall, we find that replacing coal with renewable energy would yield considerable job creation potential, exceeding the average employment potential per year (2020 to 2030) in the Current Policies scenario by a factor of almost 2.8 times.

Our findings on substantial job creation potential from a transition towards renewable energy are supported by other literature on South Korea showing substantial job creation potential from phasing out conventional energy sources that Korea has historically been dependent on.

Hong et al. (2019) find that transitioning net zero emissions of the entire South Korean energy system by 2050 could lead to large positive employment impacts in Korea, indicating that modelling a 100% renewable energy scenario which completely renounces on coal could generate almost four times more jobs in the power generation sector than their Business-as-Usual Scenario (BAU) [8]. In the follow-up study more specifically focused on employment impact (SNU 2019), in an energy transition path towards 100% of RE in 2050, about 280,000 jobs[19] will be created in 2030 [9].

Studies from Korean government institutions also support these findings. The Korea Labour Institute (2017) estimated job creation effects for different Renewable Portfolio Standards (RPS) scenarios and concluded that the RE employment impact can be over double that of conventional energy (fossil fuels and nuclear)[10]. In particular, increasing the RPS requirement to 28% (and the share of RE in electricity generation to 20%) by 2030 can create over 90,000 jobs in solar and wind together, highlighting the importance of policy measures for an energy transition [10].

In terms of economic benefits, Kim & Jeon (2020) find that deploying more renewable energy could generate induced output increases that would be higher than the estimated economic losses resulting from a nuclear phaseout by 2050 [21].

However, while the overall job gains are expected to outweigh job losses, the required changes will negatively affect certain types of jobs and people currently working in coal-related jobs and will require supporting their transition to new job opportunities. The guidelines of the International Labour Organization (ILO) emphasise that it is important to secure livelihoods of all people who may be negatively impacted by a ‘green transition’, encouraging inclusive societies and the creation of decent jobs [22,23].

[19] Renewable energy jobs here include not only solar and wind, but also hydropower and biomass.

One potential challenge for a transition process can be that certain regions are affected by job losses while it is other regions elsewhere benefiting from renewable energy-related job creation. Our analysis suggests that all provinces that would be strongly affected by job losses due to the coal phase out can still overall benefit from the transition by taking advantage of their solar and wind potential, as well as battery storage. This job creation potential related to the local built out of renewable energy capacity is estimated to be substantial, consistently outweighing jobs losses in these regions.

Another potential challenge in such a transition process can be that skills related to jobs that are phased out do not match well with required skill sets in newly created 'green' jobs. To support affected people in taking advantage of the newly created local job potential, training needs and retraining options will need to be identified and targeted strategies and policies will need to be developed.

Targeted training and re-training of local workforces is recommended to provide alternative employment opportunities in 'green' jobs and also to avoid a shortage of skilled labour needed for manufacturing, C&I as well as O&M of novel power generation infrastructure.

This study provides a picture of national and provincial job-creation potential, which may serve as a basis for a discussion and initiating a Just Transition that will support workers and communities. If well managed, the transition can be a strong driver for creating jobs, improving work conditions, fostering social justice and reducing poverty and inequality [22,23].

Historically, South Korea has played a strong role at the forefront of Green Growth Initiatives [24]. Given that South Korea has often served as a role model in the region, inspiring other Asian emerging economies to follow Korea's example (see e.g. Zimmer et al. (2013) [25]), a clear commitment of South Korea to an accelerated phase out of coal power generation would send a strong signal to other countries to follow their example.

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