IRENA

International Renewable Energy Agency

Renewable Energy and Jobs

DECEMBER 2013

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

Acknowledgements

Authors: Rabia Ferroukhi (IRENA), Hugo Lucas (IRENA), Michael Renner, Ulrike Lehr (GWS/IEA-RETD), Barbara Breitschopf (Fraunhofer ISI/IEA-RETD), Dominique Lallement and Kristian Petrick.

Contributors: Diala Hawila, Divyam Nagpal, Ghislaine Kieffer, Salvatore Vinci, Arslan Khalid, Alvaro Lopez-Peña, Troy Hodges and Noor Ghazal Aswad.

Reviewers: Sascha Van Rooijen (Ecofys/IEA-RETD), Marlene O'Sullivan (DLR), Dominique Lallement, Robert Gross (UKERC), Osvaldo Soliano (CBEM), Simon Bawakyillenuo (University of Ghana), Dolf Gielen (IRENA), Elizabeth Press (IRENA), Miquel Muñoz Cabre (IRENA) and Zuzana Dobrotkova (IRENA).

Chapter reviewers: Chapter 3: Jan-Christoph Kuntze (GIZ), Nico Pestel (IZA), Anita Richter (GIZ), Georgeta Vidican (DIE); Chapter 4: Frank Calzonetti (University of Toledo), Steffen Erdle (Union for the Mediterranean), Christine Evans-Klock (ILO), Gerard McGovern (BZEE), Michael Narodoslawsky (Graz University of Technology), Paolo Buoni (EEC); Chapter 5: Jeremy Doyle (IDLS), Harish Hande (SELCO), Andrew Scott (ODI), Emma Wilson (IIED); Chapter 6: Svati Bhogle (TIDE), Soma Dutta (ENERGIA), Ana Rojas (IUCN), Jackie Siles (IUCN).

Supporting Organisation: IEA Implementing Agreement for Renewable Energy Technology Deployment (IEA-RETD) (Chapter 2)

Cover Photos (from top to bottom, left to right)**:**
@ solar giga, flickr, creative commons; UN Women/Gaganjit Singh; Stuart Monk; Soraya Keroui; Siemens press picture

For further information or for provision of feedback, please contact Rabia Ferroukhi, IRENA, Knowledge, Policy and Finance Centre (KPFC), CI Tower, 32nd Street Khalidiyah, P.O. Box 236, Abu Dhabi, United Arab Emirates; Email: RFerroukhi@irena.org.

This report is available for download from www.irena.org/Publications.

Foreword

Renewable energy deployment continues to grow globally as a sustainable and increasingly economically viable alternative to conventional sources of energy. There is also growing recognition and interest by governments in the positive social and economic impacts of renewable energy deployment. The employment effects of renewable energy investment, in particular, are increasingly gaining prominence in the global renewable energy debate, but specific analytical work and empirical evidence on this important subject remain relatively limited.

IRENA's *Renewable Energy and Jobs* report contributes to bridging this knowledge gap and provides a first comprehensive view of the various dimensions of renewable energy employment. The study brings together available information on the current status of employment for specific renewable energy technologies and provides an overview of key methods to estimate the employment effects of deployment. It also closely examines global and country-specific jobs trends to expand the knowledge on employment effects of renewable energy deployment. The report estimates that employment in the renewable energy sector stood at an estimated 5.7 million direct and indirect jobs in 2012, and is expected to continue growing.

The report underlines the importance of an enabling policy framework to sustain momentum and realise the full potential for job creation within the sector. As such, the appropriate mix of policies needs to be in place to ensure that value creation is maximised. The report also shows that planning for adequate skills is essential to support a rapidly developing renewable energy sector. This critical skills gap is already visible in many markets, where the education and training infrastructure is unable to cater to the labour demand of the sector.

The report also highlights that the deployment of decentralised renewable energy technologies presents significant opportunities for employment generation across all segments of the value chain. Their adoption is expected to be central in meeting the goal of universal access to modern energy and in stimulating socio-economic development in rural areas. The report's analysis on the gender dimension of employment shows that removing barriers to women's participation in the sector is necessary to meet the growing demand for skills in an expanding industry.

I am confident that the findings from this report will strengthen the knowledge guiding the global discourse on renewable energy deployment and jobs. The recommendations contained in the report should be considered in the design of policies that support job creation and maximise benefits from the transition towards a more sustainable energy system.

Adnan Z. Amin
Director - General
International Renewable Energy Agency

Contents

List of Figures

List of Tables

List of Boxes

Acronyms

ARRA	American Recovery and Reinvestment Act
BZEE	Bildungszentrum für erneuerbare Energien (German Training Centre for Renewable Energies)
BNDES	Banco Nacional de Desenvolvimento Economico e Social (Brazilian Development Bank)
CAD	Canadian dollar
CEWDC	Coastal Electrification and Women's Development Cooperative
CHP	Combined heat and power
CNY	Chinese yuan
CSP	Concentrated solar power
DEEP EA	Developing Energy Enterprises Project East Africa
DLR	German Aerospace Center
EDC	Energy Development Corporation
EF	Employment factor
ENEOP	Eólicas de Portugal
ESF	European Social Fund
EU	European Union
EUR	Euro
FiT	Feed-in tariff
FTE	Full-time equivalent
GEM	Gender Equity Model
GERES	Groupe Energies Renouvelables, Environnement et Solidarités (Group for the Environment, Renewable Energy and Solidarity)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)
GW	Gigawatt
GWEC	Global Wind Energy Council
GWh	Gigawatt-hour
FDI	Foreign direct investment
ICS	Improved cookstove
ICT	Information and communications technology
IDAE	Institute for the Diversification and Saving of Energy (Institute for the Diversification and Saving of Energy)
IEA	International Energy Agency
IEC	Integrated Energy Center
ILO	International Labour Organization
I-O	Input-Output
INR	Indian rupees

IRELP	IRENA Renewable Energy Learning Partnership
IRENA	International Renewable Energy Agency
ITC	Investment Tax Credit
LCR	Local content requirement
MCI	Manufacturing, Construction and Installation
MENA	Middle East and North Africa
MNRE	Ministry of New and Renewable Energy
MW	Megawatt
MWh	Megawatt-hour
MW_{th}	Megawatt-thermal
NABCEP	North American Board of Certified Energy Practitioners
NGO	Non-governmental organisation
NLS	New Lao Stove
NSM	National Solar Mission
OECD	Organisation for Economic Co-operation and Development
O&M	Operations and maintenance
PJ	Petajoule
PPRE	International Postgraduate Programme Renewable Energy
PPP	Public-private partnerships
PTC	Production Tax Credit
PV	Photovoltaic
R&D	Research and development
RE	Renewable energy
RERL	Renewable Energy for Rural Livelihood programme
RET	Renewable energy technology
RPS	Renewable portfolio standard
SEWA	Self Employed Women's Association
SHS	Solar home system
SME	Small and medium-sized enterprise
SODECO	Solidarity and Community Development
SWH	Solar water heater
STEM	Science, Technology, Engineering, and Mathematics
TND	Tunisian dollar
TVET	Technical and Vocational Education and Training
UAE	United Arab Emirates
USA	United States of America
USD	U.S. dollar
ZAR	South African rand

Executive Summary

Renewables open new economic opportunities beyond energy

The International Renewable Energy Agency (IRENA) estimates that 5.7 million people worldwide were employed in the renewable energy sector, directly and indirectly, in 2012 (see Table 1)[1]. The largest number of jobs is found in biofuels and solar photovoltaic, 1.38 million and 1.36 million, respectively. The solar heating/cooling, wind power and biomass (heat and power) industries each employ several hundred thousand people. By comparison, biogas, geothermal energy, small hydropower and concentrated solar power are much smaller employers. Generally, better information is available for electricity-generating renewable energy technologies than for those relating to transportation and heating/cooling.

5.7 million people employed in the renewable industry worldwide in 2012

The employment dimension of renewable energy development is receiving growing attention. Around the world, policy makers are pursuing renewable energy technologies not only for greater energy security or environmental considerations, but also for the socio-economic benefits they generate. The renewable energy sector has become a significant employer, with the potential for adding millions of jobs worldwide in the coming years. Although no comprehensive global time-series data exist, evidence from individual renewable energy industries, especially wind and solar photovoltaic, for which there are better data than for other renewable energy technologies, as well as from selected countries, including Germany, Spain and the United States, highlights developments in more recent years. Wind power related employment has more than doubled in the past five years, while solar PV employment has soared nearly 13-fold.

The bulk of renewable energy employment is concentrated in Brazil, China, the European Union, India and the United States. These are the major manufacturers of renewable energy equipment, producers of bioenergy feedstock and installers of production capacity. Many other countries, however, are stepping up their investments and implementing policies in support of renewables deployment, thereby creating jobs, mostly in operations and maintenance activities.

TABLE 1: EMPLOYMENT IN RENEWABLE ENERGY GLOBALLY AND FOR SELECTED COUNTRIES/REGIONS

	WORLD	BRAZIL	CHINA	INDIA	UNITED STATES	EUROPEAN UNION (EU)		
						GERMANY	SPAIN	OTHER EU
	Thousand jobs							
Biomass	753		266	58	152	57	39	178
Biofuels	1 379	804	24	35	217	23	4	82
Biogas	266		90	85		50	1	20
Geothermal	180				35	14	0.3	37
Small Hydropower	109			12	8	7	2	18
Solar Photovoltaic	1 360		300	112	90	88	12	212
Concentrated Solar Power	37				17	2	18	
Solar Heating/ Cooling	892		800	41	12	11	1	20
Wind Power	753	29	267	48	81	118	28	124
TOTAL	5 729	833	1 747	391	612	370	105	691

[1] *Due to data limitations, this estimate excludes large hydropower and traditional biomass. For further details on this table refer to Chapter 1..*

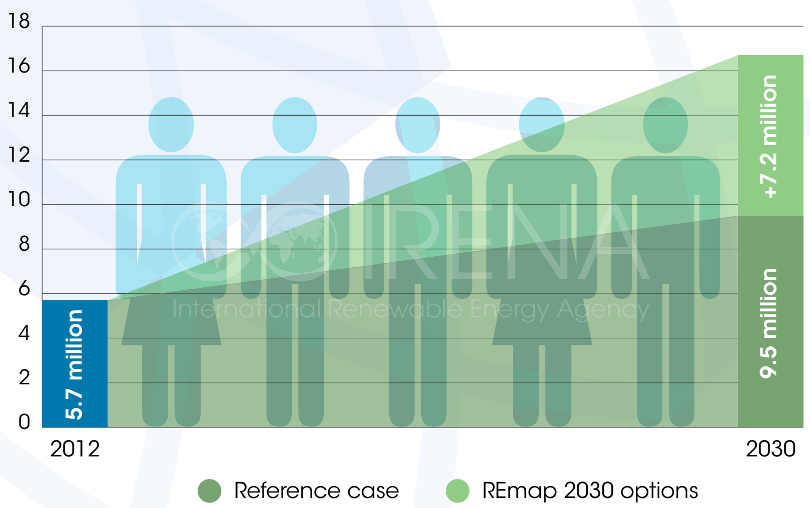
Employment trends vary widely across renewable energy technologies. Jobs in solar photovoltaic have outpaced those in wind in the last three to four years have tripled in solar heating/cooling since 2005. The increase in biofuels capacity is leading the growth of employment while the mechanisation of feedstock operations is reducing the related labour needs. Time-series data are lacking for other renewable energy technologies, but expanding capacity in both geothermal and small hydro sectors is translating into rising employment. A key question for job creation will be the future trajectories of renewable energy technologies, especially biofuels, which have seen considerable fluctuation and the trends in government support policies.

Recent trends in renewable energy costs and investment have had varying impacts on job creation in the different segments of the value chain. Renewable energy employment reflects regional shifts in renewable energy manufacturing, manufacturing overcapacities and industry realignments, growing export competition, and the impacts of austerity and policy uncertainty. It will be critical to gain a solid understanding of these trends as they continue to unfold. For instance, although declining costs of solar photovoltaic and wind equipment are introducing new challenges for suppliers and affecting manufacturing jobs, they are also driving growth in deployment and corresponding jobs in installation and operations and maintenance. These shifts will affect the relative shares of employment and thus the overall occupational and skill patterns in the renewable energy sector.

Projections of future employment largely depend on assumptions about the scale of investments and capacity additions, which in turn depend on the supportive policies that are established, the trends in the cost of renewable energy technologies, and labour productivity. The latter will reduce employment over time, but may be compensated by large-scale deployment.

In the IRENA REmap 2030 options, direct and indirect global employment in renewable energy used for power, buildings, transport and industry in 2030 would account for around 16.7 million jobs[2,3]. Of these, 9.7 million would be in bioenergy, 2.1 million in wind energy, 2 million in solar photovoltaic, 1.8 million in solar water heating, 0.6 million in small hydropower and 0.5 million in the other renewable energy technologies (concentrated solar power, landfill gas, geothermal, tidal, wave and ocean). If the REmap business as usual scenario is assumed, the total direct and indirect jobs in the renewable energy industry would be 9.5 million only, still a considerable increase from the current figure of 5.7 million.

Figure 1 IRENA REmap 2030 employment estimations



[2] *REmap 2030 is a global roadmap for renewable energy designed to demonstrate possible pathways and priority actions for meeting the aspirational target, articulated in the Sustainable Energy for All initiative, of doubling the share of renewables in the global energy mix by 2030..*

[3] *To maintain consistency and show a trend between 2012 and 2030, the REmap 2030 job estimates were adjusted to exclude large hydro and include solar water heating and indirect jobs for all renewable energy technologies. The estimate does not include traditional biomass.*

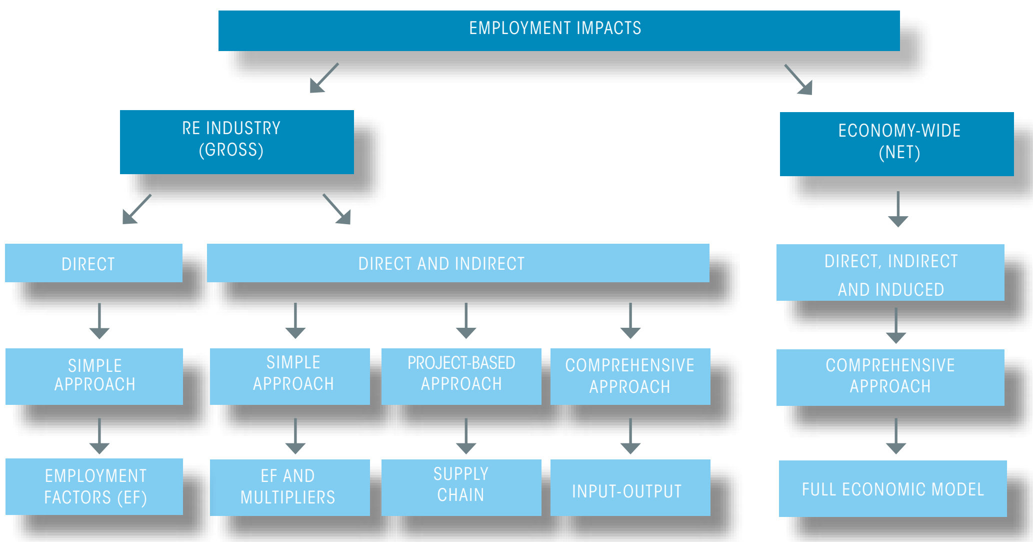
The importance of measuring employment from renewable energy

Despite recent improvements, major gaps remain in renewable energy employment data. Due to the cross-cutting nature of the renewable energy sector, such information is difficult to capture in standard national statistics. Only a few countries are gathering relevant data on renewable energy jobs. In most cases, employment figures are derived from various sources, using heterogeneous methods, assumptions and time frames. The quality of existing employment data remains uneven, necessitating greater harmonisation of data reporting categories.

Sound information on renewable energy employment is essential to enable informed policy choices. High-quality data is critical to monitor policy effectiveness, and to support policy makers in communicating the benefits of these policies to the wider public with reliable facts and figures. The most valuable data distinguishes between direct and indirect employment in different segments of the value chain (fuel production, manufacturing, construction, installation, operations and maintenance, etc.), disaggregate across different parts of the renewable energy sector (agriculture, construction, manufacturing, services), provide occupational details (gender, wages, etc.) and differentiate between domestic and export-driven employment.

The simplest and least resource-intensive method for assessing direct jobs is the employment factor approach. This is based on data for installed capacities, energy production and employment factors. However, the quality of the employment estimates depends largely on the accuracy and availability of country- and technology-specific data. Moreover, existing employment factors refer mainly to countries of the Organisation for Economic Co-operation and Development. Therefore, caution is warranted when drawing specific conclusions from the available employment factors and would benefit from sensitivity analyses to account for specific country's characteristics.

Figure 2 Schematic of key questions when choosing an approach to measure renewable energy employment



The supply chain, multiplier and Input-Output methods consider direct and indirect jobs, while full economic models broaden the scope of analysis to include net effects. These methods give a more comprehensive picture but tend to be more resource-intensive. Further increasing the sophistication of the analysis, full economic models capture the induced impact of renewable energy employment. The selection of the most appropriate method depends on the key questions, and the availability of underlying data and resources (human, financial, temporal, etc.).

Greater harmonisation of the methods used to estimate renewable energy jobs would enable more accurate comparisons across different technologies and countries. With sufficiently standardised and detailed information and analysis, the employment effects of renewable energy policies would be better understood and policy-making better targeted to maximise the benefits.

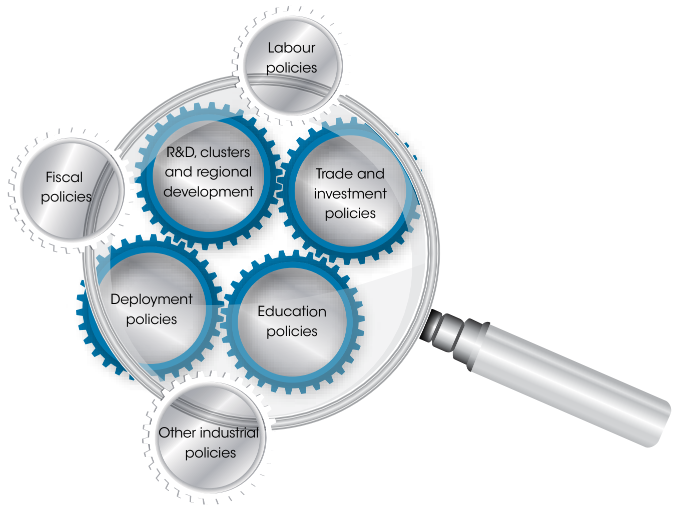
Interactions between different policy instruments in support of job creation

A broad range of policies influence renewable energy job creation. These include policies governing renewable energy deployment, trade, investment and research and development, as well as regional development and cluster formation. These policies are most effective when they are pursued in conjunction with each other, in concert with broader economic policies such as industrial, labour, and fiscal.

Steadiness and predictability in governmental policies are important to ensure stability and continued growth in employment. Although governmental support policies need to adjust to changing market conditions, the experience of recent years demonstrates the need to avoid abrupt policy reversals which may put renewable energy jobs in jeopardy.

Cross-border trade and investment flows are increasingly relevant to the renewable energy sector, with implications for employment. To maximise domestic job creation opportunities, national policies need to be calibrated carefully depending on the strengths and weaknesses of a particular country. Capacities and opportunities vary across countries, depending on respective renewable energy resource endowment, stage of industrial development, and availability of a local skilled workforce.

A free-trade regime for renewable energy technologies makes imported renewable energy equipment generally more affordable than under high import tariffs, thereby facilitating employment in installation, operations and maintenance. Trade liberalisation, however, can make it difficult for domestic manufacturers to compete with cheaper imports, impacting the chances for creating domestic renewable energy manufacturing jobs. Foreign direct investment typically provides greater opportunities than trade links do for joint ventures between foreign and domestic firms, which can set the foundation for a nascent domestic renewable energy industry.



Careful policy consideration is needed with regard to local content requirements. Many governments are adopting local content requirements, tied to deployment policies, in a push to establish local renewable energy industries. It is essential to pay attention to their design and to link them closely to a learning-by-doing process. To ensure the full-fledged development of an infant industry, local content requirements should not only be time-bound, but also accompanied by measures to facilitate the creation of a strong domestic supply chain and a skilled workforce, and to advance research and development programmes.

Industrial clusters, which facilitate information sharing and cross-pollination of ideas, can provide important benefits in the development of renewable energy capabilities. A cluster typically refers to a geographic concentration of interconnected economic and innovative activities in a particular field. Clusters and regional policies involve a variety of economic actors, including government agencies, private businesses and universities. Research and development is typically a crucial component of such efforts, often motivated by the need to overcome economic challenges, such as crises in older industries or lack of economic diversification. Governments can play an important role in setting the broad framework within which clusters can operate successfully, combining industrial, market-creating and business support policies, in order to fully mobilise the inherent potential.

Renewable energy skills, education and training: key enablers

High demand for qualified human resources in the sector is expected to continue, raising the potential for skills gaps and labour shortages. If not addressed in a timely manner, the shortage of necessary skills in the renewable energy sector could become a major barrier to the deployment of renewable energy. This can slow down progress, and installations performed by inadequately skilled personnel can result in performance issues and lead to a negative public perception of renewable energy technologies. Although renewable energy companies may be able to draw on experienced workers from other industries, this may not be a viable solution in the long term.

Successful deployment of renewable energy technologies requires forward-looking renewable energy education and training policies. There is a significant variation in the skills demanded in the renewable energy sector by occupation. Medium and high-skilled occupations, which require a certain level of education and training, are by nature more difficult to fill. Therefore, it is essential that the renewable energy sector strategy accounts for how skill needs in the future may evolve in the context of rapid technology changes.

In addition to renewable energy technology-specific skills, training programmes should also provide core technical and soft skills that increase workers' employment flexibility. In many countries, the majority of renewable energy jobs will be in installing, operating and maintaining renewable energy production facilities, rather than in manufacturing equipment. Therefore, workers need transferable skills that allow them to be employed flexibly in different jobs or projects. In the context of energy access, where the installations tend to be simpler, basic commercial skills, accounting, price design, inventory, quality assurance, etc., as well as marketing and after-sales service skills can be as important as technical skills.

Countries will be successful in the deployment of renewable energy technologies only if effective renewable energy education and training policies are in place. Policy makers have various ways of pro-actively include renewable energy topics in the existing and new educational programmes and institutions. This can be done by fostering the creation of interchangeable job and training specifications, harmonisation of curricula and the development of common quality standards for training programmes and trainers.

Off-grid solutions: catalysing local employment and economic growth

IRENA estimates that reaching the objective of universal access to modern energy services by 2030 could create 4.5 million jobs in the off-grid renewables-based electricity sector alone. This estimation provides an indication of the magnitude of the job creation potential if the other end-use sectors, *i.e.*, heating/cooling and transport, are included. Local employment is more likely to be concentrated in assembly, distribution, installation, operations and maintenance and after-sales services, rather than in manufacturing.

4.5 million jobs in off-grid renewable electricity sector by 2030

Achieving universal access to modern energy services is a vital pre-requisite to advancing socio-economic development. In addition to national and local energy access programmes, several global initiatives, such as the United Nations' Sustainable Energy for All initiative, have been launched to mobilise action towards achieving this goal. Decentralised renewable energy, in particular, can play an important role where extending the grid is more expensive or impractical, or the pace of extensions is slow. Off-grid renewable energy solutions are already cost competitive in many circumstances and bring high potential for job creation along the supply chain.

Renewable energy jobs in rural areas vary significantly depending on the specific renewable energy technologies and the deployment approach adopted. The scale of off-grid renewable energy applications, typically much smaller than grid-connected, has implications for how they are distributed, installed and operated. This, in turn, affects the type and number of jobs involved and the types of technical and business skills required. Analysis of selected case studies also suggests that the characteristics and number of jobs depend largely on local variables such as social factors (*e.g.*, family relations, societal structures), market-based factors (*e.g.*, demand fluctuations, deployment model) and policy-based factors (*e.g.*, employer legal obligations).

There is growing evidence that decentralised renewable energy solutions can create value locally in terms of both employment and economic growth. This potential is considerably enhanced when renewable energy projects are well integrated with local commercial activities. Figure 3 illustrates the supply chain for solar photovoltaic systems and identifies segments that are typically domestic or import-driven (or a mix of both). Local enterprises play an increasingly important role in extending access through the adoption of innovative business models. In addition, many of the technical and commercial skills required can be developed locally, thereby enhancing the sustainability of local economic activities.

Figure 3 Illustrative off-grid supply chain for solar photovoltaics

Dedicated off-grid renewable energy policies are key to transforming rural economies. The adoption of an integrated programmatic approach specifically targeting the sector is necessary to achieve universal access to modern energy. As such, the provision of energy access should go beyond meeting basic needs to include energy services for productive uses to enable a range of downstream micro-enterprises for rural economies. A better understanding of the employment effects of different energy access approaches (*e.g.*, number of jobs created by technology, type of employment, wages, skills and training requirements, gender dimension, etc.) can guide policy-making towards achieving the full potential of employment from renewable energy deployment.

Gender dimensions of renewable energy employment

Women's talents and insights remain under-utilised in the renewable energy sector. In both industrialised and developing countries, gender stereotypes are powerful inertial forces which continue to restrict women's participation in, and contribution to, the sector. However, the nature of the gender gap is vastly different in the modern energy context, where the entire population has adequate access to energy, than in rural areas of the developing world, where women and children typically bear the burden of inadequate energy access.

In the modern context, women are still a minority in the renewable energy workforce, particularly among technical staff and management. In industrialised countries, the share of female employees in the sector is estimated at about 20-25%, with most women working in administrative and public relations positions. Among the key constraints are issues related to self-perception, mobility and skills. For example, the low percentage of women who graduate in the so-called STEM (science, technology, engineering, and mathematics) fields directly affects women's participation in the renewable energy sector. Within the industry itself, barriers to women's advancement relate not only to ingrained views and attitudes, but also to the way that workplaces are organised and influence the work/life balance.

In the majority of developing countries, women face day-to-day challenges related to cooking and lighting their households, especially in rural areas. They are often compelled to spend long hours collecting firewood and other materials for fuel, which markedly limits their ability to pursue education or find employment. In terms of employment, female employees are a minority in most rural renewable energy enterprises, particularly in managerial and technical positions. Limited capital and mobility, as well as socio-cultural restrictions, preclude a larger role for women in many modern renewable energy technologies.

Including the gender dimension in the renewable energy equation can help simultaneously address the expected skill shortages in the industry while maximising socio-economic benefits. By removing existing barriers and working towards equal opportunity for the employment of women in the sector, the pool of talent can be substantially increased. In developing countries, renewable energy employment provides an opportunity to address the disparity in poverty between women and men, especially considering that women represent 70% of the world's 1.3 billion people in extreme poverty. The inclusion of gender dimensions in renewable energy strategies and the empowerment of women in energy decisions can multiply renewable energy co-benefits, particularly those related to access, household consumption and micro-enterprises, where women are primary actors.

KEY RECOMMENDATIONS

The findings of this report indicate that in designing and implementing policies to increase the number of renewable energy jobs, policy makers may consider:

The importance of measuring employment from renewable energy

» Systematic data collection and thorough analysis to estimate employment at the country level is essential to inform policy-making, evaluate the effectiveness of deployment policies and communicate the results to the public at large. Among the various methods available to estimate employment in the renewable energy sector, each country should consider which best suits their needs and resources. To the extent possible, countries should also seek to harmonise methods and data reporting categories.

» The most useful data would distinguish between conventional and renewable energy employment (by technology and use) and direct and indirect employment; disaggregate among the main components of the renewable energy sector (feedstock operations, manufacturing, engineering, construction and installation, and operations and maintenance) and provide occupational details (*e.g.,* wages, gender, etc.).

Interactions between the different policy instruments in support of job creation

» National renewable energy policy choices need to be combined carefully with an eye towards a country's particular strengths and weaknesses. A key requirement is that policies provide a stable, predictable framework that anchors investor confidence and supports job creation in the sector.

- Efforts to maximise socio-economic impacts of renewable energy deployment, and job creation in particular, benefit from a tailored policy mix that entails coordination between deployment and other interacting policies, such as education, trade, regional development, industrial and labour.

Renewable energy skills, education and training: key enablers

- Policy makers can facilitate the inclusion of renewable energy topics in existing and new educational programmes, and increase awareness of the career opportunities in renewable energy to attract young people entering the sector, as well as experienced workers from other industries with relevant skills.

- Governments can provide financial support for renewable energy education and training at universities or other suitable institutions, and foster international and interdisciplinary collaboration, such as the creation of interchangeable job and training specifications, harmonisation of curricula and development of common quality standards for training programmes and trainers.

- The private sector is well placed to provide relevant technical skills in a timely fashion through on-the-job apprenticeships and training programmes. Public and private sector actors should, therefore, collaborate in order to benefit from their respective strengths to most effectively meet the needs of the sector.

Off-grid solutions: catalysing local employment and economic growth

- Dedicated off-grid renewable energy policies are key to transforming rural economies. An integrated programmatic approach specifically targeting the sector should be promoted to ensure that timely expansion of energy access can generate economic growth and improve the livelihoods of millions of people.

- There is a need to develop a comprehensive framework to collect, analyse and disseminate the employment impacts of rural energy access initiatives. Data on rural renewable energy employment, both quantitative and qualitative, can be crucial in guiding policy-making towards adopting energy access approaches that maximise socio-economic development in rural areas.

Gender dimensions of renewable energy employment

- Removing barriers to entry for women's employment in the renewable energy sector is a win-win proposition, both to address the existing skills gap in a rapidly expanding renewable energy industry and to create equal opportunities for women.

- In order to maximise renewable energy co-benefits, particularly those related to energy access, household consumption and micro-enterprises, it is essential to include gender perspectives in policies and support services (*e.g.*, training, access to finance), and to provide other incentives to encourage employment of women in renewable energy.

About the report

Purpose. This report aims to offer a comprehensive view of the various dimensions of renewable energy employment, drawing on the experience of countries, regions and localities around the world. Although many studies now assess employment in the renewable energy sector, this report is unique in that it aims to: (i) assemble in one report key global data as well as to offer observations about the most recent trends and dynamics; and; (ii) articulate the numerous and often interdependent dimensions of employment in the sector, in order to contribute to the growing discussion and understanding about renewable energy jobs.

Target audience. The observations and insights in this report are directed towards policy makers who are concerned with developing the renewable energy sector, as well as towards institutions that are focused on employment issues. However, the findings are also of relevance to a broader audience seeking general information on the various dimensions addressed in the report.

Information sources. The report compiles information from a wide variety of publicly available reports, studies and databases. The underlying literature review includes publications by government ministries and international agencies, industry associations, non-governmental organisations (NGOs), consultancies and academic institutions. It also includes articles published in both print and online renewable energy journals. Data sources do not include any primary data collected directly from renewable energy enterprises. To arrive at several of the global employment figures, some data calculations and estimates were made, but no modelling was undertaken.

Definitions. As per the International Labour Organisation, a *job* is defined as "a set of tasks and duties performed, or meant to be performed, by one person, including for an employer or in self employment". *Occupation* refers to the kind of work performed in a job. The concept of occupation is defined as a "set of jobs whose main tasks and duties are characterized by a high degree of similarity". Employees are considered to have *informal jobs* if their employment relationship is, in law or in practice, not subject to national labour legislation, income taxation, social protection or entitlement to certain employment benefits (advance notice of dismissal, severance pay, paid annual or sick leave, etc.).

Technologies covered. The renewable energy resources, technologies and end-uses covered in this report include solar power (photovoltaics and concentrated solar power), solar thermal (water heating), wind, hydropower, geothermal energy (heat and power applications) and bioenergy (modern biomass for heat and power use, as well as biofuels for transportation). With regard to hydropower, the report focuses on small-scale hydro. Although large facilities account for the majority of installed hydropower generating capacity – and hence a large number of jobs – employment information for large hydro is incomplete. In addition, traditional biomass is not included in analysing the global picture given the poor and scattered data on the topic.

Analytical framework. The report considers employment throughout the renewable energy value chain. This chain includes the harvesting of natural resources (in the case of bioenergy); the manufacturing of equipment needed to process feedstock or otherwise harness renewable energy sources (wind turbines, solar panels, biogas digesters, etc.); project development for wind, solar, geothermal, hydropower and biomass plants (*i.e.*, engineering and construction work); sales, distribution and installation of equipment; and operations and maintenance of renewable energy facilities. Although increasingly relevant, the report does not consider the decommissioning stage of renewable energy installations.

Limitations. Given data limitations, the analysis in this report mainly addresses the formal sector and focuses primarily on electricity-related applications.

Structure: The analysis in this report is structured around 6 chapters spanning the various dimensions of renewable energy employment.

Chapter 1 reviews the current status of employment in the renewables sector in industrialised and developing countries, demonstrating the significance of current job levels as well as potential for the future. The chapter brings together available information for each renewable energy technology and takes a closer look at several countries that have played a prominent role in renewable energy deployment.

Chapter 2 provides an overview of the key methods that can be used to estimate the employment impacts of renewable energy deployment, noting their relative strengths and weaknesses, as well as the underlying data reporting requirements for each. It explains the essential steps required for the employment factor, multiplier, supply chain and input-output methods as well as economy-wide analysis.

Chapter 3 considers the importance of various policy instruments, and their interaction, that influence job creation from renewable energy deployment. These include market-creating policies, such as feed-in tariffs, auctions and various fiscal incentives. The chapter takes a closer look at trade and investment policies, such as local content requirements, regional development policies and the formation of industrial clusters.

Chapter 4 investigates the skills, education and training that are necessary at all levels, from project planners to design engineers and technicians in operations and maintenance, to allow the expansion of the industry. It explores the different roles of public and private stakeholders and the importance of collaboration that builds on their respective strengths to most effectively meet the needs of the sector.

Chapter 5 presents the potential for job creation and local development opportunities stemming from improved energy access through renewable energy solutions. It describes the employment dimension of various off-grid renewable technology deployment across all segments of the value chain. It also provides insights into the qualitative aspects of job creation in rural areas, such as labour quality and intensity.

Chapter 6 discusses the gender dimension of renewable energy deployment, both in modern settings and in the context of energy access. The chapter explores the opportunities and constraints associated with the increasing involvement of women in the sector, as well as their potential role in addressing the skills gap. It argues that the inclusion of the gender dimension in renewable energy strategies and the empowerment of women in energy decisions can multiply socio-economic benefits.

1 Renewable Energy Employment Figures and Trends

© Adapted from Dennis Schroeder/NREL

The renewable energy industry has grown rapidly in recent years and global investments in renewables have surged six-fold in less than a decade, from USD 39.5 billion in 2004 to USD 244 billion in 2012 (Frankfurt School-UNEP Centre/Bloomberg New Energy Finance (BNEF), 2013).

The upshot has been a substantial expansion of installed renewable energy capacities (although in some cases starting from a very small base; see Table 1.1). Some of this capacity has been built over decades, whereas other technologies are more recent. Most existing hydropower capacity was installed over the past half century, with smaller-scale hydro driven by efforts to improve energy access in specific countries. Geothermal power, which has been used in a small number of countries for several decades, has experienced sustained growth more recently. The wind, solar photovoltaic (PV), concentrated solar power (CSP), solar water heating (SWH) and

Table 1.1 Global capacity/production of selected RETs, 2000 and 2012

RET	Installed capacity/production	
	2000	2012
Capacity		
Wind power (GW)	17	283
Geothermal power (GW)	8	11.2
Solar PV (GW)	1.4	100
CSP (GW)	0.35	2.5
Solar water heating (GW_{th})	44	255
Hydropower (GW)	690	990
Production		
Ethanol (billion litres)	17	83.1
Biodiesel (billion litres)	0.8	22.5

Source: Adapted from Renewable Energy Network for the 21st Century (REN21), 2013; Musolino, 2013; Energy Information Administration (EIA), n.d..

biofuels industries, meanwhile, have risen to prominence only in the last one or two decades. This growth in renewable energy over time has translated into increasing employment in the sector.

1.1 STATE OF RENEWABLE ENERGY EMPLOYMENT

Based on a wide review of studies (primarily from 2009-13 as well as some older reports), an estimated 5.7 million people worldwide work in the renewable energy sector (see Table 1.2). These employment estimates may be on the conservative side, however, as existing reports rely on varying methods and are of uneven accuracy. Moreover, due to data limitations these estimates do not include large-scale hydropower or traditional uses of biomass.

The data in Table 1.2 include direct and indirect employment but not induced jobs (see Box 1.1 for key definitions). The global renewable energy workforce encompasses a broad variety of occupations and specialisations in agriculture and forestry, manufacturing, construction, installations, and operations

TABLE 1.2 EMPLOYMENT IN RENEWABLE ENERGY GLOBALLY AND FOR SELECTED COUNTRIES/REGIONS

	WORLD	CHINA	INDIA	BRAZIL	UNITED STATES	EUROPEAN UNION (EU)		
						GERMANY	SPAIN	OTHER EU
	Thousand jobs							
Biomass [a,j]	753	266	58		152 [f]	57	39	178
Biofuels	1 379	24	35	804 [e]	217 [g]	23	4	82
Biogas	266	90	85			50	1	20
Geothermal [a]	180				35	14	0.3	37
Small Hydropower [b]	109		12		8	7	2	18
Solar PV	1 360	300 [d]	112		90	88	12	212
CSP	37				17	2	18 [i]	
Solar Heating/ Cooling	892	800	41		12	11	1	20
Wind Power	753	267	48	29	81	118	28	124
TOTAL [c]	5 729	1 747	391	833	612	370 [h]	105	691

Notes: Totals may not add up due to rounding. The data are mostly from 2009-2012, with some underlying sources dating to 2007. Data gaps in the table do not necessarily depict zero employment and could reflect lack of specific data.

[a] Power and heat applications. [b] In this table, employment data focuses on small-hydro. Employment information for large-scale hydro is incomplete, however, preliminary estimates based on the employment factor approach (Section 2.2) indicate that in 2011 it ranged from 370 000 to 590 000 jobs depending on the assumptions for regional labour productivity. Definitions regarding the threshold used between small and large hydro are inconsistent across countries, although 10 MW is often used. Hence, a clear distinction between large and small hydro is not always possible for employment. [c] Derived from the world totals of employment (first column) for each RET. [d] Estimates ran as high as 500 000 in 2011. [e] About 365 000 jobs in sugar cane and 213 400 in ethanol processing in 2011; also includes 200 000 indirect jobs in manufacturing the equipment needed to harvest and refine sugarcane into biofuels, and 26 000 jobs in biodiesel. [f] Biomass power direct jobs run only to 15 500. [g] Includes 173 600 jobs for ethanol and 42 930 for biodiesel in 2012. [h] Includes 9 400 jobs in publicly funded research and development (R&D) and administration; not broken down by technology. [i] Estimate from Protermosolar offers figures for 2011 (28 885 jobs) and 2012 (17 862). [j] Traditional biomass is not included.

Sources: Global numbers for biomass, biogas, CSP, solar heating/cooling and wind power are aggregates of individual countries and regions shown in the table. The global biofuels figure is taken from Urbanchuk, 2012 and the solar PV figure from the European Photovoltaic Industry Association (EPIA), 2012. The geothermal and small hydro figures are author estimates. Chinese numbers are from the following sources: biomass power from Junfeng, 2007; biofuels from Urbanchuk, 2012; biogas from the Institute for Urban and Environmental Studies (IUES) and the Chinese Academy of Social Sciences (CASS), 2010; solar PV from Yunwen, Jiliáng and Lina, 2012 and IEA, 2013a; solar heating/cooling from the Institute for Labour Studies (ILS) and the Ministry of Human Resources and Social Security of China (MOHRSS), 2010; and wind from the Global Wind Energy Council (GWEC) and Greenpeace International, 2012. Indian biofuels from Urbanchuk, 2012, and Indian wind power from GWEC and Greenpeace International, 2012. All other Indian figures are from the Ministry of New and Renewable Energy (MNRE) and Confederation of Indian Industry (CII), 2010. Brazil biofuels from Ministério do Trabalho e Emprego/ Relação Anual de Informações Sociais (MTE/RAIS), 2012; from Urbanchuk, 2012; and from Almeida, Bomtempo and Souza e Silva, 2007. Brazil wind power from GWEC, 2013. The United States geothermal power calculation is based on Jennejohn, 2010 and on 2012 capacity data. Other United States figures from the following: biomass from Bezdek, 2007; biofuels from Urbanchuk, 2013; solar PV, CSP and solar cooling/heating from the Solar Foundation, 2012 and the Solar Energy Industries Association (SEIA), 2011; and wind power from the American Wind Energy Association (AWEA), 2013. EU figures derived from EurObserv'ER, 2013. German data from O'Sullivan et al., 2013. Spanish data from Association of Renewable Energy Producers (Asociación de Productores de Energías Renovables-APPA), 2012; except for CSP figures, which are from Crespo, 2013 (for 2011) and Gonzalez, 2013 (for 2012).

Box 1.1
KEY DEFINITIONS

Direct employment refers to employment that is generated directly by core activities without taking into account the intermediate inputs necessary to manufacture renewable energy equipment or construct and operate facilities. These directly involved industries are also called renewable energy industries (sectors). Direct employment data may be estimated on the basis of an industry survey, or data derived from representative projects and facilities for the industry in question (Bacon and Kojima, 2011), or derived from economic data such as labour input coefficients for selected industries.

Indirect employment includes the employment in upstream industries that supply and support the core activities of renewable energy deployment. Usually, these workers do not consider themselves as working in renewables; they produce steel, plastics or other materials, or they provide financial and other services. These industries are not directly involved in renewable energy activities but produce intermediate inputs along the value chain of each renewable energy technology (RET). A review of employment factors available in the literature indicates that the inclusion of indirect jobs typically increases overall job numbers by anywhere from 50% to 100% (Rutovitz and Harris, 2012).

Induced employment encompasses jobs beyond the renewable energy industry and its upstream industries, such as jobs in the consumer goods industry. When people who are employed directly or indirectly spend their incomes on a variety of items in the broader economy (such as food, clothing, transportation and entertainment), the expenditure gives rise to induced employment effects. Similarly, changes in consumer electricity tariffs due to higher/lower costs of RETs give rise to induced employment impacts as the disposable income of the consumer changes.

Long-term employment encompasses jobs that can be maintained for several years due to either domestic RET deployment or export markets. Examples are jobs in fuel supply (cultivating and harvesting feedstock for bioenergy) or in O&M.

Short-term employment in domestic RET deployment refers to jobs required only for a short period of time, for example in the planning of a renewable energy facility, or in construction and installation. If, however, there is a steady flow of new installations, replacements and repowering, then planning and service jobs are needed in a more permanent fashion. This could be the case given ongoing international RET deployment and strong, competitive domestic production.

and maintenance (O&M). Jobs range from low to high skilled and differ widely in duration. Estimates in this report constitute "gross employment" and do not account for any loss in employment elsewhere in the energy sector, such as in the fossil fuel or nuclear power industries.

Today, the bulk of renewable energy employment is concentrated in China, the European Union (EU), Brazil, the United States and India. These are the major manufacturers of renewable energy equipment, producers of bioenergy feedstock and installers of production capacity. Many additional countries, however, are experiencing growth in renewable energy deployment – and hence in employment, arising mostly out of O&M activities. This includes countries in Africa, which currently has limited renewable energy employment and is not represented in Table 1.2.

Throughout this report, text boxes profile a variety of countries that have not featured prominently in the literature, with the aim of widening the knowledge of employment impacts and prospects beyond the narrow range of countries for which more extensive information is available.

Renewable energy technologies (RETs) have been largely deployed for grid-connected electricity provision and urban energy use. But renewables are increasingly a solution for rural communities that lack adequate energy access. As RETs become more widespread in rural areas, increasing numbers of jobs will be available in the off-grid sector of the developing world, principally for sales staff and for technicians with middle to low levels of skill. In rural Bangladesh, selling, installing and maintaining small PV systems provides livelihoods for as many as 70 000 people, and an estimated 150 000 people are employed both directly and indirectly (Haque, 2012; Barua, 2012). Reaching the objective of sustainable energy for all could create nearly 4.5 million direct jobs globally in the off-grid renewable enlectricity sector alone by 2030 (see Chapter 5).

By RET, the largest number of jobs, about 1.38 million, is currently in the biofuels industry (Urbanchuk, 2012). Most of these jobs are in the agricultural sector, in cultivating and harvesting feedstock. In developing countries, due to the nature of the work, many of the jobs are low skilled and low paid, and can also fluctuate seasonally. The total number of people employed in these positions may shrink over time, however, as feedstock harvesting is mechanised, reducing the need for human labour – as is occurring in Brazil.

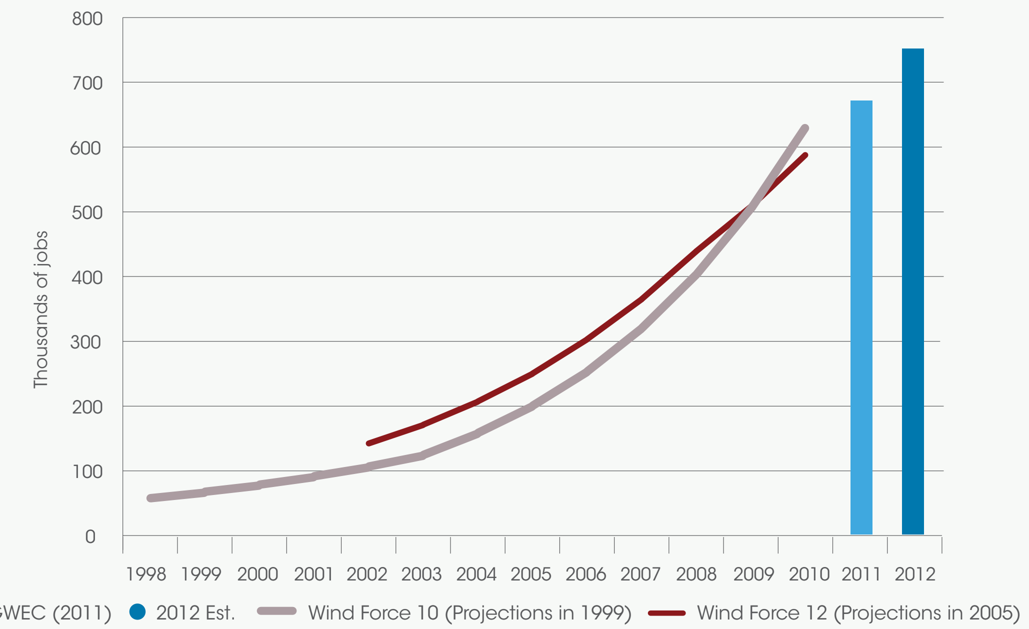
Employment in solar PV has surged in recent years and is now estimated at 1.36 million, roughly on par with biofuels (EPIA, 2012). Yet the sector is currently experiencing turbulence. Massive manufacturing overcapacities and tumbling prices have caused layoffs and bankruptcies among manufacturers. At the same time, falling costs have triggered sharp increases in new installations of solar panels, raising total PV employment to new peaks. Other renewable energy industries – solar heating/cooling, wind power and biomass (heat and power) – employ smaller numbers of people, although still in the high hundreds of thousands each. In contrast, biogas, geothermal (heat and power), small hydro and CSP are much smaller employers.

1.2 EMPLOYMENT TRENDS BY RENEWABLE ENERGY TECHNOLOGY

Data limitations make it difficult to draw a dynamic picture of employment across all RETs; however, it is possible to estimate job trends over time for some individual technologies. Worldwide employment estimates for the wind and solar PV sectors are available from the mid to late 1990s. Estimates for solar thermal employment are less extensive and less refined, due possibly to the overlap with conventional sectors, and information for biofuels is fragmented. The "snapshots" available for other RETs are even more limited and do not provide a sense of the pace and trajectory of employment trends. These are gaps that need to be filled.

Wind Energy. Between 2007 and 2012, direct and indirect jobs in wind energy worldwide have more than doubled. Figure 1.1 shows employment projections

Figure 1.1 Worldwide Wind Energy Employment (1998-2012)



Sources: European Wind Energy Association (EWEA), Forum for Energy and Development (FED), and Greenpeace International, 1999; EWEA, Greenpeace International and Global Wind Energy Council (GWEC), 2005 and GWEC, n.d.

based on trends in installed capacity published in two early Wind Force reports, first in 1999 and then in 2005 (European Wind Energy Association (EWEA), Forum for Energy and Development (FED) and Greenpeace International, 1999; EWEA, Greenpeace International and GWEC, 2005). Projections from these reports are consistent with employment figures for 2011 that range from 646 000 to 670 000 jobs (GWEC and Greenpeace International, 2012; and GWEC, n.d.) and estimates for 2012 of 753 000 jobs (see Table 1.2).

Europe has long been the wind industry leader. Employment among manufacturer of wind turbines and parts, developers and operators in the region rose from some 183 000 direct and indirect jobs in 2007 to some 270 000 in 2010 (EurObserv'ER, 2013). But the industry is expanding increasingly into other parts of the world, leading to rising employment, especially in installations. In 2012, China and the United States were the undisputed leaders in total capacity added, ahead of Germany and India (GWEC, 2013). Japan, Australia and Brazil are also becoming more prominent players. Even in countries that are not global leaders, such as Mexico (see Box 1.2), wind energy is increasingly taking off and generating employment.

Solar PV. In recent years, solar PV employment has grown so rapidly that it has surpassed wind power employment. *Solar Generation* assessments published over the years offer time-series estimates of PV employment, indicating that job creation was very modest in the 1990s and began to gather steam only in the second half of the 2000s. Projections from *Solar Generation 3*, published in 2006, appear to have been very conservative compared with the actual pace of developments (Greenpeace International and EPIA, 2006). In *Solar Generation 6*, the numbers were revised sharply upwards to more closely reflect the brisk evolution of PV trends (Greenpeace International and EPIA, 2011).

Yet the pace of new installations has been so rapid in the last 3-4 years that even these projections appear to be low and outdated (see Figure 1.2). Various national and regional estimates suggest that direct and indirect PV jobs worldwide surpassed 900 000 in 2011. For 2012, the global total may have reached 1.36 million jobs, split fairly evenly between manufacturing and installations/maintenance, according to the European Photovoltaic Industry Association (EPIA, 2012). A key driver has been substantially lower prices for solar panels, which has triggered a boom

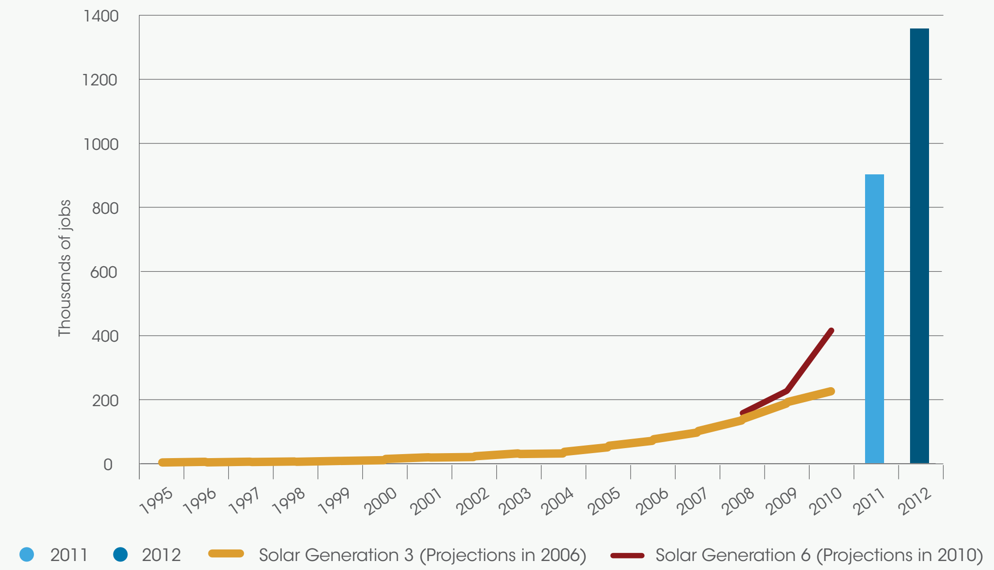
Box 1.2
JOB CREATION IN THE RISING MEXICAN WIND INDUSTRY

Mexico is experiencing a wind power boom, due in part to falling costs, new financing opportunities, improved mapping of the country's wind resources and growing awareness of the need for less carbon-intensive energy alternatives (Wood *et al.*, 2012). Installed capacity has expanded from just 84 megawatts (MW) in 2006 to 1.2 gigawatts (GW) in 2012, with another 2 GW under construction (The Wind Power, 2012; Wood *et al.*, 2012). Nationwide capacity could reach 12 GW by 2020 (Secretaría de Energía de México (SENER), 2013).

Mexico's Ministry of Energy estimates that by 2020, a total of 175 000 direct, indirect and induced jobs could be created in all RETs combined. Wind power alone, by with an added 12 GW of capacity, might offer direct employment to 48 000 people, including 9 300 jobs in construction, 4 400 in metal products, 2 000 in the plastics industry, 1 900 in electrical equipment, 1 800 in machinery and 600 in IT equipment, as well as 28 000 additional (indirect and induced) jobs (SENER, 2012).

The bulk of wind development has occurred in the southern state of Oaxaca; however, the lack of consultation and a sense that local benefits are inadequate has triggered local opposition (Wood *et al.*, 2012). The Oaxaca experience offers important lessons as wind resources are developed in northern Mexico, particularly in Tamaulipas, Baja California, Chihuahua and Nuevo León. Baja California's La Rumorosa I wind plant gained local support through sharing of information, consultation and transparency, and by making 90% of planning and construction jobs available to local people (Wood *et al.*, 2012). Mexico has attracted relatively limited investment in wind energy manufacturing thus far. Manufacturing and assembly plants in the country's north produce primarily for the United States market.

Figure 1.2 Worldwide Solar PV Employment (1995-2012)



Sources: Greenpeace International and EPIA, 2006; Greenpeace International and EPIA, 2011; EPIA, 2012

in installations (and O&M) and associated employment, even as manufacturers struggle.

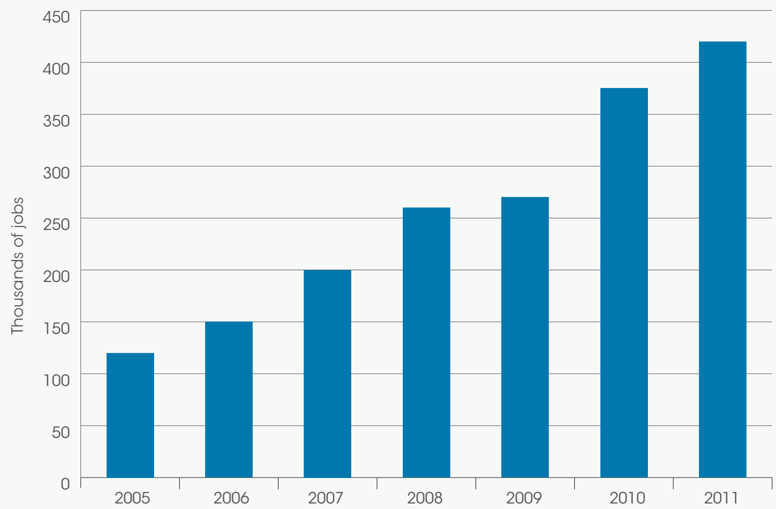
Chinese companies have rapidly become the world's largest PV manufacturers, employing some 300 000 people in the sector (IEA, 2013a). China's massive expansion of production capacities played a major part in bringing about global overcapacities, backed by cheap loans and land for factories but also by the development of turnkey production facilities that were built mostly by firms from Germany and the United States. In September 2012, China's National Energy Administration released a plan to strengthen the domestic PV market and reduce reliance on export sales, which account for the bulk of Chinese production. Complaints in the EU and the United States against unfair government subsidies have led to an agreement between the EU and China to set a minimum price for imports of RETs from China (EU, 2013).

Solar Heating/Cooling. According to the annual *Solar Heat Worldwide* report, global employment in solar heating/cooling expanded from 120 000 in 2005 to 420 000 by the end of 2011 (see Figure 1.3) (Weiss and Mauthner, 2011, 2012 and 2013). This includes jobs in production, installation and maintenance of solar thermal systems. A joint study from the International Labour Organization (ILO) and the Chinese government, however, puts employment in China's solar water heating (SWH) industry alone at 800 000, suggesting the need for closer analysis of the methods used in the analyses (ILS and MOHRSS, 2010). China is by far the world leader in solar hot water, with more than 80% of global installations. The exclusion of certain segments of the value chain, such as distribution, and diverging assumptions about labour productivity may be affecting the varying estimates.

Concentrated Solar Power. CSP is still in its infancy compared with solar PV and solar water heating. Spain and the United States currently dominate the global CSP market, with 76% and 20% of global installed capacity, respectively, at the end of 2012 (REN21, 2013). According to Protermosolar, Spain had about 29 000 jobs in the CSP industry in 2011, serving both the domestic and export markets (Crespo, 2013); however, employment is reported to have fallen below 18 000 in 2012 (Gonzalez, 2013). The future of CSP employment in Spain is clouded following a series of regulatory changes that began in early 2012, which are affecting both project development and industry revenues. A rough estimate suggests that there may be some 37 000 CSP-related jobs worldwide.

The Middle East and North Africa (MENA) region is emerging as an attractive destination for CSP deployment. In 2013, the United Arab Emirates (UAE) commissioned a 100 MW CSP plant, bringing the region's

Figure 1.3 Worldwide Employment in Solar Heating/Cooling (2005-2011)



Sources: Compiled from Weiss and Mauthner for 2011, 2010, 2009, and 2008; Weiss, Bergmann, and Stelzer for 2007; Weiss, Bergmann, and Faniger, for 2006 and 2005.

total installed capacity to 182 MW (REN21, 2013). Current targets for CSP deployment indicate strong growth in the coming decades, driven by a motivation to create local employment.

The MENA CSP Scale-up Investment Plan, supported by the World Bank and the African Development Bank, projects that up to 5 GW of CSP capacity will be installed in Algeria, Egypt, Jordan, Morocco and Tunisia by 2020. By developing the capacity to manufacture up to 60% of the CSP value chain domestically, these five countries could create between 64 000 and 79 000 local renewable energy jobs by 2025. Of these jobs, 45 000 to 60 000 would be in construction and manufacturing, and 19 000 in O&M (World Bank, 2011a).

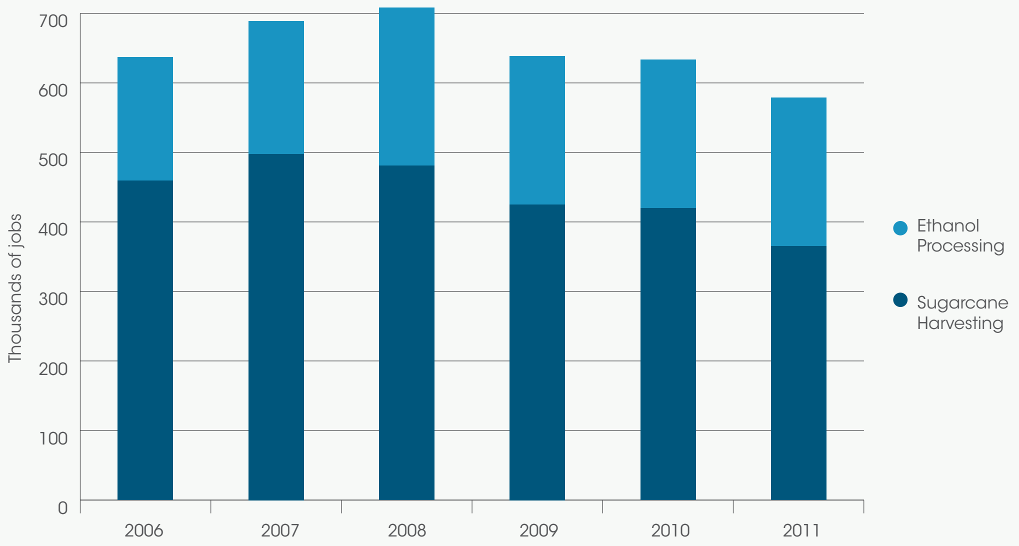
MENA countries have adopted different measures to develop appropriate policies and instruments to localise the value chain and provide more domestic employment opportunities (UAE Ministry of Foreign Affairs, IRENA and REN21, 2013). The highest local content for CSP would likely be achieved in areas such as construction, fabrication of metal structures, mirrors, float glass and certain engineering tasks (Pariente-David, 2011).

Bioenergy. Bioenergy is widely believed to have the largest employment potential of any RET, as it is considerably more labour-intensive than the other technologies. Cultivation and harvesting biomass feedstock requires large numbers of people, whereas processing the feedstock into fuels generates considerably fewer jobs. (Urbanchuk, 2012) estimates that the bioenergy industry employed some 1.4 million people directly and indirectly in 2010. The United States, Brazil and the EU are by far the dominant producers and employ the largest number of workers in the sector.

More so than for other RETs, bioenergy employment reflects widely diverging skill and pay levels. This is because agricultural operations play a large role in the sector, and much of this employment is generally low skilled and also fluctuates seasonally. Brazil's sugarcane-based industry is the single largest biofuels employer in the world, and because of lower labour productivity, it employs far more people than the United States biofuel industry, the world's leading producer. According to the Brazilian government, the country's bioethanol sector directly employed some 580 000 people in 2011, including 365 000 jobs in sugarcane harvesting and 213 400 jobs in ethanol processing (see Figure 1.4) (MTE/RAIS, 2012). The industry also supports substantial indirect jobs, including some 200 000 in manufacturing the equipment used to process sugar cane into fuel.

Rising mechanisation in Brazil's biofuels sector is reducing overall labour needs (Moraes, 2012); at the same

Figure 1.4 Direct Employment in Brazil's Bioethanol Industry (2006-2011)



Source: MTE/RAIS, 2012.

time, it is creating demand for skilled workers to operate farm machinery, albeit in smaller numbers. The country's two main feedstock-growing areas offer an interesting contrast: in south-central Brazil, where operations are more highly mechanised, biofuels workers have higher literacy rates (only 5% of the workforce is illiterate or with low levels of education) and enjoy higher wages and better work conditions than their counterparts in the north-northeast, where 55% of the workforce is illiterate or with low education and where manual labour still plays a large role in cane-cutting (Neves, Trombin and Consoli, 2010; Elbehri, Segerstedt and Liu, 2013).

For many developing countries, biofuels development holds the prospect of economic benefits, although in many cases it remains to be seen how well the potential translates into actual employment. In Indonesia, biodiesel production rose from 65 million litres in 2006 to 1 520 million litres in 2011 (Slette and Wiyono, 2012). Based on labour requirement assumptions, this might translate into 38 000 to 76 000 jobs[4] (Obidzinski *et al.*, 2012). Under a less conservative estimate, some 114 000 workers would be required to produce 1 550 million litres of biodiesel (Asia-Pacific Economic Cooperation (APEC), 2010).

Biofuels development can support rural economic development by attracting capital to the agricultural sector and increasing energy access. Yet employment and welfare impacts depend strongly on the nature of biofuels development that is being pursued. Local benefits will be relatively limited if outside workers are brought in and if there are pronounced seasonal fluctuations in employment (Elbehri, Segerstedt and Liu, 2013). Another dimension that deserves close scrutiny is the distinction between employment generated by biofuels projects and the broader livelihood impacts that such projects may have on local communities where land tenure is informal and tenuous.

Geothermal Energy. Information about geothermal employment is sparse. There is no question, however, that job numbers are low relative to other RETs, given the smaller installed capacities for geothermal versus wind, solar or hydropower. In addition, geothermal resources are concentrated in specific regions, and high economic risks in the exploration phase have traditionally prevented large-scale exploitation of the resources.

Globally installed geothermal power capacity has doubled since 1990, to 11 765 MW in 2013, and equivalent planned capacity additions are in the early stages of development or under construction (Matek, 2013a). By implication, employment can be assumed to have expanded considerably and will continue to grow. The largest installed geothermal power capacities are in the United States (3 389 MW), the Philippines (1 884

[4] *The authors argue that producing 400 million litres of biofuel requires 410 000 metric tonnes of crude palm oil, which in turn may require about 100 000 hectares of plantation land. They assume that 1 hectare of plantation land requires 5-10 workers. The bulk of Indonesia's palm oil production continues to go to food-related uses. To date, about 1% is used for biofuel production. The International Finance Corporation (2010a) reports that oil palm cultivation in Indonesia employs anywhere from 1.7 million to 3 million people, according to different estimates, with additional jobs in processing and associated activities.*

MW), Indonesia (1 333 MW), Mexico (980 MW) and Italy (901 MW), and geothermal is also heavily used in New Zealand, Iceland and Japan (Matek, 2013a). For direct use as heat, including from ground-source heat pump applications, the largest installed capacities (in megawatts-thermal) are in the United States, China, Sweden, Norway and Germany, although actual usage (in gigawatt-hours per year) is greatest in China, the United States, Sweden, Turkey and Japan (Lund, Freeston and Boyd, 2010).

Countries with installed geothermal capacities derive employment benefits in construction and O&M, which are by nature more domestic; however, the production of key inputs may result in job creation elsewhere, either in other economic sectors or in other countries. The Japanese companies Toshiba, Mitsubishi Heavy Industries and Fuji Electric play a central role in manufacturing geothermal turbines, controlling more than half the global market (The Economist, 2012). Together with Ansaldo/Tosi of Italy and Ormat of Israel, they account for more than 80% of the capacity in operation worldwide (REN21, 2013).

In the United States, geothermal employs some 35 000 people. In the EU, geothermal employment appears to be fairly stable at about 50 000 direct and indirect jobs, mostly in heat-related applications (EurObserv'ER, 2012). Geothermal district heating systems are expanding primarily in France, Iceland, Germany and Hungary (Sander, 2013). Aside from these estimates, no robust figures exist for global employment, although some information is available on selected countries, such as the Philippines (see Box 1.3). In general, the number of jobs appears to be expanding as new markets emerge for geothermal exploration and exploitation, in particular in Central and Latin America, India and the East African rift countries.

Small Hydropower. Whether connected to a national or local grid, small hydropower provides electricity to millions of people worldwide, including as many as 300 million in China, which is home to some 45 000 small hydro plants (Niez, 2010; Kumar *et al.*, 2011). Altogether, Asia has 68% of global small hydro installed capacity and Europe has 22%, while South America and Africa are marginal players (ARE, 2011). Employment estimates for small hydro are difficult to come by, in part because of the lack of agreement on what is considered "small". Generally, "large" hydropower refers to hydro-electric dams with an installed capacity of more than 10 MW, although some countries use thresholds as high as 25 MW (India), 30 MW (Brazil) and even 50 MW (Canada and China) (IRENA, 2012a).

Estimates suggest that small hydropower employs more than 50 000 people in the EU, the United States and India alone (MNRE and CII, 2010; European Small Hydropower Association (ESHA), 2011; Navigant Consulting, 2009). A rough calculation based on these capacity/employment ratios and regional shares of installed capacity suggests a global total of

Box 1.3

GEOTHERMAL ENERGY IN THE PHILIPPINES

The Philippines is the world's second largest producer of geothermal power after the United States. The country's electricity generation from geothermal doubled between 1990 and 2000 but subsequently stagnated. In addition to the existing 1 884 MW of capacity, the Philippines aims to install another 1 495 MW by 2030 under the National Renewable Energy Program (Philippines Department of Energy, 2013).

The Energy Development Corp. (EDC) controls about 60% of the Philippines' geothermal capacity and had close to 2 500 permanent employees in 2011. Local hires account for 76% of the company's workforce. With a determined skill-building effort, EDC is an all-Filipino enterprise (EDC, 2012).

Assuming that staffing levels are comparable at other companies – including Biliran Geothermal, Chevron Geothermal Philippines Holdings, Aboitiz Power Renewables, Ayala Corp. and First Gen Corp – these firms may directly employ an additional 2 000 or so workers. The industry also generates several thousand indirect jobs, although no comprehensive employment figures appear to be available (Greenpeace Southeast Asia, 2013).

at least 132 000 jobs. This figure is likely conservative, however, given higher labour intensities outside of Europe. According to one estimate, global installed small hydro capacity has roughly doubled in the past decade and may double again by 2020, indicating that employment will continue to expand (Thilak, 2010).

1.3 SELECTED COUNTRY EXPERIENCES

For most countries, renewable energy employment estimates are available at best for a single year or for scattered periods of time, limiting the conclusions that can be drawn. In many cases, the available data are not very robust, complete or up-to-date. This gap needs to be closed to gain a clearer picture of how renewable energy employment is evolving globally and what lessons can be drawn from the trends and dynamics. Countries like China, India and Brazil have experienced tremendous expansion in their renewables sectors over the last several years, but detailed employment information remains limited.

Three countries – Germany, Spain and the United States – have been among the global renewable energy leaders, and their experiences illuminate many of the broad trends and dynamics in the industry. Multi-year data on renewable energy employment are available for all three countries: in Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safet regularly commissions employment assessments across the range of RETs; in Spain, the renewable energy industry association, Asociación de Productores de Energías Renovables (APPA), as well as the public institute for energy diversification and saving, Instituto para la Diversificación y Ahorro de la Energía (IDAE), conduct such assessments regularly; and in the United States, industry associations provide data on the bioethanol, wind and solar industries (the United States federal government does not track renewable energy employment).

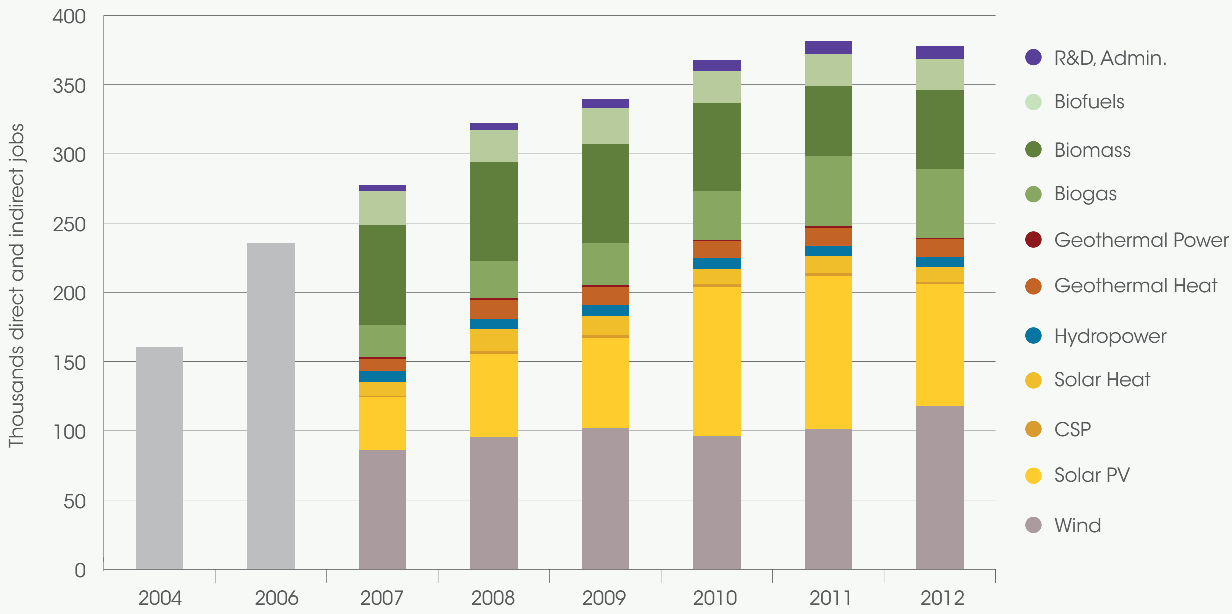
The experience of all three countries underscores the importance of providing policy makers with detailed and high-quality data about employment impacts and trends. Data also need to be generated in a methodologically clear and transparent manner so that the economic benefits can be considered when national renewable energy plans are drawn up. (See also the methodology discussion in Chapter 2.)

The available data confirm the long phase of expansion that the renewable energy sector has enjoyed in the three countries, translating into increasing employment. But the data also clearly reflect the turbulence in parts of the renewable energy sector, triggered by factors such as manufacturing overcapacities for some RETs, intensifying competition, economic crises and changes in national support policies (see Section 1.1). Until recently, renewable energy trends were generally expected to continue their upward climb – with steady policy support, growing investments and expanding installed capacity leading to rising employment in manufacturing equipment, constructing facilities and installing and operating additional renewable energy capacity. This has now given way to more mixed performance. In several countries, the capacity and willingness of governments to provide continued financial support to renewable energy has been weakened by the economic crisis, especially as the declining cost of RETs has reduced the rationale for financial support.

Germany has developed one of the largest renewable energy industries in the world, due mainly to consistent and strong support policies. Renewable energy employment in the country more than doubled during the past decade (see Figure 1.5), although the overall pace has recently slowed. Electricity-generating RETs account for 71% of German renewable energy employment and have been far more dynamic than renewable energy for heat energy and transport fuels (O'Sullivan *et al.*, 2013).

Solar PV employment in Germany grew from 38 300 jobs in 2007 to 110 900 in 2011, surpassing wind power as the largest source of renewable energy jobs. By 2012, however, the convulsive changes in the global PV industry translated into reduced module and cell production and the loss of 23 000 jobs. Wind power compensated for much of this decline and regained the top spot. In contrast with PV, the wind industry has been on a steadier trajectory. Apart from a brief blip in 2010, the industry kept up its steady expansion, increasing the number of jobs from 82 100 in 2006 to 117 900 in 2012. Nearly 85% of wind jobs are in onshore projects. But offshore employment more than doubled in 2012 alone, to reach 18 000 jobs.

Figure 1.5 Renewable Energy Employment in Germany (2004-2012)



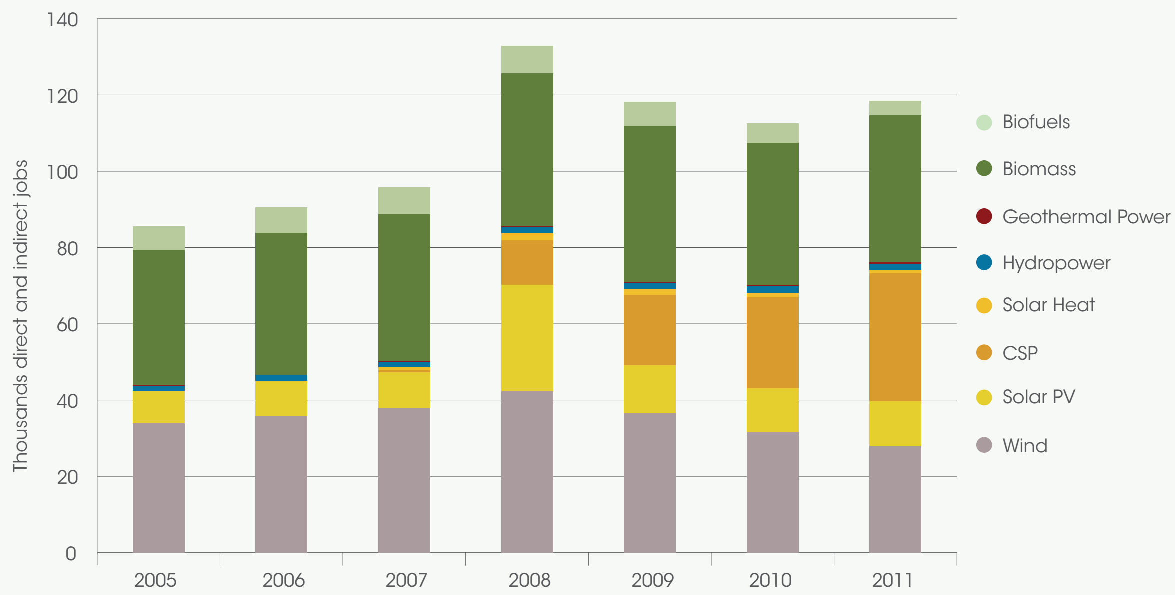
Notes: "Biomass" includes stationary liquid biomass, small-scale biomass plants, and biomass-fired heating/power stations. The 2004 and 2006 employment estimates are shown as solid bars because the breakdown by RET is not available as it is for the years since 2007.
Sources: Lehr, U. et al., 2011; O'Sullivan, M. et al., 2011 to 2013.

All types of bioenergy combined contributed 129 000 jobs in Germany in 2012. The numbers have fluctuated between 120 000 and 129 000 since 2007. The largest share by far, 49 500 jobs, is found in biogas, whose job numbers have doubled since 2007. This is followed by small-scale biomass plants, at 39 300 jobs in 2012, which is higher than the previous year but still down from 42 000 in 2007. In third place is biofuels with 22 700 jobs, a figure that has remained stagnant in recent years. The German biofuels industry faces strong competitive pressure from suppliers in Argentina and Indonesia and struggles with large overcapacities. Smaller numbers of jobs are contributed by biomass-fired heating/power plants and stationary liquid biomass (O'Sullivan *et al.*, 2013; EurObserv'ER, 2012).

In **Spain**, renewable energy employment surged from an estimated 3 500 jobs in 1998 to more than 115 000 in 2010. Official projections foresaw continued growth, to 128 000 jobs by 2020 (Ministerio de Industria, Energía y Turismo (Ministry of Industry, Energy and Tourism) and Instituto para la Diversificación y Ahorro de la Energía (Institute for Diversification and Saving of Energy) (2010)). However, the economic crisis and adverse changes in governmental support policies have triggered a turnabout. Solar PV lost close to 20 000 jobs after 2008, and wind lost more than 14 000 jobs (see Figure 1.6). This downward trend was moderated temporarily by the CSP industry, which added close to 22 000 jobs (APPA, 2012). But the adverse changes in government policy subsequently caused CSP employment to fall from 28 885 jobs in 2011 to about 17 862 in 2012 (Gonzalez, 2013). For other RETs, 2012 figures are not yet available; however, given the decrease in government support, job losses are likely.

The **United States** has seen overall expansion in renewable energy jobs (see Figure 1.7), although wind and bioethanol employment have fluctuated. Bioethanol employment grew strongly from 57 000 in 2006 to about 173 000 in 2008, then contracted the following two years before hitting a new peak of 181 300 in 2011. During 2012, a combination of factors led to another drop in employment – among them soaring feedstock prices, withering yields under severe drought conditions, and lower demand due to the economic crisis (Urbanchuk, 2013). Meanwhile, the number of wind energy jobs has fluctuated between 75 000 and 85 000 in the last five years, in part because of policy uncertainties (AWEA, 2012 and 2013). The decline in PV prices has triggered a boom in installation of solar panels, which now account for 48% of all solar jobs in the

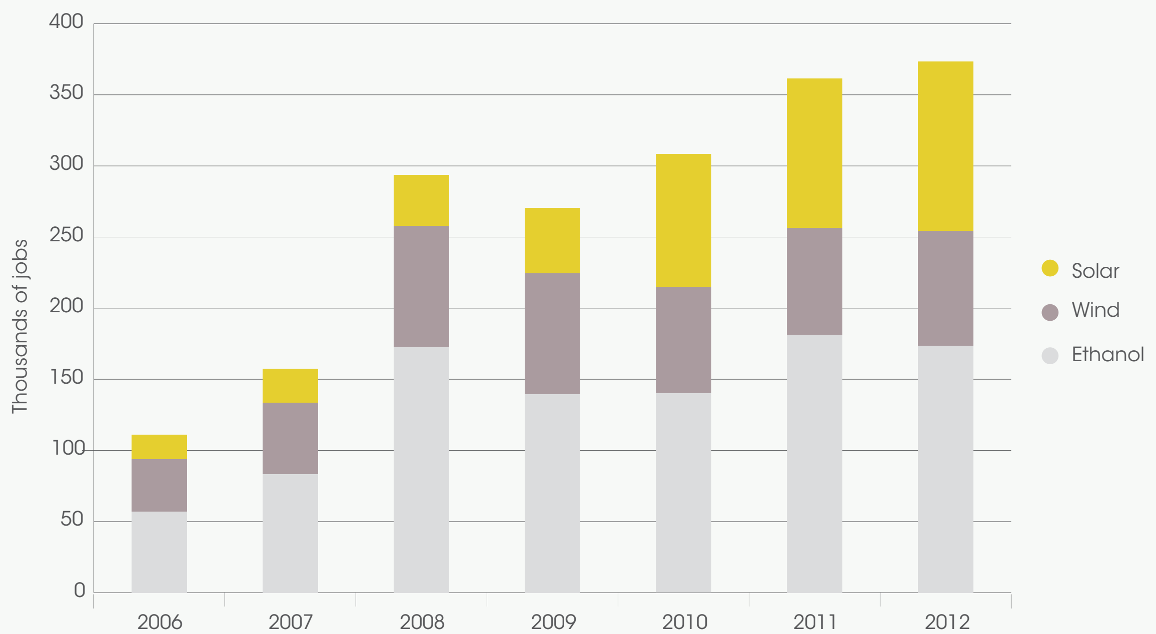
Figure 1.6 Renewable Energy Employment in Spain (2005-2011)



Source: APPA, 2012.

United States and more than compensated for the loss of more than 8 000 jobs in solar manufacturing between 2011 and 2012 (Solar Foundation, 2012). Time-series data on employment in the geothermal industry are scarce, although estimates for direct and indirect employment stand at 21 000 in 2006, 25 000 in 2008, 18 300 in 2010 and 20 100 in 2012 (Bezdek, 2007; Blodgett and Slack, 2009; Jennejohn, 2010; Matek, 2013b).

Figure 1.7 Solar, Wind and Ethanol Employment in the United States (2006-2012)



Sources: American Solar Energy Society (ASES), 2008; Solar Foundation, 2012; Baca, 2013; AWEA, 2012 and 2013; Urbanchuk, 2013 and earlier years.

Like the rest of the world, Germany, Spain and the United States find themselves in a dynamic context of evolving technologies, policies and rising international competition. With global overcapacity in solar PV manufacturing, strains on European manufacturers have intensified – resulting, for example, in the bankruptcy of former industry leader Q-Cells in Germany (it has since been acquired by the Korean company Hanwha) and in the decision by companies like Bosch to exit the PV business (O'Sullivan *et al.*, 2013). Solar manufacturers in the United States are facing similar pressures, with companies like Evergreen Solar, Solyndra and Abound Solar declaring bankruptcy and other firms laying off workers. Manufacturing jobs as a share of total solar employment in the United States declined from 36% to 25% between 2011 and 2012 (Solar Foundation, 2012). The domestically produced share of installed PV capacity varies considerably between crystalline silicon modules (ranging between 21% and 24% in 2009-10) and thin film modules (71% to 77%), where firms from the United States are global technology leaders (Platzer, 2012a). First Solar, in particular, a leading thin film manufacturer accounted for nearly 5.3% share of global solar PV module produced in 2012 and was the only US-based module manufacturer among the top five globally (REN21, 2013). Together, Europe and the US constituted around 14% of global module production in 2012, down from 17% in 2011 and 43% in 2007, thus marking the shift of manufacturing towards Asia where nearly 86% of the global solar module production occured in 2012 (Mehta, 2013).

The wind manufacturing sector has found a stronger footprint in Europe and the United States, when compared to solar module manufacturing. According to one market assessment, the US-based General Electric occupied the highest market share for wind turbine suppliers (15.5%) globally in 2012, above Vestas (Denmark), Siemens (Germany), Enercon (Germany), Suzlon (India) and Gamesa (Spain). The remaining four of the top ten suppliers in 2012 were based in China (Navigant Research, 2013). The top ten wind turbinesuppliers represent over 77% of market share, compared to nearly 40% for solar module producers further establishing the consolidation within the sector. Growing domestic demand and policy support are factors that can ensure a strong domestic renewable energy industry, as the United States wind sector experience demonstrates. Moving from a heavy dependence on imports from Europe, the number of wind manufacturing facilities in the United States blossomed from only about 30-40 in 2004 to more than 470 at the end of 2011. Additional factors were the need to reduce the cost of transporting heavy components such as towers and blades over great distances, and a desire to limit risks associated with currency fluctuations. The number of tower and blade factories in the United States tripled during that time period, and the number of nacelle assembly plants more than quadrupled. The domestic base for components such as bearings, gearboxes and power transmissions is also growing, although at a slower pace. All in all, the share of parts manufactured domestically nearly doubled from some 35% in 2005-06 to 67% in 2011 (Platzer, 2012b), leading to a tripling of wind manufacturing jobs in 2007-11, to some 30 000 (AWEA, 2012).

Export sales carry different degrees of importance for the renewable energy workforce in the three countries examined. Compared with Germany and Spain, the United States has not figured as a major renewable energy exporter (David and Fravel, 2012; Platzer, 2012a). This can be largely attributed to less-certain policies and incentives, such as the manufacturing tax incentives, which have limited capacity to scale up the industry sufficiently. Renewable energy industries that depend strongly on export markets may thrive in strong years, but they are also vulnerable to changing market dynamics and the government policies that shape these markets, which could make for a rollercoaster experience in the absence of stable and strong domestic markets.

The experiences of Germany, Spain and the United States show how much overall market trends and trade dynamics have changed the employment picture in recent years. This includes growing challenges to established renewable energy manufacturers by strong new players such as China, changing import and export shares in each country, as well as shifts in the underlying support policies for RETs. Especially in the solar PV industry, China has risen to become a formidable manufacturing competitor. As discussed in Chapter 3, recent policies have brought about a change in the orientation of China's PV industry, and the country's domestic market is now growing fast. This, in turn, may open new opportunities for European and other manufacturers and perhaps relieve some of the intense pressure that they have been under in recent years.

The three country examples examined here suggest that wind and solar continue to occupy disproportionately large shares of the overall RET mix. Key aspects for further job developments will be the future trajectories of other RETs (especially biofuels, which has seen considerable fluctuation), and support policies by governments. There has been strong pressure in many countries to reduce feed-in tariff rates and other forms of support, yet new government policies may be needed to provide a measure of steadiness and predictability.

1.4 TRENDS AND CHALLENGES

Regional shifts. The location of renewable energy manufacturing (especially wind and solar PV) has shifted among different regions of the world, with consequences for where employment is created. Asian (and especially Chinese) companies have become strong competitors. In PV manufacturing, leadership has shifted over the years first from the United States to Japan, then to Europe and finally to China. Employment shifts have been tempered somewhat by increased cross-regional collaboration and linkages among firms, as has been observed for the wind industry (Lema *et al.*, 2011). By contrast, employment in installation and in O&M is by its nature more localised and thus less subject to these kinds of shifts.

Overcapacities. Some renewable energy industries face substantial overcapacities. In the solar PV sector, it is estimated that the global module manufacturing capacity of about 60 GW is almost double the roughly 30 GW that was newly installed during 2012 (O'Sullivan *et al.*, 2013). The resulting collapse in PV panel prices has triggered a boom in installations and associated employment, but is forcing a realignment and consolidation of the PV manufacturing industry, with the loss of tens of thousands of related jobs in several countries. Several European and North American firms went bankrupt, were taken over or decided to leave the PV business. In China, too, bankruptcies during 2012 reduced the number of panel manufacturers from 624 to 454 (Energy Focus (ENF), 2013), and in early 2013, industry giant Suntech Power (with 10 000 employees) was forced to declare bankruptcy (Bradsher, 2013).

Wind power production capacities of close to 80 GW also exceed market demand (44.7 GW installed during 2012) by a substantial margin (O'Sullivan *et al.*, 2013). But the wind industry so far has not experienced the same degree of shakeout as solar PV, although reductions in government support have forced some project delays or scale-backs. Similarly, the European biofuels and biomass industries are contending with weak demand and overcapacity problems. During the 2007-12 period, only 50-60% of the available bioethanol production capacity was utilised due to low demand, high feedstock prices in 2007-08 and 2010-11, and competitive imports from Brazil and the United States. Although the impacts on the industry have not been nearly as dramatic as in the PV sector, some plants have been shut down, albeit temporarily (EurObserv'ER, 2012).

Export market competition. Although the renewable energy industry has become an established global business, new factors may intensify export competition. Often, domestic market demand is strongly influenced by the support schemes in place. In some southern European countries, the reduction or withdrawal of governmental support systems as a result of the economic crisis has compelled manufacturers to pursue sales abroad. Similarly, existing manufacturing capacities in countries that have adopted an auction-based support mechanism, such as India, are actively exploring international markets between two auction phases. The ability of the electricity system to absorb increasing shares of renewables also has an upstream impact on the dynamics of the manufacturing industry. China's wind turbine manufacturers may push increasingly into international markets, as they have done in Latin America, given China's grid-connection limitations (with domestic production of turbines far outpacing the rate at which turbines are installed) (O'Sullivan *et al.*, 2013). Expanding beyond domestic markets, German biogas companies also are orienting themselves increasingly towards export markets, particularly in North America, China, India and Japan (ARGE Kompost & Biogas, 2013).

Impact of austerity and policy uncertainty. Although the renewable energy sector as a whole appears to have weathered the global economic crisis better than other industries, it has nonetheless felt some effects. In Greece, Spain and Portugal, austerity measures have dampened governments' ability to continue their financial support of RETs, and elsewhere in Europe, governments have re-evaluated existing support systems. The most pronounced effects are in Spain, where a tremendous swing in government policies has slowed renewable energy expansion, due to a series of drastic (including retroactive) cuts in support mechanisms, with thousands of jobs lost. In some other countries, policy reversals have led to uncertain investment conditions, affecting employment. In the United States, whenever there are delays in Congressional renewal of the wind energy production tax credit, a sharp temporary upswing in industry activity occurs prior to the expiration date, coupled with fears that thousands of jobs may be lost if the credit is not renewed (AWEA, 2013).

1.5 FUTURE PROSPECTS/SCENARIOS FOR EMPLOYMENT IN THE RENEWABLE ENERGY SECTOR

What are the prospects for future employment in the renewable energy sector? Several studies have sought to develop scenarios based on assumptions about the scale of future investments and capacity additions, as well as the way that employment per unit of capacity changes as labour productivity improves (see Box 1.4). The studies employ a wide range of methods, assumptions and reporting formats (see Chapter 2).

Various editions of *Energy [R]evolution*, published since 2007, project how employment may unfold across a broad range of RETs. The latest edition offers a global estimate for renewable energy employment in 2010 and scenarios for development to 2015, 2020 and 2030 (Greenpeace International, GWEC and European Renewable Energy Council (EREC), 2012). Under the most ambitious scenario of RET deployment, renewable energy employment grows from just under 8 million jobs in 2010 to some 12.2 million in 2015 and 13 million in 2020. Employment numbers decline after 2020 – dropping to 11.9 million by 2030 – because growing labour productivity outweighs additional expansion in renewable capacity (see Figure 1.8). It should be noted that the *Energy [R]evolution* estimate for 2010 is not directly comparable to the data in Table 1.2; *Energy [R]evolution* covers only direct jobs, and the estimate of 5.2 million jobs in biomass energy appears to include traditional forms (fuelwood and charcoal), which are not counted in Table 1.2.

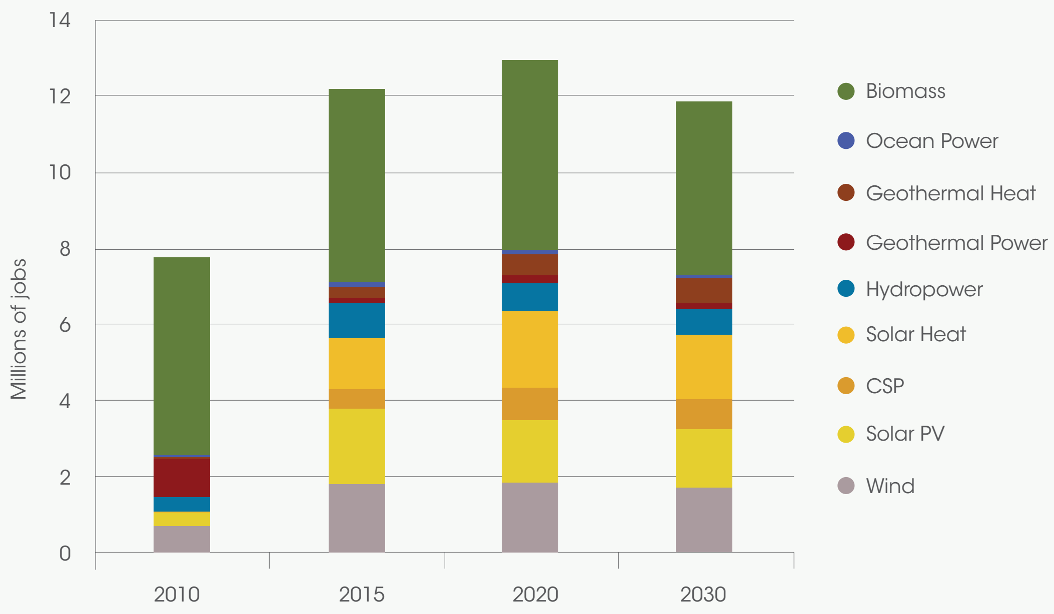
For wind power and solar PV, several regularly published reports have included global employment scenarios (see *Wind Force and Global Wind Energy Outlook*, published during 2005-12, and *Solar Generation*, published during 2006-10). These are more compatible with data in Table 1.2 because they include direct and indirect jobs. The Global Wind Energy Council and Greenpeace International project that wind deployment in 2015 will result in nearly 900 000 jobs under a moderate scenario and 1.6 million under an advanced scenario; by 2020, the scenarios range from 1.3 million to 2.9 million (GWEC and Greenpeace International, 2012).

Interestingly, for solar PV, the 2010 *Solar Generation* report's scenario for 2015 (ranging from 0.8 million to 1.37 million jobs) already has been outpaced by the very rapid rise in employment in just the last two years.

Box 1.4
TEMPORAL DIMENSION OF LABOUR PRODUCTIVITY

Technological change leads to decreasing costs, reflecting the fact that more can be produced with the same or even less input, *i.e.*, the productivity of capital and labour increases. Future estimates of renewable energy employment must, therefore, account for these effects, as the recent decline in solar PV costs illustrates. As technologies are diffused and applied more widely, they evolve or mature over time. "Learning-by-doing" effects, the organisation of production processes and improvement of industry structures, automatisation of manufacturing and increase of the scale of production translate into reduced costs and rising factor productivity. Over time, it takes fewer people to produce a wind turbine, solar panel or other piece of RET equipment, and the number of jobs per unit of output or capacity declines accordingly. One way to account for this evolution when forecasting future employment is to assume an annual percentage rate of change, or "decline rate", such as for employment factors.

Figure 1.8 Global Direct Renewable Energy Employment (2010, projections to 2015, 2020, and 2030)



Source: Greenpeace International, GWEC, and EREC, 2012.

It remains to be seen how well the 2020 projections (ranging from 1.7 million to 3.8 million jobs) will hold up. For solar heating/cooling, no comprehensive projections of future global employment appear to exist other than the *Energy [R]evolution* forecast; however, an assessment of the EU-27 domestic market concludes that, under the most ambitious scenario, employment could rise from a base of 31 400 jobs in 2006 to 470 000 jobs by 2020 and 1.3 million jobs by 2030 (Weiss and Biermayr, 2009).

IRENA is also performing its own renewable energy employment estimations as part of the the REmap 2030 initiative. The analysis indicates that a doubling of the share of renewable energy in the global energy mix can increase the employment in renewable energy from the current 5.7 million to 16.7 million in 2030 (see Box 1.5).

Given the dynamics that have unfolded in the renewable energy sector in recent years (rising investments, more countries developing their own renewables sectors, growing market competition, rising labour productivity, etc.), the assumptions underlying any scenarios will need to be checked carefully – and updated frequently – to retain sufficient predictive power.

1.6 CONCLUSIONS

Around the world, governments are pursuing renewable energy not only for greater energy security or environmental benefit, but also with an eye towards socio-economic benefits. They are understandably concerned with securing employment gains. Chapter 1 summarises the current knowledge about renewable energy employment, including the present situation as well as time-series data assessing the recent past and projections for the future.

There are now substantial numbers of renewable energy jobs worldwide – an estimated 5.7 million. Although no comprehensive global time-series data exist, evidence from individual renewable energy industries (especially wind and solar PV, for which there are better data than for other RETs), as well as from selected countries (Germany, Spain and the United States) illuminates developments in recent years. Wind power-related employment has more than doubled in the last five years, while solar PV employment has soared nearly 13-fold, albeit from a small base. Yet recent years have also seen intensifying competition and turbulence in the renewable energy sector. Greater steadiness in governmental policies

Box 1.5

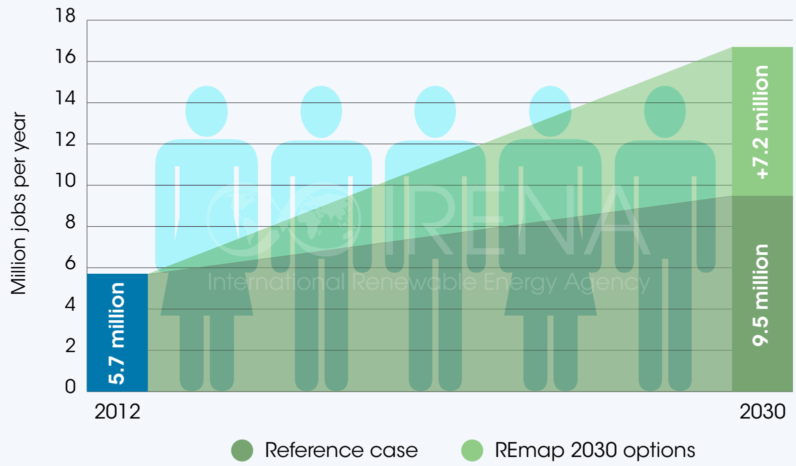
IRENA REMAP 2030: EMPLOYMENT ESTIMATIONS

IRENA is estimating future renewable energy employment within the framework of the REmap 2030 analysis. REmap 2030 is a global roadmap for renewable energy designed to demonstrate possible pathways and priority actions for meeting the aspirational target of doubling the share of renewables in the global energy mix by 2030, as articulated in the Sustainable Energy for All initiative. The REmap analysis follows a bottom-up approach, which identifies the key technological options for attaining this target and determines the associated costs and benefits. Co-benefits such as effects on health and socio-economic impacts are also analysed, including employment.

The job estimations are based on employment factors (see section 2.2) applied for each segment of the value chain (*i.e.,* manufacturing, construction and installation, O&M, fuel production and decommissioning), for all sectors analysed in REmap (*i.e.,* power, transport, buildings and industry) and for all renewable and conventional energy technologies. Temporal and geographic variations in labour productivities are accounted for through regional multipliers, and technological improvement through adjustment factors based on learning curves. In order to determine the jobs in fuel supply chain, the analysis estimates the trade of fuels such as oil, natural gas, coal and biomass based on projections from IEA's World Energy Outlook, OPEC's World Oil Outlook and, in the case of biomass, on a supply curve approach. In the absence of any credible estimate for future trade of equipment, it is assumed that it is locally manufactured.

The results of the analysis (Figure 1.9) indicate that if all the REmap 2030 options are implemented (doubling the share of renewable energy), global direct and indirect employment in renewable energy (excluding traditional biomass and large hydro) in 2030 would account for around 16.7 million jobs. Of these, 9.7 million would be in bioenergy, 2.1 million in wind energy, 2 million in solar PV, 1.8 million in solar water heating, 0.6 million in small hydropower and 0.5 million in the other renewable energy technologies (solar CSP, landfill gas, geothermal, tidal, wave and ocean). The deployment of renewable energy based on existing government plans however, would lead to 9.5 million jobs in 2030, still a considerable increase from the current figure of 5.7 million. To maintain consistency and show a trend between 2012 and 2030 (as in Figure 1.9), the REmap 2030 job estimates (IRENA, 2014a) were adjusted to exclude large hydro and include solar water heating and indirect jobs for all RETs. The estimate does not include traditional biomass.

FIGURE 1.9 IRENA REMAP 2030 EMPLOYMENT ESTIMATIONS



(see Chapter 3) will be important to avoid boom-and-bust cycles.

Renewable energy has become a relatively mature economic sector, with steadily improving technologies, complex supply chains, falling production costs and rising labour productivities. Although technological leadership and the bulk of renewable energy manufacturing are found in a small number of countries, many additional countries are stepping up their investments and policies in support of renewables deployment. In many countries, the majority of renewable energy jobs will be in installing, operating and maintaining renewable energy generation facilities, rather than in manufacturing equipment.

Although the information available about renewable energy employment has undoubtedly improved over the years, important gaps remain, particularly outside of the countries that have emerged as renewable energy leaders. For some countries and regions, no data exist at all. For many others, the information is limited to isolated snapshots which do not give a sense of the trends and dynamics in play. In general, the quality of employment data is uneven, reflecting the broad range of sources and their varying methods (see Chapter 2).

Improved information on renewable energy employment can help governments evaluate the effectiveness of policy initiatives related to the expansion of renewables, and can alert decision makers to any adjustments that may be needed in the labour market or elsewhere. The most valuable data distinguish between direct and indirect employment, disaggregate among different parts of the renewable energy sector (agriculture, construction, manufacturing, services), provide occupational details and differentiate between domestic and export-driven employment.

Governments may wish to consider the following steps to improve worldwide understanding of the employment benefits of renewable energy: supporting detailed macroeconomic studies, such as the reports commissioned annually by Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety; conducting more systematic industry surveys; and updating industrial and occupational classification systems to better capture renewable energy-related employment categories, as the United States Bureau of Labor Statistics has done. The German and United States approaches can serve as a model for countries with comparably developed industrial structures and sufficiently disaggregated sectoral data.

2 Measuring Employment from Renewable Energy

© Adapted from Charles Kook and Dusit

Employment from renewable energy technologies, next to greenhouse gas mitigation and energy security improvement, is one of the most important co-benefits of RET deployment and an important driver for policy makers to support renewables. In order to make an appropriate choice of support and other policies affecting the renewable energy sector, decision makers need detailed information on employment creation from renewables that can be measured and forecasted. This chapter provides a brief overview of the different methods available and the respective results to be expected from their application. The goal is to support decision makers in interpreting the results of the different studies based on different methods. This work is currently being broadened in the framework of another IRENA initiative, the econValue project, which assesses, among other elements, the methods available for evaluating economic value creation (including employment and Gross Domestic Product (GDP) from renewables (IRENA and Clean Energy Ministerial (CEM), 2014).

2.1 OBSERVATIONS ON RENEWABLE ENERGY EMPLOYMENT DATA

The data presented in Table 1.2 and elsewhere in this report represent an ongoing effort to create and refine a broad picture of renewable energy employment worldwide. Available information has improved tremendously in recent years as more studies and efforts are undertaken to assess the impacts of renewable energy investments. But many gaps remain, and many impediments prevent generating a fuller picture of renewable energy employment, including the following:

» **Standard national statistics.** They typically do not offer data on renewable energy employment. The industrial and occupational classification systems that underpin government data rarely break down information specifically relating to renewable energy. The North American Industry Classification System, for example, groups wind turbine manufacturers within a larger category of companies "primarily engaged in manufacturing turbines (except aircraft) and complete turbine generator set units, such as steam, hydraulic, gas, and wind" (Platzer, 2012b).

» Cross-cutting nature of the renewable energy industry. Employment in the renewable energy industry is difficult to capture statistically because it cuts across entire sectors of the economy. Some renewable energy jobs are in primary sectors (such as cultivation and harvesting of bioenergy feedstock), while others are in construction, utilities and various manufacturing industries. Others yet are in the service sector, a vast agglomeration of different occupations and activities which range from installations to repair and maintenance, from financing to project management, and so on. Additional jobs are in public administration (support, standard-setting and regulatory activities) and R&D.

» Data availability and quality. Good data are available only for a small set of countries, and the quality of data varies considerably. Relatively detailed and up-to-date employment estimates are available for the United States and several European countries. The German government, for example, has commissioned regular annual assessments, and industry associations in the United States and several other countries have conducted surveys or supported modelling efforts. For many other countries, however, data are limited or less reliable. Among the different RETs, studies tend to focus more on employment relating to electricity generation than that relating to transportation fuels and heating/cooling energy.

» Data standardisation. Data are derived from a large number of sources, with different methods, assumptions and time frames. An attempt to quantify global renewable energy employment can be like piecing together a puzzle, relying on a wide array of sources drawn from national and inter-governmental agencies, local authorities, industry associations, professional groups, labour unions, academia, non-governmental organisations (NGOs) and various other interested groups. Some sources offer detailed and careful assessments, whereas others represent only rough estimates. Some studies focus only on direct employment effects, whereas others include indirect and perhaps even induced effects. Studies also differ substantially in geographic focus, coverage of RETs and temporal aspects (some offer a snapshot whereas others provide a longer-term assessment). As a result, gaps remain in any accounting of global renewable energy employment.

Employment estimates in the renewable energy literature typically use either employment factors, supply chain analysis or input-output modelling (Breitschopf, Nathani and Resch, 2012). These assessment methods disclose different aspects of employment: the employment factor approach provides information on direct[5] employment effects, whereas both the supply chain and input-output methods also enable calculations of indirect employment. This chapter briefly describes assessment methods for both direct and indirect employment effects. It also outlines methods for a comprehensive economic analysis of RET deployment, including gross and net impacts, while also allowing for possible negative effects and for the quantification of induced employment. In all cases, understanding the concept of the economic "value chain" is useful to better comprehend the ideas behind direct and indirect employment and the different measuring methods (see Box 2.1).

2.2 MEASURING DIRECT EMPLOYMENT: THE EMPLOYMENT FACTOR APPROACH

Direct employment data provide information about the number of people working in manufacturing, construction, installation, fuels supply, O&M or decommissioning of RETs. They also indicate how important the renewable energy industry is as an employer compared to other sectors and branches in the economy. The quickest, most methodologically simple, and least expensive approach for assessing direct jobs is the "employment factor" approach.

5 *For a definition of direct and indirect employment see Box 1.1.*

Box 2.1

KEY DEFINITIONS: VALUE CHAIN

Generally speaking, "value chain" refers to a chain of activities which are performed to produce a product or service. It could refer to activities within a firm where primary activities such as logistics, operations and marketing are carried out in sequence to produce a good, but also to a string of companies or players providing their inputs to create a final product for the market. In the case of renewable energy, the final product is electricity, heating or transportation fuels. The product results from various core activities along the life-cycle phases of a renewable energy facility, from technology development to project planning and development, manufacturing of equipment and components, construction, installation, operations and maintenance, fuel supply, and finally decommissioning. Each core activity depends on inputs from other companies or sectors, such as materials for manufacturing, software to operate the machinery, and so on. The broader the analysis of upstream industries, the more branches and segments are included in the value chain.

Employment factors indicate the number of full-time equivalent (FTE) jobs created per physical unit of choice. This can be a unit of installed peak capacity or produced energy, expressed in megawatts or megawatt-hours for electricity-generating technologies (MW or MWh_{el})[6] or heat-producing RETs (MW_{th} or MWh_{th}). For fuels, employment factors can be expressed in jobs per million litres of production or in jobs per petajoule (*i.e.*, by unit of energy content). To estimate the total number of direct jobs, employment factors are, for example, multiplied by a given renewable energy capacity or generation figure. The formula in such cases would be: (MW of installed capacities [X] employment factors per MW) or (MWh of energy generation or energy content [X] employment factors per MWh or energy content).

The employment factor approach uses different employment factors for different phases of the life cycle, such as Manufacturing, Construction and Installation (MCI) or O&M activities (see Box 2.2). For bioenergy, the fuel supply phase is considered as an additional activity – growing, harvesting and transporting feedstock – which calls for a specific employment factor for every fuel source. The different factors can also relate to regional considerations, local content and dynamic developments. This is done for each technology and activity under consideration, providing estimates for technology-specific as well as activity-specific direct jobs.

Table 2.1 summarises the main elements of the employment factor methodology. It should be considered that this approach does not account for economic interactions and other dynamic effects. Furthermore, the quality of the employment estimates depends largely on the accuracy and availability of country- and technology-specific data (*i.e.*, employment factors). In principle, the data can be derived from sources ranging from industry surveys to specific enterprises or projects, feasibility studies and technical literature specifications (Breitschopf, Nathani and Resch, 2011). Especially when the estimates rely on values from the literature, it is important to be aware of all system boundaries and assumptions.

Breitschopf, Nathani and Resch (2011) review several studies that use such factors and conclude: "A major problem is the large variation in employment factors for seemingly identical technologies, which can differ by a factor of three or four. The reasons for these large differences are not clear. Possible explanations could be site-specific variations or differences due to different technology scales or system boundaries." Therefore, caution is warranted when drawing specific conclusions from available employment factors, and sensitivity analyses are highly desirable.

Review of employment factor estimates by renewable energy technology. A review of the literature suggests that far more estimates are available for electricity-generating RETs than for those that produce heat energy and transportation fuels. Among electricity-generating RETs, more detailed data are available for wind and solar PV than for other RETs. Employment factors differ by year and country/region in consideration. Table 2.2 reflects this heterogeneity and highlights the importance of looking at specific country and technology characteristics when using these factors (the table does not present an exhaustive list, but rather aims to show

[6] *For instance, Wei, Patadia and Kammen (2010) express United States employment data in terms of job-years per gigawatt-hour of electricity per year. They use an assumed capacity factor for each type of renewable energy facility and divide MCI jobs by the estimated plant lifetime. This, however, conceals the fact that MCI jobs are created at the beginning of a facility's lifetime, whereas O&M jobs are created throughout.*

Box 2.2

KEY DEFINITIONS: EMPLOYMENT FACTORS

The employment factor for MCI activities encompasses the number of jobs necessary to manufacture, construct and install one unit of renewable energy generation capacity. For solar PV, for example, the jobs in manufacturing the solar cells and modules which comprise a finished PV panel are typically considered direct jobs, although the boundary between direct and indirect jobs along the supply chain is not always clear. MCI activities relate to new capacity additions and replacements of existing ones (such as repowering for wind turbines). As such, they represent relatively temporary impulses for employment in comparison to the entire plant lifetime. However, they can be expressed as FTE job-years, or the total number of full-time jobs needed for MCI over the plant's lifetime.

Although a local workforce might undertake the installation and construction of renewable energy projects, the manufacturing of RETs may occur abroad – outside the country where a given renewable energy capacity is being installed. To account for this, the analysis must account for the degree of RET import dependence. On the flip side, countries that export renewable energy equipment and components can generate employment which is additional to that relating to their domestic renewable energy capacity by producing for export markets. Data on exports might best be collected directly from the domestic manufacturers.

The employment factor for O&M normally relies either on the cumulative installed capacities for power/heat generation (jobs per capacity installed to calculate the total number of jobs over the lifetime of the plant) or on total power/heat generation (jobs per generated unit of energy to calculate the annual jobs needed for the total energy production per year).

The number of jobs per unit of capacity is typically lower – much lower – for O&M than for MCI. This does not mean, however, that O&M necessarily offers fewer employment opportunities than MCI. Manufacturing, constructing and installing the equipment for a renewable energy project may require several months or at most a few years' worth of work. Once installed, however, the facility is designed to run for decades, generating employment over a much longer period but with lower annual required O&M inputs. Further, O&M employment factors are applied to the total installed capacity, whereas MCI employment factors refer specifically to newly added capacities. Thus, when total installed capacity expands, the impact of O&M on job creation becomes more significant.

Employment factors are not as available for the decommissioning phase (which could create jobs, especially if plants are repowered or if certain elements are recycled or reused), in part because most of the RETs in place have not yet ended their useful life. Some authors assume, however, that employment factors here are similar to those in the installation phase.

Table 2.1 Overview of Employment Factor Approach

	DIRECT JOBS FROM RET DEPLOYMENT
Data Input	Annual installed capacities per technology (MW_{peak}) Imported and exported capacities (%) if available Domestic generation per technology (MWh_e, MWh_{th}) Biomass fuel input per fuel (MWh, PJ, liter) Employment Factor per technology and activity (related to FTE)
Data sources	For Employment Factors: actual data from RE facilities, RE industry, surveys, feasibility studies, literature For capacity and generation data: national energy statistics/projections For exports/imports: trade statistics For regional adjustments: labour statistics (labour productivity multiplier)
Calculation	Simple multiplications (for details see Chapter 4.2 in Breitschopf, Nathani and Resch 2012)
Strengths	Jobs per technology (technology specific) and per phase of the life-cycle (phase specific) Simple adjustments for regional productivity Simple adjustments for technological change Quick estimates if reliable data on EF are available
Challenges	Reliable data on Employment Factors (FTE jobs per capacity or generation), per renewable energy technology and per country, and their temporal evolution Does not account for economic interactions and other dynamic effects

Source: Wei, Patadia and Kammen (2010); Rutovitz and Harris (2012); Breitschopf, Nathani and Resch (2012).

Table 2.2 Employment Factor Estimates for Different RETs

TECHNOLOGY	MCI (Jobs per newly installed MW)	O&M (Jobs per MW)	REGION	YEAR OF ESTIMATION	SOURCE
Wind, onshore	8.6	0.2	OECD countries (Average values)	Various (2006-2011)	Source 1
	27.0	0.72	South Africa	2007	Source 2
	6.0[a]	0.50	South Africa	NA	Source 3
	12.1	0.1	United States	2010	Source 4
	8.8	0.4	Greece	2011	Source 5
Wind, offshore	18.1	0.20	OECD countries (Average values)	2010	Source 1
Solar PV	17.9	0.30	OECD countries (Average values)	Various (2007-2011)	Source 1
	69.1	0.73	South Africa	2007	Source 2
	25.8	0.70	South Africa	NA	Source 3
	20.0	0.2	United States	2011	Source 4
CSP	18.0	1.33	South Africa	2007	Source 2
	36.0	0.54	South Africa	NA	Source 3
	7.0	0.6	Spain	2010	Source 6
	19.0	0.9	Spain	2010	Source 7
Hydro, large	7.5	0.30	OECD countries (Average values)	Various	Source 1
Hydro, small	20.5	2.40	OECD countries (Average values)	Various	Source 1
	20.3	0.04	South Africa	2009	Source 2[b]
Geothermal	10.7	0.40	OECD countries (Average values)	Various (2009-2012)	Source 1
	5.9	1.33	South Africa	2004	Source 2
Biomass	7.7	5.51	South Africa	2000	Source 2

[a] A probable reason for the smaller MCI employment factor in the Green Jobs report is because the authors do not account for differences in regional labour productivities.
[b] The source does not specify small hydro; however, the number provided is based on another study focused on small hydro
Sources: 1) Rutovitz and Harris (2012); 2) Rutovitz (2010); 3) Maia et al. (2011); 4) National Renewable Energy Laboratory NREL (2010); 5) Tourkolias and Mirasgedis (2011); 6) NREL (2013); and 7) NREL (2012)

this heterogeneity). It is advisable to gain in-depth knowledge on a country's situation. Moreover, employment factors tend to decline in accordance with technology maturity and labour productivity.

Indeed, the employment factors determined from the experience in leading renewable energy countries are not representative of conditions in the countries where renewable energy industries are less mature; cost structures differ and labour productivities are much lower. To assess the employment potential, allowance must be made for specific national conditions, which means that the local employment factors could vary substantially from the global value. China, for example, has risen to be a leading competitor in wind and solar energy, yet its labour productivity remains below that of Organisation for Economic Co-operation and Development (OECD) countries. Estimation of job creation therefore requires adequate adjustments. In practice, however, developing-country data that would permit such calculations or adjustments are very limited.

In a report for Greenpeace International, Rutovitz and Harris (2012) alter OECD-centric employment factors by a set of adjustment factors for different regions of the world which are based on average and economy-wide labour productivities (excluding agriculture[7]). The regional multiplier, relative to the OECD value, is 2.4 for Eastern Europe/Eurasia, 2.6 for China, 2.9 for Latin America and the Middle East, 3.0 for non-OECD Asia (but 3.6 for India) and 4.3 for Africa. These multipliers are at best a rough approximation because productivity within the energy sector varies from that of the broader economy, and productivity among individual RETs may vary from that of the energy sector as a whole. The comparison is fundamentally difficult given the load factors for the different technologies.

Technological improvement over time can also have significant effects on employment. To reflect this, employment factors are assumed to decrease over time, hence fewer jobs per unit of capacity or output will be generated. Rutovitz and Harris (2012) have estimated employment factor decline rates for different RETs and time horizons (see Table 2.3). Box 2.3 illustrates a prominent example of the employment factor methodology.

Wind power. The Wind Force 10 report, published in 1999, estimated that each MW of capacity (primarily for onshore projects) provided 22 MCI jobs in 1998 (EWEA, FED and Greenpeace International, 1999). Subsequent reports, reflecting rising labour productivity in the wind power industry, revised this estimate down to between 14 and 15 jobs per MW for MCI in 2009 and 2010 (indeed, Wind Force 10 itself had forecast a figure of 15.5 jobs for 2010). An estimate for onshore projects calculated 11 jobs per MW in 2011 (as compared to offshore projects, which are far more labour intensive, at 17 jobs per MW) (BNEF, 2012). Forward projections for all wind projects in 2020 and 2025 assume continued improvements in labour productivity and are even lower yet, at 12-13 jobs per MW (GWEC and Greenpeace International, 2010).

These data are intended to be global averages but are drawn mainly from the experience of projects in OECD economies. In emerging and developing countries, labour productivities remain considerably lower, which translates into higher per-MW job figures. A Chinese study estimated a range of 30 to 46.6 jobs per MW for MCI (8.5-9.9 direct jobs and 21.5-25.1 indirect jobs) (IUES and CASS, 2010). An study focusing on India estimated 37.5 jobs per MW for MCI (Global Climate Network (GCN), 2010), and a South African assessment estimated 27 jobs per MW for MCI but included direct employment only (Rutovitz, 2010). All of these estimates are for onshore projects.

The employment factors for O&M are much smaller than those for MCI, although the studies vary. For OECD countries, BNEF (2012) estimates a factor of 0.1 jobs per MW for onshore projects and 0.17 for offshore. GWEC

Table 2.3 Projected Employment Factor Decline Rates, by RET, 2010 to 2030

	2010-2015	2015-2020	2020-2030
	Percent annual decline		
Solar Thermal Power	5.6	5.1	2.8
Solar PV	5.3	6.4	4.9
Ocean Power	4.8	6.5	7.0
Wind, Onshore	3.6	2.8	0.2
Geothermal Power	3.5	5.4	7.3
Wind, Offshore	3.1	7.2	4.5
Geothermal CHP	2.6	3.2	4.5
Biomass CHP	2.0	2.2	2.2
Biomass	1.6	1.1	0.7
Geothermal Heat	0.0	0.9	0.9

Source: Rutovitz and Harris (2012).

[7] *Excluding the agriculture sector makes sense because its lower productivity would distort calculations for manufacturing-centered RETs like wind and solar. On the other hand, as the authors note themselves, excluding agriculture leads to an underestimate of bioenergy fuel employment.*

Box 2.3

ENERGY [R]EVOLUTION: AN EXAMPLE OF THE EMPLOYMENT FACTOR METHODOLOGY

The *Energy [R]evolution* study, commissioned by Greenpeace International together with EWEC and GWEC, uses the employment factor approach to estimate direct jobs generated in the renewable energy sector worldwide. The authors applied specific employment factors for each technology and region, and differentiated among local and export markets. Where local employment factors were not available, data are based on job ratios mainly from OECD countries and were adjusted by regional multipliers (Africa, non-OECD, Asia, etc.). This methodological approach is depicted in Figure 2.1.

FIGURE 2.1 ENERGY [R]EVOLUTION METHODOLOGICAL APPROACH

MANUFACTURING (FOR LOCAL USE)	=	MW INSTALLED PER YEAR IN REGION	X	MANUFACTURING EMPLOYMENT FACTOR	X	REGIONAL JOB MULTIPLIER	X	% OF LOCAL MANUFACTURING
MANUFACTURING (FOR EXPORT)	=	MW EXPORTED PER YEAR	X	MANUFACTURING EMPLOYMENT FACTOR	X	REGIONAL JOB MULTIPLIER		
CONSTRUCTION	=	MW INSTALLED PER YEAR	X	CONSTRUCTION EMPLOYMENT FACTOR	X	REGIONAL JOB MULTIPLIER		
OPERATIONS & MAINTENANCE	=	CUMULATIVE CAPACITY	X	O&M EMPLOYMENT FACTOR	X	REGIONAL JOB MULTIPLIER		
FUEL SUPPLY (NUCLEAR)	=	ELECTRICITY GENERATION	X	FUEL EMPLOYMENT FACTOR	X	REGIONAL JOB MULTIPLIER		
FUEL SUPPLY (COAL, GAS & BIOMASS)	=	PRIMARY ENERGY DEMAND + EXPORTS	X	FUEL EMPLOYMENT FACTOR (ALWAYS REGIONAL FOR COAL)	X	REGIONAL JOB MULTIPLIER	X	% OF LOCAL PRODUCTION
HEAT SUPPLY	=	MW INSTALLED PER YEAR	X	EMPLOYMENT FACTOR FOR HEAT	X	REGIONAL JOB MULTIPLIER		

Source: Greenpeace International, GWEC and EREC, 2012.

and Greenpeace International (2010) had offered a higher figure of 0.33 jobs per MW for onshore and offshore combined. For non-OECD economies, the estimates are even higher: 1.5-2 jobs per MW for China (IUES and CASS, 2010), 5 jobs per MW for India (GCN, 2010) and 0.5-1 jobs per MW for South Africa (Maia *et al.*, 2011; Rutovitz, 2010; GCN, 2010).

Solar PV. The MCI employment per MW in the solar PV industry, bearing in mind differences in scale, is higher than that of the wind industry. However, recent years have shown great progress in productivity. Initial estimates of 50 jobs per MW in 2006 were revised down to 43 jobs in 2007, 38 jobs in 2008 and 30 jobs in 2011 (Greenpeace International and EPIA, 2006; Greenpeace International and EPIA, 2011). Some projections for 2020, 2025 and 2050 suggest that the numbers could drop to between 18.5 and 20.4 jobs per MW. As the industry evolves rapidly towards higher labour productivity, employment factor estimates will need to be revised continually to reflect the changing realities.

Estimates for O&M employment factors for solar PV show little coherence or progression over time. Available studies offer per-MW figures which range from a low of 0.15 jobs to a high of 6 jobs, although the higher-end estimates are now at least five years old and are thus less likely to reflect current realities. A narrower range of 0.15 to 0.6 jobs seems more realistic.

Concentrated solar power. CSP has less real-world experience from which to inform estimates of employment factors. Based on a small number of plants in developed economies, a figure of 17 jobs per MW for direct and indirect MCI employment combined has been suggested (BNEF, 2012). This compares with estimates of 10 and 13 jobs per MW (for direct employment only) in the 2010 and 2012 editions of the *Energy [R]evolution* report. CSP Outlook 2009 also assumes a figure of 10 jobs per MW, but includes indirect employment. As the technology and production processes are optimised, the same report projects a decline to 8.5 jobs per MW by 2020, 8.1 jobs by 2030 and 7.2 jobs by 2050.

CSP deployment has occurred mainly in Spain and the United States. Limited experience elsewhere makes it difficult to realistically assess employment factors in other countries with CSP potential. For South Africa, Rutovitz (2010) offers an estimate of 18 jobs per MW for direct CSP employment, but Maia *et al.* (2011) provide a figure twice as high. Employment figures for O&M also reveal a wide range of estimates, from 0.3 to 1 jobs per MW. The higher figure stems from CSP Outlook 2009, which projects that employment will decline to 0.81 jobs per MW in 2020, 0.77 jobs per MW in 2030 and 0.68 jobs per MW in 2050.

Small hydropower. The 2010 edition of *Energy [R] evo lution* (Greenpeace International and EREC, 2010) estimates an average of 11.3 jobs per MW for MCI of hydropower plants, with an additional 0.2 jobs for O&M. Small hydro offers considerably greater employment potential compared to large hydro, at 20.5 jobs per MW for MCI and 2.4 jobs per MW for O&M, based on studies from Canada, Spain and the United States. In comparison, the employment in large hydro includes 7.5 jobs per MW for MCI and 0.3 jobs per MW for O&M, based on data from projects in United States (similar data from other countries is usually hard to find) (Greenpeace International, GWEC and EREC, 2012).

Bioenergy. As the Intergovernmental Panel on Climate Change has noted, the number of jobs created in various forms of bioenergy "is very location-specific and varies considerably with plant size, the degree of feedstock production mechanisation and the contribution of imports to meeting demand" (Chum *et al.*, 2011). Biofuels based on traditional agricultural crops are generally the most labour intensive of the various forms of bioenergy, although variations in the type of crop and the degree of mechanisation can make a big difference in employment. Direct and indirect jobs in ethanol production can range from as low as 45 jobs per petajoule (PJ) when corn is used as a feedstock to as high as 2 200 jobs for sugar cane. Similarly, for biodiesel, studies reveal a range from 100 jobs per PJ for soybean to 2 000 jobs per PJ for oil palm (Chum *et al.*, 2011).

For biomass power, low-mechanised plants in developing countries create an estimated 250 jobs per PJ, with 94% of the jobs found in the production and harvesting of feedstocks. This share is lower in industrialised countries: in a U.K. study, a wood power plant created some 200 jobs per PJ annually (averaged over its life cycle), with 73% of the jobs occurring in feedstock production and delivery (Chum *et al.*, 2011).

2.3 INDIRECT EMPLOYMENT: DIFFERENT APPROACHES

Analysing direct employment only tells a part of the story. Any economic activity needs inputs of labour, capital and other manufactured goods or services. Thus, the impact of expanding activities in the renewable energy sector reverberates through all economic sectors of a country. Indirect employment comprises all people who work in the production of intermediary inputs and in the related services for assembling a renewable energy system. This work can include providing raw materials or processed materials as well as supplying financial and other services. In the case of biomass, it also includes all people who contribute to feedstock provision by building harvesting machines, supplying fertilisers and so on.

This section discusses how indirect employment can be measured and estimated, as well as the importance of this exercise for developing countries. As has been pointed out, targeted policies need to be based on solid data. Three proven methods for measuring indirect employment effects are multiplier analysis, supply chain analysis and input-output analysis.

2.3.1 Multiplier analysis

Typically, there is a positive relationship between direct and indirect employment, with indirect employment approximated as a "multiplier" of direct employment. An example from the automotive sector, shows that for each 100 direct jobs in the automotive industry, some 230 additional jobs are created among automotive suppliers (Bivens, 2003). The multiplier for indirect jobs in this case is 2.3, and the total multiplier (for both direct and indirect jobs) is 3.3.

Most national statistical offices publish data on sector-specific multipliers. Given that renewable energy industries range across classical economic sectors, the multiplier in the renewables sector is a mix of the input sectors. Based on a study commissioned annually by the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, it appears that the number of indirect jobs is larger than the number of direct jobs for all RETs, with solar PV having the highest multiplier (3.4) and heat pumps having the lowest (1.6) (Lehr *et al.*, 2011). Multipliers would typically be larger for countries with a larger share of manufacturing, although more research is needed here.

Multiplier analysis makes it possible to estimate the overall economic impacts of renewable energy industries. Caution is advised, however, when using multipliers to estimate indirect employment effects on top of direct effects (estimated using employment factors). This is because the available data on employment factors and multipliers are not always uniformly defined, making it unclear which specific effects (direct or indirect) are included for each and potentially resulting in inaccuracies or double counting. Input-output analysis (discussed below) can offer a better tool for obtaining more specific or detailed information about the distribution of job gains over different contributing economic sectors.

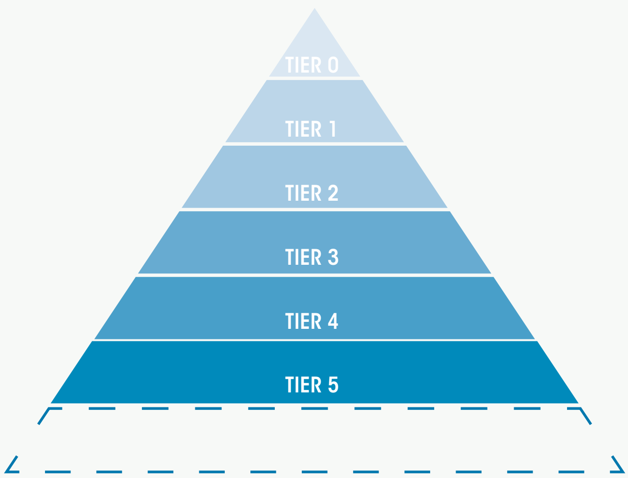
2.3.2 Supply chain analysis

The supply chain analysis seeks to map the specific supply hierarchy and relationships among companies in an economic sector, focusing on different tiers (defined below) of manufacturers and companies which provide key components and inputs. The approach generates figures about direct jobs and, to some extent, indirect jobs. Compared with employment factors and Input-output analysis, supply chain analysis is used rarely. This could be because of data unavailability, the complexity of the analysis or its more business-management (*i.e.*, micro) approach, which may not always be fully accepted by economists who normally deal with employment estimations at a more macro level.

Method. The first step in the supply chain analysis is to select the RETs to be analysed and to determine how many tiers of the supply chain to trace. The tiers represent the different stages of production and services, from the upstream provision of raw materials to the renewable energy production itself. The second step is to identify key companies in the various tiers of the supply chain. As illustrated in Figure 2.2 for the wind energy industry, the first (top) tier of the renewable energy deployment – the companies closest to the actual project – includes project developers (development), turnkey contractors (construction) and operators. The second tier comprises the suppliers to those companies, such as suppliers of renewable energy equipment and components (manufacturing). The third tier comprises suppliers of the renewable energy technology manufacturers, and so on, down to the bottom tier of raw material suppliers. The result of this stage of analysis is a technology pyramid or tree for each RET that maps its supply chain.

The third step of supply chain analysis entails collecting data on capacity, project costs, inputs and input shares, etc., and then subdividing the monetary

Figure 2.2 Supply chain pyramid for the wind energy industry



EXAMPLES

TIER 0: DEVELOPER, TURNKEY CONTRACTOR, OPERATOR

TIER 1: SUPPLIERS OF WIND TURBINE, ELECTRICAL SYSTEMS, FOUNDATION AND SERVICES, ETC.

TIER 2: FOR WIND TURBINE: SUPPLIERS OF ROTOR, NACELLE, TOWER, ELECTRONICS AND CONTROL SYSTEMS AND A SUB-CATEGORY OF MICRO TURBINES

TIER 3: FOR THE ROTOR: TURBINE BLADES, PITCH CONTROL, BEARING, NUB AND ROTOR SHAFT.

TIER 4: FOR TURBINE BLADES: BOLTS AND BLADES

TIER 5: FOR BLADE MATERIAL, RESIN AND MOULDS

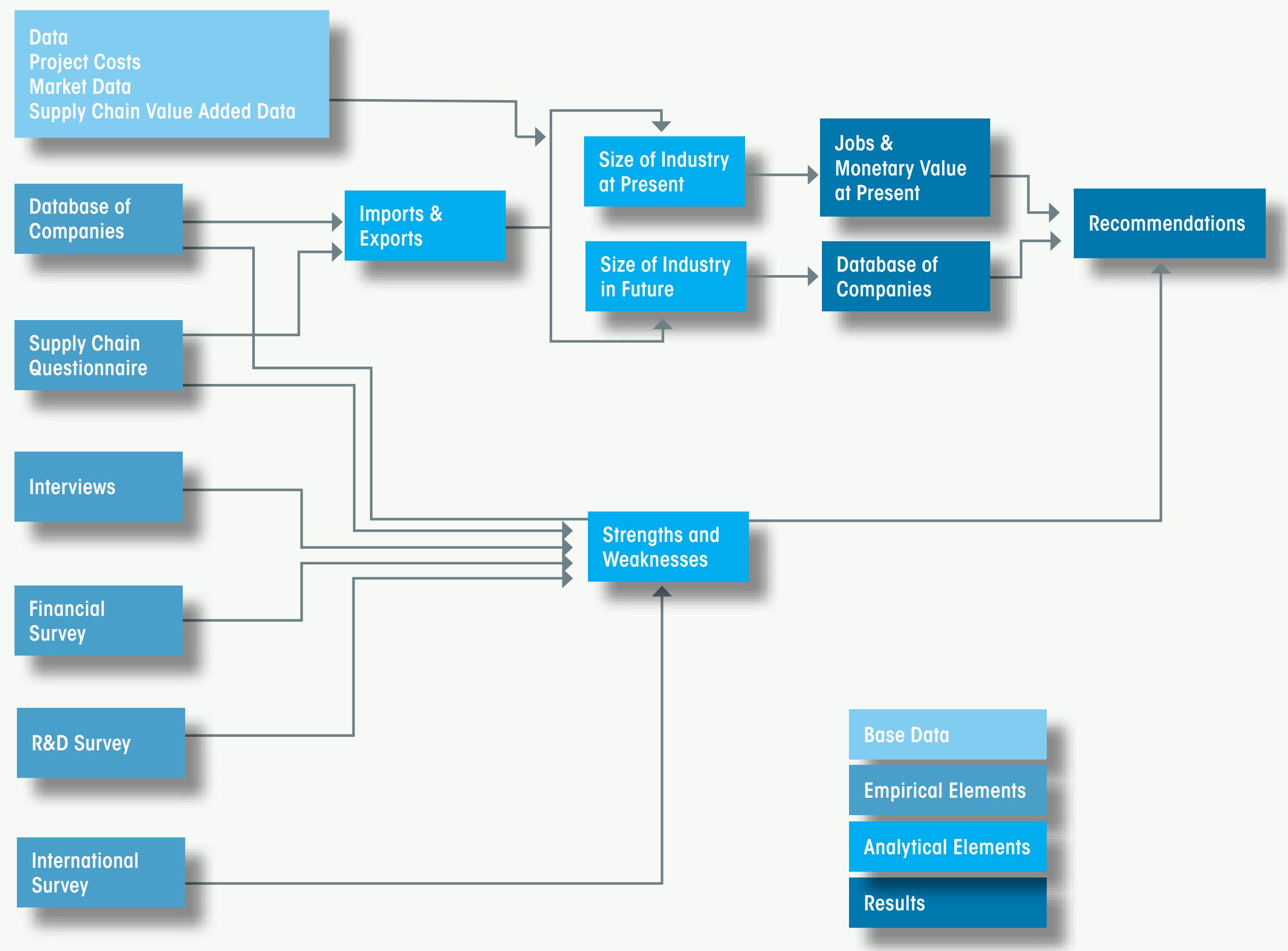
Source: UK Department of Trade and Industry DTI, (2004).

value (turnover and production value) of each tier in the supply chain into its cost components (material, services, labour) and profit. Labour costs can then be transformed into labour input (FTE) by assuming average or sector-typical wages. Material costs are further subdivided into the respective components in the next tier of the supply chain (labour, material, service and profit) and so on. After labour inputs are estimated for each tier of the supply chain, these can be related to the output capacity, resulting in a job factor per unit of capacity; adding these up provides a rough figure of the number of jobs (FTE) necessary. Adjustments must be made for import shares and export volumes (for each technology and at each tier). To estimate future impacts of renewable energy use, assumptions must be made regarding cost reductions and changes in labour productivity and wages. An illustration of the Supply Chain approach, in the context of access to modern energy, is presented in Section 5.3.

Data. Supply chain analysis rests on data that exist in industrial classification systems, such as the North American Industry Classification System or the European Community's statistical classification of economic activities, as well as on information from business directories. Extensive surveys of renewable energy companies and interviews with industry representatives and experts are also necessary to gather the required information on costs, produced quantities, intermediate inputs, imports and exports, and sales. The boxes to the left in Figure 2.3 summarise the various data inputs which may be needed.

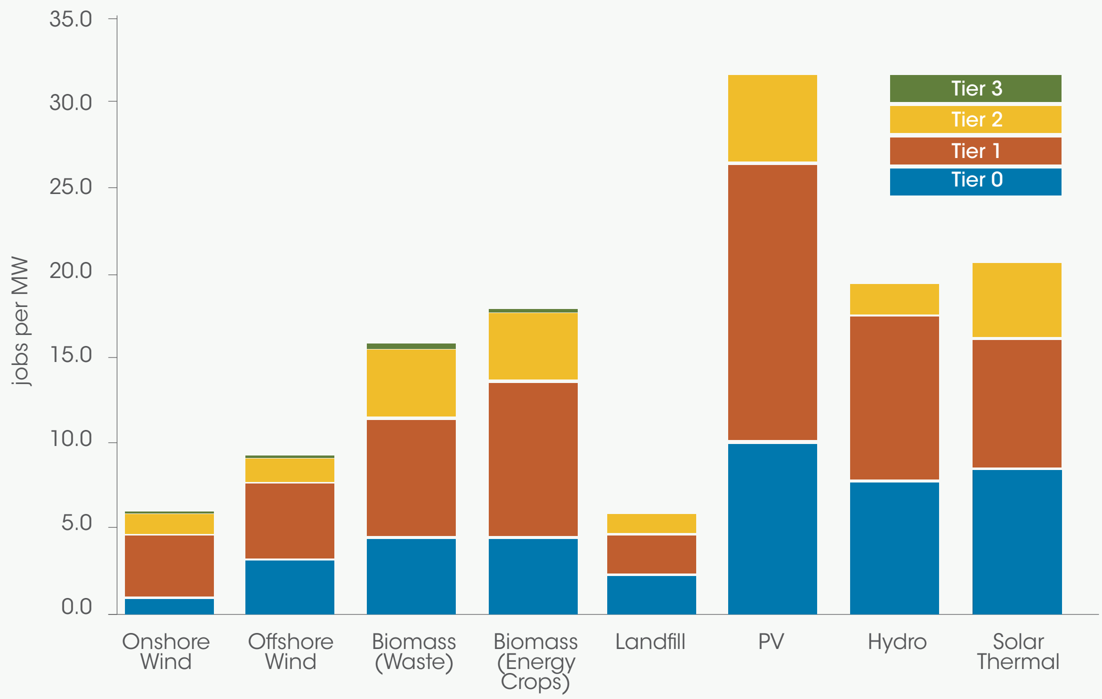
Results. Because the supply chain approach covers several tiers of the supply chain, it estimates direct as well as partly indirect jobs (in FTE), broken down by activity and tier (see Figure 2.4). The approach goes beyond the direct effects captured by employment factors, but does not cover all indirect effects, as

Figure 2.3 Data inputs needed for supply chain analysis



Source: DTI (2004).

FIGURE 2.4 NUMBER OF JOBS PER MW AT EACH SUPPLY CHAIN TIER[1] AS IN THE CASE OF THE UK



[1] Construction phase
Source: DTI, (2004)

Input-output analysis does (see below). To distinguish between direct and indirect jobs, a clear definition of tiers and system boundaries is therefore necessary.

Supply chain analysis is able to blend quantitative and qualitative information from various sources. It takes into account the complexity of technologies and supply chains and makes it possible to analyse them on a very detailed level. But it typically does not allow for comprehensive analysis of an entire sector at the macro level, an endeavour that would be very time and resource intensive (in order to aggregate project-specific analyses into a single sector-wide one).

2.3.3 Input-output analysis

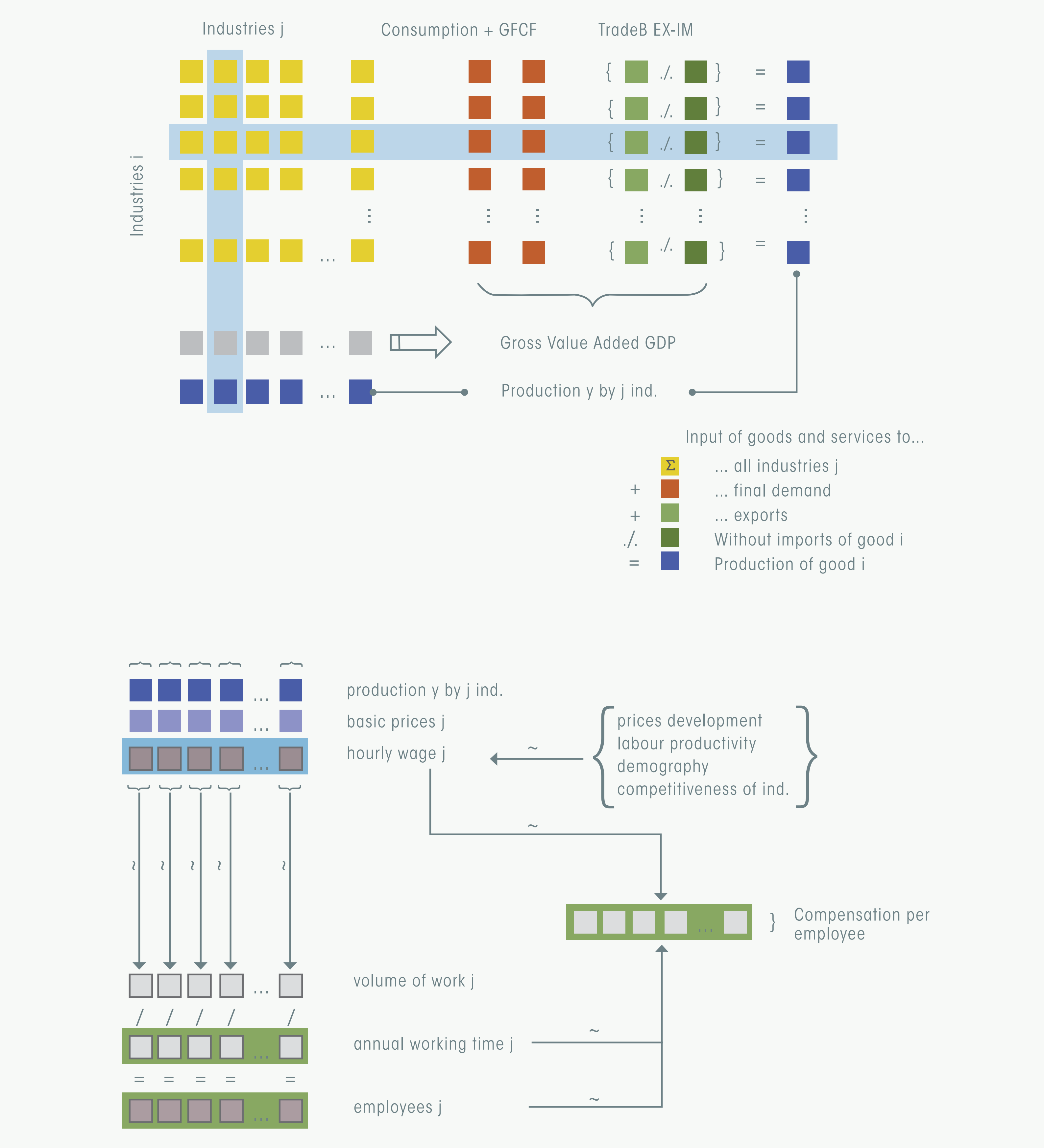
Input-output (I-O) analysis offers an analytical framework for estimating the potential of RET deployment to create direct, indirect and even induced employment. I-O analysis provides detailed insights into the flows of goods and services among all sectors of the economy and the interdependence of a country's economy with the rest of the world. As such, it provides a systematic alternative to the less comprehensive approaches discussed earlier. Input-output can be used to estimate direct and indirect employment ("gross" I-O) or direct, indirect and induced ("net" I-O), as stated in Breitschopf, Nathani and Resch (2012). This report only considers the first, and this is why I-O is placed in the current section.

Method. Producing a certain good requires fixed proportions of inputs from other economic sectors.[8] Wind turbines, for example, are produced using inputs from the steel, plastics and electronic industries, among others. Everything that is produced either serves as an input to the next level of production or is devoted to an end-use purpose.

The I-O table provides a well-established framework, based in economic theory, for analysing the flows of intermediary goods and services which, together with final demand and exports, determine the production of any economic sector. In Figure 2.5, the yellow boxes illustrate how industries depend on one another: products from the industries in the columns are produced with inputs from industries in the rows. As a consequence, additional demand for an industrial product from the column (marked in blue) influences

[8] This is the basic assumption behind the I-O methodology. It should be noted, however, that this may not apply from a medium- to long-term perspective due to economic developments and technological improvements.

Figure 2.5 Input-output table: production and employment



Note: GFCF: Gross Fixed Capital Formation
EX: exports
IM: imports
TradeB: Trade Balance

all other input industries by an amount which is given in the data in the I-O table. Total production of an industry is the sum of all inputs to other industries plus final demand plus exports minus imports.

In the first part of Figure 2.5, the portions highlighted in blue tell the following story: if the industry (*e.g.*, wind) in the highlighted column faces additional demand (such as from additional deployment of wind energy), its production has to increase. If its production increases, all yellow boxes along the highlighted column will also have to increase. The overall increased production from an industry (used, for instance, for other industries, consumption, gross fixed capital formation or trade) can be read along the rows.

The calculation shown in the second part of the figure, illustrates how employment can be estimated using data on wages and the typical hours worked for this industrial sector. The sector can pay all inputs from selling total production at basic prices, and the value added left covers profits and wages. Sector-specific data on wages and hours worked are gathered by the statistical offices which publish the I-O table.

To make I-O analysis fruitful for RET studies, the cross-cutting nature of RET sectors must be taken into consideration. The most direct (but also most resource-intensive) approach is to extend the classical economic sectors to new sectors for each RET, an approach that is not normally done in basic Input-output matrixes derived from national statistics. Staiß *et al.* (2006), for example, integrate 10 renewable energy technologies as production vectors to the I-O table for Germany, based on an industry survey. Lehr *et al.* (2008) continued this research and now conduct the survey every three years. In each cycle of the survey, 1 200 companies are asked to provide information about their input structure and to specify whether they sell to end consumers or produce intermediary goods for other industrial producers.

In a similar effort, the Desertec Industrial Initiative recently commissioned a study which used a survey-based approach to develop a technology-specific I-O vector for wind energy and for two solar technologies in the MENA region (Wiebelt and Blohmke, 2013). Assumptions about both the labour market and the use of local content are optimistic, and the results appear to be on the high side. Lehr *et al.* (2012) suggests a less resource-intensive method for developing countries that combine the I-O vector for RET production in industrialised countries, described earlier, with I-O tables from developing countries and vary the local production shares (see Box 2.4 for Tunisia's case).

Ragwitz *et al.* (2009) chose a simpler approach, breaking down final demand for RET in Europe into its main components and allocating these components to their respective economic sectors. This approach does not apply a separate survey-based I-O vector for RETs, but instead deduces renewable energy shares from the literature and other databases for each economic sector.

Results. I-O modelling is a useful tool for calculating the effects of changes in demand, such as those triggered by investments in renewable energy. Bacon and Kojima (2011) cite several advantages of I-O analysis. It permits a full analysis of all indirect employment effects, something which is not possible with other methods surveyed in this chapter. Further, I-O tables indicate the portion of the total demand for goods and services emanating from the renewable energy sector which is met by imports. This, in turn can be used to quantify the effects on domestic and foreign employment. In addition, it can enable to calculate the induced employment effects triggered by consumer demand, which is made possible by the wage income from direct and indirect renewables employment (this step in the analysis requires assumptions about how wage income is allocated among taxes, savings and household spending). This is part of what we defined above as "net I-O", which we do not describe in further detail.

Bacon and Kojima (2011) caution that even where I-O tables are available, they may not be sufficiently disaggregated: "some sectors, notably solar and wind power, are typically not identified separately so that coefficients are not fully representative." Writing from a South African perspective, Maia *et al.* (2011), similarly note that the highly disaggregated sectoral data used in industrialised countries are not available in South Africa. The same is true generally for other developing countries, although additional information can be obtained from local experts who are familiar with and monitor the infant renewable energy industries.

Box 2.4

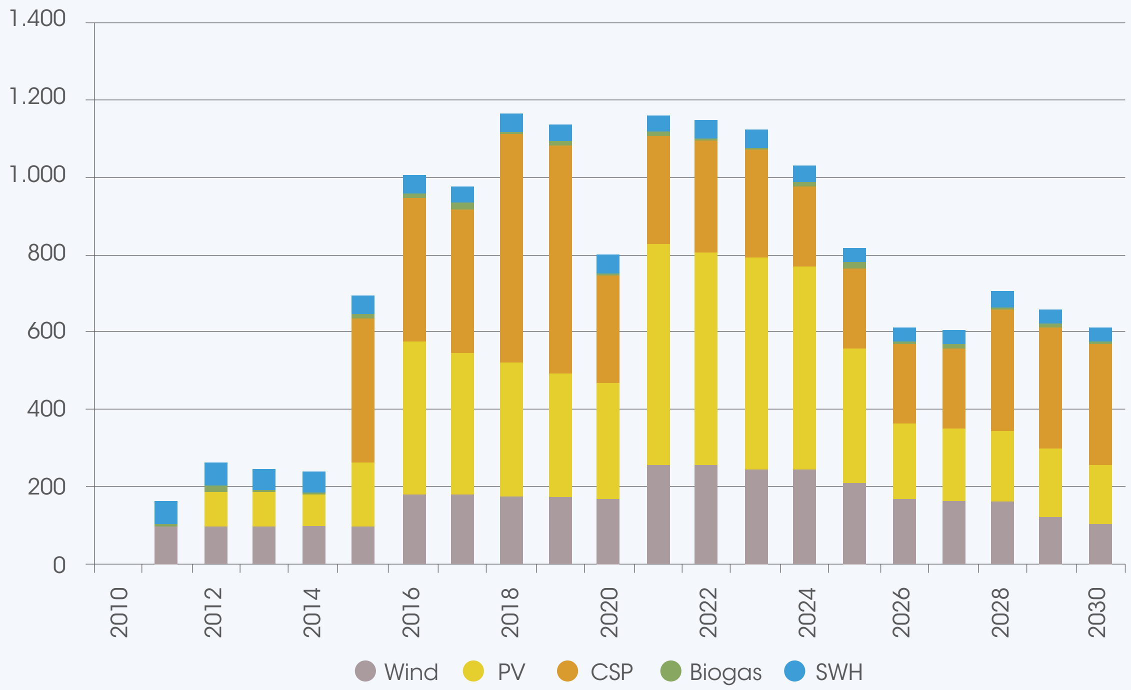
COMBINING RET-SPECIFIC COST STRUCTURES WITH NATIONAL STATISTICS: A CASE STUDY OF TUNISIA

Germany's Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Tunisian Energy Agency commissioned a study on the employment impacts of the Tunisian Solar Plan (Plan Solaire Tunisien). Lehr *et al.* (2012) applied a combination of technology-specific Input-output vectors for solar PV, SWH, CSP and wind energy, as well as for energy efficiency measures in the building sector, with Tunisian Input-output data on labour productivity and labour intensity in 17 economic sectors.

The scenarios for future development were based on the Solar Plan, which gives detailed targets for 2016 and less-specific targets to 2030 for energy efficiency and renewable energy in electricity and heat. A strategic study on the future energy mix for electricity production in Tunisia added the necessary details for development between 2016 and 2030 (Wuppertal Institute and Alcor, 2012). The analysis foresees a total investment of TND 8.3 billion (EUR 4.15 billion) in renewable energy and EUR 0.75 billion in efficiency (see Figure 2.6).

The study projects decreasing dependence on imports for all technologies except CSP. The highest local content is in SWH and in measures to improve energy efficiency in buildings. Overall, employment may rise by up to 20 000 people, depending on the rate of integration in production (Lehr *et al.*, 2012).

Figure 2.6 Projected renewable energy investments in Tunisia's energy sector (in million TND)



Similarly, accurate I-O analysis is only feasible where up-to-date tables are available. In developing countries, such tables may not be updated for several years and thus do not necessarily depict economic conditions accurately. Outdated labour productivity data, for instance, results in job creation estimates which are too high (Bacon and Kojima, 2011). But this holds for any quantitative approach. Another potential shortcoming is that I-O modelling (and most of the techniques described above) assume that the structure of the economy will remain constant; in the event of a large economic transformation, these approaches may depart significantly from reality.

Finally, most I-O models link expenditures on labour in a given sector to employment numbers by using average wages per full time equivalent worker. But wage and employment data are not always based on the same industrial classification as information in the I-O tables, or may not be available for the same year. This could introduce inaccuracies. Also, using average wage figures does not allow for wage differentiation within a given sector. The bottom line is that quantitative approaches are often prone to data problems. Any quantitative results must therefore be described carefully and with all their respective limitations.

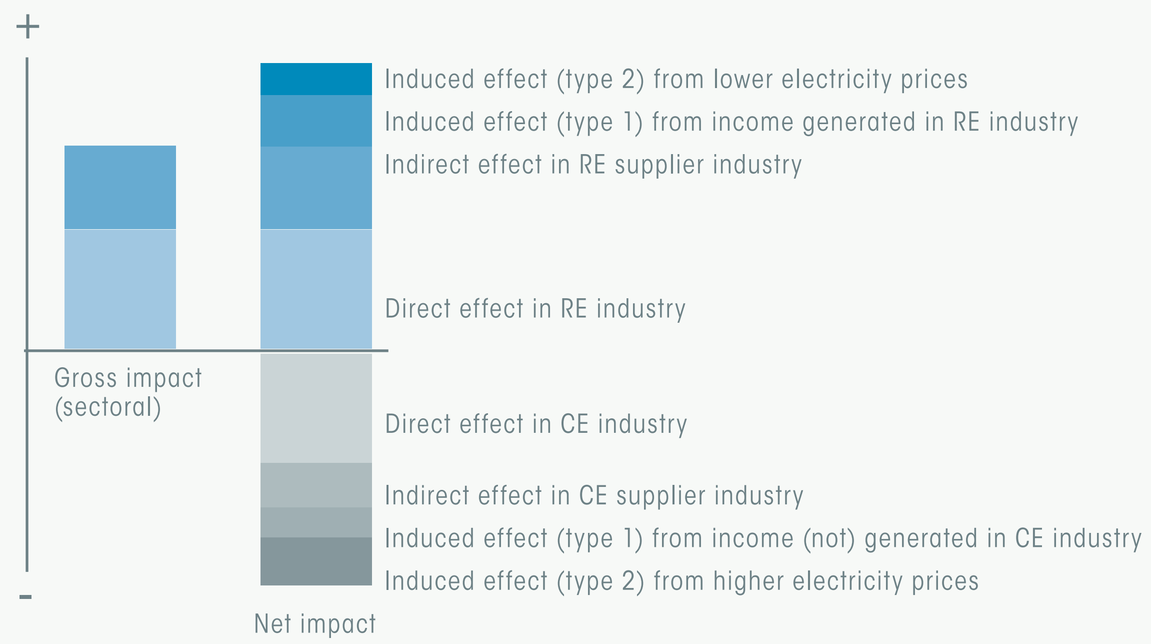
2.4 INCLUDING ALL EFFECTS: NET JOB CREATION

This chapter started from a very narrow analysis – employment factors for direct employment – and has been broadened to include indirect effects. Gross employment (see the left bar in Figure 2.7) takes into account only positive effects within the renewable energy industry and its related upstream industries. In this section, the analysis is broadened even more to include additional positive and negative job-related effects (both indirect and induced). The balance of all effects represents net employment and indicates whether RET deployment is beneficial from an economy-wide job creation perspective.

Induced effects, sometimes subsumed in the literature under indirect effects, result from changes in consumption (see definition in Box 1.1). One type of induced effect ("type 1" in Figure 2.7) is the spillover from the renewable energy industry into all other sectors of the economy which occurs when renewable energy employment translates into rising incomes and increased spending on consumption of goods. Jobs can be lost, however, when renewable energy deployment replaces activity in conventional energy sectors.

Another type of induced effect ("type 2" in Figure 2.7) stems from the costs or savings of transitioning to a renewable-based energy supply (such as changes in electricity prices), which affects spending on the consumption of other goods. If electricity from renewable energy sources is more expensive than from fossil

Figure 2.7 Two main types of induced employment impact



Note: CE = conventional energy; RE = renewable energy. In Federal Ministry for the Environment, Nature Conservation and Nuclear Safety BMU (2006) study and Lehr et al. (2011), the induced effect ("type 2") is called the budget effect. This effect is negative if RET deployment causes electricity prices to increase and positive if RET deployment causes prices to decrease. Further, the induced effect ("type 1") could be positive due to more income from renewable energy sector, but negative if people lose their jobs and hence income from the CE sector, reducing consumption. Source: Breitschopf, Nathani and Resch (2012) sources, less money is left to consume other goods. As a result, fewer consumption goods are produced and fewer people are employed in general. The effect is reversed as RETs become cheaper and, in the case of electricity generation, reach grid parity or are equal to or lower than fossil fuel generation costs. More generally, the deployment of renewable energy may change the distribution of income among different agents and hence affect economic activity and employment across all sectors.

An analysis of all effects helps to reveal the economy-wide impacts of RET deployment, as well as how strong changes in energy prices (*e.g.*, higher power prices due to renewable energy use) and displaced activities in the conventional energy industry affect economy-wide employment. Figure 2.7 illustrates the types of positive and negative effects which could occur and shows that a net impact takes into account all effects.

Method. Analysing net effects requires the comparison of two possible development paths (future scenarios). One entails the presumed ambitious development of renewables whose effects are to be analysed; the other relates to the business as usual (without ambitious renewables and with conventional energy generation) which is often called a "reference scenario". Comparing the scenarios yields the additional costs and benefits of renewables, including the net employment effects. How these scenarios are defined has a crucial impact on the results that can be obtained. If the difference in RET deployment is large, additional costs are large but opportunities for positive effects are also large. Small differences, on the other hand, can reverse the effects, because RET industries will develop only with a certain domestic market size.

Assessing economy-wide job creation under an advanced RET-deployment scenario (compared to a reference scenario) requires a complex economic model (see, for example, Box 2.5). The literature contains different approaches to economic modelling, as summarised by Breitschopf, Nathani and Resch (2012). The model which is selected should be capable of capturing investments in renewables, the share of renewable energy in trade, and energy prices, as well as the macroeconomic framework either from a System of National Accounts and Balances or from economic principles as used in general equilibrium approaches. The results will be highly dependent on the assumptions used.

Data. Economic models are either calibrated to a certain base year or based on a time series of economic quantities, using data from National Statistical Bureaus. Alternatively, the model can be developed (together with the data collection) with support from a research institute or consultancy. Handling large, sophisticated models requires important training and experience in order to interpret the results (presented

Box 2.5

NET EFFECTS OF RENEWABLE ENERGY DEPLOYMENT IN GERMANY, USING A COMPLEX ECONOMIC MODEL

The German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety recently commissioned a study assessing the short- and long-term employment effects of renewable energy expansion in Germany (Lehr *et al.*, 2011, Lehr, Lutz and Edler, 2012). Researchers calculated the net effects using the environmental macroeconometric model PANTA RHEI. They compared a scenario of ambitious RET deployment with a zero-renewable energy scenario to determine the net economic effects of RET deployment. The scenario is based on the German "Lead scenario", which assumes that both German and European renewable energy targets will be reached by 2030.

The study finds positive net employment impacts in most variations of the scenarios analysed. The main variation parameter is the position of German renewable energy manufacturers in international markets. An optimistic scenario leads to additional employment of more than 200 000 people, but employment decreases in a scenario where Germany's exports stagnate.

in tables and graphs) more easily and to tailor them to the client.

Results. Because net studies rely on full economic models, the results are much richer and deeper than mere employment analysis. Depending on the approach used, appart from employment results, others can be obtained such as variations in GDP or in economic welfare (measured as an aggregation of the utility that the consumption of different goods and services provides to the population).

2.5 CONCLUSIONS

The effects of renewable energy deployment on job creation have not been fully assessed. This is primarily because renewable energy is not a statistically classified industry, but rather a cross-cutting one that covers different economic subsectors. As such, no systematic data are available about its economic and employment effects. Several methodological approaches are available to conduct impact studies to assess these job effects, but they differ in their assumptions, results, the scope of jobs assessed and the resources necessary to conduct them.

» The employment factor approach is a relatively simple method to assess direct jobs per RET. It is based on data of newly installed capacities, energy production and employment factors. However, existing employment factors refer mainly to OECD countries, and therefore should be adjusted to a specific country's characteristics.

» Multiplier analysis, similar to the employment factor approach, applies a multiplier to the quantity of renewable energy in the system, in this case yielding the indirect employment created.

» Supply chain analysis enables capturing a broader range of jobs (direct and indirect) along the value chain. It divides the industries (renewable energy and intermediate), which are involved in production into different tiers and looks at the margins or profits, the intermediate inputs and the "remaining" labour input, from which the number of jobs can be derived. This approach is more detailed than the employment factor approach and requires interviews and expert knowledge to compile the necessary information.

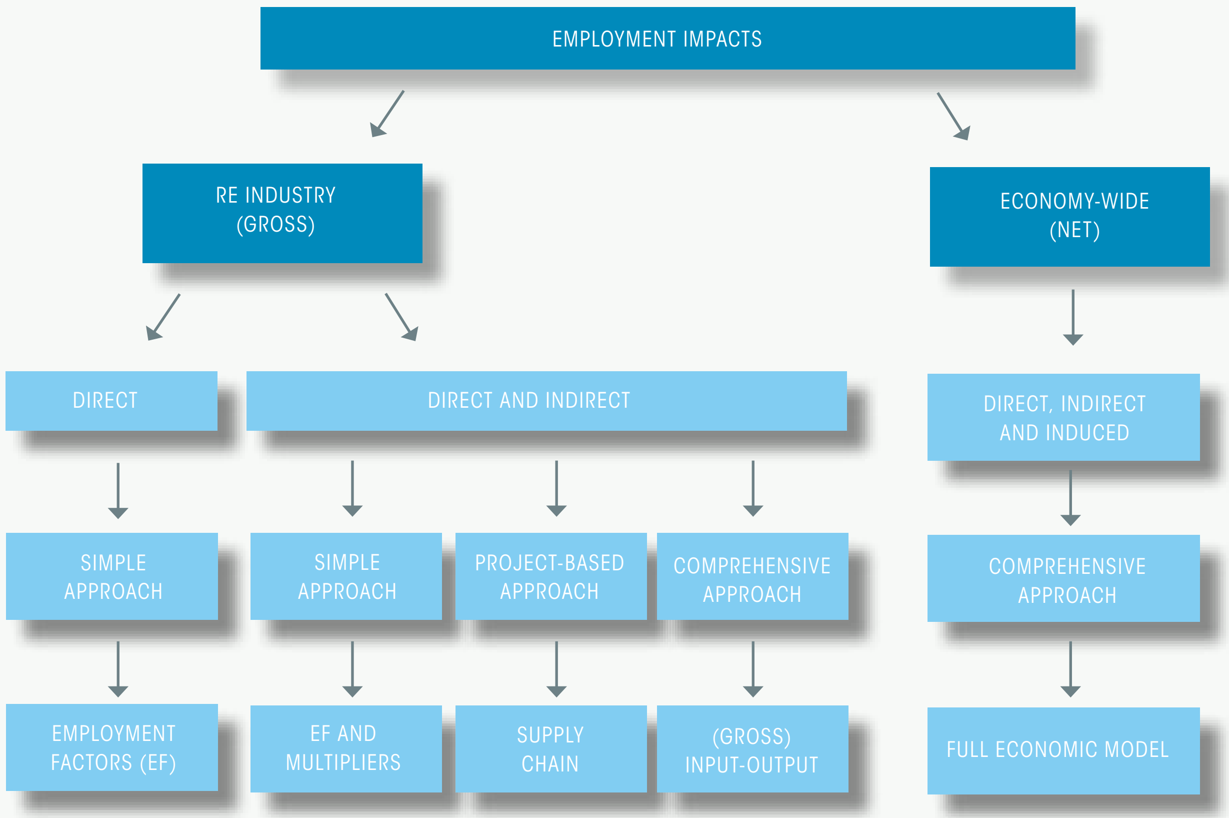
» The Input-output approach is founded on economic theory, and the data framework has been developed for many countries. Gross I-O analysis results in estimates of direct and indirect employment and is open for additional information on import quotas and export assumptions. Net I-O would also allow to account for induced effects.

» For a comprehensive analysis of all economy-wide employment impacts, balancing the positive and negative effects, a full and complex economic model is required.

Most approaches, if used for forecasts and projections, will require additional information on growth of labour productivity, technology and industrial developments. Although the methods and approaches vary in the expertise and funds required to conduct the analysis, they differ primarily in the questions asked and answered. A decision tree approach can be used as an orientation for policy makers, such as the one in Breitschopf, Nathani and Resch (2012) or in Figure 2.8. Under this approach, the first question is whether employment should be measured in the renewable energy industry (and its upstream industries), or in the total economy. The user then should decide on the type of employment he or she wants to calculate (either direct or indirect), and on the level of complexity of the approach. Other aspects to be considered when choosing an approach are whether there is sufficient data, human resources and budget availability for the analysis.

When countries deploy imported renewable energy systems, most of the jobs created domestically are either in installation (short-term work) or in O&M (longer-term work, but fewer positions). Typically, employment factor analysis can provide a rough estimate of jobs generated in these fields. If renewable energy deployment involves local manufacturing along the value chain, however, then approaches

FIGURE 2.8 SCHEMATIC OF KEY QUESTIONS WHEN CHOOSING AN APPROACH TO MEASURING RENEWABLE ENERGY EMPLOYMENT



Source: IRENA elaboration, adapted from Breitschopf, Nathani, and Resch (2012)

such as multiplier analysis, supply chain analysis, or I-O analysis are valuable to consider indirect employment effects and to ensure that all employment opportunities are analysed. If renewable energy investment and related economic activity is significant compared with other economic activity in the country, then a full economic analysis of the net effects on employment is recommended.

3 Policy Instruments in Support of Job Creation in the Renewable Energy Sector

© Jiang Zhongyan

As governments around the world adopt new renewable energy targets and roadmaps, public policy in support of renewable energy deployment has expanded greatly. Establishing ambitious policy targets plays a critical role in bringing about investments, especially in the more capital-intensive RETs such as solar PV, CSP, wind power and geothermal (European Commission, 2012). National governments, as well as state and provincial authorities, are putting in place an array of regulations and incentives to advance their renewable energy goals, although the specific mix of policies and the main motivations for adopting them vary by country.

Among the motivations shaping renewable energy policies are energy security, climate change mitigation, domestic industrial development and strengthening or reviving economic activities. Although job creation is an explicit goal of some policy measures, often it is simply a welcome side effect of pursuing other primary goals.

This chapter examines the importance of various policy instruments for job creation in the renewable energy sector. It discusses the impacts of deployment policies (such as feed-in tariffs, quota obligations and auctions); trade and foreign investment regulations; local content rules (intended to localise the renewable energy value chain and support the development of the domestic industry); R&D, cluster deployment, and regional development policies. These policies help to create an enabling framework within which renewable energy deployment can thrive and, by implication, jobs creation can be maximised.

The broader impact of these policies on value creation is analysed in the econValue project (IRENA and CEM, 2014). Although industrial, fiscal and labour policies are out of the scope of this report (but examined briefly in IRENA, 2011), they are very important as well: broad policy co-ordination is always favourable for job creation. Finally, training and education are also critical to ensure the development of an adequately skilled workforce for the sector (as analysed in detail in Chapter 4).

3.1 DEPLOYMENT POLICY: CREATING MARKETS

Policy in support of renewable energy deployment triggers investments and thus helps to generate employment in the sector. The number of countries adopting support policies (see Table 3.1) continues to expand. This section marshals evidence from selected regulatory policies, fiscal incentives and public financing programmes for which analyses or estimates of employment effects are available.

3.1.1 Regulatory policy instruments

Over the past two decades or so, governments have enacted a variety of policies intended to facilitate or mandate renewable energy deployment. Most of these policies are either price driven or quantity driven, and they range from feed-in tariffs and quota obligations to auctions and building codes.

Among regulatory policy instruments, **feed-in tariffs** (FiTs) are the most popular type of policy, particularly in high- and upper-middle income countries. Under a FiT policy, eligible renewable electricity generators are guaranteed a standard purchasing price for the electricity they produce, and priority dispatch is normally guaranteed. FiTs often entail a degression rate by which a tariff is gradually reduced over time as costs decline and as renewable energy becomes more competitive with conventional energy sources. FiTs have been adopted, and continue to be in force, in a total of 99 jurisdictions worldwide (71 national governments and 28 states/provinces) as of early 2013 (REN21, 2013).

The price and long-term market guarantees inherent in FiT policies have given investors the confidence they need to finance renewable energy projects, and have thus helped propel renewable energy job creation. FiTs were responsible for an estimated 75% of solar PV capacity and 45% of wind development worldwide as of 2008 (Deutsche Bank Climate Change Advisors (DBCCA), 2010). The experience of Germany – a pioneer in FiT usage – confirms the central role that FiT legislation has played in the expansion of renewable energy employment. According to analysis commissioned by the German Federal Ministry of Environment, Nature Conservation and Nuclear Safery, FiT-induced employment in the country has grown both in absolute terms and relative to all renewable energy employment (see Table 3.2) (O'Sullivan *et al.*, 2013).

Several governments have scaled back their FiT support, sometimes retroactively. In Spain, the abrupt reduction of PV costs and the lack of mechanisms to adapt the FiT led to an environment of overly generous rates. This was followed by a substantial escalation in the cost of support, resulting in an extreme policy swing. In 2012, the government adopted drastic rate cuts, causing a significant number of

Table 3.1 Number of countries enacting specific renewable energy support policies, as of early 2013

	POLICY TYPE	NUMBER OF COUNTRIES
Fiscal Incentives	Tax reduction	84
Regulatory policies and targets	Renewable portfolio standard (RPS)	19
	Renewable heat obligation/mandate	20
	Biofuel obligation/mandate	54
	Feed-in tariffs[a]	71
	Net metering	31
Public financing	Auctions/tenders	45

[a] *Includes feed-in premiums.*
Source: REN21, 2013.

Table 3.2 Renewable energy employment induced by feed-in tariff legislation in Germany, 2007-2012

	2007	2008	2009	2010	2011	2012
	Thousand jobs					
FiT-induced Jobs	172.7	207.3	225.0	262.1	276.5	268.0
of which:						
• Wind	85.7	95.6	102.1	96.1	101.1	117.9
• Solar PV	38.3	60.3	64.7	107.8	110.9	87.8
• Biomass Power	45.7	48.4	55.2	55.3	61.8	59.4
• Hydropower	1.9	1.8	1.8	1.7	1.6	1.7
• Geothermal	1.1	1.2	1.2	1.2	1.1	1.2
All RE Jobs	277.3	322.1	339.5	367.4	381.6	377.8
FiT-induced share of all RE Jobs	62%	64%	66%	71%	72%	71%

Source: Lehr et al., 2011; O'Sullivan et al., 2012 and 2013.

solar panel manufacturing plants to shut down (KPMG International, 2012). Altogether, more than 14 000 PV jobs were lost in Spain between 2008 and 2011 (APPA, 2012). The experience in Spain and a handful of other countries (such as Italy and the Czech Republic) demonstrates how critical the design of FiT policies is. With close monitoring of market conditions and continuous calibration of incentives and capacity targets, it may be possible to avoid damaging boom-bust cycles and resulting job fluctuations (Kimmel, 2011).

Renewable portfolio standards (RPS) and quota policies[9] represent a second approach to increasing renewable energy capacities. These regulations oblige power companies (either generators or distributors/retailers) to deliver a specified fraction of their electricity from renewable energy sources by a given target year. Such policies have been introduced, either at the national or the state/provincial level, in 76 jurisdictions, mostly in high- and upper middle-income countries. RPS and quota policies are more prominent on the sub-national level, and their numbers were boosted in 2004 when a significant number of states in India and the United States adopted such policies (REN21, 2012; REN21, 2013).

The state of Maine in the United States has had an RPS in place since 1999. A report for the Maine Public Utilities Commission estimated that even if only half of the proposed new wind projects in Maine were built (with a combined capacity of 625 MW), this could create roughly 11 700 jobs during the construction phase, a substantial number for the state (LEI, 2012). There is a concern, however, that individual states or provinces within a given country may compete against each other to secure jobs and other economic benefits (such as by attracting leading firms and investors). Several other states, for example, have taken measures to restrict out-of-state renewable energy market access or have designed policies favouring in-state renewable energy development (Corey and Swezey, 2007).

A third approach of rising importance is public competitive bidding, a support scheme, which is often called an auction or a tender. Under this mechanism, governments solicit bids to install a certain capacity (or to produce a certain quantity) of renewable-based electricity. Project developers submit offers which are evaluated on the basis of the price per unit of electricity, energy output or other criteria. Successful bidders typically enter into power purchase agreements. The number of countries relying on auctions has risen from just 9 in 2009 to 45 by early 2013. Among them are 31 developing countries, all but two of which are in the upper- and lower-middle income group (IRENA, 2013a; REN21, 2013).

Factors driving the growing interest in auctions include the decreasing costs of RETs, the increasing number of knowledgeable developers and the accumulated

9 *Tradable green certificates are considered within this category.*

experience in policy design. Well-designed auctions allow governments to avoid the pitfalls of over- or under-payments for renewable energy projects, and tend to involve lower fiscal and administrative costs than FiTs. Like FiTs, auction rules can be designed to include local content requirements, which may help to develop a domestic renewable energy industry and maximise the associated employment (IRENA, 2013a).

The employment effects of auctions and quotas are likely more predictable than those of FiTs, in the sense that they often involve capacity targets or caps, which indicate how much renewable power generation will take place and thus imply levels of likely job creation. Although policy design varies, FiTs do not always specify capacity targets or limits, and their employment effects are harder to predict. FiTs are not as prone as auctions to stop-and-go effects of bidding cycles. FiTs and auctions thus both have pros and cons with regard to job impacts, but they need not be seen as either/or propositions. In fact, currently, 29 countries worldwide rely on both types of policies (*e.g.*, different policies for different technologies within the same country) (REN21, 2013).

Many countries – including Brazil, Jordan, Israel, Puerto Rico, South Africa, South Korea, Spain and Uruguay – have used building codes to promote the incorporation of RETs, especially solar water heating (REN21, 2012; Balbo, 2012). Evidence from Brazil shows that a requirement to incorporate SWH into large-scale housing projects can have a significant impact on employment creation. The country's social housing programme Minha Casa Minha Vida ("My House My Life") aimed to build 1 million homes for low-income families in 2009-11 and 2 million more by 2014, and helped trigger a rapid expansion of the Brazilian SWH market. The ILO expected that half the houses built in the first phase would incorporate SWH, and that nearly 18 000 additional jobs could be created in the solar installation industry for the duration of the programme (Economic Commission for Latin America and the Caribbean (ECLAC) and ILO, 2010).

3.2.1 Fiscal incentives and public financing

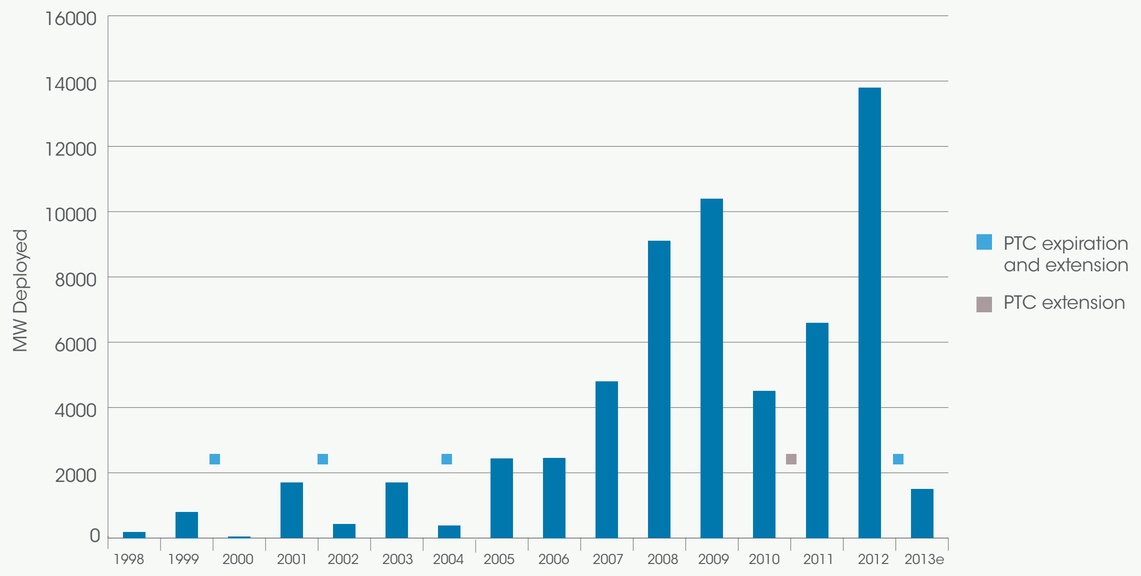
National and sub-national authorities offer a range of fiscal incentives and public financing measures to encourage private investment in renewable energy development – and thus, to indirectly stimulate job creation. These include (in declining order of how widespread their adoption has been) tax reductions, public investments, capital subsidies, investment or production tax credits, and energy production payments.

Tax reductions are being used by 84 countries worldwide to encourage renewable energy investment (REN21, 2013). Reductions of import, value-added or sales taxes are particularly critical in lower-middle and low-income countries, many of which depend heavily on imported RET equipment, especially in the early stage of renewable energy sector development. Lower-cost equipment facilitates greater deployment of RETs and thus facilitates job creation in installation and O&M. Fifty-eight countries worldwide – especially high-income countries – use capital subsidies, grants (or soft loans) and rebates, and 37 countries (mainly high-income countries) use investment or production tax credits. As shown in the example from the United States below, such policies heavily affect investments in renewable energy, leading to job creation when implemented and significant job losses when cancelled.

Although employment assessments of fiscal policies are rare, the United States offers some evidence of the impact of such policies on job creation. In the absence of national market-development policies such as FiTs, Production Tax Credit (PTC) and Investment Tax Credit (ITC) have been instrumental for wind and solar development, respectively. The PTC must be renewed regularly by Congress, but it has lapsed several times before a renewal was agreed. Such discontinuity in incentives reduces the propensity to invest (Figure 3.1) and has resulted in a repeated rollercoaster (in 2000, 2002 and 2004) for capacity additions and thus employment. When it seemed that the PTC might not be extended at the end of 2012, analysts warned that wind jobs in the United States could decline from 75 000 to 41 000. By contrast, a multi-year extension could allow an expansion to 95 000 jobs by 2016 (AWEA, 2013; Navigant Consulting, 2011).

The financial crisis of 2008-09 weakened the market mechanism through which renewable energy developers in the United States claim investment and production tax credits. In response, the USD 9 billion §1603 Grant Program, created as part of the American

Figure 3.1 US wind capacity additions and PTC



Source: Adapted from Cabré, 2007; BNEF, 2013a and b.

Recovery and Reinvestment Act (ARRA), offered a one-time cash payment to eligible renewable energy projects (in lieu of the ITC and PTC) of up to 30% of the qualified capital costs. An immediate goal was to create and retain jobs in the renewable energy sector. The programme supports projects which have a cumulative capacity of 13.5 GW (about half of the total non-hydro renewable energy capacity additions in 2009-11) and represent more than USD 30 billion in total investments. The programme supported as many as 81 000 FTE jobs annually (see Table 3.3) (Steinberg, Porro and Goldberg, 2012).

Instruments for facilitating access to finance, including **loan programmes**, for renewable energy projects are also being increasingly adopted. The ARRA, for instance, also created the Section 1705 Loan Guarantee Program, under which some USD 16 billion in loan guarantees was made available before the programme expired in September 2011. The loan guarantees helped secure more than 15 000 jobs (see Table 3.4). However, the four solar manufacturing companies which benefitted from these loan guarantees have come under substantial pressure from intense Chinese competition. Two of the manufacturers, Solyndra and Abound Solar, declared bankruptcy, defaulting on USD 935 million in loans guaranteed under the programme and laying off some 2 300 people (United States Department of Energy- Loan Programs Office (USDoE-LPO), n.d.; Platzer, 2012a).

Table 3.3 Estimated direct and indirect jobs funded under the §1603 Grant Program

AVERAGE JOBS PER YEAR (1,000 FTE)			
	Construction and Installation (2009-2011)	Operational Period (annual for system lifetime)	Total
Large Wind	44 – 66	4.5 – 4.9	48.5 - 70.9
Solar PV	8.3 – 9.7	0.61 - 0.63	8.91 - 10.33
Subtotal	52.3 – 75.7	5.1 – 5.5	57.4 - 81.2

Note: The range of job numbers reflects uncertainty about the share of local content of renewable energy projects; the study used a low estimate of 30% and a high of 70%. The jobs created or saved cannot necessarily be attributed exclusively to the §1603 Grant Program, since some of the supported projects might have continued even in its absence.
Source: Steinberg, Porro and Goldberg, 2012.

Table 3.4 Renewable energy loan programmes and jobs in the United States, 2009-2011

RET (NUMBER OF PROJECTS)	LOAN GUARANTEE (USD MILLION)[1]	PERMANENT JOBS	CONSTRUCTION JOBS
Solar Generation (12)	11 972.6	427	7 955
Solar Manufacturing (4)	1 282.0	520	3 720
Wind Generation (4)	1 687.9	59	998
Geothermal Power (3)	545.5	88	682
Biofuels (1)	132.4	65	300
Total (24)	15 620.4[2]	1 159	13 655

[1] Seven of the loan agreements offer only a partial guarantee of the full loan amount. The total amounts listed here thus somewhat overstate the level guaranteed. It should be noted that a loan guarantee does not necessarily involve an expenditure. [2] The Section 1705 Loan Program also guaranteed USD 386 million for a project related to energy storage and another for transmission that are not included here.
Source: USDoE-LPO, n.d.

The examples discussed here suggest that policies such as FiTs, production and investment tax credits, loan programmes and others need to be designed very carefully. The global dynamics of renewable energy markets, including the challenge from low-cost producers such as China, requires continuous evaluation and occasional recalibration of support measures. It is also essential to avoid extreme swings in policy measures from highly generous to harsh cuts (as occurred in Spain) and to ensure a good degree of policy continuity and predictability (as the experience from the United States has shown).

3.2 TRADE AND INVESTMENT POLICIES

This section considers international trade and cross-border investments in RETs. It provides a brief overview of international trends and then discusses impacts on importing versus exporting countries in terms of job creation. The section also discusses the pros and cons of trade and cross-border investment, including questions of technology transfer and knowledge spillover, which can have important impacts on employment. Finally, the section discusses the adoption of local content requirements within national renweable energy development programmes.

3.2.1 Trade and foreign direct investment impacts

Countries that do not possess the technological know-how required to manufacture renewable energy equipment or to construct the plants that generate the energy from renewable sources have two principal options: either rely on **imports** of renewable energy equipment and technologies, or try to attract **foreign direct investment** (FDI). The expectation is that foreign investment enhances value creation with respect to knowledge acquisition, employment creation and enhancing domestic capabilities along the value chain of different RETs, although the extent to which technology is transferred and effectively absorbed into the domestic economy is far from certain and depends on the host country's economic conditions and policies (IRENA and CEM, 2014)

Generally speaking, the expansion of trade and investment benefits the spread of renewable energy and by implication leads to growing employment in the sector. Global trade in renewable energy equipment increased by 70% in just the four years between 2007 and 2011 (UNEP, 2013). FDI in the renewable energy sector is expanding as well: the number of renewables-related FDI projects increased nearly six-fold from 2003 to 2011, accounting for almost 11% of all global FDI in 2011 (fDi Intelligence, 2013). FDI projects focused initially on renewable energy generation facilities but have more recently included renewable energy equipment manufacturing as well (Hanni *et al.*, 2011).

Altogether, FDI in the renewable energy sector created close to 35 000 jobs worldwide in 2011, 61% more than the previous year (OCO Global, 2012). Although cross-border investments in renewable energy have been considerably smaller than those in conventional energy, they are catching up quickly and created nearly as many jobs as conventional projects did in 2011 (see Table 3.5). The data imply that per billion dollars of FDI, renewable energy projects generated an average of 428 jobs, compared with 381 jobs for conventional energy projects.

FDI for renewables originates in relatively few countries. Firms from the United States, Spain, Germany and France together accounted for more than half of FDI projects in 2010-11. On the recipient side, the diversity is somewhat greater, with the top 10 recipient countries (the United States, six European countries[10], Brazil, Canada and India) accounting for more than half of global FDI projects. Some countries are increasingly attracting FDI flows: Romania and Bulgaria were the fourth and sixth largest recipients in 2011, with more than 4 000 jobs created (OCO Global, 2012).

Trade and FDI have different effects on renewable energy job creation. In the case of trade, manufacturing employment is generated in the exporting countries that produce the equipment. In the recipient country, jobs are created in the installation of renewable energy equipment and in the construction and operation of renewable energy generation facilities. In the case of FDI, in contrast, jobs are created principally in the recipient country where a new factory is set up or a project is developed; however, supply chains – and a portion of the jobs – may still be located abroad. In general, the R&D and knowledge-intensive jobs tend to remain elsewhere, meaning that FDI recipients in less-developed countries may face challenges in maximising the benefits of such an arrangement.

Low import tariffs may be assumed to trigger higher rates of renewable energy deployment in importing countries, and thus create more jobs in installation and O&M. A low-tariff policy, however, also can inhibit the creation of a viable domestic renewable energy manufacturing industry and thus limit opportunities for higher-value domestic jobs. Trade normally permits knowledge spillovers in the recipient country only to a limited extent (UNEP, 2013).

Export financing for renewable energy projects remains quite small: during 2000-2008, renewable energy accounted only for about 1% of total OECD export financing flows in any given year (Wright, 2011). It can, however, influence where jobs are created, and in some cases it may have considerably different effects in exporting versus importing countries. The Export-Import Bank of the United States and the Overseas Private Investment Corporation, for example, have offered low-interest loans to solar project developers in India on the condition that the solar equipment be purchased from firms based in the United States.

As a result, companies from the United States have manufactured an estimated half of all solar PV modules installed to date under India's National Solar Mission. Despite positive impacts on firms in the United States, this has introduced challenges to India's PV manufacturing industry: as much as 80% of the country's module manufacturing capacity and more than 90% of its cell manufacturing capacity has been idled. Contributing factors include depressed prices due to global overcapacities, economies-of-scale disadvantages of Indian firms, and a more than eight-fold increase in cheap module imports from the United States, Chinese and other foreign suppliers between 2010 and 2012 (Bhushan, 2013; Singh, 2013; IRENA, 2014b).

FDI offers a more direct route than trade does to technology transfer – and thus to creating a domestic industry and employment. Spillovers and learning effects in areas such as technology, management and organisational expertise, and entrepreneurship may occur through joint ventures between domestic and foreign companies (Altenburg, 2000). The Spanish wind power company Gamesa, for example, had

Table 3.5 FDI and employment generation in conventional and renewable energy, 2010-2011

	CONVENTIONAL ENERGY		RENEWABLE ENERGY	
	(USD billion)	(Jobs)	(USD billion)	(Jobs)
2010	144	53 000	55	21 621
2011	106	41 500	77	34 869

Source: OCO Global, 2012.

[10] *Bulgaria, France, Italy, Germany, Romania and the U.K.*

its beginnings in a joint-venture arrangement with Danish industry leader Vestas. But public policy has a critical role to play in enabling spillovers, particularly in relationships between large international companies and local small and medium-sized enterprises (SMEs) (Altenburg, 2000). This includes developing a solid domestic supplier base, promoting technology joint ventures and other measures. Although foreign investors can be sources of expertise and technology, helping to stimulate innovation, FDI could also drive local firms out of the market if they cannot compete with the foreign companies.

In the wind power industry, both cross-border trade and FDI have driven global integration. Over the years, trade has become less important in relative terms, offset by the rise of new domestically focused producers such as China, and by rapidly rising levels of cross-border investments. The increasing importance of FDI in the wind industry is driven in part by government policies (such as local content rules, discussed below). Cost considerations – for energy, transportation, labour, etc. – are another factor influencing a company's decision about where to locate production facilities. Core components of wind turbines (such as towers and blades) are difficult and expensive to transport over long distances. It thus makes sense to build manufacturing plants close to where the markets for wind turbines are, and it follows that jobs will be created in the locations that can serve as manufacturing hubs for key markets. Although some markets may simply be too small to support a domestic wind manufacturing capacity. Other components such as bearings and gearboxes are much easier to transport, and jobs supplying these parts could in principle be located farther afield (Kirkegaard, Hanneman and Weischer, 2009).

Cost structures produce different dynamics for individual RETs. Unlike the wind industry, for many other RETs the size and bulk of components is not an obstacle to shipping inputs or finished products around the world. Trade plays a major role in the solar PV sector: China, the world's dominant producer, sells the vast majority of its output abroad. Low-cost production has become a major factor in determining where factories are built and where solar manufacturing jobs are created.

As PV manufacturers in Europe and the United States struggle to remain competitive, they have demanded that anti-dumping tariffs be imposed against Chinese manufacturers, which are seen as unfairly benefiting from cheap loans, land and tax incentives. However, if one includes capital goods – the machines needed to manufacture PV cells and modules – in PV trade statistics, the United States actually runs a surplus compared with China, which amounted to USD 913 million in 2011 (Pew Charitable Trusts, 2013). In the EU, a broader look at the industry reveals that some 70% of the entire PV value chain lies within Europe. The value-added of EU suppliers of capital goods and raw materials, as well as of installers and other downstream businesses, amounts to a combined EUR 40 billion (USD 53.2 billion[11]), with many thousands of jobs (Alliance for Affordable Solar Energy (AFASE), 2013).

Nonetheless, calls for trade barriers have gained increasing traction. The United States Commerce Department imposed tariffs in 2012, and the EU has considered the same (but has since reached an agreement based on minimum price and volume limits for PV imports). The full employment impacts of such measures are complex, given contradictory impacts on manufacturers and installers. Tariffs on Chinese manufactured imports could cause the loss of larger numbers of installation and O&M jobs if higher panel prices stifle the market. PV panel importers claim that duties of as little as 15% would cut European demand for solar panels by 85%, but European manufacturers expect the impacts to be much less pronounced (Dalton, 2013). An economic modelling exercise in the United States concluded that a 100% tariff on imported PV cells and modules from China could result in a net loss of up to 50 000 jobs over three years due to decreased industry demand, with another 11 000 jobs at risk if China imposed retaliatory tariffs on United States polysilicon exports to China (Berkman, Cameron and Chang, 2012).

Tariffs may also trigger a sustained shift of employment to a third country. It has been suggested that in a bid to avoid punitive duties, Chinese PV manufacturers could simply relocate a portion of their assembly capacities. Already, Chinese companies are assembling panels in Taiwan and South Korea (although the components were made in China) (Cardwell, 2012)

11 *Currency exchange rate of 1.33 USD/EUR.*

and are considering setting up factories in Malaysia, Thailand, South Africa, Saudi Arabia and Turkey (Nicola and Sulugiuc, 2013).

3.2.2 Local content requirements

In a bid to establish a domestic renewable energy industry – and to create and secure related employment – several jurisdictions have adopted rules that are known as local content requirements (LCR). These compel manufacturers or project developers to source a specified share of equipment, or a portion of overall project costs, from domestic suppliers. These suppliers can be domestic firms, local subsidiaries of foreign-owned companies, or joint ventures between domestic and foreign-owned firms, but the key is for suppliers to invest locally rather than import renewable energy equipment. LCR are normally expressed as a percentage of total project cost and are aimed principally at manufactured inputs and (to a smaller extent) project development services, such as civil engineering and technical consultancy work (Sustainable Prosperity, 2012; Kuntze and Moerenhout, 2013).

There are also elements of LCR in the financial sector, intended to secure a role for domestic banks. In South Africa, foreign banks can provide renewable energy financing but need to be licensed to conduct regular banking business in the country. All sources of funding must be denominated in local currency. Large South African banks consequently have been key players in the country's Independent Power Producer procurement programme (Diemont, Nowak and Van der Poel, 2012).

The way in which LCR are implemented varies widely among countries (see Table 3.6 for some examples). In India and Ukraine, for example, meeting LCR is a precondition for companies being eligible for feed-in tariffs; similarly, Morocco and South Africa have linked their policies on LCR and auctions (IRENA, 2013a). Some countries – including Italy, France, Turkey and Malaysia – offer a premium over regular FiT rates to companies meeting specified content requirements. Another approach is to impose a penalty on companies that fail to meet LCR. Croatian legislation provides for increases in the FiT rate as the percentage of local content rises, but companies that fail to meet the target of 60% receive a somewhat reduced rate of between 93% and 99% of the full FiT[12] (Kuntze and Moerenhout, 2013).

In principle, LCR can lead to greater domestic employment. However, because such measures are often closely tied to FiT policies or to auctions, it is difficult to know what portion of employment generation is due to content rules per se (Kuntze and Moerenhout, 2013). Local content policies provide an incentive to foreign suppliers to establish factories in target markets, as evidence from the wind energy industry suggests. In Canada, LCR policies have helped attract wind manufacturing and assembly by General Electric, Enercon, and Repower in Quebec and Samsung in Ontario (Sustainable Prosperity, 2012; Hao *et al.*, 2010). Brazil's LCR (and the prospect of subsidised loans) led Alstom, GE Wind, Vestas, Suzlon and Gamesa to set up local assembly plants (Sciaudone, 2012b; Gamesa 2011; Hanni *et al.*, 2011).

LCR policies can be controversial in light of international trade rules. Several complaints have been brought before the World Trade Organization (Kuntze and Moerenhout, 2013). The cause célèbre is that of Ontario (see Box 3.1), where the World Trade Organization's ruling may have potentially far-reaching consequences for other countries' LCR policies. Some analysts have argued that there is a need for a more coherent trade policy approach to support schemes and procurement tenders with LCR, possibly in the form of a sectoral agreement on energy that addresses related issues like tariffs, non-tariff barriers, subsidies and public procurement (Kuntze and Moerenhout, 2013).

LCR have the potential to raise the cost of generating electricity from renewable energy sources by limiting the role of (lower-cost) foreign suppliers (Peszko and Ketterer, 2012). A related concern is that if economies of scale are less fully developed, this could imply higher costs and ultimately a lower level of job creation. It is also possible that the restricted competition inherent in LCR rules may allow local producers to extract monopoly rents, increase investment costs and possibly compromise the quality of RET equipment. This could result in fewer renewable energy projects being developed or reduced hours of operation and lower generation efficiency.

In turn, employment could be affected negatively. A LCR policy of indefinite duration runs the risk of being little more than a protectionist measure which ultimately undermines the health of the renewable energy industry. Without a stable and sufficiently

[12] *Because the Croatian government has not yet formally defined a "domestic component", this provision has not yet been applied. At present, the full FiT rate applies to all producers irrespective of local content.*

Table 3.6 Local content requirements, by RET

JURISDICTION	YEAR	REQUIREMENT
Wind Power		
China	1997	The "Ride the Wind Program" included a 20% LCR in two joint ventures for wind turbine manufacturing. The program foresaw a gradual increase to 80%, dependent on the success of mastering the technology. LCR were combined with substantial financial support to maintain attractive conditions for investors.
Brazil	2002	60% of wind equipment to be sourced locally under the PROINFA programme (Incentive Programme for Alternative Sources of Energy). Did not lead to the development of a local industry. Requirement was removed in 2009, but replaced by the rules set by the Brazilian Development Bank or Banco Nacional de Desenvolvimento Economico e Social (BNDES) (see below).
Quebec (Canada)	2003	Under a 1GW tender for wind, power purchase agreements were awarded to developers conditioned on a domestic content of 40% (first 200 MW), 50% (next 100 MW), and 60% (remaining 700 MW). A second tender of 2 GW (2005) required 60% LCR, and a third tender (2010) essentially maintained the structure of the second.
China	2003	LCR (first 50%, increased to 70% in 2004) counted for 20-35% of final evaluations of tender bids. LCR were not mandatory, but tied to beneficial tariffs that varied by province. Additionally, projects (of 50 MW or more) managed by the National Development and Reform Commission (NDRC) formally required the same degree of local content. LCR were abolished in 2009 when nationwide FiTs were introduced.
Brazil	2009	To qualify for subsidised loans by BNDES under its FINAME program, wind turbine makers participating in auctions were initially required to get 40% of components from Brazilian suppliers, rising to 60% in 2012. From 2013, manufacturers have to produce or assemble at least three of the four main wind-farm elements (*i.e.*, towers, blades, nacelles and hubs) in Brazil. (BNDES subsidised loans are also available for solar PV projects, but as of August 2012, no financing requests had been received.) This policy has led to the rapid growth of a domestic supply chain.
Solar PV		
India	2010	National Solar Mission (NSM) aims to install 22GW of on- and off-grid solar capacity. LCR is a conditionality for FiT eligibility. All cells and modules based on crystalline silicon are to be manufactured in India; these inputs typically account for over 60% of total system costs. The government has announced extension of LCR to thin film modules in the second phase of the NSM.
Italy	2011	Conto Energia 4 (RE act) offered a 5-10% FiT bonus to plants that incorporate 60% or more of components manufactured within the EU.
France	2012	A 10% bonus is offered on the price that Electricité de France pays for solar electricity, if 60% of the added value of the installed solar panels is generated within the EU.
CSP		
India	2010	The National Solar Mission entails a LCR of 30% (excluding land costs) for solar thermal power plants.
Multi-RET		
Ontario (Canada)	2009	Green Energy and Green Economy Act conditioned FiT support on minimum domestic content. Wind power projects were required to meet a minimum LCR of 25% (50% from 2012), and solar PV projects 50% (rising to 60% in 2012).
Ukraine	2009	A rising share of a renewable project's cost has to be sourced domestically to be eligible for FIT. Requirements for wind and solar projects start at 15% in 2012, and rise to 30% in 2013 and 50% in 2014. Biogas and hydro plants must meet LCR of at least 50% from 2015 on.
South Africa	2011	Wind tender requirement of 25% local content, which the government aims to raise step-by-step to 45% (first bid submission phase), 60% (second phase), and 65% (third phase). For solar PV, the local content requirement rose from 28.5% under the first window to 47,5% in the second window.
Turkey	2011	RE Law of 2010 offers renewable electricity producers higher FiT rate schemes if they use local components in their projects. The premium is in proportion to the local content of inputs to RE equipment, and varies by RET (up to 42% over the base rate for biomass, 54% for solar PV, 146% for geothermal, and 151% for wind)

Note: Because EU rules prohibit strictly national content rules, Italy and France offer bonus payments to companies anywhere within the EU. This may make the development of domestic supply chains difficult, however, given the first-mover advantages of German and Spanish companies.
Sources: Kuntze and Moerenhout, 2013; Ernst & Young, 2012; Nielsen, 2012a and 2012b; BNDES, 2012; World Trade Organisation (WTO), 2012; Peszko and Ketterer, 2012; Deloitte, 2012; Early, 2012; GL Garrad Hassan, 2012; Singh, 2013; IRENA and IEA, n.d.

Box 3.1

THE WTO DISPUTE OVER ONTARIO'S GREEN ENERGY AND GREEN ECONOMY ACT

The Canadian province of Ontario's Green Energy and Green Economy Act of 2009 made feed-in tariff support for wind and solar PV contingent on a minimum local content requirement. The Act was motivated not only by an interest in advancing clean energy, but also by a desire to help rebuild Ontario's industrial economy, which had lost more than 300 000 manufacturing jobs since 2004 (Ontario Clean Technology Alliance, 2013). The Ontario Ministry of Energy (2012) found that the FiT/LCR policy had attracted more than USD 24.8 billion in investments and more than 30 clean energy companies to the province. More than 20 000 direct and indirect jobs were created, and employment could grow to 50 000 jobs (Ontario Clean Technology Alliance, 2012).

In June 2011, Japan asked the World Trade Organization to establish a formal dispute resolution panel, claiming that Ontario's law discriminated against foreign renewable energy producers and constituted an illegal subsidy. The EU followed with its own complaint that August. In December 2012, the WTO Dispute Settlement Body ruled that the "minimum required local content level" prescribed under Ontario's FiT programme was in breach of Canada's obligation under the Trade-Related Investment Measures agreement and non-discrimination clauses of the General Agreement on Tariffs and Trade (Sustainable Trade Bulletin, 2013; GWEC, 2013). An appeal by Canada was rejected by the WTO's Appellate Body, which confirmed the earlier ruling in May 2013 (International Centre for Trade and Sustainable Development (ICTSD), 2013).

The WTO ruling may have implications far beyond Ontario if LCR in other countries also are found to be in violation of trade rules. The WTO is already investigating several other cases in India, Italy and Greece, and the Ontario ruling may encourage the filing of additional complaints (Barker, 2013). It has been argued that this might limit developing-countries' opportunity to nurture and grow domestic renewable energy industries (Public Citizen and Sierra Club, 2013).

sizeable market that offers adequate economies of scale, LCR measures are not likely to succeed (Kuntze and Moerenhout, 2013). A viable domestic RET supply chain is more likely to emerge in countries that already have an adequate manufacturing and service industry base (Sustainable Prosperity, 2012; Peszko and Ketterer, 2012).

LCR policies are concerned principally with the manufacturing of equipment or components. Yet employment also can be boosted through localising other aspects of renewable energy development, including the planning and design of projects, construction and installation, and O&M of RET facilities. In fact, O&M activities are likely to provide a large portion of the total jobs associated with renewable energy. This is especially important for countries which do not possess the requisite scientific and manufacturing experience.

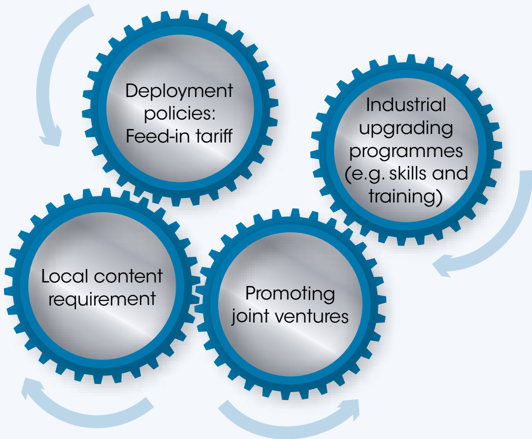
LCR efforts need to be part of a comprehensive industrial policy, complemented by training and skill-building policies. Meeting South Africa's LCR targets, for instance, will require a strong skill-building effort. In the country's wind sector alone, an estimated 6 250 engineers, technicians and skilled workers will be needed in manufacturing, construction and installation every year, as well as 2 000 skilled workers for O&M jobs by 2020 and 4 500 by 2030 (IRENA, 2014c). A new South African Renewable Energy Training Centre is to open by 2014 and train up to 2 000 people annually; however, people's basic education also needs to improve (Early, 2012).

A good match-up between foreign and local companies can bring great benefits to both: for the foreign companies, efficient local suppliers could reduce costs compared with imported inputs; for the local companies, there is an opportunity for knowledge transfer. Governments may need to set up capacity-building programmes that nurture local companies so that they can become competitive suppliers. The Turkish case, which has resulted in significant employment effects, is a case in point (see Box 3.2). Lastly, it should be noted that some types of LCR have been implemented in other industries in the past, and interesting lessons could be extracted from these experiences (see, for example, the IEA-RETD's RE-ValuePolicies Project, and IRENA and CEM, 2014).

Box 3.2

MIX OF DIFFERENT POLICIES: THE CASE OF TURKEY

Turkey represents an interesting example of coordination between LCRs and other policies including FiT, promotion of joint ventures and industrial upgrading programmes. The TurkishFiT for renewable energy is complemented by a payment for locally produced equipment used to develop the project. To ensure the transfer of appropriate technologies, the Turkish government introduced policies that support the establishment of joint ventures in thesolar energy industry. A significant number of jobs has been created as a result. One such example is the joint venture between created by China Sunergy (Chinese solar cell and module manufacturer) and Seul Energy Investment (Turkish solar system provider and project developer). The manufacturing plantfor solar cells and modules that they have set up has created as much as 1,200 new jobs. In parallel, industrial upgrading programmes have been implemented to support small and medium enterprises gain competitiveness through technical assistance programmes. These include skill upgrading and accelerated training, dissemination of relevant information to SMEs, including on investments, and support to entrepreneurship. These programmes are also contributing to enhancing local companies' attractiveness as potential partners for joint ventures.



Source: adapted from IRENA and CEM,(2014).

3.3 RESEARCH, CLUSTERS AND REGIONAL DEVELOPMENT

By facilitating information sharing and cross-pollination of ideas, industrial clusters can provide important benefits in the development of renewable energy capabilities. Such clusters reflect an important spatial element and are particularly relevant in the context of regional development policies. Clusters and regional policies involve a variety of economic actors, including government agencies, private businesses and universities. Research and development is typically a crucial component of such efforts.

3.3.1 Research and development

R&D can play an important role in the renewable energy sector. Publicly financed research (whether at government laboratories or universities) plays a critical role in pursuing the basic, pre-commercial research that the private sector typically does not undertake because of high risks and uncertainties, but which is critical for future breakthroughs. The most effective outcomes likely occur where there is strong collaboration among public and private research institutions and universities, ensuring that basic research is translated into applied research.

Global data for renewable energy R&D spending are not readily available, but the IEA (n.d.), offers comprehensive time-series statistics for its members since the mid-1970s. Public R&D spending for renewables rose from less than USD 1 billion annually for much of the 1980s and 1990s, to USD 1.9 billion in 2007 and USD 4.1 billion in 2009 and 2011 (dipping to USD 3.6 billion in 2010 during the economic crisis). In 2011, renewables received more than 20% of total energy R&D budgets – more than was spent on fossil fuels (USD 2.3 billion) but still less than the USD 5.3 billion devoted to nuclear energy. The effectiveness of R&D spending is enhanced when combined with other policies, as attempted by several countries (see Box 3.3 on the case of Malaysia).

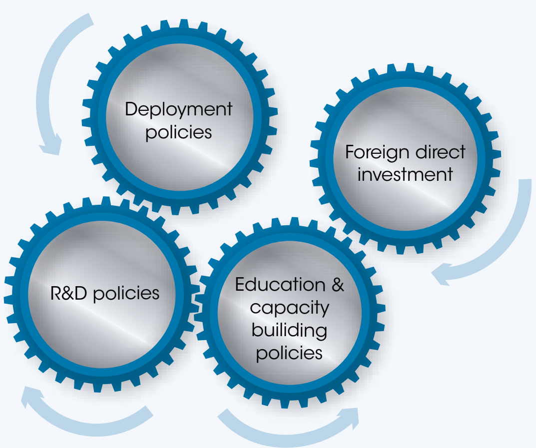
The connection between R&D budgets and employment is two-fold. R&D projects directly create employment for scientists and technicians at laboratories, but there is also a broader impact. Continuous R&D efforts help to make RETs more mature and cheaper to use, and thus more competitive compared to conventional energy sources (*i.e.*, learning-by-research), and they create knowledge spillover effects (*i.e.*, positive externalities) into other sectors and applications. As RETs become more mature and cost effective, they are able to capture a greater share of the overall energy mix, and this in turn helps to create or secure renewable energy employment, although this might mean that some jobs will be lost in the conventional energy sector. As RETs reach maturity, however, research is also one of the factors – along with learning effects and economy-of-scale impacts – which contribute to a process whereby, eventually, fewer workers are needed to produce a given amount of renewable energy.

Co-operation between public research institutions and businesses is critical for continued innovation and technological development. Growing numbers of countries have research institutions focused on renewable energy, some of which are tasked expressly with translating scientific findings into practical applications and entrepreneurial development. In the United States, the National Renewable Energy Laboratory was set up as early as the mid-1970s. In Germany, the extensive networks of the Fraunhofer Gesellschaft and

Box 3.3

MIX OF DIFFERENT POLICIES: THE CASE OF MALAYSIA

The National Renewable Energy Policy and Action Plan was approved in Malaysia in April 2010, and includes the following main elements: (i.) enhancing renewable energy research and technology; (ii.) intensifying human capital development; and (iii.) designing and implementing a renewable energy advocacy programme. The first one describes "the need for an R&D action plan which addresses the need for skilled people and adequate financing"; the second one "proposes actions that are designed to build up local expertise and skills in renewable energy and to provide individuals with the appropriate incentives to acquire these skills"; and the third one "consists of communication efforts with stakeholders and the general public, aiming to increase RE knowledge and understanding" (IRENA, 2014d). The Action Plan should benefit from existing complementary policies such as those focused on deployment (FiT), and those aiming at attracting FDI, which resulted in a significant share of the global FDI flowing into RE manufacturing, thereby impacting employment creation.



Source: adapted from IRENA (2014d).

Helmholtz Gemeinschaft include institutes focused specifically on wind, solar and bioenergy systems, such as Deutsches Biomasse Forschungszentrum in Leipzig and the Institute of Solar Research, established by the German Aerospace Centre (DLR) in 2011. In Spain, the National Renewable Energy Centre (Centro Nacional de Energías Renovables de España - CENER) was established in 2002 as a technology centre that specialises in applied research, with a focus on wind, solar thermal and solar PV, biomass, energy in buildings and renewable energy grid integration.

RET research centres are not very common in the developing world, a shortcoming which needs to be addressed. Collaboration with experienced research centres can help jumpstart this effort. In South Africa, the Renewable Energy Centre of Research and Development (RECORD) has been set up and co-operates with Germany's GIZ (RECORD, 2012). Similarly, in recognition of North Africa's tremendous potential, Germany's DLR is developing plans for a solar power research and test centre on behalf of the Moroccan Agency for Solar Energy. This centre might be based in Ouarzazate, the location of Morocco's first solar power plant (DLR, 2013).

In addition to nationally or internationally focused research institutes, some have a strong regional focus and may be part of an industry cluster. The Regional Energy Research Centre in the German state of Niedersachsen, for example, forms part of the Lower Saxony Network for Renewable Resources, a public-private partnership. The network aims to support the development of marketable renewable energy products, production processes and services (principally biofuels and biogas). It initiates joint ventures between commercial firms and research centres, provides support for pilot projects, conducts consultation and training workshops and establishes a communication platform between the local economy and scientific institutions. The ultimate intent is to strengthen the region's competitiveness in renewable energy, which helps to create or maintain jobs. Bioenergy in Lower Saxony supports more than 9 000 jobs directly (Lower Saxony Network for Renewable Resources, n.d.).

3.3.2 Clusters and regional development

Experiences in several countries indicate the value of forming industry clusters that can support RET development on a local or regional level by stimulating information sharing and the cross-pollination of ideas to mobilise a region's innovative potential. A cluster typically refers to a geographic concentration of interconnected economic and innovative activities in a particular field, such as renewable energy. It normally comprises members from industry, universities and research institutes, and government institutions which have common needs for technology and infrastructure, are willing to exchange information and work together in close-knit fashion, and expect mutually beneficial outcomes. This bundling of regional resources, strengths and competencies is thought to provide a unique competitive advantage (Porter, 1998).

Clusters can fulfil different types of functions, depending on the local circumstances and the specific role played by government authorities. They variably serve as "incubators" (creating a new industry from scratch); "reformers" (reshaping and revitalising a local economy); "multipliers" (strengthening an existing renewable energy industry); "executors" (with more limited autonomy compared with a central government); or "visionaries" (where renewable energy development is part of a broader attempt to pursue environmental policies) (University of Amsterdam and International Council for Local Environmental Initiatives (ICLEI), 2012). Research and development activities play an important role in some regional clusters, such as Germany's so-called "Solarvalley Mitteldeutschland" (see Box 3.4).

Strong local leadership is crucial, and personal relationships often help to drive such initiatives forward (University of Amsterdam and ICLEI, 2012). Governments can play an important role in setting the broad framework within which clusters can operate successfully, combining industrial policy, market-creating policies and business facilitation policies, among others (Hanni *et al.*, 2011). Besides supportive government policies, a solid infrastructure and a good skills base are critical elements of success.

There are several cluster initiatives focused on bioenergy development. France's Industrie et Agro Ressources (IAR), an agro-industrial competitiveness cluster in the northern regions of Champagne-Ardennes and Picardie, was formed in 2005 and represents more than 220 companies which employ some 29 000 people,

Box 3.4

SOLARVALLEY MITTELDEUTSCHLAND

Investment incentives, low interest loans and tax exemptions led to the emergence of "Solarvalley Mitteldeutschland", an area of solar PV module, cell and wafer production in Germany's Sachsen, Sachsen-Anhalt and Thüringen region. Having suffered from deindustrialisation and out-migration following German reunification in the 1990s, the region subsequently developed Europe's highest density of solar manufacturing facilities (Solarvalley Mitteldeutschland, n.d.). It benefitted from the synergies of previous industrial activities, including a skilled workforce and highly developed supporting industries such as microchips and semiconductors, optics, chemicals and glass (Metropolregion Mitteldeutschland, 2011).

A collaborative arrangement emerged that involves some three dozen PV manufacturers and equipment suppliers, nine research organisations and a dozen institutions of higher education. The Fraunhofer Center for Silicon Photovoltaics in the city of Halle is conducting research into new technologies, and thin film producer Calyxo GmbH had plans to more than triple its output by the end of 2012 (Nicola, 2012). Technology development, advanced training and cluster management are core activities in the region. As of early 2013, the Solarvalley area accounted for about 45% of German PV industry revenues and employed 10 500 people directly in the PV industry, plus another 2 500 in the supply chain (Solarvalley Mitteldeutschland, n.d.).

including in bioenergy and other bio-based industries (IAR, 2012 and 2010; PricewaterhouseCoopers (PwC), 2010). In Germany's state of Niedersachsen, a training and education programme provided more than 2 000 farmers with hands-on experience in biogas plant construction and operation over several years and gave the region a head start in this technology. Central to this effort was the proximity of a cluster of renewable R&D centres (EurObserv'ER, 2011). Similarly, in eastern Germany, the Energie Nord-Ost-Brandenburg (ENOB) initiative brings together farmers, planners, builders and operators of biomass facilities, grid operators, researchers and local authorities (ENOB, n.d.).

Several clusters focused on wind power and other RETs have emerged along Europe's Baltic and North Sea coasts, and they are typically centred around small and medium-sized enterprises. Examples include the Baltic Eco-Energy Cluster in Poland's Pomerania region (North Sea Supply Connect (NSSC), 2012) and the 170-plus member Renewable Energy Hamburg Cluster Agency in Hamburg, Germany, set up in January 2011. Local authorities in Hamburg concluded that the formation of a renewable energy cluster would help diversify the regional economy, and the region has since grown into a significant actor, hosting several major wind turbine manufacturers and a large number of SMEs. Counting solar and biomass power firms as well as wind, some 25 000 people are employed in the region's renewable energy sector, and employment is anticipated to grow 40% by 2015 (REHCA, n.d.).

Unlike larger, transnational companies, SMEs have strong local roots, enhancing the likelihood that employment benefits will stay in their home region. But clusters may involve firms of varying sizes. Some are driven by major renewable energy industry players. For example, a cluster has emerged around Danish wind energy giant Vestas's integrated wind energy equipment base in the Tianjin Economic-Technological Development Area in China (Hanni *et al.*, 2011). In Austria, several companies which have been dominant producers in the European solar thermal collector market are part of the network Ökoenergie-Cluster (OEC) of more than 160 companies and institutions that employs more than 8 880 people (EurObserv'ER, 2011; OEC, 2013).

Clusters are readily found in the industrialised countries that are renewable energy leaders. Yet this approach is equally valuable in other countries, although the existing scientific and technical capacities are often more limited. Clusters could play an important incubator function. In Michoacán, Mexico, for example, commercial companies, a technology institute, and the Mexican Geothermal Association have formed ClusterGEO (Cluster on Geothermal and Renewable Energies) with the intent of becoming a recognised pole of competence (International Geothermal

Association (IGA), 2012). Also in Mexico, the state of Sonora is promoting co-operation on solar energy among governmental, academic, and private sector actors (Thurston, 2012a). The absence of clusters can be a competitive disadvantage, as India's solar PV manufacturing industry has found (Singh, 2013).

The various experiences to date suggest that local and regional initiatives which set ambitious targets and provide appropriate support policies can attract high volumes of investment and create jobs. Policies in support of renewable energy development need careful matching with broader economic strategies. Including all pertinent stakeholders is critical, as is a targeted public information campaign, in order to map available local assets and fully mobilise the inherent potential.

Through cluster formation and other means, central governments as well as regional and local authorities have pursued regional development efforts. Many such efforts, although not all, have been motivated by the desire to overcome problems brought on by crises in older industries, a lack of economic diversification and other circumstances, which may translate into unemployment or out-migration.

In the United States, wind energy development has injected new life into many abandoned "rustbelt" industrial facilities in areas which have suffered from deindustrialisation. Incentives from state governments – including grants and tax breaks – have attracted private investments that helped transform a former steel mill in Pennsylvania, a freight-car factory in Illinois and a metal foundry in Ohio into facilities producing towers, rotor blades, nacelles and other components of wind turbines (UNEP, 2008).

In Canada, the province of Québec used wind energy development to overcome severe economic problems in the Gaspé peninsula triggered by crises in the fisheries, forestry and mining sectors. Wind power tenders in 2003 and 2005 included a 60% LCR (a policy discussed in Section 3.2.2) within Québec and a further requirement that 30% of turbine spending take place in the Gaspésie. A centre for turbine maintenance (TechnoCentre Éolien) was set up, and the regional development programme Action Concertée de Coopération Régionale de Développement was launched in 2007 to promote economic innovation and employment in the province. Its efforts include the formation of a manufacturing cluster capable of producing wind turbines. Gaspésie unemployment fell from 20% in 2000 to 12.4% in 2011 (OECD, 2012).

In Germany, as shipyards have increasingly lost out to Asian competitors, the workforce was slashed from 59 000 in 1990 to some 16 000 today (Hülsen, 2012). From an engineering and skills perspective, the know-how of the shipbuilding industry can be applied to wind infrastructure. A substantial number of former shipyard workers have found jobs in offshore wind, partly because their existing skillsets allowed for successful retraining. Providing inputs for the offshore wind industry could generate an estimated EUR 18 billion worth of revenues for German shipyards by 2020 and secure some 6 000 jobs as they diversify their business. At Nordseewerke in the city of Emden, for example, shipbuilding halted entirely in 2009, and the 780 remaining workers are now building towers and steel bases for offshore wind farms (Hülsen, 2012; Fornahl *et al.*, 2012).

On the Iberian Peninsula, several regional renewable energy initiatives have focused on both wind and solar development. Portugal's National Strategy for Energy is driven mainly by socio-economic development goals (see Box 3.5) (Telha and Gomes, 2011). In neighbouring Spain, the provincial government of Navarra struck a tripartite agreement with businesses and labour unions in favour of an active industrial policy, of which renewable energy development was a key element. The share of wind power in the region's electricity generation subsequently jumped from zero in 1994 to 46% in 2008-09 (with other renewables contributing a further 20%, supported by deployment policies). Renewable energy companies have created more than 6 000 direct jobs (Roig Aldasoro, 2009; Gobierno de Navarra, 2010).

In addition to state or provincial governments, municipal authorities can play an important role in supporting the establishment of renewable energy industries. Dezhou, China, a city of about 5.8 million inhabitants in northwestern Shandong province, took on the role of incubator for the local solar industry, which had suffered from poorly developed financing mechanisms, skill shortages and a lack of quality standards. The 2005 Dezhou Solar City Plan provided incentives to business such as tax waivers, reductions, rebates, preferential

Box 3.5

WIND AND SOLAR PV AS REGIONAL DEVELOPMENT TOOLS IN PORTUGAL

The Portuguese regions of Norte, Centro and Alentejo have excellent renewable energy endowment and have received most of the country's renewable energy investments to date. Wind energy has become Portugal's most dynamic form of renewable energy, enabling significant regional business investment and jobs. A large number of wind technology components are manufactured locally, including towers, rotor blades, E-modules and generators.

A wind industrial cluster has emerged around facilities set up by Eólicas de Portugal (ENEOP) in Viana do Castelo and Lanheses, two adjacent municipalities in Portugal's Norte region. ENEOP has built five new factories and a centre for R&D and training, and as part of the local supply chain, two new factories were built and 11 existing factories expanded. Along with suppliers of components and services located elsewhere, there is now a wider industrial cluster of 29 companies (ENEOP, 2012; OECD, 2012).

Locally, the companies grouped around ENEOP have to date created more than 1 900 direct jobs, most of them highly skilled (ENEOP, 2012), as well as indirect employment as high as 5 500 jobs (Martinez-Fernandez, Hinojosa, and Miranda, 2010). Two rotor blade factories are by far the largest employers in the cluster with more than 1 000 direct jobs. Additional jobs are found in activities such as electrical equipment manufacturing, transport and logistics, concrete for turbine towers, and generator production (ENEOP, 2012).

In comparison with wind energy, solar PV still has a small presence in Portugal's energy mix. Like Viana do Castelo, Baixo Alentejo in southeastern Portugal is a locality that had fallen on hard economic times, with farming as the economic mainstay and unemployment at about 11%. Large PV arrays have been installed in the towns of Serpa and Moura, and Moura also has a 44 MW peak solar PV module assembly plant. Acciona's EUR 7.5 million investment has created 115 permanent jobs (EurObserv'ER, 2010), and about 400 temporary jobs were created when the plant was constructed (Rosenthal, 2010). A renewable energy laboratory opened in February 2010, and both the laboratory and assembly plant form part of a 35-hectare science park intended to attract cutting-edge energy technology companies, with hopes for creating anywhere from 1 300 to 2 400 new jobs over a number of years (EurObserv'ER, 2010).

land use policies and low-interest loans. The Million Roof Project, launched in 2008, required that all new residential buildings be equipped with solar water heating facilities. Dezhou's SWH use now approximates that of the entire EU. A renewable energy research institute was established, and solar technology became a specialised subject taught at Dezhou Technology College and at vocational schools. By 2006, some 30 000 people were employed in solar energy-related businesses, and another 20 000 – 30% of all new jobs created in Dezhou in 2010 – were in the solar sector. The plan is to create 10 000 additional renewable energy jobs in 2011-15 (ICLEI and IRENA, 2012).

3.4 CONCLUSIONS

Experience shows that a range of policies enable the growth of the renewable energy sector and thus at least indirectly assist in renewable energy job creation. These include enabling the deployment of RETs, guiding trade and investment links, strengthening domestic capacities, fostering regional development and the formation of clusters and supporting R&D. These policies are most effective when they are pursued in conjunction with each other and together with broader economic polices (industrial, labour, fiscal, etc.), whose analysis is outside the scope of this report. Although governmental support policies occasionally may need to be recalibrated in light of changing conditions and circumstances, the experience of recent years indicates how important it is to avoid abrupt policy reversals which put renewable energy jobs in jeopardy.

Market-creating policies generally have proven to be very effective instruments. In particular, the stable framework provided by FiTs has allowed renewable energy markets to develop and to attract investors, although governments also rely on other measures such as renewable portfolio standards and quota policies, auctions and tax credits.

Policies governing cross-border trade and foreign direct investments – and, specifically, enabling technology spillovers and other learning effects – are also important. This is a matter of setting appropriate rules for exporters and investors, as well as of developing proper domestic capacities to take advantage of cross-national links. Under a regime of low import tariffs, imported renewable energy equipment becomes more affordable, and employment in installation and O&M is facilitated. By the same token, however, domestic manufacturers may find it difficult to compete against cheap imports, which could limit the creation of domestic renewable energy manufacturing jobs. FDI, by contrast, provides a greater opportunity for joint ventures between foreign and domestic firms, which can form the kernel of an emerging domestic renewable energy industry.

LCR policies can help with the establishment of domestic renewable energy manufacturing industries. But governments need to pay close attention to their design and to link them closely to a learning-by-doing process. Governments also need to accompany LCR policies with R&D programmes, measures to facilitate the creation of a strong domestic supply chain, provision of quality infrastructure and efforts to develop a sufficiently skilled workforce (for the latter, see Chapter 4). In the wake of the Ontario case ruling, governments increasingly need to find ways to reconcile LCR policies and WTO rules. This might be accomplished by negotiating a special sectoral agreement that addresses tariff and non-tariff issues, subsidies and public procurement in a manner that facilitates, rather than inhibits, the further development of renewable energy around the world.

Renewable energy deployment can be a boon for regional development, either to develop a renewable energy industry from scratch, to transform an economic backwater into a more vibrant region or to reinvigorate a crisis-shaken area. Often, such efforts involve the formation of regional clusters that bring together stakeholders such as industry, universities, research institutes and government institutions. Governments must play a key role in developing the frameworks within which clusters can operate successfully. In developing countries, clusters are still rare, but they could play an important incubator function in developing renewable energy industries.

National and regional policy choices and priorities will naturally vary, depending on a country or region's particular strength and weaknesses, and its economic conditions. The evidence from existing policies suggests that success in attracting investments, developing capacity, deploying renewable energy and generating employment requires a combination of policies and striking a careful balance between government regulation and market incentives.

This should be complemented by other policy domains which are beyond the scope of this report, notably industrial, labour, and fiscal policy. With regard to labour policy, improved mobility, information or flexibility could help to grasp the employment synergies with other existing sectors. In fiscal policy, green tax reform (for instance, reducing taxes on labour while introducing a carbon tax or other pollution-based taxes) could help with job creation and other economic benefits.

4 Renewable Energy Skills, Occupations, Education and Training

© Soraya Kerouí

Provided that global trends in RET deployment persist, the demand for qualified human resources for a thriving renewable energy sector will continue to rise, raising the potential for skills gaps and labour shortages. Already, shortages in skills are hindering the transition to sustainable energy in many countries, contributing to cost overruns, project delays, cancellations and faulty installations (ILO, 2011a). Such outcomes can lead to negative perceptions about the reliability and maturity of RETs, thereby reducing public acceptance, impeding renewable energy deployment and decreasing the potential for overall job creation in the sector.

Better training and education play an important role in developing the skills necessary to ensure the successful deployment of renewable energy. As the energy sector transforms towards a higher share of renewables, comprehensive strategies and adjustments are needed that address the requirements for renewable energy skills, education and training. Recent years offer a variety of lessons on how governments have integrated education and training into national renewable energy support policies and how the education sector and other relevant stakeholders have contributed to bridging the skills gap. This chapter explores some of these initiatives, as well as selected experiences and best practices in providing adequate education and training to serve the renewables sector. The analysis does not consider this topic in the specific context of energy access, which is addressed in Chapter 5. A variety of terms used in this chapter that appear frequently in the renewable energy literature are defined in Box 4.1.

Box 4.1

KEY DEFINITIONS: EDUCATION, TRAINING AND SKILLS DEVELOPMENT

Capacity: The ability of individuals, organisations and societies to set and achieve their own development objectives (UNDP, 2007).

Skill: The ability to do something well; know-how; expertise.

Core employability skills: Knowledge and competencies that enhance a worker's ability to secure and retain a job, progress at work and cope with change (teamwork, problem solving, information and communications technology (ICT) and communication and language skills).

Education/Training: The process of receiving or giving systematic instruction, at a school, university or other institution. Primary education covers the first 5-7 years of formal education, secondary education the following 3-5 years. These can be followed by tertiary (higher, non-compulsory) education, such as at universities or vocational schools.

Technical and Vocational Education and Training (TVET): Focus on acquiring practical/manual skills for a craft or industry.

Apprenticeship: A system of training which usually combines on-the-job training and work experience with institution-based training. It can be regulated by law or by custom.

Continuing education: Undertaken by those who have already completed basic or initial training, in order to supplement acquired knowledge or skills.

Dual-system education: Planned learning which takes place in two locations: the employer's premises and the vocational school (ILO, 2012a).

Note: Terms are based mostly on Oxford dictionaries (Oxford, n.d.) and the ILO thesaurus. More definitions can be found in ILO (2012b) and IRENA (2012b).

4.1 OCCUPATIONS AND SKILLS NEEDED IN THE RENEWABLE ENERGY SECTOR

A broad range of occupations can be found along the different segments of the supply chain for each RET. These include positions in equipment manufacturing and distribution, project development, construction and installation, and O&M, along with cross-cutting/enabling activities that apply to all technologies and segments of a RET supply chain. Many of these occupations have significant skill requirements, and filling them can be challenging. Evidence suggests that, in particular, engineers and technicians for all RETs are in short supply in many countries.

The shortage in necessary skills in the renewable energy workforce is already a major barrier to the deployment of renewable energy. Shortages of skilled labour can slow down progress, and installations performed by inadequately trained personnel can result in performance issues and lead to a negative public perception of RETs.

It should be noted that there is significant variation in the skills demanded by occupation in renewable energy and therefore there is a need for occupation-specific education and training. In addition to RET-specific skills, it is important that training programmes also provide core technical and soft skills that increase employment opportunities for workers by allowing them to be more flexible.

4.1.1 Renewable energy occupations across the supply chain

The renewable energy sector presents a wide opportunity for job creation, and a broad range of occupations exists across the various segments of the supply chain for the major RETs (see Table 4.1). Although some common occupations are found across all RETs (shown in light grey boxes in the table), the skills required for performing those jobs are unique to each RET. A manufacturing engineer for wind turbines, for example, must acquire a different set of skills than a manufacturing engineer for solar panels. In addition, many occupations are specific to each RET (shown in the boxes with RET-specific colour coding) – for example, plumbers and architects for solar, marine engineers for offshore wind, geologists for geothermal, and biochemists and agricultural scientists for bioenergy.

Table 4.1 Summary of occupations required for RETs

<table>
<tr><th></th><th>SOLAR</th><th>WIND</th><th>HYDRO</th><th>GEOTHERMAL</th><th>BIOENERGY</th></tr>
<tr><td></td><td colspan="5">Equipment Manufacture and Distribution</td></tr>
<tr><td>Common occupation</td><td colspan="5">» R&D engineers (computer, electrical, environmental, mechanical, material) (H)
» Software developers and engineers (H,M)
» Modellers (prototype testing) (H,M)
» Industrial mechanics (M)
» Manufacturing engineers (H)
» Manufacturing technicians (M)
» Logistics professionals and operators (H,M)
» Manufacturing operators (L)
» Manufacturing quality assurance experts (H,M)
» Certifiers (M)
» Equipment transporters (L)
» Procurement professionals (H,M)
» Marketing specialists (H,M)
» Sales personnel (H,M)</td></tr>
<tr><td>Occupations for each technology</td><td>» Researchers (chemists, physicists, engineers with specialisation in electrical, mechanical, chemical, materials, system design or process engineering) (H)
» Chemical laboratory technicians and assistants (M)</td><td>» R&D engineers (computer, electrical, environmental, mechanical, wind power design) (H)</td><td>» Design engineers (civil, mechanical, electrical, hydropower) (H)</td><td>» Machinists (M)
» Welders (M)</td><td>» Biochemists and microbiologists (H)
» Agricultural, biological, chemical and physical scientists (H)
» Chemical, biological, mechanical and electrical engineers (H)</td></tr>
<tr><td></td><td colspan="5">Project Development</td></tr>
<tr><td>Common occupation</td><td colspan="5">» Project designers (engineers) (H)
» Market analysts (H)
» Environmental impact assessment engineers, consultants (H,M)
» Economic/financial/risk specialists (H)
» Atmospheric scientists and meteorologists (H)
» Geographers (H) and social impact specialists (H)
» Lawyers (commercial, feed-in contract, grid connection and financing contract, construction permit, power purchase agreement, government programmes) (H)
» Sustainability specialists (natural resource/ environmental planners, social scientists, cultural consultants) (H)
» Planners (permit monitoring, amendment, application) (H)
» Resource assessment specialists and site evaluators (H)
» Archaeologists (H)
» Land development advisors (H)
» Land use negotiators (H)
» Lobbyists (H)
» Mediators (H)
» Environmental and social NGO representatives (H,M)
» Public relations officers (H)
» Procurement professionals (H,M)
» Debt financier representatives (H)
» Developers/facilitators (H,M)
» Communications specialists (H)</td></tr>
<tr><td>Occupations for each technology</td><td>» Architects (H) (small projects)</td><td></td><td>» Physical and environmental scientists (hydrologists, geologists, ecologists) (H)
» Natural resource/environmental lawyers (H)</td><td>» Hydrologists, hydrogeologists (H)
» Geologists (H)
» Geophysicists (H)
» Geothermal engineers (H)</td><td></td></tr>
<tr><td></td><td colspan="5">Construction and Installation</td></tr>
<tr><td>Common occupation</td><td colspan="5">» Project designers and managers (H)
» Engineers (civil, mechanical, electrical, environment.) (H)
» Technicians (civil, mechanical, electrical) (M)
» Construction electricians (M)
» Project and installation evaluators (H,M)
» Power line technicians (M)
» Construction workers (M,L)
» Quality control inspectors (M)
» Measurement and control engineers (H)
» Business developers (H)
» Commissioning engineers (electrical) (H)
» Instrumentation and control technicians (M)
» Transportation workers (L)
» Construction professionals (H)
» Software engineers (H,M)
» Construction equipment operators (M)</td></tr>
</table>

	SOLAR	WIND	HYDRO	GEOTHERMAL	BIOENERGY
Occupations for each technology	Solar Thermal (ST) » System designers (H,M) » Plumbers specialising in solar (M) Small Photovoltaic (Small PV) » System designers (electrical engineers or technologists) (H,M) » Electricians specialising in solar (M) Small PV, ST » Roofers specialising in solar (M) Large PV » System designers (electrical/ mechanical/structural engineers) (H) » Installers (M) Concentrated Solar (CSP) » Welders (M) » Pipe fitters (M) Small PV, Large PV, ST, CSP » Electrician solar specialists (M) » Installers (M) » Project and installation evaluators (H,M)	» Marine engineers (H)	» Skilled construction workers (heavy machinery operators, welders, pipe fitters etc.) (M)	» Hydrologists, hydrogeologists (H) » Geologists (H), » Geophysicists (H) » Geothermal engineers (H) » Geochemists (H) » Chemical laboratory technicians and assistants (M) » Drilling engineers (H) » Architects (H) » Structural engineers (H) » Surveyors (H) » HVAC technicians (H) » Drilling technicians and operatives (roughnecks) (M) » Welders (M) » Pipe fitters (M) » Plumbers (M) » Drilling equipment operators (M) » Excavators (L)	» Biochemists and microbiologists (H) » Laboratory technicians and assistants (M) » Chemical, biological, mechanical and electrical engineers (H) » General electricians, plumbers, roofers (M)
	Operations and Maintenance				
Common occupations	» Operations and maintenance specialists (M) » Power line technicians (M)	» Field electricians (M) » Inspectors (M,L)	» Recycling specialists (H)	» Measurement and control engineers (H)	
Occupations for each technology	» Photovoltaic maintenance specialists (electricians specialising in solar) (M) » ST maintenance specialists (plumbers specialising in solar) (M) » CSP maintenance specialists (M)	» Windsmith/millwright/ mechanical technicians or fitter/wind service » Mechatronics technicians (M, some H) » Operations and maintenance specialists (M) » Power line technicians (M) » Wind service mechatronics (M)	» Engineers (civil, mechanical, electrical) (H) » Physical and environmental scientists (hydrologists, ecologists) (H) » Tradespersons (M)	» Plant managers (H) » Welders (M) » Pipe fitters (M) » Plumbers (M) » Machinists (M) » Construction equipment operators (M) » HVAC technicians (M)	» Biochemists and microbiologists (H) » Laboratory technicians and assistants (M) » Agricultural scientists (H) » Biomass production managers (H,M) » Plant breeders and foresters (H,M) » Agricultural/forestry workers (L) » Transportation workers (L)
	Cross-cutting/ Enabling Activities (Apply to all technologies and segments of the supply chain)				
Common occupations	» Sales and marketing specialists (H,M) » Educators and trainers (H) » Management (H,M) » Publishers and science clients (H,M,L)	» Trade association professional society staff (H,M,L) » Writers (H,M) » Insurer representatives (H,M)	» IT professionals (H,M) » Administration (H,M,L)' » Human resources professionals (H)	» Other financial professionals (accountants, auditors, financers) (H) » Health and safety consultants (H,M)	

Source: ILO 2011a and 2011b

Where: H = High skilled; M = Medium skilled; L = Low skilled.

Table 4.1 lists some 150 different occupations and gives an indication of the wide range of skills required. Most of these occupations are categorised as either high-skilled or medium-skilled, although this does not necessarily mean that occupations with low skill requirements are scarce in the renewable energy sector. For example, agriculture-related activities within the biomass sector or work related to PV installation is undoubtedly very important for the deployment of RETs. The crucial bottleneck, however, can be expected in the medium- and high-skilled occupations, which require a minimum level of education and training and are by their nature more difficult to fill.

The table also provides a snapshot of the existing occupations in the renewable energy sector going forward. As RETs are further integrated into the electricity, transport and other sectors it is expected that new occupations and corresponding skill requirements will emerge.

4.1.2 Skill shortages and requirements

Identified skill shortages. The lack of adequate skills is a major barrier to renewable energy deployment in both industrialised and developing countries. The absence of skilled personnel can compromise the quality and performance of renewable energy systems, affecting the perceived reliability and social acceptance of RETs and hindering their uptake.

The Spanish experience in deploying SWH installations is a case in point. After Spain enacted a building code in the early 2000s requiring the use of SWH in new buildings, demand for the units skyrocketed during a boom period for Spanish real estate, leading to a shortage in skilled personnel to perform the installations and to a high share of faulty installations. Skill deficits were observed along the entire value chain, including in the design, installation and maintenance of systems. These events continue to influence public perception of solar thermal technology in Spain today (Energy Agency Barcelona, 2013a and 2013b).

Table 4.2 lists the renewable energy occupations that have been identified as "difficult to fill" in many countries, according to a survey conducted by the International Renewable Energy Alliance (ILO, 2011b). The results show a shortage of engineers and technicians for all RETs, across their entire value chains. The increasing demand for workers with particular technical skills affects not only the renewable energy sector, but other industries as well. In industrialised countries, the demographic trend showing professional engineers and technicians retiring across many industries indicates that there will be increasing competition for young professionals with technical skills.

A report by the IEA's Implementing Agreement on Renewable Energy Technology Deployment supports these findings, particularly for solar PV and onshore wind technologies[13] (IEA-RETD, 2012). It finds that:

- For solar PV, "insufficient skilled personnel for PV installations" is a medium-critical bottleneck – a bottleneck that is either already existing or very likely to occur and which has an important impact on RET deployment.
- For onshore wind technology, "limited availability of skilled personnel along the supply chain" is a medium-critical bottleneck. In the United States, (Leventhal and Tegen, 2013) estimate that the number of bachelor- and master-level programmes focusing on wind energy has to be multiplied by a factor of at least 5-10 to reach the 2030 wind targets.

Table 4.2 Renewable energy occupations identified as "difficult to fill"

RE SECTOR	OCCUPATION
Wind energy	Project developers; service technicians; data analysts; electrical, computer, mechanical and construction engineers.
Solar energy	Photovoltaic and solar thermal system installers and maintainers; building inspectors.
Hydropower	Electrical, and operations and maintenance engineers; technicians; tradespersons; sustainability specialists.
Geothermal	Trainers; geothermal engineers.
Bioenergy	R&D and design engineers; service technician; trainers.

Source: ILO, 2011b

[13] *ILO (2011a) provides additional examples for other technologies such as hydro and use of biomass.*

The impacts of such skill shortage on deployment can be high, especially in regions where the sector is growing quickly from a low base.

- Knowledge gaps related to renewable energy have been identified for non-technical occupations encompassing commercial, financial, legal and policy-making activities. For instance, the lack of relevant knowledge and skills in institutions and organisations is a common barrier to developing comprehensive public and private strategies that consider the broader socio-economic and environmental benefits of renewables. In the public sector, uncertain procedures in obtaining permits, inconsistent policies, insufficient planning, cumbersome administrative processes, etc., can be attributed in part to the lack of adequately skilled personnel. Considering the impacts that unrealised or deferred projects have on potential employment, policy makers should pay special attention to appropriate education and training measures for the public sector.

Skills gaps can affect the successful completion of various activities along the renewable energy value chain, hindering overall deployment. One major reason for the skills gaps is the general lack of trainers and teachers in the renewable energy field, which is still relatively new. Specialists who have worked in the industry and who are able to share their knowledge are in short supply, as are teachers and professors whose academic careers are focused on renewable energy (TP Wind, 2013; IEA-RETD, 2010).

Specific and portable skill requirements. The types and levels of skills required to fill occupations along the different phases of a renewable energy project – such as planning, installation and O&M – depend on their level of specificity to renewable energy. Some jobs relate exclusively to the renewables sector (*e.g.*, wind turbine maintenance), while others are linked to renewable energy on a regular basis (*e.g.*, architects or installers for SWH). The majority of jobs in the renewable energy sector, however, are exposed only occasionally to renewable energy issues (*e.g.*, administrative jobs). The risk of experiencing a shortage in skills is highest for the first group, which requires skills specific to renewable energy, whereas for the third group, basic knowledge about renewables is sufficient.

Occupations in the renewable energy sector also require skills that are "portable" (or transferrable). For example, workers and commissioning engineers who are specialised in construction and installation are needed during the installation phase of large renewable energy plants but are no longer required once the plants are operational. Such workers either need to be mobile enough to work on other renewable energy projects in different locations, or they need to possess various core skills that allow them to be employed flexibly on different (potentially non-renewable energy) jobs or projects. Other skills – such as team working, communication and problem solving – help workers better adapt to changing technologies, occupations and sectors. Because these skills and attributes are seen as desirable by almost any employer in any sector, they can be considered as portable, providing flexibility to workers and companies alike.

4.2 DEVELOPMENT OF SKILLS REQUIRED TO FILL RENEWABLE ENERGY OCCUPATIONS

New joiners to the renewable energy workforce are generally either young professionals with or without renewables-related education or vocational training degrees, workers with experience in other sectors, or previously unemployed individuals (ILO, 2011a). Given the relatively high level of skills required, and the often urgent demand to fill occupations in the short term, the sector is frequently faced with a shortage in adequate skills needed to successfully complete projects. In this case, renewable energy companies resort to recruiting experienced workers with comparable skillsets from other sectors and providing them with job-specific training. But this strategy to "outspend" other sectors is costly and risky for a sector which faces severe increases in human resource requirements.

For certain jobs, the renewable energy industry may be able to source skilled personnel from other areas in the energy sector. For example, drilling experts from the petroleum sector can be employed in geothermal energy; workers from the offshore oil and gas sector can move to offshore renewable technologies (wind, wave and tidal); and electrical engineers and technicians can be sourced from the conventional electricity industry. But the potential to transition from one industry to another has limitations. Renewable energy projects may not be located in the same region, or a temporal mismatch may occur between job availability in one sector and job losses in another. In the long run, to support large-scale renewable energy deployment, the sector will have to recruit many new entrants from within the countries where projects are implemented – making the case for policies to promote renewable energy skills development, as well as education and training to develop such skills.

4.2.1 Promoting skills development through policies

The policy and regulatory environment has a significant influence on the number of renewable energy jobs available and thus the required supply of skills. In countries with a long tradition of renewable energy use, the supply of skills has adjusted to the maturity of the market. In contrast, countries that experience sudden changes in policies typically experience either a considerable gap in adequate skills (for example, Japan faced a lack of skilled wind energy personnel after it introduced attractive renewable energy support policies) or an oversupply of skilled workers (in Spain, some 20 000 renewable energy employees lost their jobs due to the unfavourable adjustments in the regulations) (Castano, 2010). Many studies point to the need for long-term and stable renewable energy policies to facilitate skills development and support steady growth in the renewables sector.

Consistent and effective policies in the field of education and training are crucial to support the renewables sector by providing the skills necessary for renewable energy deployment. Important policy measures include strategic planning for skill needs; financing for renewable energy education, training and research; and the inclusion of renewable energy in educational programmes.

Strategic planning for skill needs, education and training

A comprehensive renewable energy strategy needs to ensure that industrial policies and other supports for renewables are underpinned by measures which make the necessary skills available. Malaysia's National Renewable Energy Policy and Action Plan, for example, is based on an analysis of the expected demand for renewable energy skills and proposes a variety of educational and supporting measures to help meet that demand (see Box 4.2). A well-planned education and training strategy can enable the

Box 4.2

SKILLS TRAINING UNDER MALAYSIA'S NATIONAL RENEWABLE ENERGY POLICY AND ACTION PLAN

Malaysia's National Renewable Energy Policy and Action Plan, approved in April 2010, includes five strategic thrusts. One of them, Intensifying Human Capital Development, proposes actions that are designed to build up local expertise and skills in renewable energy, and to provide individuals with the appropriate incentives to acquire these skills. Actions include:

- Incorporating renewable energy into technical and tertiary curricula, requiring collaboration with relevant ministries and certification of training courses according to the National Skills Development Act;
- Developing training institutes and centres of excellence, meeting international quality standards for renewable energy education and promoting high-class facilities at universities; and
- Providing financial supports, including technical training subsidies that are paid to individuals after they have completed renewable energy courses, and fiscal reliefs for higher education that allow students to treat payable fees as deductible expenses.

The measures are to be co-ordinated among various ministries (finance, higher education, human resources) and other governmental agencies. In the meantime, immediate skills gaps are likely to be covered by skilled foreign workers.

The national renewable energy plan also includes two other strategic thrusts that aim to develop knowledge and expertise: enhancing renewable energy research and technology, which describes the need for an R&D action plan which addresses the need for skilled people and adequate financing; and designing and implementing a renewable energy advocacy programme, which consists of communication efforts with stakeholders and the general public, aiming to increase knowledge and understanding.

development of a national or regional renewable energy industry and thus contribute to job creation.

In addition to quantitative assessments to determine potential job creation from planned renewable energy deployment (see Chapter 2), qualitative research based on interviews or surveys is required to (a) determine the necessary skills for the projected occupations (considering that job profiles and qualifications are subject to change) and (b) analyse the potential sources of skill supply. Sources of skills can include initial education, upskilling and training of the existing workforce, recruiting from other sectors or internationally, and activating unemployed/inactive people (ILO, 2011a). Also, tools such as CaDRE (Capacity Development Needs Diagnostics for Renewable Energy) can help to identify the skills gaps and needs for different renewable energy sectors and to determine target areas for training and skill development (CEM, 2012).

Public financial support for renewable energy education, training and research

Governments can provide different types of funding to support education and training in the renewable energy sector, including the following:

- » Energy or education ministries and other public bodies can provide funding to finance renewable energy-focused research and education institutions. For example, the Masdar Institute of Science and Technology, a graduate level research and teaching university financed by the government of Abu Dhabi, offers graduate-level courses in clean energy and sustainability (Masdar, n.d.). Another example is the New York State Energy Research and Development Authority (NYSERDA), a public benefit corporation which focuses on renewable energy and energy efficiency development and provides vocational training, among other services (NYSERDA, n.d.).

- » Public-private partnerships (PPPs) are another way to finance institutions. The main mission of the Spanish School for Industrial Organisation (EOI), a business school supported by the Ministry of Industry, Energy and Tourism, is to train professionals in new strategic sectors within the national industrial policy. The school, which has focused on environmental education since 1976, has enrolled more than 55 000 students since it was founded in 1955 and offers postgraduate education, including a master's degree in Renewable Energy and Energy Markets (EOI, n.d.). PPPs also can finance specific programmes such as dual-education systems or other vocational offerings where companies benefit directly from better-trained workers. In addition, PPPs are common in education or capacity-building programmes that are combined with renewable energy implementation projects, such as the rural-based initiatives of Nepal's Alternative Energy Promotion Center (Dhakal, 2008).

- » Governments can introduce or support direct measures such as renewable energy professorships or staff positions, trainings, research fellowships, research equipment, grants and vocational training programmes.

Research has shown that the individual and societal benefits of higher education surpass its costs in all countries studied (OECD, 2013). This means that public investments in renewable energy education have a high chance to pay off, including with positive effects on the employment market, provided that the specific country context has been well analysed and that renewable energy policies are implemented consistently.

Including renewable energy in curricula and vocational training

Policy makers can increase the visibility and accessibility of renewable energy education and training and promote the inclusion of renewable energy topics in varying types of formal education and training. Yet policy makers can influence the education sector only to a certain extent. Education is a field that is based widely on consensus between various public and private stakeholders, such as ministries, public and private institutions, and teachers' unions. Because it is difficult for governments to simply "mandate" actions, they frequently play more of a moderating role.

One area where policy makers can have a comparably strong say in defining educational content – and in fostering the inclusion of renewable energy topics – is primary and secondary education. In some countries or regions, such as Bavaria in Germany, renewable energy has become part of the standard curriculum at primary and secondary schools (mainly integrated into existing courses) (Wörner, 2010). The German Ministry of Environment supports schools by providing educational material for young students (BMU, 2012).

In contrast, policy makers have limited influence on the content of university studies and research areas, due to the general independence of these institutions. Renewable energy subjects can be included, however, in agreements between universities and the authorities which are responsible for setting the requirements for funding. Moreover, universities can be incentivised to increase renewable energy research and curricula by providing special funding for renewable energy-related projects or programmes. For example, the United States Department of Energy's Office of Energy Efficiency and Renewable Energy invites universities to solicit financial assistance (USDoE, n.d.)

In the field of vocational education and training, renewable energy-related activities can be included in officially recognised apprenticeship regulations. In Europe, the EU Renewable Energy Directive has required member states "to ensure that certification schemes or equivalent qualification schemes become available by 31 December 2012 for installers of small-scale biomass boilers and stoves, solar photovoltaic and solar thermal systems, shallow geothermal systems and heat pumps" (EC, 2009). In this case, a top-down policy approach was used.

For continuing education and training, the role of policy makers depends on the body responsible for the training institution. For instance, it may be possible to encourage publicly financed adult-learning institutions to develop new renewable energy-specific courses or to include renewable energy topics in existing ones. Private institutions, however, commonly respond to the demand of the market; in cases where they receive public co-funding, they may be able to adjust their programmes upon request of the donor.

4.2.2 Developing skills through education and training

Bridging the renewable energy skills gap requires an enabling environment created through education and training policies. Such an environment facilitates the efforts of the relevant stakeholders, such as the education sector (universities and vocational institutions) and the renewable energy industry. In addition to various stakeholder-led initiatives to provide education and training, important sector and region-crosscutting activities include continuing education and training, standardisation of qualifications across regions, international collaboration between stakeholders, and platforms for increasing the visibility of renewable energy education and job offerings.

Universities: renewable energy courses and research

Universities play a key role in equipping the workforce with the skills necessary for deployment of renewable energy. They can be important change agents or incubators of innovative ideas for RETs and deployment. They foster thinking across system boundaries (for example, explaining the broad impacts of renewable energy policies to engineers) by providing insights into issues that go beyond the normal scope of a course. Because decision makers in companies or public administration often have an academic degree, universities have a special responsibility to provide this holistic view.

University courses at the bachelor/undergraduate level generally provide a good basis for future work in the renewable energy sector, especially when they are complemented with experience gained through internships, on-the-job learning or additional coursework. Postgraduate/master-level courses, on the other hand, can offer more in-depth knowledge and training in renewable energy. Increasingly, universities around the world are providing specialised renewable energy curricula or courses that can be combined with existing courses [14].

In Germany, more than 380 study programmes include renewable energy as a major component (see Box 4.3). In addition, since 2002 the European Master in Renewable Energy programme, aimed at post-graduate students, has been offered by the European Renewable Energy Centre as well as universities in France, Germany, Greece, the Netherlands, Portugal, Spain, and the U.K. The programme hosts around 50 students per academic year. Universities also are setting up renewable energy departments where, in addition to RETs, students can explore complex issues of system integration including system modelling, smart grids, IT applications, energy storage and demand-side management.

[14] *A list of offerings around the globe can be found in the courses database of the IRENA Renewable Energy Learning Partnership (IRELP), www.irelp.org.*

Box 4.3

RAPID EXPANSION OF SPECIALIST COURSES IN GERMANY

In the past few years, German universities have continued to integrate renewable energy topics into their course offerings, and many have developed specialised renewable energy courses and programmes. A survey of state-level higher education ministries carried out by the Wissenschaftsladen Bonn (2012) has identified 380 study programmes which explicitly include renewable energy as major component. In 2012, at least 105 study programmes were dedicated entirely to renewable energy, including the "Renewable Energies" bachelor's and master's programmes at the Cologne University of Applied Sciences and the "Renewable Energy and Energy Efficiency" master's programme at the University of Kassel.

In the past few years, an increasing number of companies have begun partnering with higher education institutions and vocational colleges to develop tailor-made education and practical training for junior and specialised professionals. For example, Hamburg's Chamber of Crafts and the Vocational Academy of Hamburg initiated a dual-education programme, "Technology and Management Renewable Energies and Energy Efficiency", which combines a bachelor's programme with short vocational training at a company and includes an apprenticeship certification exam (University of Cooperative Education, n.d.).

Intergovernmental universities are also offering renewable energy-related programmes and supporting international student exchanges. For example, the United Nations University has various renewable energy-related research programmes, including the Geothermal Training Programme, and the European University Institute offers certain lectures and workshops on renewable energy topics.

Some universities (through initiatives such as edX and Coursera[15]) and institutions (such as the World Bank's e-Institute) offer free online courses focused on renewable energy and other areas related to sustainability and climate change. The open nature of these courses brings the teaching resources offered by elite schools within the reach of Internet users all over the globe.

Finally, universities are also collaborating actively with the renewable energy industry and other stakeholders in an effort to prepare students for future jobs, so that they require less on-the-job training and "time to function" and are more valuable for companies.

Vocational education: job- and trade-specific skills

In addition to purely academic instruction, students can obtain more practical and manual skills for specific trades, crafts or professions at so-called Technical Vocational Education and Training (TVET) institutions (see Box 4.1 for definition). Given the critical technical skills required for RETs, TVET institutions can play a dominant role in providing the necessary training for the renewable energy workforce. Increasingly, RETs are being introduced in the formal apprenticeship regulations which define the skillsets of "recognised occupations", such as certified electrician or plumber. They also have been introduced into college-based technician courses, both through courses specialising in RETs and through the inclusion of renewable energy content in existing courses.

Experience from Denmark and Germany suggests that dedicated technical occupations in renewable energy, such as "solarteur" or "wind installer", are not recommendable, as these jobs may be defined too narrowly to provide for consistent work. Instead, it is more important that the acquired skills be applicable for a wider range of technologies. Trainees, for example, can attend 2-3.5 years of official coursework for basic occupational skills (such as a certified plumber), which offers limited exposure to renewable energy-related content, and later specialise in a renewable energy field (such as training in solar thermal installation). The Intelligent Energy Europe (IEE) project "BUILD-UP Skills", started in 2011, aims to set up national qualification platforms and roadmaps to train craftspeople, construction workers and systems installers in the building sector, as well as to help introduce new (and/or upgrade existing) qualification and training schemes based on the roadmaps that are developed (IEE, n.d.).

[15] *edX (www.edx.org) was founded by MIT and Harvard and included 29 universities as of October 2013; Coursera (www.coursera.org) was partnering with over 90 universities worldwide as of October 2013.*

Training within the renewable energy industry

Stakeholders from the renewable energy industry (manufacturers, developers, etc.) play a critical role in providing education and training to improve skills. Many companies train their employees "on the job" – for example, a wind company may train its project development staff. Others even train their customers, such as an electric drive manufacturer training the O&M staff of a wind turbine service company. Examples of manufacturer-led education are the Gamesa Corporate University, which offers online and in-person training in wind energy equipment, and the Siemens Graduate Program, which provides two years of professional training for work in the wind industry.

As in the education sector, however, companies can face difficulties in properly planning their training programmes. One reason is that the renewable energy sector, like any other sector of the economy, depends on the policy environment, which is often subject to change. Additionally, in a competitive environment, companies may run the risk of losing employees in whose training they have invested. Nevertheless, in the long term it is beneficial for companies in the renewable energy sector to invest collaboratively in education and training measures, thereby lowering the overall investment risks and related costs. This can be done, for example, by creating interchangeable job and training specifications in accordance with international standards (see Box 4.4) or by offering apprenticeships or internships to young people, students and experienced workers who are seeking to acquire renewable energy skills.

Co-operation between companies and the education sector is institutionalised to some degree in countries such as Austria, Germany, the Netherlands and Switzerland. They have a dual-education system which combines apprenticeships in companies with classroom vocational education organised through official business associations (mainly chambers of industry, commerce, trades, etc.). Evidence from the field, however, suggests that renewable energy

Box 4.4

THE WINDSKILL PROJECT AND THE GERMAN TRAINING CENTER FOR RENEWABLE ENERGIES (BZEE)

During 2006-09, the EU's Windskill project, funded by the Intelligent Energy Europe programme, sought to develop a qualifications framework to help overcome the skills gap in the European wind industry. The project focused mainly on qualifications for O&M in onshore and offshore projects and consisted of (a) selecting a didactic model to facilitate the development of a training programme, and (b) developing quality assurance measures related to the trainings. A proposed follow-up action, establishing a Windskill Agency, has not yet materialised; however, the German Training Center for Renewable Energies (BZEE) which was part of the Windskill project has incorporated many of the recommendations, including international co-operation.

BZEE, established in 2000 out of a German wind industry initiative, offers training programmes for wind energy technicians. In addition to providing special courses – such as the "working at heights" and rescue training programmes taken by some 1 400 workers per year – it has developed a long-term training programme with several standardised modules. The modules are based on the skills demanded by the sector and also outline requirements for trainers and equipment. An estimated 3 500 to 4 000 professionals have been trained through the programme – some 70% in Germany and the rest internationally, with France and Canada being the biggest markets.

BZEE's Global Training Partnership is designed to provide services to growing wind energy markets. The BZEE support package for developing wind markets comprises a condensed train-the-trainer programme, assistance in managing learning outputs, support in designing training workshops and a full turnkey delivery of training equipment. The Partnership is expanding rapidly and now includes 29 wind energy training centres in 12 countries, with current expansion focused on Brazil, China, Japan, South Africa and South Korea. Each partner facility is geared to offering both a range of BZEE courses and specific modules tailored to regional stakeholder needs. Periodic audits and regular partner meetings ensure that the BZEE training standard is upheld at all locations.

Source: BZEE (communication with Gerard McGovern of BZEE).

stakeholders have been slow or reluctant to utilise this potential.

In countries where an official dual-education system does not exist, companies and education providers can co-operate on a voluntary basis. Examples abound of companies sharing their practical experiences with universities or other educational institutions, whether by helping to design courses and practical portions of the curricula, or by giving lectures, organising student internships and tutoring research projects. A higher degree of formal co-operation – especially between the industry and universities – can be helpful in all countries to ensure a balance between theoretical knowledge and practical skills.

Finally, in all settings, companies can post job offerings on specialised renewable energy job platforms, making the job market more accessible to students and job seekers (see Box 4.5).

Integrating renewable energy topics into continuing education and training

Lifelong learning is becoming increasingly important due to technological advancements, global competition and the greater flexibility required by employers. In the case of renewables, the rapid implementation of RETs requires significant transfer of the workforce from other sectors of the economy, raising the need for continued education and on-the-job-training. Continuing education can be particularly useful in providing experienced professionals with the relevant technical, contextual or non-technical knowledge (legal and regulatory issues, financing, communication, etc.) required to work in or support the renewable energy sector. Target occupations include industrial engineers, energy consultants, and spatial and urban planners.

Opportunities for continuing education are growing, for both technical and non-technical occupations. Among those offering courses are specialised adult-learning institutions, renewable energy companies and universities. Continuing education and training is also of strong interest for upskilling the renewable energy sector itself. For example, the Continuous Professional Development Programme in the U.K., which is approved by the European Energy Centre, was created as a guide for students and professionals

Box 4.5

IRENA RENEWABLE ENERGY LEARNING PARTNERSHIP (IRELP)

Developing a robust and highly skilled labour pool is the central motivator behind IRENA's flagship education and training portal. IRELP (www.irelp.org), launched in April 2012, aims to:

- Increase awareness of, and access to, renewable energy education opportunities and resources;
- Create awareness about skills gaps and labour shortages in the renewable energy sector;
- Raise the profile of renewable energy as an attractive career option; and
- Assist in the adaptation of education and training structures to support the global transition to renewable energy.

IRELP is designed for use worldwide by learners, including students, vocational trainees and other professionals looking to develop and update their renewable energy knowledge. The portal offers a global repertoire of more than 2 000 renewable energy education opportunities, including an internship board showcasing renewable energy career entry opportunities, an extensive catalogue of training courses and college/university programmes, a library containing training guides and manuals, a database of webinars and an academy with free e-learning lectures.

With active users in more than 180 countries, and a particularly strong following in developing markets, IRELP has emerged as a significant resource to help students, professionals and decision makers begin careers in the renewable energy sector. With the support of leading partners in the field of renewable energy, the portal will continue to promote the industry's global development through improved access to information on education and training, as well as renewable energy career opportunities. Perhaps most importantly, IRELP aims to raise awareness about these opportunities amongst young people, who will continue to drive the growth of renewable energy into the future.

already working in renewable energy to keep them up to date on new technology developments.

Numerous online platforms and social media networks provide specific renewable energy information and knowledge that can often be accessed for free. Massive Open Online Courses, offered by institutions, companies and universities, represent another avenue for providing lifelong learning in renewable energy.

Linking regional and international qualifications

Most of the skills required for renewable energy deployment – particularly the technical skills – are similar across countries. Installing a wind turbine or solar panel is not substantially different from one country or region to another, apart from considerations of site-specific conditions and regulatory requirements. Consequently, some education and training providers have started to standardise skills and qualification requirements at the national and international levels.

Within the United States solar industry, for example, the demand for certified professionals is growing. The North American Board of Certified Energy Practitioners (NABCEP) offers multiple levels of certification. The NABCEP Entry Level Programme enables candidates to demonstrate achievement of basic knowledge of the fundamental principles of applying, designing, installing and operating PV and solar heating systems (the highest level of certification is known as a "PV Installer" certificate). Initiatives on an international level include the Windskill project (discussed in Box 4.4), which has created an international qualifications framework for the wind industry.

Harmonised curricula and qualifications across countries can be helpful for their mutual recognition and increased transparency, reducing the time needed to react to market signals (since the course content can be reused), allowing companies to better select their workforce and facilitating mobility of students and workers. Examples of such harmonisation are the European Credit Transfer and Accumulation System and the European Quality Assurance in Vocational Education and Training network. Because harmonisation and international certification of curricula is useful only if the employment market (*i.e.*, the industry) accepts it, a step-by-step approach involving all relevant stakeholders, outreach and communication is paramount.

Common quality standards make it possible to evaluate training programmes in an accreditation process (or trainers in a certification process) against a set of defined requirements for competency, quality management, required resources and qualification. The European QualiCert project, which ran from 2009-11 and included a number of renewable energy industry associations, energy agencies and other stakeholders, found that the mutual recognition of individual competencies regardless of the system in place (certification of persons or certification of companies) is crucial to allow companies and individuals to work across borders.

Finally, existing standards which evaluate the quality of learning services, such as the ISO 29990 Learning Service Provider standard, can be used to provide an international framework for assessing and comparing renewable energy training initiatives. In the wind industry, for example, BZEE (discussed in Box 4.4) was one of the first entities to earn the ISO 29990 certificate.

International co-operation

Numerous international co-operation agreements in renewable energy exist between universities and between TVET institutions around the world. They focus on the exchange of students and professionals or on co-operation in studies, research activities and projects in order to exchange knowledge and increase access to learning or employment opportunities. For example, the Postgraduate Programme Renewable Energy (PPRE) of the University of Oldenburg in Germany co-operates with many universities. The PPRE aims to intensify the exchange of staff, students and curricula in the field of postgraduate renewable energy education. The programme's alumni network indicates that most former students find suitable positions within the renewable sector.

Another project focused on awareness-raising and support of renewable projects in pilot communities is the EU-funded Promoting Renewable Electricity Generation in South America project, a co-operation among universities in Germany, Latvia, Bolivia, Brazil, Chile and Guatemala. It is the successor of the Joint European-Latin American Universities Renewable Energies Project project, carried out between 2008 and

2011. Finally, BZEE's global partnership (see Box 4.4) provides an example of international co-operation driven by the private sector. The partnership has resulted in 29 centres in 12 countries and offers train-the-trainer programmes, support in designing workshops and delivery of training equipment.

Increasing the visibility of renewable energy education, training and job offerings

The profile of renewable energy education and training has been raised in recent years, and its accessibility has increased globally, contributing to the growing number of education and training programmes on renewables today. Information on these programmes, however, tends to be widely dispersed and difficult to find. In this context, the IRENA Renewable Energy Learning Partnership (IRELP) aims to address these shortcomings by providing a platform for increasing the visibility of educational and employment opportunities (see Box 4.5).

4.3 CONCLUSIONS

If not addressed properly, the looming skills gap in the renewable energy sector – the risk of skill shortages and the deficiency in the quality of skills – can slow the deployment of RETs and related job creation in many countries. Developing strategies to bridge the skills gap requires understanding the unique characteristics of the renewable energy sector, which includes a very diverse set of occupations and employment opportunities, both technical and non-technical, with significant skill requirements for most occupations.

Providing education and training for engineers and advanced technicians is crucial to facilitate the large-scale deployment of RETs. In addition, enhanced renewable energy knowledge and skills are required in areas such as management, policy, financing and economics. In the short term, it may be necessary to draw on experienced workers from other sectors to meet the demand for a skilled renewable energy workforce; however, this strategy is costly in a competitive environment and is not sustainable in the long term. Education and training aimed at young people is needed to enable their entry into the renewable energy labour market.

Countries will only be successful in the deployment of RET if effective renewable energy education and training policies are in place. Education policy makers have various ways to pro-actively include renewable energy topics in new and existing educational programmes and institutions, to financially support initiatives from universities or the private sector, and to foster international and interdisciplinary collaboration. By applying the full range of possible activities, education policy makers can make a real difference in raising the skill and knowledge level not only of the workforce within the renewable energy industry and the educational sector, but of the entire population.

Transitioning to renewable energy demands a wide spectrum of education and training, which includes new courses, modifications to existing courses, courses to enable newly qualified people with relevant skills to specialise in renewable energy, and skills development to enable experienced people with relevant skills to move into the renewable energy sector. The education sector and the renewable energy industry should continue to pursue these and other activities aimed at addressing the skills gap, as well as explore further avenues to provide the skilled workforce that is necessary to support and enable the transition towards renewable energy.

5 Job Creation in the Context of Energy Access

© Bright Green Energy Foundation

Globally, more than 1.3 billion people are without access to electricity and another 1 billion have unreliable access. At least 2.6 billion people lack access to modern fuels for cooking and heating, relying instead on traditional biomass for meeting their energy needs (IEA, 2013b). Expanding access to modern energy services is essential for reducing poverty, improving health and stimulating socio-economic development. There is growing recognition that RETs will play a crucial role in achieving universal access by 2030, one of the three objectives of the United Nations Sustianable Energy for All initiative. These technologies are becoming increasingly cost competitive, more reliable and better adapted to the needs of rural populations in developing countries that lack modern energy services.

This chapter examines what is known about employment opportunities that arise out of efforts to achieve universal access to modern energy services through renewable energy deployment. It begins by assessing the available information in the literature and then analyses in more detail the employment dimension of selected RET applications (PV solar home systems, portable solar lanterns, improved cookstoves (ICS) and biogas). The chapter describes relevant country experiences for each RET and also explains the backward and forward linkages made possible by renewable energy and their influence on job creation. The chapter concludes by addressing some of the most noteworthy characteristics of renewable energy employment in rural areas, including types of employment and salaries.[16] The chapter relies heavily on the IRENA publication *Renewable Energy Jobs and Access* (IRENA, 2012c). The role of mini-grids is essential in addressing the energy access challenge and in meeting the energy needs beyond basic lighting. This aspect is not entirely addressed in this report and will be the subject of future IRENA work.

[16] *The gender aspect is further expanded in Chapter 6.*

5.1 EMPLOYMENT DATA IN THE CONTEXT OF ENERGY ACCESS

Despite growing recognition of the role that RETs can play in contributing to employment and sustainable economic growth, limited attention has been given to the job creation benefits of its deployment in rural areas (for electricity supply, cooking, etc.)[17]. Information is lacking on a range of social indicators, such as the types of jobs, the total number of jobs created, salaries, gender and working hours (Bimesdoerfer, Kantz and Siegel, 2011). Such statistics are not being collected systematically, and relevant data are available only for some programmes or countries in the developing world. Collecting relevant data about employment and labour market conditions is more challenging in rural areas given the decentralised and often informal nature of energy access projects and programmes.

Some countries, however, are making efforts to estimate job creation in the context of energy access. In India, for example, MNRE has calculated employment factors derived from case studies of projects in the country's renewable energy sector (see Table 5.1). India's employment factors can serve as a preliminary guide for estimating employment emerging from the deployment of renewable energy in rural areas of the developing world.

TABLE 5.1 ESTIMATED EMPLOYMENT FACTORS IN INDIA'S RENEWABLE ENERGY SECTOR

	JOBS PER MW OF CAPACITY	TYPICAL PLANT SIZE
Solar PV, Off-Grid		n.a.
» Direct employment	30	
» Indirect employment[a]	60	
» Total employment	90	
Biomass Power, Grid		6 MW
» Direct employment	15[b]	
» Indirect employment[c]	28	
» Total employment[d]	43	
Biomass Gasifier		20 kW
» Employment in Manufacturing	100	
» Employment in Operations	200	
Small Hydropower		n.a.
» Direct employment	4	
» Indirect employment	1	
» Total employment	5	

[a] Indirect employment as dealers, marketing staff of dealers, lantern manufacturers, solar home lighting kits manufacturers, battery manufacturers, lamp manufacturers, etc. [b] Of which 40 percent is skilled labour managing machinery, including boilers, turbines, etc. [c] Indirect employment in fuel collection, handling, processing, etc. [d] Employment in manufacturing of power equipment not included.
Source: MNRE and CII, 2010.

Recognising the potential for job creation in rural areas is particularly important given that an estimated 60% of the additional generation that is required to achieve universal access to electricity by 2030 is projected to come from off-grid solutions, both standalone and mini-grids (IRENA, 2013b). Translating the projection of renewable electricity generation needed by 2030 under the IEA's Energy for All case into needed capacity produces an estimate of nearly 180 289 MW for off-grid technologies (see Table 5.2) (IEA, 2011). Applying the Indian job factors to these capacity figures results in an estimated 4.5 million direct jobs by 2030 in the off-grid electricity sector alone. Additional employment may be generated as access to renewable cooking fuels and improved cookstoves grows, but calculating a solid number is complicated by the diverse and fragmented nature of the cooking energy markets.

Despite positive initiatives in India and elsewhere, there remains a tangible need for better and more systematic efforts to monitor rural renewable energy employment in developing countries. Such an effort will support policy formulation that maximises value creation, and can help identify obstacles to achieving the full potential for employment opportunities. In addition to absolute job numbers, improved reporting would include employment factors per unit of capacity for each RET, which can provide better insights into RET employment potential for different rural electrification approaches. Local case studies can also help to quantitatively evaluate developments and impacts over a longer period of time. Having time-series data on employment facilitates a broader understanding of the evolution of the job creation in rural areas to support long-term monitoring and assessments.

[17] *A review of key publications – including reports by the World Bank, IEA, UN Advisory Group on Energy and Climate Change, UN agencies, and Global Alliance for Clean Cookstoves (GACC) – confirms this conclusion. With a few exceptions, such as ILO (2011a), such publications contain generic references to job creation opportunities.*

Table 5.2 Potential employment creation through off-grid renewable energy

	ELECTRICITY USE (TWh)	LOAD FACTOR (percent)	CAPACITY (MW)	JOB FACTOR (JOBS PER MW)	EMPLOYMENT (Thousands)
Solar	169.2	20	96 575	30	2 897
Small Hydro	37.6	45	9 538	4	38
Biomass	98.7	80	14 084	15	211
Wind	131.6	25	60 091	22	1 322
Total	437.1		180 289		4 469

Note: The table offers a rough sketch of potential of job creation. The employment figures in the final column are rounded to the nearest thousand.

Source: IRENA estimates based on IEA, 2011; MNRE and CII, 2010 ; and ESMAP, 2007.

5.2 DEVELOPMENTS BY SELECTED RENEWABLE ENERGY TECHNOLOGY

Renewable energy deployment in off-grid applications can be summarised in two broad categories: stand-alone installations and mini-grids. Stand-alone installations, which include PV solar home systems, portable solar lanterns, etc., can be deployed rapidly as an alternative to fossil fuel-based lighting (such as kerosene). Renewable-based mini-grids, in contrast, have proven to be an attractive option for rural electricity access, as they can service diverse loads, including for productive applications, and offer an opportunity for communities to upgrade from basic electricity access provided by stand-alone installations. In addition to traditional grid extension, a combination of the two approaches will be required to achieve the goal of universal access to modern energy services within a reasonable time frame (IRENA, 2013b).

This section examines prominent trends in the deployment of renewable energy in some off-grid applications, with a focus on the employment dimension. It provides an analysis of PV solar home systems, portable solar lanterns, improved cookstoves and biogas, and presents selected country experiences in order to better illustrate the employment aspect of these technologies. Deployment of other RETs, such as small wind, often in mini-grid configuration for diverse applications (electric power, water pumping, etc.) also present employment opportunities but are beyond the scope of discussion in this chapter.

5.2.1 Photovoltaic solar home systems

In lower-income rural communities, efforts to provide electricity access have tended to focus on small solar home systems (SHS). Currently, more than 5.1 million SHS have been installed in developing countries (see Table 5.3), up from an estimated 1.3 million in 2000 (Nieuwenhout, *et al.*, 2002). Data gaps remain, however, in the availability and relevance of information, preventing a reliable analysis of the number of SHS deployed globally.

In **Bangladesh**, rapid expansion of the small-scale solar sector has created an estimated 70 000 direct and indirect jobs (Infrastructure Development Company

Table 5.3 Solar home systems installed in selected developing countries

COUNTRY / REGION	YEAR	NUMBERS
Asia		
Bangladesh	2013 (November)	2 677 896
India	2012 (March)	892 974
China	2008	> 400 000
Indonesia	2010	264 000
Sri Lanka	2011	132 000
Nepal	2010	229 000
Latin America		
Mexico	n.a.	80 000
Africa		
Kenya	2010	320 000
Morocco	n.a.	128 000
South Africa	n.a.	150 000
Zimbabwe	n.a.	113 000
Total		~ 5.1 million

Sources: REN21, 2011, 2012; IDCOL, n.d.; Indian Ministry of Statistics and Programme Implementation (MOSPI), 2013; IFC, 2012; Renewable Energy for Rural Economic Development Project (RERED), n.d.; Lighting Africa, 2010; Ondraczek, 2012; IRENA, 2012c.

Limited (IDCOL), 2012). As a whole, the country's renewable energy sector is expected to provide jobs for at least 100 000 people by 2014 (ILO, 2011a). The bulk of jobs are held by field assistants with basic technical and vocational skills who sell and install SHS, provide maintenance and, as part of Bangladesh's microfinance network, collect monthly payments on solar loans (Bimesdoerfer, Kantz and Siegel, 2011).

Between 1996 and 2003, some 10 000 SHS were sold to Bangladeshi households. Installations have since grown rapidly under the IDCOL SHS Programme, reaching a cumulative 455 000 at the end of 2009 and 2.6 million as of November 2013, making Bangladesh the country with the largest number of SHS installations (IDCOL, 2012 and n.d.). The ongoing initiative aims to install 4 million systems by 2015, which would serve more than 20 million beneficiaries or 12% of the total population (IDCOL, 2013a). IDCOL achieves this outreach through over 46 participating organisations, such as Grameen Shakti which has built on the successful micro-lending experience of the Grameen Bank (IDCOL, n.d.).

The success of Bangladesh's domestic solar sector can be attributed to the following factors:

» Improvements in the country's vocational education system and on-the-job training have helped to build a strong local capacity to support a growing off-grid solar market (UNDESA, 2011). Under the IDCOL programme, relevant technical and management training has been delivered to over 410 000 individuals ranging from local technicians to customers (IDCOL, 2013b). In general, most of the necessary skills needed to support off-grid solar markets can be developed locally, reducing the dependence on foreign know-how.

» The country has placed an emphasis on domestic research to reduce the cost of PV panels, adapt the technology to local needs and develop customised accessories that are in demand, such as mobile phone battery chargers. Grameen Shakti, the most prominent partner organisation of IDCOL, focuses on in-house assembly of SHS through its 46 manufacturing units, where the systems are designed based on the needs of consumers (UN-ESCAP, 2013).

» There have been concerted efforts to develop a local solar manufacturing industry, which continue to generate domestic employment opportunities. Bangladesh initially imported most system components from countries like Singapore, India and China, but today Bangladesh is producing most components domestically (UNDESA, 2011). This is also partly because of the scale that the market has been able to achieve, given that nearly 80 000 systems (and rising) are being deployed every month (Barua, 2013). Solar manufacturing still accounts for only a small portion of jobs, however (Mondal, Iqbal and Mehedi, 2010).

» The introduction of quality-control mechanisms, such as system standards, physical inspections, training programmes for staff and consumers, and dedicated channels to lodge complaints (IRENA, 2013b) has helped to prevent a situation of market "spoilage", wherein low-quality products raise doubts among rural communities about the reliability and worthiness of RET in the long term (IFC, 2010b). This is crucial for sustaining both the rural renewable energy sector and the employment opportunities arising from it (IRENA, 2013b).

» Microfinance has been critical to the widespread deployment of SHS in Bangladesh. By tailoring financing schemes that consider the cash flow of rural households and their present expenditure in accessing traditional forms of energy, the programme has been able to unlock the buying potential of these households. The extensive network and outreach of micro-finance institutions across rural areas has contributed to the success of SHS (IRENA, 2013b).

These factors have together created employment opportunities across the off-grid solar industry value chain in Bangladesh. Similar widespread job creation has not been common in the developing world, however, even in countries with relatively significant deployment of SHS. For example, despite some commercial success in Kenya – Africa's leader in SHS installations with 320 000 units installed as of 2010 (Ondraczek, 2012) – its solar industry confronts numerous challenges that hamper growth and job creation. These include problems with domestic financing (SHS primarily reach only the wealthiest rural populations), the quality of imported PV panels, and lack of technical training (UNDESA, 2011).

Tanzania, too, has faced complications in enforcing quality control with SHS (Hankins, Saini and Kirai, 2009).

Country experiences demonstrate the central importance of training programmes in the solar sector, including in the downstream applications of solar technologies. Bangladesh's success shows the effectiveness of pursuing training not on a project-by-project basis, but via a broader vocational structure that allows for systematic, and across-the-board, training.

Skills gaps and labour shortages still exist in many developing countries, particularly for critical solar PV occupations such as qualified electrical engineers and technicians (ILO, 2011a). The existing gaps are not only in technical areas (assembly, installation, O&M and repair, etc.), but also in business and commercial skills (product and service design, market assessment, securing financing, organising supply chains, designing financial schemes, etc.) within enterprises and institutions. Such skills are important in the context of energy access because without a critical mass of local enterprises, timely achievement of universal access goals will be difficult (IRENA, 2013b). This makes it necessary to foster entrepreneurs and provide them with the opportunities to acquire the adequate skills (see Box 5.1). Such efforts would help stimulate growth in rural energy enterprises and provide employment opportunities in rural areas, while accelerating access to modern energy.

5.2.2 Portable solar lanterns

The global market potential for portable solar lanterns is difficult to estimate but is believed to be significant, given the immense numbers of people who have no access to electricity and rely mostly on kerosene for their lighting needs. Currently, annual expenditures for fuel-based lighting reach USD 40 billion globally – some USD 23 billion in Asia and USD 17 billion in Africa (BNEF, 2011). Lighting Africa, a joint programme of the International Finance Corporation (IFC) and the World Bank, shows that in the portable lighting market, solar products are now cost competitive with fuel-based lighting on a life-cycle basis. Innovative business and financing models can help overcome the challenges of initial capital costs, thereby unlocking the massive market for these systems. The solar lighting market is expected to expand over the next few years as both the technology and domestic markets mature, bringing costs down and allowing for the emergence of innovative and sustainable business and financing models.

Box 5.1

TECHNICAL AND ENTREPRENEURIAL CAPACITY BUILDING FOR SOLAR ENTERPRISES: THE CASE OF SUNLABOB IN LAOS

In Laos, a country with an electrification rate of 71%, a significant share of the population continues to live in remote off-grid areas with no access to electricity (World Bank, n.d.). To address this challenge, the private company Sunlabob operates as a full-service renewable energy provider, providing electric lighting in rural communities through an innovative rentsl system for solar lanterns. The commercially viable business model, based on a fee-for-service concept, has successfully established an upstream and downstream supply chain. Sunlabob sources most components locally, although it imports more sophisticated items. Once installed, the system is managed locally and the project creates employment and income-generating opportunities for micro-enterprises and the rural population.

Sunlabob has been a pioneer in building local skilled workforces in rural areas by providing accounting and technical training to the village entrepreneurs (responsible for operating the charging station) and the village energy committee (responsible for overseeing the general operation and management of the maintenance fund). The accounting training focuses on procedures to track lanterns, system-level finances and overall programme finances. The technical training, meanwhile, focuses on practical aspects of system operation, maintenance and troubleshooting. These efforts are not limited to building the skills of the target group, but also focus on sharing knowledge with members of other rural communities that hope to undertake similar solar projects in the future, thus contributing to the scale-up of energy access initiatives.

Although a full assessment of the employment implications of the growing solar lantern market is lacking, data on market trends suggest the potential for job growth. India is the largest market for solar lanterns, with an estimated 930 813 units deployed as of March 2012 (MOSPI, 2013) and a potential market size of between 300 000 and 500 000 units annually (IFC, 2012). In Africa, an estimated 5-6 million households and small businesses are expected to own solar portable lights by 2015 if the trends continue; under more optimistic scenarios, the figure could rise to 12 million (Lighting Africa, 2010).

The bulk of the world's solar lantern production takes place in China and India[18]. Although domestic manufacturing in other developing countries would create more local jobs than distributing imported lanterns, this is currently not viable from an end-cost perspective (Practical Action, 2012). Because solar lanterns and similar products do not need significant installation, there is less need for technicians and maintenance personnel than for SHS, and there are thus relatively fewer employment prospects. Employment opportunities appear to be mainly in marketing, sales and distribution, which in turn depends heavily on the deployment model adopted. For instance, employment opportunities from a solar lantern rental model (such as the Sunlabob model discussed in Box 5.1) could be different than those related to a single shop owner acting as a lantern distributor.

From a broader perspective, in addition to improving living standards for communities, renewable energy deployment for productive uses can have positive induced impacts on income generation and economic growth, as a result of overall increase in productivity (see Box 5.2) (SELCO, 2013a).

5.2.3 Improved cookstoves

The most prevalent type of ICS is the improved biomass cookstove. Unlike traditional stoves, for which fuel efficiency has not been a key consideration, improved biomass stoves burn fuel more efficiently and reduce the need for fuelwood, charcoal and other biomass fuels. Other types of ICS use cleaner fuels (including liquefied petroleum gas, biogas, methane and ethanol) and also offer higher efficiency, but their affordability in rural areas is still limited. Electric cookstoves are seldom used due to their high cost and the lack of, or unrealible, access to electricity in many rural areas of the developing world (Differ, 2012). Biogas systems occupy small niches of the market in most countries and are often restricted by affordability, attainability and cultural preferences (ClimateTechWiki, n.d.-a).

About 830 million people worldwide – some 166 million households[19] – currently use ICS (REN21, 2011). The majority (116 million stoves) are in China, which has established a successful programme to reduce indoor air pollution in rural areas by almost

Box 5.2

PRODUCTIVE USE OF RENEWABLE ENERGY AT THE MICRO-ENTERPRISE LEVEL: THE CASE OF UDUPI CITY IN INDIA

In an unelectrified slum in Udupi City in Karnataka, India, households had been using kerosene for lighting until SELCO introduced the Integrated Energy Center (IEC) model to provide solar energy services to more than 25 households. The IEC acts as a centralised charging hub that provides charging facilities for lighting devices and mobile phones. The lighting devices are then rented out to households on a daily basis, providing them with the flexibility to pay for days used, with minimal documentation.

The management of the IEC has been undertaken by an entrepreneur who is presently also running a mobile repair business. To establish the energy centre, he was able to secure a loan from a local bank of USD 1 620 for a three-year period, at 12.5% interest. In addition to his usual income from the mobile repair busi canness, the entrepreneur earns a net income of USD 50 per month from providing the lighting and mobile charging services (USD 110 per month), and paying the monthly loan installment (USD 60 per month). In addition, he no longer has to outsource the soldering jobs for repairing mobile phones due to lack of electricity, but instead utilises a solar-powered soldering gun. This has increased his overall productivity and broadened the services that his business offers locally.

18 *Worldwide, some 110 companies are active in the solar portable light manufacturing industry. About 40% of these manufacturers are in India (with 30% of global sales), 34% in China (42% of sales) and 20% in industrialised countries (19% of sales). Less than 5% of the companies are in Africa (Lighting Africa, 2010).*

19 *Based on an estimate of five persons per household.*

completely replacing traditional biomass-fired stoves with ICS and biogas-burning stoves. Another 35 million stoves are in use in India, more than 13 million in other East or Southeast Asian countries, more than 8 million in Latin America and some 7 million in sub-Saharan Africa (REN21, 2011). More than 160 ongoing programmes exist to promote ICS throughout the developing world (Chum *et al.*, 2011). One of the most prominent, the Global Alliance for Clean Cookstoves, launched in 2010, aims to provide more than 100 million stoves by 2020 (REN21, 2011 and 2012). By early 2012, the programme had raised more than USD 114 million and garnered 250 partners from governments, private sector and NGOs (U.S. Department of State, 2012).

There appear to be no broad-based figures indicating employment in ICS production by country, let alone globally. Some ICS production takes place on a large scale, with centralised production and widespread distribution channels (some firms mass-produce more than 100 000 stoves annually). A highly efficient mass assembly in a country like China is likely to be extremely cost effective and could churn out large numbers of stoves while employing comparatively few people. In contrast, small-scale, local production is often undertaken by trained artisans in rural areas in informal settings; it is typically more labour intensive than producing traditional stoves, with employment opportunities arising in the manufacturing, marketing, sales and distribution of the stoves. There is also a growing trend towards semi-industrial production of improved biomass stoves, using imported components which are assembled locally (Chum *et al.*, 2011; Differ, 2012).

In **Cambodia**, the Groupe Energies Renouvelables, Environnement et Solidarités (GERES) introduced the efficient New Lao Stove (NLS) in 1998 to address health, environmental and energy problems resulting from unsustainable cooking practices. The NLS saves 22% of wood and charcoal compared to traditional stoves in the country. By January 2013, the NLS programme reached production of more than 2 million units (GERES, 2013). The programme also created around 1 100 local jobs (GERES, 2010), although it is not clear whether this figure refers to stove manufacturers only or also to distributors.[20]

Each NLS producer[21] employs an average of 10-14 workers, with skills relating to moulding, carving, cutting, punching, bucketing and assembling (figures do not include family members who may be informally involved). An enterprise may employ 1-2 additional workers at peak production times. By comparison, enterprises producing traditional stoves employ an average of only three workers each, as the stoves have fewer parts to assemble and are faster to produce. These findings indicate that ICS can be beneficial for employment, not only quantitatively because the stoves involve more labour, but also qualitatively because they require more sophisticated skills, and workers are therefore better paid (French Agency for Development (Agence Française de Développement- AFD) & GERES, 2009).

The NLS is sold at almost three times the price of traditional stoves, reflecting higher raw material costs, labour costs and profit margins for retailers (AFD & GERES, 2009). In 2001, GERES developed the more affordable Neang Kongrey Stove targeted at rural communities (World Bank, 2010), and some 180 000 of the stoves have been sold since (GERES, n.d.). The World Bank has helped train small groups of potters to produce the Neang Kongrey Stove, such that after one year, a single potter can produce more than 200 stoves a month on average. The goal is to re-train traditional stove makers, open new production facilities and strengthen and expand distribution channels to allow for large-scale production (World Bank, 2010).

In **Africa**, although traditional cooking methods remain widespread, ICS has experienced commercial success, particularly in Kenya (GVEP, 2012a). The Kenya Ceramic Jiko charcoal stove is used in more than 50% of urban homes and 16% of rural homes in the country. Estimates indicate that the stove had been disseminated to more than 3 million households, and its design was replicated across many other countries in sub-Saharan Africa (UNDP, 2012). The majority of the stoves are produced at a small to medium scale, and production has been sustained commercially, with individual producers building a few hundred per month (GVEP, 2012a). An estimated 15 major producers currently operate, along with more than 100 independent trained artisans (IRENA, 2012c). This production activity is expected to contribute to employment in Kenya's informal economy,

[20] *It is also not understood whether these are newly created jobs or people who have switched from traditional stove production to NLS.*

[21] *In 2004, stove manufacturing and distribution enterprises set up a professional association known as Improved Cookstove Producers and Distributors Association in Cambodia (ICOPRODAC); its membership includes 253 independent business owners from 11 provinces, 84 stove producers and 171 distributors.*

which creates more than 90% of all jobs (Daniels, 2010). Such opportunities will continue to rise as the manufacturing of cookstoves expands and their availability improves in many countries.

5.2.4 Biogas: cooking and heating

Worldwide, more than 44 million households use biogas generated in small-scale digesters for cooking and heating (REN21, 2011). The use of household-size digesters has proliferated in China and India, but less so in most other developing countries. Such small-scale biogas applications have been supported mostly through government-backed programmes, but they have faced challenges due to inadequate maintenance and technical support services for facilities. The introduction of biogas digesters has been difficult in many African countries on account of factors such as insufficient water and feedstock, high capital costs, negative public perception, etc.

Key lessons can be learnt from the experiences of China, India and Nepal, all of which have conducted biogas programmes and are developing manufacturing industries for biogas plants. China leads by far in the number of biogas plants installed, while India's biogas deployment, although impressive in number, face quality concerns. Nepal's biogas efforts are considerably smaller scale in scale but highly successful, with many other Asian countries in the initial stages of such programmes.

China leads the world in installed household biogas plants, with the number of units rising from some 400 000 in 1975 to 18 million in 2006 (ClimateTechWiki, n.d.-b). Following a renewed push by the Ministry of Agriculture, another 22 million household systems were added between 2006 and 2010, resulting in at least 42.8 million systems by the end of 2011 (REN21, 2011; GACC, 2013). Overall, this effort created close to 90 000 direct and indirect jobs along the biogas value chain (see Table 5.4) (ILO, 2010). China's next target is to install 80 million household-scale units by 2020 (Raninger, Mingyu and Renjie, 2011).

The rapid expansion of biogas in China has benefited from the strong support of government funding. Between 2000 and 2010, the Ministry of Agriculture invested about USD 3.8 billion in the construction of biogas plants, and provincial and municipal governments provided additional subsidies. In its 2007 Medium and Long-Term Development Plan for Renewable Energy, the government set subsidies to CNY 1 000 (approximately USD 160) per household biogas digester, or roughly one-third the total cost. The support will be in the form of building materials and equipment, as well as the lending of technical expertise, while households provide labour. The role of subsidies is expected to gradually decline in coming years (Raninger, Mingyu and Renjie, 2011; GIZ, n.d.).

This expansion is not without problems. As of 2010, some 4 000 companies were carrying out planning, construction and maintenance activities related to biogas. Biogas technicians in China need a qualification (National Biogas Professional Technician Certificate) to be able to build and maintain digesters, and the number of certified technicians has not been sufficient to meet the expected demand for digesters

TABLE 5.4 EMPLOYMENT EFFECTS OF BIOGAS DIGESTER CONSTRUCTION IN CHINA

SECTOR	DIRECT JOBS	INDIRECT JOBS	TOTAL
Construction	4 500	6 600	11 100
Non-metal mineral products	13 100	35 100	48 200
Electronics, machinery and equipment manufacturing	2 400	8 700	11 100
Metal smelting and pressing	500	2 100	2 600
Comprehensive technical service industry	3 400	3 500	6 900
Residential and other services	2 400	7 700	10 100
TOTAL	26 300	63 600	89 900

Source: ILO, 2010.

outlined in the National Plan. The repercussions could be poorer-quality digesters with shorter life expectancies (ILO, 2011a).

India is a distant second to China, with some 4.68 million family-size biogas plants installed in 2013 (MNRE, 2013). MNRE has estimated that significant potential remains, as some 12 million plants could be supported on the available dung in the country (Arora *et al.*, 2010). The Indian government estimates the number of biogas jobs at 85 000, with some 200 000 jobs projected to be created by 2015 (MNRE and CII, 2010).

India's experience with biogas has been through several upheavals. Although the country has a large and growing number of household-scale plants, many of these have faced difficulties, mainly because of a lack of appropriate skills among installers and of training for users. Households were typically neither made aware of the need for maintenance nor trained to perform it properly, thereby rendering some of the plants non-functional within a year of construction. However, there has been grassroots-level training for engineers in the technical and managerial skills needed for construction of biogas plants. Overall, recent assessments have concluded that Indian manufacturers of biogas plants are steadily improving their technology and products. Local companies are known to have an edge over foreign companies because they have better knowledge of local conditions and requirements (Arora *et al.*, 2010).

Nepal has a growing biogas sector as well. The Biogas Support Programme, funded by the Netherlands and Germany, was started in 1992 to bring together the private sector, microfinance organisations, community groups and NGOs to develop biogas as a commercially viable, market-oriented industry in Nepal. The project added 25 000 plants in 2010, bringing total deployment to some 225 000 systems (REN21, 2011). Normally, a third of the cost (USD 280-360 for a 6 m^3 plant) is paid in-kind, with the beneficiary household providing labour and materials. As a result of this programme, a private biogas business sector has emerged in Nepal, which includes more than 55 construction companies, 15 biogas appliance manufacturers and 80 finance institutions (United Nations Conference on Trade and Development (UNCTAD), 2010). Biogas construction is a labour-intensive process, and numerous jobs were created with the setting up of biogas companies and workshops; by the end of 2005, some 11 000 direct and indirect jobs had been created (Association of District Development Committees of Nepal (ADDCN), 2009).

The experiences of China, India and Nepal illustrate that the approach to biogas development that is selected makes a critical difference to the success of such efforts and hence to the quality and sustainability of jobs in the sector. China's experience stands in stark contrast to the difficulties that India has been through, in terms of quality, reliability and skill development. Overall, although the biogas industry initially faced challenges in development, such as problems in the construction and operation of biogas plants, as well as lack of long-term follow-up services, efforts are now being made to focus more on quality as opposed to quantity. As additional countries invest in developing biogas facilities, more case studies will be invaluable to understanding successful strategies, comparing best practise and expanding lessons learnt.

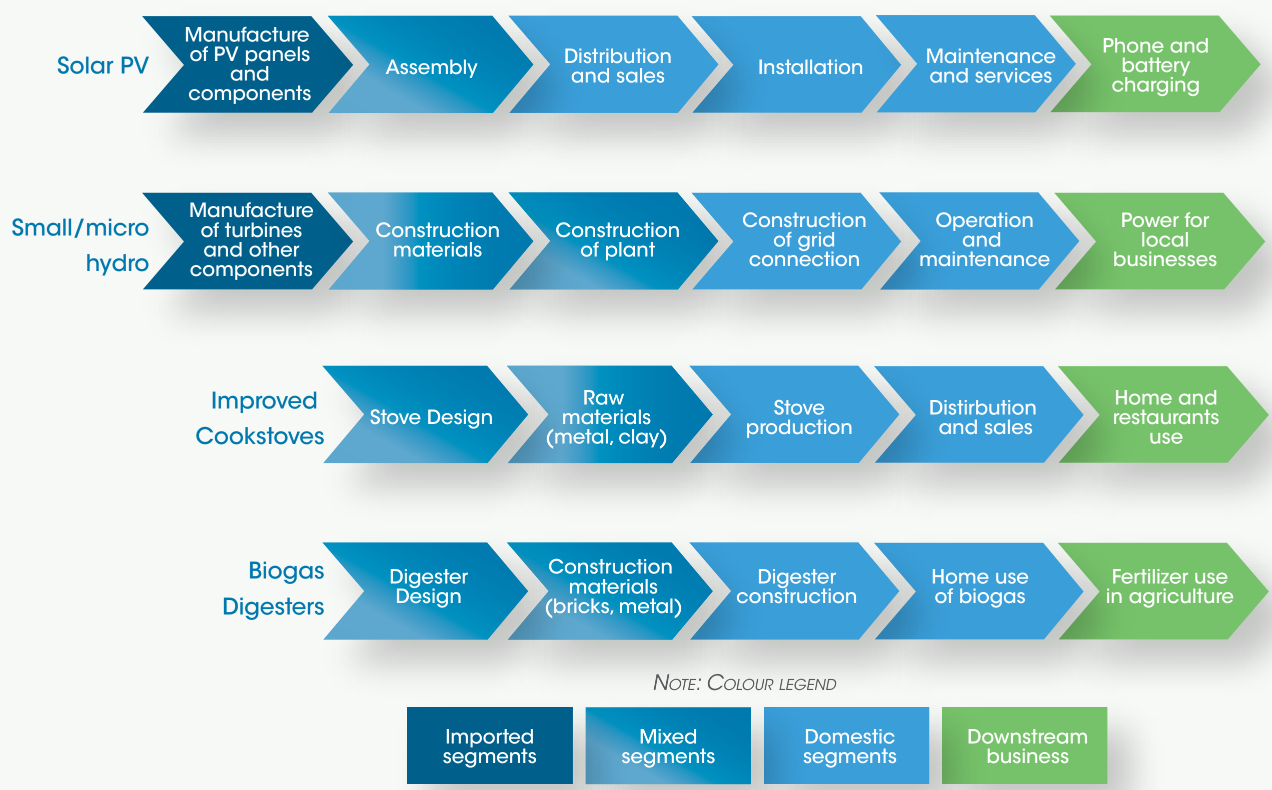
5.3 SUPPLY CHAIN: IMPORTS AND DOMESTIC SOURCING

The strength of backward and forward linkages – that is, the extent to which renewable energy enterprises are integrated into a local supply chain (backward linkages) and to which downstream businesses are made possible by the provision of energy services (forward linkages) – are important determinants of employment creation. This section brings forward important insights from the literature review and analysis of 15 first-hand case studies conducted in IRENA's *Renewable Energy Jobs & Access* report (IRENA, 2012c) [22].

In many developing countries, sales, installations, operations and maintenance will likely be more important in terms of employment generation or livelihood support than manufacturing of renewable energy equipment. This is particularly the case if renewable energy projects are locally well integrated, so that income generation and employment opportunities also emerge from downstream commercial activities which are made possible by improved energy access. Figure 5.1 illustrates schematically the supply chains for selected RETs and identifies segments that are typically domestic or import-dependent (or a mix of both).

[22] *Case studies are referred to in this Section according to the same names used in (IRENA, 2012c).*

Figure 5.1 Illustrative supply chains for selected RETs



The case studies offer specific information about the mix of domestic and imported inputs along the supply chains for different RETs:

Solar PV: Most of the inputs for the profiled solar companies are imported, particularly from Germany, the United States, China, India and Japan. There are also efforts to carry out domestic assembly of purchased components from different countries, such as by Sunlabob in Laos (see Box 5.1). Some developing countries, however, are starting to develop solar industries in which manufacturing is an important local component. Kenya, for example, now has between 15 and 40 major suppliers of solar equipment, as well as nine lamp manufacturers and three manufacturers of lead-acid batteries, making it a manufacturing centre for the wider region (Ondraczek, 2012).

Small hydropower: The various hydropower plants in the case studies indicate that although certain inputs are sourced domestically, for the most part developing countries are still importing large turbines and advanced electronics. For example, the turbine used in a project in Honduras was purchased from an undisclosed international supplier. In contrast, the turbine at a relatively smaller company in Guatemala was purchased from a local (Italian-owned) company, and other electro-mechanical equipment was also manufactured domestically. For both hydropower plants, the materials needed for facility construction were procured from domestic sources, and local labour built both plants.

Improved cookstoves: For ICS, supply chains are typically more domestic in nature, especially for clay stoves, although large exporting producers are emerging in India, China and Kenya. Imports do play a role for metal stove producers, which often rely on scrap-metal. This is the case for the FAFASO project in Burkina Faso, for instance, where recent price increases in the international scrap metal market have negatively affected producers.

Biogas: For biogas plants, a general observation which emerged from the case studies was that the majority of construction inputs- bricks or other materials- are also like to be sourced domestically, as is the labour to construct the digesters. The case studies do not offer sufficient detail beyond the general observations.

Energy access – particularly access to electricity – can create a range of downstream effects for rural economies, enabling a range of micro-enterprises. Such opportunities may come in the form of the scaling up of existing small businesses or the establishment of new ones. Table 5.5 provides a summary of supply chain and downstream effects for the individual case studies. Small-scale SHS, for instance, frequently help spawn cell-phone charging businesses, which in turn can have further positive spin-off effects for the communities. In several of the case studies, income earned from battery or lantern charging has provided the capital needed for new micro-enterprises such as restaurants, bakeries, barber shops, agriculture-related businesses, convenience stores, village cinemas and handicraft businesses (knitting, sewing, carpentry, etc.). Off-grid RETs may also provide a boost to existing businesses, by allowing them to stay open into the evening hours, which brings more customers and possibly, more income.

Similar benefits arise when renewable energy access makes it possible for households to save on conventional fuel expenses. A 2008 World Bank evaluation estimated that household lighting adds between USD 5 and 16 per month in income gains for households in developing countries that have traditionally relied on kerosene for lighting (World Bank, 2008). In Burkina Faso, fuel savings from ICS have allowed women entrepreneurs to set up small food service businesses (*e.g.* maize, cookies, etc.). In Nepal, micro-hydro plants set up under the Rural Energy Development Programme/ Renewable Energy for Rural Livelihood (REDP/RERL) project have provided support for a range of agriculture-related businesses, including agro-processing mills, irrigation pumps and poultry farming (see Box 5.3 for another example of the benefits from downstream activities).

Box 5.3

BENEFITS FROM FORWARD LINKAGES OF RENEWABLE ENERGY DEPLOYMENT IN AFRICA

The Dutch social venture, NICE International BV, promotes solar-powered ICT service centres in Gambia, Tanzania and Zambia, catering to people in unelectrified rural areas. Local entrepreneurs currently operate seven such centres, and the number is expected to reach 50 in 2014. Services offered include battery charging, access to information (TV, communication tools, Internet), value-added services (business and banking skills) and income generation possibilities (online trading, outsourcing). The centres have had important positive impacts, particularly for youth (who represent 50% of users), women (25%) and entrepreneurs (10%).

To date, the centres have helped:

- Increase local employment and disposable incomes (each centre is run by a local entrepreneur and employs five staff members on average);
- Improve the quality of the workforce available for local businesses (for example, by providing training opportunities to improve skills);
- Provide locals with access to international expertise (technical and management capacity) and information about international markets, institutions and services;
- Improve the effectiveness and competitiveness of local businesses through ICT skills and access to business networks;
- Offer low-cost access to office facilities with a stable supply of energy and good-quality equipment;
- Serve as a platform for knowledge exchange with other local entrepreneurs.

Many employers demand ICT skills that are not taught at most schools, making these skills a major asset in the youth labour market. The centres' ICT services have improved access to and the quality of education, as well as reduced the cost of delivery of information and services (by reducing the need to travel to the main cities where services are usually provided).

Source: IRENA, 2012c.

Table 5.5. Supply Chain Aspects of the Case Studies

COMPANY OR PROJECT (RET USED)	SUPPLY CHAIN	DOWNSTREAM EFFECTS
Solar		
Solar A — Nicaragua (Mostly SHS; also Solar Thermal, Small Wind)	All PV panels and components imported Roof attachment structures built in Managua	Local retailers and micro-franchises (women organised in co-operatives)Some PV owners set up small stores (refrigerating grocery supplies)
Solar B — Nicaragua (Mostly SHS; also Solar Water Pumps and Water Heaters)	No local supply chain. Entire inventory is imported.	Cell-phone charging Small shops ("pulperias")
Solar A — Tanzania (PV systems and solar appliances)	All equipment is imported	Mobile phone-charging; barber shops; village cinemas; bars and shops; guesthouses
Solar B — Tanzania (SHS)	Imported PV panels and solar lights	Mobile phone-charging; barber shops; inns and bars
REF SolarNow — Burkina Faso, Mali, Senegal, Ghana, Ethiopia, Tanzania, Uganda, Zambia, Mozambique (SHS and solar lanterns)	PV panels and charge controllers imported Batteries often manufactured domestically	No specific information given
NICE International — Gambia, Tanzania, Zambia (Solar-powered ICT)	Solar and ICT equipment purchased internationally Domestic assembly of components	Local businesses include ISP, technical installation, maintenance and repair, products and services
Sunlabob — Laos (Solar lanterns)	Components sourced locally, but sophisticated items imported with pre-assembly in Laos	Local micro-enterprise activities, including stores, handicraft, mobile phone-charging
Hydro		
Hydro A — Honduras (Hydropower)	Turbines purchased from an international supplier Local construction materials	More reliable power supply allows shopkeepers to open longer
Hydro B — Guatemala (Hydropower)	Turbine and other electro-mechanical equipment manufactured in Guatemala. Local construction materials	More reliable power supply allows shopkeepers to open longer
REDP/RERL — Nepal (Primarily MHPs, but also ICS, Biogas, SHS)	Turbine, penstock pipes, accessories locally fabricated Electronic Load Controller locally assembled Generators imported	Local micro-enterprises: agro-processing mills, irrigation pumps, refrigeration (medicines, etc.) carpentry, battery-charging, handicrafts, tailors, sewing, knitting, poultry farming, communications/computer centres
Improved Cookstoves		
FAFASO — Burkina Faso (ICS)	Small-scale production with local materials, but scrap-metal supply for metal stoves imported	Brewers and restaurant owners Fuel savings permit ICS users to set up new small businesses (maize, cookies)
All technologies		
DEEP EA — Kenya, Uganda, Tanzania (ICS, Briquettes, Solar, Biogas, etc.)	Mostly localised supply chains within area of operation	Employees and customers of micro-entrepreneurs started their own small businesses

5.4 EMPLOYMENT CHARACTERISTICS

Employment from renewable energy projects in rural areas is characterised by varying types of jobs (temporary and permanent, formal and informal) and diverging salaries. Another important aspect of rural renewable energy employment- the gender dimension- is addressed in Chapter 6.

Temporary and permanent employment. Renewable energy enterprises, along their course of development, can create a mix of temporary and permanent jobs. E+Co, was an NGO based in the United States that for many years supported clean energy initiatives in developing countries, invested in 166 enterprises, for which temporary jobs accounted for 22-26% of employment (IRENA, 2012c). Most of the temporary positions were in hydropower, where they accounted for as much as 70% of jobs. Hydropower is the only RET for which temporary positions outnumber permanent ones: a small hydro project in Honduras, for example, created local jobs for more than 100 workers between 2004 and 2008, all of which ended when the plant was commissioned. The ratios for temporary to permanent employment are far lower for other RETs such as biomass, biogas and cookstoves (see also Box 5.4). Some work is temporary due to the nature of the activity, such as construction of a hydropower plant or a biogas facility; in other cases, the distinction is related to formal versus informal employment structures.

Formal and informal employment. Small entrepreneurs in remote rural areas often take on labour in highly informal arrangements to retain the flexibility needed under fluctuating and uncertain business circumstances. Several factors can contribute to these uncertainties. In ICS production, for example, a temporary increase in employee numbers may correspond to a large order being processed – after which a decrease in orders could be experienced, causing the number of employees to drop again. Fluctuations in employment could arise because some entrepreneurs engage in energy as a part-time business activity to supplement incomes from other livelihoods (at times when their primary income is down). Seasonal variations are also a common feature in many businesses where employment rises during peak seasons and dips during low seasons. And in some situations, casual employment or community-level involvement may be more typical arrangements (see Box 5.5). In Laos, a village energy committee of 3-4 people is responsible for overseeing operations of communal solar charging stations; committee members are not full-time employees,

Box 5.4

CHANGES IN EMPLOYMENT WITHIN BRIQUETTE-MAKING AND ICS MICRO-ENTERPRISES: CASES FROM UGANDA AND BURKINA FASO

The experience of a briquette-making enterprise in Uganda, which received support from the Developing Energy Enterprises Project East Africa (DEEP EA), demonstrates the changes in employment that can arise as an enterprise expands in size. The purchase of several briquette-making machines led employment to increase from two to six, with the addition of four casual employees (earning USD 11-22 per month). The purchase of the new machines helped improve the quality and types of briquettes that could be produced, thereby increasing sales. With plans to purchase a motorised briquette machine, another five permanent employees are expected to be hired.

In Burkina Faso, the FAFASO project, sponsored by the Dutch-German Energy Partnership Energizing Development (GIZ-EnDEV), is working to disseminate improved cookstoves, mainly in the major towns of Ouagadougou and Bobo. Between 2006 and 2011, some 180 000 improved stoves were sold to households, institutions and productive units. Some 285 metal smiths, 264 masons and 180 potters have been involved in the project. Many of the metal smiths and masons employ apprentices only when needed and create temporary additional employment. Among the makers of clay stoves, most of the potters are women, whose main work remains in the field and in the household. Social structures and traditions also have an impact on employment: in Burkina Faso, pottery is caste-bound work dominated by families that only hire from within and are unlikely to employ external apprentices.

Box 5.5

LABOUR FLUCTUATIONS AT A PHONE-CHARGING BUSINESS: A CASE STUDY OF SENGEREMA, TANZANIA

The case of a phone-charging enterprise in Sengerema, Tanzania, owned and operated by a single entrepreneur, showcases the different factors affecting labour-related decisions. Upon joining the DEEP EA programme in 2010, the entrepreneur received technology and business training, and diversified the business. He now provides solar technician services and sells solar components, leading to the addition of two permanent employees (one of whom is his brother). On several occasions, particularly during solar installation, he also employs one or two casual labourers, who are paid according to the type of work being done.

With solar technology still relatively new in rural Tanzania, the enterprise often experiences fluctuations in the volume of business and, as such, avoids taking on too many permanent employees. The following issues generally affect an entrepreneur's willingness to take on permanent employees:

- Legal issues: When permanent employees are taken on, entrepreneurs are required to pay taxes and other dues to the authorities, which may be burdensome if profit margins are small. Hiring permanent employees also may be accompanied by other legal complexities, hindering flexibility in managing labour resources at times of changing business environment.
- Commitment: Casual employees may be advantageous because there is no permanent financial commitment to paying a salary, and payments are also more negotiable.
- Family involvement: Most small energy enterprises in East Africa start as family businesses, and entrepreneurs often involve family members in the running of their business. Family relations are important for start-up businesses, particularly in countries where there is little, if any, institutional support for small entrepreneurs. Entrepreneurs may be reluctant to give responsibility to unknown employees and, where possible, prefer to hire trusted family members.

although they receive a small income for their work. More generally, greater attention needs to be given to employment characteristics in the informal economy, which is known to engage a significant proportion of the rural populations in developing countries, particularly women (see also Section 6.6.2). In fact, many of the small-scale enterprises that will be needed to expand access to renewable energy products and services in rural areas will rely on existing informal structures and arrangements.

Salaries in rural renewable energy. Salary information for formal employment in the rural renewable energy sector is relatively limited among the case studies and in the literature. Cases in Central America and Tanzania offer some insights, although they omit information about management salaries. As a general conclusion, the companies surveyed appear to be paying wages that compare well with the general economic conditions of these countries, as measured by average GDP per capita (see Table 5.6).

TABLE 5.6 MONTHLY SALARIES AT HYDRO AND SOLAR COMPANIES IN CENTRAL AMERICA AND TANZANIA

	SALARIES (USD)		GDP per capita (USD)
	Technicians, Sales Officers	Operators, Administrative and Support Staff	
Solar Company A, Nicaragua	200-350		94
Solar Company A, Tanzania	150-200	70-100	44
Solar Company B, Tanzania	100-150	50-70	44
Hydro Company A, Honduras	325-455	250-350	169
Hydro Company B, Guatemala	240-360	200-300	239

Note: Technicians and sales officers' salaries at Hydro Company A in Honduras are 25-30 percent higher than those for workers and administrative staff, and 15-20 percent higher in the case of Hydro Company B in Guatemala. Source: E+Co from IRENA (2012c); World Bank (2012a), Databank (GDP per capita data are for 2010).

5.5 CONCLUSIONS

Renewable energy is at the centre of global efforts to achieve universal access to modern energy services. Bridging the gap in energy access will require widespread adoption of decentralised supply options, which present a significant potential for job creation. Estimates indicates that nearly 4.5 million direct jobs can be generated by 2030 in the off-grid renewable electricity sector alone.

Rapid growth in RET deployment in rural areas is creating job opportunities across all segments of the industry value chain, from manufacturing to installations and O&M. In the many countries where domestic manufacturing has not been feasible, the potential for job creation is found to be greater in the assembly, distribution, installation and maintenance stages. In general, employment opportunities can vary significantly among RETs, as some are more labour intensive than others. The type of employment depends largely on local factors concerning markets (demand fluctuations, deployment models), social structures (family relations, societal norms) and policy frameworks (employer obligations, etc.).

A previous (2012) IRENA analysis of 15 new case studies notes that there is a tangible need for more co-ordinated efforts to better understand the job creation aspects of renewable energy deployment in rural areas. Such efforts are crucial to inform policy-making aimed at achieving the full potential for employment opportunities. They also can contribute to assessments of the impact of energy access programmes, providing data that could prove useful for attracting community interest as well as greater investments (including from impact investors).

Although efforts are being made in some countries, there is a need for improved data reporting on rural employment, including both quantitative (number of jobs, employment factors, etc.) and qualitative aspects (impact on employment from seasonal changes, types of employment [permanent vs. temporary, salaries, etc.]). Growing recognition of the effectiveness of a sustainable and decentralised approach to meeting energy access goals, as well as the importance of local enterprises in such an approach, warrants the development of a comprehensive framework to collect, analyse and disseminate the employment impacts of rural energy enterprises. In the coming years, these enterprises could emerge as crucial inputs to rural economies in developing countries.

6 Gender Dimensions of Renewable Energy Employment

© Adapted from Candice Nyando/Black Rock Solar

As described in Chapter 1, the continued growth and widespread deployment of renewable energy will create numerous job opportunities in many sectors over the coming decades. The increased penetration of renewables will also bring about many ancillary social, economic, environmental and public health benefits. However, the challenges described in Chapter 4, particularly those relating to current and expected skilled labour shortages, can slow down the deployment of renewable energy technologies and negate many of their early co-benefits.

This chapter analyses how including the gender dimension into the renewable energy equation can help simultaneously address both issues above. First, by removing existing barriers and working towards equal opportunities for women's employment in the renewable energy sector, the pool of talent from which to draw labour can be effectively expanded. Second, the inclusion of the gender dimension in renewable energy strategies and the empowerment of women in energy decisions acts as a multiplier of renewable energy co-benefits, particularly those related to energy access, household consumption and micro-enterprises, where women are primary actors.

This chapter begins by presenting the rationale behind exploring the linkages between gender and renewable energy employment. It examines the data on renewable energy jobs from a gender perspective to get a feel for women's representation in the sector, and then analyses the constraints and opportunities that women face. It also illustrates how empowered women have featured in decision-making and entrepreneurial positions. The chapter concludes by discussing ways to promote the involvement of women in the sector and presenting a set of recommendations for further data collection, as well as practical suggestions to include gender dimensions in renewable energy policies, programmes and projects.

6.1 RATIONALE FOR ANALYSING THE GENDER DIMENSION IN RENEWABLE ENERGY EMPLOYMENT

Renewable energy employment concerns both women and men. It can be viewed as an opportunity to value both genders equally for their similarities as well as their differences, and for the diverse roles that women and men can play in all areas of RET deployment. Two of the most compelling reasons to integrate gender considerations into renewable energy employment are to ensure (a) that women and men are given equal opportunities to contribute to the renewables value chain, and (b) that both genders will share equally in the benefits from renewable energy and the positive impacts of economic and social transformation, including the welfare and social empowerment which energy generates.

Attracting all potential talents is particularly important in today's rapidly expanding renewable energy market. Already, there are indications of shortages of trained workers (see Section 4.2), a situation that will likely persist and perhaps worsen. Eliminating the existing barriers that prevent women from entering the sector, and tailoring policies to consider the gender differences, would increase the chance of being able to meet the demand for skills that would enable the successful deployment of renewable energy.

In this context, it is important to understand gender differences and commonalities in different market segments, and the appropriate ways for addressing them. In the modern energy markets, as are present throughout industrialised countries, women are known to favour "clean" energy solutions (from both an environmental and inter-generational equity perspective) and to vote for renewable energy solutions either for national projects (Eddy and Reed, 2013) or in their workplaces or enterprises (see Section 6.3.1). In this segment, women are generally less represented in the industry's workforce, especially in technical and managerial positions. They typically do not have the same influence over energy decision-making as men for a variety of reasons (discussed in Section 6.3.2), such as issues of equal opportunity, education and skills, self-perception and mobility.

In the segment of the market where energy access is limited, primarily in developing countries, energy poverty has a more significant impact on women. They are major users of renewables and their participation in the further deployment of RETs is a vital pre-requisite for addressing energy poverty (Clancy, Skutsch and Bachelor, 2002). Where the demand for modern energy services is unmet, women are often compelled to spend long hours collecting fuelwood, and their ability to pursue education and find employment is limited. As such, it is important to explore the employment opportunities for women in the context of energy access, as well as prospects for employment creation from women-led enterprises.

Studies have documented differences between men and women with respect to the energy sector, (including renewable energy). These include differences in priorities for types of services and energy needs, and in the opportunities available for participating in the planning, design and implementation of renewable energy solutions. Taking these differences into consideration, the key entry points for integrating gender equality into renewable energy employment are efforts to ensure: (a) an equal voice in the identification of needs, (b) equal participation in the labour market, (c) equal opportunity for participation in decision-making regarding the choice of energy solutions, (d) equal access to support services (which enable access to the labour market and for enterprise creation) and (e) an equal share of the benefits.

Gender equality could eventually affect the composition of the workforce in the renewable energy value chain by offering equal employment opportunities to men and women. To foster gender equity (see Box 6.1 for definitions), targeted measures can be introduced to reduce disparities where they exist. This is applicable not only in the renewable energy value chain, as well as in the policy environment and support systems, but also in the processes of giving women a voice as well as men. For example, women can be labour representatives in their companies or leaders in their communities, and they can occupy decision-making roles. More significantly, in developing economies, renewable energy employment provides the opportunity to address the disparity in poverty between women and men (currently, women constitute 70% of the world's

Box 6.1

KEY DEFINITIONS: GENDER EQUALITY AND GENDER EQUITY

Gender equality: Under the standard concept, "gender equality is achieved when men and women have equal rights, freedom, conditions, and access to endowments and social and economic opportunities for realising their capabilities and for contributing to and benefiting from economic, social, cultural and political development".

Gender equity: Related to gender equality, gender equity is "the process of being fair to women and men. To ensure equity, measures must often be taken to compensate (or reduce disparity) for historical and social disadvantages that prevent women and men from otherwise operating on an equitable basis".

Source: Lallement, 2013

1.3 billion people in extreme poverty) (PCI, n.d.). Lack of access to modern energy and other infrastructure services has been documented as one of the factors that keeps women in poverty longer, and at higher levels, than men, particularly in rural and peri-urban areas.

6.2 EMPLOYMENT DATA: WHAT DO THEY TELL ABOUT GENDER EQUALITY?

Gender-disaggregated data on renewable energy employment are both scarce and disperse, making it difficult to analyse firm trends. This is hardly surprising given the paucity of employment data on renewable energy employment in general. Moreover, the conclusions about women's employment change dramatically depending on whether the analysis includes or excludes large hydropower and informal employment in renewable energy (particularly in traditional biomass and fuel-crop production). This section examines existing employment data in the formal renewable energy sector and underscores the gender differences in energy employment, both in terms of overall share of employment and occupational distribution.

6.2.1 Women in renewable energy in the context of the modern market

Gender-disaggregated data on renewable energy employment are extremely scarce, but they broadly confirm a picture of substantial gender imbalances which result from unequal opportunities, underscoring the need for corrective policies. In industrialised countries, women hold a minority of jobs in the energy industry in general. The share of female employees is estimated at about 20 to 25%, with most women working in administrative and public relations positions. The share of women among the technical staff in the energy industry is at most 6%; in decision-making positions, it is about 4%, and in top management it is less than 1% (Stevens *et al.*, 2009).

In the United States, a 2013 report assessing the broader green economy estimated that women hold just under 30% of jobs in this sector, a significantly lower share than the 48% of jobs they hold across the economy as a whole (Hegewisch et al., 2013). Additionally, women account for less than 5% of high-quality green economy occupations. As for renewables, wind energy in particular, a survey by Women of Wind Energy (WoWE) found that the female share of full-time employees among the workforce of 22 wind energy companies in the United States was 25%, with women holding just 11% of senior-level management positions (WoWE, 2011). This share is slightly above that in the EU, where women account for 22% of the wind industry workforce and 44% of the overall regional labour market (Blanco and Rodrigues, 2009).

In Spain, a study by the labour union organisation Instituto Sindical de Trabajo Ambiente y Salud found that women accounted for just over 26% of the renewable energy workforce in 2008 (Arregui *et al.*, 2010). This is somewhat higher than the 24% average for the country's industrial sector. Only 2% of the renewable energy jobs in Spain are part-time jobs or involve reduced work hours, and women hold 67% of these part-time positions. The study also shows that women constitute only 14-15% of management positions and 28% of engineering and technical positions, but as much as 36% of sales positions among the 22 leading firms (see Figure 6.1). The greatest representation of female workers is in sales, followed by administrative positions and then engineers and technicians. This is a familiar picture, where female employees are found mostly in non-technical occupations.

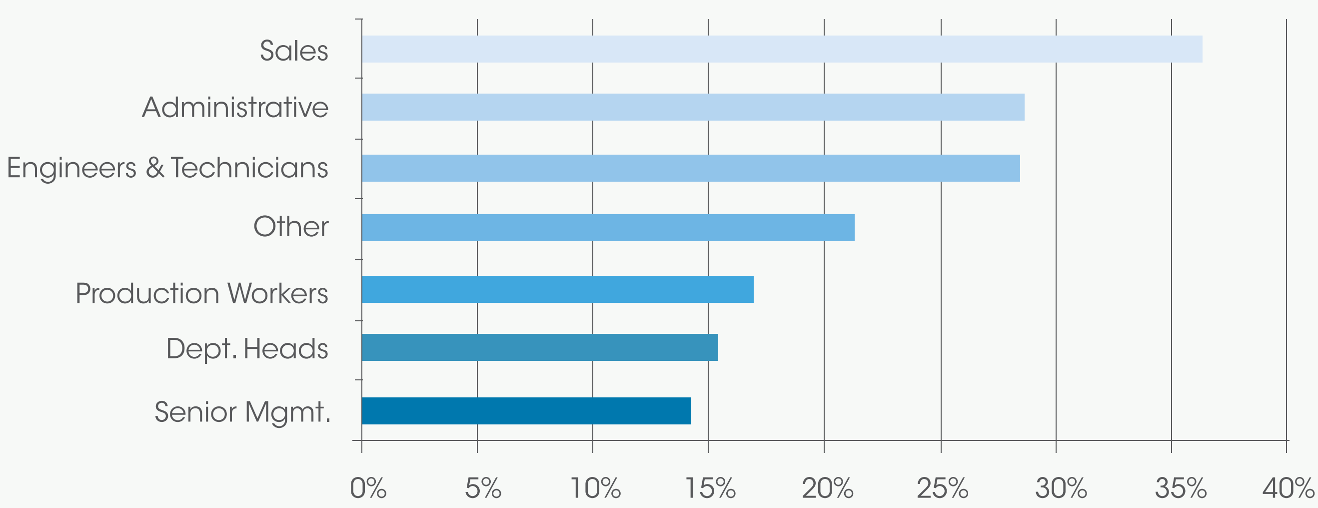
The Italian company ENEL Green Power employed 14% women in 2010, up from 5.7% in 2008, though the proportion varied widely by location, with women accounting for only 1.7% of workers in the company's North American subsidiary but for 39% of workers in the Iberian region (see Figure 6.2). These varying shares may not account for differences in the types of jobs required in the different geographic locations, however.

Similar to the situation in Spain, the share of women in Germany's renewable energy workforce averaged below 24% in 2007. Confirming findings in other countries, Lehr *et al.* (2011) found that women are under-represented in technical occupations. Their share of the total renewable energy workforce is much lower than in some other sectors, such as services (70%), trade and gastronomy (54%), and credit services and insurance (51%). Women's share in renewables matches their share in the overall energy and water supply sector (24%) but is far below the 45% share of women workers in the German economy as a whole.

Assessed by individual RETs, the rate of female employment in Germany ranges from a low of just 10% in liquid biomass jobs to a high of more than 30% in solar PV (see Figure 6.3). The reasons for this variation in women's share of employment need closer scrutiny, but they likely relate to factors such as the occupational profiles of each RET, perceptions and stereotypes of what constitutes women's work, wage rates and the availability of flexible work hours and arrangements. In some cases, the need for mobility may also be a limiting factor for women's involvement, as some jobs, such as wind energy technicians, require extensive travel to installations within a region. Other jobs in the sector may involve frequent international travel, which can be difficult to reconcile with other priorities.

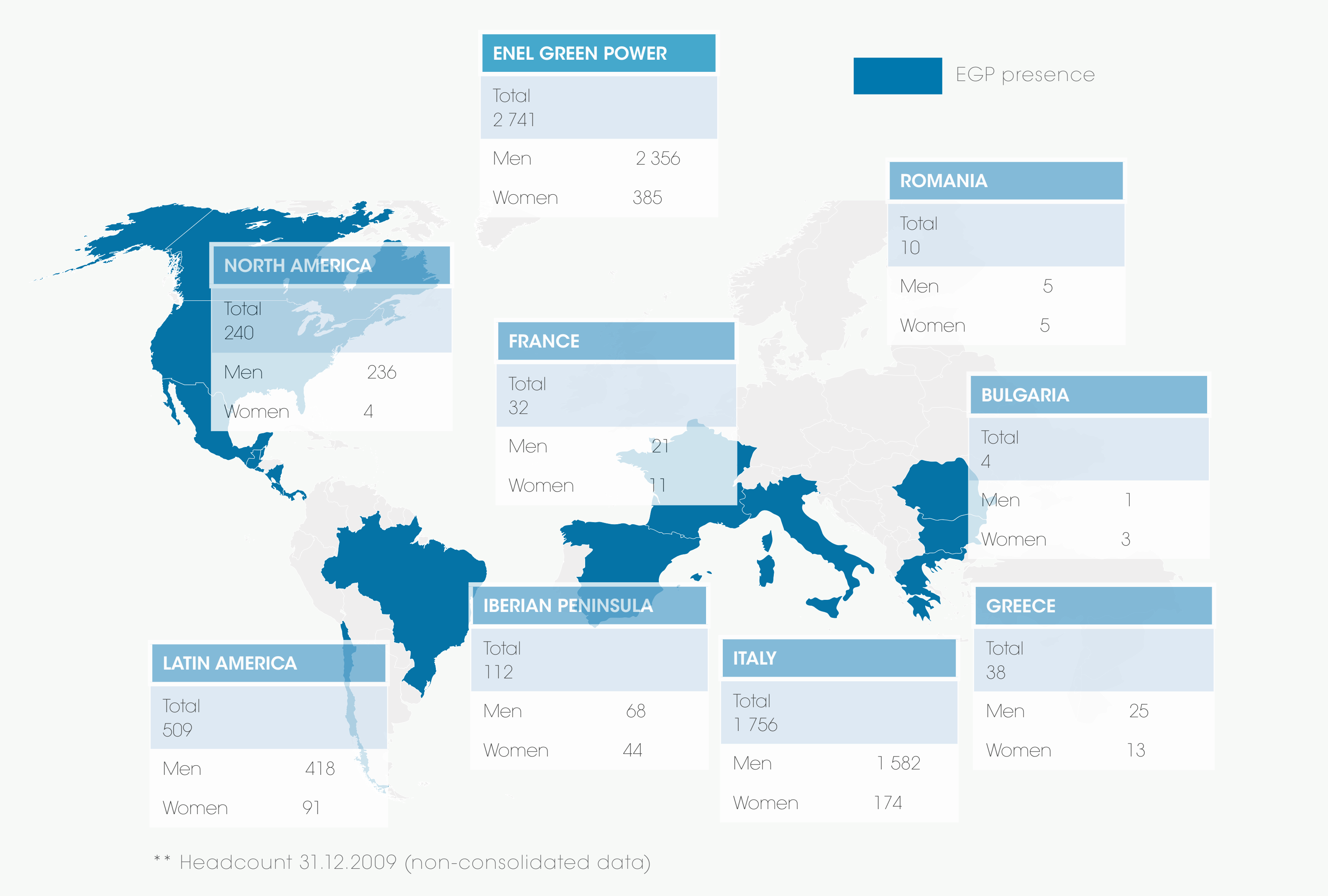
Given the paucity of gender-disaggregated data in many countries, rough estimates for global employment in RET by gender were calculated by applying the German male/female ratios of renewable energy employment by technology to the global employment figures presented in Table 1.2. Although one cannot generalise from the limited data of one country, this

Figure 6.1 Share of female workers at 22 leading RET companies in Spain, 2008



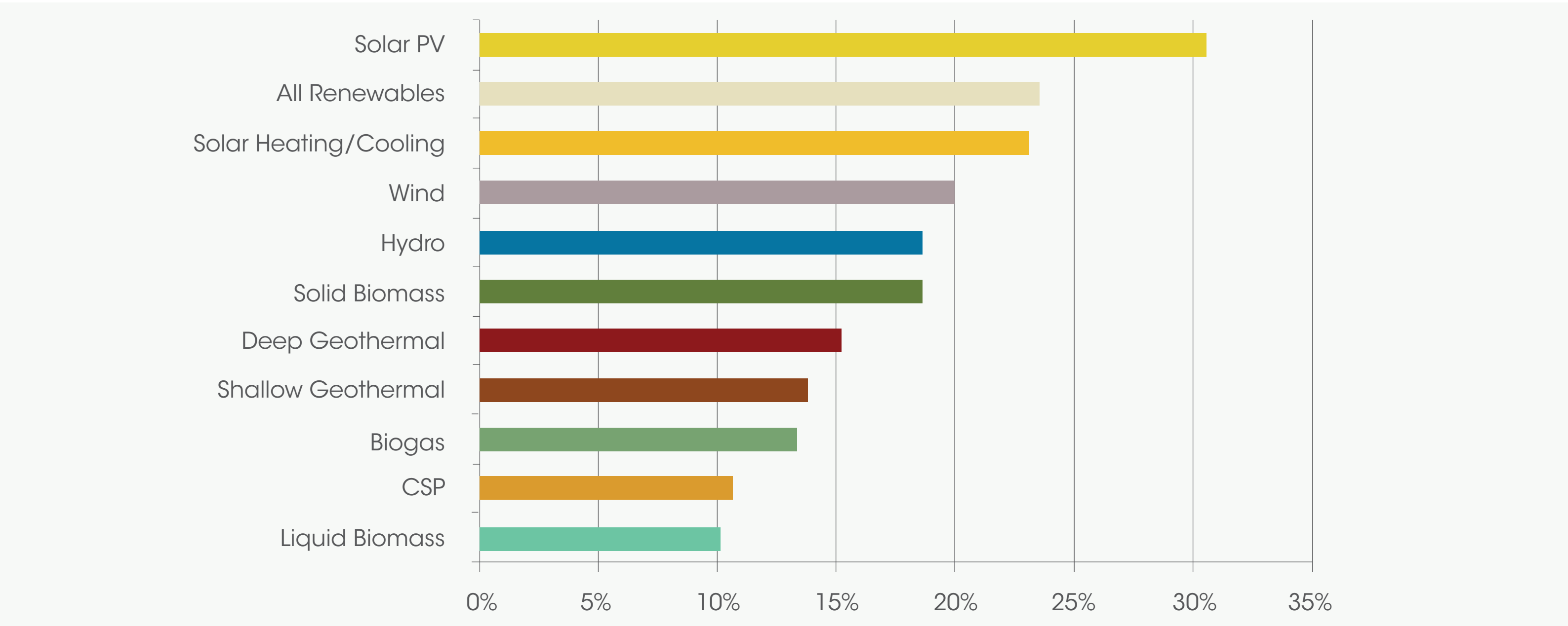
Source: Arregui et al., 2010.

Figure 6.2 Gender-disaggregated data for ENEL Green Power



Source: Lanaro, 2010.

Figure 6.3 Share of female workers in Germany's renewable energy workforce, 2007



Source: Lehr et al., 2011.

was deemed a good approach for approximating women's share of employment in the sector. Obvious limitations relate to the relative shares of employment between the different segments of the value chain which are country-specific, and further research in this area would be essential.

The results suggest that nearly 1.2 million women, or 20% of the total labour force, may be employed in the modern renewable energy industry. In absolute numbers, the largest sources of employment for women are solar PV, solar heating/cooling, wind power, modern biomass and biofuels.

6.2.2 Women in renewable energy in the context of energy access

No global data are available on employment in traditional renewable energy, however some regional estimates are available. For instance, studies were conducted in Malawi to estimate the supply and demand of household energy and the resulting jobs created in production, transport and trade of commercial biomass. The findings, when applied to overall sub-Saharan wood energy consumption, estimate that about 13 million people are employed in commercial biomass (Openshaw, 2010). Given the similarities in the nature of the activities, the percentage of women employed in the agriculture sector in sub-Saharan Africa of 50% (Food and Agriculture Organization (FAO), 2011) can provide an estimate of the gender composition within commercial biomass. This section explores the involvement of women in the renewable energy workforce in the context of energy access, with a focus on informal jobs in fuelwood collection and formal jobs in the deployment of ICS and other modern RETs.

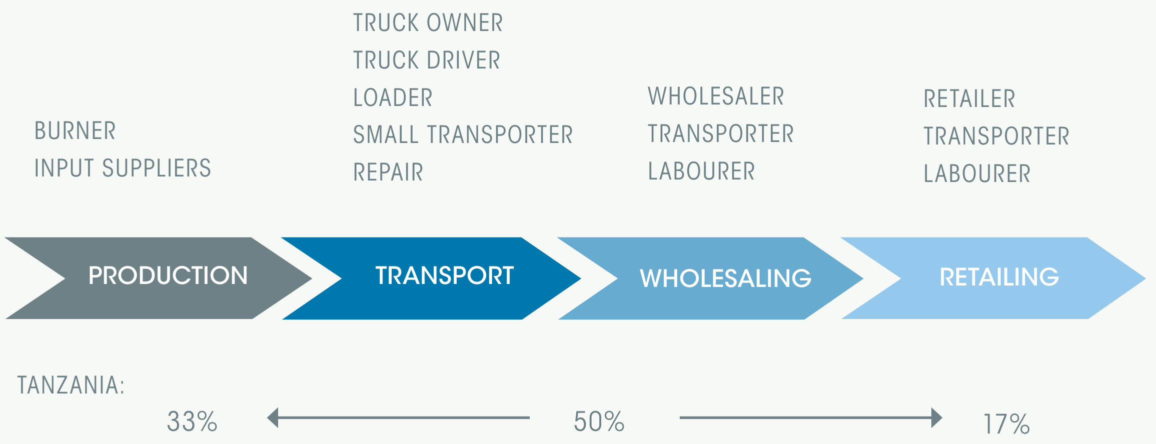
Fuelwood and charcoal. Fuelwood and charcoal represent 50-90% of all energy needs in developing countries and 60-80% of total wood consumption (ESMAP, 2012). Although these renewable resources are used in both rural and urban areas, demand is shifting increasingly to urban areas as a result of rural migration and urban poverty. In addition to domestic applications, charcoal and wood are used in a large number of traditional industries (furniture making in Southeast Asia; food industries such as restaurants, fish and meat smoking, and seed and plant drying; iron and silicon-based industries and brick manufacturing, etc.). The fuelwood and charcoal sector is therefore extremely important for employment, and for women's employment in particular. But there is no readily available accurate estimate of employment in the production and supply of these fuels.

Several studies have documented the time spent collecting fuelwood for cooking in many developing countries, mostly by women (Ilahi, 2000), as well as the linkages between time allocation and "unpaid" household work and poverty (Blackden and Wodon, 2006). Other studies document the disproportionate time that women devote to fuelwood collection and preparation as compared to men in most developing countries, at the expense of their health, of young girls' ability to attend school, and more generally, of women's ability to engage in other productive, often income-earning, activities.

With regard to the charcoal value chain, there is more information about its value-added than about related employment and gender aspects. In Tanzania, the sector contributes an estimated USD 650 million annually to employment, rural livelihoods and the wider economy, providing jobs and income to several thousand people in urban and rural areas. These tend to be members of poorer households, who work as small-scale producers or traders and who often have limited alternatives for earning a living (World Bank, 2009). As Figure 6.4 illustrates, however, half of the gains go to transporters and wholesalers, with only lower levels of benefits accruing to producers and retailers (World Bank, 2009).

Large numbers of people are employed in different phases of charcoal making and distribution, including in collection; sizing the wood; preparing the kilns for converting wood into charcoal; loading the wood into the kilns (and unloading charcoal after conversion); unloading, bundling, packaging and transportation; and marketing and utilisation. On average, charcoal production generates an estimated 200-350 person days of employment per Terajoule of energy (Bhattarai, 1998). By gender, men tend to be more involved in transporting and wholesaling the charcoal, and women in retailing (World Bank, 2009).

Figure 6.4 Distribution of profits along the charcoal value chain in Tanzania



Source: Beukering, et al., 2007; author's adaptation

Improved cookstoves (see related section in Chapter 5) are an important technology in the wood and charcoal value chain and also bring important environmental and health benefits. In addition to reducing the unsustainable use of biomass, the stoves provide a substitute for indoor open fires, which kill an estimated 1.9 million people annually due to pneumonia, chronic respiratory diseases and lung cancer. Approximately 60% of indoor air pollution's victims are women, and 56% of all deaths attributable to indoor air pollution occur in children under five years of age (ESMAP, 2011).

The market for improved cookstoves can be a major source of employment for both women and men. Jobs in manufacturing or construction of the cookstoves can vary depending on the stove model, whether it is designed for an indoor or outdoor kitchen, and whether it uses local materials or manufactured parts. Women seem to dominate in the producion of ICS liners and are prevalent in ICS stocking, selling and assembly (GVEP, 2012b). Lessons learnt from decades of work on the adoption of cookstoves suggest that it is important to give women a voice and to involve them early on in the selection and design of stoves (Lewis and Pattanayak, 2012). Experience also demonstrates that cookstove manufacturing can be a profitable business and source of employment for women.

Fuel crops. Production of fuel crops is an important source of both formal and informal renewable energy employment in developing countries (Kammen, 2011). Although traditional knowledge exists on how to use oilseeds for lighting, significant breakthroughs have been made with biodiesel feedstocks such as jatropha, which can be integrated into farm production systems as a complement to (not a substitute for) food crops. A review of various biofuel projects concluded that village-level production of biofuels can be sustainable, create employment and increase access to energy in rural areas of developing countries (ENERGIA, 2009). On a small scale, locally produced plant oils and biodiesel can be used successfully in rural villages to power diesel engines and generators, which in turn encourage agricultural processing and new enterprises, generating income (see Box 6.2). These systems can ease women's burdens and foster their participation in decision-making processes. A major potential risk, however, is the shift from fuel crop production that is integrated into the traditional farming system to mono-cropping for commercial production, which may entail loss of land and income (ENERGIA, 2009).

6.3 RENEWABLE ENERGY EMPLOYMENT FOR WOMEN: OPPORTUNITIES AND CONSTRAINTS

The previous section established the discrepancy between women and men in renewable energy employment in both the modern market segment and the energy

Box 6.2

JOB CREATION FROM JATROPHA IN CAMBODIA

As part of a project organised in Bot Trang by Solidarity and Community Development (SODECO), an NGO which works on development issues in rural communities, entrepreneurial farmers in Cambodia have started growing jatropha trees and extracting oil from the seeds to power a diesel generator that supplies electricity to a mini-grid serving a small village of 80 homes. Although the project was not targeted at women specifically, a majority of women have participated in the training offered by SODECO at the village level.

Because the plants are inexpensive and harvesting the seeds does not require special equipment, women have integrated jatropha into their other cropping activities. In addition, some are employed in processing the seeds for oil. Women also were found to be the most sensitive to the energy independence that jatropha could provide the village. Once a mini-grid provides power, other activities emerge (such as silk production) which are also sources of employment and income generation (ENERGIA, n.d.).

access segment. This section discusses the opportunities that are presented to women in decision-making roles, highlighting the business case for having gender balance in decision-making and demonstrating the capability of women to own renewable energy businesses. The section also explores the constraints to women's employment in the renewable energy sector and gives a brief overview of the risks and vulnerabilities. It presents different actions that the public and the private sector can take to help overcome the barriers to entry of women into the sector.

6.3.1 Opportunities for women in renewable energy

Although some information exists on the participation of women in the renewable energy sector, most studies do not explore their participation in decision-making roles. There is a sound economic rationale, however, for having gender balance in decision-making. Moreover, advancing opportunities for women-owned renewable energy businesses can serve as a significant source of self-employment and growth.

Voice in decision-making. In the modern market segment, several studies have analysed the business case for promoting gender balance on companies' board of directors and in executive teams. In corporate governance, one study found that Fortune 500 companies with the highest shares of women board directors outperformed those with the lowest shares by 53% on return on equity, 66% on return on sales and 52% on return on invested capital (Joy *et al.*, 2007). These results stand across industries and are therefore a strong strategic element to be used in the development of the renewable energy sector.

Another study by the Haas School of Business at the University of California at Berkeley investigated the corporate performance of more than 1 500 companies across environmental, social and governance categories (McElhaney and Mobasseri, 2012). Among the key findings, most of which are relevant for development of the renewable energy market, the study found that companies with more women on their board of directors are significantly more likely to: (a) invest in renewable power generation and to proactively take steps to improve operational energy efficiency, (b) have integrated climate change into their actuarial models and developed products that help customers manage climate change risk, (c) measure and reduce carbon emissions of their products, (d) have supplier programmes to reduce the carbon footprint of their supply chain, (e) reduce the environmental impacts of their packaging, (f) address environmental risks in their financial decisions and (g) not disturb large and/or fragile areas of biodiversity.

In the market segment that lacks energy access, giving women a voice in decision-making is a key element given that men and women have different needs and preferences due to their differing responsibilities. Because women are the main consumers of RETs in this context, integrating the gender perspective in the design of policies, products and services relevant to energy access is vital for the success of these efforts. When improved cookstoves were first introduced, for example, many cookstove programmes failed to achieve the initial dissemination targets, due likely to the fact that women had been excluded from the stove design process (Foley and Moss, 1983; Manibog, 1984). After an effort was made to consult with women and to integrate their experiences as energy users and managers through focus groups and surveys, designers benefitted from a better understanding of the features of stoves which most appealed to women, such as the types of cooking pots, visual elements, and the kinds of food items cooked (Caceres, Ramakrishna and Smith, 1989; Ki-Zerbo, 1980).

In the context of energy access, decentralised renewable energy systems in particular offer a great opportunity for women to participate in decision-making, as these are deployed at the local level where women are more likely to be involved in the procurement, design, installation, maintenance and consumption of energy (Smith, 2000). In comparison, decisions associated with conventional energy models are often made at the generation, transmission and distribution stages by higher-level professionals.

Women can also have a voice in decision-making when enterprises are created for community-based renewable energy investments. Women tend to be more active in the establishment of small-scale renewable energy enterprises which are either privately or individually owned or collectively and community owned. The women's co-operative in Char Montaz, Bangladesh, established with assistance from the World Bank's Energy Sector Management Assistance Program (ESMAP), illustrates the benefits of involving women in local renewable energy decision-making (see Box 6.3).

Self-employment and entrepreneurship. Women-owned businesses are a significant source of self-employment and economic growth around the world. Data from the 2013 State of Women-Owned Businesses reveal that over the past six years (since the depth of the economic slowdown), the only businesses that have provided a net increase in employment are large, publicly traded corporations and privately held majority women-owned firms. In emerging economies, small and medium-sized enterprises with full or partial female ownership account for an estimated 31-38% of formal SMEs, or some 8-10 million (IFC, 2011). These enterprises represent a significant share of employment generation and economic growth potential.

Evidence reveals that women-owned businesses come in all sizes and are not limited to micro-enterprises or the informal sector. However, analysis of enterprises across different regions shows that Africa and South Asia, despite being home to the majority of the global population, have relatively fewer women-owned firms compared to most other regions (see Figure 6.5) (World Bank, 2011b; ILO, 2008). This trend presumably also applies to renewable energy enterprises.

Box 6.3

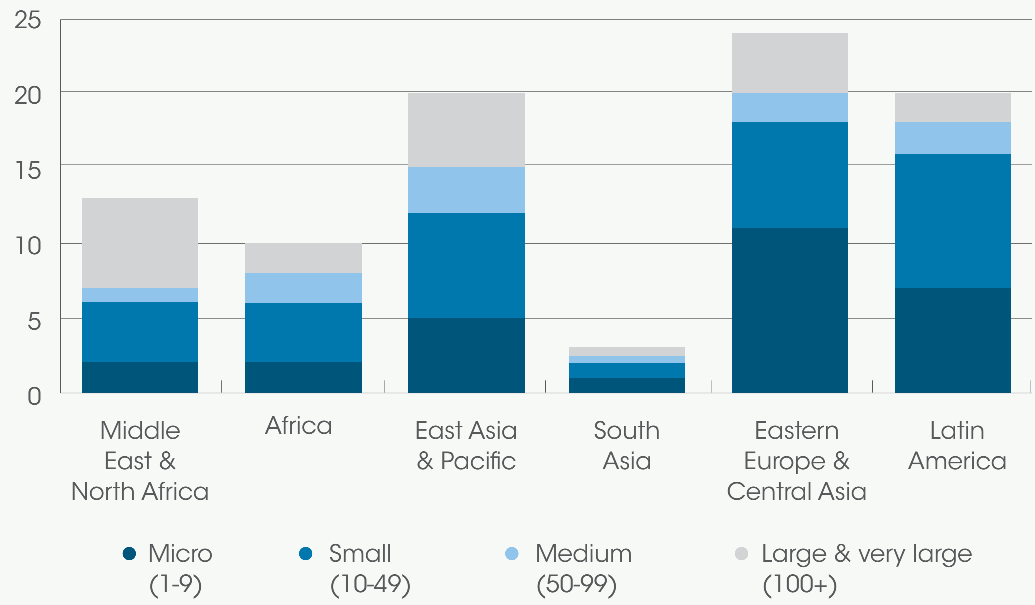
A WOMEN'S SOLAR CO-OPERATIVE ON A REMOTE BANGLADESHI ISLAND

In Char Montaz, a remote unelectrified village in Bangladesh, the Coastal Electrification and Women's Development Cooperative (CEWDC) was set up with the objective of delivering reliable power and creating employment. CEWDC assembles and sells solar home systems and accessories and runs a PV-powered battery-charging service for portable lanterns. The co-operative was set up by Prokaushali Sangsad Ltd., a development consultancy that provided co-operative members, mostly women, with extensive training in assembling electronic components as well as in quality control, business development, marketing, micro-finance, and solar battery charging.

The initiative has brought employment to local women, who now earn USD 10-50 per month, a significant salary under local circumstances. In addition to employing some 40 women in solar assembly, another 15 people found employment in CEWDC's satellite sales office, which sells units further afield. As of 2009, the co-operative had sold 7 500 SHS, 3 000 solar lamps and 8 000 batteries. Two similar co-operatives inspired by CEWDC's success were set up on neighbouring islands, with other communities also expressing interest.

Source: Ashden Awards, 2009.

Figure 6.5 Female-owned firms across regions



Source: World Bank, 2011b; ILO, 2008.

Women-owned businesses, in general, are still mostly in trade and services (only 6.7% of women-owned businesses are in construction and 29% in industry). Around the world, however, women are establishing new renewable energy enterprises, ranging from small electricity production and distribution networks hooked to multi-functional platforms in Mali, to charcoal production businesses in Senegal, to solar businesses in Guatemala, Bhutan and India. In sub-Saharan Africa, the innovative Solar Sister initiative trains female solar entrepreneurs to distribute portable solar lights in rural areas (see Box 6.4). All of these businesses require management, technical and marketing skills. Unfortunately, there are no systematic data documenting employment (including self-employment) in these businesses for either women and men, or their representation in governance structures.

6.3.2 Constraints to women's employment in renewable energy

Historically, women's participation in the labour market has been determined largely by social and cultural norms and values, with women's roles and responsibilities geared towards household duties as well as to providing most of the unpaid family labour. That said, norms are changing all over the world, with women increasingly participating in the labour market (Boudet, Petesch and Turk, 2013). Although the evolution of norms is culture and history specific, this section discusses three main constraints that are relevant to women in both the modern market segment and the energy access segment: self-perception, mobility and skills. The section also briefly explores several other explanations for women's lower participation in the sector.

Self-perception is a recognised constraint for women's employment and progression in renewable energy markets worldwide, but only a few studies that exist on the topic were found. Experience from the broader construction industry in India, however, provides an idea of how women perceive themselves in technical and engineering fields. A study of the career progress of 440 male and 440 female construction workers attempted to discern why women in the construction sector (a sector closely relevant to RETs) were not able to acquire skills for higher-paid masonry work. The study found that there was a shared belief (among men and women) that women construction workers are unfit to be trained like men in the sector even though they have the necessary skills, capability and desire to

Box 6.4

SOLAR SISTER JOB CREATION INITIATIVE IN SUB-SAHARAN AFRICA

Founded in 2010, Solar Sister is a job creation initiative which distributes portable solar lights in rural sub-Saharan Africa through female solar entrepreneurs. The pilot project started in Kampala, Uganda, where electrification rates are as low as 5%. Two female entrepreneurs were trained and provided with a small inventory to sell. As of early 2013, the number of female entrepreneurs had reached 315, mostly from Uganda, Rwanda and southern Sudan.

Because women were seen to be the primary managers of household energy needs, involving women directly was found to be the most effective solution. Targeting women allowed Solar Sister to tap into extensive social networks, where women are better able to communicate the benefits and the utility of the products to their neighbours, friends and relatives.

Solar Sister decided to use micro-solar products, such as solar portable lamps, specifically to address a perceived "technology gender gap": women were not as familiar with technology due to cultural or educational biases and were expected to have difficulty adjusting to the use of renewable energy technology. Aside from being more affordable, solar lanterns were also much easier for women to maintain on a daily basis without outside help. The robustness, simplicity and ease of use of the solar portable lamps also made them a favourable first product to launch.

Solar Sister uses a system of micro-consignment: female entrepreneurs selling solar lights do not pay for their inventory until a sale is made and cash flow is available, and no interest is charged. This model addresses the specific needs of women, including their lack of access to start-up capital and low-threshold for risk, while allowing them to build sales out of their network of friends and families. When an entrepreneur sells her solar products, she earns a commission and the remainder of the money is re-invested in fresh inventory, enabling a sustainable business.

Establishing a single entrepreneur requires Solar Sister to invest USD 500, of which USD 200 covers the one-time cost of recruiting, training and sales support, and USD 300 is the inventory cost. One dollar invested in a Solar Sister entrepreneur generates more than USD 46 of economic benefit in the first year, through earned income for the entrepreneurs, reinvestment and customers' avoided kerosene expenses.

Over the next five years, Solar Sister aims to build a network of 5 000 entrepreneurs in five African countries. It is already expanding into Tanzania and Nigeria and aspires to eventually reach all parts of sub-Saharan Africa where energy poverty exists. Solar Sister is also looking to expand its inventory to include household appliances such as solar radios, mobile phone chargers and water filters.

Source: Lucey, 2013.

become masons (Barnabas, Anbarasu and Clifford, 2013). In another study from Brazil, women were initially reluctant to adhere to a technical training programme because they perceived that working in hydropower and other technical infrastructure jobs was only for men, and that they would be subject to harassment in the workplace.

Although issues related to self-perception exist in both the modern market segment and the energy access segment, it may be a less prevalent obstacle in cases where self-employment and entrepreneurship are more common. In the energy access segement, women encounter social norms and traditional division of labour that imapct their participation in energy development activities. However, women seem to start businesses with ease when given the opportunity to acquire the appropriate knowledge and skills to run a business.

Mobility. As with the energy industry overall, the renewable energy industry is highly demanding in terms of geographic mobility. This affects both men and women, but women may be at a greater disadvantage in this regard, both in the modern market and energy access segment. The locations of large renewable energy construction projects are determined in part by the geography of natural resources and are often in isolated areas, which requires special accommodation for staff and workers, and long absences from families. For example, not all women supervision engineers are able to stay away from home for the better part of a year, as did Irina Lurke of Germany's EWE, who spent most of 2012 on the low sandy island of Borkum in the North Sea while supervising the construction of a 30-turbine offshore wind farm (Eddy and Reed, 2013). In rural areas of developing countries, women often face mobility contrains owing to social responsibilities and traditional norms, thereby limiting their participation in activites that require relocating or traveling. Yet trends are emerging from both industrialised and developing countries that suggest an increase in women's mobility.

Skills. Skills, particularly for engineering and technical occupations, are a significant challenge in both market segments. In the energy access market segment, there is often a lack of the technical and business skills, especially among women, that are necessary for renewable energy employment (as described in Section 4.3). Limited access to basic education and training form a barrier to acquiring these skills, hampering women's ability to participate in the sector (Danielsen, 2012). Related training that utilises customised solutions and cross-mentoring among local entrepreneurs can help to overcome this barrier.

In the modern market segment, it is safe to assume that the low percentage of women who graduate as engineers overall also affects the RET sector. In Germany, it was estimated for 2011 that out of 1 million engineers, only 13% were women (albeit an increase of 10% from a decade ago) and that out of 384 000 engineering students, only 79 000 (21%) were women (Blau, 2011). This is consistent with trends in science, technology, engineering, and mathematics (STEM) fields in the rest of Europe (Association of German Engineers (VDI), 2009). In the United States, according to the National Science Foundation, "between 2000 and 2008, the total number of four-year engineering degrees awarded annually ... increased by about 10 000 to 69 895, with almost all of the increase going to males. This reduced the percentage of women receiving undergraduate engineering degrees to 18.5% from 20.5%" (Mahmud, 2012).

One constraint that is particular to the modern market segment is the glass ceiling. Anecdotal evidence suggests that still today, relatively few women hold executive positions in enterprises along the renewable energy value chain (as shown in Section 6.2). Lack of equal representation of women in decision-making roles at corporations and influential organisations is described as the glass ceiling, where invisible barriers keep women and minorities from advancing their careers to influential positions, regardless of their qualifications (Federal Glass Ceiling Commission, 1995). However, better female representation exists in support industries such as project design, banking and environmental impact assessment[23].

Within the industry, specific risks and vulnerabilities affect women in particular and could potentially discourage them from entering the sector. In the modern market segment, these can range from the difficulty to maintain work/life balance to the lack of childcare facilities, harassment in the workplace, gender discrimination in hiring procedures and wage determination (in OECD countries, women earn 15% less than their male counterparts across the economy (OECD, 2013)). These constraints have been documented for the labour market at large and prevail in many industries, but they have not been documented specifically for the renewable energy sector, and it is difficult to confirm their validity.

With regard to the energy access market segment, many risks and vulnerabilities exist in traditional renewable energy activities. The difficulties that women face in the fuelwood and charcoal trade have long been documented, ranging from the use of traditional methods for transporting heavy loads, to physical assault when fetching the wood, to the meagre payment received from traders for the raw material. Some countries are striving to improve the conditions of women in the fuelwood and charcoal value chains (ESMAP, 2012).

6.3.3 Enabling the participation of women in renewable energy

A variety of actions can be taken in the public and private sectors to help remove the barriers to entry of women into the renewable energy industry. and help overcome the existing and anticipated shortage of skills These include conducting an assessment of the mainstreaming of women in renewable energy employment, and implementing the necessary measures to provide women with an adequate environment and with the right incentives and support services they need to participate in different technologies, roles and occupations in the sector.

23 *In large-scale hydropower, Hydro-Québec is an interesting case: women are a majority on the board of directors (8 out of 15 members), but the executive team includes only 3 women out of 12 members (Hydro-Québec, 2013).*

Assessing gender mainstreaming in renewable energy employment. In order to promote gender equality in renewable energy employment, it is important to assess whether the gender perspectives that have a direct or indirect impact on the participation of both genders are factored into decision-making in the sector. Gender audits offer a useful tool for analysing whether gender is mainstreamed into public policy, including legislation, regulations, allocations, taxation and social projects (Swirski, 2002). Gender audits are a starting point towards an energy sector policy that is supported by programmes that promote gender equality and are enacted through appropriate institutions (ENERGIA, 2009). For instance, Nicaragua seeks to reach a 50% job participation by women in the energy sector given the country's new legislation on gender equality. Unfortunately, only a few comparative reviews of gender in renewable energy policies, legislations and regulations have been undertaken.

Gender audits of energy sector policy have been implemented in several developing countries, including Botswana, India, Kenya, Mali and Senegal, mainly with support from ENERGIA (Clancy, 2011). In Botswana, a gender audit led the government to invite and consult with communities, particularly with women, to prepare its new energy policies (ENERGIA, 2008). The audit was followed by training workshops on gender and energy concepts for relevant staff of the Ministry of Minerals, Energy and Water Resources and the Botswana Power Corporation. The Botswana Power Corporation has since initiated a gender mainstreaming programme for its rural electrification initiatives. A gender analysis of renewable energy in India was conducted in 2009. The analysis provided recommendations towards making national energy policies that focus on household energy more gender responsive (ENERGIA, 2009). In the case of Kenya, the gender audit identified a gender office in the Ministry of Energy, but the office lacked focused activities and results. The audit concluded that although there was political commitment to gender mainstreaming, gender was perceived only from a human resource perspective. In Mali, the Household Energy Universal Access Project had gender integrated after the project design stage, and has since established a formal gender focal point with specific duties within the dedicated Malian Agency for the Development of Household Energy and Rural Electrification. Multilateral development agencies are undertaking similar initiatives in an effort to maximise the impact of their energy access efforts within communities (ESMAP, 2013).

Conducting gender audits of government policies and programmes can lead to the adoption of more gender-sensitive energy activities and to the provision of appropriate policy frameworks, support services and other types of incentives to increase equal opportunity, as described below.

Government measures to enable women's participation in the renewable energy sector. There is growing recognition of the need for policies to create equal opportunity for women's participation in the economy as a whole. A resolution by the European Parliament on jobs in a sustainable economy calls on governments to "create work environments that attract and retain women, promote work-life balance through adequate, high-quality childcare and adaptable family-friendly workplace arrangements, create opportunities as well as conditions under which both men and women can participate in the labour market on equal terms, promote female participation in male-dominated representative bodies, reduce gender-based job segmentation and wage gaps" (European Parliament, 2010). This section describes some of the actions that governments can take to support gender equal opportunity in renewable energy employment.

Government action can create policy frameworks to encourage (or mandate) private sector action to promote the role of women and improve the gender balance in the renewable energy sector, ranging from training and recruiting women to ensuring equal pay, adequate labour standards and non-discriminatory workplace practices. Stevens (2010) argues that governments should mandate the industry to adopt family-friendly practices, including childcare, flexible work and extended leave, as well as strengthen enforcement of existing anti-discrimination laws.

Renewable energy companies could be encouraged to establish at least informal targets for the share of women among their employees, and perhaps specifically among their technical, engineering and management staffs (Stevens, 2010). The case for such an approach is strongest where government funding plays a critical role, such as in stimulus spending or public procurement in support of renewable energy, or where companies benefit from financial incentives. Additionally, governments can mainstream gender in policy measures that target the development of skills (as described in Section 4.2.1). This can include planning for skill needs for both women and men, attracting female students into the STEM education fields and renewable energy educational programmes, and financing renewable energy education and training for women.

Support services and other incentives to increase the opportunity for women's participation in the sector. The provision of appropriate support services and other types of incentives to increase gender equality in the renewable energy sector are similar to those in other industries, as they stem from comparable issues. These measures are sometimes derived from labour laws, resulting in significant differences among countries. Gender-specific support services are attracting increasing attention, and they include providing women with the adequate education and training to join the renewable energy workforce, as well as with access to finance to start up their own businesses. Other measures, such as gender certification of enterprises, are available to incentivise organisations to provide a suitable working environment for women in order to increase their participation in the workforce.

Access to education and training. Education and training are critical in advancing the deployment of RETs (see Chapter 4) and in achieving gender diversity in the renewable energy industry. Ensuring that women have access to adequate education and training opportunities is important for developing their skills and empowering them to seize employment opportunities in the sector.

Several ongoing efforts are encouraging greater participation of women in the STEM educational fields. Australia, Denmark, Mexico, Norway, South Africa, Sweden, the United Arab Emirates, the United Kingdom, and the United States are participating in a Clean Energy Education and Empowerment initiative to encourage women to seek careers in clean energy. Efforts include attracting women into STEM fields, connecting women with role models and mentors, and providing opportunities for scholarships, internships and academic and industry research (Clean Energy Ministerial, 2012).

Equally important for the participation of women in the renewable energy sector is the provision of adequate training or vocational apprenticeship programmes. This can be facilitated through government-funded financial assistance programmes that aim to meet targets for female participation. This might also be combined with other measures, including directed information campaigns in schools and universities for women to consider entering into careers that are key to the renewable energy sector. Funding for training that is targeted to assist women is still limited, however.

In the EU context, the European Social Fund (ESF) finances training projects in several areas, including renewable energy. But female participation in EFS-supported projects is less than 10%. The European Parliament (2010) has called for the introduction of gender budgeting in the ESF context to ensure that its programmes attract and integrate women and men equally. Similarly, the 2009 United States economic stimulus programme (ARRA) contained USD 500 million for workforce-training funds; however, only USD 5 million of that was earmarked for programmes to train women for non-traditional jobs (US DOL, n.d.; Lefton, Madrid and Sadiku, 2012).

Education and training in the context of energy access is important as well. The discussion on education and training in rural areas (see Chapter 5) is oriented more towards imparting hands-on, practical skills in order to build local capacities for production, installation and O&M of renewable energy systems, including managing these systems as entrepreneurs. The case of Solar Sister in sub-Saharan Africa (see Box 6.4) demonstrates the importance of training entrepreneurs in the use of renewable energy products, such as solar portable lamps, in order to address a perceived "technology gender gap". In India, the Barefoot College plays a similar role in providing hands-on solar installation training for mostly uneducated women in rural areas (see Box 6.5).

Although many training programmes now target women entrepreneurs, there is still much to accomplish. In most instances where skills training and local capacity building are implemented, the effort is inadvertently directed at men. Yet the evidence shows that providing women with the opportunity to receive the technical training they need in a specific area can foster opportunities for enterprise creation. In energy access settings, many argue that it is more beneficial

Box 6.5

INDIA'S BAREFOOT COLLEGE: ENABLING WOMEN SOLAR INSTALLERS

The Barefoot College has been providing solutions to problems in rural communities in India since 1972. A major component of their service is education and training of the rural poor, in addition to providing solar energy, clean water and a platform for debate on social issues such as gender bias, illiteracy, caste discrimination and feudal practices.

The college's approach is based on the belief that the existing knowledge, skills and wisdom in villages should be the first source of inspiration in any rural development activity. Modern technology, when utilised, should be under complete control of the rural population to avoid exploitation and ensure best results. This practical and time-tested approach has led to a programme that trains women, usually illiterate or semi-literate women and usually grandmothers, to become solar engineers. At present, the college trains some 100 Indian and 80 international solar engineers every year.

The conscious emphasis on training women is based on the practical insight that rural women (especially elderly women), compared to men, are less likely to leave their families for opportunities in urban areas and are more likely to implement the acquired skills and knowledge (Butler, 2013). In six months of hands-on training, women learn to fabricate, install and maintain solar lighting systems. Later, the trained solar engineers, also known as "Solar Grandmothers", use their skills to electrify villages and train other women to do the same. In Africa, some 140 women solar engineers trained by Barefoot College have supported the electrification of more than 9 100 houses (Roy, 2011).

to impart these skills to women than to men because women are often the primary users of lighting, cooking and other home-based technologies. Moreover, women are less likely to migrate to urban centres looking for work once skills are gained, thereby retaining the skills within rural communities (Hande, 2013).

One way to ensure greater involvement of women is to provide access to training environments where women feel comfortable to participate. Providing a safe environment can allow for increased self-confidence and a feeling of "team spirit", while also encouraging increased partnership and collaboration. Case studies from around the world illustrate the transformational impact that training can have on the success of projects that train women to become entrepreneurs (see Box 6.6).

Access to finance. Women generally do not have the same access to capital and resources as men, nor

Box 6.6

LEARNING FROM SUCCESSFUL TRAINING IN NEPAL AND GUATEMALA

In Nepal, a UNDP/World Bank RERL programme supporting the construction of community micro-hydro projects required that each participating household send a male and a female member to the respective gender-specific community organisations. This segregation was intended to provide a platform for women to discuss and speak freely about problems being faced. This had a tangible impact on the integration of women into mainstream activities, with a 75% increase in the number of women owning or employed by small-scale businesses from 1996 to 2005 (mostly in basket-making and knitting). As of 2012, 41% of all energy-based enterprises in RERL-supported communities were owned by female entrepreneurs (IRENA, 2012c).

Fundación Solar, while managing a PV project in Guatemala, found that it was mostly men who attended the training sessions on equipment maintenance, while the women quietly watched their husbands participate in the hands-on activities. As a result, when the PV system was in need of maintenance, such as battery charging or otherwise, and the husband was out of the home, women did not have the skills or the assurance needed to take action. Because this inevitably had a negative influence on the long-term success of the project, Fundación Solar then decided to train the women in the maintenance of the project while the men were out of the home, providing them with a relaxed learning environment (Wides, 1998).

do they typically have equal rights of inheritance and ownership (Stevens *et al.*, 2009). Reasons for women's limited access to finance include gender disparity, perception of risk, limited ability to place collateral due to ownership structures, social constructs and lack of awareness. This has far-reaching consequences for women's abilities to launch enterprises. Around the world, women entrepreneurs find it more difficult to access finance than male entrepreneurs; they are less likely to take loans, and in many cases the terms of borrowing can be less favourable (IFC, 2011).

With regard to energy-related activities, financing opportunities and frameworks are often different for women and men, with women relying more on informal lending networks and personal money management than formal banking structures (Alstone *et al.*, 2011). Studies in Africa, for example, indicate that women might need to wait longer or to pay bribes to secure finances (IFC, 2011). This is because collateral requirements may be difficult to meet when property is held in the name of men, and banks (which are usually farther away from the home) are less accessible to women. Women entrepreneurs in Kenya who venture into businesses in rural areas find it difficult to secure bank loans because of requirements of collaterals, given that less than 1% of women own property (Mwobobia, 2012).

India's Self-Employed Women's Association (SEWA), launched in 1972, provides an example of successful microfinance for women entrepreneurs. Under a project facilitated by SEWA bank and the energy company SELCO India, rural women belonging to two unelectrified villages in the Indian state of Bihar have become solar power entrepreneurs (Sharma, 2011). The project enabled a women's Self Help Group to buy customised solar home lighting systems and then distribute them to end-users under "hire-purchase agreements" to replace kerosene oil lanterns. These energy entrepreneurs are now using the lights in their own homes and are renting out systems to other families for INR 90 (USD 2) a month. To date, the project has covered more than 57 homes in two villages, and the track record for repayments is impressive (SELCO, 2013b). The low default rates have been due primarily to increasing productivity, income and savings from procuring kerosene fuel or mobile charging. Among the success factor for SEWA bank has been its strategic partnership with a strong energy company (SELCO India) that shares their organisational values and goals (SEEP, 2007). The bank also has created a separate portfolio for improved access to energy services among SEWA members, based primarily on solar and biogas (SEWA, n.d.). Box 6.7 highlights a case from Africa of experience from enabling micro-energy entrepreneurs to access finance.

Gender certification of enterprises, such as the Gender Equity Model (GEM) developed and tested in Mexico with World Bank support (see Box 6.8), is another proven tool for promoting gender equality in the private sector and encouraging women to join the labour force. Because the RET industry is expanding, adopting a gender certification programme could accelerate the rate at which the sector can attract the needed female and male talents and become a model for gender-equitable employment. Participation in gender certification programmes is voluntary, and a firm's commitment on gender-equality is based on a self-assessment of gender disparities in the company. The company then uses the assessment to implement an action plan to address the identified gender disparities. Usually, the diagnosis and the certification process are done through an independent agency.

Given the multiple benefits of greater gender diversity in the corporate world (as discussed in Section 6.3), companies in the renewable energy sector should actively seek to attract and retain more women throughout their organisational hierarchy. They should develop better work/life balance policies that combine flexible or reduced working hours with viable career paths for women. This is part of a broader need for more gender-sensitive approaches, including equal treatment of men and women in recruitment, equal opportunities for career advancement (including measures to break through the glass ceiling) and reduced workplace discrimination (such as gender pay gaps).

Beyond specific legislative mandates or public policy incentives, there is a need to change underlying workplace cultures and attitudes, so that women are understood as valued long-term employees. Different policies and perspectives are more likely to emerge to the degree that female perspectives are more strongly represented in renewable energy decision-making in both the private and public sectors.

Box 6.7

LEARNING FROM AFRICA AND INDIA ON FINANCE FOR MICRO-ENERGY ENTERPRISES

The DEEP EA initiative, launched in 2008 and concluded in February 2013, focused on providing the support necessary to enable the development of a widespread and sustainable industry of micro and small energy enterprises in Kenya, Uganda and Tanzania. Women entrepreneurs run more than 38% of DEEP EA-supported businesses, providing energy services based on a diverse set of RETs, including ICS, solar PV and biogas. Most of these enterprises are informal (non-registered) businesses, and owners have little formal education (usually less than secondary school level) and lack business and entrepreneurial know-how. They tend to work in isolation, characterised by sole proprietorship, low production capacity and unclear boundaries between personal and business finances (Rai and Clough, 2012).

To address this challenge, GVEP International developed the Loan Guarantee Fund to provide a guarantee to financial institutions for loans they make for the energy products and to businesses supported by the programme. To ensure long-term sustainability, GVEP provides a guarantee only for two loans per entrepreneur, after which the entrepreneurs are expected to be able to demonstrate their creditworthiness to the financial institution and borrow through normal means (GVEP, 2013). Key aspects that emerged from this experience of financing energy entrepreneurs include (GVEP, n.d.):

- Male entrepreneurs borrow twice as much as female entrepreneurs. This is primarily because the average loan size for women is smaller than men, possibly because the smaller scale of the businesses undertaken by female entrepreneurs (such as liner production for ICS and briquettes) require smaller amounts of credit than other technologies.
- Women tend to be more cautious in the size of loans requested. Although more female entrepreneurs are active in the area of briquette production, almost as many male briquette entrepreneurs borrowed as did women. For most women entrepreneurs, this is the first loan they have had from a formal financial institution.
- Women in the male-dominated solar technology sector borrowed more than men on average. The women, primarily from Uganda, who took these loans are involved in selling solar lanterns and providing phone-charging services; the men are involved mainly in providing charging services.

Box 6.8

GENDER CERTIFICATION OF ENTERPRISES IN MEXICO

Mexico's GEM Initiative, run by the National Institute for Women (Inmujeres), has been in place since 2003. As of December 2010, the initiative had certified some 300 Mexican organisations or companies as "gender equitable", and an average of 63 new participants adopt the programme each year. The initiative has benefitted an estimated 300 000 employees, with 55% from the private sector, 44% from the public sector and 1% from NGOs.

Results from the pilot study in Mexico found that:

- Participating firms have eliminated pregnancy discrimination from recruitment practices;
- 90% of participating firms reported an increase in workers' performance and productivity; and
- Participants reported a 50% reduction in gender gaps, as well as the increased promotion of women to managerial positions.

Participating firms also have taken measures to improve the work/life balance of men and women (including through flexible hours) and to engage families in the company's gender equity activities (World Bank, 2012b).

6.4 CONCLUSIONS

In both industrialised and emerging economies, greater gender equality in employment can increase the expansion and productivity of RETs, as well as advance development outcomes for the next generation. Women now represent 40% of the global labour force, 43% of the world's agricultural labour force and more than half of the world`s university students (Aguilar and Rogers, 2012). Global experience suggests that tapping into the skills of the female workforce in the modern and traditional renewable energy sectors will positively affect the productivity of the entire value chain. Small-scale renewable energy services potentially offer more opportunity for certain social co-benefits – such as increased employment, particularly for women – than grid-connected renewable energy applications (Aguilar and Rogers, 2012).

The business case for integrating gender in renewable energy employment is clear. To make it happen, three basic principles could be applied:

- Policy makers should ensure that related policy, legislation and regulation is gender sensitive, where relevant;
- All support systems for enterprise creation (access to assets, finance and training) should be made equally available for women and men to create and develop RET enterprises; and
- All institutions and organisations in the value chain, whether in the public or the private sector, should strive to tap the best available talents, both male and female, and ensure their most suitable engagement.

These principles are relevant for both industrialised and developing economies where opportunities for renewable energy employment exist. The starting point, however, is to build up good baselines with gender-disaggregated data on employment. This will help to move gender considerations away from being viewed as part of a political agenda, towards being an essential component of developing the industry and the effectiveness and efficiency of various programmes.

In the context of developing economies, despite the increasing prominence of gender issues in the renewable energy debate, the overall integration of the gender perspective into renewable energy policy design is yet to be fully realised. Gender mainstreaming can be done at different levels of policy, programme or project, as well as at the organisational level, to ensure that (a) the challenge of gender equality (and equity) becomes visible and (b) renewable energy creates equal opportunities for both men and women (FAO, 2006).

For any renewable energy employment policy to be a success, policy makers will need to take into account the different roles and responsibilities that men and women have within their communities and households. Better understanding these roles can help to better survey, design and plan for programmes and increase impact (AFREA, 2012). Not only will women have to become more empowered about making choices regarding their energy needs and solutions, but the renewable energy sector will have to be more responsive to women.

Increased education and training of women is needed to enhance their role in energy policy and planning as well as in industry and enterprises. Special training, fellowship and scholarship programmes are needed in various institutions and at universities to create a cadre of energy professionals, allowing women and men to have equal voices and competence (Parikh and Sharma, 2004).

Gender-sensitive entrepreneurship development is an area which requires a more systematic approach, not only for community-based projects, where many good practices already exist, but also for the modern renewable energy sector. More dissemination of information on the potential for renewable energy businesses through women's professional and business organisations is needed, as well as more-tailored training on business models and access to finance for this type of investment. As a means to develop gender equality, the renewable energy industry could partner with organisations that support women-led enterprises to succeed in local and global markets.

In conclusion, it is worth reiterating that tremendous opportunities exist to grow the renewable energy industry, in both the modern and traditional sectors, and that implementing gender equality in renewable energy employment can be a win-win solution for women and men, for the industry as a whole and for sustainable development.

7 Recommendations

This report estimates that 5.7 million people were employed in the renewable energy sector globally in 2012. It establishes the current status of gross employment in the sector in industrialised and developing countries, including direct and indirect jobs. It brings together suitable information from a wide range of sources and highlights key trends on jobs for each RET and in selected countries at various stages of renewable energy deployment.

The report also provides an overview of key methods that can be used to estimate the employment impacts of renewable energy deployment, noting the relative strengths and weaknesses of different approaches, as well as their underlying data requirements. The report examines the role played by key policies, including deployment, trade and investment, local content requirements and cluster formation. It offers additional insights into the importance of education and training in meeting the skills requirements of the sector. The report also offers dedicated chapters discussing the employment aspects of renewable energy deployment in the context of energy access, as well as the gender dimension.

This report represents an important milestone in bridging the knowledge gap in renewable energy employment data and analysis, and contributes to the larger understanding of the socio-economic benefits of renewable energy deployment. As such, it serves IRENA's mandate as a global reference point and voice to inform policy makers and increase public awareness with relevant analysis and information.

The report's key recommendations are as follows:

The importance of measuring employment from renewable energy

» Systematic data collection and thorough analysis to estimate employment at the country level is essential to inform policy-making, evaluate the effectiveness of deployment policies and communicate the results to the public at large. Among the various methods available to estimate employment in the renewable energy sector, each country should consider which best suits their needs and resources. To the extent possible, countries should also seek to harmonise methods and data reporting categories.

» The most useful data would distinguish between conventional and renewable energy employment (by technology and use) and direct and indirect employment; disaggregate among the main components of the renewable energy sector (feedstock operations, manufacturing, engineering, construction and installation, and operations and maintenance) and provide occupational details (*e.g.,* wages, gender, etc.).

Interactions between the different policy instruments in support of job creation

» National renewable energy policy choices need to be combined carefully with an eye towards a country's particular strengths and weaknesses. A key requirement is that policies provide a stable, predictable framework that anchors investor confidence and supports job creation in the sector.

» Efforts to maximise socio-economic impacts of renewable energy deployment, and job creation in particular, benefit from a tailored policy mix that entails coordination between deployment and other interacting policies, such as education, trade, regional development, industrial and labour.

Renewable energy skills, education and training: a key enabler

- Policy makers can facilitate the inclusion of renewable energy topics in existing and new educational programmes, and increase awareness of the career opportunities in renewable energy to attract young people entering the sector, as well as experienced workers from other industries with relevant skills.

- Governments can provide financial support for renewable energy education and training at universities or other suitable institutions, and foster international and interdisciplinary collaboration, such as the creation of interchangeable job and training specifications, harmonisation of curricula and development of common quality standards for training programmes and trainers.

- The private sector is well placed to provide relevant technical skills in a timely fashion through on-the-job apprenticeships and training programmes. Public and private sector actors should, therefore, collaborate in order to benefit from their respective strengths to most effectively meet the needs of the sector.

Off-grid solutions: catalysing local employment and economic growth

- Dedicated off-grid renewable energy policies are key to transforming rural economies. An integrated programmatic approach specifically targeting the sector should be promoted to ensure that timely expansion of energy access can generate economic growth and improve the livelihoods of millions of people.

- There is a need to develop a comprehensive framework to collect, analyse and disseminate the employment impacts of rural energy access initiatives. Data on rural renewable energy employment, both quantitative and qualitative, can be crucial in guiding policy-making towards adopting energy access approaches that maximise socio-economic development in rural areas.

Gender dimesions of renewable energy employment

- Removing barriers to entry for women's employment in the renewable energy sector is a win-win proposition, both to address the existing skills gap in a rapidly expanding renewable energy industry and to create equal opportunities for women.

- In order to maximise renewable energy co-benefits, particularly those related to energy access, household consumption and micro-enterprises, it is essential to include gender perspectives in policies and support services (*e.g.*, training, access to finance), and to provide other incentives to encourage employment of women in renewable energy.

References

ADDCN (Association of District Development Committees of Nepal) (2009), *Decentralised Rural Energy Development in Nepal*, Proceedings of two days National Conference, Kathmandu, Nepal, 22-23 January, Kathmandu, Nepal.

AFASE (Alliance for Affordable Solar Energy) (2013), Open Letter to EU (European Union) Commissioner De Gucht, 3 April, Brussels, *http://afase.org/sites/default/files/docs/media/afase_open_letter_signatories_130403.pdf*

AFD (Agence Francaise de Développement) and GERES (Groupe Energies Renouvelables, Environnement et Solidarités) (2009), "Dissemination of domestic efficient cookstoves in Cambodia", *www.cambodia.geres.eu/pages/download/2705801542680NLS_2009_REP_Dissemination_Domestic_Efficient_Cookstoves_in_Cambodia_EN.pdf*

AFREA (Africa Renewable Energy Access Programme) (2012), "Institutional Approaches to Electrification - The Experience of Rural Energy Agencies/Rural Energy Funds in Sub-Saharan Africa", *http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305-1327690230600/8397692-1327690360341/AEI_Dakar_Workshop_Proceedings_As_of_7-30-12.pdf*

Aguilar, L. and F. Rogers (2012), "Gender Review: Climate Investment Funds", IUCN (International Union for Conservation of Nature), *www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/Engendering%20Climate%20Finance.pdf*

Almeida, E.F. de, J.V. Bomtempo and C.M. de Souza e Silva (2007), *The Performance of Brazilian Biofuels: An Economic, Environmental and Social Analysis*, Joint Transport Research Centre Discussion Paper No. 2007-5, International Transport Forum, OECD (Organisation for Economic Co-operation and Development), Paris.

Alstone, P., *et al.* (2011), "Expanding Women's Role in Africa's Modern Off-Grid Lighting Market. Lighting Africa", Lighting Africa, IFC (International Finance Corporation) and the World Bank, *www.esmap.org/sites/esmap.org/files/gender_lighting_highres_LOW%20RES.pdf*

Altenburg, T. (2000), *Linkages and Spill-overs between Transnational Corporations and Small and Medium-Sized Enterprises in Developing Countries – Opportunities and Policies*, German Development Institute, Bonn.

APEC (Asia-Pacific Economic Cooperation) (2010), *A Study of Employment Opportunities from Biofuel Production in APEC Economies*, APEC, Singapore.

APPA (Asociación de Productores de Energía Renovables) (2012), "Estudio del Impacto Macroeconómico de las Energías Renovables en España" (Study of the Macroeconomic Impact of Renewable Energies in Spain), APPA, Madrid, *www.appa.es/descargas/Informe_2012_Web.pdf*.

ARE (Alliance for Rural Electrification) (2011), "Rural Electrification with Renewable Energy: Technologies, Quality Standards and Business Models", ARE, Brussels, *www.ruralelec.org/fileadmin/DATA/Documents/06_Publications/ARE_TECHNOLOGICAL_PUBLICATION.pdf*

ARGE Kompost & Biogas (2013), "Biogasmarkt im Umbruch. Europa wächst – deutscher Markt bricht ein" (Biogas market in transition. Europe is growing - a German market collapses), *www.kompost-biogas.info/index.php?option=com_content&task=view&id=902&Itemid=288*

Arora, D.S., *et al.* (2010), Indian Renewable Energy Status Report Background Report for DIREC 2010, NREL (National Renewable Energy Laboratory), Oak Ridge.

Arregui, G., *et al.* (2010), "Estudio sobre el empleo asociado al impulso de las energías renovables en España 2010" (Survey on employment associated with the promotion of renewable energies in Spain 2010), ISTAS, English summary at *www.istas.net/web/abreenlace.asp?idenlace=8769*

ASES (American Solar Energy Society) (2008), Defining, Estimating and Forecasting the Renewable Energy and Energy Efficiency Industries in the U.S. and in Colorado, December.

Ashden Awards (2009), "Prokaushali Sangsad Ltd. (PSL), Bangladesh", December, *www.ashden.org/files/PSL%20Bangladesh%20case%20study%20full.pdf.*

AWEA (American Wind Energy Association) (2012), *U.S. Wind Industry Annual Market Report 2011*, AWEA, Washington, DC.

AWEA (2013), "Congress Extends Wind Energy Tax Credits for Projects that Start in 2013," press release 1 January, AWEA, Washington, DC.

Baca, J. (2013), Private communication, 22 March, Director of Research, Solar Energy Industries Association, Washington, DC.

Bacon, R. and M. Kojima (2011), "Issues in Estimating the Employment Generated by Energy Sector Activities", World Bank, Washington, DC, *http://siteresources.worldbank.org/INTOGMC/Resources/Measuring_the_employment_impact_of_energy_sector.pdf*

Balbo, L. (2012), "Jordan Mandates Domestic Solar Water Heating," Green Prophet, 14 October, *www.greenprophet.com/2012/10/jordan-solar-water-heater-law/*

Barker, M. (2013), *WTO Delivers Blow to PV Domestic Content Proponents*, PV Magazine, 13 May.

Barnabas, A., D.J. Anbarasu and P.S. Clifford (2013), "A Study on the empowerment of women construction workers as masons in Tamil Nadu, India", *Journal of International Women's Studies*, Vol. 11, No. 2, pp. 121-141.

Barua, D. (2012), e-mail communication with author, 25 March, Bright Green Energy Foundation.

Barua, D. (2013), "Building Bangladesh the First Solar Nation", CleanTech Marketplace Forum, Singapore, *www.amiando.com/eventResources/M/k/LW5FwTeVyrCD7M/10_Sep_PM_-_BSREA_-_Singapore_September_2013.pdf*

Berkman, M., L. Cameron and J. Chang (2012), *The Employment Impacts of Proposed Tariffs on Chinese Manufactured Photovoltaic Cells and Modules*, report prepared for the Coalition for Affordable Solar Energy, The Brattle Group, Cambridge.

Beukering, P. van, *et al.*, (2007), *Optimization of the Charcoal Chain in Tanzania – A Gap Analysis*, Poverty Reduction and Environmental Management (PREM), Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Bezdek, R. (2007), *Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century*, American Solar Energy Society, Boulder.

Bhattarai, T.N. (1998), "Charcoal and its Socio-Economic Importance in Asia: Prospects for Promotion", Paper presented at Regional Training on Charcoal Production, which was held in Pontianak, Indonesia in February 1998, *www.fao.org/docrep/006/AD583E/AD583E00.HTM.*

Bhushan, C. (2013), "Who is the one not playing by the rules – India or the US?", Centre for Science and the Environment, *www.cseindia.org.*

Bimesdoerfer, K., C. Kantz and J.R. Siegel (2011), "Killing Two Birds with One Stone: Driving Green Jobs through Creating a Rural Renewable Energy Systems Industry", Paper presented at United Nations Research Institute for Social Development (UNRISD) conference *Green Economy and Sustainable Development: Bringing Back the Social Dimension*, UNRISD, Geneva.

Bivens, J. (2003), "Updated Employment multipliers for the US Economy" Economic Policy Institute Working Paper, *http://s4.epi.org/files/page/-/old/workingpapers/epi_wp_268.pdf*

Blackden C.M., and Q. Wodon (2006), "Gender, Time Use, and Poverty in Sub-Saharan Africa", World Bank working paper No. 73, *http://siteresources.worldbank.org/INTAFRREGTOPGENDER/Resources/gender_time_use_pov.pdf*

Blanco, M.I., and G. Rodrigues (2009), "Direct employment in the wind energy sector: An EU study", *Energy Policy* , Vol. 37, No. 8, pp. 2847-2857.

Blau, J. (2011), "Germany Faces a Shortage of Engineers", *http://spectrum.ieee.org/at-work/tech-careers/germany-faces-a-shortage-of-engineers*

Blodgett, L., and K. Slack (2009), "Geothermal 101: Basics of Geothermal Energy Production and Use", Geothermal Energy Association, *http://smu.edu/smunews/geothermal/Geo101_final_Feb_15.pdf*

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) (2006), Wirkungen des Ausbaus der Erneuerbaren Energien auf den Deutschen Arbeitsmarkt unter besonderer Berücksichtigung des Außenhandels, Teil 2, (Impacts of the expansion of renewable energy on the German labour market, with special consideration for foreign trade, Part 2), BMU, Berlin.

BMU (2012), "Bildungsmaterialien Grundschule: Erneuerbare Energien" (Renewable Energy Educational Materials), *www.bmu.de/service/publikationen/downloads/details/artikel/bmu-bildungsmaterialien-grundschule-3/*

BNDES (Banco Nacional de Desenvolvimento Economico e Social) (2012), "BNDES Improves Rules for Accreditation of Wind Turbines", *www.bndes.gov.br/SiteBNDES/bndes/bndes_en/Institucional/Press/Noticias/2012/20121212_geradores.html*

BNEF (Bloomberg New Energy Finance) (2011), "LEDS: The Energy Efficiency Game Changer, Bloomberg New Energy Finance Summit", BNEF, New York, *http://bnef.com/Presentations/download/63*

BNEF (2012), "Solar and Wind Sectors on Course to Employ 2m People Worldwide by 2020", Bloomberg New Energy Finance Research Note,5 March.

BNEF (2013a), Sustainable Energy in America 2013 Factbook, *www.bcse.org/factbook/pdfs/BCSE_BNEF_Sustainable_Energy_in_America_2013_Factbook.pdf*

BNEF (2013b), H2 2013 North America Wind Market Outlook, November, BNEF, New York.

Boudet, A.M.M., P. Petesch and C. Turk, (2013), "World Bank, 2013: On Norms and Agency. Conversations about Gender Equality with Women and Men in 20 Countries" the World Bank, Washington, DC, *http://siteresources.worldbank.org/EXTSOCIALDEVELOPMENT/Resources/244362-1164107274725/On-Norms-Agency-Book.pdf*

Bradsher, K. (2013), "Chinese Solar Panel Giant Is Tainted by Bankruptcy", 20 March, New York Times.

Breitschopf, B., C. Nathani and G. Resch (2011), "EID (Economic and Industrial Development)-EMPLOY: Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment", *www.isi.fraunhofer.de/isi-media/docs/x/de/publikationen/Assessment-approaches.pdf*

Breitschopf, B., C. Nathani, and G. Resch (2012), "EID-EMPLOY-Project: Methodological Guidelines for Estimating the Employment Impacts of using Renewable Energies for Electricity Generation", *www.isi.fraunhofer.de/isi-media/docs/x/de/publikationen/EMPLOY-Guidelines.pdf*

Butler, E. (2013), "Solar Mamas': Barefoot College Women Turn on the Lights in Off-grid Villages", Christian Science Monitor, *www.csmonitor.com/World/Making-a-difference/Change-Agent/2013/0124/Solar-Mamas-Barefoot-College-women-turn-on-the-lights-in-off-grid-villages*

Cabré, M.M. (2007), *Renewable electricity policies: an analysis of quotas, feed-in laws and a proposal for EU harmonization of feed-in laws*, Universitat Autónoma de Barcelona, Bareclona.

Caceres, R., J. Ramakrishna and K.R. Smith (1989), "Stoves for people". In Proceedings of the *Second International Workshop on Stoves Dissemination,* IT Publications, London.

Cardwell, D. (2012), *Solar Tariffs Upheld, but May Not Help in U.S.*, New York Times, 7 November.

Castano, I. (2010), "Spanish Renewables Grew 30% in 2010," Renewable Energy World, 15 December, *www.renewableenergyworld.com/rea/news/article/2010/12/spanish-renewables-grew-30-in-2010.*

CEM (Clean Energy Ministerial) (2012), "Capacity Development Needs Diagnostics for Renewable Energy (CADRE) - Volume 1: The Handbook", *www.irena.org/DocumentDownloads/Publications/Volume1_CaDRE_Handbook.pdf*

Chum, H., *et al.* (2011), "Bioenergy", in Edenhofer, O., *et al.* (eds.), *IPCC (Intergovernmental Panel Climate Change) Special Report on Renewable Energy Sources and Climate Change Mitigation*, Cambridge University Press, Cambridge and New York.

Clancy, J. (2011), "Integrating Gender Awareness into Energy Policies", ENERGIA, *www.energia.org/fileadmin/files/media/energianews/en122011_clancy.pdf*

Clancy, J.S., M. Skutsch, and S. Batchelor (2002), "The Gender-Energy-Poverty Nexus: Finding the energy to address gender concerns in development", *http://doc.utwente.nl/59061/1/Clancy99gender.pdf*

ClimateTechWiki (n.d.-a), "Biogas for cooking and electricity", *http://climatetechwiki.org/technology/biogas-cook*, accessed 9 December 2013.

ClimateTechWiki (n.d.-b), "Improved Cookstoves", *http:// climatetechwiki.org/technology/imcookstoves*, accessed 9 December 2013.

Corey, K.S. and B.G. Swezey (2007), *Renewable Portfolio Standards in the States: Balancing Goals and Implementation Strategies*, NREL (National Renewable Energy Laboratory), Golden.

Crespo, L. (2013), *The Spanish Success Case of STE (Solar Thermal Energy) Power Plants*, Workshop on Local Solar industry: Opportunities and Challenges, January, Skhirat, Morocco.

Dalton, M. (2013), *EU to Slap Tariffs on Chinese Solar Panels*, Wall Street Journal, 6 May.

Daniels, S. (2010), "Making Do: Innovation in Kenya's Informal Economy", *http://issuu.com/steveddaniels/docs/making-do*

Danielsen, K. (2012), "Gender equality, women's rights and access to energy services", Ministry of Foreign Affairs of Denmark, *www.gender-climate.org/Content/Docs/Publications/IUCN_GenderEqualityWomenRightsAccessEnergyServices.pdf*

David, A.S. and D. Fravel (2012), *U.S. Wind Turbine Export Opportunities in Canada and Latin America*, U.S. International Trade Commission, July, Washington, DC.

DBCCA (Deutsche Bank Climate Change Advisors) (2010), "GET FiT Program", Global Energy Transfer Feed-in Tariffs for Developing Countries, *www.dbadvisors.com/content/_media/GET_FIT_-_042610_FINAL.pdf*

Deloitte (2012), "The Million Jobs Question: Localisation for Renewables in Africa", Johannesburg, *http://deloitteblog.co.za.www102.cpt1.host-h.net/wp-content/uploads/2012/10/The-benefits-and-challenges-of-localising-renewable-energy-in-Africa.pdf*

Dhakal, N.R. (2008), "Public and Private Partnerships", Presentation at Financing Village Level Energy for Development in Asia Pacific conference, 9-11 April, *www.slideshare.net/nrdhakal/promoting-re-ts-thru-ppp-nr-dhakal-presentation*

Diemont M., R. Nowak and J. Van der Poel (2012), "Chapter 28: Renewable Energy", in: Webber Wentzel (Eds.), Investing in South Africa 2012/2013, pp. 642-650, Cape Town, *www.webberwentzel.com/wwb/action/media/downloadFile?media_fileid=7598*

Differ (2012), "A Rough Guide to Clean Cookstoves", Differgroup.com, Oslo, *www.cleancookstoves.org/resources_files/a-rough-guide-to-clean.pdf*

DLR (Deutsches Zentrum für Luft- und Raumfahrt) (2013), "A Solar Research and Test Centre for Morocco", 23 May, *www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-7107/year-all/#gallery/10409*, accessed 15 September 2013.

DTI (UK Department of Trade and Industry) (2004), "Renewable Supply Chain Gap Analysis", DTI (ed.), London.

Early, C. (2012), "South Africa: Investing in People to Make Wind Work", Wind Power Monthly, 23 August, *www.windpower-monthly.com/article/1147007/investing-people-wind-work*

EC (European Commission) (2009), "European Employment Observatory Review: The employment dimension of economy greening", EC, Brussels, *www.eu-employment-observatory.net/resources/reviews/EN-EEOReviewAutumn2009-OOPEC.pdf.*

EC (2012), "Exploiting the Employment Potential of Green Growth". Commission Staff Working Document, SWD(2012) 92 final. Strasbourg. 18 April, *http://eur- lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0031:FIN:EN:PDF.*

ECLAC (United Nations Economic Commission for Latin America and the Caribbean) and ILO (International Labour Organization) (2010), "The employment situation in Latin American and the Caribbean", *www.eclac.cl/publi-caciones/xml/5/42005/2010-995-ECLAC-ILO_Bulletin_4_WEB.pdf*

EDC (Energy Development Corporation) (2012), "Higher Peaks, New Horizons", 2011 Integrated Report, Manila, *www.energy.com.ph/wp-content/uploads/2012/05/2011-EDC-IR.pdf*

Eddy, M. and S. Reed (2013), "Germany's Effort at Clean Energy Proves Complex", The New York Times, *www.nytimes.com/2013/09/19/world/europe/germanys-effort-at-clean-energy-proves-complex.html?pagewanted=all&_r=0*

EIA (US Energy Information Administration) (n.d.), "International Energy Statistics", US EIA, *www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm*

Elbehri, A., A. Segerstedt and P. Liu (2013), "Biofuels and the Sustainability Challenge: A Global Assessment of Sustain-ability Issues, Trends and Policies for Biofuels and Related Feedstocks", FAO (Food and Agriculture Organization), Rome.

ENEOP (Eólicas de Portugal) (2012), *www.eneop.pt*, retrieved 10 December 2013.

ENERGIA (2008), "Gender audits of Botswana and Senegal", *www.hedon.info/docs/BP57_WrightEtAl.pdf*

ENERGIA (2009), "Biofuels for Sustainable Rural Development and Empowerment of Women: Cases Studies from Africa and Asia" ENERGIA, Leusden, the Netherlands, *www.theworkingcentre.org/sites/default/files/ENERGIA_Biofu-els_book_text_pages.pdf*

ENERGIA (n.d.), "Cambodia: Use of Jatropha Oil for Decentralized Rural Electrification", *www.energia.org/fileadmin/files/media/pubs/ENERGIA%20IUCN%20Biofuels%20Cambodia%20Case%20Study.pdf*

Energy Agency Barcelona (2013a), "UrbanSolPlus Project, Development Strategy Barcelona, fifth meeting", Ptuj (Slovenia), 13-14 June 2013, *www.urbansolplus.eu; www.urbansolplus.eu/pt/downloadsdocuments/cat_view/35-downloads/45-materials-from-project-meetings/47-project-meeting-in-ptuj-13-14-june-2013*

Energy Agency Barcelona (2013b), Seminar on solar energy in Barcelona, w*ww.solartermicabcn.cat/fileadmin/user_upload/PDF/03_Conclusions_Taules_treball.pdf*

ENF (Energy Focus) (2013), "Small Chinese Solar Manufacturers Decimated in 2012", 8 January, *www.enfsolar.com/news/Small-Chinese-Solar-Manufacturers-Decimated-in-2012*

ENOB (Energie Nord-Ost-Brandenburg) (n.d.), website at *www.energie-nord-ost-brandenburg.de/*, accessed 13 February, 2013.

EOI (Spanish School for Industrial Organisation) (n.d.), Master in Renewable Energy and the Energy Market web page, *www.eoi.es/portal/en/master-renovable-energy-market-madrid-programme-content*

EPIA (European Photovoltaic Industry Association) (2012), "Sustainability of Photovoltaic Systems. Job Creation", *www.epia.org/uploads/tx_epiafactsheets/Fact_Sheet_on_Job_Creation.pdf*

Ernst & Young (2012), *Renewable Energy Country Attractiveness Indices*, Issue 34, August.

ESHA (European Small Hydropower Association) (2011), "Stream Map" Database, *http://streammap.esha.be/26.0.html*

ESMAP (Energy Sector Management Assistance Program) (2007), "Improved Cookstoves to Conserve Biomass Resources", *www.esmap.org/node/1271*

ESMAP (2007), "Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies", Washington, DC, *http://siteresources.worldbank.org/EXTENERGY/Resources/336805-1157034157861/ElectrificationAssessmentRpt-SummaryFINAL17May07.pdf*

ESMAP (2011), "Improved Cookstoves to Conserve Biomass Resources", *www.esmap.org/node/1271*

ESMAP (2012), "Commercial Woodfuel Production", *www.esmap.org/sites/esmap.org/files/FINAL-CommercialWoodfuel-KS12-12_Optimized.pdf*

ESMAP (2013), "Integrating Gender Considerations into Energy Operations", *www.esmap.org/sites/esmap.org/files/ESMAP_Integrating_Gender_Into_Energy_Operations.pdf*

EU (European Union) (2013), "Office Journal of the European Union", *http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:209:0026:0032:EN:PDF*

EurObserv'ER (2010), *The State of Renewable Energies in Europe 2010*, Observatoire des Énergies Renouvelables, Paris.

EurObserv'ER (2011), *The State of Renewable Energies in Europe 2011*, Observatoire des Énergies Renouvelables, Paris.

EurObserv'ER (2012), *The State of Renewable Energies in Europe 2012*, Observatoire des Énergies Renouvelables, Paris.

EurObserv'ER (2013), *The State of Renewable Energies in Europe 2013*, Observatoire des Énergies Renouvelables, Paris.

European Parliament (2010), "Developing the job potential of a new sustainable economy", P7_TA(2010)0299, Official Journal of the European Union, *www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+REPORT+A7-2010-0234+0+DOC+PDF+V0//EN*

EWEA (European Wind Energy Association), FED (Forum for Energy and Development) and Greenpeace International (1999), "Wind Force 10: a Blueprint to Achieve 10% of the World's Electricity from Wind Power by 2020", EWEA, London, *www.inforse.dk/doc/Windforce10.pdf*

EWEA, Greenpeace International and GWEC (Global Wind Energy Council) (2005), "Wind Force 12: A Blueprint to Achieve 12% of the World's Electricity from Wind Power by 2020". EWEA, London and Greenpeace International, Amsterdam, June, *www.ewea.org/fileadmin/ewea_documents/documents/publications/WF12/wf12-2005.pdf*

FAO (Food Agricultural Organization) (2006), *Energy and Gender in Rural Sustainable Development*, FAO, Rome.

FAO (2011), *The State of Food and Agriculture in 2010-2011*, FAO, Rome.

fDi Intelligence (2013), "The fDi Report 2012", *www.fdiintelligence.com/Landing-Pages/fDi-Report-2012.*

Federal Glass Ceiling Commission (1995), "A Solid Investment: Making Full Use of the Nation's Human Capital" (Final Report of the Commission), US Government Printing Office, Washington, DC, *http://digitalcommons.ilr.cornell.edu/key_workplace/120/*

Foley, G. and P. Moss (1983), *Improved cooking stoves in developing countries*, Energy Information Programme, Earthscan, London.

Fornahl, D., *et al.* (2012), "From the Old Path of Shipbuilding onto the New Path of Offshore Wind Energy? The Case of Northern Germany". European Planning Studies, Vol. 20, No. 5, pp. 835-855.

Frankfurt School-UNEP Centre/BNEF (2013), "Global Trends in Renewable Energy Investment 2013", *www.unep.org/pdf/GTR-UNEP-FS-BNEF2.pdf.*

GACC (Global Alliance for Clean Cookstoves) (2013), "Cookstove Fuels", *www.cleancookstoves.org/our-work/the-solutions/cookstove-fuels.html*

Gamesa (2011), "Gamesa Starts Production of Wind Turbines in Brazil, the Launch Pad for Gamesa's Growth Strategy in Mercosur," 8 July, *www.gamesacorp.com/en/communication/news/*

GCN (Global Climate Network) (2010), "Creating Opportunity: Low-Carbon Jobs in an Interconnected World", Discussion Paper No. 3, *www.globalclimatenetwork.info/ecomm/files/creating_opportunity.pdf*

GERES (Groupe Energies Renouvelables, Environnement et Solidarités) (2010), "10 Years in Cambodia: The Success Story of Improved Stoves", GERES, Aubagne, *www.gvepinternational.org/sites/default/files/resources/GERES_-_10_years_in_Cambodia_-_The_success_story_of_improved_stoves.pdf*

GERES (2013), "2 million improved cookstoves distributed across Cambodia", *www.geres.eu/en/press-release/436-2-million-stoves-nls*

GERES (n.d.), "Dissemination of improved domestic cookstoves", *www.geres.eu/en/energy-efficiency/34-activ- nrjmenag-es-cambg-foyers*, accessed 7 December 2012.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) (German Society for International Cooperation) (n.d.), "China Biogas Sector. Political and Financial Supports", Sino-German Biogas Project for Optimisation of Biomass Utilisation | Biogas, *www.biogas-china.org*, accessed 28 March 2012.

GL Garrad Hassan (2012), *Assessment of Training and Skills Needs for the Wind Industry in South Africa*, Deutsche Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation) and SARETEC (South African Renewable Energy Technology Centre), Pretoria, pp. 86.

Gobierno de Navarra (Government of the Navarra autonomous community of Spain) (2011), "Renewable Energies in Navarra: Third Energy Plan, 2020 Horizon", *www.navarra.es/NR/rdonlyres/87FD0727-B234-4CB3-9403-B81C78D88895/269991/Renovables2020eng.pdf*

Gonzalez, B. (2013), *Weekly Intelligence Brief: 25 March – 1 April*, CSP Today, 2 April.

Greenpeace International and EPIA (European Photovoltaic Industry Association) (2006), "Solar Generation 3", Greenpeace International/EPIA, *www.greenpeace.org/international/Global/international/planet-2/report/2006/10/solargen3.pdf*

Greenpeace International and EPIA (2011), "Solar Generation 6", Greenpeace International/EPIA, *www.greenpeace.org/international/Global/international/publications/climate/2011/Final%20SolarGeneration%20VI%20full%20report%20lr.pdf*

Greenpeace International and EREC (European Renewable Energy Council) (2010), "Energy [R]evolution 2010", *www.greenpeace.org/international/Global/international/publications/climate/2010/fullreport.pdf*

Greenpeace International, GWEC (Global Wind Energy Council), and EREC (European Renewable Energy Council) (2012), "Energy [R]evolution 2012", *www.greenpeace.org/international/Global/international/publications/climate/2012/Energy%20Revolution%202012/ER2012.pdf*

Greenpeace Southeast Asia (2013), "Green is Gold: How Renewable Energy Can Save Us Money and Generate Jobs", Quezon City, Philippines, *http://issuu.com/gpsea/docs/green-is-gold-how-renewable-energy*

GVEP (Global Village Energy Partnership) (2012a), "Kenya Market Assessment: Sector Mapping", *www.cleancookstoves.org/resources_files/kenya-market-assessment-mapping.pdf*

GVEP (2012b), "The Improved Cookstove Sector in East Africa: Experience from the Developing Energy Enterprise Programme (DEEP)", *www.gvepinternational.org/sites/default/files/deep_cookstoves_report_lq_for_web.pdf*

GVEP (2013), "Final Report: Terminal Evaluation of the Developing Energy Enterprises Project in East Africa", *www.gvepinternational.org/sites/default/files/final_report_deep_terminal_evaluation.pdf*

GVEP. (n.d.), "GVEP's experience with working with women entrepreneurs in East Africa", *www.gvepinternational.org/sites/default/files/gveps_experince_with_working_with_women.pdf*, accessed March, 2012.

GWEC (Global Wind Energy Council) (2013), "Global Wind Report: Annual market Update 2012", GWEC, Brussels, *www.gwec.net/wp-content/uploads/2012/06/Annual_report_2012_LowRes.pdf*

GWEC (n.d.), "Wind in Numbers", GWEC, www.gwec.net/global-figures/wind-in-numbers/, accessed December 2013

GWEC and Greenpeace International (2010), "Global Wind Energy Outlook 2010", *www.gwec.net/publications/global-wind-energy-outlook/3543-2/*

GWEC and Greenpeace International (2012), "Global Wind Energy Outlook 2012", *www.gwec.net/publications/global-wind-energy-outlook/global-wind-energy-outlook-2012/*

Hankins, M., A. Saini, and P. Kirai (2009), "Target Market Analysis: Tanzania's Solar Energy Market", *www.gtz. de/de/dokumente/gtz2010-en-targetmarketanalysis-solar- tanzania.pdf*

Hande, H. (2013), interviewed by IRENA on 24th June 2013.

Hanni, M.S., *et al.* (2011), "Foreign Direct Investment in Renewable Energy: Trends, Drivers and Determinants", *Transnational Corporations,* Vol. 20, No. 2, pp. 156, August.

Hao, M., *et al.* (2010), "Local Content Requirements in British Columbia's Wind Power Industry. Faculty of Business - Pacific Institute for Climate Solutions", University of Victoria, *http://pics.uvic.ca/sites/default/files/uploads/publications/WP_Local_Content_Requirements_December2010.pdf*

Haque, N. (2012), "IDCOL Solar Home System Program in Bangladesh," International Off-Grid Renewable Energy Conference, Accra, Ghana, 1-2 November 2012, *http://iorec.org/pdf/1_Session%203.pdf.*

Hegewisch, A., *et al.* (2013), "Quality Employment for Women in the Green Economy: Industry, Occupation, and State-by-State Estimates", *Institute for Women's Policy Research*, Washington, DC.

Hülsen, I. (2012), "German Shipyards See Future in Wind Power." Spiegel Online, 30 August, *www.spiegel.de/international/business/german-shipyards-see-future-in-wind-power-a-850368.html*

Hydro-Québec (2013), Senior Management and the Board of Directors, *www.hydroquebec.com/about-hydro-quebec/who-are-we/corporate-governance/senior-management-board-directors.html.*

IAR (Industries and Agro-Resources) (2010), "Non-Food Uses of Biomass," Presentation, *www.iea-bioenergy.task42-biorefineries.com/*

IAR (2012), website, *www.iar-pole.com.*

ICLEI (International Council for Local Environmental Initiatives) and IRENA (International Renewable Energy Agency) (2012), "Dezhou, China: Green Economic Development with Renewable Energy Industries", *www.irena.org/Publications/RE_Policy_Cities_CaseStudies/IRENA%20cities%20case%201%20Dezhou.pdf*

ICTSD (International Centre for Trade and Sustainable Development) (2013), "WTO Appellate Body Rules against Canada in Renewable Energy Case", 8 May, *http://ictsd.org/i/news/bridgesweekly/163192/*

IDCOL (Infrastructure Development Company Limited) (2013a), "IDCOL's Renewable Energy Initiatives", *www.energyforall.info/wp-content/uploads/2013/04/IDCOL.pdf*

IDCOL (2013b), "IDCOL Solar Home System Program", *http://sustainabledevelopment.un.org/content/documents/4923haque.pdf*

IDCOL (2012), "Effective and innovative business model: What viability for privately led initiatives?, IDCOL Solar Home System Program in Bangladesh, *www.iorec.org/pdf/1_Session%203.pdf*

IDCOL (n.d.), "Renewable Energy Projects", *www.idcol.org/energyProject.ph*p, accessed September 2013.

IEA (International Energy Agency) (2011), "Energy for All: Financing Access for the Poor", *A Special early excerpt of the World Energy Outlook 2011*, IEA, Paris, pp. 52.

IEA (2013a), *Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries between 1992 and 2012*, IEA, Paris

IEA (2013b), "World Energy Outlook 2013", *www.worldenergyoutlook.org/media/weowebsite/energydevelopment/WEO2013_EnergyForAll.pdf*

IEA (n.d.), "RD&D Statistics Database", *http://wds.iea.org/wds/default.aspx.*

IEA and IRENA (n.d.), "IEA/IRENA Joint Policies and Measures databse", *www.iea.org/policiesandmeasures/renewableenergy/*, accessed 12 December 2013.

IEA-RETD (Renewable Energy Technology Deployment), Factor CO_2 Ennova (2010), "REEDUCATION A Scoping Study into Renewables and Education", IEA-RETD, Utrecht, *http://iea-retd.org/archives/publications/re-education*

IEA-RETD (2012), "Securing the supply chain for renewable energy (RE-SUPPLY)", IEA-RETD, Utrecht, *http://iea-retd.org/archives/publications/re-supply*

IEE (intelligent Energy Europe) (n.d.), "About BUILD UP Skills," *www.buildupskills.eu/en/about*, accessed 1 October, 2013.

IFC (International Finance Corporation) (2010a), "Environmental, Economic and Social Impacts of Oil Palm in Indonesia: A Synthesis of Opportunities and Challenges," Discussion Paper, May, *www.ifc.org/ifcext/agriconsultation.nsf/AttachmentsByTitle/WB+discussion+paper/$FILE/WB_Oil+Palm+SynthesisDiscussionPaperMay2010.pdf*

IFC (2010b), "Solar Lighting for the Base of the Pyramid: Overview of an Emerging Market", *www.ifc.org/wps/wcm/connect/a68a120048fd175eb8dcbc849537832d/SolarLightingBasePyramid.pdf?MOD=AJPERES*

IFC (2011), "Strengthening Access to Finance for Women-owned SMEs in Developing Countries", *www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/publications/publications_report_accesstofinanceforwomensmes*

IFC (2012), "Lighting Asia: Solar Off-grid Lighting", *www1.ifc.org/wps/wcm/connect/311790804b5ca8d783fbc3bbd57889 1b/Lighting-Asia-offgrid-lighting-Report072512.pdf?MOD=AJPERES*

IGA (International Geothermal Association) (2012), *IGA News*, No. 87 (January-March).

Ilahi N. (2000), "The Intra-household Allocation of Time and Tasks: What Have We Learnt from the Empirical Literature?", World Bank, Washington, DC, *http://siteresources.worldbank.org/INTGENDER/Resources/wp13.pdf*

ILO (International Labour Organization) (2008), "Global Employment Trends for Women 2008", ILO, Geneva, *www.ilo.org/wcmsp5/groups/public/—dgreports/—dcomm/documents/publication/wcms_091225.pdf*

ILO (2010), *Study on Low Carbon Development and Green Jobs in China*, ILO office for China and Mongolia, Beijing.

ILO (2011a), "Skills for Green Jobs: a Global View, Synthesis Report Based on 21 Country Studies", ILO, Geneva, *www.ilo.org/wcmsp5/groups/public/—ed_emp/—ifp_skills/documents/publication/wcms_156220.pdf*

ILO (2011b), "Skills and Occupational Needs in Renewable Energy", ILO, Geneva, *www.ilo.org/wcmsp5/groups/public/@ed_emp/@ifp_skills/documents/publication/wcms_166823.pdf*

ILO (2011c), "Comparative Analysis of Methods of Identification of Skill Needs on the Labour Market in Transition to the Low Carbon Economy", ILO, Geneva, *www.ilo.org/wcmsp5/groups/public/—ed_emp/—ifp_skills/documents/publication/wcms_166824.pdf.*

ILO (2012a), "Overview of apprenticeship systems and issues", ILO contribution to the G20 Task Force on Employment, ILO, Geneva, *www.ilo.org/wcmsp5/groups/public/—ed_emp/—ifp_skills/documents/genericdocument/wcms_190188.pdf*

ILO (2012b), International Standard Classification of Occupations, ISCO-08, Geneva, *www.ilo.org/wcmsp5/groups/public/—dgreports/—dcomm/—publ/documents/publication/wcms_172572.pdf*

ILS (Institute for Labor Studies) and MOHRSS (Ministry of Human Resources and Social Security, China) (2010), *Study on Green Employment in China*, ILO Office for China and Mongolia, Beijing.

IRENA (International Renewable Energy Agency) (2011), *Renewable Energy Jobs: Status, Prospects and Policies*, IRENA, Abu Dhabi.

IRENA (2012a), "Renewable Energy Technologies: Cost Analysis Series- Hydropower", *www.irena.org/DocumentDownloads/Publications/RE_Technologies_Cost_Analysis-HYDROPOWER.pdf*

IRENA (2012b), *Capacity Building Strategic Framework for IRENA (2012-2015)*, IRENA, Abu Dhabi.

IRENA (2012c), "Renewable Energy Jobs & Access", *www.irena.org/DocumentDownloads/Publications/Renewable_Energy_Jobs_and_Access.pdf*

IRENA (2013a), "Renewable Energy Auctions in Developing Countries", *www.irena.org/DocumentDownloads/Publications/IRENA_Renewable_energy_auctions_in_developing_countries.pdf*

IRENA (2013b), "IOREC 2012: Key Findings and Recommendations", *www.irena.org/DocumentDownloads/Publications/IOREC_Key%20Findings%20and%20Recommendations.pdf*

IRENA (2014a), "REmap 2030: A Renewable Energy Roadmap. Doubling the Share of Renewable Energy and Strengthening Global Sustainability", forthcoming.

IRENA (2014b), *India Case Study, IRENA econValue project*, forthcoming.

IRENA (2014c), *South Africa Case Study*, IRENA econValue project, forthcoming.

IRENA (2014d), *Malaysia Case Study*, IRENA econValue project, forthcoming.

IRENA and CEM (Clean Energy Ministerial) (2014), "econValue", *http://www.irena.org/ireValue* , forthcoming.

IUES (Institute for Urban and Environmental Studies) and CASS (Chinese Academy of Social Sciences) (2010), "Study on Low Carbon Development and Green Employment in China", ILO Office for China and Mongolia, Beijing.

Jennejohn (2010), "Green jobs through geothermal energy", Geothermal Energy Association, *www.geo-energy.org/pdf/reports/GreenJobs_Through_Geothermal_Energy_Final_Oct2010.pdf*

Jennejohn, D., *et al.* (2012), *Geothermal: International Market Overview Report*, Geothermal Energy Association, Washington, DC.

Joy, L., *et al.* (2007), "The bottom line: Corporate performance and women's representation on boards", Catalyst, New York.

Junfeng, L. (2007), Deputy Director General of the Energy Research Institute of the National Development and Reform Commission in Beijing, and General Secretary of the Chinese Renewable Energy Industries Association (CREIA), *personal communication with Yingling Liu*, Worldwatch Institute, 12 November.

Kammen, D. (2011), "Biofuels: Threat or opportunity for women?" *http://blogs.worldbank.org/climatechange/biofuels-threat-or-opportunity-women*

Kimmel, M. (2011), "Italy's Make-or-Break Chance to Fix Its PV Feed-In Tariff", ReVolt blog, 25 March, *http://blogs.worldwatch.org/revolt/italys-make-or-break-chance-to-fix-its-pv-feed-in-tariff/*.

Kirkegaard, J.F., T. Hanemann and L. Weischer (2009), *It Should Be a Breeze: Harnessing the Potential of Open Trade and Investment Flows in the Wind Energy Industry*, World Resources Institute, Working Paper 09-14, December 2009, Washington, DC.

Ki-Zerbo, J. (1980), *Improved Woodstoves: Users' Needs and Expectations in Upper Volta*, Volunteers in Technical Assistance Incorporated, Washington, DC.

KPMG International (2012), "Taxes and Incentives for Renewable Energy", *www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Documents/taxes-incentives-renewable-energy-2012.pdf*

Kumar, A., *et al.* (2011), "Hydropower", in: Edenhofer, O., *et al.* (eds), *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, Cambridge University Press, Cambridge and New York.

Kuntze, J.C. and T. Moerenhout (2013), *Local Content Requirements and the Renewable Energy industry - A Good Match*?, International Centre for Trade and Sustainable Development, Geneva, Switzerland.

Lallement D. (2013), "Infrastructure and Gender Equity", In Figart and Warnecke, (eds.), Handbook of Research on Gender and Economic Life, Edward Elgar Publishing Limited, Chapter 9, pp. 133, *www.elgaronline.com/abstract/9780857930941.00019.xml*

Lanaro, A., (2010), "Are Green Jobs Pink Jobs? The Role of Social Dialogue", Presentation, ENEL Green Power, ADAPT, Rome, *http://www.bollettinoadapt.it/site/home/bollettino-adapt/speciale/26-october-2010-n-35/documento9145.html*

Lefton, R., J. Madrid and L. Sadiku (2012), "Gender Equality In Green Jobs: A Promising New Sector Must Ensure Pay Equality," Think Progress blog, 17 April, *http://thinkprogress.org/climate/2012/04/17/465657/gender-equality-in-green-jobs-new-sector-pay-equality/*

Lehr, U., *et al.* (2008), "Renewable energy and employment in Germany", *Energy Policy*, Vol. 36, No. 1, pp. 108–117, doi:10.1016/j.enpol.2007.09.004

Lehr, U., *et al.* (2011), "Kurz- und langfristige Auswirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt" (Short- and Long-term Impacts of RET Deployment on the German Job Market), GWS, DIW, Fh-ISI, ZSW, *www.erneuerbare-energien.de/fileadmin/ee-import/files/pdfs/allgemein/application/pdf/ee_arbeitsmarkt_bf.pdf*

Lehr, U., *et al.* (2012), "Renewable energy and energy efficiency in Tunisia – employment, qualification and economic effects", GIZ, Tunis,Project Promotion of renewable energy and energy efficiency in Tunisia, *www.giz.de/expertise/downloads/giz2012-en-employment-renewable-energy-tunisia.pdf*

Lehr, U., C. Lutz and D. Edler (2012), "Green jobs? Economic impacts of renewable energy in Germany", *Energy Policy*, Vol. 47, pp. 358-364

LEI (London Economics International) (2012), "Maine RPS Summary", *http://renewablemaine.org/pdfs/LEI%20Study%20–%20Summary%20by%20MREA.pdf*

Lema, R., *et al.* (2011), "Competition and Cooperation between Europe and China in the Wind Power Sector", *IDS (Institute of Development Studies) Working Paper 377*, IDS, Brighton.

Leventhal M. and S. Tegen (2013), "A National Skills Assessment of the U.S. Wind Industry in 2012", NREL, Golden, *www.nrel.gov/docs/fy13osti/57512.pdf*

Lewis J.J. and S.K. Pattanayak (2012), "Who Adopts Improved Fuels and Cookstoves?" A Systematic Review, *http://ehp.niehs.nih.gov/wp-content/uploads/120/5/ehp.1104194.pdf*

Lighting Africa (2010), "Solar Lighting for the Base of the Pyramid- Overview of an Emerging Market", pp. 80, *www.ifc.org/wps/wcm/connect/a68a120048fd175eb8dcbc849537832d/SolarLightingBasePyramid.pdf?MOD=AJPERES*

Lower Saxony Network for Renewable Resources (n.d.), "Centre for Experts", *www.rapido-fp6.eu/download/3n_rottmann_meyer_de.pdf*, accessed September 2012.

Lucey, K. (2013), Solar Sister, interviewed by IRENA on 22nd January 2013.

Lund, J.W., D.H. Freeston and T.L. Boyd (2010), "Direct Utilization of Geothermal Energy 2010 Worldwide Review", *Proceedings of the World Geothermal Congress 2010*, 25-29 April, Bali, Indonesia.

Mahmud, A. (2012), "Graduate Studies Spur Success in Engineering", https://www.asme.org/career-education/articles/graduate-students/graduate-studies-spur-success-in-engineering.

Maia, J., *et al.* (2011), "Green Jobs: An Estimate of the Direct Employment Potential of a Greening South African Economy", Industrial Development Corporation, Development Bank of South Arica, and Trade and Industrial Policy Strategies, *www.idc.co.za/projects/Greenjobs.pdf*

Manibog, F. R. (1984), "Improved cooking stoves in developing countries: problems and opportunities", *Annual Review of Energy*, World Bank, Washington DC, Vol. 9, No. 1, pp. 199-227.

Martinez-Fernandez, C., C. Hinojosa, and G. Miranda (2010), "Greening Jobs and Skills Labour Market Implications of Addressing Climate Change", OECD, Paris, *www.oecd.org/cfe/leedprogrammelocaleconomicandemploymentdevelopment/45484420.pdf.*

MASDAR (n.d.), *www.masdar.ac.ae/index.php*, accessed December 2013.

Matek, B. (2013a), "2013 Geothermal Power: International Market Overview", *http://geo-energy.org/events/2013%20International%20Report%20Final.pdf*

Materk, B. (2013b), Personal communication with Benjamin Mate, US Geothermal Energy Association, March 7 2013.

McElhaney, K.A., and S. Mobasseri, (2012), *Women Create a Sustainable Future Centre for Responsible Business*, University of California, Berkeley.

Mehta S. (2013), "GTM Research: Yingli Gains Crown as Top Producer in a 36 GW Global PV Market", *www.greentechmedia.com/articles/read/Yingli-Gains-Crown-As-Top-Producer-in-a-36-GW-Global-PV-Market*

Metropolregion Mitteldeutschland (2011), Wisenschaftsatlas, Dresden, Germany, September, *www.leipzig.de/imperia/md/content/80_wirtschaftsfoerderung/03_downloads/wissenschaftsatlas_metropolregion_mitteldeutschland.pdf.*

Ministerio de Industria, Energía y Turismo (Ministry of Industry, Energy and Tourism of Spain) and Instituto para la Diversificación y Ahorro de la Energía (Institute for Diversification and Saving of Energy) (2010), "Plan de Acción Nacional de Energías Renovables 2011-2020 (PANER)" (National Action Plan for Renewable Energy 2011-2020), *www.minetur.gob.es/energia/desarrollo/EnergiaRenovable/Documents/20100630_PANER_Espanaversion_final.pdf*

MNRE (Ministry of New and Renewable Energy) (2013). "Achievements", *http://mnre.gov.in/mission-and-vision-2/achievements/*

MNRE and CII (Confederation of Indian Industry) (2010), *Human Resource Development Strategies for Indian Renewable Energy Sector,* New Delhi.

Mondal, A.H., Z. Iqbal and S. Mehedi (2010), *Skills for Green Jobs in Bangladesh,* (Unedited Background Country Study), ILO, Geneva.

Moraes, M.A.F.D. (2012), "Bioenergy: Social Welfare and Development," Grupo de Extensão em Mercado de Trabalho (Extension Group on Labour Market), Escola Superior de Agricultura "Luiz de Queiroz", University of Sao Paulo, presentation at Workshop - ESALQ & PIK: *The Future of Sugarcane Sector – Potentials, Limits and Perspectives*, Piracicaba, Brazil, 30 November.

MOSPI (Ministry of Statistics and Programme Implementation) (2013), *"Energy Statistics 2013",* Central Statistics Office, India, http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2013.pdf?status=1&menu_id=216.

MTE/RAIS (Ministério do Trabalho Emprego (Ministry of Labor and Employment)/Relação Anual de Informações Sociais (Annual Report of Social Information) (2012), "Annual List of Social Information" Database: including active and inactive employments for sugarcane cultivation and alcohol manufacture", accessed December, 2012.

Musolino, E. (2013), "Hydropower and Geothermal Growth Slows", Worldwatch Institute, *http://vitalsigns.worldwatch.org/vs-trend/hydropower-and-geothermal-growth-slows*

Mwobobia, F.M. (2012), *The Challenges Facing Small-Scale Women Entrepreneurs: A Case of Kenya,* Limkokwing University of Creative Technology. Botswana, Gaborone-Botswana

NREL (National Renewable Energy Laboratory) (2010), "Jobs and Economic Development Model (JEDI) - Photovoltaics", *https://jedi.nrel.gov/*

NREL (2012), "Concentrating Solar Power Projects: La Florida", Project information page, status dated 14 August, 2012, *www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=27*, accessed 10 October, 2013.

NREL (2013), "Concentrating Solar Power Projects: La Risca (Alvarado 1), Project Information Page, status dated 20March, 2013, *www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=5*, accessed 10 October, 2013

Navigant Consulting (2009), "Job Creation Opportunities in Hydropower", Final Report presented to National Hydropower Association, 20 September, 2009, *www.hydro.org/wp-content/uploads/2010/12/NHA_JobsStudy_FinalReport.pdf*

Navigant Consulting (2011), *Impact of the Production Tax Credit on the U.S. Wind Market.* Report prepared 11 December for the American Wind Energy Association, Washington, DC.

Navigant Research (2013), "World Market Update 2012: International Wind Energy Development, Forecast 2013-2017", *www.navigantresearch.com/wp-assets/uploads/2013/03/WWMU-13-Executive-Summary.pdf*

Neves, M.F., V.G. Trombin and M.A. Consoli (2010), "Measurement of Sugar Cane Chain in Brazil," *International Food and Agribusiness Management Review*, Vol. 13, No. 3, pp. 37-54.

Nicola, S. and G. Sulugiuc (2013), "China Solars Move Factories Overseas to Avoid EU Duties", Bloomberg News, 24 June, *www.bloomberg.com/news/2013-06-23/china-solars-move-factories-overseas-to-avoid-eu-duties.html*

Nicola, S. (2012), "China Price War Draining Jobs in Germany's Solar Valley: Energy", Bloomberg News, 7 September., *www.bloomberg.com/news/2012-09-06/china-price-war-draining-jobs-in-germany-s-solar-valley-energy.html*

Nielsen, S. (2012a), "BNDES Shuts $3.5 Billion Wind Market to Five Companies," Business Week, 20 July, *www.businessweek.com/news/2012-07-19/bndes-shuts-3-dot-5-billion-wind-market-to-five-companies,*

Nielsen, S. (2012b), "Local Content Rule Thwarts Solar Development in Brazil," Renewable Energy World, 9 August, *www.renewableenergyworld.com/rea/news/article/2012/08/local-content-rule-thwarts-solar-development-in-brazil*

Nieuwenhout, F.D.J., et al., (2002), "Monitoring and evaluation of solar home systems: experiences with applications of solar PV for households in developing countries". ECN-C–00-089.

Niez, A. (2010), *Comparative Study on Rural Electrification Policies in Emerging Economies. Keys to Successful Policies*, IEA, Paris.

NSSC (North Sea Supply Connect) (2012), "Energy Industries," Baltic Sea Region Programme 2007-2013, *www.northsea-supplyconnect.eu/images/uploads/Cluster_organization_information_Energy_June_2012_1.pdf*

NYSERDA (New York State Energy Research and Development Authority) (n.d.), Main web page *www.nyserda.ny.gov/About.aspx*

Obidzinski, K. *et al.* (2012), "Environmental and Social Impacts of Oil Palm Plantations and their Implications for Biofuel Production in Indonesia," *Ecology and Society*, Vol. 17, No. 1, pp. 25.

OCO Global (2012), "FDI in Renewable Energy: A Promising Decade Ahead", OCO Global Ltd., London, *www.ocoglobal.com/uploads/default/files//FDI_in_Renewable_Energy_-_A_promising_decade_ahead.pdf*

OEC (Oekoenergie-Cluster) (2013), "Das Netzwerk der Ökoenergieund Energieeffi zienz-Unternehmen in Oberösterreich" (Upper Austria`s Network of Green Energy and Energy Efficiency Businesses), *www.esv.or.at/english/oekoenergie-cluster/*

OECD (Organisation for Economic Co-operation and Development) (2012), *"Linking Renewable Energy to Rural Development"*, October, Paris.

OECD (2013), "Jobs and wages", in OECD Factbook 2013: Economic, Environmental and Social Statistics, OECD, Paris, *http://dx.doi.org/10.1787/factbook-2013-106-en*

Ondraczek, J. (2012), *The Sun Rises in the East (of Africa): A Comparison of the Development and Status of the Solar Energy Markets in Kenya and Tanzania*, Hamburg University, Working Paper FNU-197.

Ontario Clean Technology Alliance (2012), "Ontario's Feed-in Tariff Program Two-Year Review Report", *www.ontario-cleantechalliance.com/storage/FIT-Review-Report1.pdf*

Openshaw, K. (2010), "Biomass Energy: Employment Generation and its Contribution to Poverty Alleviation", *Biomass and Bioenergy*, Vol. 34, pp. 365-378.

O'Sullivan, M., *et al.* (2011), *Gross Employment from Renewable Energy in Germany in 2010*, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

O'Sullivan, M., *et al.* (2012), *Gross Employment from Renewable Energy in Germany in 2011*, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

O'Sullivan, M. *et al.* (2013), *Gross Employment from Renewable Energy in Germany in 2012*, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Berlin.

Oxford Dictionaries (n.d.), *http://oxforddictionaries.com*, accessed June 2013.

Pariente-David, S. (2011), "Promoting Clean Tech Manufacturing: Case of Concentrated Solar Power (CSP) in the MENA Region", Presentation at Climate Investment Funds Partnership Forum 2011, *www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/The%20Case%20of%20Concentrated%20Solar%20Power%20(CSP)%20in%20the%20MENA%20Region.pdf.*

Parikh J. and S. Sharma (2004), "Mainstreaming Gender in Energy Policy". *http://siteresources.worldbank.org/INTGENDER/Resources/336003-1289616249857/MainstreamingGender_into_EnergyPolicyIndia.pdf*

PCI (Project Concern International) (n.d.), "Women's Empowerment and Poverty", *www.pciglobal.org/womens-empowerment-poverty/*

Peszko, G. and J. Ketterer (2012), "Local Content Requirements for Renewable Energy: An Unnecessary Evil," EBRD Blog, 23 November, *www.ebrdblog.com/wordpress/2012/11/local-content-requirements-for-renewable-energy-an-unnecessary-evil/.*

Pew Charitable Trusts (2013), "Advantage America: The U.S.-China Clean Energy Technology Trade Relationship in 2011", Pew Charitable Trusts, Philadelphia and Washington, DC, *www.pewenvironment.org/uploadedFiles/PEG/Publications/Report/US-China-Report-FINAL.pdf*

Philippines Department of Energy (2013), "Renewable Energy Outlook of the Philippines", *www.egnret.ewg.apec.org/meetings/egnret41/[E07]%20Philippines%20EGNRET41.Phil.Country%20Report.pdf*

Platzer, M.D. (2012a), "U.S. Solar Photovoltaic Manufacturing: Industry Trends, Global Competition, Federal Support", CRS (Congressional Research Service) Report for Congress R42509, Washington, DC, 13 June, *www.fas.org/sgp/crs/misc/R42509.pdf*

Platzer, M.D. (2012b), "U.S. Wind Turbine Manufacturing: Federal Support for an Emerging Industry", CSR Report for Congress R42023, Washington, DC, 18 December, *www.fas.org/sgp/crs/misc/R42023.pdf*

Porter, M.E. (1998), "Clusters and the New Economics of Competition", *Harvard Business Review*, November/December, Vol. 76 Issue 6.

Practical Action (2012), *Poor People's Energy Outlook 2012: Energy for Earning a Living*,Practical Action, Rugby.

Public Citizen and Sierra Club (2013), "Ontario's Feed-in Tariff: Will the WTO Trump Climate Imperatives?", *www.citizen.org/documents/ontario-feed-in-tariff-briefing-paper.pdf*

PwC (PriceWaterhouseCoopers) (2010), "Industries & Agro-Resources (IAR) Cluster Report", Regional Biotechnology, 10 August, *http://circa.europa.eu/Public/irc/rtd/biocluster/library?l=/cluster_francepdf/_EN_1.0_&a=*

Ragwitz M., *et al.* (2009), "EmployRES: Impact of Renewable Energy policy on economic growth and employment in the EU", EC, Burssels, http://ec.europa.eu/energy/renewables/studies/doc/renewables/2009_employ_res_report.pdf

Rai, K. and L. Clough (2012), "Micro energy enterprise development in East Africa: Challenges for marketing technologies", *www.hedon.info/Micro%20Market%20Africa*

Raninger, B., Q. Mingyu and D. Renjie (2011), "China Entdeckt Biogas Neu" (China discovered New Biogas), Biogas Journal, Vol. 3, pp. 84-89.

RECORD (Renewable Energy Centre of Research and Development) (2012), "About", 14 June, *www.record.org.za/about*, accessed 14 June, 2013.

REHCA (Renewable Energy Hamburg Cluster Agency) (n.d.), *http://en.erneuerbare-energien-hamburg.de/*, accessed 13 February 2013.

REN21 (Renewable Energy Policy Network for the 21st Century) (2011), *Renewables 2011 Global Status Report*, REN21 Secretariat, Paris.

REN21 (2012), *Renewables 2012 Global Status Report,* REN21 Secretariat, Paris.

REN21 (2013), *Renewables 2013 Global Status Report*, REN21 Secretariat, Paris.

RERED (Renewable Energy for Rural Economic Development Project) (n.d.), "Projects Implemented under ESD and RERED", *www.energyservices.lk/statistics/esd_rered.htm*, accessed 1 December 2013.

Roig Aldasoro, J.M. (2009), *Navarre: Renewable energies,* Regional Minister of Innovation, Enterprise and Employment, Government of Navarre (Pamplona), April.

Rosenthal, E. (2010), *Portugal Gives Itself a Clean-Energy Makeover,* New York Times, 9 August.

Roy, B. (2011), "Women Barefoot Solar Engineers: A Community Solution", United Nations, New York, *www.un.org/womenwatch/daw/csw/csw55/panels/Panel1-Roy-Bunker.pdf*

Rutovitz, J. (2010), "*South African Energy Sector Jobs to 2030*", Greenpeace Africa by the Institute for Sustainable Futures, University of Technology, Sydney, Greenpeace Africa, Johannesburg.

Rutovitz, J. and S. Harris (2012), "*Calculating Global Energy Sector Jobs: 2012 Methodology"* Prepared for Greenpeace International by Institute for Sustainable Futures, University of Technology, Sydney, Greenpeace Africa, Johannesburg.

Sander, M. (2013), private communication to IRENA, the International Geothermal Association, 20 February.

Sciaudone, C. (2012b), "Bank's local-content audit 'could destroy Brazil's wind industry' ", Recharge, 30 July, *www.rechargenews.com/energy/wind/article316617.ece*

SEEP (2007), "Using Microfinance to Expand Access to Energy Services: Summary of Findings", *www.arcfinance.org/pdfs/pubs/Energy_Summary_FINAL.pdf*

SEIA (Solar Energy Industries Association) (2010), *US Solar Industry Year in Review 2009*, SEIA, Washington, DC.

SELCO (2013a), Author communication with Mr. Harish Hande from SELCO India.

SELCO (2013b), "Case study: the potential for off-grid solar in Bihar", *www.selco-india.com/pdfs/bihar_case%20study_aug%202012.pdf*

SENER (Secretaría de Energía) (Energy Secretariat) (2012), Energía Eólica, Iniciativa para el Desarrollo de las Energías Renovables en México (Wind Energy, Initiative for the Development of Renewable Energies in Mexico), November, Mexico City, *www.sener.gob.mx/webSener/res/0/Wind%20power_01.pdf*

SENER (2013), "Initiative for the development of wind power in Mexico", *www.sener.gob.mx/res/0/Wind%20power_01.pdf*

SEWA (n.d.), Project URJA- An intiative by SEWA Bank, *//nexus.som.yale.edu/design-selco/sites/nexus.som.yale.edu.design-selco/files/imce_imagepool/Project%20Urja.pdf,* accessed December 2013.

Sharma, B. (2011), "Rural Women Turn Solar Energy Entrepreneurs in Indian Village", *www.huffingtonpost.com/betwa-sharma/post_1716_b_821762.html*

Singh, S. (2013), "Swamped by a Flood of Imports", PV Magazine, June, *www.pv-magazine.com/archive/articles/beitrag/swamped-by-a-flood-of-imports-_100011660/572/*

Slette, J.P. and I.E. Wiyono (2012), *Indonesia Biofuels Annual 2012*, US Department of Agriculture, USDA Foreign Agricultural Service, Global Agricultural Information Network.

Smith, J.A. (2000), "Solar-based rural electrification and microenterprise development in Latin America: A gender analysis", National Renewable Energy Laboratory, , Boston, US . *www.nrel.gov/docs/fy01osti/28995.pdf.*

Solar Foundation (2012), "National Solar Jobs Census 2012", A Review of the U.S. Solar Workforce, Washington, DC, *http://thesolarfoundation.org/sites/thesolarfoundation.org/files/TSF%20Solar%20Jobs%20Census%202012%20Final.pdf*

Solarvalley Mitteldeutschland (n.d.), website at *www.solarvalley.org.*

Staiß, F., *et al.* (2006). "Wirkungen des Ausbaus der erneuerbaren Energien auf den deutschen Arbeitsmarkt unter besonderer Berucksichtigung des AuXenhandels", (Impacts of the expansion of renewable energy on the German labour market, with special reference of AuXenhandels), Studie im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit- BMU (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety), *www.dlr.de/Portaldata/1/Resources/portal_news/NewsArchiv2006/EE_Arbeitsplatzeffekte_lang_web.pdf.*

Steinberg, D., G. Porro and M. Goldberg (2012), *Preliminary Analysis of the Jobs and Economic Impacts of Renewable Energy Projects Supported by the §1603 Treasury Grant Program*, NREL, Golden.

Stevens, C. (2010), "Are Women the Key to Sustainable Development?", S*ustainable Development Insights*, Frederick S. Pardee Center for the Study of the Longer-Range Future, Boston University, Boston.

Stevens, C., *et al.* (2009), "Green Jobs and Women Workers: Employment, Equity and Equality", *www.sustainlabour.org/IMG/pdf/women.en.pdf*

Sustainable Prosperity (2012), *Domestic Content Requirements for Renewable Energy Manufacturing*, Policy Brief, Ottawa.

Sustainable Trade Bulletin (2013), *WTO Declares Ontario's Green Energy Act Illegal*, Issue 1, March.

Swirski, B. (2002), What is a Gender Audit, Adva Center, *http://internationalbudget.org/wp-content/uploads/What-is-a-Gender-Audit.pdf*

Telha, J. and H. Gomes (2011), "Expert Evaluation Network Delivering Policy Analysis on the Performance of Cohesion Policy 2007-2013. Year 1 – 2011", *Task 1: Policy Paper On Renewable Energy And Energy Efficiency Of Residential Housing. Portugal,* A report to the European Commission Directorate-General Regional Policy, by Centro de Estudos e Desenvolvimento Regional.

The Economist (2012), "Storm in a Hot Tub," 7 April, *www.economist.com/node/21552207*

The Wind Power (2012), online database at *www.thewindpower.net/index.php*

Thilak, A.B.G. (2010), "Global Small Hydro Power Market Analysis to 2020 - Installed Capacity, Generation, Investment Trends", The Alternative Energy eMagazine, August-September, *www.altenergymag.com/emagazine.php?art_id=1532*

Thurston, C.W. (2012a), "Mexico's Sunny Sonora State Fosters Solar PV Growth," Renewable Energy World, 6 November, *www.renewableenergyworld.com/rea/news/article/2012/11/mexicos-sunny-sonora-state-fosters-solar-pv-growth*

Tourkolias, C., and S. Mirasgedis (2011). "Quantification and monetization of employment benefits associated with renewable energy technologies in Greece", *Renewable and Sustainable Energy Reviews,* Vol. 15, No. 6, pp 2876-2886, Elsevier Ltd.

TP Wind (European Wind Energy Technology Platform) (2013), "Workers wanted: The EU wind energy sector skills gap", TP Wind, Brussels, *www.windplatform.eu/report/workers-wanted*

UAE (United Arab Emirates), IRENA and REN21 (2013), "MENA Status Report", *www.ren21.net/Portals/0/documents/activities/Regional%20Reports/MENA_2013_lowres.pdf*

U.S. Department of State (2012), "The United States Commitment to the Global Alliance for Clean Cookstoves: Year Two Progress Report". *www.state.gov/r/pa/prs/ps/2012/09/198181.htm*

UNCTAD (United Nations Conference on Trade and Development) (2010), *Renewable Energy Technologies for Rural Development*, UNCTAD, New York and Geneva.

UNDESA (United Nations Department of Economic and Social Affairs) (2011), "World Economic and Social Survey 2011", The Great Green Technological Transformation, UNDESA, New York.

UN-ESCAP (United Nations Economic and Social Commission for Asia and the Pacific) (2013), *Partnership experiences from Grameen Shakti, www.unescap.org/esd/Energy-Security-and-Water-Resources/meetings_energy/meeting-5Ps-RTWS/Presentations_PDF/Day2/Session_6_Islam_Bangladesh.pdf.*

UNDP (United Nations Development Programme) (2007), "Capacity Assessment Methodology", *http://europeandcis.undp.org/uploads/public/File/Capacity_Development_Regional_Training/UNDP_Capacity_Assessment_Users_Guide_MAY_2007.pdf*

UNDP (2012), "Integrating Energy Access and Employment Creation to Accelerate Progress on the Millennium Development Goals in Sub-Saharan Africa". New York, *www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Sustainable%20Energy/EnergyAccessAfrica_Web.pdf*

UNEP (United Nations Environment Programme) (2008), Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World, UNEP, Nairobi, *www.unep.org/publications/contents/pub_details_search.asp?ID=4002*

UNEP (2013), *Green Economy and Trade Trends, Challenges and Opportunities*, UNEP, Nairobi.

University of Amsterdam and ICLEI (International Council for Local Environmental Initiatives) (2012), *Role of Local Governments in Promoting Renewable Energy Businesses.* A Contribution to a Green Urban Economy, ICLEI, Bonn.

University of Cooperative Education (n.d.), "Technology & Management of Renewable Energies and Energy Efficiency", *www.ba-hamburg.de/studieninteressierte/duales-studium.html#c143, accessed September 2013.*

Urbanchuk, J.M. (2012), *Contribution of Biofuels to the Global Economy*, Report prepared for the Global Renewable Fuels Association, 12 May.

Urbanchuk, J.M. (2013), *Contribution of the Ethanol Industry to the Economy of the United States*, Report prepared for the Renewable Fuels Association, 31 January, and earlier annual editions.

U.S. Department of Labour (n.d.), "DOL Information Related to the American Recovery and Reinvestment Act of 2009," *www.dol.gov/recovery/implement.htm,* accessed September 2013.

USDoE (U.S. Department of Energy) (n.d.), www1.eere.energy.gov/financing/business.html, accessed September 2013.

USDoE-LPO (U.S. Department of Energy, Loan Programs Office) (n.d.), "The Financing Force Behind America's Clean Energy Economy", *https://lpo.energy.gov/?page_id=45.*

VDI (Association of German Engineers) (2009), "European Engineering Report", *www.vdi.de/uploads/media/2010-04_IW_European_Engineering_Report_02.pdf.*

Wei, M., S. Patadia and D.M. Kammen (2010), "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the US?" *Energy Policy,* Vol.. 38, pp. 919–931.

Weiss, W. and F. Mauthner (2010), *Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2008* IEA Solar Heating and Cooling Programme, Gleisdorf, Austria.

Weiss, W. and F. Mauthner (2011), *Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2009.* IEA Solar Heating and Cooling Programme, Gleisdorf, Austria.

Weiss, W. and F. Mauthner (2012), *Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2010.* IEA Solar Heating and Cooling Programme, Gleisdorf, Austria.

Weiss W. and F. Mauthner (2013), "Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2011", *http://solarthermalworld.org/content/solar-heat-worldwide-markets-and-contribution-energy-supply-2010-2012*

Weiss, W. and P. Biermayr (2009), *Potential of Solar Thermal in Europe*, European Solar Thermal Industry Federation, Brussels.

Weiss, W., I. Bergmann and G. Faniger (2007), *Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2005.* IEA Solar Heating and Cooling Programme, Gleisdorf, Austria.

Weiss, W., I. Bergmann, and G. Faniger (2008), *Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2006.* IEA Solar Heating and Cooling Programme, Gleisdorf, Austria.

Weiss, W., I. Bergmann, and R. Stelzer (2009), *Solar Heat Worldwide. Markets and Contribution to the Energy Supply 2007*, IEA Solar Heating and Cooling Programme, Gleisdorf, Austria.

Wiebelt, M. and J. Blohmke (2013), "Macroeconomic Impacts and Employment Effects of Solar and Wind Energy Production in the EU and MENA until 2050", *www.dii-eumena.com/fileadmin/Daten/Others/Events/Detailed%20 agenda_DIE%20workshop%20Feb4.pdf*

Wides, L., (1998), "Gender lessons from community based PV Projects in rural Guatemalan villages," *ENERGIA News*, Vol. 2, No. 1, pp. 9.

Wissenschaftsladen Bonn (2012), "Study offerings for renewable energies", Bonn, *www.wilabonn.de/images/PDFs/ Erneuerbare/studienangebote-ee-dez-2012.pdf.*

Wood, D. et. al. (2012), *Wind Energy Potential in Mexico's Northern Border States*, Woodrow Wilson International Center for Scholars, Washington DC, May.

World Bank (2008), "Designing Sustainable Off-grid Rural Electrification Projects: Principles and Practices", World Bank, Washington, DC.

World Bank (2009), "Environmental Crisis or Sustainable Development Opportunity? Transforming the Charcoal Sector in Tanzania", *www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2009/09/01/000334955_20090901084035/Rendered/PDF/502070WP0Polic1BOx0342042B01PUBLIC1.pdf*

World Bank (2010). "Cambodia: Supporting Self-Sustaining Commercial Markets for Improved Cookstoves and Household Biodigesters", The World Bank and Asia Sustainable and Alternative Energy Program (ASTAE), h*ttp://siteresources. worldbank.org/INTEAPASTAE/Resources/Camb-Web-FINAL.pdf*

World Bank (2011a), *Middle East and North Africa Region Assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects*, Energy Sector Management Assistance Program (ESMAP), January, Washington, DC.

World Bank (2011b), "Home - Enterprise Surveys", The World Bank Group. August 19, 2011, *www.enterprisesurveys. org/*

World Bank (2012a), "GDP (gross domestic product) per capita (current USD)", *http:// data.worldbank.org/indicator/ NY.GDP.PCAP.CD.*

World Bank (2012b), "Setting International Standards for Gender Equality in the Private Sector", *http://siteresources. worldbank.org/INTGENDER/Resources/Results2012PREMPrivateSector.pdf*

World Bank (n.d.), "Lao PDR: Rural Electrification Programme", *http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/ EASTASIAPACIFICEXT/LAOPRDEXTN/0,,contentMDK:22858227~pagePK:141137~piPK:141127~theSitePK:293684,00.html*

Wörner, L. (2010), "Erneuerbare Energien als Lerninhalt an bayerischen Schulen," Bayerischer Landtag, 9 November, *www.ludwig-woerner.de/File/EE%20als%20Lerninhalt%20an%20bayerischen%20Schulen%20Antwort%2023_02_2011(1).pdf*

WoWE (Women of Wind Energy) (2011), "Moving Towards an Understanding of Women in the Wind Energy Workforce", *www.womenofwindenergy.org/assets/files/WoWE%20Poster%20WP2011.pdf.*

Wright, C. (2011), "Export Credit Agencies and Global Energy: Promoting National Exports in a Changing World", *Global Policy*, Vol. 2, pp. 133-143.

WTO (World Trade Organization) (2012), "Dispute Settlement: WTO Issues Panel Reports on Canada's Renewable Energy Measures," 19 December, *www.wto.org/english/news_e/news12_e/412_426r_e.htm.*

Wuppertal Institute and Alcor. (2012). "Strategic study on the energy mix for the electricity production in Tunisia", *http:// wupperinst.org/en/projects/details/wi/p/s/pd/332/*

Yunwen, B., C. Jiliáng and L. Lina (2012), *Climate Protection Requires a Prosperous Global Solar Photovoltaic Market*, On the China EU Solar Trade Dispute, Greenovation Hub, 26 November.

IRENA

International Renewable Energy Agency

IRENA Headquarters
CI Tower, Khalidiyah
P.O. Box 236, Abu Dhabi
United Arab Emirates

www.irena.org