

# EMPLOYMENT ASSESSMENT OF RENEWABLE ENERGY:

Power sector pathways  
compatible with NDCs and  
national energy plans



# Employment assessment of renewable energy: Power sector pathways compatible with NDCs and national energy plans

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Global Green Growth Institute  
Jeongdong Building 19F  
21-15 Jeongdong-gil  
Jung-gu, Seoul 04518  
Republic of Korea

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**Project lead:** Dr Stelios Grafakos

**Lead Authors:** Dr Stelios Grafakos, Dr Dereje Senshaw, Diana Alejandra Quezada Avila

**Consultants:** Andres Toro (International), Emmanuel Sindikubwabo (Rwanda), Jaya Wahono (Indonesia), Jose Castro – Ithaca Environmental (Mexico)

**Intern:** Soim Lee

### GGGI Country Offices

Dr Kurnya Roesad and Wira Tenaya (Indonesia), Dr Pablo Martinez and Jose Ayala (Mexico), Michelle DeFreese and Dr Brigitte Nyirambanguste (Rwanda)

### Reviewers within GGGI

Dr Frank Rijsberman, Susanne Pedersen, Jan Stelter and Dr Lilibeth Acosta

### International Experts Group and Partner Organizations

#### International Organizations

Dr Marek Harsdorff - *International Labour Organization (ILO)*

Michael Renner and Celia Garcia-Baños - *International Renewable Energy Association (IRENA)*

Dr Nicola Cantore - *United Nations Industrial Development Organization (UNIDO)*

#### International Research Institutes

Harry Fearnough - *New Climate Institute (NCI)*

Jasper Donker and Xander van Tilburg - *Energy Research Centre of The Netherlands (ECN part of TNO)*

Hector Rodriguez and Dr Helgenberger Sebastian - *Institute of Advanced Sustainability Studies (IASS)*

Prof Shobhakar Dhakal - *Asian Institute of Technology (AIT)*

Dr Spyridon Stavropoulos - *Erasmus Happiness Economics Research Organization (EHERO)*

Dr Ho-Seok Kim - *Korean Environment Institute (KEI)*

#### Evidence-based and advocacy Organizations

William Brent and Rebekah Shirley - *Power for All*

### National Ministries, Institutes and Energy Associations

Ministry of National Development and Planning (Bappenas), Indonesia

Indonesia Geothermal Association

Indonesia Hydropower Association

National Institute of Ecology and Climate Change (INECC), Mexico

**Copy editor:** Marijke Vermaak

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## PREFACE

I am pleased to introduce this GGGI technical report entitled “Employment Assessment of Renewable Energy: Power Sector Pathways Compatible with NDCs and National Energy Plans”. As economies transit from fossil fuel-based energy to renewable energy sources, employment is a critical aspect of this transition, as much of the resistance to the green transformation comes from the fear of job losses in the brown economy. As the results of our study demonstrate, renewable energy technologies have great potential to create jobs in short and medium-term. This is highly relevant during the post-Covid19 crisis period when countries formulate their economic stimulus packages. This report represents, therefore, an important and timely contribution to the current process of identifying sectors and projects with high employment creation potential.

GGGI has prioritized green employment and climate mitigation issues. Reduction of GHG emissions and creation of green jobs are two of GGGI’s six Strategic Outcomes. GGGI has also conducted extensively analytical work in the fields of sustainable energy and green jobs. However, this is the first GGGI study that focuses on the nexus of sustainable energy and green jobs.

The current technical report is based on research conducted in three GGGI member countries - Mexico, Indonesia and Rwanda. The study assessed the job creation potential of renewable energy technologies under various power sector pathways based on National Energy Plans and countries’ NDCs. Furthermore, the study identified and assessed the occupations and skills required by the renewable energy sector for each stage of the value chain. The analysis highlights the important role that assessments of employment effects can play during the revision of countries’ NDCs while simultaneously addressing the achievement of Sustainable Development Goals (SDGs) related to affordable and clean energy (7), decent work and economic growth(8) and climate action(13). Despite the very different energy context and economic background in Mexico, Indonesia and Rwanda, the renewable energy sector is, according to our analysis, an important driver of employment creation in all of them and its importance is expected to continue to grow.

Our research team worked in close collaboration with a number of partners, including national renewable energy agencies in Indonesia, Mexico and Rwanda, as well as other international organisations and research institutes. At the same time, the study results inform and support policymakers and stakeholders in the three countries assessed, and beyond. Quantifying the employment effects of investments in renewable energy provides valuable support to countries that are developing their renewable energy strategies and power sector decarbonization plans. The creation of employment opportunities is an important co-benefit of NDC implementation. Job creation potential should, therefore, be included and highlighted as countries revise their NDCs in 2020.

We hope that energy and climate change departments, NDC responsible agencies, planning, environmental and energy ministries, labor organizations, energy companies, project developers, and vocational training institutes and universities could benefit from the study outcomes. The GGGI research team aims to continue working with its partners and follow up on providing policy recommendations to the governments for incorporating the results in their revised NDCs and National Energy Plans.



**Dr. Frank Rijsberman**  
GGGI Director-General

A handwritten signature in black ink, which appears to be 'Frank Rijsberman'. The signature is written in a cursive, flowing style.



# EXECUTIVE SUMMARY

The development and gradual enhancement of countries' Nationally Determined Contributions (NDCs) have gained considerable attention since the 2016 Paris Agreement, ratified by 189 countries to date. Raising the level of ambition in the NDCs can lay the foundation for limiting the global temperature rise to well below 2°C or even further to 1.5°C to mitigate climate change. Climate mitigation action could generate benefits locally, in addition to the global benefits of the GHG emissions reductions and therefore, could be the catalyst for setting more ambitious NDC targets. Reducing GHG emissions by enhancing renewable energy (RE) generation could also contribute to job creation and become a driving force of countries' economic growth. According to the International Energy Agency (IEA), the power sector contributes to 42% of global energy-related CO<sub>2</sub> emissions. Simultaneously, RE electricity generation is becoming cheaper compared to coal and natural gas<sup>1</sup>. In this context, it is becoming essential to explore and estimate the RE employment opportunities of different decarbonization pathways and RE targets under the NDCs.

While the potential for job creation in RE has been assessed at the global level, there is an increasing demand for RE employment studies at the national level. This study aims to assess the employment creation potential of RE technologies based on future power sector scenarios for three GGGI Member countries: Mexico, Indonesia, and Rwanda. Goals of this study include estimating the jobs that can be created by selected RE technologies compared to selected fossil fuel-based technologies, providing estimates of the required investments for achieving NDC RE targets, and identifying and assessing the occupations and skills required by the RE sector for each stage of the value chain.

The study applied a scenario analysis to investigate the employment implications of RE technologies under different power sector scenarios up to 2030. Two scenarios each for Mexico and Indonesia and three scenarios for Rwanda were investigated for assessing the employment effects of selected RE technologies. In the case of Mexico, the study compared the employment effects of the Business-as-Usual (BAU) and NDC scenarios, whereas in Indonesia and Rwanda the scenarios were not compared with each other as they were developed based on different policy documents. The study utilized a RE value chain analysis for assessing the direct jobs that can be potentially created, and Input-Output (I-O) modeling for assessing indirect and induced jobs and value-added created in the overall economy. The study also analyzed the occupations and skills required at each stage of the RE value chain. The labor force supply for RE was estimated and classified by the type of human resource and skill level using national statistics, particularly in the case of Mexico. Gaps between the supply of and demand for occupations and skills were identified based on the estimated local labor force supply at the state level.

For Mexico, the results show that installing the additional RE capacity required to reach the 2030 NDC target will result in the creation of more than 600 thousand total job-years. Compared to the BAU scenario, this will create 370 thousand more direct job-years, 170 thousand more indirect, and 110 thousand more induced job-years between 2020 and 2030. Deploying solar PV distributed generation (DG) is essential to reach the NDC target and is expected to generate between 36% and 57% of the total job-years by 2030. The BAU scenario requires 18 billion USD of direct investment for new RE capacity and operations while reaching the NDC target requires an additional 13 billion USD of investment for RE. Direct value-added generated is USD 6 billion higher in the NDC scenario than the BAU scenario over the period 2020-2030. Selected RE technologies such as onshore wind, solar PV DG<sup>2</sup> and utility-scale create more direct job-years per TWh from new capacity than combined cycle<sup>3</sup>

<sup>1</sup>International Renewable Energy Agency, *Renewable Power Generation Costs in 2018*, May 2019, <https://www.irena.org/publications/2019/May/Renewable-power-generation-costs-in-2018>.

<sup>2</sup>Distributed Generation refers to distributed energy generation systems.

<sup>3</sup>Combined cycle refers to the combined cycle gas turbine (CCGT), which is highly efficient electricity generation technology from otherwise lost waste heat exiting from one or more gas (combustion) turbines.

under the NDC scenario. Human resources demand and supply are compared in Mexico's case, showing that there is a surplus of labor in all fields of study<sup>4</sup> related to RE for the projection period from 2020 to 2030.

For Indonesia, the analysis included two power sector scenarios, namely the Power Supply Business Plan of the State Electricity Company (PLN) and the General Plan of National Electricity (RUKN). The RUKN scenario is more ambitious in terms of installed RE capacity, reaching 43 GW by 2030, compared to 28.5GW under the PLN scenario. Under the RUKN scenario the selected RE technologies such as hydro, geothermal and solar PV, could create about 3.7 million direct jobs, whereas about 2.1 million direct jobs could be created under the PLN scenario. Every direct job created in the RE sector will create one additional job in the overall economy under both scenarios. Reaching the RUKN scenario RE target by 2030 would require significant investments in RE of about USD 49 billion, while it could generate around USD 24 billion in value-added to the Indonesian economy. According to the skills assessment for solar PV in Indonesia, more than 120 thousand jobs will be in demand in project development (PD) by 2030. Furthermore, 64% of the PD employment will be created for management professionals, while technicians, engineers, and project non-professionals will be in higher demand in the other stages of the solar PV value chain.

For Rwanda, three scenarios were looked at: NDC unconditional, High Ambition (HA), and Sustainable Energy for All (SE4All), whereas the first two scenarios were analyzed in depth as they represent the high and low ambition plans. The NDC unconditional scenario requires a direct investment of USD 295 million on new RE capacity and operations to reach its RE target. Under the NDC unconditional scenario, 14 thousand direct job-years and USD 136 million in value added will be created by 2030. Reaching the RE target under the High Ambition (HA) scenario by 2030 requires a direct investment of USD 645 million in RE. The additional 171 MW RE capacity required under the HA scenario will generate around 31 thousand direct jobs. The direct investments in RE under the HA scenario generate around 316 USD million in value-added to the economy of Rwanda. Moreover, it was concluded that more than 75% of the direct job-years generated from solar PV technology relate to the technical and non-professional workforce requiring medium to low skill sets. Therefore, less than 25% of the direct job-years created relate to high skill occupations such as engineers and management professionals.

Overall, all three countries assessed in the study will benefit from investments in RE compared to investments in fossil fuel-based technologies, as RE has greater potential in terms of employment and economic value-added in the wider economy beyond the RE sectors. Since the transition to RE involves high skilled occupations and human resources, policymakers in each country should consider how to equip their labor force to undertake these tasks when developing policy measures such as education and vocational training programs.

Considering the benefits of enhancing RE job creation, establishing emission reduction targets for the electricity sector with RE targets which enable both decarbonization and job creation will be an effective way to facilitate a positive spillover effect. By setting more ambitious goals in their NDCs, countries could create a significant number of quality jobs and economic value-added as co-benefits to reducing GHG emissions, while simultaneously making progress toward multiple Sustainable Development Goals (SDGs).

In order to harness the employment benefits of RE, low and middle-income countries need to create an enabling policy environment. Countries in need of financial support can explore smart financing mechanisms. Extending helping hands from multilateral organizations and international development agencies can reinforce a friendly financing environment for those countries.

Lastly, future RE employment assessment studies should further investigate geographical and gender aspects. Identifying where RE jobs are likely to be located, assessing and mapping the potential occupations and skills gaps, and collecting good quality and detail disaggregated data will provide insights to design more appropriate policy programs.

<sup>4</sup>Fields of study refer to Engineering and Construction, Technicians, Natural Sciences, Logistic and Quality Assurance, Management, Finance and Legal, and Health and Safety.

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## LIST OF ABBREVIATIONS

<b>AMDEE</b>	Mexican Association of Wind Energy	<b>LCPDP</b>	Least cost power development plan (Rwanda)
<b>ASOLMEX</b>	Mexican Association of Solar Energy	<b>MW</b>	Megawatt
<b>BAU</b>	Business-as-Usual	<b>MWh</b>	Megawatt hour
<b>CAPEX</b>	Capital expenditures	<b>NDCs</b>	Nationally Determined Contributions
<b>C&amp;I</b>	Construction and installation	<b>NRE</b>	New and renewable energy
<b>DG</b>	Distributed Generation	<b>OPEX</b>	Operational expenditures
<b>EM&amp;D</b>	Equipment manufacturing and distribution	<b>O&amp;M</b>	Operations and maintenance
<b>ESSP</b>	Energy Sector Strategic Plan (Rwanda)	<b>PD</b>	Project development
<b>FTE</b>	Full-time equivalent	<b>PLN</b>	Power Supply Business Plan of the State Electricity Company (Indonesia)
<b>GHG</b>	Greenhouse gas	<b>PRODESEN</b>	Programa de Desarrollo del Sistema Eléctrico Nacional
<b>GIZ</b>	Deutsche Gesellschaft für Internationale Zusammenarbeit	<b>PV</b>	Photovoltaic
<b>GW</b>	Gigawatt	<b>RE</b>	Renewable energy
<b>GWh</b>	Gigawatt hour	<b>RUKN</b>	National Electricity General Plan (Indonesia)
<b>GoR</b>	Government of Rwanda	<b>SDGs</b>	Sustainable Development Goals
<b>HA</b>	High Ambition (Rwandan scenario)	<b>SE4All</b>	Sustainable Energy for All
<b>IEA</b>	International Energy Agency	<b>TVET</b>	Technical and Vocational Education and Training
<b>ILO</b>	International Labor Organization	<b>TW</b>	Terawatt
<b>INECC</b>	National Institute of Ecology and Climate Change (Mexico)	<b>TWh</b>	Terawatt hour
<b>I-O table</b>	Input-Output table	<b>UNIDO</b>	United Nations Industrial Development Organization
<b>I-O modeling</b>	Input-Output modeling	<b>USD</b>	United States Dollar
<b>IRENA</b>	International Renewable Energy Agency	<b>USDk</b>	Thousand United States Dollars
<b>LCR</b>	Local content requirement		



# 1 INTRODUCTION

## 1.1 BACKGROUND



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Under the Paris Agreement, governments have developed their Nationally Determined Contributions (NDCs). NDCs are voluntary commitments by countries on GHG emissions reductions based on their priorities, capacity, and historical responsibilities, and are essential elements of the Paris Agreement. Under the Agreement, countries are expected to increase the ambition of their NDCs every five years. The sum of countries' NDC pledges lay the foundation for reducing GHG emissions and limiting global temperature rises to 1.5°C relative to pre-industrial levels<sup>5</sup>, as backed by science. When formulating or revising their NDCs, countries should consider the additional benefits that can be generated by taking more ambitious action. Assessing the co-benefits of mitigation actions highlights the importance of setting more ambitious NDCs not only for limiting global warming but also for delivering multiple socio-economic benefits. Job creation is one of the most compelling climate mitigation co-benefits that resonates with policymakers at both the national and local levels. Recent evidence shows that climate mitigation action has significant job creation potential and therefore is becoming increasingly relevant and important for policymakers<sup>6</sup>.

The power sector is one of the main carbon-emitting sectors, with fossil fuels representing the highest share in the electricity mix in many countries. According to the IEA, the power sector contributes to 42% of global energy-related CO<sub>2</sub> emissions<sup>7</sup>. On the other hand, renewable energy (RE) penetration in the electricity system has been increasing globally in recent years as its investment costs have been plummeting<sup>8</sup>. Electricity from RE is, in many cases, cheaper compared to coal and even compared to natural gas. However, in most countries, RE is still far from reaching its vast potential. The share of renewables represents only 26% of total electricity generation in 2018.

Several global studies highlight the opportunities for job creation provided by RE<sup>9</sup>. The International Renewable Energy Agency (IRENA)'s research shows that if the targeted global RE investments in the energy sector were met,<sup>10</sup> "by 2050, the energy transformation would provide a 2.5% improvement in GDP and a 0.2% increase in global employment, compared to business as usual". The International Labour Organization (ILO)'s flagship 2018 report, *Greening with Jobs*, estimates that GHG reduction measures in the energy sector to meet the long-term goal of the Paris Agreement, will create around 24 million jobs<sup>11</sup>. Although the potential for job creation in RE has been assessed at the global level, there is a growing need to investigate the employment effects at the national level. Despite the importance of RE employment co-benefits, few national-level assessments of employment effects of RE capacity targets under the NDCs exist, particularly in low and middle-income countries (see Annex 7). It is increasingly relevant to study the employment effects of the energy transition at the national level as more and more countries commit to carbon neutrality by 2050 and explore pathways to power sector decarbonization.

<sup>5</sup> IPCC, *Global Warming of 1.5°C*, 2018, [https://www.ipcc.ch/site/assets/uploads/2018/10/SR15\\_SPM\\_version\\_stand\\_alone\\_LR.pdf](https://www.ipcc.ch/site/assets/uploads/2018/10/SR15_SPM_version_stand_alone_LR.pdf).

<sup>6</sup> New Climate Economy, *Unlocking the Inclusive Growth Story of the 21st Century*, 2018, <https://newclimateeconomy.report/2018/>.

<sup>7</sup> International Energy Agency, *Tracking Power*, May 2019, <https://www.iea.org/reports/tracking-power-2019>.

<sup>8</sup> International Renewable Energy Agency, *Renewable Power Generation Costs in 2018*, 2019.

<sup>9</sup> Jay Rutovitz, Elsa Dominish, and Jenni Downes, *Calculating global energy sector jobs: 2015 methodology*, (Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology Sydney, 2015), <https://opus.lib.uts.edu.au/bitstream/10453/43718/1/Rutovitzetal2015Calculatingglobalenergysectorjobsmethodology.pdf>.

<sup>10</sup> International Renewable Energy Agency, *Global Energy Transformation: A Roadmap to 2050 (2019 Edition)*, 2019, [https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Apr/IRENA\\_Global\\_Energy\\_Transformation\\_2019.pdf](https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Apr/IRENA_Global_Energy_Transformation_2019.pdf).

<sup>11</sup> International Labour Organization, *World Employment Social Outlook 2018: Greening with Jobs*, 2018.



Furthermore, policymakers can gain valuable insights from comparing the employment creation potential of RE with fossil fuel-based technologies. Lastly, the transition to RE can also lead to losses in certain sectors in certain regions, which need to be understood to be addressed and managed in a socially just manner.

International organizations and research institutes have recently started to respond to the need for assessing the potential for RE employment creation at the national level. Two international projects funded by the International Climate Initiative (IKI), *Co-benefits*, and *Ambition to action*, assess the employment impacts of power sector decarbonization on selected low and middle-income countries. GGGI completed a green jobs employment study in Fiji in 2019<sup>12</sup>. GGGI also provides support to its Member and partner countries in enhancing their NDCs. GGGI has also assessed the RE conditional targets and required investments in the NDCs of GGGI countries, identifying investment needs and the potential for raising the level of ambition on RE<sup>13</sup>. In this study, GGGI aims to bridge the knowledge gap on national level RE employment studies, and to support GGGI countries to identify employment co-benefits of the RE targets set in their NDCs and national energy plans. To avoid duplication and maximize potential synergies with other RE employment assessment initiatives, GGGI formed an international experts group (IEG) consisting of experts from international organizations such as IRENA, ILO, UNIDO, research-based institutes such as the New Climate Institute, Energy Research Centre of the Netherlands (ECN), Institute of Advanced Sustainability Studies (IASS), Erasmus School of Economics (ESE), and evidence-based policy organizations such as Power for All. The IEG provided technical guidance and advice throughout this study. Lastly, the study benefited from feedback from the Sustainable Energy and Jobs Platform, initiated by IRENA in January 2020, where GGGI is a core member.

The study is also particularly pertinent to the discussion and debate on post-COVID19 economic recovery measures. As countries' economies enter into recession and unemployment levels increase rapidly, the study results shed some light on the employment potential of RE. Evidence on employment potential provides policymakers with an excellent opportunity to harness the environmental benefits of RE technologies while at the same time boosting the economy.

## 1.2 STUDY OBJECTIVES

The study assesses the potential for employment generation of new installed capacity of RE in the power sector in three GGGI countries. The analysis highlights the important role that assessments of employment effects can play during the revision of countries' NDCs. Quantifying the employment effects of investments in RE could provide significant support to countries that are developing their RE strategies and power sector decarbonization plans. Ultimately, the study provides evidence-based policy support to national governments for assessing the employment effects of RE targets in the power sector during the revision of their NDCs while simultaneously addressing the achievement of Sustainable Development Goals (SDGs) 7 (affordable and clean energy), 8 (decent work and economic growth) and 13 (climate action).

The study has the following objectives:

- to identify and assess **RE technologies' potential to generate employment** under different future power sector pathways;

<sup>12</sup> GGGI, *Fiji Green Jobs Assessment: A Preliminary Study of Green Employment in Fiji*, July 2019, <https://ggi.org/report/fiji-green-jobs-assessment-a-preliminary-study-of-green-employment-in-fiji/>.

<sup>13</sup> Dereje Azemraw Senshaw and Jeong Won Kim, "Meeting conditional targets in nationally determined contributions of developing countries: Renewable energy targets and required investment of GGGI member and partner countries," *Energy Policy* 116, (May 2018): 433–443, <https://doi.org/10.1016/j.enpol.2018.02.017>.

- to support and strengthen **evidence-based policy frameworks** of countries NDC revision and implementation concerning power sector RE targets from an employment perspective;
- to support countries to incorporate the assessment of the employment generation potential in the development of **RE strategies and NDCs**; and
- to identify and **assess the occupations and skills** required by the RE sector to support and advance the energy transition.

The study results are intended to inform and support different stakeholders and policymakers in the three countries assessed. Countries' NDC related agencies, climate change-related and energy departments, planning, environmental and energy ministries, labor organizations, energy companies and developers, and vocational training institutes and universities could benefit from understanding the study outcomes.

The geographical scope of the study covers three pilot countries from three different continents: Mexico, Indonesia, and Rwanda<sup>14</sup>. In Mexico and Indonesia, fossil fuels currently dominate the electricity mix, however, their governments have put forward plans to reduce their share considerably by 2030. There are various future development pathways for the electricity supply systems that would lock the economies of Mexico and Indonesia into or out of different carbon emission levels for the next decades. Policymakers can gain valuable insights by studying the employment implications of these pathways. Mexico has identified RE targets under its NDC, whereas Indonesia has yet to align its NDC and climate policy with its energy plans. Rwanda has a relatively much smaller electricity supply system, with a high percentage of hydropower in the electricity mix compared to fossil fuels. However, great potential remains to enhance hydropower and solar energy penetration and the government is planning to increase their capacity and share over the next ten years.

The study applies a scenario analysis approach to investigate the employment effects of RE technologies under different power sector scenarios. The power sector scenarios are based on national energy policies and plans of the countries assessed. In the case of Mexico, the study compared the employment effects of the Business-as-Usual (BAU) and NDC scenarios, whereas in Indonesia and Rwanda the scenarios were not compared with each other as they were developed based on different policy documents.

The study also provides estimates on the number of jobs that can be created by selected RE technologies per unit of electricity generation (TWh) and unit of investment (USD) compared to selected fossil fuel-based technologies. The integrated methodology that combines power sector scenario analysis with RE value chain analysis to assess the direct jobs in the RE sector, and I-O modeling to assess indirect and induced jobs and value-added<sup>15</sup> created in the overall economy. Lastly, the study assesses the occupations and skills required to tap the employment opportunities of the energy transition at the different stages of RE value chains. It is recognized that assessing the quality of jobs that can be created in RE is an important issue, however, this is not in the scope of this study.

The report is structured as follows: Chapter 2 describes the overall methodological approach, the data collection and data analysis methods, along with information on the input variables. Chapters 3, 4 and 5 outline the cases and reporting the results for Mexico, Indonesia, and Rwanda respectively. The three country chapters have a common structure that consists of five sections. The first section briefly describes the current situation of the electricity supply system and relevant policies, the second section presents the different power sector scenarios, the third section focuses on the results of the jobs assessment, the fourth section presents the results of the occupations and skills assessment, and the last section draws policy recommendations. Chapter 6 presents the conclusions of the study.

<sup>14</sup> As the electricity systems of the three selected countries are very different in terms of scale, technology mix and RE potential, the study does not aim to draw any direct comparisons between them.

<sup>15</sup> Value-added is the contribution of an industry to the national GDP of the country.

## 2 METHODOLOGY AND CONCEPTUAL FRAMEWORK

### 2.1 METHODOLOGY

After conducting a comprehensive literature review, detailed in *Annex 7*, the project team developed the research methodology. The study utilized different data collection methods, stakeholder engagement processes, and conducted scenario analysis in the selected countries, looking at different power sector scenarios up to 2030. The overall employment modeling methodology combined two methods: (i) value chain analysis of the different RE technologies for direct jobs assessment, and (ii) I-O modeling for assessment of indirect and induced jobs and added value creation. The study also analyzed the occupations and skills required for each stage of the RE value chain and, in the case of Mexico, compared requirements with the current supply of skills from universities and vocational training institutes. In this study, the employment assessments resulted in the estimation of the number of job-years at full-time equivalent (FTE) that could be generated by the new capacity of RE technologies during the modeling horizon 2020 - 2030. The terms “jobs” and “job-years” are hereafter used interchangeably and refer to job-years.

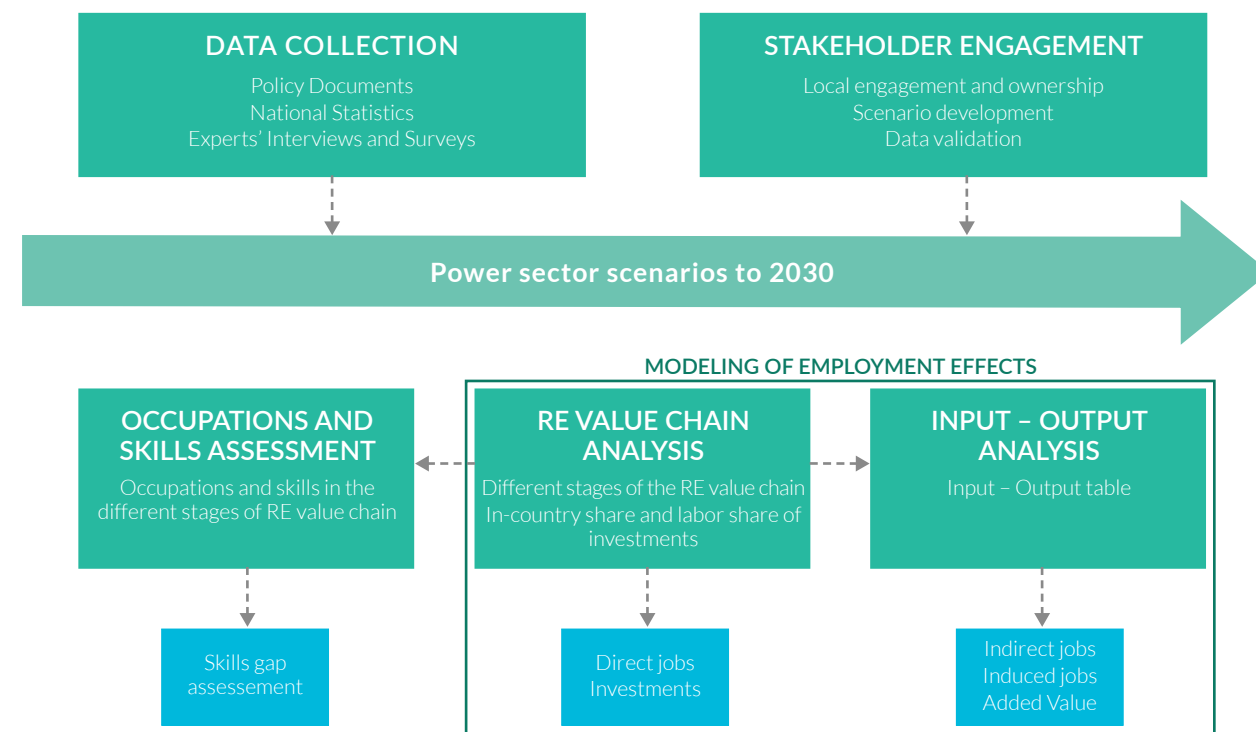


Figure 2.1 Methodology framework

Further detail on the activities and methods incorporated in the methodological approach follows:

#### Data collection

Mexico, Indonesia and Rwanda's NDCs and national energy policies and plans were reviewed, focusing on the RE targets and shares in the electricity mix by 2030. An extensive desk review to collect data and information on countries' NDCs and national electricity plans focused on electricity supply scenarios while looking at RE capacity targets during the NDC time horizon of 2020 to 2030.

Selected RE technologies were assessed in each country. RE project developers' surveys and experts' interviews were conducted to collect data on value chains and cost structure in all three countries for the selected RE technologies.

Data on capital expenditures (CAPEX) and operational expenditures (OPEX) were collected from national energy sources. CAPEX, OPEX and Levelized Cost of Energy (LCOE)<sup>16</sup> information for each technology in each country are summarized in *Annex 4*. Data on the share of CAPEX and OPEX invested in the country (in-country or domestic share of investment<sup>17</sup>) were collected from secondary sources for Mexico, interviews and secondary sources for Indonesia, and interviews for Rwanda.

Technology-related data such as load and learning factors were collected from national energy sources. Learning factors indicate how fast the costs of RE technologies decline through the modeling horizon due to learning and improvements in RE deployment. Learning factors for all three countries for all technologies were collected from secondary national energy sources.

Average annual salaries by economic sector were collected from national statistics. National I-O tables for Mexico and Indonesia were obtained from the OECD statistics database<sup>18</sup>. Given the data availability and quality challenges in Rwanda, particularly concerning annual average salaries and the lack of availability of Input-Output tables, the study estimates only the direct employment and economic impacts of RE deployment for Rwanda.

#### Stakeholder Engagement

The research team engaged with national stakeholders through workshops, interviews, and surveys to validate and discuss different electricity supply and power sector scenarios and their assumptions formed an essential part of the study. During these consultations, stakeholders such as government officials and experts from related ministries and departments and RE associations were able to validate technology and cost data that were collected.

#### Power sector Scenario Development and Analysis

In close collaboration with government officials from relevant ministries, future power sector pathways were selected and analyzed under different assumptions. Assumptions included different RE capacity targets according to countries' NDCs and national energy policies and plans. In all three countries, the study analyzed existing scenarios developed by the energy planning departments which have been published in policy and planning documents. In all three countries, at least two scenarios, with different levels of RE capacity shares, were analyzed. In Mexico's case, two electricity generation scenarios, BAU and NDC, were compared, where both meet the country's energy demand. However, in Indonesia's case, two power sector scenarios were analyzed with

<sup>16</sup> Levelized Cost of Energy (LCOE) is the present value of the price of electricity production over the lifetime of a plant, including construction, operation and maintenance, and fuel costs.

<sup>17</sup> "In-country share" or "domestic share" of investment is the percentage of the investment that is spent in the country.

<sup>18</sup> OECD, *Input-Output Tables 2018 edition*, updated December 2018, [https://stats.oecd.org/Index.aspx?DataSetCode=IOTS14\\_2018](https://stats.oecd.org/Index.aspx?DataSetCode=IOTS14_2018).

different levels of capacity by 2030, as they were developed by different agencies and published in different policy documents based on different assumptions. In Rwanda's case, the study analyzed three power sector scenarios that were derived from national energy policy documents.

### Modeling of employment effects

The employment effects of the different power sector pathways were modeled and assessed by combining a bottom-up technology value chain analysis and a top-down macroeconomic analysis based on I-O modeling. The combination of the RE value chain analysis with I-O modeling resulted in the estimation of **direct, indirect and induced jobs** that can be created by investing in a new capacity of RE sectors.

### Analysis of the different stages of the RE Value Chain

The study analyzed the different stages of the RE value chain according to the ILO classification<sup>19</sup>, Equipment Manufacturing and Distribution (EM&D), Project Development (PD), Construction & Installation (C&I), Operation & Maintenance (O&M), Cross-cutting/Enabling Activities and Others. Investment costs (CAPEX and OPEX) of each technology were broken down into technology cost components such as, in the case of solar PV, module, inverter, racking, installation, etc. Annex 8 provides an example of the solar PV components considered in the study. The direct job-years were calculated by following a stepwise approach, as illustrated in figure 2.2. and Annex 8.

- **Step 1: Identify each component's share of the CAPEX and OPEX that has been invested in the country (in-country or domestic share, %).** Investment on imports or imported components produced in other countries are not accounted for as they generate employment in the component's country of production.
- **Step 2: Match each RE technology component with an economic sector from the Input-Output (I-O) table.** The objective of this step is to identify the economic sector that corresponds to the different RE technology components. The I-O tables do not specify RE-related sectors and industries. Therefore, to estimate the employment impacts in the RE industries we constructed them by associating each RE technology component with the corresponding economic sector from the I-O table. For instance, the solar PV components correspond to industries from the I-O table, such as "electrical equipment", "fabricated metal products", "construction", "other business sector services", "real-estate activities", etc. By associating all RE technology components with corresponding I-O table sectors we can estimate the jobs that can be created by increased spending in RE technologies. An example of how solar PV components are matched with economic sectors from the I-O table is provided in Annex 8.
- **Step 3: Identify the part of the investment for each RE technology component that is spent on labor (labor share, %).** This step identifies the level of investment for each component that is spent in the labor market. In Indonesia and Rwanda, data on labor share were collected mainly from primary sources. In Indonesia, in the case of solar PV, labor share estimates for each technology component associated with an economic sector were derived from the I-O table. For Mexico, labor share estimates for technology components associated with an economic sector were derived from the I-O table.
- **Step 4: Estimate the direct job-years per MW installed by dividing the domestic investment on labor per economic sector by the average annual salary in the sector.** The best way to approximate the salaries related to the RE technology value chain is by looking at the average salary in the associated economic sectors. As the average salary in the economic sector might not reflect the exact salary of the workers at the different stages of the RE technologies value chain, a sensitivity analysis to investigate the impact of 10% changes in the average salary of the economic sectors to the employment was conducted.

- **Step 5: Estimate the direct job-years for new capacity installed for the period of 2020-2030.** In order to estimate the direct job-years for new capacity installed through the modeling horizon, results were scaled linearly, extrapolating into the future and multiplying by the MW of new installed capacity under each power sector scenario.

Figure 2.2 provides a diagrammatic representation of the steps in the methodology.

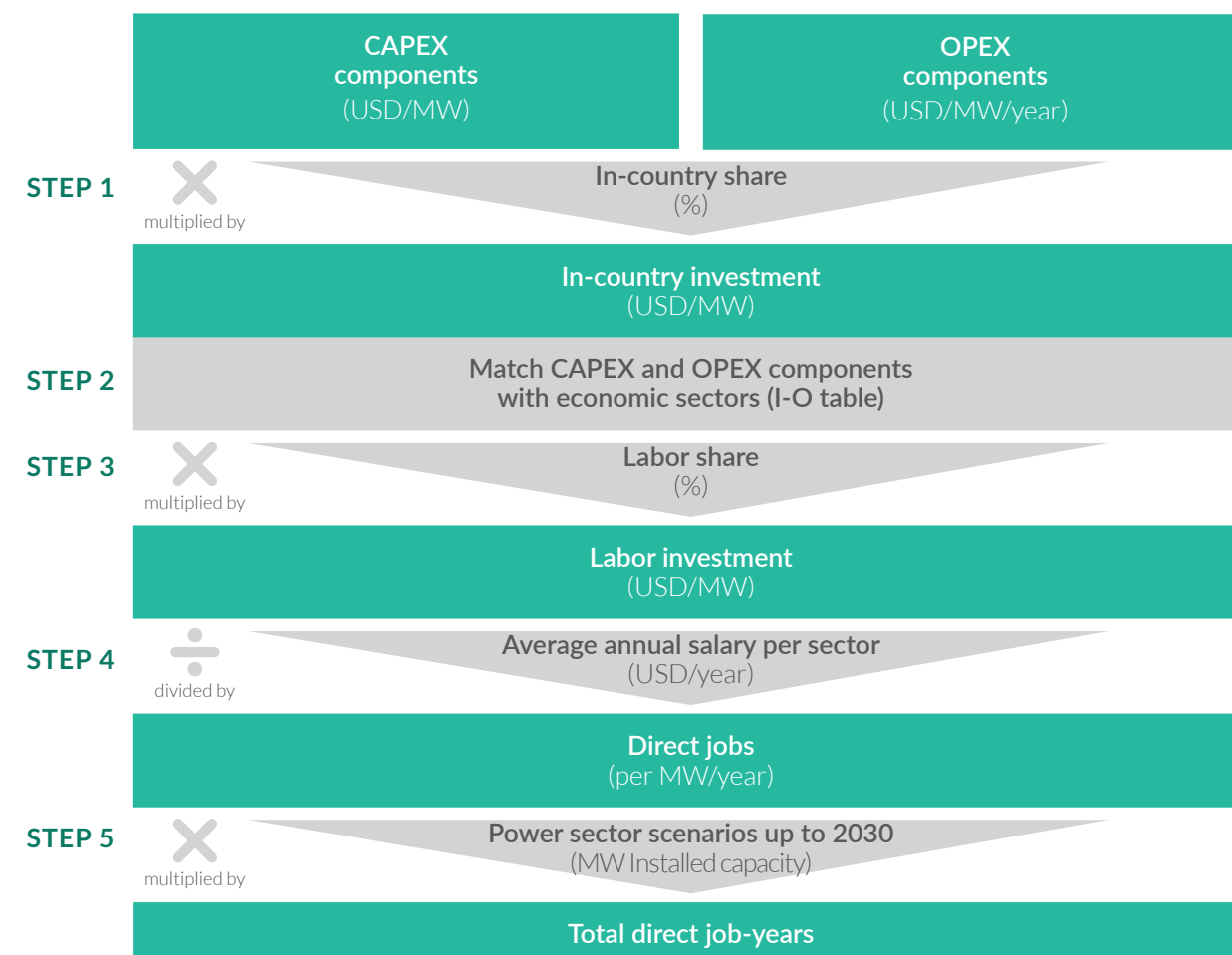


Figure 2.2 Steps to estimate direct job-years

### Estimating indirect and induced employment effects

The study also utilized an I-O modeling approach to estimate the indirect and induced jobs and added value that could be created in the overall economy by the required investments in RE.

I-O modeling is a macroeconomic analysis method that utilizes I-O tables describing the interdependencies between the different sectors/industries in an economy. This method is widely applied to estimate the impacts of positive or negative economic shocks, for example from changes in aggregate demand, by analyzing the ripple effects of sectoral investments in the overall economy.

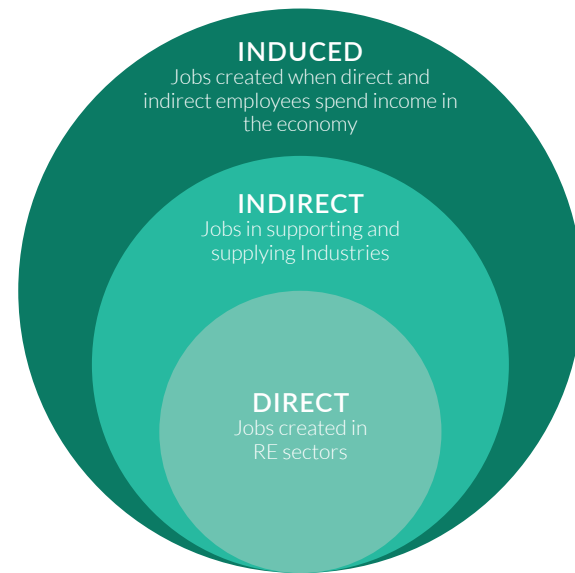
The mathematical equations utilized to estimate direct, indirect and induced job-years during the modeling horizon are provided in Annex 2. Modeling was performed using the Economic Impact Model for Electricity Supply (EIM-ES)<sup>20</sup> developed by the New Climate Institute.

<sup>19</sup> International Labour Organization, *Skills and Occupational Needs in Renewable Energy*, November 2011, [https://www.ilo.org/skills/pubs/WCMS\\_166823/lang-en/index.htm](https://www.ilo.org/skills/pubs/WCMS_166823/lang-en/index.htm).

<sup>20</sup> New Climate Institute, *Economic Impact Model for Electricity Supply v1.0*, November 2018, <https://newclimate.org/2018/11/30/eim-es-economic-impact-model-for-electricity-supply/>.



Overall, the modeling approach estimates the total direct, indirect and induced employment measured in FTE job-years, employment per USD invested, per GWh generated, and employment impact disaggregated per stage of the RE value chain. Furthermore, the approach assesses the direct domestic investment, the portion of the energy technology investment that is spent in the country and the value-added created in the overall economy by the indirect and induced effects of the domestic investment. Figure 2.3 represents the employment effects captured in the study.



**Figure 2.3** Diagrammatic representation of employment effects captured in the study

### Occupations and skills assessment

The study estimates the number of jobs by type of human resource as defined by IRENA<sup>21</sup> and by skill level as defined by the ILO<sup>22</sup>, disaggregated by RE value chain stages (EM&D, PD, C&I, O&M, Cross-cutting/Enabling Activities and Others) per technology. The study calculates the proportion (%) of identified human resources or occupations at each stage of development for solar PV and wind technologies by using the human resource factors estimated by IRENA<sup>23</sup>. Each stage requires occupations categorized broadly as *engineers*, *technicians*, *management professionals*, and *non-professionals*. The ILO<sup>24</sup> and IRENA<sup>25</sup> provide examples of occupations for each category (see also annex 6). For example, “engineers” include software and manufacturing engineers. The broad category “technicians” includes technicians that could be chemical laboratory technicians or electrical technicians and factory and construction workers. Representative examples of “management professionals” that require high skill levels include logistics specialists, procurement professionals, financial analysts, environment and safety experts and land development advisors. Equipment transporters, truck drivers and logistics operators that require relatively low skill levels are considered “non-professional” occupations in the RE sector. “Non-professional” jobs are the occupations that do not require specialized professional knowledge or skills. The study estimates the demand for human resources or occupations, measured in jobs. For example, if construction and installation account for 1,000 jobs over 10 years, and 30% of the time that is allocated to solar PV construction and installation is for engineers, it is estimated that roughly 300 engineers will be needed over the same period.

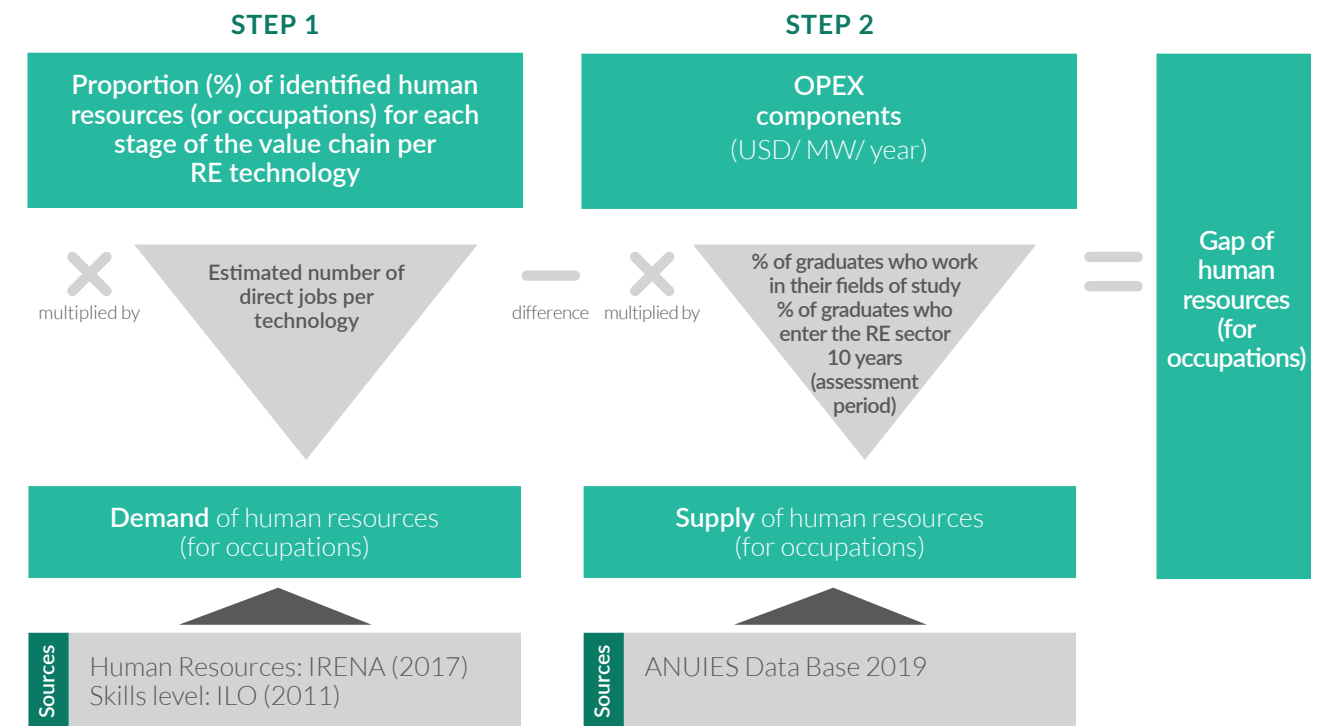
The study utilizes the ILO<sup>26</sup> and IRENA<sup>27</sup> (see also annex 6) skill level of occupations coding for solar PV and onshore wind technologies to identify the skill level per occupation:

- H = High skilled – Professional/ managerial

<sup>26</sup> International Labour Organization, *Skills and Occupational Needs in Renewable Energy*, 2011.

<sup>27</sup> International Renewable Energy Agency, *Renewable energy benefits: Leveraging local capacity for onshore wind*, 2017; International Renewable Energy Agency, *Renewable energy benefits: Leveraging local capacity for solar PV*, 2017.

- M = Medium skilled – Technician/ skill craft/ supervisory
- L = Low skilled – semi-skilled and unskilled



**Figure 2.4** Methodology of the occupations and skills gap assessment applied in Mexico

For Mexico, human resources were matched with education/study fields based on ANUIES database<sup>28</sup>. Then the labor force supply was quantified and classified by type of human resource and skill level, using national statistics (i.e. ANUIES database) on the number of graduates and technicians per education/study field and per state, as shown in figure 2.4. Gaps between the supply of and demand for occupations and skills were identified by comparing the estimated local supply of labor force at the state level to estimates of occupations required based on the future development of RE in different states. Annex 6 presents how different human resources/occupations required for the different stages of the solar PV value chain are associated with different education/study fields.

<sup>28</sup> ANUIES, *Información Estadística de Educación Superior*, accessed November 12, 2019, <http://www.anui.es.mx/informacion-y-servicios/informacion-estadistica-de-educacion-superior/anoario-estadistico-de-educacion-superior>.

## 2.2 ASSUMPTIONS, LIMITATIONS AND UNCERTAIN VARIABLES

Every model is an abstraction of reality. It simplifies the complex interrelations of multiple agents into fewer manageable variables that can be more easily manipulated and analyzed. The overall modeling approach makes the following assumptions:

- Cost estimates for different electricity supply technologies (per MW / GWh) are scaled linearly;
- Economic sectors in the model are aggregated into 34 sectors. Aggregation applies to I-O tables, sector allocations for component parts, and the labor share of investments and salaries;
- I-O tables represent an overall picture of the economy at one point in time (the most recent year that the I-O table was constructed). Therefore, the analysis is static, i.e. it does not incorporate dynamics of the economy and labor markets that may affect employment generation in RE technologies in the future;
- The modeling horizon is aligned with the NDC timeframe of 2020 to 2030. This means the study estimated the jobs that can be created from new power capacity installed within this timeframe, although some jobs related to the operation and maintenance of different energy technologies will be generated beyond the 2020 -2030 time horizon. This is particularly relevant for energy technologies with high fuel operation and maintenance costs that require a continuous supply of fuel (for example, biomass and fossil fuels) and will continue to generate jobs for operation and maintenance. In that sense, the modeling horizon selection is favorable towards energy technologies that create jobs mainly during the construction and installation stages (for example, wind and solar);
- Any increase in labor supply required to meet the higher labor demand is readily available at current wage rates. The calculated employment effects therefore represent an upper bound of the actual employment increase that might be realized. The magnitude of overestimation depends on the specific context of a country's overall economy, labor force, unemployment rate, energy sector, and the project being considered. The lower the unemployment rate is for qualified workers, or the less mobile the needed workers are among sectors or geographical locations, the greater the degree of over-estimation. However, when economies experience high unemployment rates, as is the case during the recession brought on by the COVID-19 crisis, a higher labor supply is available, maximizing the employment opportunities of RE investments presented in the study. In Mexico, the analysis of the labor demand and supply was conducted at the state level to partly capture location factors. The study also disregards macroeconomic variables such as the labor retirement rate and the labor migration rate;
- Estimates do not consider other drivers of the future labor markets, such as digitalization, radical technological change, and automation. Technological change may be particularly important in relatively immature RE industries which, as technology develops, may lower the electricity production costs by improving material or energy performance or by reducing labor requirements. A certain level of technology improvement has been considered in the form of technology learning factors, as described in section 2.1.;
- The study didn't consider any other positive impacts associated with renewable energy such as reduction of GHG emissions, reduced air pollution and improved health quality.

- Sex-disaggregated data collection is required to track the manner in which actions towards the energy transition may benefit women and increase their participation in the RE sector. The research team chose to pilot efforts for identifying sex-disaggregated data on labor composition and existing pipeline for future professionals in Mexico and Rwanda. The team sought to understand the degree to which existing data on the labor composition of the RE sector could be used to project women's participation in the new labor force and the potential benefits their increased participation could generate. The research confirmed that there were no centralized databases that could provide sex-disaggregated data on the labor composition of the renewable energy sub-sector in these two countries. When data sources on women's participation were found, these related to either a utility in particular or to data for the energy sector as a whole, not the RE sub-sector in particular. The discussion paper *Tracking Increase in Women's Participation in the Renewable Energy Sector under NDC targets*<sup>29</sup>, elaborates on a series of elements identified in the research process, the current status of women's participation in the energy sector, the focus on assessing women's participation in Mexico and Rwanda, and lessons learned that can inform future labor projection models and the assessment of co-benefits.

As explained above, some of the input variables such as in-country share and labor share of investments, annual salaries, future investment costs, and fuel costs are uncertain. Therefore, the employment results should be treated with caution and considered as best possible estimates that provide an idea of the order of magnitude of the jobs that can be created under different power sector development pathways under certain assumptions. To partially address the issue of uncertainty, a sensitivity analysis of the three main input variables, in-country share, labor share, and salaries, was conducted for all scenarios in all three countries. The results of the sensitivity analysis for the three selected countries are presented in *Annex 5*. The main outcomes of the sensitivity analysis indicate that a 10% change in these three key variables would lead to changes of between 8% to 11% to the direct employment outcomes. This suggests that the model is quite robust to changes of the input variables.

<sup>29</sup> Ana V. Rojas, *Tracking Increase in Women's Employment in the Renewable Energy Sector under NDC Targets* (GGGI, forthcoming).

### 3 MEXICO

#### KEY FINDINGS:

- ▶ Under the NDC scenario, the addition of RE installed capacity by 2030 will result in the creation of about 1.5 million total job-years, that consists of 830 thousand direct, 440 thousand indirect, and 250 thousand induced job-years. This represents the creation of more than 600 thousand total job-years by 2030 compared to the BAU scenario. This further reflects 82% more direct (370 thousand), 62% more indirect (170 thousand), and 72% more induced job-years (110 thousand) in the NDC Scenario compared to the BAU scenario by 2030.
- ▶ Reaching the NDC RE target by 2030 requires USD 31 billion in direct domestic investments in onshore wind, utility-scale solar PV and solar PV DG. This is an additional USD 13 billion over the period 2020-2030 compared to the BAU scenario. The BAU Scenario requires a direct domestic investment of USD 18 billion on new RE capacity and operations.
- ▶ The direct domestic investments in RE under the NDC scenario will contribute USD 14 billion in value-added to the Mexican economy. This is USD 6 billion more compared to the BAU scenario over the period 2020-2030.
- ▶ Under the NDC scenario, almost half (46%) of the direct job-years created in the three RE sectors analyzed will be in Construction & Installation. The other 54% of the direct job-years will be created in Equipment Manufacturing & Distribution (16%), O&M (15%), and Project Development (around 11%).

Mexico has an extensive literature on green job creation potential, particularly for the clean energy sector. Studies from international organizations have focused on national level analysis considering multiple economic sectors. For example, the ILO published an *Evaluation of Green Jobs potential in Mexico* in 2013, which assessed nine major economic industries in the country, including RE. Government studies benefit from primary data, collected by the census from the National Institute of Statistics (INEGI). These studies contain extensive deep-dive analyses of the energy sector at the national and sub-national levels. For example in 2015, as part of the Strategic Program for Human Capital Development in Energy, the energy ministry (SENER), the education ministry (SEP), and the National Council of Science and Technology (CONACTY), developed a baseline analysis on the current and future talent requirements to meet the energy reform demands. The analysis identified the future occupation and technical skill gaps for the energy sector.

Furthermore, studies developed by RE sectoral associations and private sector consultancies assess the required financial investment, job creation potential, and human capital availability link to the achievement of Mexican clean energy targets at national and sub-national levels. Among the most recent studies, the *Clean Energy Study in Mexico 2018 -2032*, developed by the Mexican Association of Wind Energy (AMDEE), Mexican Association of Solar Energy (ASOLMEX) and Iniciativa Climática de México (CLIMA) is regularly cited as it assesses the necessary investments for Mexico to meet the clean energy generation target of 35% by 2024 qualitatively and quantitatively, along with its employment and CO<sub>2</sub> mitigation implications. Similar studies have been developed

by international development agencies such as the Deutsche Gesellschaft Für Internationale Zusammenarbeit (GIZ). For example, the GIZ study links the job creation assessment in the RE sector to the latest national sector ambitions, highlights its sub-national implications and provides policy recommendations. Besides the available studies, open source online tools such as the International Jobs and Economic Development Impact Model (I-JEDI) from the National Renewable Energy Laboratory (NREL) allow any user to estimate the job creation and investment impact of the construction of a project for most RE technologies. This analysis aims to complement the existing literature by providing an updated estimate of the job creation potential and skills requirements to meet the Mexican NDC and the Energy Transition Law (LTE) targets by 2030, using a bottom-up approach.

### 3.1 CURRENT SITUATION

Mexico's energy market transformation, under the 2013 energy reform, triggered an energy transition. The country has substantially advanced its RE deployment. As a result, by 2018 Mexico had a total energy installed capacity<sup>30</sup> of 70 GW of which approximately 33% constituted clean energy<sup>31,32</sup>. Mexico's clean energy capacity generated 23% of the total energy generation, equivalent to 317 TWh<sup>33</sup>. Currently, the country's primary source of clean energy is hydropower which generates 44% of total clean energy generation, followed by wind (17%), nuclear energy (18%), efficient cogeneration (9%)<sup>34</sup>, geothermal (7%), utility-scale solar PV (3%), and biomass (1%). Figure 3.1 shows the breakdown. RE for distributed generation is accounted for separately as it currently only generates 0.97 TWh, with 0.69 GW of installed capacity. However, distributed generation capacity is expected to substantially increase<sup>35,36</sup>.

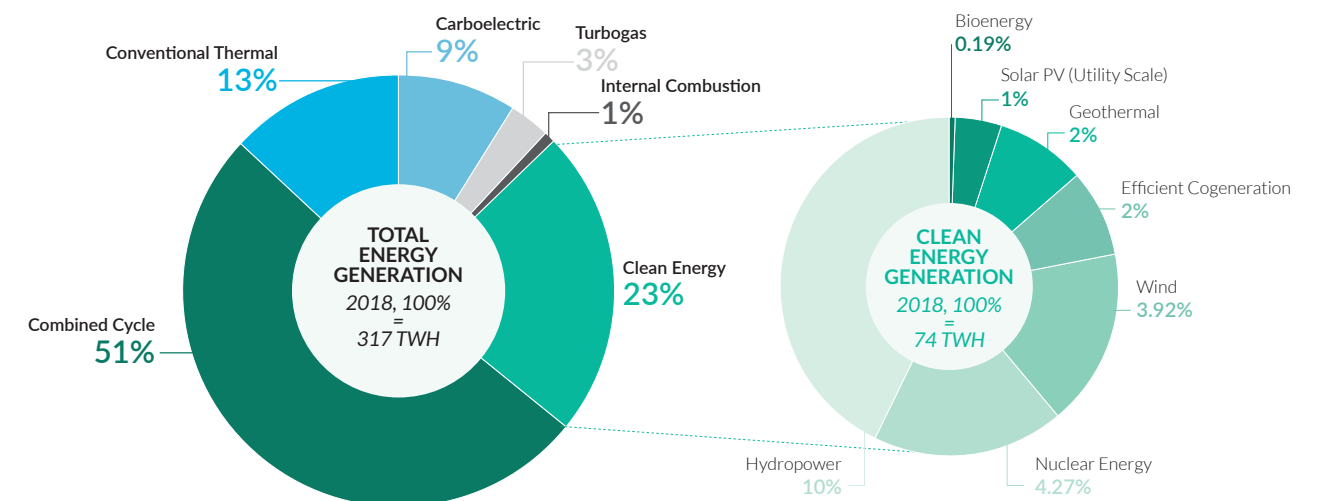


Figure 3.1 Breakdown of Mexico's Energy Generation (TWh) in 2018<sup>37</sup>

Source: SENER, PRODESEN 2019

<sup>30</sup> Total installed capacity does not consider the capacity of Solar PV Distributed Generation by 2018 - equivalent to 0.693 GW. Comisión Reguladores de Energía, *Evolución de Contratos de Pequeña y Mediana Escala- Generación Distribuida*, accessed October 21, 2019, [https://www.gob.mx/cms/uploads/attachment/file/483322/Estadisticas\\_GD\\_2019-1.pdf](https://www.gob.mx/cms/uploads/attachment/file/483322/Estadisticas_GD_2019-1.pdf).

<sup>31</sup> Clean energy includes renewable energy sources, efficient cogeneration with natural gas, and thermoelectric plants with CO<sub>2</sub> capture. SENER, PRODESEN 2019-2033, (Mexico City: Secretaría de Energía, 2019), [https://www.gob.mx/cms/uploads/attachment/file/475504/PRODESEN\\_IV.pdf](https://www.gob.mx/cms/uploads/attachment/file/475504/PRODESEN_IV.pdf), Chapter V, p.27.

<sup>32</sup> SENER, PRODESEN 2019-2033, 2019, Chapter V, p.27.

<sup>33</sup> SENER, PRODESEN 2019-2033, 2019, Chapter V, p.27.

<sup>34</sup> Efficient Cogeneration is defined as the generation of electrical energy in accordance with what is established in section II of article 36 of the Law of the Public Service of Electric Energy (LSPEE), provided that the process has an efficiency higher than the minimum established by the Commission Energy Regulator (CRE). The minimum efficiency criterion established by the CRE is calculated as the additional electrical energy that is generated in a Cogeneration system from the same amount of fuel that would be used in an efficient conventional system. The minimum efficiency criterion increases according to the installed capacity of the system. Efficiency tables, and the calculation methodology are available in SENER, Resolución Núm. RES/003/2011, 22 March, 2011, [www.cre.gob.mx/documento/2299.pdf](http://www.cre.gob.mx/documento/2299.pdf).

<sup>35</sup> Comisión Reguladores de Energía, *Evolución de Contratos de Pequeña y Mediana Escala- Generación Distribuida*, Mexico City, 2019.

<sup>36</sup> It is expected that solar PV DG capacity will reach at least 2.9 GW by 2023.

<sup>37</sup> SENER, PRODESEN 2019-2033, 2019, Chapter V, p.27.



Under the current energy policy, Mexico will further increase its fossil fuel energy capacity<sup>38</sup>, focusing on a transition towards natural gas and “clean energy”. According to the Program for the Development of the National Electric System - Programa de Desarrollo del Sistema Eléctrico Nacional (PRODESEN) 2019-2033<sup>39</sup>, combined cycle technology capacity which currently represents 55% of the country’s total fossil fuel energy capacity, will increase to 74% by 2030 with the aim of substituting heavy fuels in national industry. The installed capacity of RE sources will also continue towards the goal of reaching the country’s GHG emission targets and energy-related targets.

Mexico’s clean energy targets are stated in its 2015 LTE and its General Law for Climate Change. Mexico aims to reach a target of 35% clean energy generation by 2024, 40% by 2035, and 50% by 2050. A slightly more ambitious target was previously stated in Mexico’s first Intended National Determined Contribution (INDC). According to its NDC, the country aims to reach 35% of clean energy by 2024 and 43% by 2030 unconditionally. This means reaching a higher percentage of clean energy five years earlier than planned in the LTE. Additionally, Mexico’s NDC unconditional mitigation targets aim to reduce GHG emissions by 31% and the black carbon produced by the electricity sector by 33% by 2030. Under 2019 PRODESEN parameters, Mexico could potentially reach the 2024 and 2035 targets established in the LTE, but falls short of reaching the slightly more ambitious NDC 2030 target. This study compares the employment effects for the 2020-2030 period of the aspirational NDC scenario to the employment effects of the PRODESEN BAU scenario.

Table 3.1 outlines the baseline data utilized to construct the scenario, the scope of technologies and the targets considered for the analysis.

**Table 3.1** Summary of Mexico’s background information

<b>Total current installed capacity (2018)</b>	70 GW
<b>Total current RE installed capacity<sup>40</sup> (2018)</b>	20 GW
<b>RE technologies analyzed</b>	<ul style="list-style-type: none"> <li>• Utility-scale solar PV</li> <li>• Solar PV distributed generation (DG)</li> <li>• Onshore wind</li> </ul>
<b>Fossil fuel-based technologies analyzed</b>	<ul style="list-style-type: none"> <li>• Combined cycle (Natural gas)</li> </ul>
<b>NDC power sector related targets</b> (considered for the NDC Scenario) <sup>41</sup>	<ul style="list-style-type: none"> <li>• Generate 35% of clean energy in 2024 and 43% by 2030<sup>42</sup></li> <li>• 31% reduction on GHG emissions from electricity generation by 2030 (Against 2030 baseline) equivalent to a level not maximum than 139 MTCO<sub>2e</sub></li> </ul>
<b>6th National Communication of Climate Change and Second Biennial Update Report to the United Nations Framework Convention on Climate Change (INECC)<sup>43</sup></b>	<ul style="list-style-type: none"> <li>• Generate 35% by 2024; 37.7% by 2030 and 50% by 2050.</li> </ul>
<b>Updated energy targets based on the Energy Transition Law (LTE)</b> (considered for the BAU Scenario) <sup>44</sup>	<ul style="list-style-type: none"> <li>• Generate 25% by 2018, 35% by 2024, 40% by 2035, and 50% by 2050</li> </ul>

<sup>38</sup> Nathaniel Parish Flannery, “Political Risk Analysis: Mexico’s Problematic Energy Policy,” *Forbes*, January 07, 2019, <https://www.forbes.com/sites/nathanielparishflannery/2019/06/07/political-risk-analysis-mexicos-problematic-energy-policy/#384e4b9c2386>.

<sup>39</sup> The energy strategy reflected in the PRODESEN 2019 regarding the increase in fossil fuel differs from the strategy reflected in previous versions of PRODESEN. Therefore, the current scenario analysis was contextualized using the information from 2019.

<sup>40</sup> Renewable energy includes installed capacity from hydroelectric, wind, geothermal, and solar PV technologies.

<sup>41</sup> Government of Mexico, *Intended Nationally Determined Contribution*, 2014, [https://www.gob.mx/cms/uploads/attachment/file/162973/2015\\_indc\\_ing.pdf](https://www.gob.mx/cms/uploads/attachment/file/162973/2015_indc_ing.pdf).

<sup>42</sup> The 2030 NDC target was updated to 37.7% on the *6a Comunicación Nacional sobre Cambio Climático*.

<sup>43</sup> “Sexta Comunicación Nacional y Segundo Informe Bial de Actualización ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático,” México ante el Cambio Climático, [https://cambioclimatico.gob.mx/sexta-comunicacion/economia\\_cc.php](https://cambioclimatico.gob.mx/sexta-comunicacion/economia_cc.php).

<sup>44</sup> SEMARNAT, *6a Comunicación Nacional sobre Cambio Climático*, (Mexico City: Secretaría de Medio Ambiente y Recursos Naturales, 2018), <https://cambioclimatico.gob.mx/sexta-comunicacion/introduccion.php>.

## 3.2 POWER SECTOR SCENARIOS

The study analyzes two scenarios for Mexico, the BAU scenario and the NDC scenario, shown in table 3.2. As described below, the BAU scenario is based on PRODESEN 2019-2033 capacity data and aims to achieve the LTE targets, while the NDC scenario increases the RE capacity of wind, utility-scale solar PV, and solar PV DG to reach the NDC target.

**Table 3.2** Scenario comparison of energy generation by 2030 for Mexico

Scenario	Total energy generation (TWh, 2030)	Renewable Energy		Fossil fuel-based Energy	
		Energy Generation <sup>45</sup> (TWh, 2030)	Share (%)	Energy Generation (TWh, 2030)	Share (%)
<b>BAU</b>	531	191	36%	340	64%
<b>NDC Scenario</b>	552	259	47%	294	53%

### 3.2.1 BASELINE SCENARIO (BAU SCENARIO)

The BAU Scenario was developed based on the prospective capacity data from 2019-2033 per technology from the Ministry of Energy’s latest PRODESEN. Under this scenario, the Mexican electricity system will have a total installed capacity of 135 GW<sup>46</sup> by 2030. This represents a 92% increase compared to 2018. Clean energy will contribute 57% of the additional capacity with 43% coming from conventional fossil fuel-based energy sources.

Additionally, this scenario considers a future capacity of 26 GW of solar PV DG by 2030. This capacity is almost two times higher than the estimate of a potential 15GW by the Energy Regulatory Commission (CRE). This adjustment was necessary to reach the LTE targets by 2035.

Under the BAU scenario 32% clean energy generation is achieved by 2024 and 36% by 2030. It therefore comes close to the LTE energy target of 35% by 2024. Based on PRODESEN data, this scenario does not assume retirements of conventional or clean energy sources for the 2020 – 2030 period. It is assumed that the total energy demand grows by 3.10% per annum up to 2032, as indicated by PRODESEN 2019-2033. This scenario covers 116% of the energy demand<sup>47</sup> in 2030.

Lastly, this scenario uses constant load factors based on real operations, as indicated in the PRODESEN 2019.

### 3.2.2 NDC SCENARIO

In the NDC scenario, Mexico’s total installed electricity generation capacity reaches 156 GW by 2030<sup>48</sup>. The NDC Scenario increases the capacity of onshore wind by 18 GW and utility-scale solar PV by 15 GW. The installed capacity of all other clean energy technologies remains equal to the BAU scenario. Under the NDC scenario, the total installed capacity of clean energy reaches 90 GW by 2030.

<sup>45</sup> Including energy generation from solar PV distributed generation.

<sup>46</sup> Not considering the installed capacity for distributed generation.

<sup>47</sup> Considering the energy generation from solar PV distributed generation technology.

<sup>48</sup> Not considering the installed capacity for distributed generation.

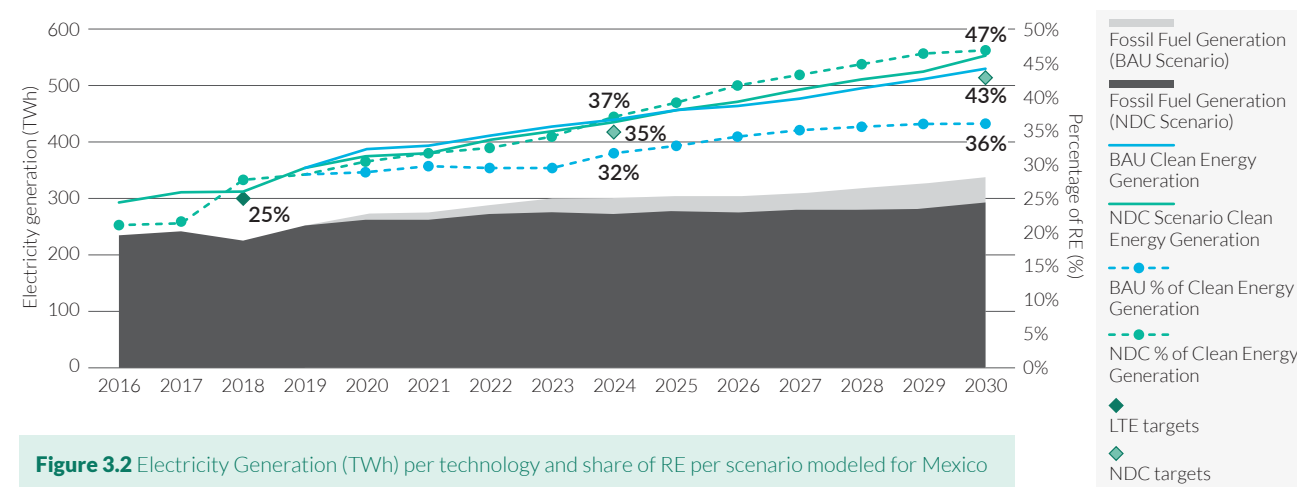
The installed capacity for solar PV DG slightly increases by 2 GW compared to the BAU scenario to ensure that the NDC target of 43% of clean energy generation by 2030 can be reached with no fossil fuel retirements.

The NDC Scenario considers the retirements of 11 GW of conventional fossil fuel-based energy sources for the 2020 -2030 period. The indicated retirements from PRODESEN 2018 were used as a reference for the retirements. The cumulative retirements are distributed as follows: 62% conventional thermoelectric, 13% coal-fired Power Stations, 13% combined cycle; 10% turbogas; 1% internal combustion. The capacity additions of fossil fuel- based energy sources remain the same as in the BAU scenario. The total installed capacity of fossil fuel-based energy sources is 66 GW in 2030.

The annual demand was assumed to be equal to the level of demand estimated for the BAU scenario. This scenario covers the aggregate annual demand by 120%<sup>49</sup> in 2030. Neither scenario considers energy efficiency measures or energy storage solutions which might affect the energy demand.

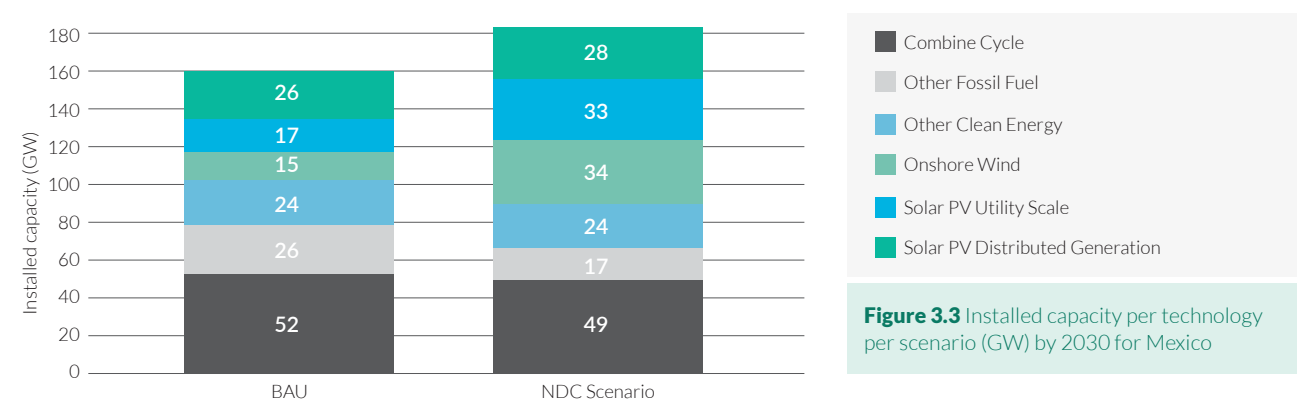
The NDC scenario uses the same load factors as the BAU scenario.

Figure 3.2 shows the electricity generated in TWh per technology type for BAU and NDC scenarios as time series. Figure 3.3 presents the installed capacity in GW per technology for both scenarios.



**Figure 3.2** Electricity Generation (TWh) per technology and share of RE per scenario modeled for Mexico

Source: GGGI Analysis using PRODESEN data for historic values.



**Figure 3.3** Installed capacity per technology per scenario (GW) by 2030 for Mexico

Source: GGGI Analysis using PRODESEN data as BAU

<sup>49</sup> Considering the energy generation from solar PV distributed generation technology.

## 3.3 JOBS ASSESSMENT

### 3.3.1 VARIABLES AND DATA COLLECTION

Mexico benefits from various reliable and high-quality data sources for energy analysis from both public and private sources.

For this assessment, the investment costs per technology per component, and its corresponding share of “local content” for utility-scale solar PV and solar PV distributed generation technologies, were gathered via surveys. The consultancy firm Ithaca Environmental, conducted face to face interviews with the following nine companies in Mexico: Exertis, Elekrika, Grand Solar, Atlas, ANEX, Voltalia, GCL, HEG, and Global Solare.

The investment costs for other technologies (i.e. onshore wind and combined cycle) were retrieved from secondary data specific to Mexico such as Mexico’s I-JEDI Model Data and the Selected Energy Technologies Value Chain study from the National Institute of Ecology and Climate Change (INECC). Global studies from IRENA and the U.S. Energy Information Administration (EIA) were used as a benchmark for local data.

Fuel prices from 2017 till 2020 were retrieved from the U.S. Short-Term Energy Outlook, 2019<sup>50</sup>. Prices from 2021 onwards were assumed to remain constant and equal to real prices of 2020. The cost structure per technology is provided in Annex 4.

The annual wages per economic sector and subsector were retrieved from the 2019 first trimester results of the National Survey of Occupation and Employment (ENOE)<sup>51</sup> and the Monthly Manufacturing Industry Survey<sup>52</sup> of 2019 developed by the National Institute of Statistics and Geography.

The I-O table for Mexico utilized in the model is based on 2015 data updated in December 2018 and was retrieved from the OECD database.

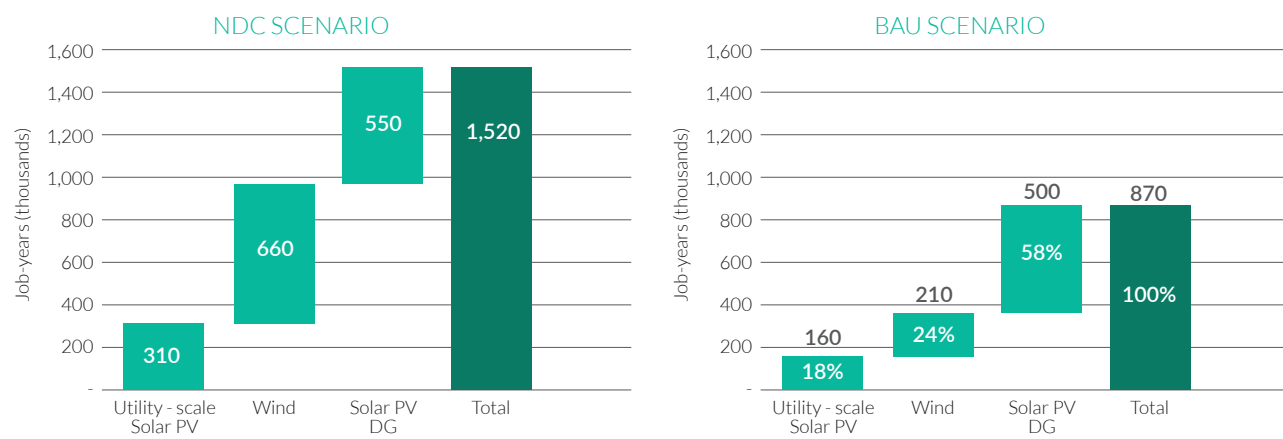
### 3.3.2 EMPLOYMENT EFFECTS OF RE TECHNOLOGIES

The deployment of solar PV distributed generation is essential to reach the LTE and the NDC targets. As shown in figure 3.4, in both scenarios, solar PV distributed generation technology represents at least 36% of the creation of total (direct, indirect and induced) jobs generated. Under the BAU scenario, solar PV distributed generation creates 500 job-years while wind power and utility-scale solar PV create relatively less employment at 210 and 160 job-years respectively. On the other hand, wind power plays a pivotal role in the NDC scenario, creating 660 job-years. Solar PV distributed generation is the second highest employment creator in the NDC scenario at 550 job-years, with utility-scale solar PV creating the least jobs.

<sup>50</sup> U.S. Energy Information Administration, Short-Term Energy Outlook, 2019, accessed October 2019, <https://www.eia.gov/outlooks/steo/report/natgas.php>.

<sup>51</sup> INEGI, Encuesta Nacional de Ocupación y Empleo (ENOE), población en 15 años y más de edad, accessed October 2019, <https://www.inegi.org.mx/programas/enoe/15ymas/>.

<sup>52</sup> INEGI, Encuesta Nacional de Ocupación y Empleo (ENOE), población en 15 años y más de edad, 2019.



**Figure 3.4** Employment effects per RE technology per scenario for Mexico

Source: GGGI Analysis

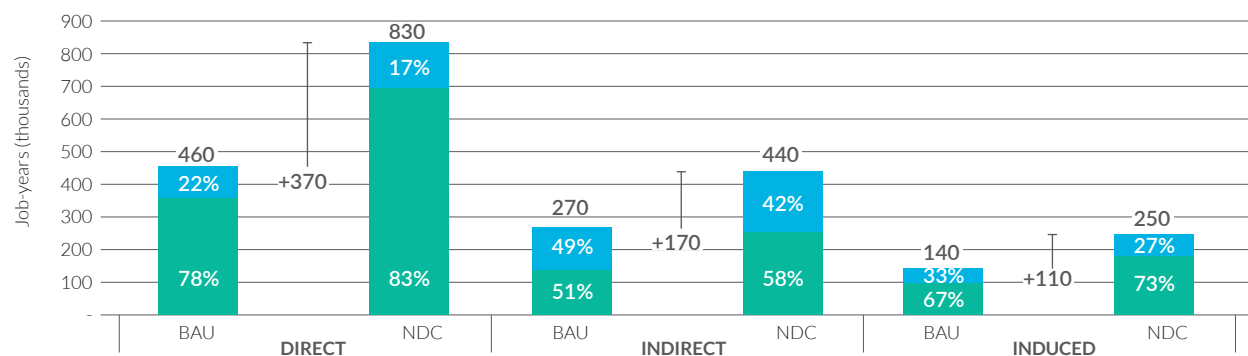
Annex 9 illustrates the temporal distribution of direct job-years for each analyzed RE technology through the modeling horizon. This information provides important insights to policy makers on the time frame of the jobs creation of the two power sector pathways. Under the NDC scenario, the direct jobs created from solar PV technologies gradually increase up to 2024 and then gradually decrease up to 2030. Onshore wind will continue having an increasing rate of jobs creation until 2027 and then will start gradually declining.

### 3.3.3 EMPLOYMENT EFFECTS OF RE TECHNOLOGIES FOR EACH POWER SECTOR SCENARIO

The addition of 35 GW of RE capacity, in the NDC scenario compared to the BAU scenario, will result in the creation of more than 600 thousand additional total jobs, including direct, indirect, and induced jobs, than the BAU.

Figure 3.5 shows that the BAU scenario generates 460 thousand direct jobs for the 2020 -2030 period. In comparison, the NDC scenario generates 830 thousand jobs. For every direct job, more than 0.5 indirect and around 0.3 induced jobs are created in both scenarios.

About 50% of the total jobs will be generated in the sectors where CAPEX is spent, such as EM&D, PD and C&I. Sectors where OPEX is spent, such as O&M and replacement of equipment will generate a smaller percentage of jobs. This is true for all technologies assessed.



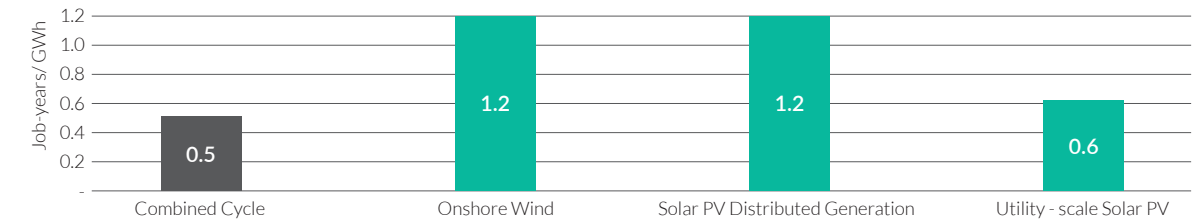
**Figure 3.5** Direct, indirect and induced job creation per type of expenditure for each scenario<sup>53</sup> for Mexico

■ CAPEX ■ OPEX

Source: GGGI Analysis

### 3.3.4 EMPLOYMENT EFFECTS COMPARISON BETWEEN RE AND FOSSIL FUEL TECHNOLOGIES

All the RE technologies assessed (i.e. utility-scale solar PV, solar PV distributed generation, and onshore wind) generate more jobs per GWh than combined cycle technology, as shown in figure 3.6. Among RE technologies, onshore wind technology and solar PV DG produce the highest number of jobs per unit of electricity output.



**Figure 3.6** Direct job creation per unit of electricity generation (GWh) from new capacity under the NDC Scenario in Mexico

Source: GGGI Analysis

Onshore wind and solar PV distributed generation create around 2 and 2.4 times more job-years per GWh compared to utility-scale solar PV and combined cycle respectively. Furthermore, figure 3.7 shows that among the analyzed RE technologies, onshore wind generates the most jobs per million USD invested. These results can be explained by a higher in-country share for onshore wind technology components such as engineering, Project Development, electrical systems installation, etc. (except for turbines, blades, and spare parts) than the in-country share for solar PV components. For example, for solar technology, it is assumed that most of the value in the manufacturing phase remains outside of Mexico. For wind technology, while Mexico does not have local wind turbine manufacturing, it has local tower manufacturing and limited blade production<sup>54</sup>. It is also assumed that 100% of the engineering design and Project Development is done in-country for an onshore wind project. This assumption is based on insights from interviews with local producers and on information from INECC's supply chain report on RE which states that most of the local enterprises in the onshore wind sector focus on the planning and operation stages<sup>55</sup>. For solar PV, only 60% for the design and civil engineering is assumed to take place in-country<sup>56</sup>. The higher number of jobs for wind energy technology than solar PV is also due to differences in labor share per sector. Although the labor share of spending per sector was calculated using the I-O tables, more onshore wind technology components matched with sectors such as construction and other business services which have a higher labor share of investment than the sectors producing solar PV components. For example, the construction sector has a labor share of investment of 18% while the manufacturing, repair, and installation of machinery and equipment has a labor share of 14%.<sup>57</sup> It is assumed that more components of onshore wind relate to the construction sector compared with components of solar PV.

<sup>53</sup> All numbers in the figure are rounded to the second decimal.

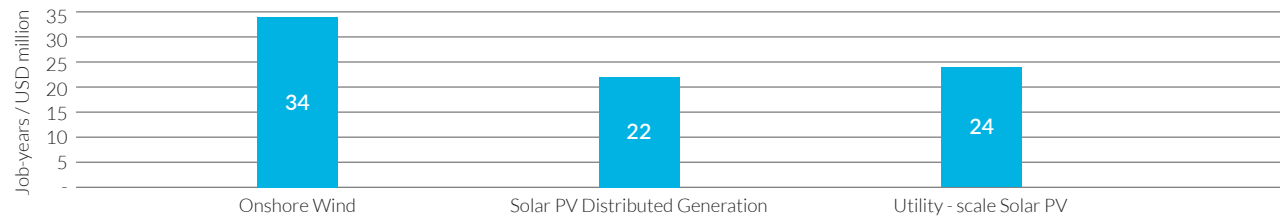
<sup>54</sup> MP, *Reporte de Inteligencia Tecnológica: Energía Eólica en Tierra*, (Mexico City: Instituto Mexicano del Petróleo, 2017), [https://www.gob.mx/cms/uploads/attachment/file/280276/IT\\_E\\_lica\\_12DIC17.pdf](https://www.gob.mx/cms/uploads/attachment/file/280276/IT_E_lica_12DIC17.pdf).

<sup>55</sup> Boston Strategies International, *Estudios de Cadenas de Valor de Tecnologías Seleccionadas Para Apoyar la Toma de Decisiones en Materia de Mitigación en el Sector de Generación Eléctrica y Contribuir al Desarrollo de Tecnologías*, (Mexico City: Instituto Nacional de Ecología y Cambio Climático, 2016), [https://www.gob.mx/cms/uploads/attachment/file/279633/CGMCC\\_2016\\_Cadenas\\_de\\_valor\\_generacion\\_energia\\_electrica.pdf](https://www.gob.mx/cms/uploads/attachment/file/279633/CGMCC_2016_Cadenas_de_valor_generacion_energia_electrica.pdf).

<sup>56</sup> INECC, *Estudios de Cadenas de Valor de Tecnologías Seleccionadas para la Toma de Decisiones*, (Mexico City: Instituto Nacional de Ecología y Cambio Climático, 2016), [https://www.gob.mx/cms/uploads/attachment/file/279633/CGMCC\\_2016\\_Cadenas\\_de\\_valor\\_generacion\\_energia\\_electrica.pdf](https://www.gob.mx/cms/uploads/attachment/file/279633/CGMCC_2016_Cadenas_de_valor_generacion_energia_electrica.pdf).

<sup>57</sup> Authors' calculation based on I-O tables.





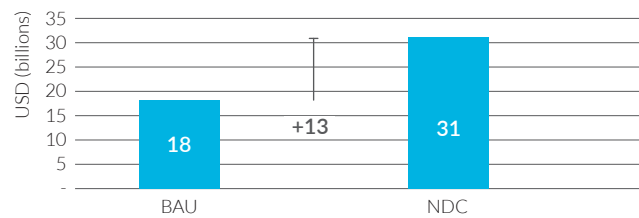
**Figure 3.7.** Direct job creation per unit of investment (USD million) under the NDC Scenario in Mexico

Source: GGGI Analysis

### 3.3.5 ECONOMIC IMPACTS OF EACH SCENARIO

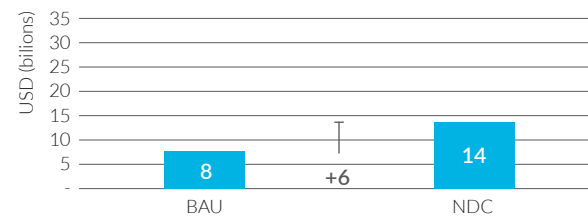
Figure 3.9 shows that the NDC Scenario requires an additional direct domestic investment of 13 billion USD for selected RE technologies compared to the BAU scenario. Due to the steep increase in RE capacity required in the NDC scenario, approximately 80% of the required additional direct domestic investment is allocated for CAPEX while only 20% is allocated to OPEX. According to IRENA, with the right mix of policies, Mexico can attract large-scale investment in renewables<sup>58</sup>. Mexico could attract up to USD 110 billion in investment for the generation, transmission, and distribution sector in RE up to 2030<sup>59</sup>. The results show that achieving the RE target under the NDC would require domestic investment in RE generation of about USD 31 billion that could create value-added of USD 14 billion, as shown in figure 3.10.

The total estimated investment, including the indirect and induced economic effects, required under the NDC scenario is USD 57 billion, which could create a total value-added to the economy of USD 28 billion.



**Figure 3.9** Direct domestic investment for RE per scenario for Mexico

Source: GGGI Analysis



**Figure 3.10** Direct domestic value-added from RE for Mexico

Source: GGGI Analysis

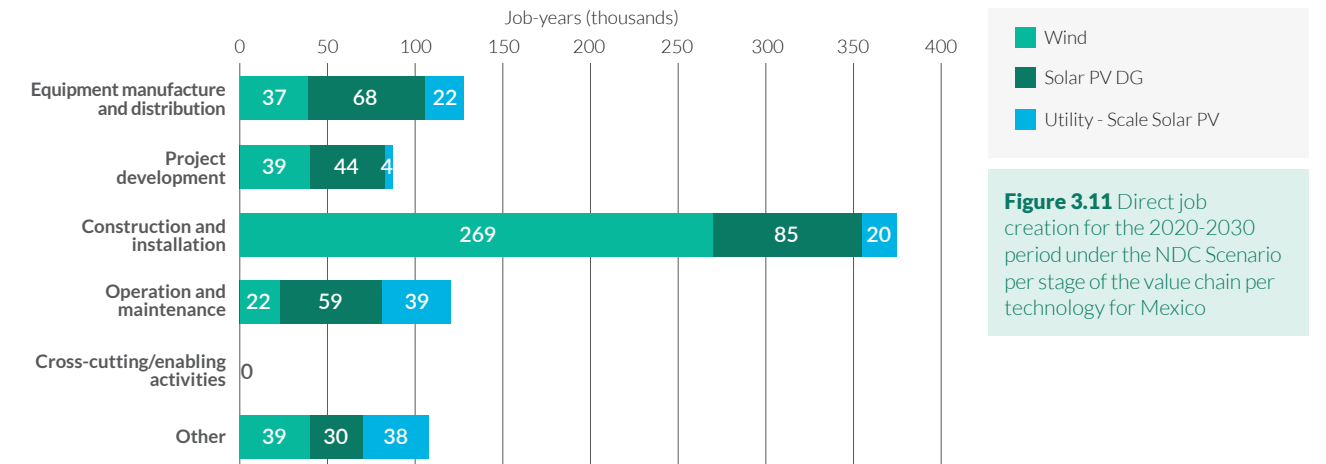
### 3.3.6 EMPLOYMENT EFFECTS ACROSS THE RE VALUE CHAINS

Under the NDC scenario, the direct employment effects of wind, utility-scale solar PV and solar PV distributed generation were assessed for each stage of the value chain as shown in figure 3.11.

Almost half (46%) of the direct jobs created will be in the C&I stage. The other 54% of the direct jobs will be created in EM&D (16%), O&M (15%), and PD (around 11%). This 16% of direct jobs generated in EM&D is lower than the 20% reported in international studies<sup>60</sup> because Mexico imports most of the technology components for solar and wind technologies.

<sup>58</sup> International Renewable Energy Agency, *Renewable energy prospects: Mexico*, May 2015, <https://www.irena.org/publications/2015/May/Renewable-Energy-Prospects-Mexico>.  
<sup>59</sup> German-Mexican Energy Partnership, *Growing Investment Opportunities Mexico's New Energy Era From Framework Fundamentals to Power Sector Focus*, (Federal Ministry for Economic Affairs and Energy of Germany (BMWi) and Ministry of Energy of Mexico (SENER), 2018, [https://www.energypartnership.mx/fileadmin/user\\_upload/mexico/media\\_elements/reports/Mexico\\_s\\_New\\_Energy\\_Era\\_-\\_Web2.pdf](https://www.energypartnership.mx/fileadmin/user_upload/mexico/media_elements/reports/Mexico_s_New_Energy_Era_-_Web2.pdf).  
<sup>60</sup> International Renewable Energy Agency, *Renewable energy benefits: Leveraging local capacity for onshore wind*, 2017; International Renewable Energy Agency, *Renewable energy benefits: Leveraging local capacity for solar PV*, 2017; International Renewable Energy Agency, *Renewable Power Generation Costs in 2018, 2019*.

The number of jobs in PD represent 10% of the direct onshore wind jobs and 15% of the direct jobs in PV distributed generation. However, there are significant differences between different technologies in terms of the share of jobs in the C&I stage – 66% of the total for onshore wind and 16% of the total for utility-scale solar PV. There is also a difference between the share of jobs in the O&M stage from onshore wind (5%) and utility-scale solar PV (32%). International studies have found similar differences in construction and operation stages<sup>61</sup>.



**Figure 3.11** Direct job creation for the 2020-2030 period under the NDC Scenario per stage of the value chain per technology for Mexico

Source: GGGI Analysis

## 3.4 OCCUPATIONS AND SKILLS ASSESSMENT

This simplified preliminary assessment aims to identify the availability of labor resources to meet the total number of direct jobs necessary to deliver the renewable electricity capacity as set out in the NDC scenario for the period 2020-2030. Moreover, the analysis recognizes Mexican efforts to develop a specialized labor force for the RE sector.

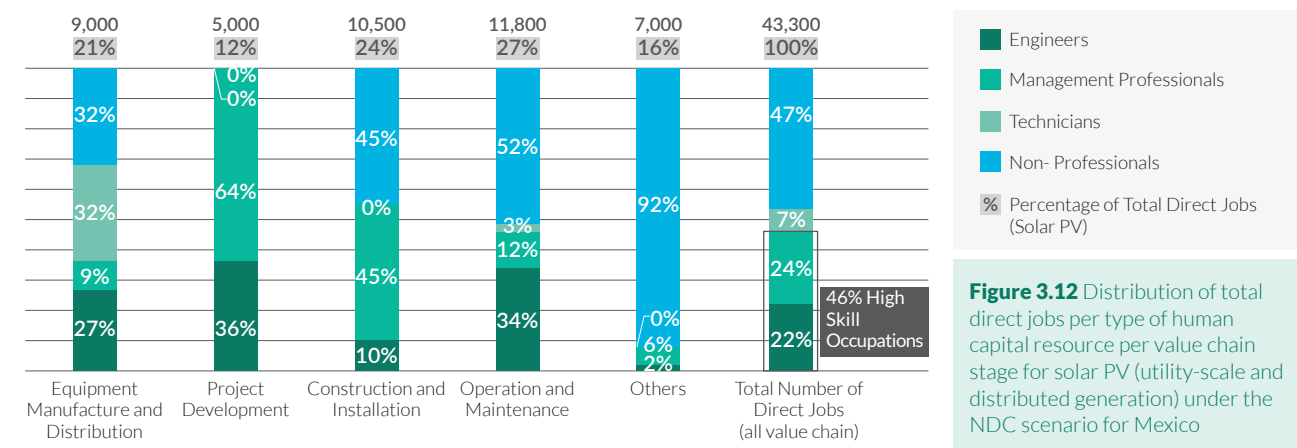
As explained in the methodology, to perform the assessment, the total number of direct job-years per component of the value chain, or human resource demand, was translated into the number of job-years per type of occupation per value chain stage for each technology assessed. This was done using data from IRENA<sup>62</sup> and the key occupations identified by SENER<sup>63</sup>. For example, the total direct job-years in the EM&D stage of the value chain were divided into job-years per occupation (i.e., electrical and mechanical engineers, quality control technicians, management professionals, and primary occupations considered non-professional according to the factors calculated by IRENA). Job-years were converted into jobs during the modeling period (2020 - 2030) by dividing them by ten years.

The human resource demand was then compared with the human resource supply. The supply was estimated at 40%<sup>64</sup> of the total number of graduates or enrolled students at a national level from selected graduate and technical degrees for the 2018-2019 period. It was also taken into account that approximately 5% of graduates from non-energy specialized professions such as management, finance, and legal services enter the energy

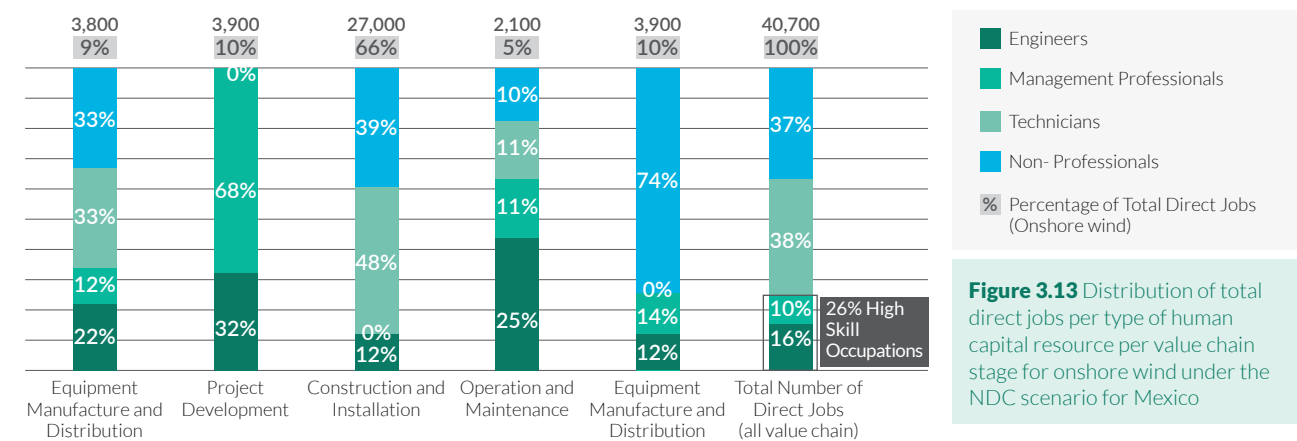
<sup>61</sup> Total direct jobs refer to the summation of direct jobs across all stages and all analyzed renewable energy technologies.  
<sup>62</sup> International Renewable Energy Agency, *Renewable energy benefits: Leveraging local capacity for onshore wind*, 2017; International Renewable Energy Agency, *Renewable energy benefits: Leveraging local capacity for solar PV*, 2017.  
<sup>63</sup> SENER, *Prospectiva de Talento del Sector Energía*, (Mexico City: Gobierno de México, 2016), [https://www.gob.mx/cms/uploads/attachment/file/54342/Prospectiva\\_de\\_Talento\\_Volumen\\_3\\_27\\_01\\_16.compressed.pdf](https://www.gob.mx/cms/uploads/attachment/file/54342/Prospectiva_de_Talento_Volumen_3_27_01_16.compressed.pdf).  
<sup>64</sup> According to the ENOE 2009, approximately 40% of Mexican graduates work in jobs related to their area of studies. Tania M. Moreno, "El 63% no trabaja en lo que estudió," *Expansión*, July 17, 2009, <https://expansion.mx/mi-carrera/2009/07/16/el-63-no-trabaja-en-lo-que-estudio>.

sector<sup>65</sup>. It was assumed that 30% of technicians and 20% of engineers enter the RE sector<sup>66</sup>. The analysis included graduates and enrolled students from selected careers per field which are relevant to the RE sector, although it is recognized that with proper training and substantial field experience graduates from other careers can perform the same roles. The number of graduates and enrolled students were retrieved from the National Association of Universities and Higher Education Institutions (ANUIES) Database. Table 1 in Annex 6 shows the relationship between field of study, occupations, and skills level utilized. To project future supply, the number of available graduates to work in the RE sector from the 2018-2019 period was multiplied by 10 to correspond to the assessment period. It is assumed that the number of graduates will remain constant until 2030.

The results show that the expanding solar PV and onshore wind capacity will increase the demand for high skilled professionals and engineers and low to medium skilled technicians. In Mexico, at least 46% of the total direct jobs for solar PV and 26% of the total direct jobs for onshore wind, that will be created for the 2020 - 2030 period, under the NDC Scenario will require human resources with high skill and qualification levels – university graduates or engineers, as shown in figures 3.12 and 3.13.



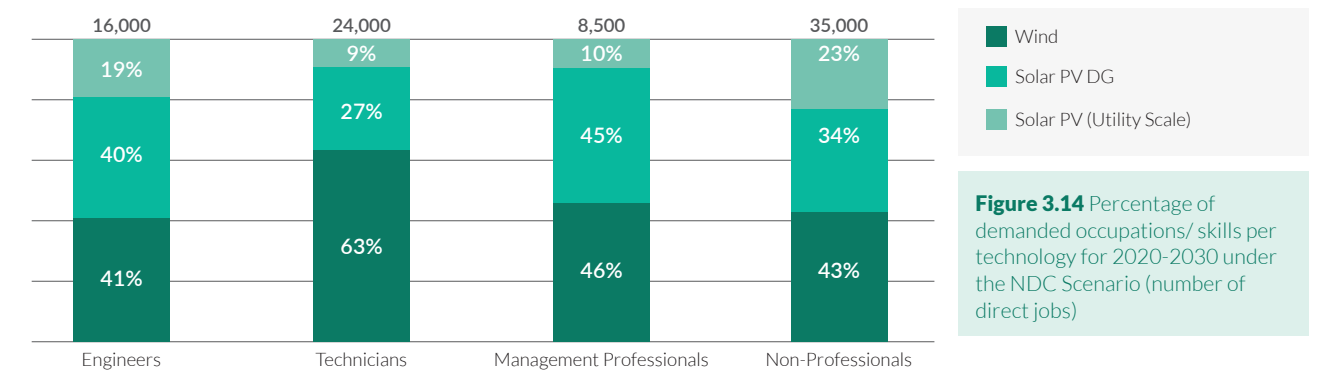
**Figure 3.12** Distribution of total direct jobs per type of human capital resource per value chain stage for solar PV (utility-scale and distributed generation) under the NDC scenario for Mexico



**Figure 3.13** Distribution of total direct jobs per type of human capital resource per value chain stage for onshore wind under the NDC scenario for Mexico

Source: GGGI Analysis

The growth in demand will be driven by an increase in small to medium size companies dedicated to solar PV distributed generation, which require a higher rate of technicians to engineers compared with larger companies<sup>67</sup>. Additionally, in the NDC Scenario, the high deployment of onshore wind will create an additional demand boost for technicians. For the 2020 -2030 period under the NDC scenario, the required number of high skilled workers such as engineers and management professionals (approximately 24.5 thousand jobs) represents at least 30% of the total demand for direct jobs. Another 30% of the total demand for direct jobs is for low and medium skilled workers such as technicians (around 24 thousand jobs). Figure 3.14 shows the breakdown of the percentage of occupations and skills demanded per technology.



**Figure 3.14** Percentage of demanded occupations/skills per technology for 2020-2030 under the NDC Scenario (number of direct jobs)

Source: GGGI Analysis

Reportedly, tasks that required specialized technicians and engineers, with detailed knowledge of specific materials, equipment, systems, computer modeling, and design of solar PV and wind systems are the hardest to recruit for<sup>68</sup>. It follows that additional technical training is needed for the design, fabrication, and installation tasks of RE systems.

The demand for jobs was compared with the future supply of jobs - based on the number of university and technical graduates. Table 3.3 shows the demand and supply comparison.

**Table 3.3** Availability of human capital per field of study<sup>69</sup>

Fields of Study	Total Demand Number of Jobs (2020-2030)	Expected Available Graduates for RE Generation Sector (2018-2019)	Total Supply Number of graduates (2020-2030)	Difference between Supply and Demand	Gap Ratio Supply vs Demand
Engineering and Construction	7,300	7,600	76,000	68,700	10.42
Technicians (Engineering, Manufacturing, and Construction)	24,000	3,000	30,000	6,000	1.07
Natural Sciences	600	100	1,000	400	2.03
Logistic and Quality Assurance	2,800	600	6,000	3,200	2.09
Management, Finance, and Legal	9,000	4,000	40,000	31,000	4.43
Health and Safety	4,500	500	5,000	500	1.07

Source: GGGI Analysis with data from ANUIES

<sup>65</sup> Assumption based on the average share of hires in the energy sector from top business schools worldwide. "Energy – Best Business Schools," Bloomberg Businessweek, December 2018, <https://www.bloomberg.com/business-schools/2018/industries/energy/>.

<sup>66</sup> Assumption based on the percentage of graduates entering wind energy. David Keyser and Suzanne Tegen, *The Wind Energy Workforce in the United States: Training, Hiring, and Future Needs*, (U.S. Department of Energy National Renewable Energy Laboratory (NREL), July 2019), <https://www.nrel.gov/docs/fy19osti/73908.pdf>.

<sup>67</sup> GIZ, *Estudio para determinar cualitativamente y cuantitativamente la demanda de personal calificado en energías renovables y eficiencia energética en México*, 2012, [https://www.gob.mx/cms/uploads/attachment/file/97144/Demanda\\_personal\\_EE\\_y\\_ER\\_2012-GIZ.pdf](https://www.gob.mx/cms/uploads/attachment/file/97144/Demanda_personal_EE_y_ER_2012-GIZ.pdf).

<sup>68</sup> Esther Herrera, "Falta de personal calificado en energía "electrocute" a NL," *El Financiero*, November 21, 2017, <https://www.elfinanciero.com.mx/monterrey/falta-de-personal-calificado-en-energia-electrocute-a-nl>.

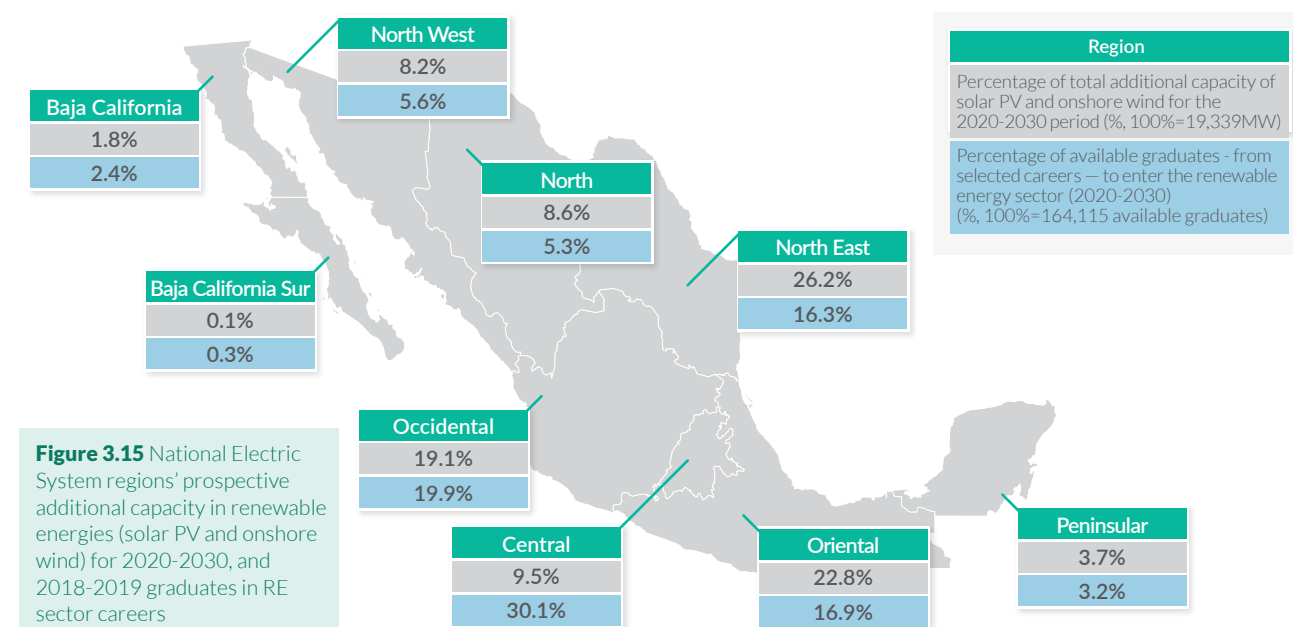
<sup>69</sup> Numbers rounded to the second significant digit.

The results show that all fields of study have a surplus. Under the assumptions used, there will be a sufficient supply of professionals to cover the human capital demand for areas such as management, finance, and legal services in the RE sector. Professionals in these fields of study will not require any further specialization as the competences required in the RE sector are similar to those demanded in other industries such as heavy manufacturing and infrastructure. A supply surplus also exists for engineers, however, further specialization in the form of certifications and focused training might be required as only 8% of enrolled engineers are specialized in energy technologies, RE, the environment, sustainable development or related fields. Mexico's first generation of highly specialized engineers capable of performing key occupations across the RE value chain are starting to graduate as a result of the Strategic Program for Human Capital Training in Energy (PEFRHME). Yet, many private sector companies have identified the need for further preparation. Local companies may incur additional expenses providing additional training and specialized capacity development. For Mexico, this can represent an additional investment of around USD 1500 per each new employee<sup>70</sup>.

There is only a marginal supply surplus for technicians. Therefore, there could be a potential deficit between the available number of graduates and enrolled students against the future demand of technicians. It follows that there is a need to improve the attractiveness of technical careers in Mexico, as the demand for specialized technicians is expected to increase substantially.

The results show that although there is enough availability of highly skilled human resources at a national level, mobilizing graduates to states with high RE potential, prospective RE projects, and a low number of local graduates will further facilitate the energy transition (see figure 3.15).

Figure 3.15 shows the regional percentages of additional capacity and available graduates.



**Figure 3.15** National Electric System regions' prospective additional capacity in renewable energies (solar PV and onshore wind) for 2020-2030, and 2018-2019 graduates in RE sector careers

Source: GGGI Analysis

Simultaneously, implementing long-term measures to locally develop qualified and specialized human capital could accelerate the energy transition. For example, the Oriental zone, which includes Oaxaca, one of the states with the highest wind energy potential in the country<sup>71</sup>, will be allocated around 23% of the total new RE capacity of

<sup>70</sup> Gerardo Hernández, "La industria de la energía solar prevé crear 10,000 empleos en 2019," *El Economista*, July 31, 2018, <https://www.eleconomista.com.mx/capitalhumano/La-industria-de-la-energia-solar-preve-crear-10000-empleos-en-2019-20180731-0056.html>.

<sup>71</sup> Several areas in Oaxaca are estimated to have good to excellent wind resources (wind power Classes 4 to 7, with 7 being the highest). D.Elliott et al., *Atlas de Recursos eólicos del Estado de Oaxaca*, 2004, <https://www.nrel.gov/docs/fy04osti/35575.pdf>.

solar PV and onshore wind<sup>72</sup> for the 2020-2030 period. However, the oriental zone has 17% of the total national graduates. On the contrary, the Central region will add only 10% of the solar and wind energy capacity between 2020 and 2030 and has almost double the number of relevant graduates for the sector at 30%.

## 3.5 RECOMMENDATIONS

### 3.5.1 RECOMMENDATIONS TO INCREASE EMPLOYMENT OPPORTUNITIES IN THE RE SECTOR

#### Strengthen RE targets

Mexico has clear, legally binding and achievable RE targets. However, the country would benefit from setting RE objectives per sector, for example by establishing a percentage of RE to be used in the transport, cooling and heating, buildings, and industry sectors. Integrating sectoral RE objectives could enhance the level of certainty provided the long-term government energy strategy, thereby strengthening future investment forecasts. Including an assessment of potential job creation related to each of the sectoral RE targets can be a persuasive in strengthening the rationale for prospective RE deployment. The creation of employment opportunities is an attractive co-benefit of NDC implementation. Thus, it needs to be included and highlighted while undertaking Mexico's NDC revisions by 2020. According to the "climate action tracker", Mexico's NDC is inefficient in light of the Paris Agreement goal<sup>73</sup>. An updated version of the existing energy efficient and RE deployment roadmaps including a section on job creation potential will provide additional value for policymakers and other key sector stakeholders.

#### Integrate the RE supply chain and fortify technology qualifications

As the share of RE in Mexico increases, its RE value chain develops further.

However, in the case of the wholesale electricity procurement market, qualified suppliers in Mexico require hedging contracts to operate but have limited capacity to sell their retail products. Without a strong retail segment requiring hedging and bilateral contracts, the wholesale market cannot prosper<sup>74</sup>.

In the case of solar PV distributed generation, Mexico can further integrate existing national companies into the supply chain. The energy cluster of the Bajío region already has this objective - integrated by the states of Queretaro, Aguascalientes, San Luis Potosi and Guanajuato<sup>75</sup>. Enhanced supply chain integration can be achieved by leveraging existing national directories<sup>76</sup> for products and services provided by local companies and experts, particularly for the construction and maintenance stages of the value chain. Supply chain integration can also be improved through digitalization<sup>77</sup>. For example, digitalization could reduce operational costs by optimizing operations, expanding opportunities to sell additional solar energy services (aside from the installation of solar panels), and maximizing peer to peer (P2P) energy business models, especially for SMEs.

<sup>72</sup> SENER, *PRODESEN 2019-2033*, 2019.

<sup>73</sup> "Mexico," *Climate Action Tracker*, 2019, <https://climateactiontracker.org/countries/mexico/>.

<sup>74</sup> Mexico Business Publishing, *Mexico Energy Review 2019*, February 2019, [https://issuu.com/mexicobusinesspublishing/docs/mer\\_2019\\_complete\\_book-web](https://issuu.com/mexicobusinesspublishing/docs/mer_2019_complete_book-web), pp 8-11.

<sup>75</sup> Viviana Estrella, "Nace el Clúster de Energía en Querétaro," *El Economista*, August 30, 2018, <https://www.eleconomista.com.mx/estados/Nace-el-Cluster-de-Energia-en-Queretaro-20180830-0024.html>.

<sup>76</sup> SEMARNAT, *Program Guide for the Promotion of Energy Generation with Renewable Resources*, 2015, Annex B.

<sup>77</sup> Solar Power Europe, *Digitalización y Energía Solar Edición México*, (Mexico City: GIZ, ASOLMEX, 2019), <https://asolmex.org/pdf/3619-SPE-Digitalizacion-Energia-Solar.pdf>.



Policies and planning to improve the competitive advantage of local players in the global market and promote innovation and digitalization in the sector should be put in place. Policies could include increasing fiscal and market incentives to deployed intelligent meters and consolidating the NRELMx tool to ease the management of distributed generation projects.

The Mexican market has multiple solar systems with varying degrees of quality and performance. Thus, the establishment of minimum quality standards in the domestic market is a key driver for promoting the development of local RE technologies such as solar. To maximize the market potential, the private and public sectors must strengthen quality standards and certifications for locally manufactured solar systems and their installation. The Ministry of Energy oversees the quality of Mexican products and services, chairing the National Standardization Commission, responsible for approving the National Standardization Program, with the official Mexican standards and norms for all manufacturing products. ASOLMEX is proposing the introduction of a grading system for minimum requirements, i.e. a minimum qualification of BBB, to increase the general performance of installed PV systems in the Mexican markets and reflect the degree of investment requirements.

### Mainstream and support distributed generation

To reach its energy targets, Mexico needs to exploit the market potential for distributed generation. The market has already witnessed exponential growth in the number of distributed generation interconnection contracts with further potential to create a significant number of green jobs throughout the country. However, Mexico needs to extend its electricity transmission and distribution infrastructure. Currently, the market is limited by the grid's interconnection capacity of 28 GW, as estimated by the Federal Commission of Electricity (CFE). Under both scenarios assessed the 28 GW interconnection capacity is exhausted by 2030.

Updates to the standards, norms and grid code outlining the requisites for energy transmission into the grid should be contemplated as solar PV distributed generation develops to avoid future problems in the electricity system. Policies encouraging substantial investments in smart grid solutions should be introduced to allow even more efficient management of the grid's capacity for integrating RE. Simultaneously, the government of Mexico should plan and invest in the future integration of energy storage solutions as they will impact the deployment of distributed generation.

Mexico should also develop sub-national policies to promote the use of distributed generation. For example, the state of Jalisco offers fiscal benefits such as the 100% reduction of income tax (ISR) over the infrastructure investment. Each state should improve communication to increase the population's awareness of the available incentives<sup>78</sup> and the benefits of PV distributed generation technology to foster demand across multiple sectors including households and small and medium-sized enterprises (SMEs).

Lastly, the number of projects that support finance mobilization for the use of RE in productive activities, particularly in rural areas, should be increased. These projects strengthen decentralized energy generation, consequently boosting local- rural employment in the energy sector. The "Agro-Energy for Sustainability Project" (PAES) supported by the World Bank, the Mexican government, and the French Development Agency; The Rural Electrification (using RE) Project – Integral Energy Services, operated by the Energy Ministry (SENER); and the Financing of Micro Generation Projects and Co-Generation of Electric Power, operated by the Trust for the Saving of Electric Power (FIDE) are good examples of such projects.

<sup>78</sup> SEMARNAT, *Program Guide for the Promotion of Energy Generation with Renewable Resources*, 2015.

### Share RE job related information between public and private sector

RE associations (ANES, ASOLMEX, AMDEE, and others) can jointly advocate the benefits of RE technologies and related job opportunities through exhibitions and public events. RE companies and developers should be encouraged to provide data on the labor force they employ in the different stages of the RE value chain to allow better assessment of the occupations and skills required for the energy transition.

### Increase in-country share of RE technology components

The findings of this study show that jobs created per RE technology vary because of the different level of in-country investments in different stages of the value chain of RE technologies. The Mexican government can consider how to increase the in-country share of investments in different stages of the value chain of RE technology to increase the job creation potential of pursuing national RE targets. Mexico could channel investments towards the stages of the value chain from planning and production to operation, where there will be more jobs created per unit of investment and unit of electricity generation.

### Others

Guaranteeing grid reliability and renewable grid integration is a major milestone for the energy sector and another way to boost its job creation potential. Although not covered in this report, energy efficiency offers considerable potential for job creation. Policies supporting energy efficiency should be considered to increase overall employment in the sustainable energy sector.

## 3.5.2 RECOMMENDATIONS TO IMPROVE THE QUALITY AND AVAILABILITY OF HUMAN CAPITAL, OCCUPATIONS, AND SKILLS

The Strategic Program for Human Capital Training in Energy (PEFRHME), arising from the energy reform, has boosted the development of specialized human capital in the country to satisfy the future demand of engineers and technicians for the RE sector. Under this program, Mexico has increased the number of careers specialized in RE and strengthened engagement with multiple sector stakeholders. For example, in 2018 the National Polytechnic Institute of Mexico (IPN) opened its first career in energy which includes specialization in renewable and conventional technologies, based on feedback from the Federal Commission of Electricity (CFE) and the Ministry of Energy<sup>79</sup>. To further strengthen the development and inclusion of energy experts into the human capital pool the following initiatives should be considered:

### Increase government engagement with individual sub-national energy clusters

Government engagement with and promotion of individual sub-national energy clusters would help improve the quality and availability of human capital in Mexico. The regional networks related to energy clusters can incentivize the development of highly skilled local talent. Sub-national energy clusters typically work under a triple helix approach connecting local private enterprises, educational institutions, research centers, and local government. The triple helix approach boosts regional investments and identifies human capital and innovation requirements for the development of the local RE sector. For example, the energy cluster in Querétaro integrated a human capital development committee to assess the educational offering for the energy sector in the state and take action to improve it together with local universities<sup>80</sup>. Sub-national energy clusters can create an alignment between companies' needs for expertise and universities' human capital development by strengthening and simplifying frameworks of collaboration. However,

<sup>79</sup> Gerardo Hernández, "IPN forma capital humano para las nuevas necesidades de la industria energética," *El Economista*, 2018, <https://factorcapitalhumano.com/primer-empleo/ipn-forma-capital-humano-para-las-nuevas-necesidades-de-la-industria-energetica/2018/08/>.

<sup>80</sup> Viviana Estrella, "Nace el Clúster de Energía en Querétaro," 2018.

although the performance of a cluster partially depends on the availability of government support for the industry, it also relies on the availability of competitiveness studies, and the existence of specialized development units<sup>81</sup>. Thus, the parallel creation of state energy agencies under the local government such as Campeche's energy agency in 2017 or Queretaro's Energy Agency in 2019 should be encouraged to further support the development of in-depth local studies which can identify a broad portfolio of sub-national projects in the energy field and its human capital requirements.

### **Strengthen information-sharing efforts**

Human capital development programs and opportunities at international, national, and sub-national levels play a role in informing potential new students pursuing a career in the energy sector or facilitating a match between graduates and companies looking for qualified human capital. Mexico has multiple high-quality programs for human capital development in the energy sector. These programs are often led by a collaboration between public, private, and independent technology centers and have a strong potential to be scaled up or replicate. However, information on these programs is generally held by people already in the sector and not known to potential new students or recent graduates. Therefore, generating a central information source for all human capital programs in the sector could help to increase participation in the existing programs, attract young talent to the industry, and facilitate new collaborations between stakeholders.

### **Increase the offering of private and public education financial support**

Scholarships to students at the postgraduate, graduate, and technical level enrolled in specialized RE programs in states with a current low number of graduates but with a high number of prospective RE projects, for example Oaxaca, would be an effective tool. Scholarships can be operationalized by expanding existing programs such as CONACYT- SENER scholarships program or by engaging with private sector scholarship programs such as Iberdrola scholarships. This would help to ensure the availability of specialized human capital in regions where there will be a high demand for specialists. It could also encourage students from the center to migrate to other regions to seek opportunities.

### **Promote the creation of transformative partnerships and new business**

Transformative partnerships and new business models to provide financial support to technical education centers and universities for the development of state of the art and real field type facilities for practice will help to improve the quality of graduates. This will also facilitate access to certifications and training for non-specialized engineers.

### **Provide incentives for research institutes with collaboration between universities and the private sector**

Incentives for the co-creation of technological research institutes between universities and private sector companies in regions with high RE potential should be provided. This will promote and strengthen partnerships and collaboration between sub-national governments, universities, and energy companies on the development of joint research and training programs in the field of RE and might increase national postgraduate programs on offer.

### **Strengthen existing employment promoting programs**

Another helpful measure would be to promote governmental internship and employment scholarship programs<sup>82</sup> by including a knowledge transfer, tutoring or shadowing training component by experts close to retirement for recent graduates. To maintain and build upon the existing internal knowledge of companies, it is necessary to bridge the existing knowledge with incoming talent. A shadowing program between recent graduates and senior workers would therefore be a valuable addition to the existing internship program. This will also help workers through their transition period into retirement.

<sup>81</sup> Mauricio, I.P. Rivas, Cluster Y Competitividad, [http://biblioteca.utec.edu.sv/siab/virtual/elibros\\_internet/55792.pdf](http://biblioteca.utec.edu.sv/siab/virtual/elibros_internet/55792.pdf).

<sup>82</sup> 'Jovenes Construyendo el Futuro' Internship program, 'Beca a la Capacitacion para el Trabajo' (BECATE) Employment Scholarship Program.



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# 4 INDONESIA

## KEY FINDINGS:

- ▶ Under the RUKN scenario, the new RE capacity added by 2030 will generate around 7.2 million total job-years. This represents 3.7 million direct, 1.72 million indirect and 1.74 million induced job-years that will be generated by 2030. The new RE capacity added under the PLN scenario will generate around 3.9 million total job-years. This represents 2.1 million direct, 0.88 million indirect and 0.89 million induced job-years that will be generated by 2030.
- ▶ Reaching the RE target under the RUKN scenario by 2030 requires significant direct domestic investments in large and small hydro, geothermal and solar PV of about USD 49 billion. The PLN scenario requires a direct domestic investment of around USD 26 billion on new RE capacity and operations to reach its RE target.
- ▶ The direct domestic investments in RE under the RUKN scenario will contribute around USD 24 billion in value-added to the Indonesian economy. The direct domestic investments in RE under the PLN scenario will contribute around USD 10 billion in value-added by 2030.
- ▶ Under the RUKN scenario the RE technologies assessed will generate direct employment, mostly in Construction & Installation and Project Development. More than half, around 53%, of the direct job-years created in the RE sectors analyzed will be in Construction & Installation. The other 47% of the direct job-years will be created in Project Development (25%), Equipment Manufacturing & Distribution (20%), and O&M (3%).

The low carbon development study for Indonesia<sup>83</sup> analyzed various low carbon measures in priority economic sectors under different development scenarios. Although the study looked at different co-benefits of low carbon development in the energy sector, sectoral employment impacts were not addressed. The low carbon development study assessed job creation in the different development pathways at an aggregate level for the whole economy. This study has benefited from the “Ambition to Action” project that was implemented in Indonesia and investigated the employment effects of three solar PV deployment scenarios<sup>84</sup>, as stated in the introduction. No other studies have assessed the employment effects of different scenarios of power sector development in Indonesia and therefore, this study aims to bridge this gap.

The Indonesia case study assesses the employment effects of small hydro (<10MW), large hydro (>10MW), geothermal, and utility-scale solar PV under two scenarios. The fossil fuel energy technology assessed is coal.

<sup>83</sup> BAPPENAS, *Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia*, 2019, [https://www.un-page.org/files/public/indonesia\\_lowcarbon\\_development\\_full\\_report.pdf](https://www.un-page.org/files/public/indonesia_lowcarbon_development_full_report.pdf).

<sup>84</sup> International Climate Initiative Ambition to Action Project, *Three Indonesian Solar Powered Futures*, December 2019, <http://ambitiontoaction.net/wp-content/uploads/2020/01/A2A-2019-Three-Indonesian-solar-powered-futures.pdf>.

## 4.1 CURRENT SITUATION

According to the State Electricity Company (PLN) statistics for 2018<sup>85</sup>, the total Installed capacity in Indonesia was 57.8 GW in 2018, an increase of about 5.2% compared to the previous year. It is made up of 41.7 GW of installed capacity by PLN, 2.5 GW of rented capacity and 13.6 GW of purchased capacity from private companies. Figure 4.1 shows the installed capacity classified by technologies.

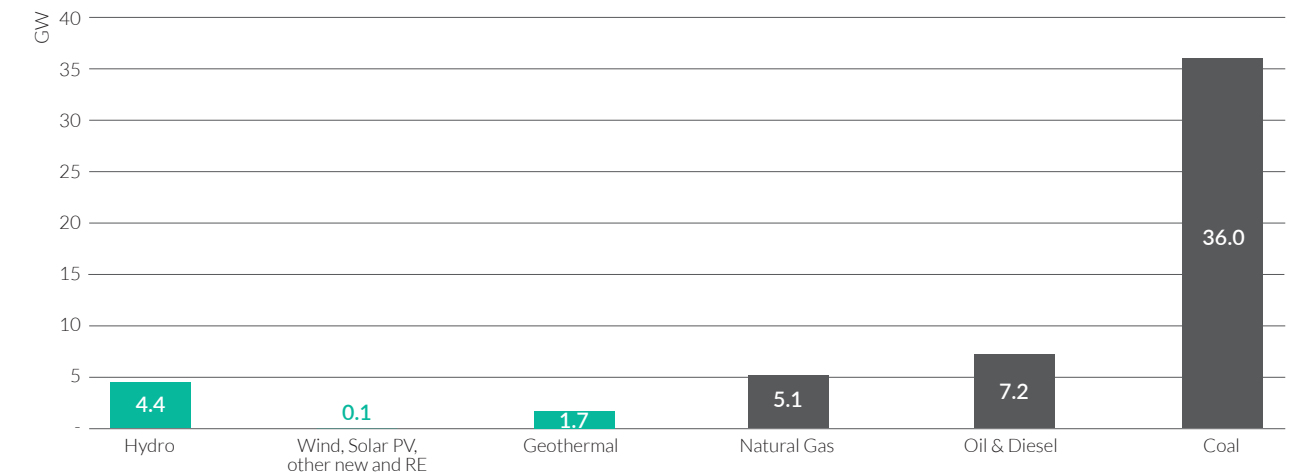


Figure 4.1 Breakdown of Indonesia's Installed capacity (GW) in 2018

Most of the installed capacity in Indonesia in 2018 consisted of conventional energy, composed of natural gas, oil & diesel, and coal, at 88.5% of the total. Large hydro had the highest share of RE technologies in the Indonesian energy mix at 7.7% of the total. Wind, solar PV (11MW), and other new and RE together reach only 0.1GW of installed capacity which is about 0.3% of the total. Figure 4.2 provides information on the share of the composition of installed capacity in Indonesia in 2018.

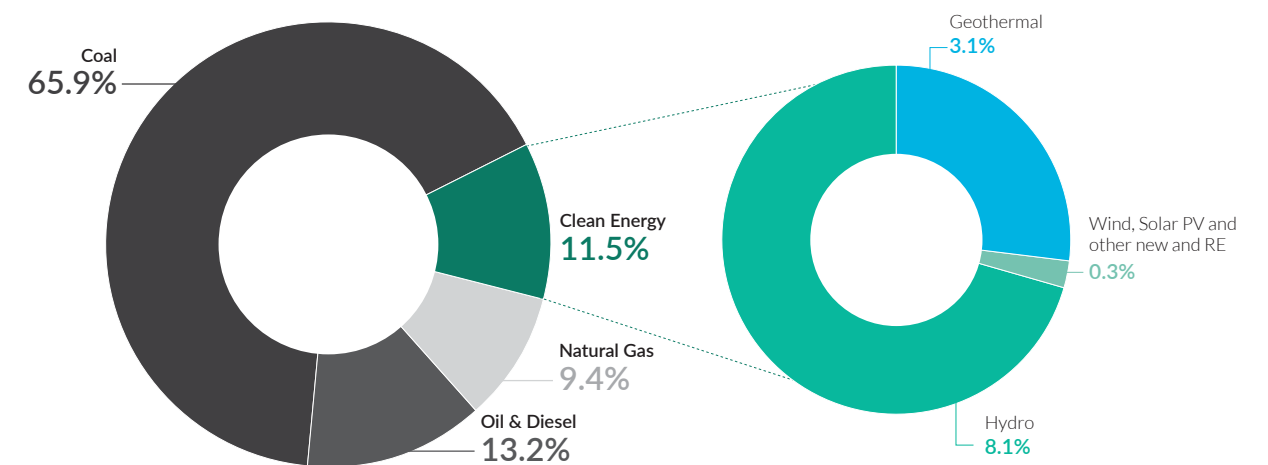


Figure 4.2 Breakdown of Indonesia's Installed capacity (%) in 2018

<sup>85</sup> PLN, *Statistics PLN 2018*, 2018.



The Government Regulation No. 79/2014, on National Energy Policy sets out the ambition to transform the energy mix, setting targets for 2025 and 2050:

- New and renewable energy (NRE) should be at least 23% in 2025 and 31% in 2050;
- Oil should not exceed 25% in 2025 and 20% in 2050;
- Coal should not exceed 30% in 2025 and 25% in 2050; and
- Gas should be at least 22% in 2025 and 24% in 2050.

According to Indonesia's NDC, the country pledges unconditionally to reduce its GHG emissions by 29% by 2030 compared to the business as usual scenario and sets a conditional emissions reduction target of 41%<sup>86</sup>. The Indonesian NDC does not include any specific emission reduction targets for the power sector or RE capacity targets for the power sector. The study assesses different power sector pathways based on national electricity planning documents. Table 4.1 provides background information on the Indonesia case study.

**Table 4.1** Summary of Indonesia's background information

Total Current installed capacity (2018)	57.8 GW
Total Current RE installed capacity (2018)	6.8 GW
RE Technologies analyzed	<ul style="list-style-type: none"> <li>• Hydro (small and large)</li> <li>• Solar PV</li> <li>• Geothermal</li> </ul>
Fossil fuel-based technologies analyzed	<ul style="list-style-type: none"> <li>• Coal</li> </ul>
NDC power sector related target	NO reference to power sector targets

### Electricity Planning in Indonesia

Aiming to achieve a 100% electrification ratio for the benefit of its people<sup>87</sup>, Indonesia reached 98.14% in 2017<sup>88</sup>. The government and PLN released a plan to guide investment and funding in the context of increasing electricity demand nationwide. Two policy documents, the National Energy Plan (RUEN) and the National Electricity General Plan (RUKN), have been published by the Indonesian government. PLN leads the execution of the electrification program with contributions from the national government and regional governments<sup>89</sup>.

PLN provides more than 70% of the installed capacity in Indonesia. In 2018, PLN released the Electricity Supply Business Plan (RUPTL<sup>90</sup>), a 10-year electricity development plan for operating areas. Thus, there are two governmental plans for electricity in Indonesia, the PLN-RUPTL and the RUKN (described above). The PLN-RUPTL has been developed by the state-owned electricity utility company, while the Indonesian government developed the RUKN<sup>91</sup>. The RUKN planning horizon is up to 2038, while the PLN-RUPTL provides plans up to 2028. The RUKN considers both supply and demand sides by including energy efficiency measures, while THE PLN-RUPTL focuses only on supply. The study assesses the employment effects of both the PLN-RUPTL and RUKN plans.

<sup>86</sup> UNFCCC, *First Nationally Determined Contribution Republic of Indonesia*, 2016. [https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Indonesia%20First/First%20NDC%20Indonesia\\_submitted%20to%20UNFCCC%20Set\\_November%20%202016.pdf](https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Indonesia%20First/First%20NDC%20Indonesia_submitted%20to%20UNFCCC%20Set_November%20%202016.pdf).

<sup>87</sup> Asian Development Bank, *Achieving Universal Electricity Access In Indonesia*, 2016. <https://www.adb.org/sites/default/files/publication/182314/achieving-electricity-access-ino.pdf>.

<sup>88</sup> World Bank World Development Indicators (ID:EG.ELC.ACCS.ZS; Accessed 2019), <https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ID>.

<sup>89</sup> Korea Energy Economics Institute, *World Energy Market Insight*, 2016, 16(34).

<sup>90</sup> PLN, Statistics PLN 2018.

<sup>91</sup> Ministry of Energy and Mineral Resources, *Power Supply Business Plan PT State Electricity Company (Rencana usaha Penyediaan Tenaga Listrik PT Perusahaan Listrik Negara)*, 2018.

## 4.2 POWER SECTOR SCENARIOS

The study analyzes two scenarios for the Indonesian electricity sector, the PLN-RUPTL, hereafter referred to as the PLN, and the RUKN. The PLN is based on the business plan released by the state-owned electricity company PLN (RUPTL-PLN, 2019-2028), while the RUKN is based on the National Electricity Plan 2019-2038, Rencana Umum Ketenagalistrikan Nasional (RUKN). Table 4.2 compares the capacity targeted in the PLN and the RUKN scenarios.

**Table 4.2** Scenario comparison of installed capacity by 2030 for Indonesia

Scenario	Total installed capacity (GW, 2030)	Renewable Energy		Fossil fuel-based Energy	
		Installed capacity (GW, 2030)	Share (%)	Installed capacity (GW, 2030)	Share (%)
PLN	123	28.5	23%	94.5	77%
RUKN	166	43	26%	123	74%

### 4.2.1 PLN SCENARIO

The PLN scenario represents the current capacity based on historical information from PLN's Power Supply Business Plan report<sup>92</sup> and its projected future capacity. For the period 2019-2028, the PLN scenario includes all reported additions disaggregated by technology. For the period 2029-2030, a 5-year compound annual growth rate (CAGR) was used to extrapolate the scenario for each technology.

According to PLN scenario projections, by 2030 Indonesia will reach a total installed capacity of 123GW, of which 28.5GW (23.2%) will come from RE while 94.39GW (76.8%) is projected to come from conventional energy.

The PLN scenario uses constant load factors based on actual operations as indicated in PLN 2018 statistics.

### 4.2.2 RUKN SCENARIO

Capacity additions from 2019 to 2030 are based on the RUKN<sup>93</sup> projections. This scenario projects renewable capacity to be 26% of the total and conventional energy capacity to be 74% of the total by 2030. According to the RUKN, there will be retirements for conventional energy facilities such as natural gas, oil and diesel, and coal by 2030 but not for RE. The existing conventional energy capacity was around 48 GW in 2017 but according to the RUKN scenario will be decreased to about 38 GW in 2030 due to the retirements. However, new capacity additions both in RE and conventional energy will continue to increase every year during the forecasting period.

Large hydro is projected to have the highest newly installed capacity of approximately 16 GW, followed by solar PV with 9 GW newly installed capacity by 2030. Oil and diesel are the only technologies with an expected net decrease in capacity from about 7.2 GW in 2017 to about 5.4 GW in 2030.

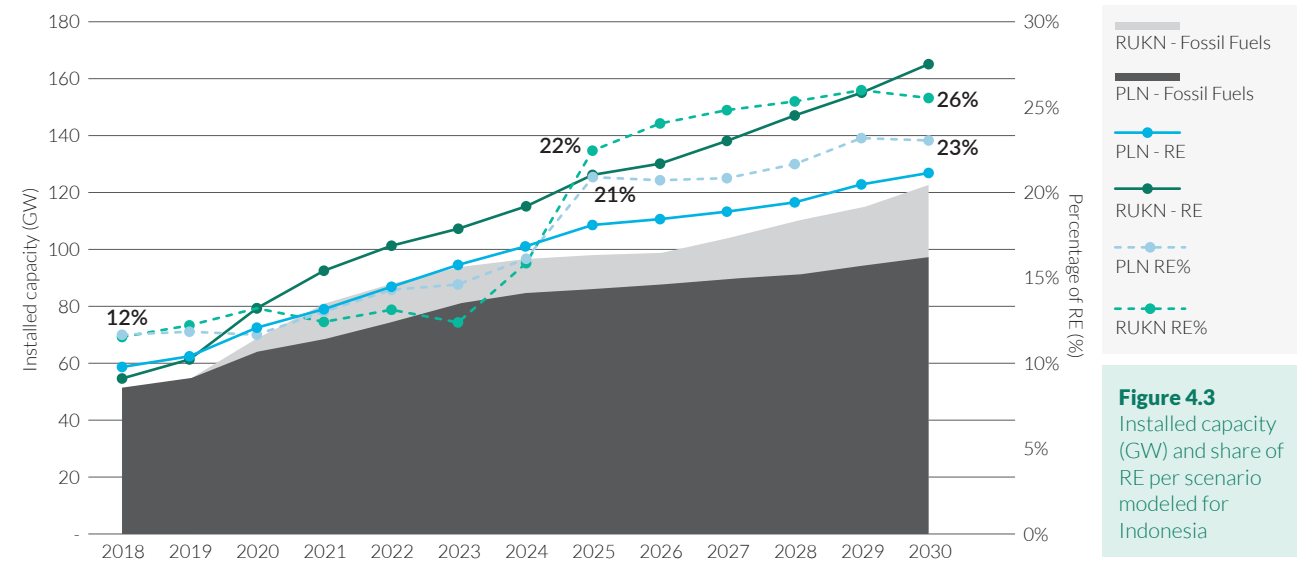
The total installed capacity in 2030 is projected to be more than three times larger than it was in 2017. Total RE installed capacity in 2030 is projected to be seven times larger than it was in 2017, while total conventional installed capacity in 2030 is about 2.5 times larger than it was in 2017. The total RE capacity share is 11.5% (6.26 GW) in 2017 which increases up to around 26% (43.26 GW) in 2030. The total conventional energy share is around 88.5% (48.3 GW) in 2017 which decreases up to around 74% (122.83 GW) in 2030.

<sup>92</sup> Ministry of Energy and Mineral Resources, *Power Supply Business Plan PT State Electricity Company*, 2018.

<sup>93</sup> Kementerian Energi Dan Sumber Daya Mineral Jakarta, *Rencana Umum Ketenagalistrikan Nasional*, 2019.

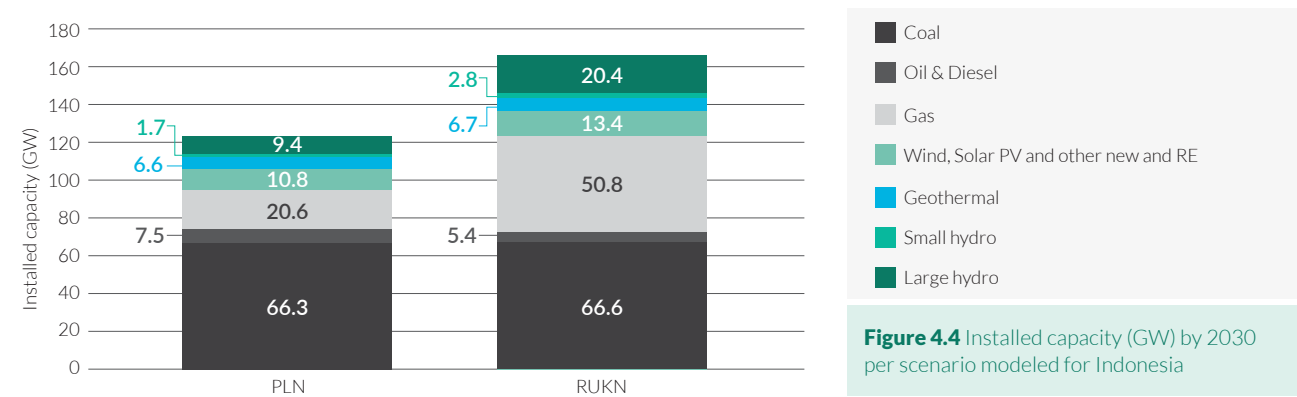
The RUKN scenario uses the same constant load factors as the PLN scenario, which are based on actual operations as indicated in the PLN's 2018 statistics.

Figure 4.3 shows the installed capacity over time in both the PLN and RUKN scenarios.



**Figure 4.3**  
Installed capacity (GW) and share of RE per scenario modeled for Indonesia

Figure 4.4 shows the breakdown of installed capacity in 2030 for both the PLN and RUKN scenarios.



**Figure 4.4** Installed capacity (GW) by 2030 per scenario modeled for Indonesia

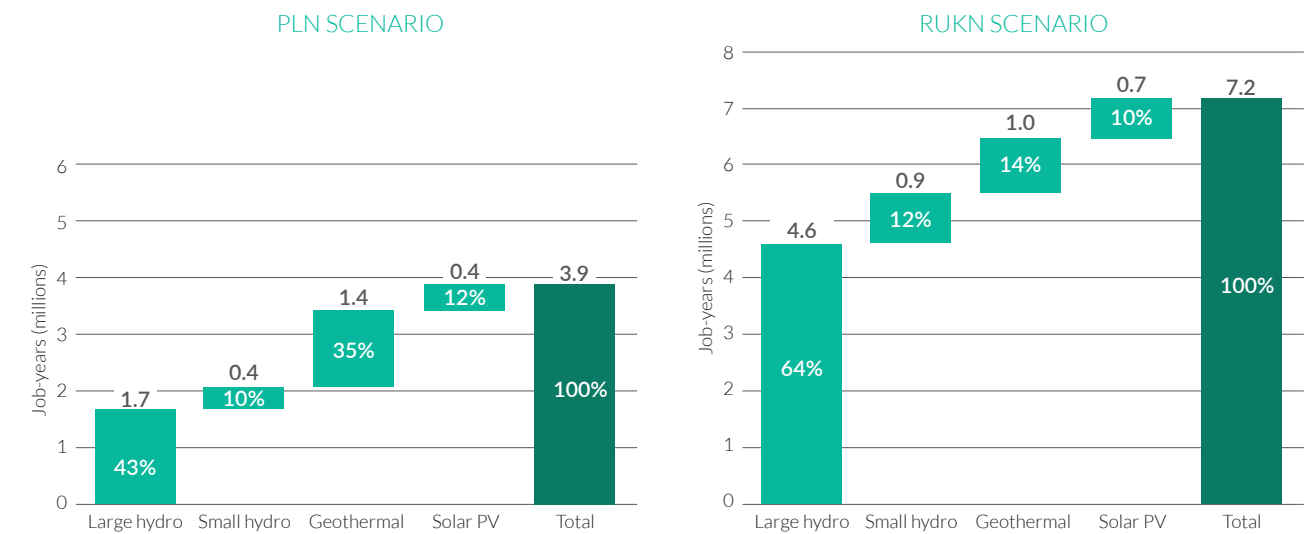
## 4.3 JOBS ASSESSMENT

### 4.3.1 VARIABLES AND DATA COLLECTION

Surveys and interviews with large and small hydro and geothermal project developers and experts, including the Indonesian Hydropower Association and the Indonesian Geothermal Energy Association, were conducted to collect technology cost data, along with in-country share of investment data and labor share data. The Danish Energy Agency (DEN)<sup>94</sup> provided secondary data for technology cost data for solar and coal. Local content requirement (LCR) figures for solar PV according to the Ministerial Decree or Order No. 54/M-IND/PER/3/2012 and No. 05/M-IND/PER/2/2017 were used to estimate the in-country share of investment for solar PV. The LCR for solar PV is 42% for goods and 100% for services. Salary data were collected from national statistics and the Indonesian I-O table was derived from the updated OECD database. Learning factors for all energy technologies assessed were also obtained from the 2017 DEN technology data. Fuel costs for coal were assumed to meet the price cap at USD 70 per ton of coal as set by the government through the MEMR Decree No. 1395/K/30/MEM/2018, issued in March 2018.

### 4.3.2 EMPLOYMENT EFFECTS OF RE TECHNOLOGIES

Under the PLN scenario, large hydro creates the most total job-years at around 1.7 million, followed by geothermal that creates 1.4 million, whereas solar and small hydro can create 0.5 and 0.4 million jobs, respectively. Large hydro is also the highest jobs creator of all RE technologies assessed under the RUKN scenario, generating around 4.6 million total jobs<sup>95</sup>, followed by geothermal with 1 million jobs, small hydro with 0.9 million jobs, and solar PV with 0.7 million jobs. The job-years numbers are broken down by technology in figure 4.5.



**Figure 4.5** Employment effects (in million job-years) per RE technology per scenario for Indonesia

Source: GGGI Analysis

<sup>94</sup> Danish Energy Agency, *Technology Data for the Indonesian Power Sector: Catalogue for Generation and Storage of Electricity*, 2017, [http://www.ea-energianalyse.dk/reports/1724\\_technology\\_data\\_indonesian\\_power\\_sector\\_dec2017.pdf](http://www.ea-energianalyse.dk/reports/1724_technology_data_indonesian_power_sector_dec2017.pdf).

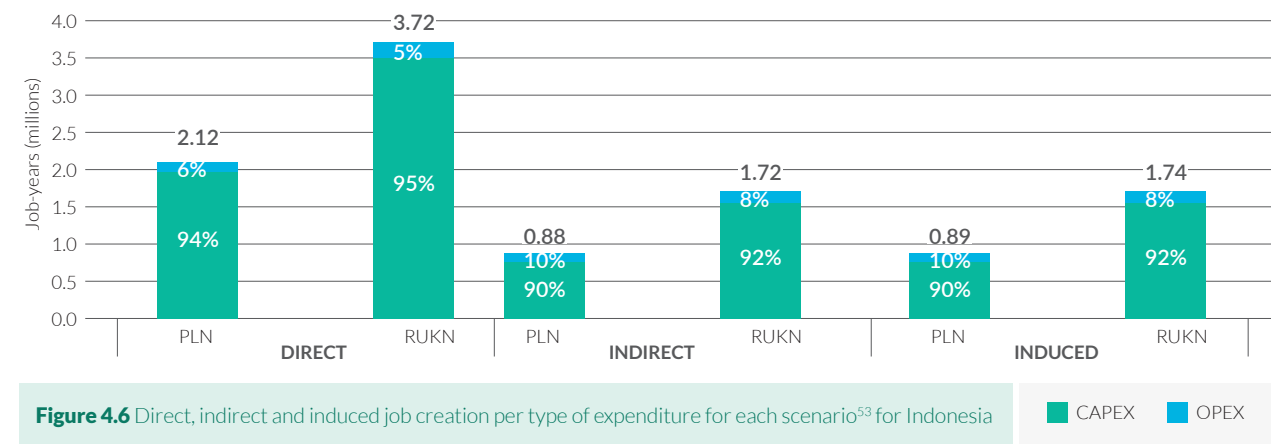
<sup>95</sup> Total jobs include direct, indirect, and induced jobs.

Annex 9 illustrates the temporal distribution of direct job-years for each analyzed RE technology through the modeling horizon. Under both scenarios, the highest share of jobs will be created in the first years until 2024. Under the RUKN scenario, large and small hydro will provide most of the jobs during the first years of the modeling horizon, whereas after 2026 a gradual increase of geothermal capacity will provide a high share of the direct jobs.

### 4.3.3 EMPLOYMENT EFFECTS OF RE TECHNOLOGIES FOR EACH POWER SECTOR SCENARIO

Under the RUKN scenario, all hydro (large and small), geothermal and solar energy together could generate about 3.72 million direct jobs. Under the PLN scenario, the RE technologies assessed could generate around 2.12 million direct jobs. Under the RUKN scenario a further 1.72 million indirect and 1.74 million induced jobs can be created, whereas under the PLN scenario, 0.88 million indirect and 0.89 million induced jobs can be created. This means that under both the PLN and RUKN scenario, for every direct job created, 0.5 additional indirect jobs and 0.5 additional induced jobs can be created in the overall economy.

In both scenarios, around 94-95% of potential direct jobs would be in sectors where CAPEX is spent, such as equipment manufacturing and distribution. Sectors where OPEX is spent, such as O&M and the replacing of equipment, will generate far fewer direct jobs at around 5-6% of the total. Similarly, around 90-92% of the indirect and induced jobs created in both scenarios would be in (EM&D), PD and C&I where CAPEX is invested. The remaining 8-10% of indirect and induced jobs will be created in sectors related to O&M and equipment replacement. Figure 4.6 shows the creation of direct, indirect and induced jobs for both scenarios.



Source: GGGI Analysis

### 4.3.4 EMPLOYMENT EFFECTS COMPARISON BETWEEN RE AND FOSSIL FUEL TECHNOLOGIES

Under the RUKN scenario, all RE technologies analyzed provide a higher return of job-years per GWh of electricity generated by new capacity compared to coal. Large hydro generates 3.8 times more job-years per electricity output than coal, followed by small hydro at 3.2 times more than coal, and geothermal and solar, both generating 2.8 and 2.5 times more jobs per GWh respectively compared to coal.

Per USD million invested in new capacity under the RUKN scenario, small hydro has the potential to create the most jobs at 165 job-years, whereas geothermal, large hydro and solar create approximately 126, 63, and 55 job-years per USD million respectively. Coal generates the least number of jobs per USD million invested, at 31 job-years, when compared to the selected RE technologies. Figure 4.7 shows the job creation per unit of capacity and added in terms of capacity and USD investment.

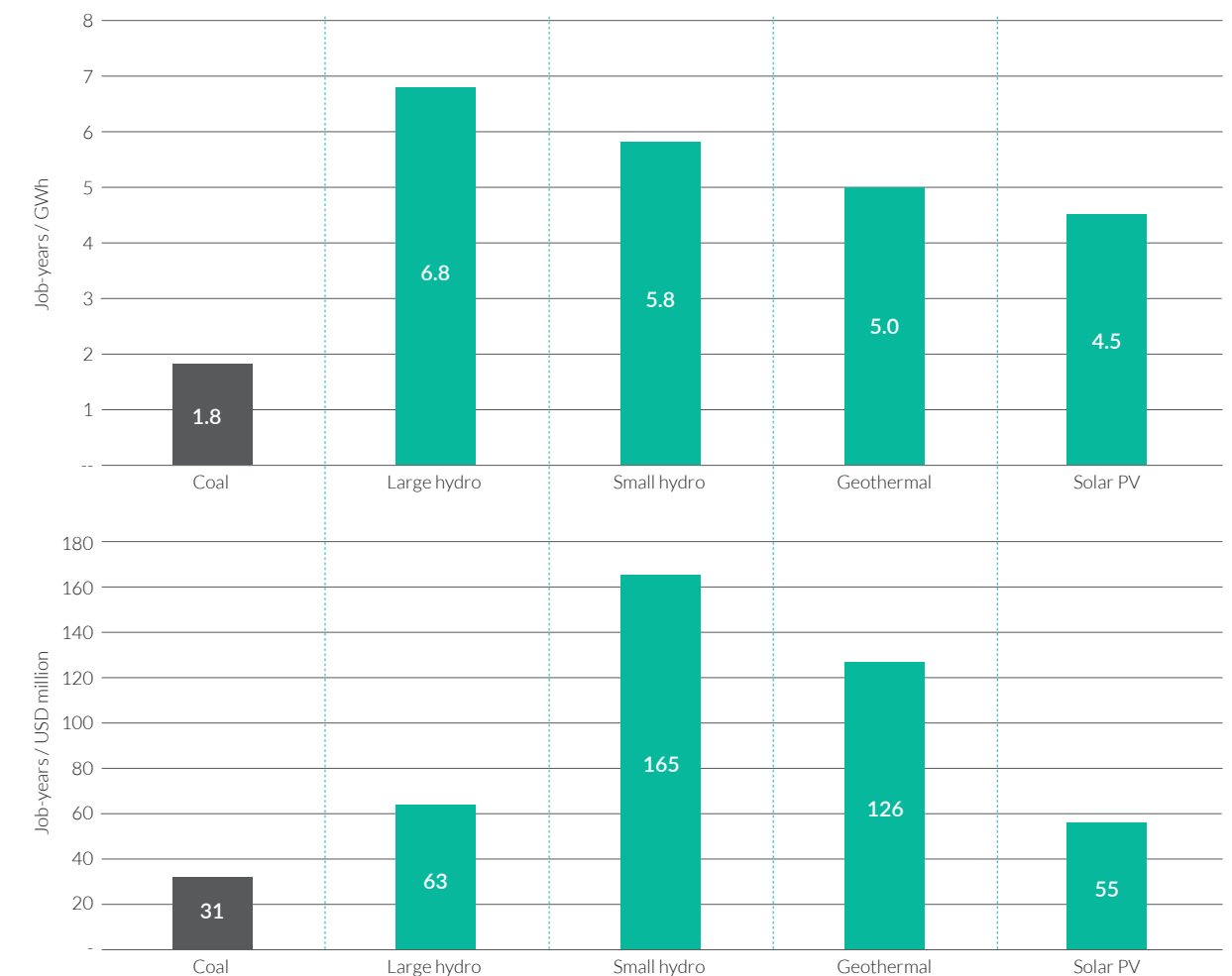


Figure 4.7 Direct job creation per unit of electricity generation (GWh) from new capacity and per unit of investment (USD million) under the RUKN scenario in Indonesia

Source: GGGI Analysis

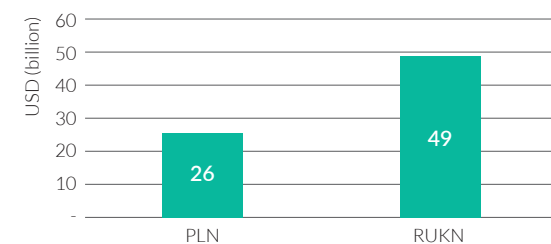


The study results show that RE technologies can create more jobs per unit of electricity generated and unit of investment than coal. One of the main reasons for this is that, as the interviews with the hydro and geothermal associations revealed, large hydro, small hydro, and geothermal have higher in-country share compared to coal. For large hydro for instance almost all, around 94% of the investment in project development (in other business sector services) and civil works (in construction) is spent in Indonesia. In addition, small hydro and geothermal have a considerably higher labor intensity (higher labor share) compared to coal<sup>96</sup>, particularly on construction and installation and project development stages of the value chain.

### 4.3.5 ECONOMIC IMPACTS OF EACH SCENARIO

Reaching the RUKN RE target would require significant direct investments of around USD 49 billion, which could generate around USD 24 billion direct value-added to the Indonesian economy. Under the PLN scenario around USD 26 billion of direct investments would be required, which could generate around USD 10 billion value-added to the Indonesian economy. Figures 4.8 and 4.9 highlight the difference in domestic investment value-added to the Indonesian economy from the two scenarios.

When including the indirect and induced economic effects, the total domestic investments that will be required will be around USD 110 billion and USD 57 billion for RUKN and PLN respectively, and could create total value-added of USD 53 billion and USD 23 billion respectively.



**Figure 4.8** Direct domestic investment per scenario from RE for Indonesia

Source: GGGI Analysis



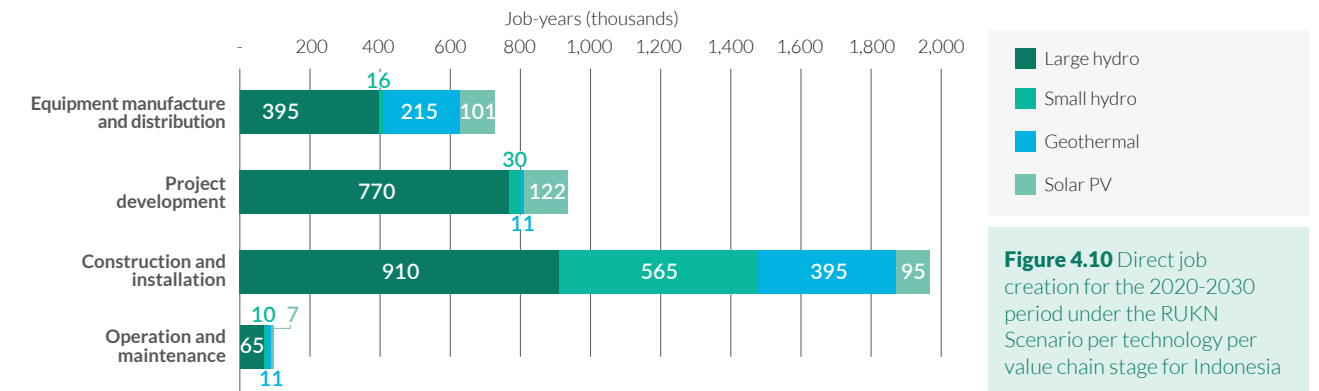
**Figure 4.9** Direct domestic value-added per scenario from RE for Indonesia

Source: GGGI Analysis

### 4.3.6 EMPLOYMENT EFFECTS ACROSS RE VALUE CHAINS

The study quantified the number of direct jobs required at each RE stage of the value chain for the RUKN scenario. Figure 4.10 shows the breakdown of job creation by technology for each stage of the value chain under the RUKN scenario.

More than half, around 53%, of the direct job-years created in the RE sectors analyzed will be in C&I. The other 47% of the direct job-years will be created in PD<sup>97</sup> (25%), EM&D (20%), and O&M (3%). Large hydro and small hydro together generate more than 1.4 million job-years in the C&I sector. As explained also in 4.3.4 both the in-country share and labor share of investments in hydro are very high in construction and installation stage of the value chain. Solar PV generates more jobs in PD (almost 40%) than in C&I. More than 50% of job-years generated from geothermal are in C&I.

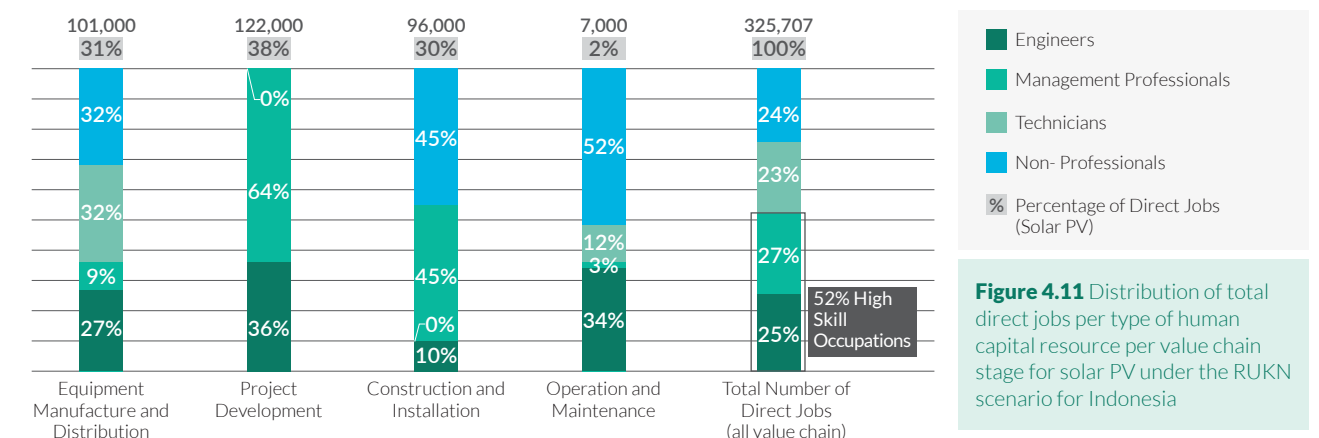


**Figure 4.10** Direct job creation for the 2020-2030 period under the RUKN Scenario per technology per value chain stage for Indonesia

## 4.4 OCCUPATIONS AND SKILLS ASSESSMENT

The study estimates the type of occupations and skills in demand in each stage of the solar PV value chain (see also Annex 6). Under the RUKN scenario, solar PV generates more than 325 thousand direct jobs. A high demand for highly skilled occupations such as engineers and management professionals is estimated, accounting for more than 170 thousand jobs (52%). The technical and non-professional workforce accounts for more than 155 thousand jobs, almost half of the direct jobs (48%). These occupations are identified as technical and construction workers that require a medium to low skill set.

Figure 4.13 shows the distribution of jobs along the value chain.



**Figure 4.11** Distribution of total direct jobs per type of human capital resource per value chain stage for solar PV under the RUKN scenario for Indonesia

Source: GGGI Analysis

The Indonesian equipment manufacturing sector is estimated to require more than 100 thousand direct jobs, of which 64% will be created for medium and low skilled occupations for technicians and factory workers<sup>98</sup> (see also annex 6). Additionally, more than 36 thousand highly skilled jobs are required, including more than 10 thousand (9%) management professionals and around 26 thousand engineers.

More than 120 thousand jobs are created in the PD phase, with several professional occupations from different fields in demand. Around 36% of these jobs will be from several engineering fields such as electrical, civil and mechanical, the equivalent of 44 thousand jobs. In PD, around 78 thousand (64%) people working in management

<sup>96</sup> As explained in the introduction, the employment effects are estimated for the modeling horizon 2020-2030. Additional jobs that might be generated during operation and maintenance of the energy systems assessed beyond 2030 were not considered.

<sup>97</sup> Financing and permitting related activities were considered to fall in the PD stage of the value chain.

<sup>98</sup> Factory workers refer to human resources required to manufacture the main components of solar PV plant; International Renewable Energy Agency, *Renewable energy benefits: Leveraging local capacity for solar PV*, 2017.

related jobs including jobs in the financial sector, administrative staff, logistics and environment and safety experts will also be in demand (see also annex 6). All jobs in PD require high skilled labor.

The C&I stage of the value chain requires more than 96 thousand jobs, where around 43.5 thousand (45%) are estimated to be low skilled jobs, identified as non-professional workers, and around 43.5 thousand jobs (45%) are estimated to be medium to low skilled jobs, identified as technicians. It is estimated that the remaining 1600 jobs (10%) are engineers.

O&M generates 7 thousand jobs, with a high number of jobs in low skilled occupations (non-professionals) for more than 3.5 thousand non-professional staff. It is estimated that around 2.4 thousand high skilled engineers will be required. There are also more than 800 jobs for low and medium skilled technicians.

## 4.5 RECOMMENDATIONS

### 4.5.1 RECOMMENDATIONS TO INCREASE EMPLOYMENT OPPORTUNITIES IN THE RE SECTOR

#### Establish RE and GHG emission reduction targets for the power sector under the NDC

The current Indonesian NDC does not include any power sector RE targets or GHG emissions reduction targets for the power sector. Indonesia's economy is growing fast and the electricity system is currently dominated by fossil fuel-based technologies, particularly coal. Therefore, Indonesia should consider the alignment of energy and climate policies<sup>99</sup> and the introduction of power sector RE targets in combination with higher emission reduction targets in the next NDC revision by the end of 2020. According to the "climate action tracker" the Indonesia's current NDC is highly insufficient in the context of the Paris Agreement goal<sup>100</sup>. Establishing higher emission reduction targets will set Indonesia's electricity system on a decarbonization pathway, where RE technologies could play a vital role. Incorporating RE targets and emission reduction targets could reinforce the process of decarbonization of the Indonesian power sector, while simultaneously tapping into the co-benefits of RE that could be generated, including employment benefits. Exploring the most cost-effective technologies to reduce carbon emissions can be supported by an assessment of the employment and wider economy benefits of these technologies, providing the necessary evidence for well-informed decision-making. This study provides clear evidence of the significant employment opportunities that could arise from investments in RE compared to coal. Indonesia should incorporate this evidence in the revision of its NDC.

#### Create an enabling policy environment for RE

The Indonesian government should work towards creating a stable and enabling policy environment, including fiscal and financial incentives, to attract investors and RE project developers. According to IISD (2018)<sup>101</sup>, RE project developers identify the lack of stable regulatory and policy framework as one of the main challenges for developing RE projects. As a result of frequent changes in the regulations, project development costs could be increased while some projects might become unfeasible to be developed. Therefore, providing clear policy signals of long-term support for RE by setting medium and long term RE targets in NDCs and National Energy Plans could provide project developers and investors with more certainty. In 2017, Indonesia abandoned through new regulations the feed-in tariff scheme to support REs and introduced a new pricing scheme where PLN should pay

up to only 85% of the average regional generation costs, effectively capping RE purchase prices. This is certainly a very unfavorable policy for RE, with projects paid less for than average prices. Furthermore, an IISD study<sup>102</sup> found that in 2015, the Indonesian government provided around USD 664 million in subsidies and fiscal supports to the coal industry creating an even less favorable policy and pricing framework for RE. In order to achieve the RE targets set under the RUKN and harness the employment benefits among other additional co-benefits of RE, the Indonesian government needs to revisit these policies.

#### Decrease capital costs and enhance bankability of RE projects

Despite steadily decreasing costs of electricity generation from RE and increasing returns in most middle-income countries, governments and project developers still do not have direct access to the initial capital required. Financing costs are still high in Indonesia, with commercial cost of capital at levels even higher than 10%<sup>103</sup>. High capital costs lead to higher Power Purchase Agreement prices to ensure financial viability. To improve this imbalance, multilateral organizations and international development agencies could act as intermediaries and enabling agents by supporting governments to develop smart and blended financing options while supporting them to develop bankable projects, e.g. by conducting pre-feasibility studies and to improve access to international climate financing. RE projects that meet certain eligibility criteria could qualify for receiving funding from international climate financing schemes and climate funds (for example, the Green Climate Fund). Furthermore, multilateral organizations and international development agencies can support countries to access climate finance by providing support for the establishment of national institutional structures (for example, a fund-specific national designated authority or national implementing entity).

#### Align Local content requirement (LCR) with other policies

This study was conducted under the assumption that the LCR for solar PV that was set by regulations such as the Ministerial Decree or Order No. 54/M-IND/PER/3/2012 and No. 05/M-IND/PER/2/2017 was met by the project developers. However, additional research is needed to investigate the extent to which project developers meet the LCRs in practice for goods and services in solar energy. Further research should also examine how the LCRs for RE in Indonesia could potentially lead to the creation of new industries and create even greater employment opportunities. However, meeting the LCR in some cases may lead to higher RE investment costs and consequently to less RE deployment and fewer jobs. Therefore, an LCR for different REs should be carefully designed, including long term planning and a combination of industrial and labor policies to create an enabling policy environment, while simultaneously preparing the local labor force with the necessary skills and competences to support the energy transition.

#### Report RE jobs

The Indonesian government should support and encourage RE companies to report and regularly and systematically share information on the labor force employed in the RE sector. Regular reporting on the number of employees per the different stages of the RE value chain can be incorporated in regular annual enterprise surveys. RE associations could play a major role in coordinating the collection of employment data and occupations and skills requirements on different RE sectors and report back to the government to inform the design of energy and labor policies. Project developers' surveys could also be conducted to collect investment and labor share data for RE to fully understand the labor intensity of the different stages of RE value chains and to complement data collection from secondary sources. Another option could be to mainstream RE-related questions in existing business and household surveys to assess the number of employees currently working in different RE sectors.

<sup>99</sup> International Climate Initiative, Ambition to Action Project, *Power sector NDC-alignment*, November 2019, <https://ambitiontoaction.net/wp-content/uploads/2019/04/A2A-2018-Power-sector-NDC-alignment-Indonesia.pdf>.

<sup>100</sup> "Indonesia," Climate Action Tracker, 2019, <https://climateactiontracker.org/countries/indonesia/>.

<sup>101</sup> International Institute for Sustainable Development, *Missing the 23 Per Cent Target: Roadblocks to the development of renewable energy in Indonesia*, 2018, <https://www.iisd.org/sites/default/files/publications/roadblocks-indonesia-renewable-energy.pdf>.

<sup>102</sup> International Institute for Sustainable Development, *Financial Supports for Coal and Renewables in Indonesia*, 2017, <https://www.iisd.org/sites/default/files/publications/financial-supports-coal-renewables-indonesia.pdf>

<sup>103</sup> International Renewable Energy Agency, *Renewable Energy Prospects: Indonesia, a REmap analysis*, Abu Dhabi, 2017, [https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA\\_REmap\\_Indonesia\\_report\\_2017.pdf?la=en&hash=79237811C02D9722E35F5049ACBA278B126493BB](https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Mar/IRENA_REmap_Indonesia_report_2017.pdf?la=en&hash=79237811C02D9722E35F5049ACBA278B126493BB).



### Further research to other RE sectors

Further research is needed to explore the employment opportunities created by other RE technologies in Indonesia that have great technical potential. Biomass and wind energy could play a major role in the decarbonization of Indonesia's power sector. The employment benefits of biomass could be especially significant considering the labor-intensive process of feedstock for biomass.

## 4.5.2 RECOMMENDATIONS TO IMPROVE THE QUALITY AND AVAILABILITY OF THE HUMAN CAPITAL, OCCUPATIONS, AND SKILLS

### Locate RE jobs needs

This study estimates the employment effects of different future power sector pathways at the national level, providing information on the jobs that could be created at different stages of RE value chains. However, identifying and assessing the locations of these potential RE jobs could provide important insights to support the development of training and vocational programs in provinces and regions where specific occupations and skills in RE will be in high demand. Assessing and mapping the potential occupations and skills gaps, similar to the analysis performed in the case of Mexico as described in section 3.4, would provide valuable information to local and national policymakers. Therefore, additional research on RE deployment potential and the required skills and occupations at the provincial or regional level is necessary. This type of evidence could enhance policy coherence between energy, labor, and education and training policies, and policy alignment at the national, sub-national, and local levels.

### Align vocational and RE policies and programs

The study showed that more than 50% of the direct jobs created in the RE sectors analyzed will be in C&I stage with a significant share in PD. For these stages of the RE value chains different level of skills are required. Further assessment is needed to review the Technical and Vocational Education and Training (TVET) institutions RE skills development programs and evaluate their alignment with RE and industrial policies in Indonesia, as well as human resources requirements. Such an assessment could identify opportunities for and barriers to coordination on skills development to boost the deployment of RE and job creation. In close collaboration with multilateral agencies, the government can leverage international experiences and best practices for learning and building institutional capacity from successful RE vocational programs and partnerships. Skills gap assessments for different RE sectors, like the one conducted for Mexico in section 3.4, should be conducted to inform these policies.

### Enhance Universities' curricula

Besides the RE skills development, training and vocational programs that can be developed and tailored towards RE related occupations and technical universities' curricula could be enriched with RE related specialized subjects and courses. According to the results of the study, achieving the RUKN target for solar PV would require around 52% of high skill occupations such as engineers and management professionals. Such courses would enable students to acquire the necessary skills, capacities, and knowledge that will allow them to enter high skill occupations in demand in the RE sectors.



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# 5 RWANDA

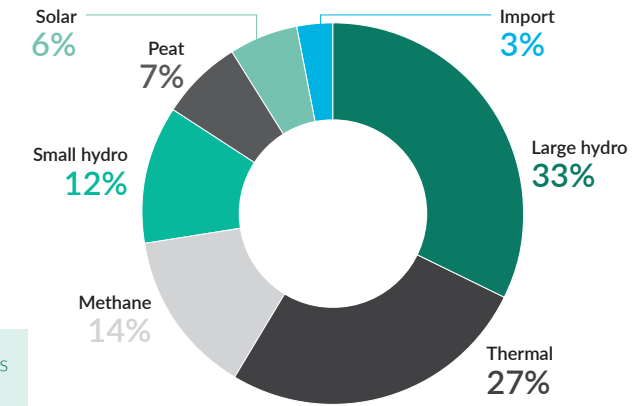
## KEY FINDINGS:

- ▶ Under the High Ambition (HA) scenario, the addition of RE capacity by 2030 will result in the creation of around 31 thousand direct job-years. Under the NDC unconditional scenario 14 thousand direct job-years will be created by 2030.
- ▶ Reaching the RE target under the HA scenario by 2030 requires a direct domestic investment of USD 645 million in large hydro and solar PV. The NDC unconditional scenario requires a direct domestic investment of USD 295 million on new RE capacity and operations to reach its RE target.
- ▶ The direct domestic investments in RE under the HA scenario generates around 316 USD million in value-added to the economy of Rwanda. The NDC unconditional scenario creates USD 136 million value-added by 2030.
- ▶ Under the HA scenario, most of the direct job-years, around 69%, that are generated for large hydro and solar PV utility-scale are concentrated in Construction & Installation. In addition, O&M creates around 22% of all direct job-years, whereas Project Development and Equipment Manufacturing & Distribution create 6% and 3% of all direct job-years, respectively.

## 5.1 CURRENT SITUATION

To the best of our knowledge this is the first employment study in the field of RE that is being conducted in Rwanda. In 2018, Rwanda has reached 218 MW installed power capacity, half of which is provided by renewable energies. Large hydro makes up the highest proportion of the clean technologies while thermal power plants (oil and diesel) make up the highest fossil fuel energy source (see figure 5.1). The government has estimated an increase in the demand for electricity at an annual rate over 10% in the short-to-medium term. To ensure supply reliability, planners have established 15% reserve margin of power to be available by 2024. Planning, financing and building power stations entail significant uncertainties, thus, project pipeline has been established which will deliver the required additional capacity by 2024<sup>104</sup>.

Rwanda's households' access to electricity reached 52.8% in December 2019, of which 38.5% connected to the national grid and 14.3% accessing through off-grid systems, particularly through solar; the government aims to achieve universal electricity access by 2024.<sup>105</sup>



**Figure 5.1** Breakdown of Rwanda's installed capacity (%) in 2018

Given Rwanda's natural endowments, this study concentrates on regional/ large hydro and utility-scale solar PV, excluding small hydro due to data availability from developers<sup>106</sup>. In comparison, the report considers that the two main fossil fuel technologies, methane and peat, will increase in capacity by 2030. According to Energy Sector Strategic Plan (ESSP) 2018 and Least Cost Power Development Plan (LCPDP) (both used to construct NDC unconditional scenario), thermal power will remain at 27.8MW<sup>107</sup> until 2030, while methane and peat will add new capacity. This is the reason why thermal was excluded from the analysis.

Rwanda's NDC does not account for specific RE targets in the power sector<sup>108</sup>. Table 5.1 provides background information on the Rwanda case study.

**Table 5.1** Summary of Rwanda's background information

<b>Total Current installed capacity (2018)</b>	218 MW
<b>Total Current RE installed capacity (2018)</b>	110 MW
<b>RE Technologies analyzed</b>	<ul style="list-style-type: none"> <li>• Large hydro</li> <li>• Solar PV</li> </ul>
<b>Fossil fuel – based technologies analyzed</b>	<ul style="list-style-type: none"> <li>• Methane</li> <li>• Peat</li> </ul>
<b>NDC power sector related targets</b>	NO reference to power sector targets

### Energy Planning in Rwanda

In 2013, the Government of Rwanda (GoR) launched the Economic Development and Poverty Reduction Strategy II (EDPRS II),<sup>109</sup> setting out medium-term (2013-2018) objectives and indicative financial allocations. Aligned to the EDPRS II, the Ministry of Infrastructure (MoI) develops the Rwanda Energy Policy<sup>110</sup> and ESSP<sup>111</sup> for nationwide energy governance.

<sup>106</sup> The study focuses on the highest hydro contribution, as large/regional hydro plants represents 71% of additional "Total" hydro capacity (118.5 MW), while small hydro accounts for the remaining 29% or 49MW, under NDC unconditional.

<sup>107</sup> Thermal power is planned to be decreased from 58MW in 2018 to 27.8MW in 2020 and remain at that capacity until 2030 under NDC unconditional.

<sup>108</sup> However, the NDC has mentioned that it will further increase grid connected RE's electricity share towards 2030. In addition, in off-grid space Rwanda's NDC targets to establish 100 solar PV mini-grids for rural communities totaling installed capacity of 9.4 MWp, and will establish rural productive zones using electricity for increasing income generating potential of rural communities.

<sup>109</sup> Ministry of Finance and Economic Planning (MINECOFIN), Economic Development and Poverty Reduction Strategy II 2013-2018, 2013, [http://www.minecofin.gov.rw/fileadmin/templates/documents/NDPR/EDPRS\\_2.pdf](http://www.minecofin.gov.rw/fileadmin/templates/documents/NDPR/EDPRS_2.pdf).

<sup>110</sup> Ministry of Infrastructure, *Rwanda Energy Policy*, 2015, [https://www.mininfra.gov.rw/fileadmin/user\\_upload/new\\_tender/Energy\\_Policy.pdf](https://www.mininfra.gov.rw/fileadmin/user_upload/new_tender/Energy_Policy.pdf).

<sup>111</sup> Ministry of Infrastructure, *Energy Sector Strategic Plan*, 2018.

<sup>104</sup> Ministry of Infrastructure, *Energy Sector Strategic Plan*, 2018, [https://www.mininfra.gov.rw/fileadmin/user\\_upload/infos/Final\\_ESSP.pdf](https://www.mininfra.gov.rw/fileadmin/user_upload/infos/Final_ESSP.pdf).

<sup>105</sup> "Electricity Access," Rwanda Energy Group, <https://www.reg.rw/what-we-do/access/>.

Rwandan energy planning offers high-level guidance to the national energy sector to produce and use its energy resources in sustainable ways towards longer-term goals and priorities. The framework of the Rwanda Energy Policy includes laws and regulations, strategic directions, and guiding principles that national institutions and partners should align their activities and institutional plans. The ESSP functions as a detailed plan focusing on implementation that measures short-term progress toward long-term goals.

The GoR, on the other hand, adopted the corporatization model to take action and achieve goals set in EDPRS II. The GoR established two corporate entities: The Energy Utility Corporation Limited (EUCL) and The Energy Development Corporation Limited (EDCL) as subsidiaries of The Rwanda Energy Group Limited (REG), entrusted with energy development and utility service delivery. REG therefore plans to produce and provide energy to its end-users according to the National Energy Plans and ESSP which are aligned to the EDPRS II. REG built the LCPDP<sup>112</sup> which was used in conjunction with the ESSP to develop the power sector scenarios that were analyzed in this study.

## 5.2 POWER SECTOR SCENARIOS

Three scenarios were developed and looked at for Rwanda's RE and conventional energy mix until 2030, according to key power development and governmental policy documents. These scenarios include: i) NDC unconditional, ii) Sustainable Energy for All (SE4All) – 60% RE, and iii) High Ambition (HA) – 66% RE. However, only the NDC unconditional and the HA scenarios were analyzed in depth and their results herewith presented, as they represent the low and high ambition plans, regarding RE targets for Rwanda.

The power sector capacity development scenarios cover two periods 2019-2025, and 2026-2030. Two major official government plans were used to develop the scenarios: the future capacity development for the period 2019-2025 is based on ESSP<sup>113</sup> published in 2018, while the 2026-2030 period is based on the LCPDP<sup>114</sup> published in June 2019. Additional resources used include the 2016 SE4ALL Action Agenda<sup>115</sup> and journal articles<sup>116</sup>.

Rwanda's total installed power capacity by 2030 will reach 533 MW in the NDC unconditional scenario, 605 MW in the SE4All scenario, and 678 MW in the HA scenario. Table 5.2 provides a summary of the RE scenarios in terms of installed capacity.

**Table 5.2** Scenario comparison of installed capacity by 2030 for Rwanda

Scenario	Total installed capacity (MW)	Renewable energy		Fossil fuel-based energy	
		Installed capacity (MW)	Share (%)	Installed capacity (MW)	Share (%)
NDC unconditional	534	279	52.0%	255	48.0%
SE4All-60%	605 <sup>117</sup>	355	58.6%	228	37.7%
HA-66%	678	450	66.4%	228	33.6%

<sup>112</sup> Rwanda Energy Group, *Least Cost Power Development Plan (LCPDP) 2019-2040*, 2019, [https://www.mininfra.gov.rw/fileadmin/user\\_upload/LCPDP\\_REPORT\\_June\\_2019.pdf](https://www.mininfra.gov.rw/fileadmin/user_upload/LCPDP_REPORT_June_2019.pdf).

<sup>113</sup> Ministry of Infrastructure, *Energy Sector Strategic Plan*, 2018.

<sup>114</sup> Ministry of Infrastructure, *Least Cost Power Development Plan*, 2019, [https://www.mininfra.gov.rw/fileadmin/user\\_upload/LCPDP\\_REPORT\\_June\\_2019.pdf](https://www.mininfra.gov.rw/fileadmin/user_upload/LCPDP_REPORT_June_2019.pdf).

<sup>115</sup> Ministry of Infrastructure, *Sustainable Energy for All Action Agenda 2016 Update – Draft*, 2016, [https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country\\_AAs/Rwanda\\_Action\\_Agenda.pdf](https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_AAs/Rwanda_Action_Agenda.pdf).

<sup>116</sup> Théoneste Uhorakeye and Bernd Möller, "Assessment of a climate-resilient and low-carbon power supply scenario for Rwanda," *International Journal of Sustainable Energy Planning and Management* 17, (June 2018), <https://doi.org/10.5278/ijsep.2018.17.5>.

<sup>117</sup> Total installed capacity includes 22MW of Imported Capacity.

### 5.2.1 NDC UNCONDITIONAL SCENARIO

The NDC unconditional scenario was based on the ESSP and LCPDP. Therefore, all firmly committed power plants and small hydro power plants that are being commissioned in 2019/2020 are fixed within the model for the period of 2019-2025. For the period 2026-2030, the NDC unconditional scenario assumes that least-cost capacity addition of pipeline and alternative supply technologies are considered. The NDC unconditional scenario also assumes that power trading (i.e. import and export) will only be possible up to 2025. The country will add a total of 127 MW including 40 MW of natural gas by 2030.

### 5.2.2 SUSTAINABLE ENERGY FOR ALL (SE4ALL-60%) SCENARIO

The SE4All scenario proposes that the share of RE in Rwanda's electricity mix increase to 60% by 2030, based on the government policy/planning document, *Sustainable Energy for All Action Agenda 2016 Update – Draft, (SE4All)*<sup>118</sup>. The SE4All scenario assumes that only RE plants will be added for the period 2026-2030. This results in RE capacity of up to 52-66% of total capacity, depending on the level of electricity demand growth. A mid-point in this range of 60% has been adopted as the government's target. However, like NDC unconditional this scenario assumes and follows the 2018 ESSP's capacity additions for the initial 2019-2025 period.

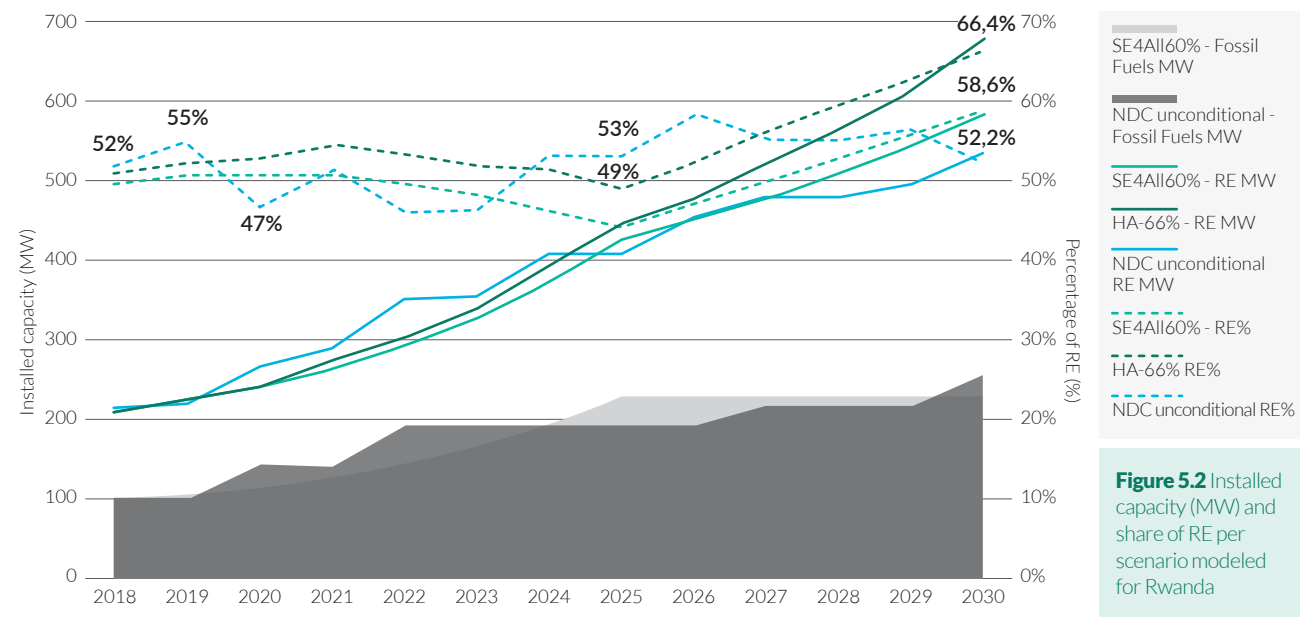
### 5.2.3 HIGH AMBITION (HA-66%) SCENARIO

The HA scenario proposes that the share of RE in Rwanda's electricity mix increase to 66% by 2030, based on two additional government policy/planning documents, the *Sustainable Energy for All Action Agenda 2016 Update – Draft, (SE4All)* and the 2018 *Assessment of a climate-resilient and low-carbon power supply scenario for Rwanda* journal article by Uhorakeye and Möller<sup>119</sup>. While the HA also assumes the 2018 ESSP added capacity for the 2019-2025 period, for the 2026-2030 period it is assumed that all capacity additions will be from RE. Additionally, a full implementation of hydro and solar is undertaken to reach their maximum potential in 2030. Hydro energy potential is estimated at 400 MW. The Uhorakeye and Möller study found that solar power generation capacity can reach 39.75 MW by 2025 and 100 MW by 2050. Therefore, solar capacity in the HA scenario reaches 32 MW by 2025 and 50 MW by 2030, assuming that the power grid will be improved to support additional solar PV capacity.

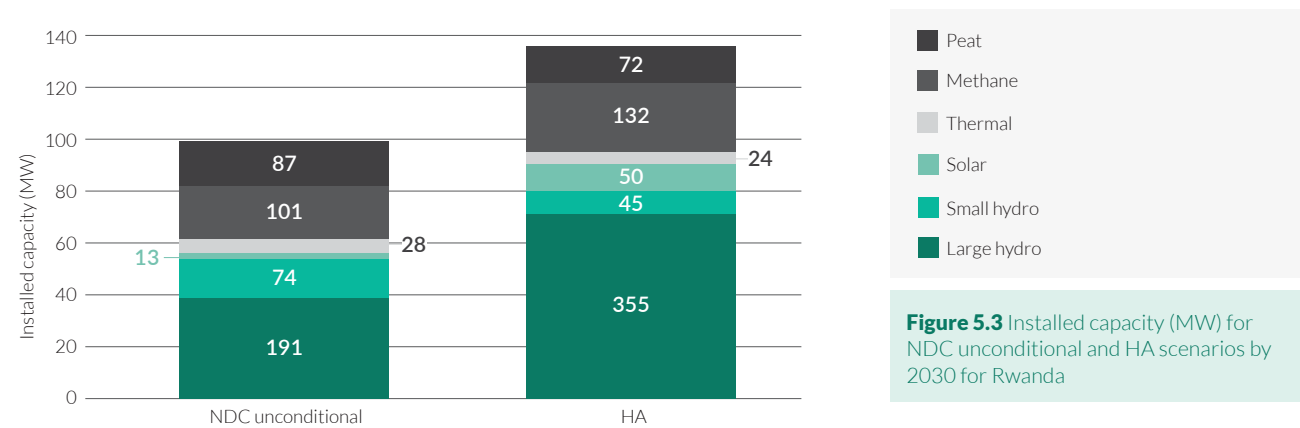
Figure 5.2 shows the development in the energy mix for all three scenarios and figure 5.3 shows the breakdown in installed capacity in the NDC unconditional and HA scenarios.

<sup>118</sup> Ministry of Infrastructure, *Sustainable Energy for All Action Agenda 2016 Update – Draft*, 2016.

<sup>119</sup> Théoneste Uhorakeye and Bernd Möller, "Assessment of a climate-resilient and low-carbon power supply scenario for Rwanda," 2018.



**Figure 5.2** Installed capacity (MW) and share of RE per scenario modeled for Rwanda



**Figure 5.3** Installed capacity (MW) for NDC unconditional and HA scenarios by 2030 for Rwanda

## 5.3 JOBS ASSESSMENT

### 5.3.1 VARIABLES AND DATA COLLECTION

Although collecting reliable data stills possess a major challenge, especially for a Least Developed Country (LDC) like Rwanda, several assumptions and inputs were derived and used in the analysis.

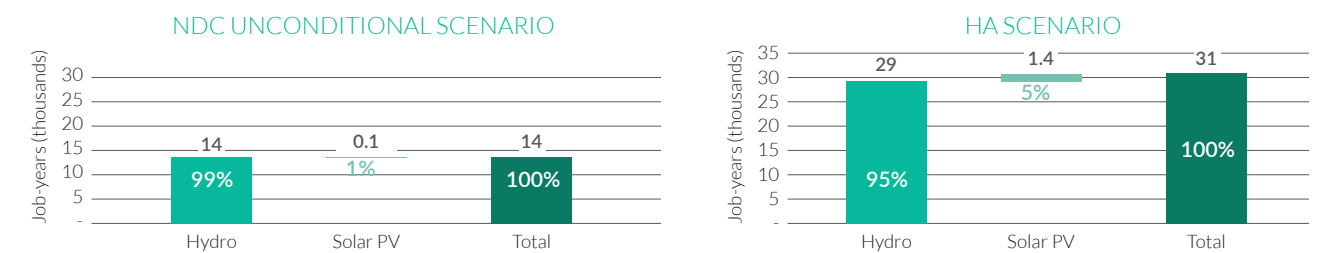
Technology cost structure data in the form of cost per component were collected through a series of interviews with large hydro and solar PV utility project developers. For fossil fuel technologies (methane and peat), the study collected information from interviews and secondary sources. Assumptions on solar and large hydro future capacity development under the different scenarios were validated through a stakeholders' consultation workshop held in Kigali in September 2019.

Data regarding in-country share were collected through interviews with project developers and were also validated in the stakeholders' workshop.

Rwanda does not possess an I-O table; therefore, information on the structure of the Rwandan economy was obtained through a proxy I-O table from the MRIO/EORA database<sup>120,121</sup>. Since there are no available salary data<sup>122</sup> disaggregated by economic sector for Rwanda, a 36% discount<sup>123</sup> was applied on salary data derived from Kenya's Economic Survey 2018<sup>124</sup>, to approximate the salary differences between the two countries. Due to the lack of I-O table data for Rwanda, the analysis estimates only the direct jobs (and not the indirect and induced jobs) that can be generated by RE investments.

### 5.3.2 EMPLOYMENT EFFECTS OF RE TECHNOLOGIES

As shown in figure 5.4, hydro has the highest share of the total installed capacity in the HA scenario, therefore generating the most direct jobs at 29 thousand, representing 95% of all RE direct jobs and 64% of all direct jobs including fossil fuel technologies. In comparison, solar PV generates 1400 jobs.



**Figure 5.4** Employment effects per RE technology for NDC unconditional and HA scenarios for Rwanda

### 5.3.3 EMPLOYMENT EFFECTS OF RE TECHNOLOGIES FOR EACH POWER SECTOR SCENARIO

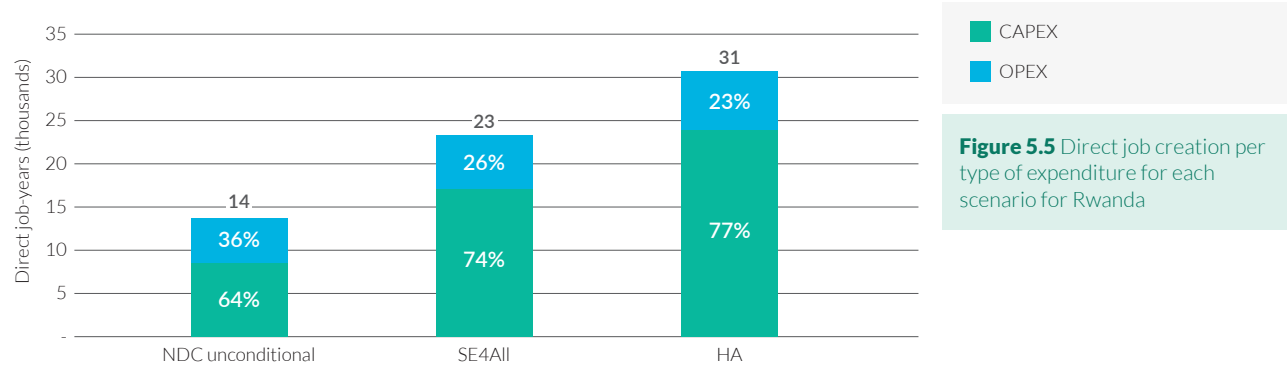
This section compares the number of direct job-years created over the RE (large hydro and solar PV) stages of the value chain<sup>125</sup> over a ten-year period (2020 – 2030) across the three scenarios assessed. This is based on changes in the installed capacities of the large hydro and solar PV assumed in each scenario.

NDC unconditional generates 14 thousand job-years over the modeling horizon. In comparison SE4All scenario generates 23 thousand job-years and HA scenario generates 31 thousand job-years over the same period, representing an increase of 69% and 124% more direct job-years respectively.

Figure 5.5 shows that the majority of direct jobs are generated in CAPEX related sectors such as equipment manufacture and distribution, PD and C&I, although OPEX generates a significant number of jobs too.

<sup>120</sup> Eora Global Supply Chain Database, <https://worldmrio.com/>; Manfred Lenzen et al., "Mapping the Structure of the World Economy," *Environmental Science & Technology* 46, 15, (July 2012), 8374–8381, <https://doi.org/10.1021/es300171x>.  
<sup>121</sup> Lenzen et al., "Building Eora: A Global Multi-regional Input-Output Database at High Country and Sector Resolution," *Economic Systems Research* 25, 1 (March 2013), 20–49, <https://doi.org/10.1080/09535314.2013.769938>.  
<sup>122</sup> National Institute of Statistics Rwanda, Rwanda's Labour Force Survey Annual Report, <https://www.statistics.gov.rw/publication/labour-force-survey-annual-report-2019>.  
<sup>123</sup> "Cost of Living Comparison Between Kenya and Rwanda," Numbeo, [https://www.numbeo.com/cost-of-living/compare\\_countries\\_result.jsp?country1=Kenya&country2=Rwanda](https://www.numbeo.com/cost-of-living/compare_countries_result.jsp?country1=Kenya&country2=Rwanda).  
<sup>124</sup> Kenya National Bureau of Statistics, <https://www.knbs.or.ke/>.  
<sup>125</sup> International Labour Organization, *Skills and Occupational Needs in Renewable Energy*, 2011.



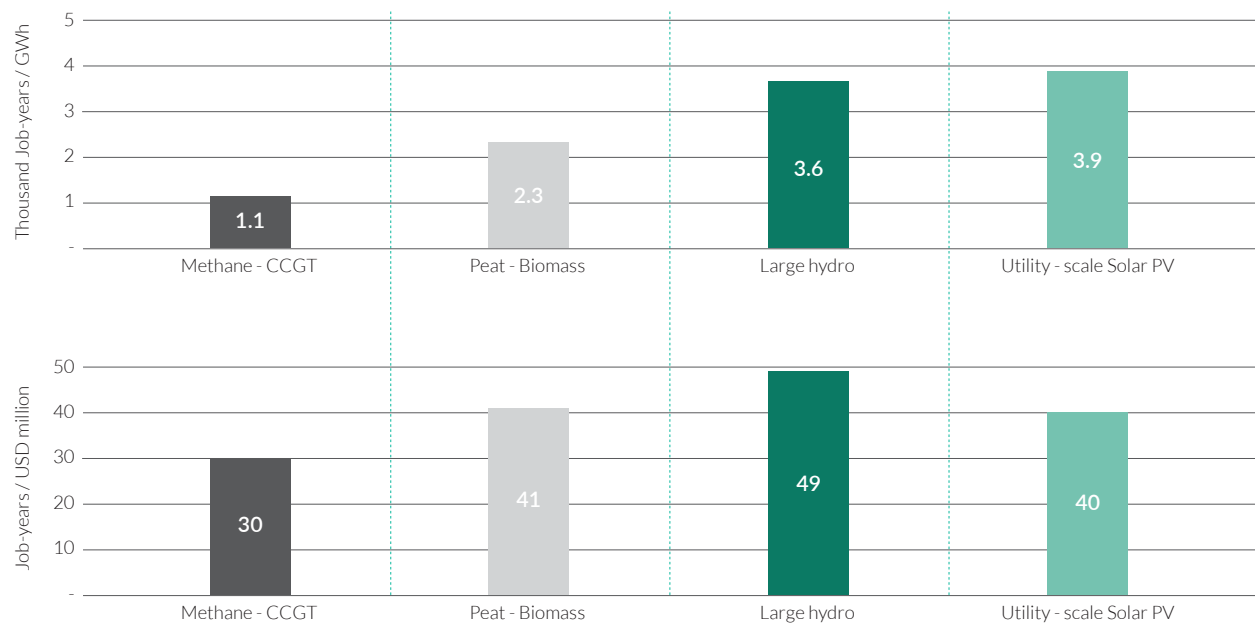


**Figure 5.5** Direct job creation per type of expenditure for each scenario for Rwanda

### 5.3.4 EMPLOYMENT EFFECTS COMPARISON BETWEEN RE AND FOSSIL FUEL TECHNOLOGIES

Under the HA scenario, solar PV generates around 3.5 times more employment per GWh than methane and around 1.7 times more employment than peat. Solar PV costs are decreasing rapidly, however, in Rwanda it is still costly compared to locally sourced peat and methane. Solar PV has greater potential for job creation, as it has the highest employment per GWh ratio from new capacity, at 3.9 thousand jobs. In comparison, methane and peat create only 1.1 and 2.3 thousand jobs per GWh respectively.

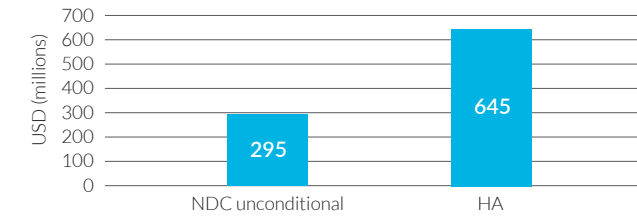
Hydro creates 49 job-years per USD million and solar PV creates 40 job-years per USD million. Combined, these RE investments create 18 more job-years per USD million invested in new capacity compared to non-renewables (30 job-years/USD million for methane, and 41 job-years/USD million for peat). Figure 5.6 shows the job creation per unit of investment and capacity.



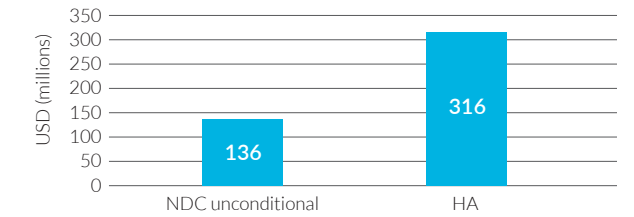
**Figure 5.6** Direct job creation per unit of electricity generation (GWh) from new capacity and per unit of investment (USD million) under HA scenario for Rwanda

### 5.3.5 ECONOMIC IMPACTS OF EACH SCENARIO

The economic impacts of the NDC unconditional and HA scenarios were assessed for large hydro and solar PV technologies. Figure 5.8 shows that reaching the HA scenario RE capacity target by 2030 requires USD 645 million of domestic direct investment in large hydro and solar PV, whereas reaching the RE capacity target under the NDC unconditional scenario requires USD 295 million of domestic direct investment.



**Figure 5.8** Direct domestic investment for NDC unconditional and HA scenarios for large hydro and solar PV for Rwanda

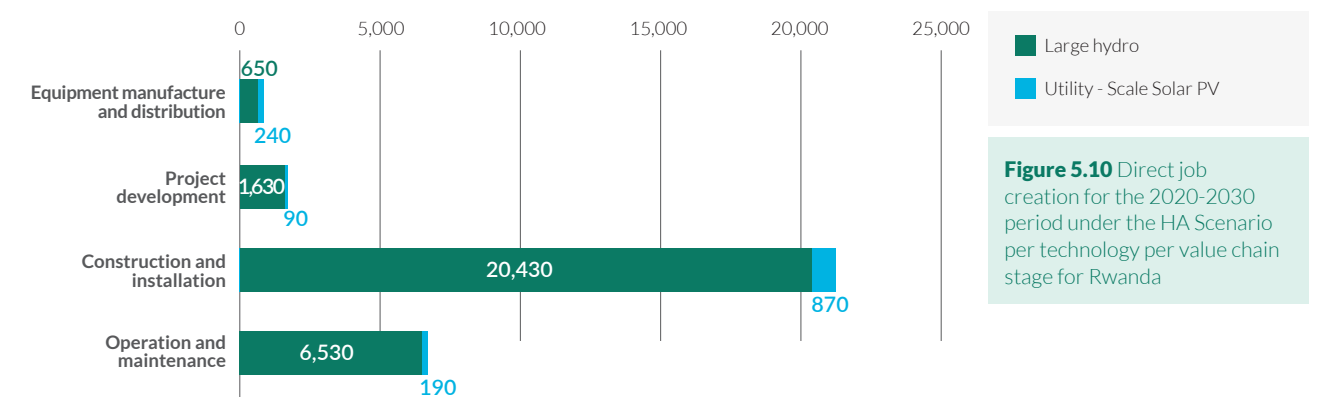


**Figure 5.9** Direct value-added from RE under the NDC unconditional and HA scenarios for Rwanda

The HA scenario generates around 316 USD million direct value-added by 2030, whereas the NDC unconditional scenario generates around USD 136 million direct value-added in the Rwandan economy, as can be seen in Figure 5.9.

### 5.3.6 EMPLOYMENT EFFECTS ACROSS RE VALUE CHAINS

Looking at the employment effects across the RE value chains, most of the direct jobs generated are concentrated in C&I, providing around 21 thousand job-years (69%) under the HA scenario as shown in figure 5.10. In addition, O&M creates around 6.7 thousand direct jobs (22%), whereas PD and EM&D create 1.7 thousand (6%) and only 891 (3%) job-years, respectively. These sectors create significantly less jobs since they require many high skilled and medium skilled professionals such as manufacturing engineers and several specialists in logistics, construction, and project design. Project developers tend to meet these labor requirements with foreign specialized labor<sup>126</sup>. Even for some low skilled occupations, particularly for solar PV in the C&I and O&M value chain stages, project developers tend to hire foreign labor.



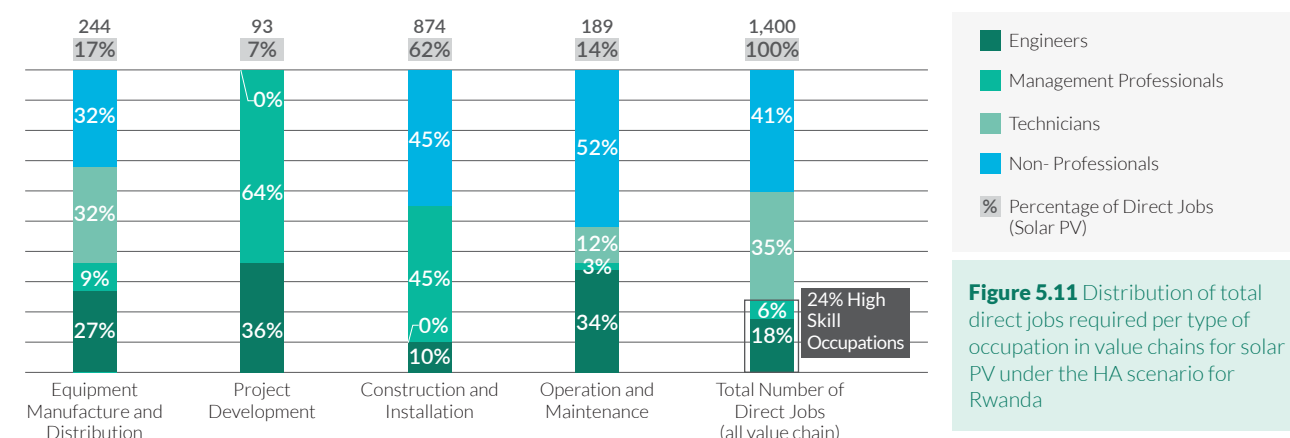
**Figure 5.10** Direct job creation for the 2020-2030 period under the HA Scenario per technology per value chain stage for Rwanda

C&I accounts for the most jobs generated in hydro, representing 70% of total jobs created in hydro and a large majority of the jobs in solar PV, as shown in figure 5.10. Most of the jobs in C&I are low to middle skilled as is discussed in section 5.4.

<sup>126</sup> Comprehensive Skills Audit Report, Northern Corridor Integration Projects (NCIP), 2017 and Interviews with project developers conducted by GGGI.

## 5.4 OCCUPATIONS AND SKILLS ASSESSMENT

Human resources in the required fields are essential in realizing the additional solar PV and large hydro capacity for the HA scenario. Figure 5.11 shows the breakdown of the required occupations and skills for each stage of the solar PV value chain.



Under the HA scenario solar PV generates 1,400 direct jobs. The technical and non-professional workforce accounts for more than 1,000 jobs. These occupations are identified as technical and construction workers requiring medium to low skill sets. They represent the majority of jobs created over the whole study period, with 35% and 41% of total employment respectively. High skills occupations such as engineers and management professionals accounts for less than 25% combined.

Rwanda manufactures balance of system<sup>127</sup> components for solar PV plants, where the EM&D sector is estimated to require 244 direct jobs. These jobs include 90 high skilled jobs, ranging from industrial engineers to marketing and administrative jobs to logistics to quality control experts. Approximately 155 jobs are medium-skilled factory workers and technicians.

The high skilled occupations are concentrated in the PD stage, with almost 100 experts in several fields such as legal, energy, real estate, finance, electrical civil and mechanical engineering.

The C&I sector requires almost 900 jobs, where 90% of them are estimated to be medium to low skilled technical personnel and construction work jobs. It is estimated that 170 jobs will be required in installation and maintenance, a hard to fill medium skill occupations. The remaining occupations are high skilled jobs. It is estimated that there will be 79 jobs created in high skilled occupations such as civil engineering, health and safety, electrical and mechanical engineering, and building and maintenance inspection.

O&M generates 190 jobs, this stage of the value chain is concentrated mostly in construction work, at 50% and safety experts at around 20%. The remaining 30% consists of a number of high and medium skills occupations such as industrial engineers, telecommunications, technicians and operators.

<sup>127</sup> Balance of System (BOS) components include, wiring, switches, mounting system, solar inverters, battery bank, and battery chargers.

## 5.5 RECOMMENDATIONS

### 5.5.1 RECOMMENDATIONS TO INCREASE THE EMPLOYMENT OPPORTUNITIES OF RE SECTOR

#### Increase the RE target in NDC revision

Achieving Rwanda's RE targets in the analyzed scenarios by 2030 will require concerted efforts by various stakeholders including government agencies, the private sector, financing institutions, NGOs, universities, and other TVET institutions. The GoR has several national development policies, strategies and plans that could be aligned with the deployment of RE and create and enhance employment opportunities in the RE sector.

Increasing the RE capacity target in 2020 NDC revision offers a socio-economic opportunity for Rwanda that could bring additional employment of more than 25 thousand jobs than the current economic development and energy pathway. Based on this evidence, the GoR should include RE installed capacity targets in its next and revised NDC that will be submitted by the end of 2020. This socio-economic opportunity will be even greater if the young labor force of Rwanda is well equipped with the necessary skills and knowledge to accelerate the energy transition.

#### Enhance investment to the grid capacity

Investment in the deployment of utility-scale solar PV by expanding the capacity of the national grid will enable the sector to reach its potential of 100MW. Investing in the enhancement of the national grid capacity is likely to create additional jobs. However, as this was not in the scope of this study, further research will be needed to analyze the employment implications of enhancing grid capacity. The GoR should prioritize financing the enhancement of the capacity of the national grid and the deployment of solar PV.

#### Design training and vocational programs to enable local sourcing

Training and vocational programs, in coordination with higher educational institutions, should be designed specifically for RE technologies to support the development of necessary skills and equip the young labor force for the energy transition. Such programs could set the foundations for local sourcing of RE projects' minimum requirements for labor and technology components. These regulations should be gradually introduced to allow developers and labor force to prepare, as they may increase the cost of RE technologies.

#### Improve employment data collection

The GoR, through the National Institute of Statistics Rwanda agency, should improve employment data collection by requiring developers to report labor relevant information. This information could include the number of employees and type of occupations and skills required, along with information on wages/salaries, working hours and safety measures. Energy associations play an important role as they could coordinate collection of data and reporting mechanisms specific for RE technologies.



## 5.5.2 RECOMMENDATIONS TO IMPROVE THE QUALITY AND AVAILABILITY OF THE HUMAN CAPITAL, OCCUPATIONS AND SKILLS

### Promote public-private collaboration

The Ministry of Education should promote public-private collaboration to enhance TVET in the field of RE and promote close partnership with the tertiary education sector to add value to and scale up locally made and installed or constructed RE technologies, including hydro and solar PV. There are nearly 100 active private sector companies working on energy sector development in Rwanda, including in the RE sub-sector. Rwanda has several associations in the energy/ RE sub-sector, including Rwanda's Energy Private Developers Association, Rwanda's RE Association and the TVET Association. Private developers, in collaboration with local universities, TVET, and energy associations, can establish capacity building programs to close the specific skills gaps in their current and future labor force.

### Increase awareness of skills training in RE

Rwanda has initiated some specific skills training associated with RE with support of different development partners including GIZ and JICA programs on TVET associated with clean energy development. Educational institutions, in collaboration with energy associations and project developers, should promote awareness of and training for specific skills required in RE jobs. This skills training is not only required for Science, Technology, Engineering, and Mathematics (STEM) majors, but also for business and administrative careers to increase participation in all RE stages, including PD and 'Cross-cutting Activities'.



© Nyabarongo Hydropower plant. Photo by Rwanda Energy Group Limited



© Launch of Nyabarongo Hydropower Plant- Muhanga, Rwanda, 5 March 2015. Photo from the Office of the President



## 6 CONCLUDING REMARKS

### 6.1 ENHANCING RE JOB CREATION

The study results suggest that by investing in RE, jobs will be created in different stages of the value chain, not only in the RE sectors but also through ripple effects in the overall economy. According to the results, for every direct job created in the RE sectors, up to 0.35 (for Mexico) and 0.5 (for Indonesia) additional indirect jobs could be created in other sectors of the economy that supply goods and services in the RE sectors. Up to 0.2 (for Mexico) to 0.5 (for Indonesia) additional induced jobs could be created in other sectors of the economy. Induced jobs result from employees in the RE sector and supply chain spending their income on buying goods and services, thus triggering more production and creation of more jobs. **Investing in RE sectors creates spillover effects in terms of employment and economic value-added in the wider economy beyond the RE sectors.** Countries should aim to increase the local content share at all stages of the value chain, particularly in the equipment manufacture and distribution stages, where the spillover effects found in the study are higher.

In all three country studies, investments in RE generate more jobs per GWh generated and USD invested compared to fossil fuel-based technologies. Various fossil fuel-based technologies were selected for analysis in each country: combined cycle for Mexico, coal for Indonesia, and peat and methane for Rwanda. The drivers behind the results in the three countries assessed were also different. In Mexico, differences found in job creation among RE technologies can be explained by the differences in the in-country share of each energy technology's components. In the case of Indonesia, the fact that geothermal, large hydro, and small hydro have higher in-country share and higher labor share compared to coal can explain the higher employment generation per GWh generated and USD invested. Solar PV also proves to potentially generate more jobs than coal, given that solar PV developers meet the LCR set by the Indonesian government. In Rwanda, peat and methane create less jobs compared to hydro and solar PV technologies per GWh and USD generated. **All three country cases demonstrate that investing in RE is more beneficial for the country in terms of socio-economic benefits than investing in fossil fuel-based technologies.** Job creation is, therefore a criterion to be considered by policymakers in addition to cost minimization.

The results show that investments in solar and wind technology to meet the countries' RE targets specified in their NDCs and/or national energy plans will require between 24% and 52% of high skilled occupations and human resources. This **increasing demand for high skilled labor in the RE sectors must be carefully addressed through collaboration between higher education and vocation training institutions, the private sector and national governments.** The design of vocational and on-the-job training programs for difficult to fill RE occupations is particularly important. It is also important to create a robust and ongoing two-way communication process between businesses/associations in the RE industries and the higher education institutions (including TVETs and universities) so that i) RE companies' provide inputs to keep curricula relevant and updated and ii) connect students to RE companies for more effective job placements. Multilateral organizations can also provide support and could bring in international experience for enhanced learning and sharing best practices, in partnership with government. International and national associations of TVETs and universities could disseminate RE job tasks and competencies based curricula, instead of each institution creating their own. Sharing across the TVETs and university systems would prevent duplication of effort and investment in curricula.

O&M generates fewer jobs than the other stages of the RE value chain, according to the results of the studies. However, countries should aim to **create more jobs and economic value-added in O&M stages by adopting an integrated approach to energy services provision, promoting services such as information sharing and**

**energy efficiency improvements.** The creation of Energy Service Companies<sup>128</sup> (ESCOs) could provide a promising opportunity to provide integrated energy services to customers while enhancing employment creation and value-added. Another option to enhance the creation of jobs and value of certain RE systems during the stage of decommissioning could be end-of-life management. End-of-life management should follow principles of the circular economy, particularly for wind<sup>129</sup> and solar PV<sup>130</sup>.

**Matching the potential for RE deployment with the local provision of human resources and occupations will be necessary to ensure alignment between supply and demand of the specialized labor force** in the various RE value chain stages. Vertical alignment, between national and state level, and horizontal alignment, between labor and energy ministries, should both be strengthened, together with policy alignment and coordination. This will ensure that the labor force needed at specific RE project locations is available and equipped with the relevant skills. Enhanced coordination between RE Associations and national and state government energy agencies is needed to support the development of vocational programs in the areas targeted for RE development.

### 6.2 STRENGTHENING RE TARGETS IN NDCS AND NATIONAL ENERGY PLANS

**Indonesia will benefit by establishing RE and GHG emission reduction targets for the power sector under its revised NDC.** The current Indonesian NDC does not include any power sector RE targets or GHG emissions reduction targets for the power sector. Indonesia's economy is growing fast and the electricity system is currently dominated by fossil fuel-based technologies, particularly coal. Therefore, Indonesia should consider the alignment of energy and climate policies and the introduction of power sector RE targets in combination with higher emission reduction targets in the next NDC revision by the end of 2020. According to the "climate action tracker" the Indonesia's current NDC is highly insufficient in the context of the Paris Agreement goal. Establishing higher emission reduction targets will set Indonesia's electricity system on a decarbonization pathway, where RE technologies could play a vital role. Incorporating RE targets and emission reduction targets could reinforce the process of decarbonization of the Indonesian power sector, while simultaneously tapping into the co-benefits of RE that could be generated, including employment benefits. Exploring the most cost-effective technologies to reduce carbon emissions can be supported by an assessment of the employment and economic benefits of these technologies, providing the necessary evidence for well-informed decision-making. This study provides clear evidence of the significant employment opportunities that could arise from significant investments in RE compared to coal. Indonesia should incorporate this evidence in the revision of its NDC.

Based on the analysis, it is evident that there is a great opportunity for low and middle-income countries to **increase their RE targets in the electricity sector** under their NDCs and National Energy Plans. By utilizing higher shares of RE sources, low and middle-income countries can contribute to global carbon emission reductions, while simultaneously generating considerable socio-economic benefits such as a high number of good-quality jobs and economic value-added. Establishing emission reduction targets for the electricity sector will pave the road towards countries' electricity systems decarbonization, where RE technologies will play a vital role. Combining RE targets and carbon emission reduction targets could reinforce the process of decarbonization of countries' power sectors and boost job creation.

<sup>128</sup> International Institute for Sustainable Development, *Energy Services Companies (ESCOs) in Developing Countries*, May 2010, [https://www.iisd.org/sites/default/files/publications/bali\\_2\\_copenhagen\\_escos.pdf](https://www.iisd.org/sites/default/files/publications/bali_2_copenhagen_escos.pdf).

<sup>129</sup> Niklas Andersen et al., "Wind Turbines' End-of-Life: Quantification and Characterisation of Future Waste Materials on a National Level," *Energies* 9, (December 2016):999, <https://doi.org/10.3390/en9120999>.

<sup>130</sup> International Renewable Energy Agency, *End-of-life Management Solar Photovoltaic Panels*, June 2016, [https://www.irena.org/documentdownloads/publications/irena\\_ieapvps\\_end-of-life\\_solar\\_pv\\_panels\\_2016.pdf](https://www.irena.org/documentdownloads/publications/irena_ieapvps_end-of-life_solar_pv_panels_2016.pdf).



**Even countries with relatively low GHG emissions per capita can benefit from incorporating this evidence on the socio-economic benefits in the revision of their NDCs.** The current process of NDC revision to be completed by the end of 2020 provides an opportunity for Indonesia to include RE targets and carbon emission reduction targets for its electricity sector. Mexico and Rwanda can consider further raising the ambition of their existing conditional RE and carbon emission reduction targets in the electricity sector. By setting higher RE targets in their NDCs, countries can contribute to the achievement of multiple SDGs such as SDG 7 (affordable and clean energy), SDG 8 (decent work and economic growth), and SDG 13 (climate action).

**Countries can benefit from setting RE targets in other high-emitting sectors, such as transport, cooling and heating, buildings and industry.** Integrating sectoral RE objectives into governments' long-term energy strategies will increase the certainty required to strengthen investment prospects. Including an assessment of potential job creation related to each of the sectoral RE targets can also be a persuasive way to strengthen the rationale for supporting RE deployment. The creation of employment opportunities is an important co-benefit of NDC implementation. Therefore, countries' NDC revision should include estimates of the short, medium- and long-term job creation potential of mitigation actions.

Furthermore, Indonesia could benefit from setting **RE targets in other emitting sectors**, for example, transport, cooling and heating, buildings, and industrial sectors. Integrating RE objectives per sector in the governments' long-term energy strategies creates certainty that enhances future investment forecasts.

## 6.3 MAINSTREAMING EMPLOYMENT STUDIES IN NDCs, NATIONAL ENERGY PLANS, AND OFFICIAL DEVELOPMENT ASSISTANCE

Additionally, including an assessment of potential job creation related to each of the sectoral RE targets can be persuasive in strengthening the narrative for prospective RE deployment. The creation of employment opportunities is an important co-benefit of NDC implementation. **Job creation potential should, therefore, be included and highlighted as countries revise their NDCs for 2020.** An assessment of the short- and long-term employment opportunities of climate action, including RE, could be mainstreamed in the NDC enhancement processes and the development of Long-Term Low Emissions Development Strategies (LT-LEDS). RE technologies and climate actions under the NDCs and LT-LEDS could be assessed and rated against their job creation potential to supplement the assessment of their abatement potential and associated costs. This is particularly relevant during the post-Covid19 crisis period where countries seek to identify sectors and actions to include in their economic stimulus packages.

Additionally, **updated versions of RE deployment roadmaps and RE strategies could include a section on assessment of the potential for RE job creation**, providing valuable insights to policymakers and other key sector stakeholders. Medium to long term energy strategies and plans like the RUPTL (in Indonesia), and the PRODESEN (in Mexico) are essential electricity plans for setting high RE targets for the future. These plans can establish a level playing field and a long – term certainty for RE developers and investors.

RE projects supported by official development assistance could incorporate **project requirements related to employment generation potential**. The ability to measure the employment effects of RE projects accurately will improve the efficiency and effectiveness of the design of projects and programs. Furthermore, this will provide the opportunity to transparently compare RE technologies, projects, and programs. An employment generation potential assessment should be incorporated at the early stage of design of a project or program. This will maximize the synergies among improved quality of life, the creation of decent jobs and sustainable development.

## 6.4 BOOSTING RE DEPLOYMENT THROUGH AN ENABLING POLICY ENVIRONMENT, FINANCING, AND GREEN STIMULI

The study provides estimates of the investment requirements for achieving RE targets set under countries' NDCs and national energy/electricity plans. **Governments should work towards creating a stable and enabling policy environment to attract private investments in the RE sector while reducing borrowing costs for developers.** This can be done by introducing or strengthening existing policies and regulations that promote RE deployment, including fiscal and financial incentives. Providing clear policy signals of long-term support for RE by setting medium and long term RE targets in NDCs and National Energy Plans could provide project developers and investors with more certainty.

Despite steadily decreasing costs of electricity generation from RE and increasing returns in most low- and middle-income countries, governments and project developers still do not have direct access to the initial capital required. Where loan options or financing models for RE development exist, they pose high debt risks to developers<sup>131</sup>. **Low and middle-income countries should explore smart financing mechanisms by incentivizing RE deployment through low debt financing schemes.** Multilateral organizations and international development agencies can play an important role as intermediaries by supporting governments to develop smart and blended financing options through national financing vehicles (NFVs)<sup>132</sup>. It has been proven empirically that public investments in RE technologies could also have a positive effect on private investments<sup>133</sup>. Public investments in RE and fiscal policies to attract private investments are becoming even more important in cases of economic recession, such as the aftermath of the COVID-19 crisis, where governments are seeking suitable measures to include in the economic stimulus packages for boosting aggregate demand and economic activity in a labor-intensive industry such as the RE sector.

Climate finance could be particularly relevant in cases where RE technology deployment is considered important for decarbonizing the electricity sector. RE projects in low-income countries that meet certain eligibility criteria could qualify for receiving funding from climate financing schemes and climate funds (for example, the Green Climate Fund). **Multilateral organizations and international development agencies can support countries to access climate finance by providing support for the establishment of national institutional structures** (for example, the creation of a fund-specific national designated authority or national implementing entity). International climate funds and multilateral agencies could support readiness programs and activities in eligible countries to secure improved access to international climate financing for recipient countries.

### Improving the quality and availability of the human capital, occupations, and skills

This study estimates the employment effects of different future power sector pathways at the national level, providing information on the jobs that could be created at different stages of RE value chains. However, **identifying and assessing the locations of these potential RE jobs could provide important insights to support the development of training and vocational programs** in provinces and regions where specific occupations and skills in RE will be in high demand. Therefore, additional research on RE deployment potential and the required skills and occupations at the provincial or regional level is necessary. This type of evidence could enhance policy coherence between energy, labor, and education and training policies, and policy alignment at the national, sub-national, and local levels.

<sup>131</sup> Climate Policy Initiative, *Finance Mechanisms for Lowering the Cost of Renewable Energy in Rapidly Developing Countries*, January 2014, <https://climatepolicyinitiative.org/wp-content/uploads/2014/01/Finance-Mechanisms-for-Lowering-the-Cost-of-Clean-Energy-in-Rapidly-Developing-Countries.pdf>.

<sup>132</sup> GGGI, *Technical Report no. 9: Review of GGGI's Experience to Design and Operationalize National Financing Vehicles to Finance Climate and Green Growth Policy Implementation*, December 2019, <https://gghi.org/site/assets/uploads/2020/01/GGGI-Technical-Report-No.-9-1.pdf>.

<sup>133</sup> SOAS Department of Economics, *Neither crowding in nor out: Public direct investment mobilising private investment into renewable electricity projects*, (working paper, London: SOAS University of London), September 2019, <https://www.soas.ac.uk/economics/research/workingpapers/file142704.pdf>.

Further assessment is needed to review **RE skills development programs and policies and evaluate their alignment with RE and industrial policies** in Indonesia. Such an assessment could identify opportunities for and barriers to coordination on skills development to boost the deployment of RE and job creation. In close collaboration and with the support of multilateral agencies, the government can leverage international experiences and best practices for learning and building institutional capacity from successful RE vocational programs and partnerships.

Besides the RE skills development, **training and vocational programs that can be developed and tailored towards RE related occupations, and technical universities' curricula** could be enriched with RE related specialized subjects and courses. Such courses would enable students to acquire the necessary skills, capacities, and knowledge that will allow them to enter into occupations in demand in the RE sectors.

## 6.5 OPPORTUNITIES FOR FUTURE RESEARCH AND IMPROVED METRICS

It is important to identify and address opportunities and limitations of assessing the employment impacts of RE plans, targets, and projects. **Policymakers would welcome the definition and standardization of suitable indicators, taxonomies, and methodologies** to better understand and measure the direct, indirect, and induced employment effects of RE projects and plans. The Sustainable Energy and Jobs Platform<sup>134</sup> aims to advance the development of methodologies and metrics for RE employment assessment to support research and evidence-based policymaking and advocacy in the field of RE. This study and methodology developed aims to contribute to these efforts, particularly in supporting national governments to analyze the employment effects of the RE targets under their NDCs and national energy plans.

Based on the experience of conducting RE employment study in Rwanda, it is evident that there are substantial constraints to the availability of good quality data for conducting research in least developed countries. **Good quality data, data availability and accessibility are fundamental conditions for conducting employment assessments in the RE sector in low-income countries.** A forthcoming discussion paper<sup>135</sup> highlights the importance of sex-disaggregated data collection. Precise and sex-disaggregated data enables the identification of gender gaps in the labor force, its socio-economic impact, and the development of vocational training and employment policies. The role of multilateral agencies is vital for providing institutional capacity development to selected departments and ministries, such as the statistics department, ministry of energy, and ministry of finance. Support could include improving data collection protocols and methods and enhancing monitoring and reporting procedures and systems.

The Indonesian government should support and **encourage RE companies to report and regularly and systematically share information on the labor force employed in the RE sector.** Regular reporting on the number of employees per the different stages of the RE value chain can be incorporated in regular annual enterprise surveys. RE associations could play a major role in coordinating the collection of employment data and occupations and skills requirements on different RE sectors and report back to the government to inform the design of energy and labor policies. Project developers' surveys could also be conducted to collect investment and labor share data for RE to fully understand the labor intensity of the different stages of RE value chains and to complement data collection from secondary sources. Another option could be to mainstream RE-related questions in existing business and household surveys to assess the number of employees currently working in different RE sectors.

The study may have underestimated the total employment generation due to some assumptions on specific input variables during the modeling horizon. The model does not consider changes in the in-country share of investments and

local labor share throughout the modeling horizon. The model therefore disregards country's capacity to strengthen its supply chain and start manufacturing of specific RE technology components. In Mexico, for instance, the model does not consider an increase in the local manufacturing of RE components during the whole modeling horizon, assuming that all technology components will continue to be manufactured overseas and imported. In Indonesia, it is assumed that solar PV developers comply with the LCR set by government regulation, with the LCR assumed to remain constant through the whole modeling horizon. However, Indonesia could achieve higher LCR for specific components of solar PV systems in the coming decade, with the right blend of energy, industrial and human resource policies,<sup>136</sup> tapping in its human resources, and further maximizing the potential for employment and value-added creation. **More in-depth research on the opportunities and challenges relating to the application of LCR government regulations is needed.**

This study estimates the employment effects of different future power sector pathways at the national level, providing information on the jobs that could be created at different stages of RE value chains. **Identifying where RE jobs are likely to be located could provide insights to support the development of training and vocational programs in provinces, states, and regions where specific occupations and skills in RE will be in high demand.** Furthermore, assessing and mapping the potential occupations and skills gaps, as was demonstrated in the Mexico country case, could provide sub-national and national policymakers with valuable information. Therefore, additional follow-up research on RE deployment potential and the required skills and occupations at the provincial /regional level in Indonesia and Rwanda is needed. This type of evidence could enhance policy coherence between energy, labor and education and training policies and policy alignment at the national, sub-national, and local levels.

Gender aspects of RE employment were not explicitly discussed in this report. According to the above-mentioned forthcoming discussion paper, more women participate in the global labor force, the better the socio-economic benefits. Guaranteeing women's participation at levels similar to that of men is estimated to add trillions of USD in investment to the global annual GDP. Better performance and decision-making are made possible by gender diversity in high-level positions. Women are also expected to play a critical role in energy justice and energy democracy. Therefore, **the consideration of the gender aspects of RE employment is crucial to further research on the co-benefits of mitigation and adaptation plans in NDCs.**

Future research is necessary to **explore the employment opportunities created by other sectors and technologies** not assessed in this study. For instance, biomass and wind energy have great technical potential in Indonesia and could play a major role in Indonesia's power sector decarbonization. Assessing the employment benefits of wind and biomass will provide policymakers with valuable insights on designing economic stimulus packages to be aligned with energy planning. Biomass job opportunities could be particularly significant considering the labor-intensive production process of feedstock for biomass. Although this study assessed and compared the job creation potential of selected RE technologies and fossil fuel based technologies in terms of job creation per unit of electricity generation and unit of investment, additional research is needed to address any potential job losses in sectors like the mining industry by including all the technologies of different power sector scenarios. In Rwanda's context and more generally in Sub-Saharan Africa, distributed RE generation has great technical and employment potential that should be further explored. Power For All<sup>137</sup> utilized the first jobs census for distributed RE in Kenya and Nigeria (and India) for 2017-18. Focusing on the distributed RE generation sector where employment data is rare is the first step towards modeling and assessing the job potential from expanding distributed RE generation in sub-Saharan African and other regions to provide power to those who still lack access. This can be done by conducting a survey to collect data and considering the types of jobs most likely to be created in the sector. Lastly, conducting job assessment studies on energy efficiency in buildings is a promising direction for further research as the sector could have great potential for local jobs creation while delivering significant environmental benefits. This is particularly pertinent in times of economic crisis when countries experience sharp increases in unemployment rates, and governments are urgently looking to invest in sectors with high employment generation potential.

<sup>134</sup> Sustainable Energy Jobs Platform, <http://www.sejplatform.org/>.

<sup>135</sup> Ana V. Rojas, Tracking Increase in Women's Employment in the Renewable Energy Sector under NDC Targets (GGGI, forthcoming).

<sup>136</sup> International Climate Initiative Ambition to Action Project, *Three Indonesian Solar Powered Futures*, 2019.

<sup>137</sup> Power For All, *Powering Jobs Census 2019: The Energy Access Workforce*, 2019, <https://www.powerforall.org/resources/reports/powering-jobs-census-2019-energy-access-workforce>.

# ANNEXES

## ANNEX 1: VARIABLE TABLES

	Input variables	Unit	Output
Technology and cost data	CAPEX: Cost structure per technology component	USDk/MW	Direct employment impacts, Required investment
	OPEX fixed: Cost structure per technology component	USDk/MW/yr	
	OPEX variable: Cost structure per technology component (utilities)	USDk/MWh	
	OPEX variable: Cost structure per technology component (fuel cost)	USDk/MWh	
	In-country share (share of domestic investment)	%	
	Labor share (share of labor expenses)	%	
	Actual and future capacity per technology	MW	
	Electricity Generation per technology	GWh	
Average annual salary per sector	FTE		
Macroeconomic data	IO table values (in combination with Technology and cost data)	USD	Indirect employment impacts, Induced employment impacts, Added value
Skills demand	IRENA's occupations per stage of RE Value Chain	%	Number of occupations per stage of RE Value Chain, Number of RE hard-to-fill occupations
	ILO's hard-to-fill RE occupations	Type of Occupations	
Skills supply (Mexico only)	Ministry of Education, Ministry of Labor's graduate database	Number of graduates	Number of professionals per occupation

## ANNEX 2: EQUATIONS UTILIZED FOR THE ASSESSMENT OF DIRECT, INDIRECT AND INDUCED JOB-YEARS

### 1. Direct jobs per MW

The equations below illustrate how the direct jobs per MW have been calculated.

#### a. CAPEX direct jobs

The number of direct CAPEX jobs "x" for the CAPEX component "c<sub>1</sub>" is calculated as follows. We estimate the share of the CAPEX of component c<sub>1</sub> that is spent in the country, denoted by  $\%IC_{c_1}$  and its share spent on labor denoted by  $\%L_{c_1}$ . That results on the overall CAPEX of component c<sub>1</sub> spent on labor. By dividing the CAPEX of component 1 (c<sub>1</sub>) spent on labor by the average annual salary of the economic sector of component 1, denoted by  $S_{es-c_1}$  we estimate the number of direct jobs per MW of CAPEX component 1.

$$x_{c_1} = \frac{CAPEX_{c_1} * \%IC_{c_1} * \%L_{c_1}}{S_{es-c_1}}$$

By following the same approach for all CAPEX components, we can estimate the CAPEX direct jobs per MW created per every CAPEX component as illustrated at the following equation:

$$x_{cn} = \frac{CAPEX_{cn} * \%IC_{cn} * \%L_{cn}}{S_{es-cn}}$$

#### Total CAPEX jobs per MW

The total CAPEX jobs per MW then is calculated as the summation of the direct jobs per MW of all CAPEX components as illustrated by the following equation:

$$X_{CAPEX-total} = \sum x_{cn}$$

#### Total CAPEX direct jobs during the modeling horizon

The total CAPEX job-years are calculated by multiplying the total CAPEX jobs per MW by the number of MW of new installed capacity during the modeling horizon 2020-2030.

#### b. OPEX direct jobs

Direct OPEX jobs x of operation is calculated as follows. We estimate the share of the OPEX of operation that is spent in the country, denoted by  $\%IC_o$  and its share spent on labor denoted by  $\%L_o$ . That results in the overall OPEX of operation spent on labor. By dividing the OPEX of operation (o) spent on labor by the average annual salary of the economic sector of OPEX of operation, denoted by  $S_{es-o}$  we estimate the number of OPEX direct jobs per MW related to the operation of the technology assessed.

$$x_o = \frac{OPEX * \%IC_o * \%L_o}{S_{es-o}}$$

By following the same calculations for the maintenance part of the OPEX we can estimate the OPEX direct jobs per MW created by the maintenance of the technology assessed as illustrated at the following equation:



$$X_m = \frac{\text{OPEX} * \%IC_m * \%L_m}{S_{es-m}}$$

### Total OPEX jobs per MW per year

The total OPEX jobs per MW then is calculated by adding the direct jobs per MW of operation part of OPEX () and the direct jobs per MW of maintenance part of OPEX () as illustrated by the following equation:

$$X_{\text{OPEX-total}} = X_o + X_m$$

### Total OPEX direct jobs during the modeling horizon

The total OPEX job-years are calculated by multiplying the total OPEX jobs per MW per year with the number of MW of new installed capacity during the modeling horizon 2020-2030.

### Total direct jobs per MW per year

Lastly, the Total direct jobs per MW is calculated by adding the CAPEX direct jobs per MW ( $X_{\text{CAPEX-total}}$ ) and the OPEX direct jobs per MW ( $X_{\text{OPEX-total}}$ ) as it is illustrated by the following equation:

$$X_{\text{total}} = X_{\text{CAPEX-total}} + X_{\text{OPEX-total}}$$

#### c. Indirect and induced jobs

As described in the methodology, the indirect and induced jobs are calculated by utilizing an Input-Output modeling approach. The standard representation of the Input-Output model in matrix notation can be defined as follows:

$$X = (I - A)^{-1} Y$$

Where  $X$  is the vector of final production of the economy assessed, whereas  $Y$  is the vector of final demand of the economy.

" $A$ " is an  $n \times n$  matrix of technical coefficients. A technical coefficient  $a_{ij}$  is defined as the amount of production of sector  $i$  that sector  $j$  requires to produce one unit of output. Through these technical coefficients the direct impacts from an increase in final demand for a particular product on the various economic sectors can be estimated. " $I$ " denotes the identity matrix.

The  $(I - A)^{-1}$  is the Leontief inverse  $n \times n$  matrix that determines the input-output multipliers. The rows and columns of the Leontief inverse matrix indicate the economic sectors and each element  $a_{ij}$  of the matrix shows the total required increase in the production of sector  $i$  to meet an increase of one unit in the final demand of sector  $j$ . The sum of all the elements of the column  $j$  of the Leontief inverse matrix gives the output multiplier of the sector  $j$ . The output multiplier for the sector  $j$  is the total change in gross output of the entire economy by an initial change in the final demand in sector  $j$  of USD 1.

There are two types of Leontief inverse matrices. The first matrix, Type I, includes the relationships between the various economic sectors and is used to estimate the **indirect economic effects**. The second matrix, Type II, is expanded by one column to include the effect of households' consumption (expenditure) and by one row to include labor compensation. The Type II Leontief inverse matrix is combined with the Type I Leontief inverse matrix to estimate the induced effects of a project or investment.

The **Type I employment multiplier** is the ratio of the sum of direct and indirect employment effects by direct employment effect. The **Type II employment multiplier** is the ratio of the sum of direct, indirect and induced employment effects by direct employment effect.

## ANNEX 3: SHARE OF INVESTMENT LOCALLY SOURCED (IN-COUNTRY SHARE)

Table 1 Mexico

Technology	Development stages	EM&D	PD	C&I	O&M	Other	Data source
Natural Gas		9%	80%	80%	73%	30%	CENACE, 2016 <sup>138</sup>
Onshore wind		13%	100%	100%	46%	100%	Interview/survey
Utility-scale solar PV		27%	93%	100%	93%	100%	Interview/survey
Solar PV (DG)		33%	100%	100%	100%	100%	Interview/survey

Table 2 Indonesia

Technology	Development stages	EM&D	PD	C&I	O&M	Other	Data source
Large hydro		47%	93%	94%	100%		Interview/survey
Small hydro		18%	74%	100%	100%		Interview/survey
Geothermal		59%	66%	100%	70%		DEN, 2017 <sup>139</sup> and interview
Solar PV		42%	100%	100%	42%		DEN, 2017
Coal		38%	77%	77%	76%	100%	DEN, 2017

Table 3 Rwanda

Technology	Development stages	EM&D	PD	C&I	O&M	Other	Data source
Large hydro		7%	85%	70%	92%	0%	Interview/survey
Solar PV		16%	35%	53%	51%	0%	Interview/survey
Methane		6%	12%		20%	100%	Interview/survey
Peat		5%	20%	18%	46%	82%	Interview/survey

<sup>138</sup> CENACE, *Informe de la Tecnología de Generación de Referencia*, 2016.

<sup>139</sup> Danish Energy Agency, *Technology Data for the Indonesian Power Sector: Catalogue for Generation and Storage of Electricity*, 2017, [http://www.ea-energianalyse.dk/reports/1724\\_technology\\_data\\_indonesian\\_power\\_ector\\_dec2017.pdf](http://www.ea-energianalyse.dk/reports/1724_technology_data_indonesian_power_ector_dec2017.pdf).

## ANNEX 4: COST STRUCTURE PER TECHNOLOGY

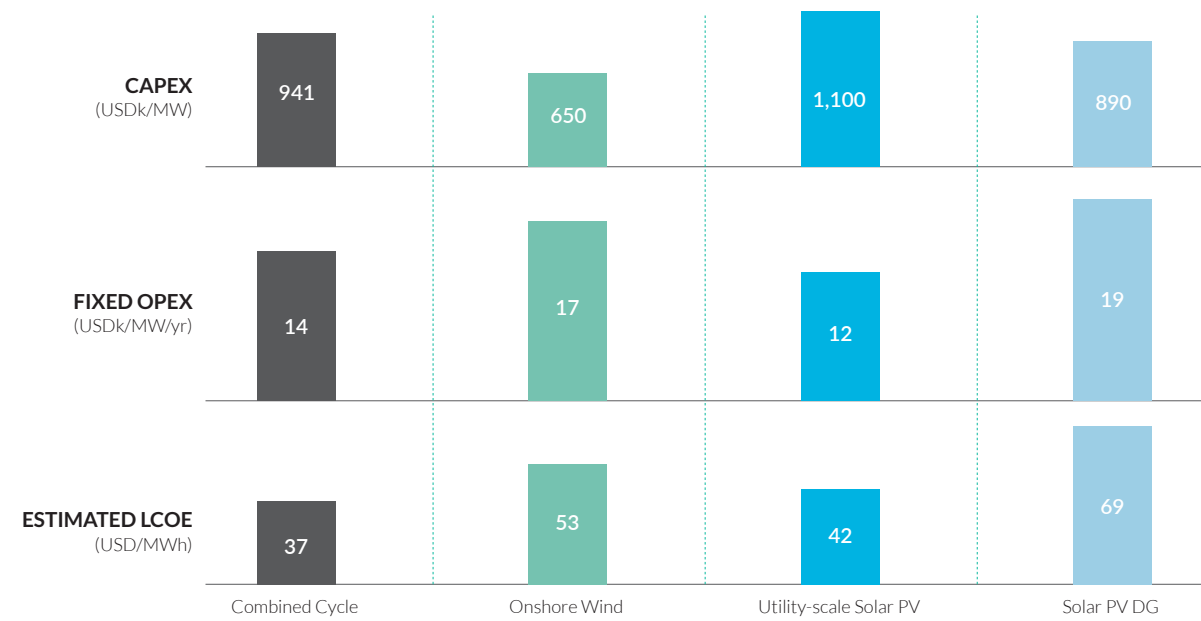


Figure 1 Cost structure per technology for Mexico<sup>140</sup>

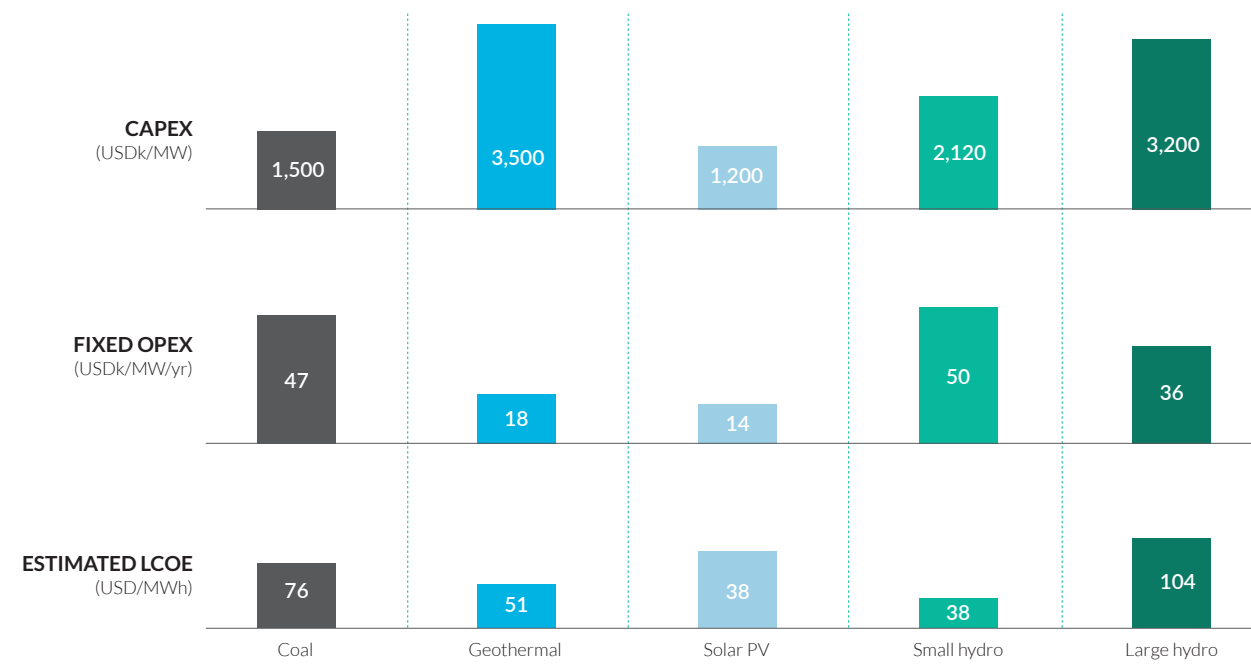


Figure 2 Cost structure per technology for Indonesia

Source: DEN (2017) and interviews

<sup>140</sup> A discount rate of 7.5% was assumed. International Renewable Energy Agency, *Renewable Power Generation Costs in 2018, 2019*.

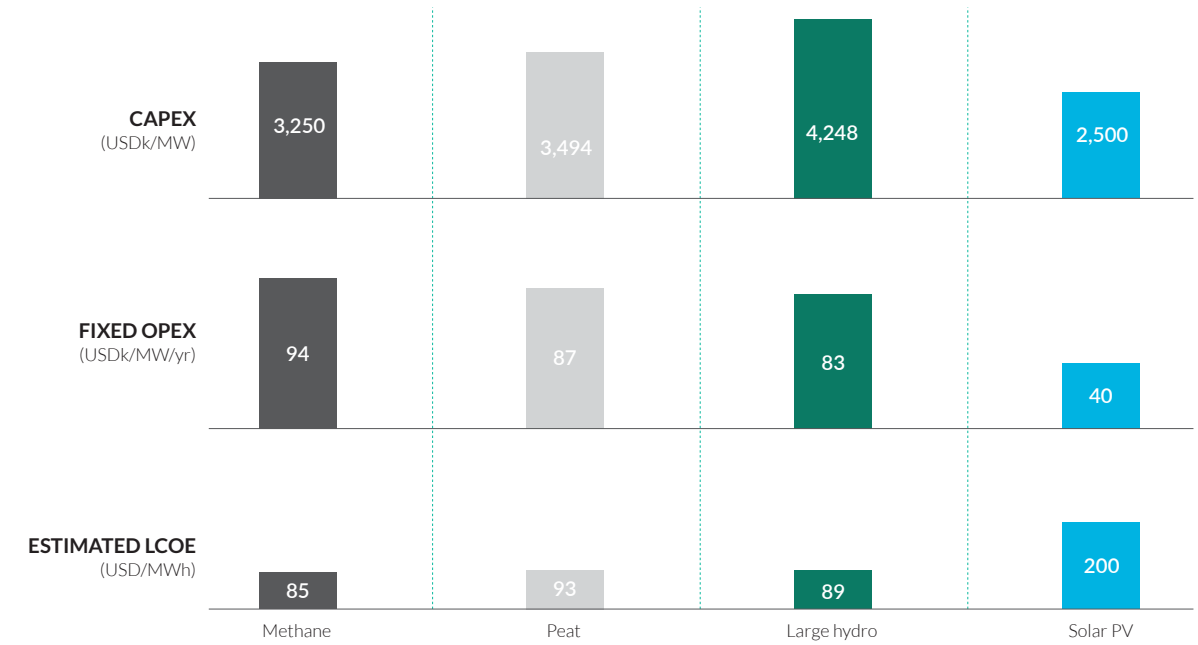


Figure 3 Cost structure per technology for Rwanda

## ANNEX 5: SENSITIVITY ANALYSIS

Sensitivity analysis explores how the change of selected input variables affects the final results. Sensitivity analysis is particularly relevant and useful in cases where input variables are uncertain.

Sensitivity Analysis was conducted to measure the robustness of the results of direct employment on +/-10% changes in the following key input variables:

1. **Average annual salary per economic sector**, measured in USDk/year,
2. **In-Country share or local share**, share of domestic spending,
3. **Labor share**: share of domestic spending allocated to labor.

### Mexico

The Sensitivity Analysis was conducted for Mexico for utility-scale solar PV, solar PV distributed generation and onshore wind technologies for the NDC scenario. When salaries increase by +10%, the total direct jobs decrease by 9%, whereas when salaries decrease by 10%, the total direct jobs increase by 11%. Labor share has a positive relationship with the number of direct jobs. When labor share changes by 10%, the total number of direct jobs changes at the same direction by 10%.

The impact of increasing the “in country share” on the total number of direct jobs is comparable to the impact of changing the “labor share”. A 10% increase in “in-country share” will increase the direct job-years in Mexico by 10%, while a 10% decrease in “in-country share” will decrease direct jobs by 10%.

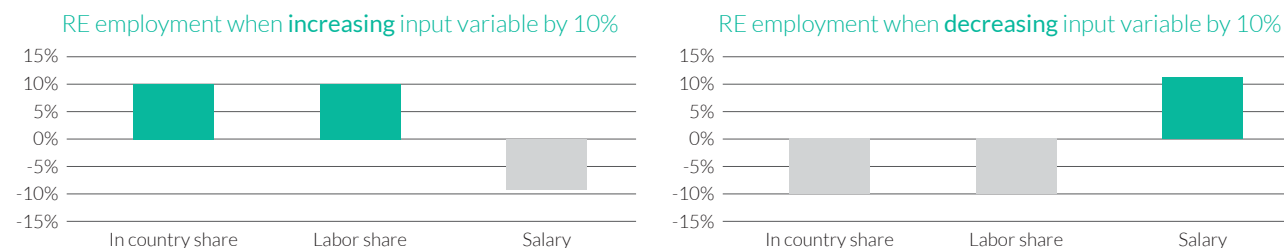


Figure 1 RE employment sensitivity analysis for Mexico

### Indonesia

The Sensitivity Analysis that was conducted for Indonesia indicates that salary has an inverse relationship with the number of direct jobs, while in-country share and labor share both have a positive relationship with direct employment.

Under the RUKN scenario, when salary decreases by 10%, direct jobs increase by 11%. When labor share increases by 10%, direct jobs will also increase by 10%. Finally, an increase of 10% in ‘in-country’ share, will increase direct jobs by 8%.

On the contrary, a 10% increase in salary will reduce direct employment by 9%. In the same vein, a decrease of 10% of the labor share results in a 10% decrease in direct jobs.

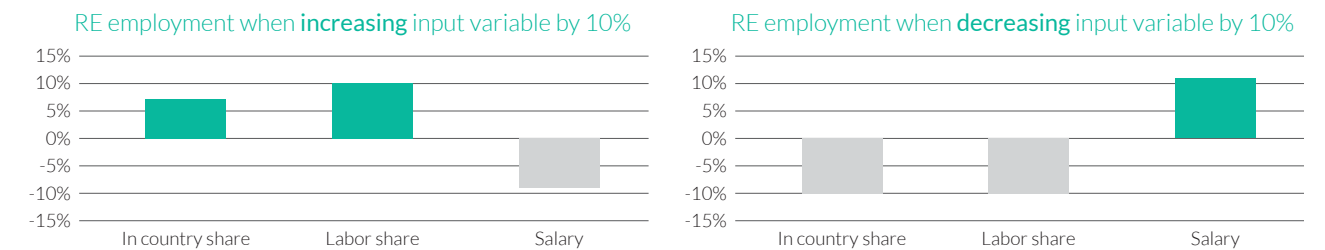


Figure 2 RE employment sensitivity analysis for Indonesia

### Rwanda

In the case of Rwanda, the results indicate that salaries have an inverse relationship with direct jobs, while in country share and labor share both have a positive relationship with direct jobs. In other words, when salaries decrease by 10%, direct jobs increase by 9%. Conversely, when labor share or in country share increase by 10%, direct jobs will also increase by 10%. A 10% increase in salary will reduce direct employment by 11%. In the same vein, a 10% reduction in “in-country share” results in 7% decrease in direct jobs.

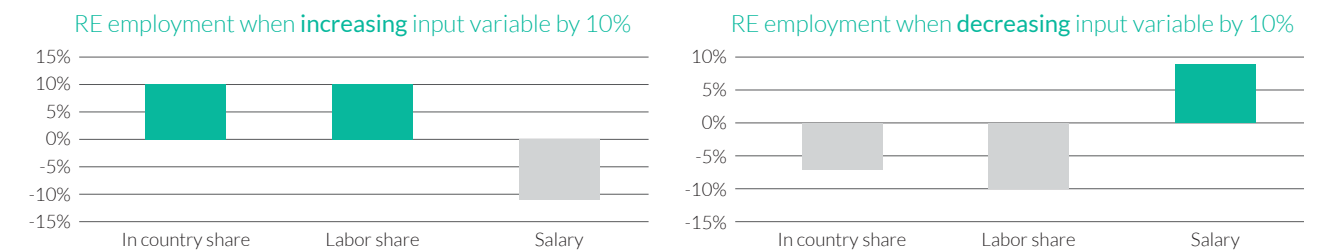


Figure 3 RE employment sensitivity analysis for Rwanda



# ANNEX 6: OCCUPATIONS, EDUCATION FIELDS, AND LEVEL OF SKILLS OF EACH STAGE OF THE RE VALUE CHAIN

**Table 1** List of occupations of each stage of the value chain stage, education fields, and skills level

Value Chain Stage	Occupation	Education Fields	Skills Level		
			High	Medium	Low
Equipment manufacture and distribution (EM&D)	Factory Workers and technicians	Technicians		X	X
	Industrial engineers	Engineering	X		
	Administrative personnel	Management	X		
	Marketing and sales personnel	Management	X		
	Logistics experts	Engineering & Logistics and Quality Assurance	X		
	Quality control experts	Engineering & Logistics and Quality Assurance	X		
	Health and safety experts	Health and Safety	X		
	Regulation and Standardization experts	Management	X		
	Chemical Engineers	Engineering	X		
	Project development (PD)	Legal Energy regulation, real estate and taxation experts	Law	X	
Financial Analyst		Finance	X		
Electrical, Civil, Mechanical, and Energy engineers		Engineering	X		
Logistic experts		Engineering & Logistics and Quality Assurance	X		
Environmental experts		Engineering & Natural Sciences	X		
Health and safety experts		Health and Safety	X		

Value Chain Stage	Occupation	Education Fields	Skills Level		
			High	Medium	Low
Construction and installation (C&I)	Construction workers and technical personnel	Technicians		X	X
	Civil engineers and foremen	Engineering	X	X	
	Health and safety experts	Health and Safety	X		
	Electrical and mechanical engineers	Engineering	X		
	Environmental Experts	Engineering & Natural Sciences	X		
	Quality-control Experts	Engineering & Logistics and Quality Assurance	X		
Operation and maintenance (O&M)	Construction workers	N/A			X
	Safety experts	Health and Safety	X		
	Industrial, electrical and telecommunication engineers	Engineering	X		
	Operators	Technicians		X	
	Technical Personnel	Technicians		X	
	Administrative and Accountant personnel	Management	X		
	Environmental experts	Engineering & Natural Sciences	X		
	Lawyers, experts in energy regulation	Law	X		
	Management	Management	X		
	Others (I.E. Transportation and Storage)	Logistic experts	Engineering & Logistics and Quality Assurance	X	
Quality Control agents		Engineering & Logistics and Quality Assurance	X		
Administrative personnel		Management	X		
Shipping agents		Management	X		
Loading staff		N/A			X
Truck drivers		N/A			X

Sources: IRENA (2017)<sup>141</sup>, ILO<sup>142</sup> and ANUIES<sup>143</sup>

<sup>141</sup> IRENA. 2017. Renewable energy benefits: Leveraging local capacity for solar PV. Abu Dhabi: International Renewable Energy Agency. Retrieved from [https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA\\_Leveraging\\_for\\_Solar\\_PV\\_2017.pdf](https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Jun/IRENA_Leveraging_for_Solar_PV_2017.pdf)

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## ANNEX 7: LITERATURE REVIEW

**Table 1** Literature review on renewable energy employment assessment studies

Type of publication	Year	Title	Author	Energy technologies examined	Methodology	Type of employment (direct, indirect, induced)	Scope	Country/ Region
Academic	2017	Promoting renewable energy and energy efficiency in Africa: a framework to evaluate employment generation and cost effectiveness	Cantore et al.	[RE] Renewable energy [CE] Fossil fuels, nuclear [Others] Energy efficiency	Employment factor approach, scenario analysis	Direct and indirect	Regional	Africa
Academic	2016	Employment from renewable energy and energy efficiency in Tunisia - new insights, new results	Lehr et al.	[RE] Biogas, wind, solar water heaters and PV	Ex-post analysis, Input-Output Analysis	Direct and indirect	National	Tunisia
Academic	2016	Employment impact assessment of renewable energy targets for electricity generation by 2020 - An IO LCA approach	Henriques et al.	[RE] Biowaste, biomass, biogas, wind, PV, hydropower large and small, geothermal [CE] Coal, natural gas, oil	Input-Output Analysis in combination with Life Cycle Assessment (LCA)	Direct, indirect and induced	National	Portugal
Academic	2013	Employment impacts of CDM projects in China's power sector	Wang et al.	[RE] Wind, hydro, biomass, solar [CE] Gas (fuel switch), nuclear, oil, small and large thermal power	Input-Output Analysis	Direct and indirect	National	China
Academic	2013	Green economy and green jobs: Myth or reality? The case of China's power generation sector	Cai et al.	[RE] Wind, hydro, biomass, solar PV [CE] Small and large coal-fired, oil, gas, nuclear	Project-level survey, Input-Output Analysis	Direct and indirect	National	China
Report	2020	Measuring the socio-economics of Transition: Focus on Jobs	IRENA	[RE] Solar, bioenergy, wind, [CE] Fossil Fuels, Nuclear [Others] Energy Efficiency, Energy Grid	E3M3 Macroeconometric model	Direct, indirect and induced	Global/ Regional	Africa, Middle East OPEC, Southern Europe, China
Report	2019	Future skills and job creation through renewable energy in Vietnam	IASS	[RE] Biomass, wind, hydropower, solar [CE] gas, coal	In depth interviews, Input-Out Analysis	Direct, indirect and induced	National	Vietnam
Report	2019	Future skills and job creation through renewable energy in South Africa	IASS	[RE] Hydro, wind, geothermal, biomass, PV, solar thermal [CE] Coal, gas, diesel, nuclear	In depth interviews, General Equilibrium Model approach, Input-Output Analysis	Direct, indirect and induced	National	South Africa
Report	2018	Renewable Energy Job Creation in Thailand	Greenpeace	[RE] Biomass, biogas, solar, wind [CE] Coal	Scenario analysis, Employment factor approach, qualitative assessment	Direct and indirect	National	Thailand
Report	2015	Global Green Growth: Clean Energy Industry Investments and Expanding Job Opportunities. Volume I: Overall Findings	GGGI and UNIDO	[RE] Renewable energy	Input - Output analysis	Direct, Indirect, Induced	National	Brazil, Germany, Indonesia, the Republic of Korea and South Africa
Report	2015	Clean Energy Powers Local Job Growth in India	CEEW team and NRDC team	[RE] Solar PV, wind	Scenario analysis	Direct and indirect	National	India
Report	2009, 2012, 2015	Energy Sector Jobs to 2030: A global Analysis	Rutovitz and Atherton	[RE] Hydropower large and small, wind, biomass, solar PV, geothermal, concentrating solar thermal power, ocean power [CE] Coal, gas, nuclear	Employment factor approach	Direct	Global	Global
Academic (review)	2015	Employment factor for wind and solar energy technologies: A literature review	Cameron et al.	[RE] Wind, solar PV, concentrated solar power	Employment factor approach	Direct	Global	Global
Academic (review)	2012	The challenges of determining the employment effects of renewable energy	Lamber et al.	[RE] Solar PV, solar thermal, wind, biomass [CE] Coal, natural gas	Literature review	Direct	Global	Global

## ANNEX 8: BACKGROUND METHODOLOGY RELATED INFORMATION

**Table 1** Example and illustration of Methodology steps 1 to 4 for solar PV in Indonesia

CAPEX Components	CAPEX Value (USDk/MW)	STEP 1		STEP 2		STEP 3		STEP 4	
		In-country share (%)	In-country Investment (USD k/MW)	Match Economic sectors (I-O table)	Labor share (%)	Labor Investment (USD k/MW)	Average Annual Salary per sector (USD k/yr)	CAPEX Direct Jobs (yr/MW)	
PV module	409	42%	172	D27: Electrical equipment	13%	22	3.48	6.4	
Inverter	72	42%	30	D27: Electrical equipment	13%	4	3.48	1.1	
Racking/ Mounting	111	42%	47	D25: Fabricated metal products	9%	4	3.97	1.1	
Installation	149	100%	149	D41T43: Construction	20%	30	2.33	12.8	
BOS, grid connection	206	42%	87	D27: Electrical equipment	13%	11	3.48	3.2	
Developer cost	145	100%	145	D69T82: Other business sector services	22%	32	3.01	10.6	
Land	3	100%	3	D68: Real estate activities	5%	0	3.08	0.0	
Fees and contingencies	106	100%	106	D64T66: Financial and insurance activities	20%	21	3.75	5.7	
OPEX Components	OPEX Value (USDk/MW)	In-country share (%)	In-country Investment (USD k/MW)	Match Economic sectors (I-O table)	Labor share (%)	Labor Investment (USD k/MW)	Average Annual Salary per sector (USD k/yr)	OPEX Direct Jobs (yr/MW)	
Maintenance	6	100%	6	D27: Electrical equipment	13%	0.8	3.48	0.22	
Operation	8	42%	3	D35T39: Electricity, gas, water supply, sewerage	12%	0.4	2.65	0.14	

**Table 2.** Assumptions for Learning factors variable for different energy technologies used

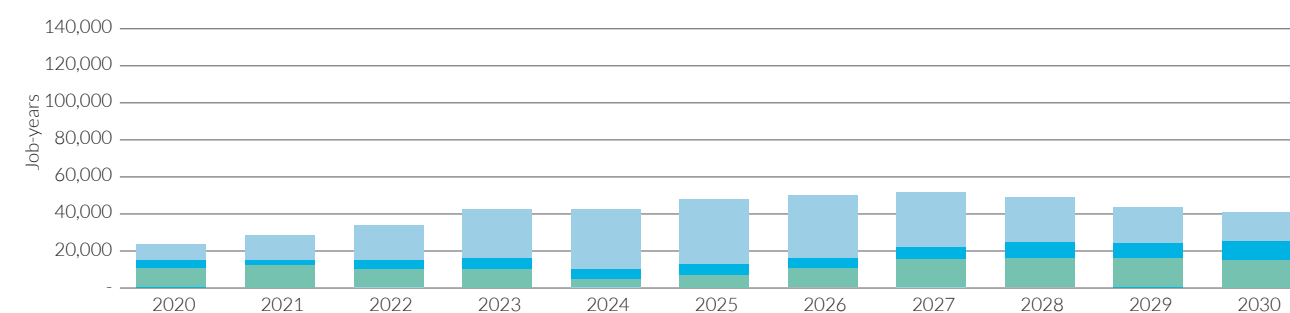
Technologies/ Countries	Mexico	Indonesia	Rwand
Large hydro			0.4%
Utility-scale solar PV		1.8%	2.7%
Solar PV DG		1.8%	
Onshore wind		1.5%	
Geothermal			0.9%
Combined cycle		0.5%	
Coal			0.3%
Methane			1.0%
Peat			1.0%
Source	SENER <sup>144</sup> (2018)	DEN <sup>145</sup> (2017)	Authors

<sup>144</sup> SENER, PRODESEN 2018-2032, 2018.

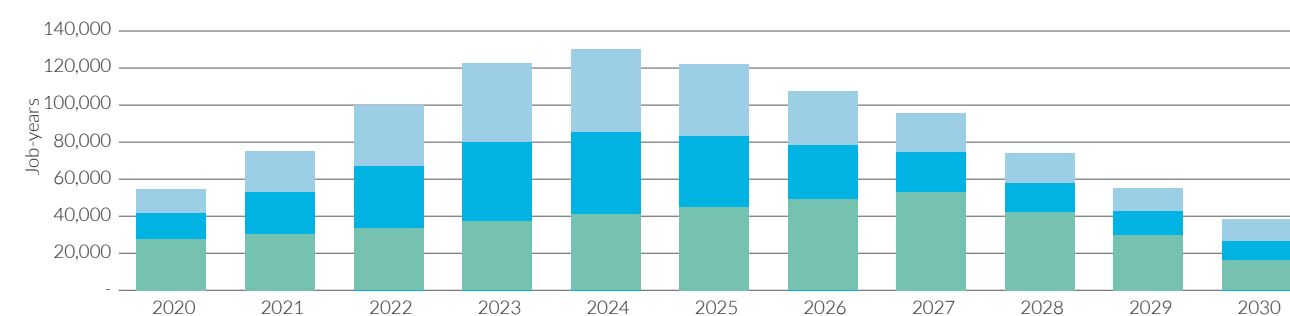
<sup>145</sup> Danish Energy Agency, Technology Data for the Indonesian Power Sector: Catalogue for Generation and Storage of Electricity, 2017.

## ANNEX 9: TEMPORAL DISTRIBUTION OF JOBS GENERATION PER TECHNOLOGY THROUGH THE MODELING HORIZON

### Mexico

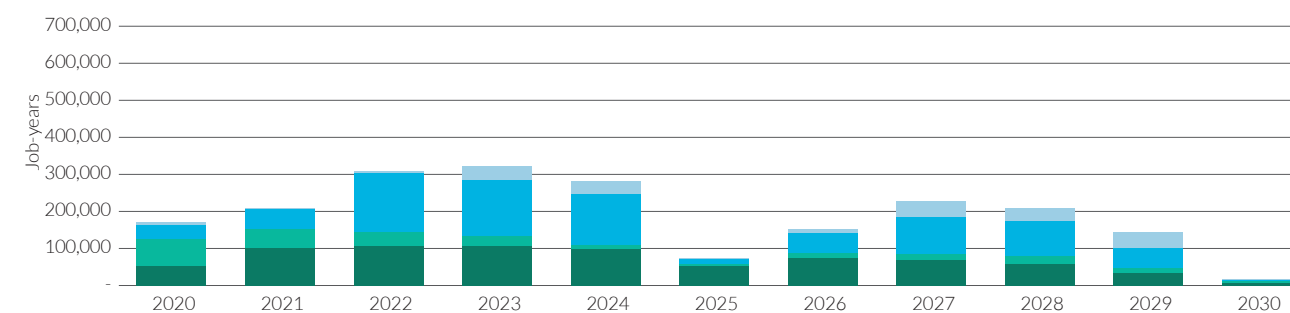


**Figure 1** Direct jobs break down by technology by year under BAU scenario



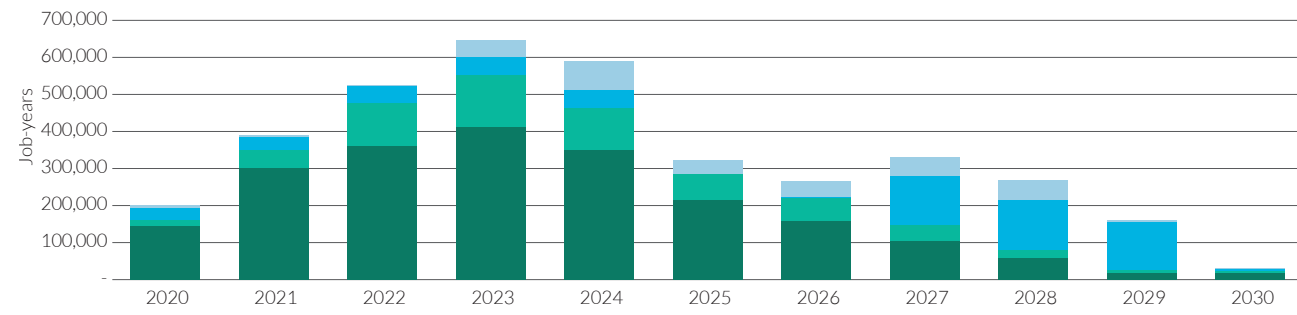
**Figure 2** Direct jobs breakdown by technology by year under NDC scenario

### Indonesia



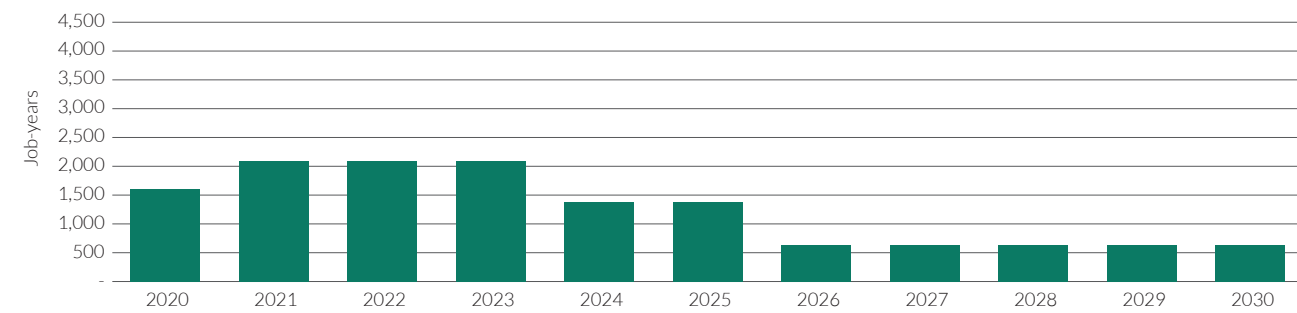
**Figure 3** Direct jobs breakdown by technology by year under PLN scenario



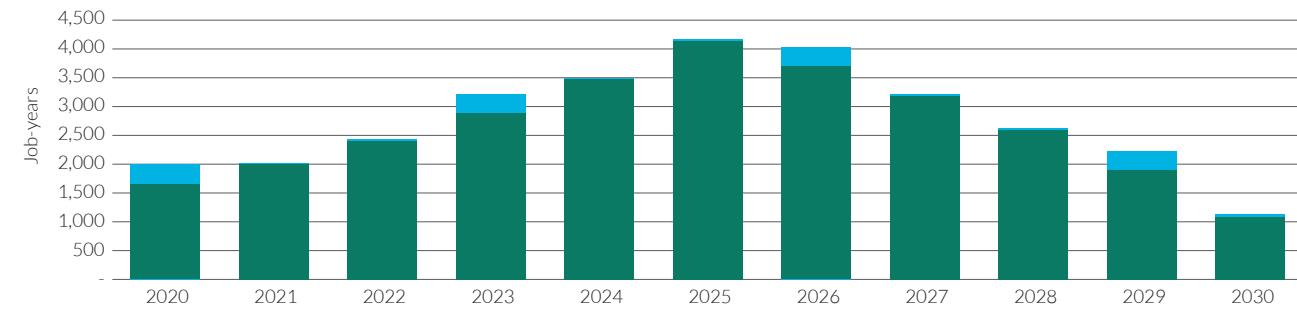


**Figure 4** Direct jobs breakdown by technology by year under RUKN scenario

**Rwanda**



**Figure 5** Direct jobs breakdown by technology by year under NDC unconditional scenario



**Figure 6** Direct jobs breakdown by technology by year under HA scenario



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