Ruth Kattumuri and Tobias Kruse

Renewable technologies in Karnataka, India: jobs potential and co-benefits

Article (Accepted version)
(Refereed)

Original citation: Kattumuri, Ruth and Kruse, Tobias (2017) *Renewable technologies in Karnataka, India: jobs potential and co-benefits.* Climate and Development. pp. 1-14. ISSN 1756-5529

DOI: 10.1080/17565529.2017.1410085

Renewable Technologies in Karnataka, India: Jobs Potential and Co-benefits

Abstract:

The tangible benefits of renewable energy technologies are a crucial parameter when determining the political feasibility of adopting a low-carbon development path, particularly for emerging economies. We present that these potential benefits consist of "green jobs" and of a wider set of socio-economic and environmental "co-benefits" that are generated simultaneously from renewable technologies in India. Based on case studies from the Indian state of Karnataka we obtain estimates for jobs and describe co-benefits enabled by wind, off-grid solar and biomass technologies. Furthermore, we use these estimates to project the potential for future benefits that could be generated by further enhancing the use of renewable technologies toward sustainable energy policy and security. We show that enhancing green economy offers benefits that include the creation of jobs, but also delivers a much wider set of socio-economic and environmental welfare gains for emerging economies such as India. Our paper also provides valuable evidence-based analyses for policy-makers when assessing the benefits of low-carbon sustainable development.

Keywords: Renewable Technologies, Green jobs, Co-benefits, Socio-economic benefits, Low-carbon Sustainable development

1. Introduction

The Rio+20 declaration provided a strong basis for the integration of economic, social and environmental development to achieve sustainable development. Persistent poverty, growing inequality and diminishing resources have indicated the need to move away from traditional models of development towards a low-carbon economy (ADB, 2013). The Sustainable Development Goals (SDGs) launched in 2015 build on the Millennium Development Goals (MDGs), to progress toward achieving global sustainable economic, social and environmental development. There are inter-relations among the seventeen SDGs and goals 7 (access to affordable, reliable, sustainable, and modern energy), 13 (take urgent action to combat climate change and its impact), 14 (conserve and sustainably use oceans, seas and marine resources) and 15 (protect and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss), specifically pertain to achieving environmental security (Kattumuri, 2015).

The Paris agreement of the 21st Conference of Parties (COP21) by United Nations Framework Convention on Climate Change (UNFCCC) currently has 195 signatories and has been ratified by 153countries. After it had been ratified by at least 55 parties to the Convention accounting for at least 55% of estimated total global greenhouse gas emissions, it has become the first legally binding agreement to reduce the risks and impacts of climate change by holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels (UNFCCC, 2016). India ratified the Paris agreement on 2nd October 2016, whilst marking Mahatma Gandhi's 147th birth anniversary.

The development and deployment of renewable technologies is central toward attempting to meet the targets of the Paris agreement and achieving a low-carbon future. The global mitigation effort is facilitated through the growing importance of green technologies at different levels – global, national, and regional. Indeed, if a green economy is "low-carbon, resource efficient and socially inclusive" (UNEP, 2011:16) then green technologies provide an essential starting point towards transformation for resource efficiency and a more socially inclusive economy. Furthermore it will hasten the transition towards a low greenhouse gas (GHG) emissions development-path in a cost-efficient manner (UNFCCC, 2013). Thereby many countries, including India, have committed to expand their use of renewable technologies (Shrimali et al, 2015, Lewis and Wiser, 2007).

The far-reaching impacts of green technologies are assessed with reference to Karnataka, India in this paper, with particular attention drawn to the co-benefits of the development and deployment of green technologies. We classify these co-benefits into environmental, social and economic contexts. Environmental co-benefits refer to any advantages to the environment derived from the development and/or deployment of a green technology, ranging from more quantifiable by-products like avoided CO2 emissions to more qualitative dimensions such as environmental awareness. The social co-benefits include qualitative improvements in individual or community wellbeing such as targeting gender inequalities or stimulating rural employment as well as health benefits to the household. Economic co-benefits involve direct and indirect economic impacts, where green jobs are understood as a direct co-benefit of the development and/or deployment of a green technology and dimensions such as time and monetary savings or rising value of land in an area provide additional economic co-benefits. It is important to acknowledge that green technologies can also provide substantial co-costs in parallel to the co-benefits. The most important being job losses in pollution- and energy-intensive industries (e.g. coal mining, steel production etc.). Furthermore, it has been shown in some advanced economies that the installation of renewable energy technologies (e.g. wind parks) can provide substantial costs for individuals living in their proximity, as they experience declining house prices and reduced amenity values (Gibbons, 2015). Hence the costs resulting from renewable energy technologies are important to estimate for a comprehensive cost-benefit analysis particularly in advanced economies. In this paper we have focused on the co-benefits relevant for a developing country context. The estimation of costs may be considered in future research further to countries like India achieving improvements in economics, social and environmental developments.

2. Background and Literature

Green jobs generated by promoting economic growth, reliant on green technologies, provide an opportunity to grow the economy while achieving sustainable development. The notion of green jobs is embedded within broader discussions of 'green growth' and brings to the fore the role of labour market shifts facilitated by different aspects of national environmental management (Bowen, 2012). However, the concept of 'green jobs' is not unproblematic: there is no widely accepted definition of a 'green job' in academic or practitioner literature (Box 1).

Box 1: Defining green jobs

Estimates for potential green jobs creation vary according to the definition used, as shown by an OECD study (2012) that contrasts three different definitions: a 1999 OECD/Eurostat definition, a 2010 US Commerce Department's definition and a UNEP (2008) definition. They find that according to OECD and US Commerce Department's definitions, green jobs in the EU and the US were in the range of 1.5% - 2% of all jobs in 2010. At the same time, UNEP's broader definition generated estimates ranging up to 20% for the EU. This is because they defined a larger set of industries as 'green' relative to the previous two definitions, namely industries that rely heavily on environmental quality (eco-tourism) and natural resources (agriculture and forestry) (Bowen, 2012). The Brookings Institution (2011) and the Pew Charitable Trust (2009) take a different approach by defining first the green sectors, in which they consider all the jobs to be green. The former defines these green sectors as those which produce "goods and services with an environmental benefit" (Brookings: 3). The Pew Charitable Trust (2009) counts jobs as being green if they are within "clean energy economy" (2009: 5) sectors, including clean energy production, energy efficiency, and the reduction of environmentally harmful emissions. A more detailed approach is taken by the US Bureau of Labour Statistics (BLS, 2013). It uses two measures to capture different types of green jobs: One measures the jobs that produce green goods and services, i.e. focusing on their output. The second approach counts jobs associated with environmentally friendly production processes. This disparity in findings highlights not only the current lack of consensus over what comprises a 'green job' but also how different definitions pose a challenge and have the potential to generate very different estimates and findings. Hence, we caution against relying on a single definition of green jobs and suggest a broader understanding of green economy that views green jobs as one dimension of the co-benefits of green technology development and deployment (see also Pollin, 2009)

The transition to a green economy has been, for the most part, documented in the context of OECD countries (OECD, 2012; OECD 2017). Academic interest in green jobs and the correlated depiction of green growth as offering win-win solutions – stimulating national economies and pushing forward a sustainable transition – is inherently associated with OECD-centric research programme (GHK Report, 2010, Blanco and Rodrigues, 2009). Within the context of the Eurozone crisis investments in renewable energies have been advocated as a strategy to provide economic stimuli to southern European countries, with the potential to reduce trade deficits and generate employment, as well as increased trust and solidarity among European states and improved energy security (Creutzig et al., 2014). In line with UNEP's recognition that the "greening of economies has the potential to be a new engine of growth" (2011:16) we find that a green economy may provide the necessary stimulus for a more socially inclusive development path (ADB, 2013) where co-benefits are crucial. Hence this has relevance for emerging economies and therefore we have attempted to examine these concepts for India.This paper finds that a transition to a green economy goes beyond creating green jobs by generating a range of other externalities: environmental, social and economic co-benefits.

This study builds upon the analytical model from Kammen et al. (2006), which introduced a top-down approach for counting green jobs for the US. A similar top-down approach has been employed in Borel-Saladin and Turok (2013) for South Africa, estimating a net employment potential for the short-term (2 years) of 98000 jobs and around 462000 jobs in the long term (8 years). Kim et al. (2012) count existing green companies within renewable energy industries, recycling industry, and environmentally friendly agriculture for Korea, and provide some jobs counts for the recycling industry (52000 jobs in 2009) and renewable energy equipment installation (13000 jobs in 2010). On a global scale IRENA (2016) estimates that the renewable energy employment in 2015 reached 8.1 million with most jobs existing in China (3.5 million), Brazil (918,000) and the US (769,000). For India they count 416,000 jobs in 2015. Compared to such top-down studies, bottom-up approaches tend to require more granular data and are more resource intensive relative to the area they can cover, and they require the existence of systematic surveys of employment in green industries. Llera et al. (2010) show the evolution of employment within renewable energies in the Spanish region Aragon, using detailed survey information. Blanco and Rodrigues (2009) surveyed firms in the wind industry and established that there are 50,000 direct jobs in the EU in the wind energy sector. Connolly et al. (2016) combine a "bottom-up" approach using detailed sector data from industry surveys and a "top-down" approach using aggregate employment for their green jobs estimation for Scotland, counting 75,000 to 92,000 jobs in 2012. Yi (2015) and Yi (2014) measures green jobs respectively at the city level in China and the state level in the US. Through regression techniques they are able to identify some drivers of green businesses such as clean energy policies and renewable portfolio standards. This provides analytic insight into how governments can try to attract green businesses and jobs.

This study is furthermore directly related to literature on the employment implications of green growth policies. It has been shown that well-implemented environmental policies, can stimulate the economy and generate new jobs. The focus is often on stereotypical green jobs such as in solar- or wind parks. However, more recently it has been shown that the impacts of environmental policies can provide benefits to more sectors beyond solar and wind (OECD, 2012; OECD, 2017). British Columbia has shown how to successfully implement a revenue-neutral carbon price by recycling the revenue to reduce income taxes and through direct transfers to low-income households. While typical green jobs provide a substantial part of employment benefits from environmental policies, it is important to appreciate that all sectors which are relatively clean can benefit. This has been shown very robustly in the case of the British Columbia carbon tax. Sectors with low energy-intensity have gained most from the policies (e.g. health care sector, education, and other professional services such as financial and administrational services). These sectors are not traditionally considered to be green, however, by being relatively less emissions-intensive they can still experience job gains from environmental policies like carbon pricing (Harrison, 2013; Murray and Rivers, 2015; Yamazaki, 2017). Furthermore, it has been shown for advanced economies that the most carbon-intensive sectors employ relatively few workers. While, these sectors are likely to face substantial relative reductions, the absolute number of jobs lost appears to be small. Net employment effects have been estimated to be relatively modest and bear the potential of even generating jobs. Nevertheless, it is important to bear in mind that environmental policies are implemented to improve the environment or human wellbeing, and not primarily to create jobs. If they are able to provide additional employment this can already be considered a co-benefit of such policies (OECD, 2012; OECD, 2017).

Our study assesses the key opportunities and challenges presented by the transition to a low-carbon economy by accounting for both the creation of green jobs and the co-benefits arising from the development and deployment of renewable energy technologies in the state of Karnataka, India. This contributes to very limited literature of a non-OECD context examining the benefits of transition towards a green economy associated with job creation and other additional co-benefits. This discussion is analysed as particularly crucial to the development path of emerging economies such as India, which extends beyond the focus on the potential of a green economy to generate green jobs in post-industrial economies.

3. Methodology and Data

This study is based in the state of Karnataka, in southern India, which reported installed renewable energy capacity of 4386 megawatt at the end of 2013-14 and the government plans to add a minimum of 3600 megawatt by 2020 through additional investments in wind power (target of 2600 megawatt), hydro (target of 600 megawatt) and biomass (400 megawatt) (Government of Karnataka, 2014). Karnataka is among eight states identified to have high wind energy potential and has been targeted for wind installation projects by the government toward meeting the country's targets and commitments for the Paris agreement (MNRE, 2017).

Our research is based on empirical case studies where relevant renewable technologies were prevalent in Karnataka. Small case studies of green technologies of off-grid solar, wind energy and biomass which were accessible have been examined. This research is field based and involved qualitative discussions and participant observation with the following:

i. Tata Power officers (3) based in the central sustainability office based in Mumbai and site visit to Gadag Wind Park in Karnataka and discussion with Tata wind plants manager and 3 other officials based at the plant. Data to estimate jobs for wind power were obtained from their offices in Mumbai and at Gadag plant

j. Infosys sustainability officers (3) based at their head office in Tech City in Bangalore and observation of their experimental project to convert plastic to oil

k. Selco Foundation (discussion with 3 staff members) - a social entrepreneurship, and visits and discussion with 8 households at two of their community settlements based in Bangalore. Data to estimate jobs for off-grid solar were obtained from this organisation

l. RK Power Gen Private Ltd. involved in development and deployment of biogas, biomass and cookstoves for households and community organisations in Chitradurga in Sirsi district in Western Ghats region of Karnataka. Data for jobs estimate for biomass was secured from this company. Visited and discussed with 3 officers involved in installations, operations and maintenance of the projects; 6 households and a community temple where these technologies were deployed. The biogas and biomass plants deployed by the households in this region and have been supported by public sector incentives with government subsidies and financial support from other international environmental programmes.

m. Karnataka renewable energy development Ltd (KREDL) officers (3) based in Bangalore

The general paucity of data pertaining to green growth in Asia, particularly green technologies for sustainable development has been a major challenge: as there have been very limited research (GGGI, 2011). Hence this paper relied on qualitative discussions with senior public and private sector officials as stated above and very limited secondary data (such as Indiastat) and publications which provided some reference points as well as information available online from websites. Data required for the analyses according to Kammen et al (2006) was collected directly from companies where the relevant technologies were deployed – Selco for Off-grid solar; Tata Power for wind; the RK Power Gen Private Ltd for Biomass. These were supplemented further through site visits and discussions with implementers and consumers of these technologies.

Site visits to locations of the renewable technologies have been rewarding albeit being widespread, remote and extremely resource intensive. Both public and private sector sources contacted were supportive and helpful with discussions. However, primary data from public and private sector organisations contacted had been inadequate for additional analyses. Data, such as specific recorded or registered details on employment figures, were not available or accessible due to data protection and also as the jobs were often integrated with multiple activities and the organisations were unable to provide accurate classification of employments specific to green jobs.

Measuring and quantifying co-benefits has been a difficult task rendered complex by the inherently qualitative nature of some of these aspects and gap in relevant literature. In particular, the social and health dimensions of the transition to a low-carbon economy are noted here. This paper has undertaken an exploration of these issues and offers scope to expand on this work in future research. Our analysis of green jobs and co-benefits of green technologies in Karnataka is first of its kind and is an important contribution to this knowledge.

In the absence of definitive data, an assessment of potential gross green job creation has been by noting the extent of current and projected employment in specific green industries where these estimates can be determined. While there are differences in contexts between developed and developing economies related to nature and number of employees and implementation of technologies, Kammen et al's analytical framework provided a suitable technique (this has been reiterated by other studies Rutovitz, 2010) that could be replicated for the purposes of this study. While the figures represent rough estimates, nevertheless they provide indicative evidence relevant for policy making.

It is important to note that this study analyses 'gross' job potentials. An estimation of net jobs needs to include job losses in e.g. conventional power sectors such as coal, oil and gas etc. Estimating potential job losses in these sectors is not yet relevant in an Indian context and is beyond the scope of this study.

4. Green Jobs Estimation

Calculating green jobs is a relatively new exercise within economics and social sciences. While previously the focus has largely been on the impacts on economic growth, the impacts on employment from a shift to a low-carbon development path have become of interest to policymakers. In general it can be assumed that regions with a lower level of development and with high populations have more labour intensive economies. India's population of over 1 billion requires a balance of the opportunities and challenges from the demand and supply of a large labour force. In other words, development in India is likely to be comparatively more labour-intensive than in developed economies in order to provide for its high volume and diverse human capital. A similar assumption has indeed been made in a recent study on green jobs in South Africa (Rutovitz, 2010). When local employment factors were not available for the South Africa study, OECD employment factors were multiplied by a factor of 2.15 to adjust for this tendency. Thus, we have taken the employment factors found by Kammen et al. (2006) as a credible lower bound to estimate green jobs potential in Karnataka. Kammen et al. (2006) use 13 independent reports and studies on employment impacts of the clean energy industry. Their findings across the broad range of scenarios showed that renewable energies generate per unit of energy (average MW) more jobs than the fossil fuel-based energy sector (Tables 1 and 2).

Table 1: Comparison of jobs/MWp, jobs/MWa and person-yrs/GWh across various technologies for the US

In order to calculate jobs per MW, it is necessary to convert energy capacities from different sources into comparable units. Thus, peak-capacity values (MWp) need to be converted into average-capacity values (MWa) to adjust for the factor that 1 MW of installed solar capacity does not produce the same amount of electricity in one day as 1 MW of installed coal capacity, as solar energy can only be generated during sunshine, while coal-fired electricity can in principle run 24 hours. Kammen et al., (2006) state that a coal power plant is likely to operate for 80% of the time with the remaining time likely to be shut down for maintenance. Thus, 1MW of installed coal capacity generates 1 x 0.8 x 24 hrs/day = 19.2 megawatt-hours (MWh) in one day. In comparison solar energy can only be generated when the sun is shining. In the US there is on average 5 hours of peak sunshine in one day, which leads to a solar capacity factor of 5hrs/24hrs = 0.21. Thus, the 1MW of solar capacity generates: 1MW x 0.21 x 24hrs/day = 5 MWh electricity in one day. These simple calculations show the large difference between peak- and average capacity. A 1 MWp coal-fired power plant generates 19.2 MWh in a day, whereas the solar PV panel with the same 1 MWp only generates 5 MWh in a day. Thus, Kammen et al (2006) convert all peak capacities into average capacities. This is why a 1MWp coal plant is counted as 0.80 MWa and a 1 MWp solar plant is counted as 0.21 MWa. The assumed capacity factors are shown in the following figure (Fig 1). When multiplying the estimates by Kammen et al (2006) with Karnataka specific current values and targets, one estimates a lower bound of the values due to the above argument on higher labour intensity in India (Table 2).

Table 2: Total Jobs potential for Karnataka

4.1. Green jobs estimators for the state of Karnataka

Here we derive job estimates using local employment factors for each of the sectors considered for Karnataka. These estimates vary substantially from the US factors, which however reflects the much larger working age population in India. We were able to replicate the Kammen et al. (2006) model for technologies that occur in India and where required data was available and could be secured. Thus we have been able to calculate green jobs potential for off-grid solar, wind and biomass. For these sectors, the following 4 steps are applied to calculate jobs estimates:

1. Conversion of installed capacity at plant level from peak-capacity values into average-capacity values: MWp*capacity factor = MWa
2. Calculate the employment factor per energy sector:
   [(Number of Employees) / MWa] = employment factor
3. Conversion of the state's peak-energy potential/energy target into average energy potential/target as in step 1)
4. Calculate total employment:
   (employment factor)*average energy potential or target = total employment

These 4 steps can be compiled into one equation:

[(Number of employees) / (MWp*capacity factor)]*[(peak-energy potential)*(capacity factor)] = **Employment**

This equation can be simplified to:

[(Number of Employees) / (MWa)]*[Average Energy Potential of the state] = **Employment**

While for wind energy we are able to decompose the job estimation into high- and low-skill jobs, we are unable to provide a further break-down into short- and long-term employment or high- and low-quality employment. These are important dimensions when assessing the net benefit of a shift to renewable energy. If long-term jobs in emissions-intensive industries are replaced by short-term jobs in the maintenance of solar PV plants, we experience a net decline in employment. However, the literature on the length, quality and required skills of green jobs is still in its infancy (OECD, 2017).

4.1.1. Wind

The state of Karnataka hosted the third largest installed base of wind capacity in the country (GGGI, 2014), which deployed total wind power capacity of circa 2200 MW.. To estimate local employment factors for wind energy, our study uses data from the Gadag (Karnataka) plant of World Ltd (formerly Enercon). Through qualitative discussions with Tata Power managers based at the wind farms based in Gadag and renewable technology managers based in Mumbai, we found that the capacity factor of 0.35 used in the US reference scenario is higher than the Indian capacity factors and we obtained the accurate capacity factor for the Tata wind plants in Gadag to be 0.22.

The Gadag plant had an installed capacity of 50.4 MWp, which translates into 11.09 MWa (50.4*0.22) when multiplying it with the wind capacity factor. From discussions with officers at the plant, we found that the plant employs approximately 155 people (70 skilled; 85 unskilled). Thus the total local employment factor for wind energy is calculated as 13.98 (155/11.09).

The state-wise estimates of the wind power potential, which estimates 8591 MWp (1890.02 MWa) for Karnataka (Indiastat, 2012). Using the total employment factor and multiplying it with the MWa total wind power potential leads to a total estimate of 26422 (13.98*1890.02) jobs for Karnataka. Economies of scale are incorporated to some extent into these estimates - the respective employment factor for skilled workers is 6.31 (70/11.09) and for unskilled 7.66 (85/11.09). Using these employment factors the total employment potential for skilled workers is approximately 12000 (6.31*1890.02) and for unskilled workers 14477 (7.66*1890.02) (Table 2). This estimate for wind is based on the Gadag power station, which is a large scale wind plant.

Karnataka is among the eight states that have high wind potential in India (MNRE, 2017). The estimate from our study of 12,000 people for the state of Karnataka, is based on Gadag power station, which is a large scale wind plant and supplies wind energy to the government grid and is consistent with the article which reported that 48,000 people (Mallapur, 2015) were employed in Wind power across India in 2014.

4.1.2. Biomass

For its Clean Development Mechanism (CDM) the UNFCCC (2013) estimates that Karnataka has a biomass surplus of 1000 MWp, of which about 90MW have been harnessed. These values are derived from estimating the amount of mainly agricultural by-products e.g. paddy, corn, sugarcane, wood waste and forest residues. Thus, Karnataka state has a large amount of unharnessed potential (at least 910 MWp) for CDMs.

The largest biomass power plant in Karnataka is the RK Power Gen Private Ltd. in Chitradurga with a licensed capacity of 20 MWp (KERC, 2013). UNFCCC (2013) estimated that this plant employs approximately 300 people (directly and indirectly). Thus, using this as a reference, the total employment potential from harnessing the available 910 MWp or biomass-surplus can easily be calculated. To convert peak-capacity into average capacity we use the capacity factor (0.85) by Kammen et al. (2006). Specifically it states that a biomass plant operates 85% of the time over a year. Thus the 20MWp biomass capacity is converted into 20 x 0.85 = 17 MWa capacity. Thus the local employment factor for biomass based on this reference case is 300/17 = 17.65 (jobs/MWa). Multiplying this with employment factor and the surplus capacity gives 17.65 x (910 x 0.85) ≈ 14000 jobs that could potentially be generated when all the estimated surplus biomass was used for electricity generation (Table 2). Our estimate based on a case study in Karnataka is consistent with the report that 58,000 people were employed in Biomass across India in 2014 (Mallapur, 2015)

4.1.3. Off-Grid Solar

A case study of SELCO Foundation is used to estimate the job potential from off-grid solar energy. SELCO Foundation has established centres to rent solar-powered lamps to people living in slums and other localities where they do not have access to electricity, as observed at two of their sites we visited in Bangalore. These lamps are left at SELCO offices set up within the locality to be charged during the day when people are out at work and the fully charged lamps are collected when they return home to provide light at night for cooking, children's studying, and any entrepreneurial work that the women and family might be engaged in. SLECO's Bangalore operations consisted of 10 such centres, where each charged 30 lights with a capacity of 12W each. Thus, 360W are generated per centre per day leading to a total installed capacity of 3600 W or 0.0036 MW. The capacity equals the capacity of the charged lamps and not the peak capacity of the PV modules. Therefore, MWp = MWa i.e. the capacity factor is 1. SELCO Foundation had 15 full time employees, which leads to a job factor for off-grid solar of 15 jobs/0.0036 MWa = 4166.67 (Jobs/MWa). The Karnataka solar policy notification indicates that the state aimed to install 200 MW of solar capacity between 2011 and 2016 with 40 MW per year. To achieve its solar mission with off-grid solar power centres, a rough forecast of total jobs that can be generated if the state could achieve its potential opportunities through off-grid solar would be 4166.67 x 200 ≈833,000 jobs (Table 2). While this appears to be a high estimate for off-grid solar, this is based on the case study of one off-grid solar energy social enterprise where their 15 employees worked full time in Bangalore and include a range of additional tasks including maintenance, monitoring, evaluation and other social service delivery and provisions. Further as off-grid solar is decentralised, it is also more labour intensive and economies of scale are not easy to estimate as in the case of a centralized power plant.

Off-grid and on-grid solar power are complementary technologies and Karnataka state has high potential for expanding both technologies. For this study, we had attempted to get data for both off-grid and on-grid solar power, but were not able to obtain reliable data for on-grid solar power. Here our calculation of green jobs potential based on a small case study of off-grid solar energy is evidently an overestimate as every employee was involved in multiple jobs and activities providing opportunities for socio-economic development of local communities. However, it provides a useful initial indicator.

An article by Mallapur (2015) reported that 200,000 people were employed in India in solar energy sector (125,000 people in solar PV + 75,000 in solar heating/cooling) across India in 2014. A recent study (CEEW – NRDC, 2017) estimates that over 300,000 workers would be employed in India, mostly in rooftop solar, in the next five years. It suggests that 21,000 people were employed in 2016-17 and estimates that an additional 25,000 are expected to be employed in 2017-18. These findings also suggest that rooftop solar work is more intensive relative to other renewables and requires about 25 job-years per megawatt comparable to 3.5 job-years per megawatt for ground-mounted solar and 1.3 job-years per megawatt for wind power.

5. Co-benefits from renewable technologies

This section describes some socio-economic and environmental co-benefits generated by the deployment of renewable technologies of wind, off-grid solar and biomass based on six different cases studied in the state of Karnataka (Table 3).

5.1. Wind Power

The Gadag wind farm was commissioned in 2006 and is the largest of its kind in the State of Karnataka. "*Wind World Ltd*" (formerly Enercon) operates around 235 wind turbines, which supply directly to the state power sub-station located approximately 20km away from the Gadag office, in Harthi. *Wind World Ltd* guarantees at least 20 year life span for each of the wind turbine. Tata Power owns 63 units of the 800 kilowatt turbines (peak-capacity) (CDM PDD, 2013; and data collection through meetings and discussions and follow up communication by email); the average output per machine, per year was 16 000 000 units.

- *Economic Co-benefits*

The site employed 70 skilled employees on a permanent basis. In addition, they contracted (needs based) another 85 semi-skilled and unskilled workers on-site as cleaners, drivers, office boys and security staff. The unskilled workers were local employees, whereas among the skilled workers, 20 people were from nearby villages and towns and the remaining 50 were from across the state of Karnataka. The industry occasionally faced challenges particularly related to land acquisition and maintenance. For example, people who sold land at the beginning were reportedly disgruntled when the value of the land had increased over the years after they had sold their land and when other landowners in the region sold later and accrued higher financial benefits. Some people who sold their land to companies earlier took out their frustration by causing damage to company property, technologies and machineries and encroaching with their cultivation into company land.

- *Environmental Co-benefits*

The renewable energy generated is the important primary environmental benefit of the wind power plant. Other co-benefits include the increased CSR activities conducted by TATA

Power with local schools, such as tree planting, which supports the District's reforestation programme. *World Wind Ltd* engages strongly in CSR activities in the area, and has developed a water irrigation pond near Harthi village, which also benefits agricultural activities in the neighbourhood and enhances groundwater sources.

- *Socio-economic Co-benefits*

Development of these companies in the area has improved service provision for water, electricity, infrastructure, schools, etc. through improved services for the industry. While this could be caused by many other industries, the point still remains that these areas are typically chosen due to their amenability to such renewable technologies. Tata Power's presence in the area has generated increased CSR activity through providing local communities with health programmes such as free anaemia detection in local schools as well as hosting health camps in surrounding villages. The overall value of land has increased in the region, thus benefitting local landowners and farmers. In addition, local infrastructure (roads in particular) has improved. Furthermore, local energy shedding has decreased since the plant was deployed as the power supply to the Gadag substation increased overall energy supply in the region.

5.2. Off-grid Solar

For off-grid solar energy, we considered the case of SELCO Solar Pvt. Ltd., a solar energy social enterprise established in 1995. Their core work focuses on creating and distributing customised off-grid solar energy products suited to end-user needs, as well as developing accessible financing packages. As part of its mission, this foundation conducts research and outreach projects in sustainable energy services to develop field-proven technological and financial models. SELCO Foundation's Integrated Energy Centre (IEC) project is one such effort.

The project improves access to clean, affordable energy and communal space through solar-powered independent service centres among some disadvantaged communities. The provision of energy services begins with a focus on home lighting (through batteries), and mobile charging that were identified as the communities' basic needs. One full day of charging provided up to 8 hours of lighting on low-intensity setting of the light bulbs. When running on high-intensity, the lights lasted approximately 5 hours. The innovation behind IECs is that by centralising the source of energy - solar panels installed on the roofs of IECs, instead of on each household - reduced cost and risk. Operation and maintenance is taken care of by SELCO Foundation and they also flexible to provide advice and help meet the community's other needs, such as lobbying for provision of water, electricity and welfare of women and children.

In 2012, SELCO Foundation operated on 15 full-time employees to cater to 10 IECs (and other Foundation projects), an increase of 10 people since 2011. This estimate did not take into account the range of part-time employees and interns who also worked with the Foundation. By 2016, the Foundation had intensified its activities of their existing 10 energy centres whilst simultaneously creating 12 new IECs in Bangalore. This required the creation of 9 additional full-time jobs; for each four new IECs opened, 1 field operator, 1 manager, and 1 headquarter employee were needed, along with at least one more part-time technician per three centres.

- *Economic Co-benefits*

The home lighting systems were initially aimed at facilitating both consumptive and productive uses of solar energy at the household level. However, as the model supported various new activities in the second phase, the potential for indirect job creation increased within the IEC. Beyond creating direct job opportunities both within the community and within Selco Foundation, the provision of effective light through IECs enabled household members to engage in productive activities during the evening, as at Thannissandra centre where community members engaged in enterprises such as making *tablas* (Indian drums) and could increase their production if they had access to secure markets. In addition, the cost of home solar lighting systems enabled savings, on household expenditure for lighting (relative to expenditure before the solar lighting household systems as reported). Selco Foundation estimates these savings to be in a range of INR50 (US$0.75) to INR100 (US$ 1.5) monthly, which comprises a significant proportion of their income.

- *Environmental Co-benefits*

IECs generate two key environmental co-benefits. Firstly they enable moving away from greenhouse gas-intensive lighting technologies (such as kerosene lamps), which have important relevance for local and global climate mitigation efforts. In addition, it appears that IECs raise awareness – at the local community level regarding climate change and the potential role individuals can play toward climate mitigation. While these efforts are not easily measurable, they are most likely to impact mitigation in the longer-term (including when children grow up and make consumption decisions).

- *Social Co-benefits*

SELCO's IECs are particularly effective in inclusion of marginal social groups into the transition to a green economy. By specifically targeting communities facing a variety of broader challenges affecting their energy choices, including the nature of their settlements, their low and irregular income flow, their lack of social and legal recognition of their existence, their geographical remoteness and broader information- and communication-system inadequacies, IECs have the potential to draw attention to these issues and enable access to energy services, and social services more broadly. To a certain extent, IECs can also help tackle gender inequalities, in particular in communities where women are responsible for collecting firewood for home-lighting and cooking. In addition, certain IEC projects have engaged in providing skills and training opportunities for women. A third social co-benefit generated by Selco Foundation's energy centres was to indirectly increase households' sense of security at night-time by providing a source of light (up to 8 hours each night). Finally, solar home lighting systems, through replacing kerosene lamps or candles, had potential health benefits by reducing the amount of smoke generated within small enclosure households.

5.3. Biomass

The RK Power Gen Private Ltd. Biomass powerplant is situated in Hiriyur, Chitradurga District in Karnataka. It was commissioned by Karnataka Renewable Energy Development Ltd. (KREDL) on 17th January 2004. This renewable energy biomass project is currently credited under UNFCCC's CDM, generating Certified Emission Reductions (CERs), which provide the necessary additional income to meet the plant's operational costs, and has an expected operational lifetime of 25 years. . Biomass refers to material that is derived from living, or recently living biological organisms, usually plant material but also by-products and waste from livestock farming, food processing and domestic waste and is considered a zero-emission fuel since the CO_2 emitted during the combustion of biomass is further absorbed on equivalent basis by the plants life-cycle. With this wide range of material, the range of methods to process it is equally broad. The energy generated by this plant is incorporated into the Indian Southern regional grid (that includes the states of Tamil Nadu, Andhra Pradesh, Karnataka, Kerala and Pondicherry). This was part of KREDL's (2013) ambition to include more sources of renewable energies (RE) into the grid and for in-house consumption. This combustion biomass power plant operates on two main types of agro-waste: husk from contracted coffee processing units and sawmills within a 100km range.

- *Environmental Co-benefits*

Relative to the plant's environmental impact, the CDM report suggests that approximately 4763t CO_2 emissions were avoided in 2006, accounting for CO_2 emissions due to diesel used internally (767tCO_2) and emissions from fuel transportation (1248tCO_2).

- *Socio-economic Co-benefits*

In terms of the socio-economic co-benefits of the RK Power Gen Private Ltd. Biomass power plant, TERI (2013) suggests that the effective utilisation of biomass residues for grid connected power generation has the potential to generate additional income opportunities for rural communities around the plant. These include indirect job-creation collection and transportation of biomass resources to the plant (UNFCCC, 2013). This was particularly labour-intensive in Chitradurga because it revolves around dispersed agents collecting and transporting biomass to the plant, within a radius of 100km.

Further, the RK Power Gen Private Ltd. Biomass plant contributes to improving the overall power supply in the region, by supplying energy to the Southern Regional grid. On a larger scale, similar contributions to the regional grid has the potential to improve overall level of power supply which, in turn, has the potential to generate (or render more efficient) indirect jobs benefitting from a stable energy supply.

6. Conclusion and Policy Implications

The study and understanding of the potential for green jobs creation through the transition to a low-carbon economy, in the past, has mostly been directed and determined mainly in the context of OECD countries. Our analysis in the context of Karnataka, India discusses the benefits of investing in renewable technologies in an emerging economy context for low-carbon growth, inclusion and sustainable development. We suggest that consideration of environmental, social and economic dimensions and interactions of green growth, particularly in developing countries, requires in-depth understanding of the co-benefits generated by this transition, of which green jobs creation is an important aspect. Our analyses focus on six green technologies being deployed in Karnataka through in-depth case studies.

The development and deployment of green technologies as a strategy for green growth offered great potential for growth of jobs in Karnataka.. Off-grid solar energy and wind power appeared to have the greatest jobs potential. Finally, although there remains a lack of academic consensus on the measurement of green jobs, our methodology provides a starting point for measuring jobs potential. We additionally argue for context-specific understandings and calculations in future research on socio-economic benefits of green growth.

While we have used as robust a methodology as possible under the prevailing constraints of resources, methods, and data availability, our estimates are based on specific local case studies for each type of green technologies and could be applied to other contexts but have to be considered with caution and structured according to their circumstances. Our analyses across different organisations and technologies makes our green jobs potential estimates sensitive to selection bias and the context within which the data was collected. For example, in the case of off-grid solar, jobs potential and co-benefits for SELCO Foundation was inherently integrated because of the organisation's mission to go beyond assessing quantifiable deliverables and explicitly incorporated co-benefits into their social entrepreneurship model. It was also not possible to distinguish employee's roles in green jobs and other work in the case of Infosys. We also acknowledge the limitations involved in scaling up data from a single case study into estimates for the state of Karnataka as a whole, and have highlighted this throughout our paper.

Based on Karnataka specific employment factors, we find a potential of 26000 jobs in wind energy, of which 12000 are skilled and 14000 unskilled jobs. For biomass we estimate a total potential of 14000 jobs. For solar energy, we were able to obtain reliable estimates for small-scale off-grid energy generation and find a job potential of 833,000 jobs if the entire solar energy potential were harvested through small-scale off-grid technology. The local employment estimates are in all cases significantly larger in Karnataka relative to Kammen and colleagues' (2006) US estimates. While it has been expected that our estimates are larger in general, some of the local factors might have led to overestimation of the total jobs potential, which can stem from the fact that we used single case studies to calculate the employment factors and extrapolated it to state-level. Thus, our estimates, particularly off-grid solar, are likely to have overestimated the employment potential. Furthermore, learning curves and potential reduction in jobs when operation and maintenance might require less jobs when companies were established and matured, have not been incorporated in the analysis due to lack of data. It can be expected that the employment factors decline annually, as the power generation process becomes more efficient over time. A key challenge will be to identify how the potential of the transition to green jobs can best be tapped for economic growth alongside sustainable and inclusive development in the state and country overall. Workers have to shift from declining to emerging sectors. Flexible labour markets and stable regulatory frameworks, as well as active labour market policies (such as increased investment in re-training and education) are important to smoothen the transition and facilitate investment. To mitigate distributional consequences it is important to consider support for regions reliant on fossil fuels, which might experience a decline in employment. Since fossil-fuel industries tend to be geographically clustered this can be an important tool to obtain regional political support.

As co-benefits are by nature, context-dependent and inter-related, besides the fact that collecting this information through primary consultations is very resource intensive, they have not been easy to estimate and required careful consideration. . The systematic organisation of co-benefits as environmental, social, and economic was an attempt to structure our research along ILOs guidelines of sustainable development but it is important to remember that these dimensions overlap and reinforce each other in practice.

The uptake of renewable technologies depends on a variety of socio-economic factors, which is a challenge for emerging economies such as India. Socio-economic factors affect the ability to deploy technologies but the way they are perceived and subsequently utilised by different communities also impacts their uptake and the nature of ensuing co-benefits. There exists the need for careful and contextualised consideration to develop and provide differentiated access to renewable technologies to make them affordable to all socio-economic strata of households and communities. Another challenge relates to the potential infrastructural co-benefits from the development and deployment of green technologies on a large scale. Comparing such investments borne out and benefits of green technology projects to equivalent efforts from 'conventional' technology deployment – for example the evaluation of high costs of the construction and deployment of a coal power plant to people versus any benefits – is necessary to understand the ways in which a low-carbon transition has the potential for greater sustainable and more inclusive development (Ahluwalia, Gupta and Stern, 2016).

A salient issue pertains to the deployment, operation and scaling up of large-scale technologies by industries, which was of particular relevance in the context of wind power plants in Karnataka. Concerns around the impact of large-scale wind-farms on land availability, procedures for acquisition and land prices have been voiced during qualitative discussions. There appear to be trade-off between rising land prices that benefit local landowners based on the development of the industry, which increases the costs of expansion for the industry itself. Further it increases the negative affect on landless inhabitants, particularly in rural Karnataka where agricultural systems are already greatly affected by environmental stresses. Related to the issue of scaling up technologies is the necessity to improve opportunities for large-scale renewable energy technologies to be incorporated into the national electricity grid which could benefit development policies more generally by supplying more energy to an already stressed national system. In certain circumstances, it might be possible to access funding from UNFCCC and other international development organisations including the New Development Bank, under sources for development of CDM. Development and deployment of large-scale renewable technologies would benefit from greater public-private collaborations, both nationally and internationally. For example, the transmission capacity of integration of power generated into national grid considerations would be beneficial for 'deepened' development. Furthermore, a crucial step to expand capital-intensive renewable technologies is to reduce the cost of financing. Reducing uncertainty about financial and regulatory conditions, as well as political and exchange rate risks, is an important driver in making capital-intensive renewable technologies more competitive (Creutzig et al., 2017).

India has been making rapid progress in developing renewable technologies. The Nationally Determined Contributions (NDCs) have aimed for fivefold increase in renewable capacity from 35 GW (in March 2015) to 175 GW by 2022 (MNRE, 2017). The budget in 2015-16 had factored instillation of 60 GW wind power capacity, and 100 GW of solar power capacity and the balance from other alternative sources by 2022. Studies suggest 400,000 jobs had been created in the renewable energy sector until 2014 with a potential for creating a million jobs by 2022 in India (Mallapur, 2015). Ambitious goals for expanding renewable technologies are crucial for India towards lowering its GHG emissions, and addressing its vulnerabilities to climate change and achieving sustainable development. Simultaneously, they also provide an opportunity for economic growth. However, they will require strong commitment and efficient implementation with regular monitoring and evaluation against targets nationally. It will also require greater co-operation among Indian public and private sectors for developing strategies and for implementation, operations and maintenance. Stronger multi-sectoral collaborations are also essential for sharing technologies and financing internationally.

References

Ahluwalia, M., Himanshu Gupta and Nicholas Stern, 2016. *A more sustainable energy strategy for India*. Grantham Research Institute Policy report available at http://www.lse.ac.uk/GranthamInstitute/publication/a-more-sustainable-energy-strategy-for-india/. (accessed 30/07/16).

Asian Development Bank, 2013. *Low-Carbon Green Growth in Asia – Policies and Practices*. Hong Kong: ADB. Available at: http://www.adbi.org/files/2013.06.28.book.low.carbon.green.growth.asia.pdf (accessed on 14/12/2013).

Blanco, M. I. and Gloria Rodrigues, 2009. Direct employment in the wind energy sector: An EU study. *Energy Policy* 37, pp. 2847-2857.

Borel-Saladin, J.M., and Ivan N. Turok, 2013. The impact of the green economy on jobs in South Africa. *South African Journal of Science*, 109 (9-10).

Bowen, A., 2012. Green' growth, 'green' jobs and labour markets, *in Centre for Climate Change Economics and Policy Working Paper No. 88*. Grantham Research Institute on Climate Change and the Environment: London.

Brookings Institution, 2011. *Sizing the Clean Economy: A National and Regional Green Jobs Assessment*, Metropolitan Policy Program.

Bureau of Labour Statistics (BLS), 2013. The BLS Green Jobs Definition, available on: https://www.bls.gov/green/green_definition.htm

Clean Development Mechanism – Project Design Document Form (CDM PDD), 2012. *Wind Power Project at Gadag district, Karnataka*, Version: 08, Date: 29.10.2012.

Connolly, K. Grant J. Allan, and Stuart G. McIntyre, 2016: The evolution of green jobs in Scotland: A hybrid approach, *Energy Policy*, 88, pp. 355-360.

Creutzig, F., Peter Agoston, Jan C. Goldschmidt, Gunnar Lederer, Gregory Nemet, Robert C. Pietzcker, 2017: The underestimated potential of solar energy to mitigate climate change, *Nature Energy*, Vol. 2, 17140, pp. 1-9.

Creutzig, F., Jan C. Goldschmidt, Paul Lehmann, Eva Schmid, Felix von Blücher, Christian Breyer, Blanca Fernandez, Michael Jakob, Brigitte Knopf, Steffen Lohrey, 2014: Catching two European birds with one renewable stone: Mitigating climate change and Eurozone crisis by an energy transition, *Renewable and Sustainable Energy Reviews*, 38, pp. 1015-1028.

Gibbons, S., 2015. Gone with the wind: Valuing the visual impacts of wind turbines through house prices, *Journal of Environmental Economcis and Management*, Vol. 72, pp. 177-196.

Global Green Growth Institute (GGGI), 2014. *Funding Landscape for financing green growth – Identifying funds for development of green economy and climate resilience*. Karnataka: Global Green Growth Institute.

Global Green Growth Institute (GGGI), 2011. *Green Growth in Motion: Sharing Korea's Experience*. Seoul: Global Green Growth Institute.

GHK, 2010. *Estimating Green Jobs in Bangladesh – A GHK Report for the ILO*. London: GHK.

Government of Karnataka, 2014. Karnataka Renewable Energy Policy 2014-2020. Available at: http://kredlinfo.in/Policy/RE%20Policy%202014-20.pdf (accessed on 07/08/2017).

Harrison, K., 2013. The Political Economy of British Columbia's Carbon Tax, *OECD Environment Working Papers*, 63, OECD Publishing, Paris.

Infosys, 2013. *Sustainability Report 2012-13: Relevance through innovation*, available on: http://www.infosys.com/sustainability/Pages/sustainability-report.aspx.

IRENA, 2016. *Renewable Energy and Jobs: Annual Review 2016*, available on: http://www.se4all.org/sites/default/files/IRENA_RE_Jobs_Annual_Review_2016.pdf.

Jarvis, A, Varma, A. and Ram, J., 2011. *Assessing green jobs potential in developing countries: A practitioner's guide*. Geneva: International Labour Office. Available at: http://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/@publ/documents/publication/wcms_153458.pdf (Accessed on 14/12/2013).

Kammen, D.M, Kapadia, K, and Fripp, M, 2006. *Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? RAEL Report*, University of California, Berkeley.

Karnataka Renewable Energy Development Limited, KREDL, 2013. *Bioreport on Biomass in Karnataka*. Available at http://www.kredlinfo.in/bioreport.aspx (Accessed on 14/12/2013).

Kattumuri, R, 2015. *Sustainable development: the goals and challenges ahead*. Available at http://www.theigc.org/blog/sustainable-development-the-goals-and-the-challenges-ahead/.
Lewis, J. I. and Ryan H Wiser, (2007). Fostering a renewable energy technology industry: An international comparison of wind industry policy support mechanisms. *Energy Policy*, 35 (3), pp.1844-1857.

Kim, H-W., Jae-Kak, Han, Jin-Hee, Park., 2012: *Green Growth and Green Jobs in Korea: Potentials and Perspectives*, available at: https://ems-online.org/uploads/media/Quelle1_GreenGrowth_GreenJobs.pdf

Murray, B., and N. Rivers, 2015. British Columbia's revenue-neutral carbon tax: A review of the latest "grand experiment" in environmental policy, *Energy Policy*, 86, pp. 197-216.

Llera Sastresa, E., Alfonso Arandra Uson, Ignacio Zabalza Bribian, and Sabina Scarpellini, 2010 ; Local impact of renewables on employment : Assessment methodology and case studies, *Renewable and Sustainable Energy Reviews*, 14(2), pp. 679-690.

Mallapur, C, 2015. *India eyes a million jobs from renewable energy by 2020.* Available at http://www.business-standard.com/article/specials/india-eyes-a-million-jobs-from-renewable-energy-by-2022-115052200188_1.html (accessed on 7/08/2017).

Ministry of New and Renewable Energy (MNRE), 2017. http://www.mnre.gov.in/ (accessed june 2017).

NRDC and CEEW, 2017. *Greening India's Workforce – Gearing up for expansion of Solar and Wind Power in India.* Available at: https://www.nrdc.org/sites/default/files/greening-india-workforce.pdf (accessed on 7/08/2017).

Organisation for Economic Co-operation and Development, 2012. *The jobs potential of a shift towards a low-carbon economy – Final Report of the European Commission, DG Employment*. Available at: http://www.oecd.org/els/emp/50503551.pdf (accessed on 14/12/2013).

Organisation for Economic Co-operation and Development, 2017. *Impacts of green growth policies on labour markets and wage income distribution: a general equilibrium application to climate and energy policies*, OECD Publishing, Paris.

Organisation for Economic Co-operation and Development, 2017. Employment Implications of Green Growth: Linking jobs, growth, and green policies, OECD Report for the G7 Environment Ministers, June 2017, Paris, available at: http://www.oecd.org/environment/Employment-Implications-of-Green-Growth-OECD-Report-G7-Environment-Ministers.pdf

Pew Charitable Trust, 2009. *The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America*, Washington, DC.

Pollin, R., 2009. *Response to "Seven Myths about Green Jobs" and "Green Jobs Myths"*, PERI Working Paper 198, University of Massachusetts, Amherst, USA.

Rutovitz, J., 2010. *South Africa energy sector jobs to 2030*. Prepared for Greenpeace Africa by the Institute for Sustainable Futures, University of Technology, Sydney, Australia.

Shrimali, G., Sandhya Srinivasan, Shobhit Goel, Saurabh Trivedi and David Nelson, 2015. Reaching India's renewable energy targets cost-effectively. *Climate Policy Initiative* article available at http://climatepolicyinitiative.org/publication/reaching-indias-renewable-energy-targets-cost-effectively/. (accessed 09/09/16).

Tata Power, 2011. *Sustainability Report 2010-11 – Powering a Greener Tomorrow*, from: www.**tatapower**.com/sustainability/pdf/sustainability_report-10-11.pdf (Accessed on 27/01/2013)

TERI, 2013. *Study on the sustainability of Biomass based power generation in Karnataka for Karnataka Electricity Regulatory Commission (KERC)*. Bangalore: TERI.

UNEP/ILO/IOE/ITUC, 2008. *Green Jobs: Towards Decent Work in Sustainable, Low-Carbon World*. Nairobi: UNEP.

United Nations Environment Programme, 2011. *Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication – a Synthesis for Policy Makers.* Nairobi:

UNEP. Available at:
http://www.unep.org/greeneconomy/portals/88/documents/ger/GER_synthesis_en.pdf (Accessed on 14/12/2013).

UNFCCC, 2016. *The Paris Agreement*. Available at http://unfccc.int/paris_agreement/items/9485.php. (accessed 13/12/2016).

UNFCCC, 2013. *Clean Development Mechanism Project Design Document Form (CDM-PDD) version 02: R K Powergen 20MW Grid Connected Renewable Energy Biomass Power Project*. Available at: http://cdm.unfccc.int/filestorage/m/e/3ML9T8QHP6AJR105ECYV2XSKDFUW4B.pdf/PDD_08_03_2013_Clean.pdf?t=Y258bXhzb21sfDDTN3YqArSw6OezPVorV-l5 (Accessed on 14/12/2013).

Yamazaki, A., 2017. Jobs and climate policy: Evidence from British Columbia's revenue-neutral carbon tax, *Journal of Environmental Economics and Management*, 83, pp. 197-216.

Yi, H. and Yuan Liu, 2015. Green economy in China: Regional variations and policy drivers, *Global Environmental Change*, 31, pp.11-19.

Yi, H., 2015. Green businesses in a clean energy economy: Analysing drivers of green business growth in US states, *Energy*, 68, pp. 922-929.

Tables and Figures

Box 1: Defining green jobs

UNEP/ILO/IOE/ITUC (2008:35): "positions in agriculture, manufacturing, construction, installation, and maintenance, as well as scientific and technical, administrative, and service-related activities that contribute substantially to preserving or restoring environmental quality (…) but also need to be good jobs"

Jarvis et al. (2011:5): "jobs which are sustained by economic activities that are more environmentally sustainable than the conventional alternative *and which also* offer working conditions that meet accepted standards of decent work."

OECD (2012): Each OECD country uses its own definition.

Brookings Institution (2011): Green jobs are counted within sectors of the economy that produce "goods and services with an environmental benefit" (2011: 3).

Pew Charitable Trust (2009): Jobs within a Clean Energy Economy are considered green, which includes jobs in "clean energy production, increasing energy efficiency, reducing greenhouse gas emissions, waste and pollution, and conserving water and other natural resources" (2009:5).

Bureau of Labour Statistics (2013): Green jobs are either:

- "Jobs in business that produce goods or provide services that benefit the environment or conserve natural resources" or
- "Jobs in which workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources."

Table 1: Comparison of jobs/MWp, jobs/MWa and person-yrs/GWh across various technologies for the US

work-hrs per year	2000	Capacity Factor	Equip-ment lifetime (years)	Employment Components			Average Employment Over Life of Facility					
							Total jobs/MWp		Total jobs/MWa		Total person-yrs/GWh	
Energy Technology	Source of Numbers			Construction, Manufac-turing and Installation (person-yr/MWp)	Operation and Maintenance (jobs/MWp)	Fuel extraction and processing (person-yrs/GWh)	Construction, Manufac-turing, Installation	O&M and fuel processing	Construction, Manufac-turing, Installation	O&M and fuel processing	Construction, Manufac-turing, Installation	O&M and fuel processing
PV 1	REPP, 2001	21%	25	32.33	0.25	0	1.29	0.25	6.21	1.20	0.71	0.14
PV 2	Greenpeace, 2001	21%	25	30.00	1.00	0	1.20	1.00	5.76	4.80	0.66	0.55
Wind 1	REPP, 2001	35%	25	3.80	0.10	0	0.15	0.10	0.43	0.27	0.05	0.03
Wind 2	EWEA/Green-peace, 2003	35%	25	22.00	0.10	0	0.88	0.10	2.51	0.27	0.29	0.03
Biomass – high estimate	REPP, 2001	85%	25	8.50	0.44	0.22	0.34	2.08	0.40	2.44	0.05	0.28
Biomass – low estimate	REPP, 2001	85%	25	8.50	0.04	0.04	0.34	0.32	0.40	0.38	0.05	0.04
Coal	REPP, 2001	80%	40	8.50	0.18	0.06	0.21	0.59	0.27	0.74	0.03	0.08
Gas	Kammen, from REPP, 2001; CALPIRG, 2003; BLS, 2004	85%	40	8.50	0.10	0.07	0.21	0.60	0.25	0.70	0.03	0.08

Table 2: Comparison of jobs/MWp, jobs/MWa and person-yrs/GWh across technologies.

Source: Kammen et al., 2006:10

Table 2: Total Jobs potential for Karnataka

Type of Energy	Capa-city Factor (Karna-taka)	Employ-ment factor, US (Jobs/ MWa)	Employ-ment Factor, Karna-taka (Jobs/ MWa)	Energy Potential/Target	Total Jobs Potential using upper US employment factors	**Total Job Potential with employment factors obtained for Karnataka**
Off-grid solar	1	-	4166.67	200 MW by 2016	NA	**833,000 (by 2016)**
Wind	0.22	0.79 – 2.79	13.98 (skilled: 6.31) (unskilled : 7.66)	8591 MWp = 1890.02 MWa (8591*0.22)	8389	**26000 (approx. 12000 skilled and 14000unskilled)**
Biomass	0.85	0.78 – 2.84	17.65	910 MWp = 773.5 MWa	2197	**14,000**

Table 3

Summary of jobs potential and co-benefits of Renewable Technologies

Green Technology	Environmental	Social	Economic
Off-grid Solar (SELCO Foundation centres in Bangalore)	Raise awareness within the community Shift away from environmentally harmful sources of lighting (reduced GHG emissions) Renewable energy	Social inclusion through Integrated Energy Centres (IECs) (inclusion of marginal social groups) providing access to electricity to marginalised groups Gender inequalities targeted Safety (at night especially) Health & Hygiene: less smoke in household Reduced exposure to air pollution from kerosene lamps	Operator and entrepreneur model creates long-term job opportunities within community Potential for other productive activities (indirect job creation, especially for night-time activities) Savings for the household from reduced cost of lighting
Wind Power (Tata Power plant in Gadag)	Renewable energy Reduced GHG emissions	Improved infrastructure in the area (roads) Increased CSR activities being undertaken in the area: tree planting initiative with local schools, health camps (anaemia detection in schools)	Improved power supply in the region, through provision of supply required for industry Rising value of land due to increased activities Infrastructure development (roads) Local employment (particularly for unskilled workers) More efficient use of unproductive agricultural land Increased tax paid to Gram Panchayat generates revenues for the local government which can enable further community

			development
Biomass (RK Power Gen Private Ltd. in Sirsi district)	Reduced CO_2 emissions	Reduction of waste and improved recycling More efficient fuel	Additional income opportunities in rural areas in proximity of plant (collection and transportation of biomass) Improved power supply in the region
Biogas (RK Power Gen Private Ltd. in Sirsi district)	Forest conservation and related biodiversity conservation Promotes ecosystem health More efficient energy than firewood and similar	Targets gender inequalities (women typically in charge of collecting firewood) Stimulates rural employment Health & Hygiene benefits from reduced ash production (particularly women's health), less smoke, more light & airy (reduces blackening of walls)	Time saving (less time collecting firewood + cutting firewood + cleanliness of kitchen/bathroom (hot water supply)) Cost savings (smoke free kitchens require less frequent repainting; respiratory and related health risks avoided)
Cookstoves (RK Power Gen Private Ltd. in Sirsi district)	Reduced deforestation Reduce black carbon emissions, particle emissions, toxic combustion residuals and GHGs (climate mitigation potential) More efficient energy	Time saving (less time spent collecting biomass) Reduced indoor pollution improves health Improved facilities at temple festivals and other community activities,	Monetary savings from cheaper fuel source Trained entrepreneurs
Information Technology (Infosys, Bangalore)	Reduced CO_2 emissions Aiming for carbon neutral settings	Raising awareness within workforce Sets a precedent in the industry	Monetary savings and cost cutting Innovation and entrepreneurship