Employment in renewables: Literature review and case study

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Contents

Summary

In this report we present an up-to-date literature review on employment opportunities associated with the deployment of renewable energy technology. We identified approximately 60 studies and data sources published over the past decade that report analysed or observed employment impacts of renewable energy growth. These publications cover many different countries and several technology options, and present widely varying results derived from distinct methodological approaches. Our first overall conclusion is that there is clear lack of authenticity of findings in this literature, since recursive referencing abounds and relatively few studies yield truly original research. When we omit non-authentic analyses, as well as those that aggregate results in a way that does not allow us to calculate 'employment factors' (defined as the number of jobs or amount of work generated per unit of electricity production capacity), the total list of references is cut down to 27 independent items. Of these, only 10 references provide separate estimates for the employment factors of the stages of manufacturing and installation, respectively, as opposed to employment factors for these two activities combined. A total of 19 items provide values for operation and maintenance (O&M) employment factors. We observe significant uncertainties in quoted figures for job creation, both across and within publications. A case study is performed for a renewable energy stimulus plan for the state of Kuwait, in which wind and solar power are assumed to account for approximately 10% of total electricity supply (that is, 16 TWh of an overall level of 146 TWh generated from 36 GW of installed capacity) by 2030. For this scenario we estimate a total work force in Kuwait of ultimately about 16,500 direct and 12,300 indirect jobs, based on assumptions regarding which components of the respective wind and solar energy technologies can be manufactured domestically. All jobs generated by installation and O&M activities are assumed to be domestic.

1 Introduction

Renewable energy technologies are deployed with rapidly increasing shares in many countries, most notably for reasons of mitigating climate change, reducing air pollution and enhancing energy supply independence. It is argued that the deployment of renewables may also be beneficial in terms of the stimulation of employment in a broad range of sectors directly or indirectly related to their use [1, 2]. The purpose of this report is essentially twofold: (1) we review the energy technology literature published to date for inspecting the job creation potential of the expansion of renewables, (2) we perform a case study for the state of Kuwait for assessing what the employment implications are of this Gulf country achieving a renewable electricity share of about 10% in 2030, in accordance with a renewable energy diffusion scenario developed by KISR (Kuwait Institute for Scientific Research) [3, 4].

KISR's renewable energy stimulus plan is driven by at least three main considerations. First, Kuwait's per capita greenhouse gas (GHG) emissions level is high, as a result of a fossil fuel intensive national energy system, and with climate change mitigation efforts and intentions across the world mounting there is growing need to also curb emissions in Kuwait [5]. Second, fuel consumption for electricity and fresh water supply has recently reached 13% of domestic oil production - a share which is expected to increase to 20% by 2020 under business-as-usual assumptions - and especially with current high oil prices it is attractive to retain oil predominantly for foreign export [3]. Third, over the coming years Kuwait is likely in need of increasing the number of jobs in the private sector, in order to meet an imminently growing demand from new job entrants, and the establishment of a domestic renewable energy industry may constitute a window of opportunity to bridge the foreseen employment gap [6].

From a policy perspective, Kuwait constitutes an interesting country to investigate, since its primary energy supply currently involves virtually no renewable energy resources: it is particularly relevant to optimally design instruments enabling their deployment along with rigorously analysing the ramifications ensuing from their diffusion, including in terms of employment opportunities. From an analytical point of view this case study is also pertinent because of the paucity of renewable energy use in Kuwait today, since the job numbers drawn from our employment assessment will be verifiable during the forthcoming years as Kuwait's renewable energy scenario unfolds.

In Chapter 2 of this report we present an exhaustive review of the current literature on employment factors associated with the deployment of renewables, notably for wind and solar energy technologies. Chapter 3 describes the methodology we apply for performing our case study. We present our main findings in Chapter 4 and summarise our conclusions in Chapter 5.

2

Literature review

A substantial body of literature is dedicated to the effects of the use of renewable energy on employment. As starting point for our study we reviewed this literature, which today covers at least 60 publications. The literature we identified can be categorized in three major ways.

First, with regards to the approach of analysis employed, three more or less exclusive types of publications can be distinguished: i) studies that calculate ex ante linkages between renewable energy technologies and employment opportunities through an explicit methodology (which can involve more or less intricate models, industry surveys, simple exogenous estimates, or adaptations of values from other studies), ii) studies that conduct a literature review and directly adopt employment values reported elsewhere without further analysis, interpretation and/or modification (like we do in the first part of the present report), and iii) publications that present *ex post* historical employment data, on the basis of which linkages between renewable energy technology capacities and national employment levels can be inferred. All three publication types are relevant to us and represent potential data sources, but ultimately classes i) and iii) are of most interest for this study since they yield the authentic data required for our analysis. When non-authentic (class ii) data sources are omitted from our original set of references, 34 authentic publications remain. This is another way of saying that many studies rely on the same sources of original research results [1].

Second, with regards to the applicability of the reported results, some studies provide findings that cannot be readily adapted to other contexts or compared across studies. For example, a number of studies for Germany [7, 8, 9] and the EU [22, 18] calculate overall employment impacts of renewables deployment in Germany and the EU respectively, but provide results aggregated at a level that renders them hard to compare with those from more detailed studies. Although interesting from a methodological standpoint, these types of studies have limited value for our present analysis, in which we attempt to collate findings on employment and renewables into a single common format. Omitting those items from our literature database that do not allow employment factors to be readily calculated leaves us with 27 from the 34 authentic data sources.

Third, with regards to the source of data or nature of selected publications, they can be distinguished on the basis of whether or not they were peer-reviewed. We confirm the observations of Perry [10], who conducted a detailed analysis of literature related to renewables deployment and employment opportunities in Canada and found that the majority (~75%) of published documents were non-peer-reviewed, in the sense that they did not appear in academic journals. In our sub-set of peer-reviewed sources, 10 articles present novel data for employment opportunities associated with the use of renewables [8, 9, 11, 12, 13, 19, 20, 29, 32, 44] and 2 provide some form of literature review and/or synthesis analysis [40, 37].

2.1 Approaches to estimating jobs

Studies that focus on calculating employment impacts through models as meant under class i) can be broadly grouped into two main types: a) those that use input-output (IO) or computable general equilibrium (CGE) models of the economy; and b) those that use simpler largely spreadsheet-based analytical models [14, 15].

The economic interdependencies of different sectors and sub-sectors between one another are used as starting point for IO models. These models can be used to estimate the results of a change in any particular industry – for example, related to renewable energy – in terms of its impacts on other industries. IO models thereby usually provide estimates of employment effects across many or all sectors of an economy, and are often capable of calculating total employment impacts of a given impulse into the economy, e.g. through the use of employment multipliers [1]. The ability of IO models to generate macroeconomic outcomes as well as to investigate shifts between sectors means that they can be used to quantify net job impacts by simultaneously accounting for gains in one sector (e.g. associated with the deployment of renewables) and losses in another (such as related to the phasing out of conventional fossil-based electricity generation). These models imply a large burden on its user in terms of data collection, as they require detailed knowledge of how industries link to one another. Their outcomes may sometimes be rather opaque, as not rarely neither the underlying primary data nor the final input-output matrices are provided. In addition, reports published on the basis of IO modelling efforts generally present findings in highly aggregated format, so that the specific impacts of a certain technology or policy cannot always be easily extracted from a given study [14]. For this report we reviewed 13 studies that utilised either a static or dynamic IO model – which, respectively, ignore or account for the impacts of employment changes on income and revenues – or a CGE model to determine the potential employment impacts of the diffusion of renewables [7, 8, 9, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26].

In contrast to IO techniques, a high level of transparency and simplicity are key advantages of simpler analytical approaches to estimating job impacts. Unlike IO models though, such simpler models generally ignore multiplier effects and are thus more likely to under-report overall employment impacts [14]. In these more concise models the factors linking renewable energy technology diffusion to employment are often based on interviews or questionnaires with industry. Such interviews yield job intensities or employment factors, defined as the number of jobs derived from a certain renewable technology investment or capacity. An advantage of this approach is its factual basis, but it tends to limit the analysis to those jobs most directly associated with the technology under consideration. Only a small number of the studies we reviewed based on a simple analytical approach collect their own data on job intensities by using some kind of survey [27, 28, 29]. A much larger number of publications rely on job intensity numbers found in the broader literature – or on occasion in unpublished sources – to develop estimates of employment impacts [30, 31, 32, 33, 34, 35, 36, 37, 38, 39].

In addition to these two categories – IO models and simple analytical approaches – seminal studies by Kammen *et al*. [14] and Wei *et al*. [40] attempt to synthesise existing literature in order to determine average employment factors. Our study also broadly adopts the approach of determining job impacts from a synthesis of available literature, but differs in three aspects with these previous two publications. First, we consider a more up-to-date and wider range of published sources. Second, we compare job figures reported by different studies not on the basis of generated electricity, but rather per unit of installed capacity (in megawatts). Third, in the present study we consider not only median employment factors but also minimum and maximum values in order to illustrate the range of employment outcomes that the current literature reports. A number of other studies similarly collate different sources, but do not calculate average or median employment factors, nor select or analyse figures for a particular technology [1, 41, 42].

2.2 Definitions of jobs

The 'proximity' of a created job vis-à-vis a given technology – in terms of how directly it can be attributed to a certain investment or, in our case, increase in renewable electricity generation capacity – hints at another major distinction between studies on employment impacts: that is, in terms of the type of jobs they consider. In this regard a common language of 'direct', 'indirect' and 'induced' jobs is found in nearly all of the literature pertaining to renewables and employment. The International Renewable Energy Agency (IRENA) provides not only a clear and operational definition of these terms, but also elaborates appropriately on the slight but important variations in their interpretation across studies [1]:

Direct jobs. Precise definitions vary, but in general these are jobs related to core activities, such as manufacturing/fabrication/construction, site development, installation, and operation and maintenance (O&M). Direct jobs are relatively easy to measure and their absolute number unequivocally correlate to the rate of growth of renewable technologies. All studies we contemplated consider direct renewable energy job impacts.

Indirect jobs. These are jobs related to the supply and support of the renewable energy industry at a secondary level. This can best be thought of as jobs relating to activities such as the extraction and processing of raw materials (e.g. to produce copper and steel), marketing and selling (including at trade-fairs), administration at ministries, or the work performed by regulatory bodies, consultancy firms and research organisations. While some types of indirect jobs scale roughly in accordance with installed or domestically manufactured capacity (like jobs in material supply), others such as in support organisations have less obvious linkages. Only a small fraction of available studies explicitly calculate indirect jobs. Some others note that indirect effects can be expected, or explicitly estimate these effects via a simple multiplier.

Induced jobs. Induced jobs arise from the economic activities of direct and indirect employees, shareholders and governments (via associated tax revenues). The spending of their earnings can stimulate other industries that are entirely disconnected from renewable energy, but nevertheless have a substantial job creation potential. Induced jobs can be simply conceptualised. Consider the example of a renewable energy industry employee dining out in a restaurant: this leisurely outing contributes to creating demand for staff in the culinary sector. In practice, however, induced jobs are often difficult to accurately determine, since tertiary (and quaternary) employment effects of the deployment of renewables may be hard to isolate. For this reason, and given the paucity of literature in the domain of induced jobs, we do not include induced jobs in the present study.

2.3 Employment factors

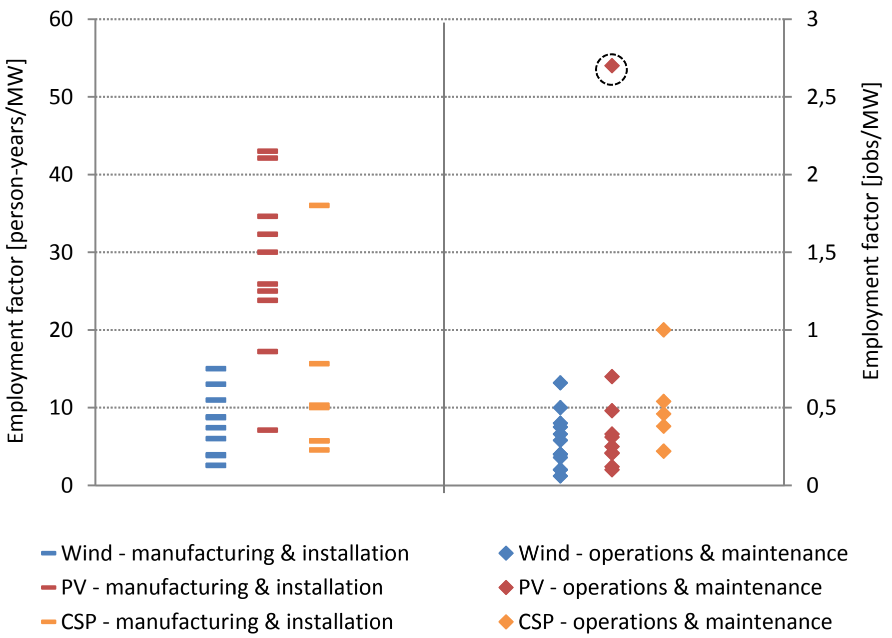
Studies of employment opportunities have been performed for many different types of renewables, including wind power (on- and offshore), solar energy (PV and thermal), biomass-based energy (from various sources of fuel and feedstock) and geothermal power (for multiple geological formations and depths). A series of conventional energy technologies such as nuclear energy, hydropower, as well as natural gas and coal based power generation, have also been subjected to job creation assessments. Studies that focus on renewable technologies make up the majority of the available literature we found and only few studies consider conventional fossil-based technologies. This makes it hard to compare the employment impacts of renewable and conventional technologies, which we therefore will not do in our analysis.

This study does not intend to provide an exhaustive list of job studies related to all generation technologies, but focuses on those renewable technologies that are most relevant for our case study for Kuwait: onshore wind, solar photovoltaics (PV) and concentrated solar power (CSP). In Appendix A we collate employment factors related to direct jobs for these three technologies. In those instances where an examined study used data from industry to calculate employment factors while more recent data have become available from the same original sources, an updated employment factor is calculated by ourselves (and indicated by ‘own calculation’). Indirect employment factors for different phases of deployment are described in only a small number of studies. Given this small sample size and the difficulties experienced in determining indirect jobs accurately, they are not listed in Appendix A. The same holds for induced employment factors, which are only described and split by deployment phase in

Tourkoliasa and Mirasgedis based on an input-output model for the Greek economy [19].

Figure 1 summarizes the employment factors we assembled in Appendix A, grouped by technology and deployment phase. Employment factors for manufacturing and installation are aggregated, since most studies do not distinguish between the two. No distinction is made between when or where a study was conducted, which methodology was applied or what assumptions were used. These are among the factors at the origin of the wide spread in employment factor values that different studies report. As one can see, the range of published employment factors for both manufacturing & installation and operation & maintenance is roughly an order of magnitude. We exclude a single data point for the O&M employment factor of PV (indicated with a circle): it is clearly an outlier and we consider it impertinent for our analysis as it derives from an industry survey conducted in only a small unique region of northern Spain [29]. It is possible that there is an unusually high concentration of companies working on PV O&M centred in this region relative to the actual capacity installed.

Figure 1: Comparison of direct employment factors for manufacturing and installation (in person-years/MW, left half) and operation and maintenance (in jobs/MW, right half) for three renewable energy technologies across 27 publications (see Appendix A)



Even while the spread in depicted employment factors is large, Figure 1 unequivocally suggests that the manufacturing and installation job creation potential of PV technology is typically several times higher than for onshore wind energy, at least when expressed per unit of deployed capacity. Pairs of publications can be found, however, that would contradict this statement. For CSP roughly the same holds as for PV, but the equivalent claim here hinges on one data point of 36 jobs/MW retrieved from a study on South Africa, which makes it less certain. Indeed, leaving out this single number would imply that CSP and wind power have actually very similar manufacturing and installation employment factors. In any case, the median PV employment factor is more than two times the median value for CSP. Figure 1 also suggests that O&M employment requirements for all three technologies are broadly comparable. Beyond an examination of these data, a number of relevant remarks ought to be made regarding the approach and scope of the studies that are summarised in Figure 1 and Appendix A.

First, few studies provide detailed assumptions on the scale of power generation capacity considered. This is rather peculiar, since it may matter considerably for the level of employment factors what the size is at which the manufacturing plant operates. If certain publications report such assumptions along with calculated employment factors, then these are rarely re-stated when adopted by subsequent studies. For example, an often cited study by REPP [27] calculates the "the labour requirements to create a 2 kW residential photovoltaic system" based on interviews with 10 firms producing a total of 60 MW annually. These job figures have been used in successive studies that consider centralised utility-scale solar PV with little questioning of their relevance. One might expect that the manufacturing labour requirements of small-scale decentralised PV units spread across a number of producers is significantly different from those of large-scale mass-produced PV panels intended for centralised power generation. Equally, the installation labour requirements of small-scale distributed PV systems can be quite different from those of a large centralised plant.

Second, only few studies of employment potentials of renewables have been conducted in developing or emerging countries. For those cases where such studies have been performed, often surrogate figures are quoted from OECD country studies [30, 31], with only rarely an attempt to adapt them to the local context [39]. Lehr's study for Tunisia provides one of the very few exceptions with a detailed analysis of employment impacts of renewables deployment outside the OECD [25]. Just as there are few examples of studies for developing or emerging economies, there is little attention being paid to countries that have a negligible or non-existent domestic renewable energy market as starting point for renewable energy development. Most estimates of employment factors are developed for countries that already have some (sometimes large) level of installed capacity hence usually extensive domestic manufacturing capability [1]. As installation and O&M jobs must be performed locally, they are quite likely to use domestic labour resources right from the beginning. Equipment, on the other hand, is in many cases relatively simple to import from elsewhere and domestic manufacturing jobs will only be created when some fraction of the components are produced and/or assembled locally, which typically only occurs once renewable energy has obtained a certain level of national power production.

Third, in terms of robustness of results, only few studies exist that compare findings on job estimates to those reported on other countries that might have a similar level of renewable energy deployment. Such validity checks of estimated employment factors against actual employment data may sometimes be valuable. One study that inclines towards doing so is Lehr [25], who shortly compares the situation in the Portuguese wind sector with that in Tunisia where a comparable capacity of wind is planned to be soon developed. One aspect that limits the comparability of results, however, is the fact that the fraction of locally generated labour content in Tunisia is likely to be lower than that in Portugal, given the higher level of imports required for the former.
Notwithstanding these three categories of limitations of published job impact studies,

the literature we scanned almost unanimously shows that renewable electricity generation is associated with significant job creation. A comparison of renewable electricity technologies with other (e.g. conventional) forms of power generation is a good way to put 'significant job creation' in context and may help determining whether there are actually any net effects.

2.4 Renewable versus conventional technologies

Across the range of literature we reviewed, the net employment effect of renewable energy technologies is generally shown to be positive in comparison to the conventional power generation options that they replace. In other words, for a given level of electricity production capacity the combination of manufacturing, installation and O&M activities for renewables such as wind and solar energy create more jobs than the equivalent capacity for coal or gas based power generation [1]. Occasional dissenting views can be found that question whether renewables actually create net jobs or do so at a reasonable cost [43, 44], but these are in the minority and are based on assumptions or research findings that are often refuted by subsequent studies [7, 45, 46, 47]. Although there is generally broad agreement that renewables induce net job creation in comparison to the same capacity of fossil fuel based electricity generation, based on the limited number of studies that investigate and compare the employment impacts of renewables versus those of traditional methods of power production the case for net job creation is arguably not certain. The large range of renewable technology employment factors observed across different studies confirms this uncertainty. We have not been able to identify a rigorous comparison of the employment effects of renewable technologies and those of thermal power generation, l*et al*one one that uses a common and transparent methodology for determining job impacts across distinct technologies[1]. Most macro-scale studies are concerned with the employment impacts in various economic sectors as a result of public policies, rather than comparing technologies at a level playing field.

Data sources for employment factors for conventional power generation technologies are rather limited, generally quite dated and rarely revisited by subsequent studies. We therefore do not list employment factors for technologies such as coal or gas based power production in Appendix A. All studies we found that make an analytical comparison of renewable and conventional energy technologies draw essentially on only two sources in the literature. The first is a study by Heavner and Churchill [72], who provide employment data for a number of gas-fired powers stations in the US based on a mix of operational plants and regulatory filings for proposed plants. Yet they quote the findings of other studies when considering renewable energy alternatives. The second study is from REPP [27], whose authors estimate employment numbers for coal fired power stations in the US based on 1997 census data and a number of exogenous assumptions. In contrast, for their approach towards renewable technologies they use industry surveys. Both these studies observe that renewables have relatively high

1 Even the most advanced models are susceptible to being swayed by assumptions. For instance, the detailed input-output model developed by the German government predicts net job creation for most scenarios, but requires export of renewable technologies to achieve net job creation. This requirement favours renewable energy since for conventional technologies no exports are assumed [7].

employment factors in comparison to conventional electricity production technologies, which makes net job creation likely. The lack of detailed studies, however, reduces the veracity of this claim.

Most studies claiming net job creation consider the context of a particular country, and it is unlikely that their conclusions can be more broadly applied to other countries. The limited number of synthesis studies considering results from a number of countries simultaneously similarly conclude that a net job creation potential exists for renewable energy technologies [14, 40, 36]. These studies, however, only cover a small set of OECD countries and their results are often hardly transferrable to non-OECD countries. The number of jobs created through the deployment of renewable energy technologies depends on a range of factors and circumstances that can strongly differ between countries. A study by IRENA [1] suggests that key aspects include: industrial and labour policy; ability to take advantage of export markets; and the extent of multiplier effects on the rest of the economy. Another fundamental facet is labour productivity, which is an aspect addressed in only a small number of studies [36,31]. Labour productivity expresses the average number of people employed per unit of output. The lower the cost of labour in a country, the greater typically the number of workers that will be employed to produce a unit of any particular good [36]. Another important point is that if it is assumed that renewable technologies have a favourable employment intensity in comparison to conventional technologies, this may simply be the result of the relative immaturity of renewable technology and consequently lead to higher costs of deployment. Indeed, the IEA recognizes this and reports that renewable technologies may use more input in terms of capital and labour for a certain capacity or level of electricity generation simply because they are not a least-cost generation option [48]

3

Case study for Kuwait: methodology

We next investigate how and to what extent we can apply the findings from our literature review to the case of Kuwait. All electricity in Kuwait is currently generated from steam power plants running on oil or natural gas, many of which serve with the dual purpose of providing both electricity (for industry and household consumption) and heat (mostly for multi-stage flash water desalination).

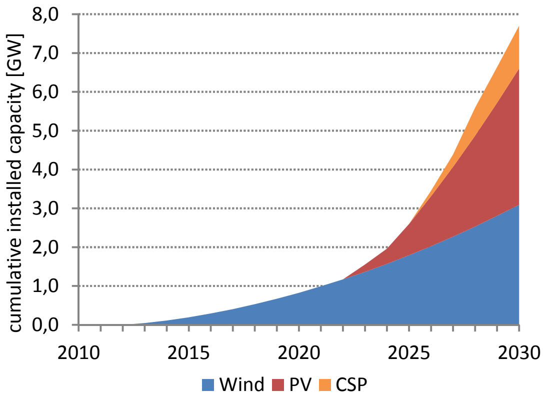
3.1 Electricity generation in Kuwait

KISR has developed a number of scenarios that consider alternatives to the use of domestic reserves of oil and natural gas for power generation, driven by both environmental concerns and potential for economic benefits. The ETSAP-TIMES modelling framework was used to develop these scenarios, including an exogenously stipulated demand profile and different possible evolutions for the future Kuwaiti electricity supply mix. The least-cost (hence optimal) energy technology mix was found to involve 10% of renewable power generation in 2030. This renewable power generation level and associated capacity deployment profile between today and 2030 (see Figures 2A and 2B) provides the basis for our employment analysis. More details of the derivation of this and related electricity supply scenarios can be found in Alsayegh *et al*. [4] and Alsayegh and Fairouz [3].

We limit our analysis to inspecting the job impacts of the deployment of only three renewable electricity production options – wind, PV and CSP – as only these generation technologies emerge in KISR's 10% renewable electricity scenario. Our literature review yielded insufficient detail on employment factors for different PV and CSP technologies to allow for any distinction to be made between, for example, trough versus hybrid Fresnel CSP, or between centralised and distributed PV, so that we do not make such disaggregation. While anticipated construction profiles are known for conventional oil and gas fired power generation plants, we do not include them in our employment analysis, essentially for three main reasons. First, as mentioned, there is a lack of studies that satisfactorily deal with the topic of employment impacts from conventional power generation and, in fact, we found no studies that considered the employment intensity of oil-based electricity generation, probably because oil is (unlike in the 1970s) no longer used on a large scale for power production. Second, in particular for Kuwait there is a general lack of detailed data on such aspects of power production as its level of labour requirements e.g. related to the construction phase of existing individual power plants or their actual operation and maintenance. Third, exceptional labour market conditions in Kuwait imply that approximately 80% of Kuwaiti nationals have jobs in the public sector, mostly a result of the fact that the provision of utilities and extraction of resources are managed by state-owned entities [49]. Although data are not readily available, anecdotal evidence suggests that labour efficiencies at public utilities in Kuwait are lower than elsewhere in the world due to over-employment. This deviation from global standards makes comparisons with existing renewable energy studies - generally based on labour intensities for fairly efficient independent power producers - rather difficult.

Figure 2: (A, left) Overall levels of power generation and capacity by technology in Kuwait for 2020 and 2030 [ ]; (B, right) Cumulative renewable capacity by technology until 2030 under the (approximately) 10% renewable electricity scenario [4]

	2020		2030	
Option	**TWh**	**GW**	**TWh**	**GW**
Fossil Fuels				
CCGT	55.8	9.3	83.1	16.1
CCGT/MSF	18.1	3.7	21.2	3.7
RHSPP/MSF	29.2	6.1	24.8	5.2
OCGT	1.1	3.0	1.1	3.0
Total (oil and gas)	**104.2**	**22.1**	**130.1**	**28.0**
Renewables				
CSP trough	-	-	2.6	0.8
CSP hybrid	-	-	0.6	0.3
PV centralised	-	-	2.6	1.6
PV distributed	-	-	2.6	1.9
Wind (onshore)	2.0	0.8	7.5	3.1
Total (RE)	2.0	0.8	16.0	7.7
Grand total	106.2	22.9	146.1	35.7
RE share	1.9%	3.5%	11.0%	22.0 %



3.2 Calculating direct and indirect jobs

For our case study we adopt a simple analytic approach (class i-b) to estimate the job impacts of KISR's renewable energy strategy. We have chosen for this approach for two main reasons. The first one relates to the transparency of results. An analytic approach provides a clear link between installed capacity and number of ensuing jobs, which is most illustrative for clarifying the impacts on employment of the 10% renewable electricity scenario for Kuwait. The other reason is that the alternative approach of an IO model (class i-a) cannot really be used due to a lack of relevant data. At present no IO model is available for the Kuwaiti economy that includes renewables based electricity generation with any level of sufficient detail. Existing IO models of Kuwait aggregate electricity generation and gas supply in a single energy sector and possess no separate sectors for renewable energy technology manufacturing or installation activities [51]. Extending an existing IO model is a possibility, but in order to include renewable energy many ad hoc exogenous assumptions are required, since today no renewable energy industry exists in Kuwait on which realistic assumptions regarding domestic inter-sector linkages can be based. In principle IO studies of other countries could be used as starting point for expanding an existing model for Kuwait. It cannot a priori be assumed, however, that the renewable energy sector in other countries have the same linkages to the rest of the economy as in Kuwait. To make an assumption on input-output linkages based on those from other countries is, arguably, no more precise than adopting the employment factors that have been found in other countries. Our case study thus focuses on calculating direct jobs with a concise analytic method, to which we add a simple calculation for estimating indirect jobs. At first instance we focus primarily on direct jobs, because they can be more reliably attributed to growth in renewable power generation capacity and are more likely located in Kuwait than indirect jobs. Also, only a couple of studies exist that calculate explicitly employment factors for indirect jobs. This study adopts therefore the approach used by Wei *et al*. [40] in which indirect jobs are estimated from direct jobs using a straightforward multiplier.

We collected direct employment factors for each major phase of renewable energy deployment – manufacturing, installation and O&M – from the available studies and sources assembled in Appendix A. Many of the publications listed in Appendix A aggregate manufacturing and installation related jobs into one single employment factor. They do thus not allow for the individual phases of manufacturing and installation to be examined independently. We consider it important to examine the two phases of manufacturing and installation separately, as installation jobs are more likely to be domestic than manufacturing jobs in a country such as Kuwait that does not yet have an established renewable technology manufacturing industry. From the studies and sources reported in Appendix A only 10 publications provide employment factors for the individual phases of manufacturing and installation: 7 report on onshore wind, 8 on PV and 2 on CSP. We use this subset of 10 data sources for our estimates of employment effects in Kuwait for manufacturing and installation activities, and abstract thus in this context from the other 17. With regards to O&M employment impacts, on the other hand, almost the full set of studies and sources listed in Appendix A can be used, since the vast majority of these publications estimate O&M employment factors separately from those for manufacturing and installation. We present the minimum, median and maximum employment factors for these three phases, and per technology, in Table 1.

Table 1: Minimum, median and maximum direct employment factors for the three main phases of deployment for wind, PV and CSP

	Manufacturing	Installation	O&M
Option	**(person-years/MW)**	**(person-years/MW)**	**(jobs/MW)**
Wind			
Minimum	2.7	0.5	0.1
Median	3.9	1.3	0.2
Maximum	12.5	6.1	0.6
PV			
Minimum	6.0	7.0	0.1
Median	16.8	13.2	0.3
Maximum	34.5	33.0	0.7
CSP			
Minimum	4.0	6.0	0.2
Median	12.8	10.2	0.5
Maximum	21.6	14.4	1.0

Overall we observe a similar tendency in Table 1 as in Figure 1: manufacturing and installation employment factors for PV, and to almost the same extent also for CSP, are well above those for wind power, while O&M activities for these three electricity generation options are approximately equally job-intensive. We also see in Table 1 that manufacturing and installation employment factors for PV are somewhat (and, in the maximum case, significantly) higher than for CSP. For the installation phase this may be explained by the scale at which PV and CSP projects currently are mostly implemented. Although CSP typically involves the installation of a more complex set of equipment than PV, the former is usually implemented in large scale installations that are relatively efficient in terms of installation labour. PV is at present most commonly utilised in the form of small systems installed on e.g. rooftops. This is notably the case for the 10% renewable energy scenario for Kuwait, in which more than half of the installed PV capacity is considered to be in the form of small panels. Such distributed PV is by its nature relatively inefficient in terms of labour intensity, as it is often installed by small companies with few employees [52]. Differing scales of facilities may also partially explain the observed differences in PV and CSP manufacturing employment factors. Yet these observations cannot be taken too generally, as precise values of employment factors much depend on the type of PV respectively CSP technology under consideration, as well as the country where these technologies are deployed. When we add the individual manufacturing and installation employment factors in Table 1, we get slightly different results from the combined manufacturing and installation employment factors plotted in Figure 1. This is the result of the use of two different underlying sets of publications: Table 1 uses 10 data sources that provide employment factors for the individual phases of installation and manufacturing, while Figure 1 draws on 22 data sources that provide employment factors for the two phases aggregated. For most technologies and estimates (i.e. minimum, median and maximum values) Table 1 shows slightly higher employment factors for installation plus manufacturing activities than Figure 1.

3.3 Normalising employment factors

For this report we adopt the convention to present employment factors related to manufacturing and installation in person-years per MW and those related to O&M in jobs/MW (see notably Figure 1 and Table 1). Most studies we investigated report jobs in manufacturing and installation in terms of person-years per MW (where one person-year implies full-time employment for one person for a duration of 1 year) to reflect the transient nature of jobs associated with the creation of power production capacity, in particular when involving renewable resources[2]. In contrast, jobs related to O&M (as well as fuel processing in the case of conventional energy options) are best reported in terms of jobs per MW, as they usually last during the entire lifetime of the plant and so, in some sense, are permanent positions (certainly on the time scale considered in this study – until 2030 – under the premise that renewable power capacity is typically designed for a lifetime of at least 20 years). This is a fundamental nuance not rarely overlooked in employment studies, which sometimes confuse the units of jobs/MW respectively person-years/MW. We thus have had to pay close attention to the units that were – or were intended to be – used in different studies and have had to be especially alert for possible confusions. In addition, we have had to convert some of the published numbers in order to compare studies that use, rightly or wrongly, different approaches for reporting employment factors.

The different nature of employment in manufacturing and installation versus O&M can be most accurately represented by using separate units, but this justified bifurcation yields a disadvantage in terms of ease of interpretation of job figures across different phases of energy technology deployment. In order to compare total average job impacts between diverse technologies it can be necessary to aggregate employment factors over different phases of deployment, for which they need to be normalised to a common unit of measurement. We therefore adopt the approach of Kammen *et al*. [14] and Wei *et al*. [40] who present an expression for average full-time permanent jobs across all phases of deployment through converting manufacturing and installation jobs (in person-years/MW) into O&M units (jobs/MW) by averaging this type of employment over the life of the facility[3]. This conversion allows transient jobs in manufacturing and installation, concentrated at the beginning of a plant's life, to be compared to long-term jobs in O&M[4]. This approach is also justified by the observation that in any given economy with a growing share of renewable energy many plants are simultaneously being built (and eventually replaced) at any given point in time, so that the life-time average employment factor is indicative of the ongoing labour in manufacturing and installation of these plants [14].

2 For example, suppose it took a factory of 80 workers 6 months to manufacture 10 MW of a certain energy technology, and another team of 20 people 3 months to install it, then the total labour requirement would be (80 x 0.5 + 20 x 0.25)/10 = 4.5 person-years/MW.

3 For example, if a technology's manufacturing and installation involves 4.5 person-years/MW and it has a designed lifetime of 20 years, then the average employment factor for this phase is 4.5 / 20 = 0.225 jobs/MW expressed over the technology's expected lifetime.

4 Decommissioning at the end of a technology's life will also have non-negligible labour requirements. We do not consider them here, as they are not addressed in any of the considered studies, perhaps given the lack of experience in this domain for renewables.

Few studies have explicitly dealt with the topic of manufacturing and installation workforce fluctuations over time. Maia *et al*. [39] create technology-specific annual build profiles that reflect capacity additions deployed in South Africa every year. Despite this, their final job impact results are presented in terms of averages over longer time frames, as they note that for South Africa "technologies exhibited significant annual fluctuations in employment". Lehr [25] similarly calculates yearly employment impacts for the renewable energy and energy efficiency sectors in Tunisia based on annual investment profiles. The assumed investment paths in these sectors of the Tunisian economy are also shown to produce significant fluctuations in annual employment. For example, up to 5,000 jobs are lost and subsequently regained over the course of two years within a maximum pool of 25,000 employees in one of the reported scenarios. In addition to exhibiting employment fluctuations, these two studies indicate that, depending on the actual rates of capacity expansion, employment levels in manufacturing and installation may prove to be unsustainable over the longer term. Such unsustainability is not much of an issue for our renewable energy scenario for Kuwait, as the examined renewable expansion profile shows essentially always constant or expanding annual capacity additions, so nearly always substantial growth occurs. The only exception is an approximate plateau in the assumed capacity of hybrid Fresnel CSP technology for a period of a couple of years after 2028, but this makes up less than 4% of total renewable capacity in 2030 so generates overall a small effect.

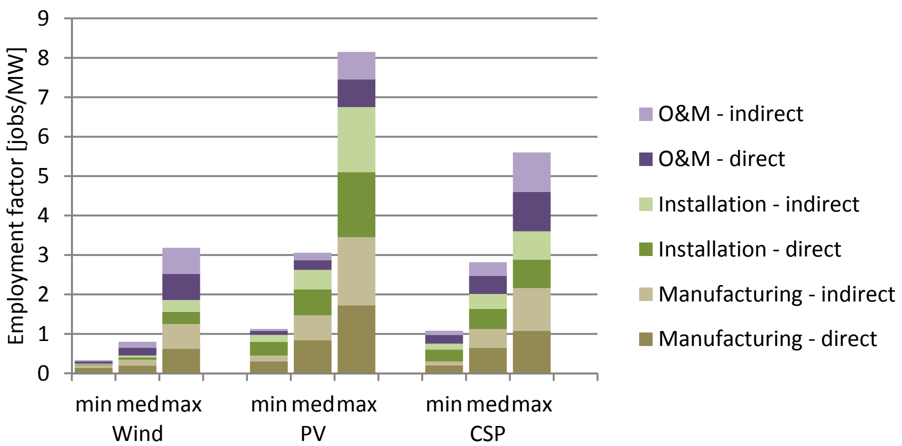
Kammen *et al*. [14] and Wei *et al*. [40] take the process of normalisation another step further by accounting for each technology's average capacity factor, whereby they effectively determine the number of jobs created per unit of generated electricity (jobs/MWh). Croucher [53] rightly observes that this approach leads to technologies with lower capacity factor, and thus requiring a larger installed capacity to produce a given level of electricity, possessing a greater job creation potential. He thus notes that extending this line of reasoning could lead one to conclude that a renewable power generation plant in a location with poor (wind or solar) resources produces more jobs than a plant situated at a site with outstanding resources, thereby unwillingly crediting the former rather than the latter. One of course wants to avoid creating such an unintended impression. Given that normalising on the basis of the amount of electricity generated favours technologies with lower capacity factors, it is unsurprising that Kammen *et al*. [14] and Wei *et al*. [40] find that solar technologies (with relatively low assumed capacity factors) create more jobs than other forms of renewables, and that intermittent renewable electricity generation yields more jobs than conventional fossil fuel based power plants. To circumvent this caveat and avoid potential criticism regarding normalising on the basis of generated electricity, we prefer to normalise employment impacts for wind, PV and CSP technologies in terms of jobs/MW, hence on the basis of an assumption of their average plant lifetimes.

3.4 Accounting for uncertainty

Like with Figure 1, the wideness of the range of direct and indirect employment factors listed in Table 1 result from a rather large number of factors. For Table 1 these particularly include: i) differences in methodology used for calculating employment impacts, ii) varying coverage of what types of labour are accounted for under the notion of direct job, iii) variable country context in terms of the degree of local job content, iv) diverging country context in terms of average overall employment intensity, v) different assumptions with regards to the types of technology deployed, and vi) – especially for those studies in which no methodological description is provided - differences regarding representing renewables favourably or unfavourably in terms of job creation potential given possible vested commercial or ideological interests of the institutions behind the respective publications.

We show the range of employment factors, based on the data presented in our subset of 10 authentic sources, in another fashion in Figure 3, by plotting the span of minimum to maximum direct employment factors for each of our three technologies along with their corresponding median values. Figure 3 shows the employment factors not only for each technology but also for each phase of deployment, normalised using the common metric of jobs/MW. Figure 3 also presents indicative values for indirect employment factors. Like in Wei *et al*. [40], these are calculated as a ratio of the corresponding direct employment factors. For this study the minimum, median and maximum indirect employment factors are assumed to equal 50%, 75% and 100% of the respective direct employment factors. These ratios broadly reflect the variation between direct to indirect employment factors observed in most of the literature [19, 54, 55], while we intentionally remain at the conservative side vis-à-vis a small number of studies that state significantly higher indirect effects [24]. We think we can safely assume that no distinction is necessary in multipliers between technologies.

Figure 3: Direct and indirect jobs per deployment phase (in jobs/MW) for different technologies based on minimum, median and maximum values for employment factors in the available literature



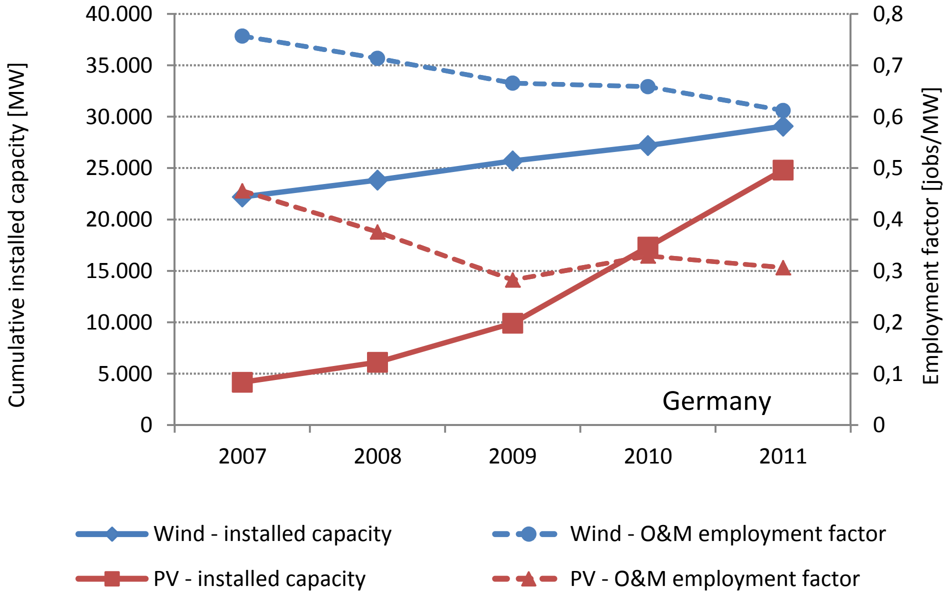
The results depicted in Figure 3 show that the public literature involves a large variation in total normalised employment factors. Maximum values suggest that the job creation intensity of PV is significantly higher than that of CSP, while when median or minimum values are adopted this difference largely disappears. In all instances PV and CSP have a significantly higher overall employment factor than wind energy. With regards to the breakdown between different phases of deployment, Figure 3 demonstrates that a greater proportion of the jobs created by wind power are expected to be in O&M than for the other two technologies. Especially the share of O&M jobs for PV is relatively modest.

3.5 Economies-of-scale and learning-by-doing

An important aspect that receives little attention in the literature we reviewed is the possibility of employment factors changing over time as a result of economies-of-scale and learning-by-doing. Job requirements and thus employment factors are expected to reduce as technologies and production techniques mature, both as a result of the expanding size of and growing experience accumulation in the renewable energy industry. Data on O&M employment needs in the German renewable energy industry support this claim. In Germany a clear decrease in O&M employment intensity has recently been observed, with 5%/yr and 8%/yr average annual improvements for wind and PV respectively from 2007 to 2011 (see Figure 4).[5] Few studies attempt to quantify reductions in employment factors over time resulting from scaling and learning effects. Heavner and Churchill [72] assume an annual decrease of 10%/yr in construction times and 5%/yr in O&M times, while noting that “it is difficult to quantify this decrease based on historical precedent” and that these assumptions lead to “very conservative job growth estimates”. Rutovitz and Atherton [36] use, where possible, industry references for estimating job intensity reductions and anticipating annual decline rates for the costs of each technology as proxy for the decline in required employment. When the assumptions of Heavner and Churchill are compared to those of Rutovitz and Atherton, the difference in ensuing job reduction rates for certain technologies may be as high as an order of magnitude. This subject matter clearly deserves more analysis, especially as the scale and maturity of the renewable energy industry evolves, but it will not be addressed in detail in this study.

5 The stages of manufacturing and installation undoubtedly show similar effects. We have not been able to examine them for changes in employment intensity, however, as we lack data on the volume of manufactured wind and PV products that were exported from Germany.

Figure 4: Cumulative installed capacities for wind and PV in Germany (left axis) compared to the corresponding O&M employment factors in the German wind and PV industries (right axis) (own derivation based on [56, 57, 58, 59, 60, 61)



Employment factor reductions following economies-of-scale and learning effects are not included in our case study for Kuwait for three main reasons. First, the employment factors listed in Table 1 are largely drawn from studies focusing on OECD countries with established renewable energy markets. These employment factors are therefore, arguably, already on the low side for a country like Kuwait that would be developing a new industry. Second, Kuwait has a higher average overall employment intensity than most OECD countries [62, 63], so that more jobs are typically needed across sectors for the same unit of economic output[6]. This higher employment intensity similarly implies that employment factors drawn from OECD country studies are likely to be already conservative. Third, the range of quoted employment factors in Table 1 that we use for our sensitivity analysis is rather large, in comparison to which relatively small potential annual reductions as a result of economies-of-scale and learning effects are probably outshadowed. We thus think it is appropriate to adopt the range of employment factors summarized in Table 1 until 2030 for our Kuwaiti case study.

[6] Reliable data on the relative employment intensity of the Kuwaiti industrial sector are hard to find. We only found economy-wide figures for 1999-2003, which show a high employment factor in comparison to OECD countries [62]. Recent regional studies similarly conclude that employment factors are relatively high in the Middle East and Africa i.e. labour productivity is relatively low [63].

3.6 Jobs in manufacturing: domestic versus foreign

The literature behind the estimates reported in Table 1 rarely makes a clear distinction with regards to where specific manufacturing activities take place. Whether or not a technology is manufactured domestically, and whether certain components or entire systems are imported from other countries and assembled in the country under consideration, matters substantially for a national employment study like ours. Naturally, assumptions on how much of the manufacturing process takes place abroad impacts the job creation potential that can be expected locally. In the absence of explicit assumptions on the extent of local content for many of the reviewed studies, and given that the majority of studies are for OECD countries that have established domestic renewable technology manufacturing sectors, it is assumed that the employment factors in Table 1 account for nearly all labour related to manufacturing[7]. The renewable technology manufacturing situation in Kuwait is quite different though, since almost an entire renewable energy industry still needs to be developed. It is unrealistic to assume that all of the necessary components for wind, PV and CSP technologies can be produced in Kuwait itself in the short to medium term. Hence we have attempted to estimate a realistic level of local manufacturing in Kuwait, based on those components that we considered could be readily produced domestically.

[7] Some studies, such as by Tourkolias and Mirasgedis [19], attempt to calculate the employment impact of imported equipment. Without the import assumptions behind the input-output tables developed for this study, however, or similar assumptions for most of the other literature sources, it is impossible to normalise manufacturing employment factors to a common level of domestic production.

Figure 5: Capital cost breakdown for wind, PV and CSP with manufacturing and installation cost shares and an indication of which manufacturing cost components we assumed can be localised for domestic production in Kuwait [adapted from 64, 65 and 66 in 67].

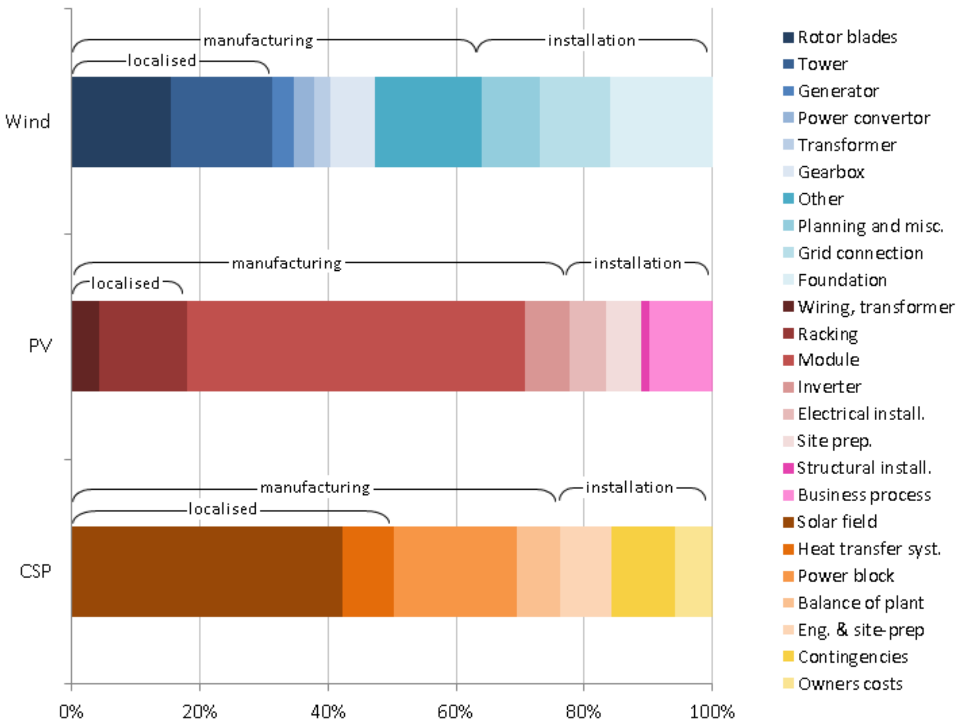


Figure 5 shows the cost shares of all main components of wind, PV and CSP technology, and indicates how these can be grouped into two main classes of manufacturing and installation costs respectively. Whereas we can reliably assume that all installation activities are domestic, for manufacturing in Kuwait a fair share is likely to take place abroad. We also indicate in Figure 5 the cost contribution of those combined manufacturing components that we suppose can be produced domestically. While only a rough approximation, we assume that the cost share of locally produced components in the overall manufacturing process is a reasonable proxy for the local labour percentage for each technology with respect to the total manufacturing job requirements (that include local plus foreign employment content). This yields a local manufacturing content of 49% for wind, 23% for PV and 66% for CSP technology. These percentages are used to interpret the manufacturing employment factors in Table 1, that is, to revise them downwards in order to reflect more realistically employment opportunities in the 10% renewable power production scenario for Kuwait. Exports of manufactured technology from Kuwait are not considered: while they are not realistic at present, they may well materialise by the horizon of 2030.

4

Case study for Kuwait: results

We apply the employment factors given in Table 1 to the 10% renewable electricity scenario developed for Kuwait, the result of which is depicted in Figure 6 in terms of the evolution of the total number of direct jobs aggregated over all three technologies and all phases of their deployment. Two different ranges are shown, depending on the extent to which manufacturing occurs in Kuwait or abroad. In the upper case (in green) all manufacturing is assumed to be localised, while in the lower case (in grey) only the shares derived in Figure 5 are assumed to be manufactured domestically. In each of these two cases, minimum, median and maximum graphs are plotted, based on our earlier findings. The simulated overall employment patterns account for the transient nature of manufacturing and installation activities, in the sense that corresponding jobs are calculated from the incremental capacity produced every year averaged over the capacity's lifetime (under the assumption that within a year these activities are spread uniformly). O&M jobs in any given year are calculated based on the cumulative installed capacity.

Figure 6: Direct employment until 2030 in Kuwait for an 10% renewable power pathway with uncertainty ranges under two scenarios: all manufacturing is produced locally (green), respectively, the local content is 49% for wind, 23% for PV and 66% for CSP (grey)

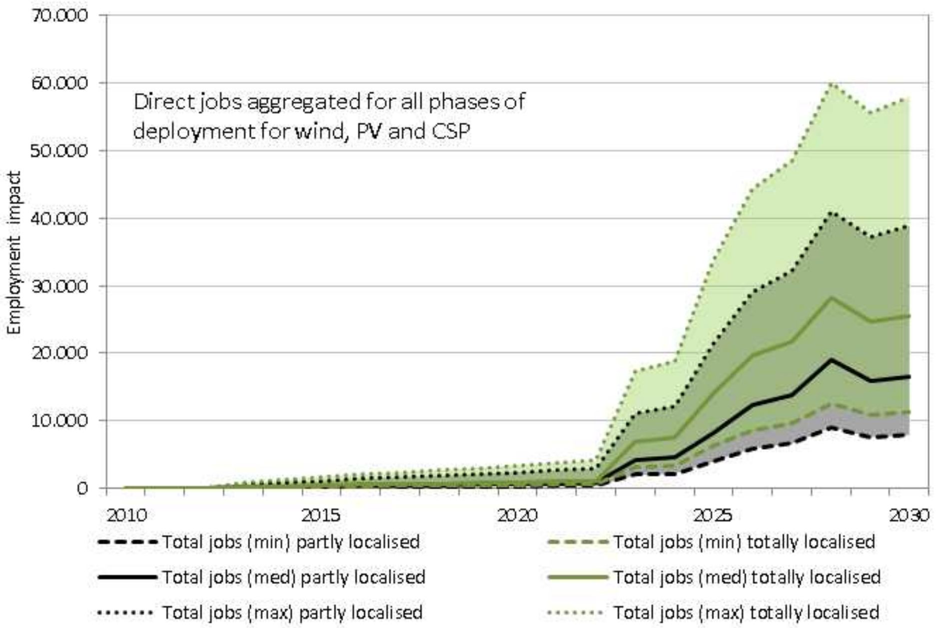
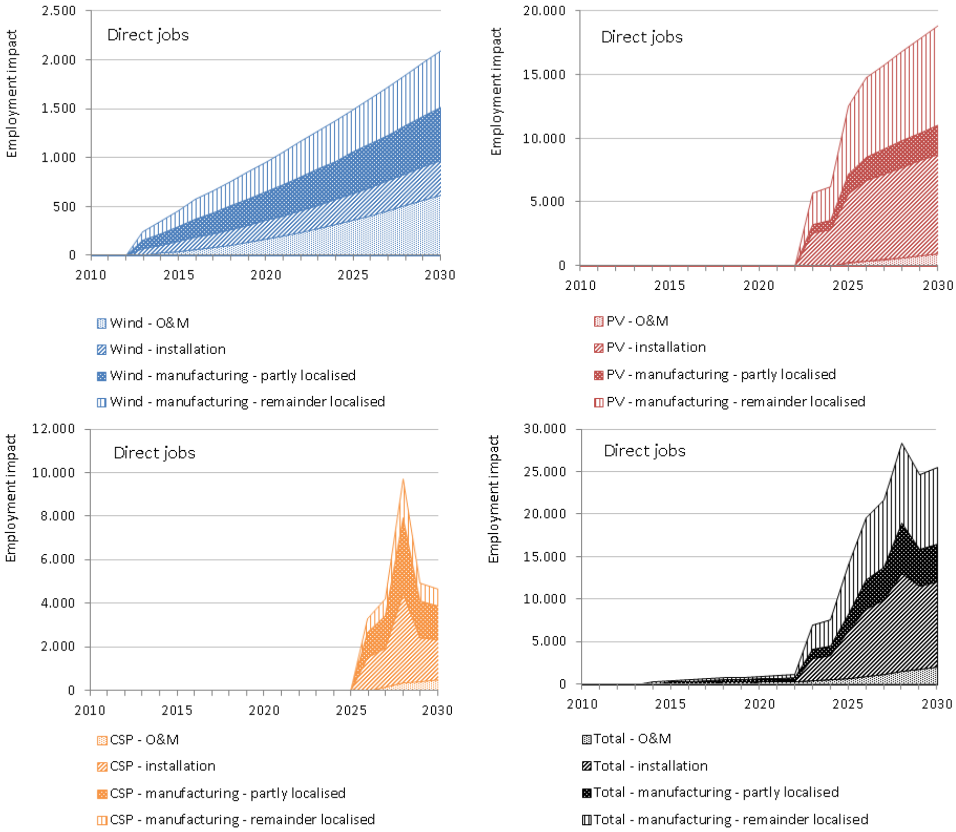


Figure 6 demonstrates that our two diverging assumptions with regards to the local content of manufacturing employment may result in a wedge of as high as 3,500, or even 19,000, direct jobs in 2030 for our minimum and maximum estimated pathways respectively. By comparing the maximum and minimum pathways depicted in Figure 6, we see that the most optimistic values for the employment factor result in about five times more jobs at any given point in time than the most conservative ones found in the literature. Hence uncertainty in this domain matters a lot. Real employment figures are likely to lie somewhere in between these two extremities, so henceforth we adopt median employment factor values for further comparison. These imply approximately 16,500 direct jobs in Kuwait in 2030 if we assume that the local manufacturing content amounts to 49% for wind energy, 23% for PV and 66% for CSP.

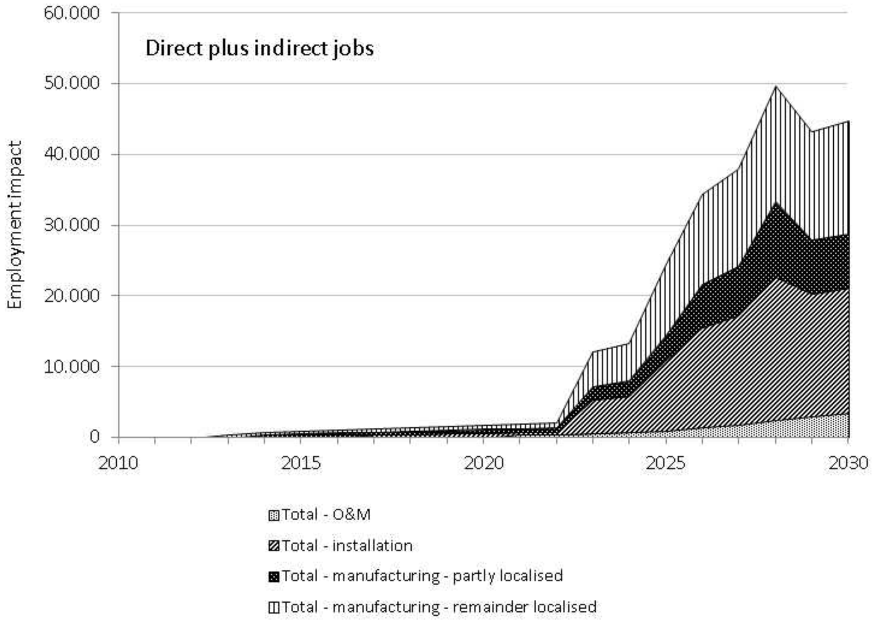
When examining these 16,500 direct jobs by phase of deployment and technology, as we do in Figure 7, we see that the largest share of total employment is expected to be related to installation activities, mostly because PV and (to a lesser extent) CSP are broadly deployed and are relatively installation-intensive. In 2030, installation activities in Kuwait amount to about 10,000 of the total level of necessary direct jobs. The next largest contributor is (local) manufacturing, with approximately 4,500 direct jobs in 2030, followed by O&M with about 2,000 jobs. Wind power has a proportionally high share of O&M related jobs, representing in 2030 well over a third of all direct wind capacity related jobs. Even while wind power contributes to about 40% of renewable energy capacity in 2030, its share in total local job creation is hardly 10% – which is another of way saying, as we observed before, that the relative maturity of wind power has rendered it a less labour-intensive electricity generation option than PV and CSP. The discrepancy between the shape of the job growth curve for CSP as compared to that for wind and PV is a direct result of the capacity planning in the 10% renewable electricity scenario for Kuwait. Both wind and PV capacity have either stable or even increasing growth rates over the entire period until 2030, which correspondingly yields a stable or increasing need for manufacturing and installation activities. For CSP, however, significantly fewer new facilities are manufactured and installed after 2028 than during the years prior. This explains the strong dip in the CSP related jobs plot of Figure 7.

Figure 7: Direct employment until 2030 in Kuwait for an 10% renewable power scenario split by project phase and technology. Median employment factors are assumed and partly localised manufacturing of 49% for wind, 23% for PV and 66% for CSP



We estimate indirect employment impacts by using a simple multiplier of 0.75 applied to the level of direct jobs, as the current literature does not suggest a more sophisticated method of estimating indirect job impacts. Although this is admittedly a somewhat simplistic way of calculating indirect jobs, it serves fairly well our purpose of providing a conservative estimate of the sum of direct and indirect employment impacts for Kuwait's 10% renewable electricity scenario. Our findings are shown in Figure 8, which indicates that indirect employment adds another 12,300 jobs to the primary level of 16,500 direct jobs. In particular, an additional 3,300 jobs in manufacturing, 7,500 in installation and 1,500 in O&M are created in indirect employment in 2030. Total direct plus indirect employment creation in 2030 is thus estimated at approximately 7,700 manufacturing jobs, 17,600 installation jobs and 3,500 O&M jobs, totalling 28,800 positions across all technologies and phases of their deployment.

Figure 8: Total direct and indirect employment until 2030 in Kuwait for an 10% renewable power scenario split by project phase. Median employment factors are assumed and partly localised manufacturing of 49% for wind, 23% for PV and 66% for CSP



The results reported above are all gross employment effects associated with a growth of wind, PV and CSP technologies. We did not calculate whether there are net employment effects resulting from the 10% renewable electricity scenario, with respect to a reference case with no or less renewable energy capacity. It is highly likely though that such a net impact exists, for at least two reasons. First, the available studies we consulted are in broad agreement that renewable technologies are today probably stimulating more jobs expressed per MW than conventional power generation, even when one needs to bear in mind the limitations of most of these studies both in terms of their number and the robustness of their findings. Second, the reference case given by Alsayegh and Fairouz [3] suggests that in Kuwait only 2 GW of oil and gas based power capacity would need to be developed instead of 7.7 GW of renewable capacity. As mentioned earlier, the lower capacity factor or intermittency of renewables work in their favour when job impacts are concerned, since a larger installed capacity is required to generate the same amount of electricity. The much larger total capacity in the 10% renewable energy scenario in comparison to the reference case means that it is highly likely that net employment effects are positive.

5

Conclusions

A review of the available literature on the impact of growth in renewable energy on employment opportunities shows that, although there are fairly large numbers of publications that address this topic, only a much smaller subset can be considered as presenting original research, even when we use the broad definition of the term 'original research' to include employment studies based largely only on a set of exogenous assumptions. Indeed, there is a high degree of recursive referencing, meaning that many studies merely utilise, re-use or recycle employment factors from earlier publications. Another complication is that there is a large variation in methodologies used, assumptions made and country contexts analysed across the reviewed publications, which does not facilitate mutual comparability of results. This issue is even more pronounced with regards to the few studies we found that also examine employment factors for conventional electricity generation, for which different approaches are used than the ones utilised for assessing the employment impacts of renewables. Through our tabulation of authentic studies and data sources that allow calculation of employment factors for wind, PV and CSP technologies, we demonstrate the existence of a large spread (by as much as an order of magnitude) in reported employment factors, for manufacturing and installation as much as for O&M activities. We also point out that few studies provide a split in manufacturing and installation employment factors, and fewer still explicitly calculate indirect or induced job impacts. All these observations impede proving the generally convincing belief and credibility of claims that jobs are created from renewable technologies diffusion. Notwithstanding these concerns, the available literature is in broad agreement that renewable technology deployment may be at the origin of significant job creation, and probably creates more jobs than conventional (mostly fossil-based) power production, at least under the current industrial state-of-the-art. This is particularly true if jobs are compared per unit of generated electricity, which clearly favours renewable technologies given that they possess low capacity factors due to their intermittent nature.

Our case study for a 10% renewable electricity scenario for the state of Kuwait shows that when median employment factors from the available literature are adopted, renewable sources of power production could yield about 25,600 direct jobs in Kuwait in 2030 if all manufacturing activities were domestically located. If more conservative assumptions on local content are used, this figure would drop to approximately 16,500 direct jobs. Approximately 27% of these 16,500 jobs are related to manufacturing, 61% to installation and 12% to O&M activities. Indirect labour is estimated to provide roughly 12,300 additional jobs when determined using a simple multiplier of 0.75 with respect to the figure of direct jobs. These estimates provide a starting point for investigating the necessary skills and training in Kuwait in support of the 10% renewable electricity scenario.

Literature abounds describing the types of professions required for the manufacturing, installation and O&M stages of renewable energy systems implementation [68]. These include predominantly technicians and engineers, but also involve economists, business administrators and public affairs specialists familiar with the main features of renewable energy. Little literature is available, however, on the relative proportions of these professions, or the precise level of the necessary qualifications. Some studies for Germany and Spain indicate that the qualification level of workers in the renewable energy sector exceeds the average qualification level of the total workforce in a country; in Spain, for example, roughly 50% of renewable energy sector employees have university degrees as compared to 24% across the wider economy [68]. Given the still relative immaturity of the renewable energy market, there is a lack of information on career development in renewable technology, although numerous university programmes exist that focus on it. Furthermore, there is little data available on the number of people directly or indirectly employed in the renewable energy sector working in standard professions such as accountants, computer analysts, secretaries, factory workers and truck drivers.

A study by the American Solar Energy Society finds that the majority of jobs induced by the renewable energy sector are standard jobs as opposed to specialised ones [26]. This study proposes that most employees in renewable energy related firms perform the same types of activities as employees in firms that have little or nothing to do with renewable energy: the occupational distribution of a typical wind turbine manufacturing company appears to differ relatively little from that of a company manufacturing entirely different products. It is thus suggested that many non-renewable energy industries can provide a starting point for estimating the split of different types of professions likely to be required for the deployment of renewable energy. With a negligible renewable energy industry in Kuwait today, a shift towards renewable energy sources will probably require a number of relatively new professions that are specific to renewable energy technologies, such as electrical and mechanical technicians and engineers with expertise dedicated to the main stages of wind and solar power systems [1]. An understanding of what type of jobs must be created may help designing necessary educational and academic programmes as well as public policies to meet these needs [14].

Even though increasing private sector employment is an important priority for Kuwait, job benefits should not be considered the primary reason for deploying renewables [1]. The probable beneficial employment impacts quantified in this study must be viewed alongside essential features of renewables in terms of their ability to contribute to mitigating climate change, reducing air pollution and enhancing energy security. In particular for Kuwait, the economic gains obtainable from reducing domestic fossil resource consumption may be substantial. The present analysis proffers an additional element towards designing an optimal energy strategy and taking a balanced view regarding the role that renewables could play in Kuwait's future electricity system.

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Appendix A. Employment factors

Table 2: Employment factors for direct jobs in different phases of deployment and operation for three renewable generation technologies – onshore wind, PV and CSP – across 27 studies and data sources

Tech.	Year	Region	Manu.& install.	Manu.	Install.	O&M	Employment factor derivation	Notes	Publication type	Source
			person-years/MW			jobs/MW				
Wind (onshore)	2010	Germany				0.61	Industry data	Based on 2010 employment and installed capacity. We assume that O&M labour force works on domestic capacity.	Own calculation	[60, 61]
	2004	Canada	3.92	3.04	0.88	0.1	None given	Claims a mix of literature review and industry information, but provides no methodology for calculating figures.	Private sector study	[69]
	2006	Asturias, Spain	13			0.2	None given	Considers a region of Spain and assumes employment factors based on two other studies	Journal article	[32]
	2001	US	3.83	3.3	0.53	0.1	Supply chain questionnaire	Figures derived from Table 4 which reports on labour requirements per MW for a 37.5 MW wind park	Private sector study	[27]
	2001	California	2.57			0.29	None given	Number of employees per nominal plant is an exogenous assumption. Nominal plant for wind is 50 MW	Public sector study	[70]
	2011	Greece	8.8	2.7	6.1	0.375	Input-output model	We assume a 20yr lifetime and determine manufacturing jobs as the difference between the default case and scenario A	Journal article	[19]
	2009	Europe	8.7	7.5	1.2	0.33	Industry data	We report here only direct employment factors from Table 07 but "other direct employment" which consists of "utilities, consultants, research institutions, universities, financial services and other"	Private sector study	[71]
	2002	California	2.57			0.2	Literature review / synthesis	Selects values from a literature review; uses a source that is not publically available.	Private sector study	[72]
	2009	OECD	15	12.5	2.5	0.4	Literature review / synthesis	Derives values from Blanco and Kjaer [71], but seems to include direct jobs. The resulting values are presented as OECD employment factors with labour multipliers provided for other regions.	Private sector study	[36]
	2011	South Africa	6	4.5	1.5	0.5	Literature review / synthesis	Adapts values from a literature review to local conditions; this is not a very transparent process. Seems to mix jobs with person-years. We assume that stated employment factors are in person-years/MW	Private sector study	[39]

Tech.	Year	Region	Manu.& install.	Manu.	Install.	O&M	Employment factor	Notes	Publication type	Source
	2012	US			1.25	0.06	Input-output model	Estimates the employment impacts for 197 projects supported by government incentives. Uses a definition of indirect jobs that includes all manufacturing jobs. Direct jobs only shown here.	Public sector study	[21]
	2004*	UK	16			0.12	Supply chain questionnaire	Includes indirect jobs which cannot be de-aggregated from available data	Public sector study	[28]
	2006	US	10.96			0.18	None given	Compares wind industry employment with the coal, gas and nuclear power industries	Private sector study	[73] in [40]
	2002	California	7.4			0.2	Input-output model	California Energy Commission figures as quoted in Heavner and Churchill	Public sector study	[72]
PV	2008	EU	43	10	33		None given	Although no firm details of the derivation of employment factors is provided, the numbers are stated to come from "the industry".	Industry report	[74]
	2011	EU	30				None given	Although no firm details of the derivation of employment factors is provided, the numbers are stated to come from "the industry".	Industry report	[75]
	2011	Germany				0.31	Industry data	Based on 2010 employment and installed capacity. We assume that O&M labour force works on domestic capacity.	Own calculation	[60, 61]
	2007	Germany		34.5			Industry data	Based on German data, but unclear if this is corrected for exports	Private sector study	[36]
	2009	US		26.8			Industry data	Calculated from Table 3.1 (domestic manufacturing only) and Table 3.16	Own calculation	[76]
	2004*	UK	84			0.45	Supply chain questionnaire	Includes indirect jobs which cannot be de-aggregated from available data	Public sector study	[28]
	2001	California	7.1			0.12	Assumption	Number of employees per plant is an exogenous assumption. Plant size for determining employment is 10 kW	Public sector study	[70]
	2004	Canada	25.9	18.8	7.1	0.1	None given	Claims a mix of literature review and industry information but provides no methodology for calculating figures.	Private sector study	[69]
	2001	US	32.3			0.25	Supply chain questionnaire	Extrapolates based on data for a 2 kW system	Private sector study	[27]
	2010*	Europe	68-69				Input-output model	All phases of a project, including O&M collated into a single figure	Public sector study	[18]
	2006	Asturias, Spain	34.6			2.7	None given	Considers a region of Spain and assumes employment factors based on two other studies	Journal article	[32]

Tech.	Year	Region	Manu.& install.	Manu.	Install.	O&M	Employment factor	Notes	Publication type	Source
	2005	Spain	25			0.31	None given	Net employment impacts are estimated for 2010 based on a given scenario for growth in various renewables	Own calculation	[77]
	2011	Greece	17.2	6	11.2	0.205	Input-output model	We assume a 20yr lifetime and determine manufacturing jobs as the difference between the default case and scenario A	Journal article	[19]
	2011*	EU				1.04	Industry data	Derived from those countries that declare their employment split. Assumes that O&M for domestic capacity is predominantly domestic labour. Includes indirect jobs.	Own calculation	[78]
	2009	OECD	42.1	10.2	31.9	0.48	Literature review / synthesis	Selects values from two sources following a literature review. The resulting values are presented as OECD employment factors with labour multipliers provided for other regions.	Private sector study	[36]
	2011	South Africa	23.8	16.8	7	0.7	Literature review / synthesis	Adapts values from a literature review to local conditions, but does not provide detailed reasoning. Seems to mix jobs with person-years. We assume that stated employment factors for manufacturing and installation are in person-years/MW	Private sector study	[39]
	2002*	California	7.14			0.12	Literature review	Sometimes stated as an independent source of data, but the employment factors for PV are based on [70]	Private sector study	[72]
	2012	US			15.1	0.21	Input-output model	Estimates the employment impacts for more than 23,000 projects supported by government incentives. Uses a definition of indirect jobs that includes all manufacturing jobs. Direct jobs only shown here.	Public sector study	[21]
	2004*	Morocco		98 - 514			Input-output model	Provides aggregate figures for both direct and indirect impacts. Range shown here assumes either domestic manufacturing or imported cells.	Journal article	[20]
CSP	2001	California	5.71			0.22	None given	Number of employees per nominal plant is an exogenous assumption. Nominal plant for solar thermal is 100 MW	Government study	[70]
	2009	Europe	10	4	6	1	None given	No derivation for employment factors provided. We assume that for manufacturing and installation the provided figures are for jobs for a period of a year.	Industry report	[79]

Tech.	Year	Region	Manu.& install.	Manu.	Install.	O&M	Employment factor	Notes	Publication type	Source
	2011	South Africa	36	21.6	14.4	0.54	Literature review – local adaptation	Adapts values from a literature review to local conditions, but does not provide detailed reasoning. Seems to mix jobs with person-years. We assume that stated employment factors for manufacturing and installation are in person-years/MW	Private sector study	[39]
	2004	Nevada	15.65			0.46	Input-output model	Calculates employment impacts over time from 1000 MW of CSP. Employment factors are the authors' own calculation from Table 4.	Government study	[23]
	2006	California	4.55			0.38	Input-output model	Values include assumptions about what percentage is manufactured locally	Government study	[24]
	2009	California	10.31			1	Input-output model	Comes from 2009 data that was provided to Wei *et al*. [40] as a personal communication.	Joint public and private sector study	[40]
	2002*	California	5.71			0.22	Literature review	Sometimes stated as an independent source of data, but the employment factors for CSP are based on [70]	Private sector study	[72]
	2009*	Spain	111 - 189				Input-output model	Provides aggregate figures for all phases of deployment and both direct and indirect impacts in "1-year jobs". These are assumed to be equivalent to "person-years"	Journal article	[13]

NB:

- Items marked with a * are not included in Figure 1, as they a) include indirect jobs, b) aggregate project phases together, or c) directly adopt the employment factors in another study listed here.
- 'Manu' refers to jobs related to manufacturing, 'Install' refers to jobs related to installation.

Appendix B. Survey of graduate courses on renewable energy

Below a non-exhaustive list of mostly (but not exclusively) naturally scientifically oriented or engineering focused masters programs in the field of renewable or sustainable energy technology and policy, in random order and with a bias towards programs that the authors are to some extent familiar with. There are few universities or engineering schools these days that are not in some way involved in research and teaching in the field of energy and environmental matters, and many exist that possess specific graduate programs in the field. The concise survey below should be indicative for the types of such programs, the way in which they are organized, and the kinds of classes that are taught and research subjects performed. Most of these masters programs are established at the science or engineering departments of their universities, but today a reputable list of schools for international and public affairs offer master programs with a specialization in the field of energy and environmental policy, such as at Harvard University (BCSIA, Kennedy School of Government), Columbia University (SIPA), and Johns Hopkins University (SAIS). Not listed here are obvious places like MIT, Stanford University and Berkeley University, with a plethora of teaching in energy and environmental matters, several different masters programs herein, and a concentration of funding.

Table 3: Masters programs in the field of renewable or sustainable energy technology and policy

University	Program	Website
Utrecht University	Master in Energy Science	http://www.uu.nl/university/masters/NL/energyscience
Delft University of Technology	Master of Science Sustainable Energy Technology	http://set.msc.tudelft.nl/
University of Twente	Master Sustainable Energy Technology	http://www.utwente.nl/set/
Swiss Federal Institute of Technology Zurich	Master in Energy Science and Technology	http://www.master-energy.ethz.ch/
Carnegie Mellon University	Master in Energy Science Technology and Policy	http://neon.materials.cmu.edu/energy/
Johns Hopkins University	Master of Science in Energy Policy and Climate	http://advanced.jhu.edu/academic/environmental/master-of-science-in-energy-policy-and-climate/
SciencesPo, Paris	Master in International	http://www.psia.sciences-po.fr/content/master-

School of International Affairs	Energy	international-energy
University of Groningen	Master in Energy and Environmental Sciences	http://www.rug.nl/prospectiveStudents/degreeProgrammes/ mastersProgrammes/masters/croho60608
Ulm University	Master in Energy Science and Technology	http://www.uni-ulm.de/index.php?id=6675
ParisTech, Paris Institute of Technology	Master in Renewable Energy Science and Technology	http://master.paristech.fr/index.php/mas_eng/Labelled-Masters/Energy/Renewable-Energy-Science-Technology
Columbia University	Master in Earth Resources Engineering, Sustainable Energy	http://www.eee.columbia.edu/pages/academics/graduateprogram/MS-ERE.html
Imperial College London	Master in Sustainable Energy Futures	http://www3.imperial.ac.uk/energyfutureslab/students/msc

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